12. ASSESSMENT OF WETLANDS EFFECTS

12.1 INTRODUCTION

Wetlands are dynamic, depressional, or slightly sloping areas on the landscape that are saturated with water for a significant period of time during the growing season. The effect of this saturation is reflected in the soil development and vegetation community composition found within wetlands. They are important ecosystems, as they fulfill a wide range of ecological, hydrological, biochemical, and habitat functions and are valued by society for the services they provide (Milko 1998; Mitsch and Gosselink 2000; Hanson et al. 2008). They maintain water quality, regulate water flow, and provide erosion control. They provide habitat for a wide variety of wildlife, including red- and blue-listed wetland dependant species (Cox and Cullington 2009) and many economically important species. In British Columbia (BC), wetlands comprise about 5.6% of the provincial land base.

Wetlands are present within the immediate vicinity of the Murray River Coal Project (the Project) footprint; thus the Project has the potential to affect wetlands, including effects on wetland extent and function. This chapter will identify, assess, and discuss the significance of residual effects of the Project on wetland extent and function after implementation of mitigation measures and management plans. The assessment will consider the magnitude of change from baseline conditions; geographic extent over which effects occur; duration and frequency of effects; reversibility of effects; context or resiliency of the ecosystems affected; probability of effects; and confidence in the cause-effect relationships.

Wetland values were incorporated into the Project environmental assessment because a preliminary effects screening identified the potential of the Project adversely affecting wetlands, and First Nations and government regulators identified them as important components of a comprehensive assessment. This assessment and the supporting wetland baseline study (Appendix 12-A) were drafted be consistent with the objectives of the *Federal Policy on Wetland Conservation*, which is to "promote the conservation of Canada's wetlands to sustain their ecological and socio-economic functions, now and in the future" (Environment Canada 1991).

12.2 REGULATORY AND POLICY FRAMEWORK

There are a number of federal and provincial policy statements, acts, and best management practices pertaining to wetland aspects such as function, wildlife, and fish habitat.

12.2.1.1 Mines Act

Under the *Mines Act* (1996a), the BC Ministry of Energy and Mines (MEM) requires that wetland mapping of a proposed mine site be completed for all mining permit applications according to provincial standards (BC MEM 1998). Wetlands in the proposed Murray River Mine Site must be mapped to a 1:5,000 scale, and vegetation must be sampled and analyzed to establish baseline metal levels and trace element uptake (BC MEM 1998). In addition, the British Columbia Ministry of

Environment (BC MOE) standards for environmental baseline programs identify wetlands as a component of aquatic ecosystems that need to be studied (BC MOE 2009).

12.2.1.2 Federal Policy of Wetland Conservation

Wetlands in Canada are managed and conserved through the *Federal Policy on Wetland Conservation* which states that there will be "no net loss of wetland functions on all federal lands and waters" (Environment Canada 1991). The policy also states that the functions and values derived from wetlands will be maintained, and wetlands will be enhanced and rehabilitated in areas of continuing loss and alteration (Milko 1998).

12.2.1.3 Forest and Range Practices Act

The *Forest and Range Practices Act* (2002a) governs all forestry activities including logging, road building, reforestation, and floodplain area management. The Act requires that all forestry-related development be conducted in accordance with the rules and regulations identified in the Act to ensure the protection of environmental values. The *Forest and Range Practices Act* (2002a) addresses ecosystems such as wildlife habitat through the Identified Wildlife Management Strategy. As unpaved roads have potential to contribute significantly to soil erosion, road construction within forested areas of BC is governed by the *Forest and Range Practices Act*. The Act requires that road construction adheres to codes provided in the Forest Service Road Use Regulation (BC Reg. 70/2004), which focuses extensively on erosion prevention.

12.2.1.4 Species at Risk Act

The purpose of the SARA (2002b) is to prevent species at risk from becoming extirpated or extinct and to ensure the appropriate management of species to prevent them from becoming at risk. Certain species are also protected under the SARA as part of wildlife habitat and in accordance with the Canadian Biodiversity Strategy. The Canadian Biodiversity Strategy provides federal legislation that supports the conservation of particular species and populations to ensure continuance of biological diversity over time (Federal-Provincial-Territorial Biodiversity Working Group 1995).

12.2.1.5 BC Conservation Data Centre

The BC Conservation Data Centre (CDC; BC MOE 2007), which is part of the Environmental Stewardship Division of the BC MOE, classifies plant species and ecosystems at risk in the province as either red-listed (extirpated, endangered, or threatened) or blue-listed (of special concern), and tracks information regarding their conservation status and individual locations. Best management practices and guidelines for land developments recommend that red- and blue-listed plants and ecosystems be protected (BC MOE 2006).

12.2.1.6 Fisheries Act

The federal *Fisheries Act* (1985) provides the legal framework to protect fish habitat. Section 35 establishes rules guiding development within the Fisheries Sensitive Zones and watercourses. Section 36 establishes rules for erosion control related to land development activities, such as clearing land, grading slopes, and road construction and maintenance.

12.2.1.7 *Fish Protection Act*

The *Fish Protection Act* (1997) and associated amendments to the provincial *Water Act* (1996b) regulate provincial approvals of alterations and work in and around watercourses. The regulations focus on riparian area retention and activities which may be involved in vegetation removal and introduction of harmful debris (clay, silt, sand, rock, or any material, natural or otherwise) into waterways.

12.2.1.8 *Weed Control Act*

The *Weed Control Act* (1996c) regulates the management of noxious plants in BC. The Act requires all land occupiers to avoid establishment and dispersal of noxious weeds as defined by the Act.

12.2.1.9 *Wildlife Act*

The provincial *Wildlife Act* (1996c) provides for conservation of specific ecosystems and ecosystem components as they provide habitat for species managed by the BC MOE.

12.2.1.10 *Environmental Management Act*

Combining the provisions of the previous Waste Management and Environment Management acts into a single statute, the *Environmental Management Act* (2004) prohibits the introduction of deleterious substances into the environment in any manner or quantity that may cause pollution to the environment as defined in the Act. This includes substances that would degrade or contaminate soil and water, which could in turn have deleterious effects on terrestrial ecosystems. The Contaminated Sites Regulation (BC Reg. 375/96) included in BC's *Environmental Management Act* (2004) lists Soil Criteria for Toxicity to Soil Invertebrates and Plants. These provide numerical standards to define whether a site is contaminated, to determine liability for site remediation, and to assess reclamation success.

12.2.1.11 *Environmental Protection Act*

The Environmental Protection Act (1999) provides governance on pollution prevention to reduce the risk of toxic substances on human health and the environment. It applies the precautionary principle that, where there are threats of serious or irreversible damage, lack of full scientific uncertainty cannot be used as a reason for postponing cost-effective measures to prevent environmental degradation, and promotes and reinforces enforceable pollution prevention approaches (1999).

In addition to these regulations, draft best management practices (BMPs) for the mining industry include the following key management practices for protecting wetlands in BC (Cox and Cullington 2009):

- controlling leaching and sedimentation;
- ensuring dewatering production processes do not affect wetland hydrology;
- limiting the effects of noise;
- re-vegetating using pre-development area species;
- using low impact re-vegetation techniques;

- re-establishing wetland functions; and
- monitoring of enhancement, restoration, and creation activities to ensure success.

The BMPs also emphasize caution around planning, construction, and use of trails and roads because they can:

- be a major source of sediment;
- cause habitat loss and/or fragmentation through infilling or dewatering;
- enable exotic invasive species (for the purposes of the assessment the term invasive species includes only exotic invasive species) colonization; and
- increase recreational impacts (Cox and Cullington 2009).

12.3 REGIONAL OVERVIEW

Wetlands account for 2.7% of the Local Study Area (LSA) for the Project and 4.5% of land cover in the Regional Study Area (RSA); the LSA and RSA are described further in Section 12.5.2.1. The amount of wetland habitat in the LSA is less than the provincial average (5.6%).

The five classes of federally recognized wetlands include fens, swamps, bogs, marshes, and shallow open water (SOW). Wetlands in northeast BC typically include fens, swamps, and bogs. Marshes and shallow open water wetlands are less common. Wetland vegetation is diverse and is closely connected with wetland class. Some notable exceptions are the sedges *Carex aquatilis*, *C. utriculata*, and *C. sitchensis*, which are common in a number of wetland classes and associations.

Wetlands provide specific habitat features for a number of wildlife species, including early season forage for bears, mid-summer forage for moose, and breeding habitat for waterfowl and amphibians such as the provincially blue-listed *Anaxyrus boreas* (western toad). Wetlands throughout the region are not considered threatened or at risk, although a number of specific associations are listed by the BC CDC as red- or blue-listed, depending on the biogeoclimatic subzone and forest district where they are found.

12.4 HISTORICAL ACTIVITIES

Historic and current human activities are within close proximity to the proposed Project Area. These include mining exploration and production, oil and gas, forestry, tourism/recreation, and hunting/trapping.

The Murray River Project's License Area is located within the Peace River Coalfield, known for producing metallurgical grade (hard coking) coal. In the 1950s and 1960s, 15 significant coal deposits were discovered in this region. In response to rising coal prices in the mid-1970s, the Government of Canada examined the viability of accessing and transporting coal to the Pacific Coast for export. In 1981, the governments of BC and Canada, two Canadian mining companies and a consortium of Japanese steel mills signed an agreement to develop the mining industry in the area. As a result, the District of Tumbler Ridge was built as well as two coal mines (Quintette and Bullmoose), and

Highways 52 and 29 connecting the municipality with Highway 97. A power line from the W.A.C. Bennett Dam and a rail line through the Rocky Mountains were also built to support economic development in the region. Quintette and Bullmoose mines started production in 1982 and were closed in 2000 and 2003 respectively. Oil and natural gas exploration and development are also active in the region, with gas wells and pipelines located within the LSA.

The Quintette Coal Mine consisted of five open pits in three discrete areas: Sheriff (Wolverine and Mesa Pits), Frame (Shikano Pit), and Babcock (Windy and Window Pits). Mine permits for the Wolverine and Mesa Pits were issued in December 1982, and mining commenced in 1983 and continued until 1998 (Wolverine) and 2000 (Mesa). Raw coal was transported via an overland conveyor from the Mesa and Wolverine Pits to the Quintette plant site for processing. The coal processing plant has been under care and maintenance since the end of mining in 2000; the overland conveyor, which previously crossed through a portion of HD Mining's Decline Site, was decommissioned by Teck in 2011. Teck is currently securing the necessary approvals to re-initiate mining in the Babcock area.

The Bullmoose Coal Mine was the largest open pit coal mine at the time, producing about 3 million tons of metallurgical coal. The 1.7-million-tonne-per-year operation consisted of an open-pit mine, a plant facility in the Bullmoose Creek valley below the mine, and a separate rail loadout facility on the BC Rail branchline.

Previous exploration in the area included seismic lines and drilling for oil and gas wells. These drilling programs helped target areas for coal exploration and resulted in the development of natural gas wells in the area now encompassed by the LSA.

Canadian Forest Products Limited (Canfor) holds the rights to Tree Farm License (TFL) 48. The TFL consists of five supply blocks and has an area of 643,239 ha. Block 5 of the TFL overlaps much of the LSA (Figure 12.4-1). Canfor’s mill is located in Chetwynd, which is the community most dependent on harvesting in the TFL (Benskin 2007). Mining related activity has had a minor impact on the timber harvesting land base (THLB), which is reflected in the 2007 annual allowable cut (AAC) calculations. An area of 2,236 ha was removed from the THLB related to mine sites, of which 479 ha were forested. At the time of the AAC calculation, 29 mine sites were proposed in the Peace Forest District. In his report, Deputy Chief Forester Henry Benskin stated that all mine sites were to be permanently excluded from the THLB as there were no examples of reclaimed mine sites in TFL 48 being restored to forested conditions (Benskin 2007).

In the LSA, Canfor has 13 licenses to cut. Two of these are proposed blocks for 2020, seven have been harvested but have not yet met free-to-grow obligations (the silvicultural obligation of reforesting the sites still reside with Canfor), and three licenses have been declared free-to-grow and have reverted to the crown. The remaining license is stagnant.

The District of Tumbler Ridge holds the rights to a new community forest license that overlaps the LSA (Figure 12.4-1). The community forest is 19,739 ha and has an AAC of 20,000 m^3. The goals of the community forest are to practice environmentally sound and ecologically sustainable forestry that provides multiple benefits to the community.

BC Hydro currently operates a 230 kV transmission line that intersects the LSA. This line supplies power to the community of Tumbler Ridge as well as other communities and commercial enterprises in the region.

Subsistence activities, such as trapping, hunting, and fishing are common land uses regionally. Three trapping tenures and four guide-outfitting tenures overlap the RSA. Multiple recreation tenures, as well as temporary and permanent residences exist within the Project area. The nearest trapline cabin is 1.7 km from the Project on the west bank of Murray River; the nearest campground is 9.5 km north from the Project (near Tumbler Ridge); the nearest hunt camp is 26 km west from the Project; and the nearest residential area (Tumbler Ridge) is 12.4 km north from the Project.

There are multiple previously recorded archaeological sites (pre-contact lithic scatters) within 5 km of the proposed Project infrastructure.

The Project is located near two provincial parks and protected areas. Bearhole Lake Provincial Park and Protected Area is located approximately 17 km east of the Project, and Monkman Provincial Park is located approximately 27 km south of the Project.

This description is not exhaustive but does illustrate decades of human activity. A more comprehensive review of historic, current, and future lands uses is provided in the analysis of cumulative effects in Section 12.11.

12.5 BASELINE STUDIES

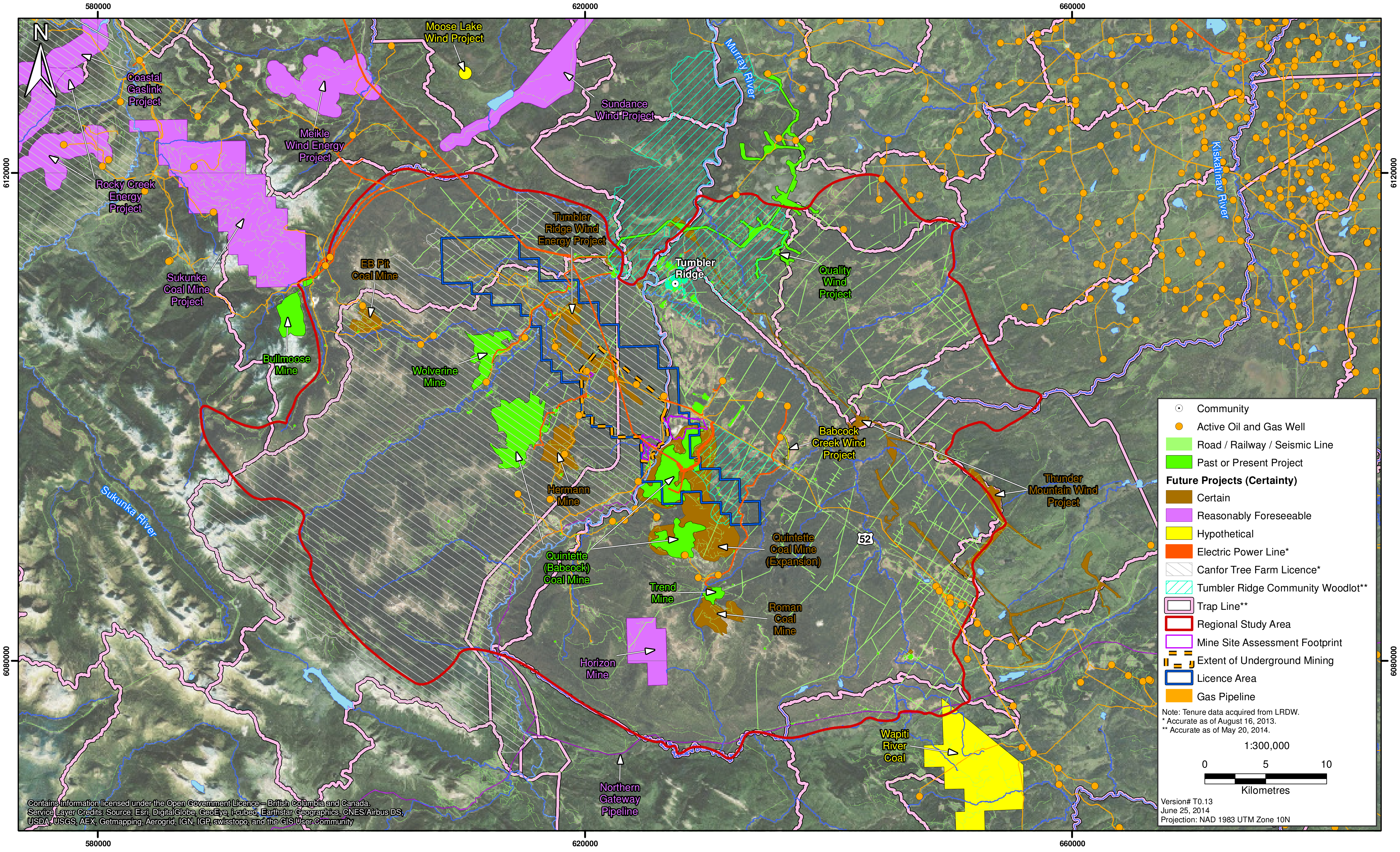
Wetlands were mapped and a subset of wetlands were surveyed to assist in photo interpretation, identify wetland class, and to collect vegetation, soil, and hydrologic information to assist in characterizing wetland function (Appendix 12-A).

12.5.1 Data Sources

A number of data sources were consulted to guide the wetland baseline studies and effects assessment. These sources included the following:

- Terrestrial Ecosystem Mapping (TEM) line work and descriptions (2008 and 2012);
- Terrain Resource Information Management (TRIM);
- BC CDC (for provincially blue- and red-listed plants and ecosystems);
- publically available data associated with relevant adjacent projects;
- stereo aerial photography interpretation using ArcGIS and Purview;
- relevant literature;
- data acquired via data sharing agreements;
- the Dawson Creek Land and Resource Management Plan (BC Ministry of Forests and Range 1999; BC ILMB 2000);
- data made available from First Nations, local stakeholders, and the general public.

Figure 12.4-1
Current and Historical Land Use Adjacent to the Project



Note: Tenure data acquired from LRDW.
* Accurate as of August 16, 2013.
** Accurate as of May 20, 2014.

Version# T0.13
June 25, 2014
Projection: NAD 1983 UTM Zone 10N

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12.5.2 Methods

This section provides an overview of the study areas and methods used to characterize wetland type, distribution, extent, and function. Baseline studies included field data collection, wetland classification, and mapping.

12.5.2.1 Baseline Study Area

Ecosystems and vegetation were characterized for a regional and a local study area surrounding the Project (Figure 12.5-1; Figure 12.5-2). The regional study area (RSA) is 227,615 ha in size and was delineated to encompass an area on which to base regional characterizations (Figure 12.5-1). It is intended to be ecologically relevant based on the home range of key wildlife species known to inhabit the region, which is used to evaluate the potential effects of the Project on wildlife and wildlife habitat (Chapter 13) valued components (VCs). Ecosystem mapping in the RSA provides a regional context for ecosystem distribution.

The Local Study Area (LSA) is 14,852 ha in size and encompasses an area surrounding the proposed Project infrastructure and the adjacent area in which direct effects from the Project may be anticipated (Figure 12.5-2). Its boundary has also been developed following follows natural terrain and drainage boundaries in order to be ecologically relevant in assessing wetlands, terrestrial ecosystems, vegetation, and soil VCs.

12.5.2.2 Wetland Mapping and Classification

Wetland Mapping

Surveyed wetland polygons were delineated in the field using a 2005, 1:30,000 colour aerial photograph. The polygons lines were then digitized using ArcView 10. Wetlands identified in Terrain Resource Inventory Management (TRIM) were incorporated into a GIS product. Purview (ArcGIS based stereo viewing software) was then used to refine these wetland polygons at a 1:5,000 scale and to type new polygons based on aerial photo interpretation (Figure 12.5-2). Where possible, terrestrial ecosystems were not included as part of wetland polygons to assist in analysis and bring clarity to subsequent management decision making processes.

Wetland Surveys

Surveys of wetlands were completed in August 2010, June 2011 and September 2012. In total, 32 wetlands were surveyed and field plots were established (Figure 12.5-2). Survey methods followed *Field Description of Wetland and Related Ecosystems in the Field* (MacKenzie and J. R. Shaw 1999) and *Wetlands of British Columbia: A Guide to Identification* (MacKenzie and Moran 2004a). Wetland survey locations are displayed in Figure 12.5-2; wetland field data are available in Appendix 12-A.

Data collected during these field surveys were used to classify wetland ecosystems according to the Canadian Wetland Classification System (class level; Warner and Rubec 1997). Wetlands visited in the field were also classified according to the provincial classification system (association level; MacKenzie and Moran 2004a). Each federal wetland class (bog, fen, marsh, swamp, shallow open water) can be further classified using the provincial system as site associations, which are defined as sites capable of supporting a similar community at climax (MacKenzie and Moran 2004a).

Figure 12.5-1
Wetland Regional Study Area

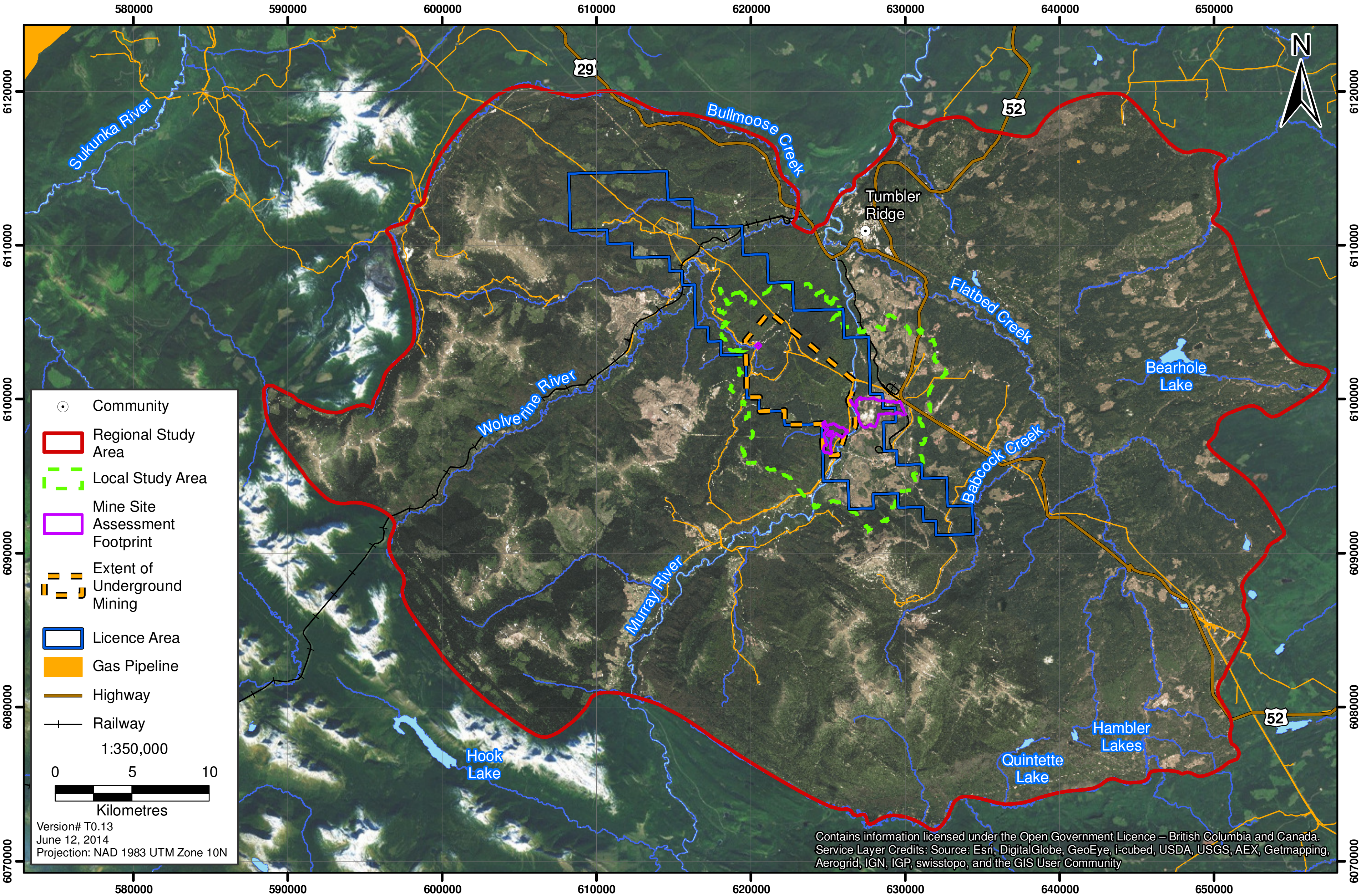

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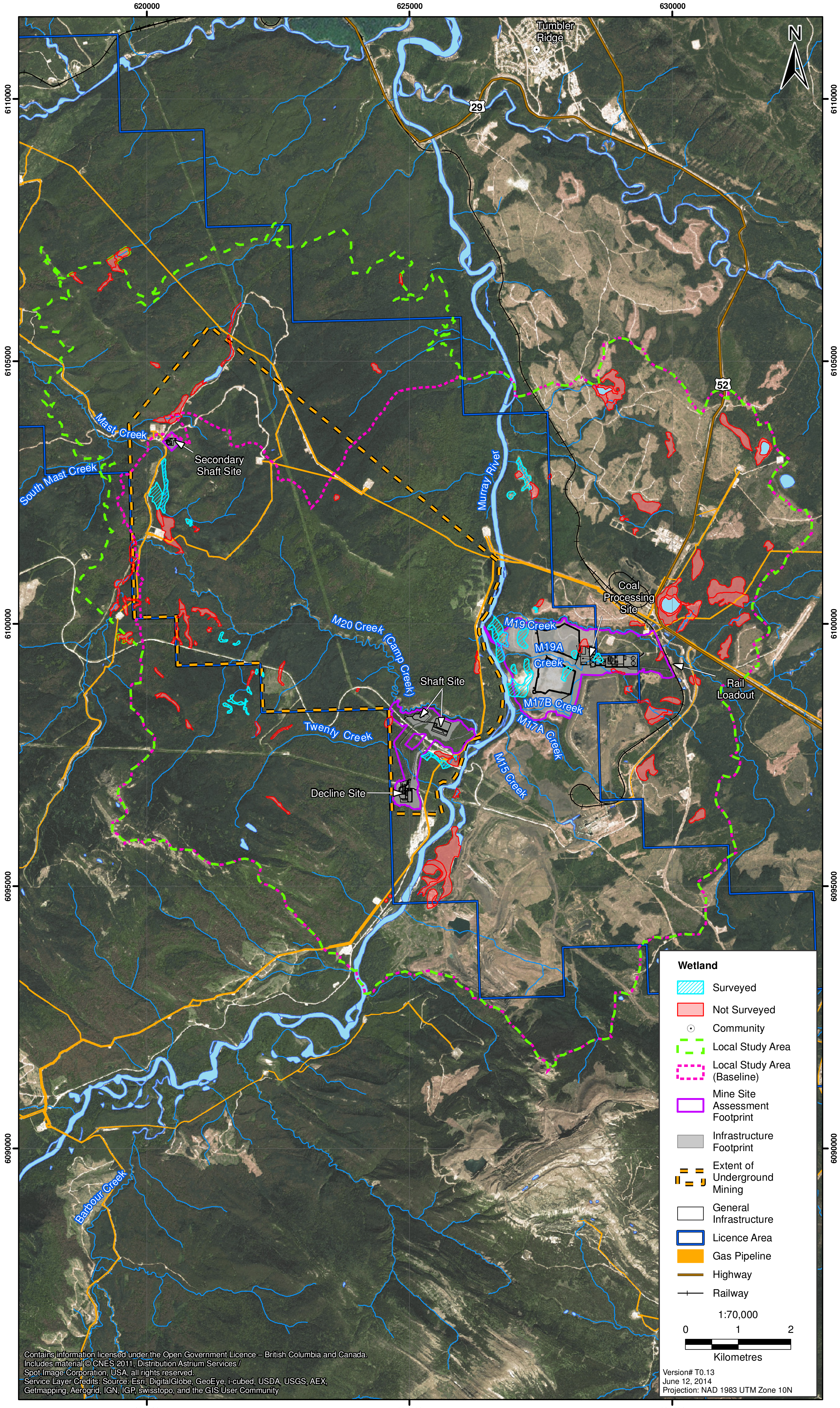
Figure 12.5-2

Local Study Area, Infrastructure, Wetlands, and Survey Locations



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Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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Wetland surveys were planned at all TRIM identified wetlands and at areas of interest identified through aerial photograph interpretation. Areas of interest include level or slightly sloping areas near mapped surface water features such as streams, rivers, and lakes. A plot was established at each survey site. At each survey location soil cores data, vegetation species, habitat information, and wetland function information were recorded.

The soil survey methodologies for wetland ecosystem classification incorporated aspects from *The Canadian System of Soil Classification* (Canada Soil Survey Committee 1987), *Towards a Taxonomic Classification of Humus Forms* (Green, Trowbridge, and Klinka. 1993), *Describing Ecosystems in the Field* (Luttmerding et al. 1990), and *Field Description of Wetland and Related Ecosystems in the Field* (MacKenzie and J. R. Shaw 1999).

Vegetation species and the relative percent cover of plant classes (forb, shrubs, and trees) were recorded at each plot. Special focus was placed on the identification of wetland indicator species.

Wetland Habitat Information Forms (Appendix 12-B) were completed at each sample site to assist in characterizing habitat function. These forms, developed by ERM Rescan, are based on the provincial Ground Inspection Forms but were adapted for use in wetland studies.

Information was collected during field surveys to assist in an analysis of wetland function. Wetland functions are the processes that wetlands carry out, such as storage and filtration of water. Four primary functions – hydrological, biochemical, functional diversity (ecological function), and habitat – are considered during an environmental assessment (Tables 12.5-1 and 12.5-2). Table 12.5-1 shows which field work components provide field data to describe aspects of the wetland functions.

Table 12.5-1. Wetland Function and Associated Fieldwork Component

Wetland Function	Fieldwork Component
Hydrological Function	• Wetland classification (wetland class) • Ecosystem survey (hydrodynamics) • Ecosystem survey (hydrogeomorphic position)
Biochemical Function	• Wetland classification (wetland class) • Vegetation tissue samples
Functional Diversity	• Ecosystem survey (wetland size and distribution) • Wetland classification (wetland complexes, rare or unique wetlands)
Habitat Function	• Ecosystem survey (wildlife observations) • Wetland classification (wetland class)

The principle wetland functions for each wetland class were determined by integrating survey data, individual wetland class, landscape position, and scientific literature (Hanson et al. 2008).

12.5.3 Characterization of Wetlands Baseline Condition

Wetlands within the LSA were found to include all five federally defined wetland classes (see Plates 12.5-1 through 12.5-5) and ten provincially described wetland associations (Appendix 12-A). In addition to these, wetland types were also identified through ecosystem mapping and TRIM data. Table 12.5-2 shows the area and occurrence of each federal wetland class by decile. Secondary and tertiary deciles indicate that the wetland polygons contain more than one wetland class. Polygons where wetlands were 10% or less of the polygon area were considered primarily terrestrial ecosystems and were not included in the assessment of wetlands.

Table 12.5-2. Wetland Class Areas in the Local Study Area

	Area (ha)				
Wetland Class	Primary Decile	Secondary Decile	Tertiary Decile	Total	% of Total
Bog	174.3	3.9	0.6	178.7	45%
Fen	10.4	4.4	1.1	15.9	4%
Marsh	31.2	17.6	0.7	49.4	13%
SOW	13.1	11.5	6.0	30.6	8%
Swamp	113.8	4.3	2.0	120.1	30%
Total	**342.6**	**41.7**	**10.4**	**394.8**	

A total of 394.8 ha of wetlands and were mapped in the LSA. Bogs and swamps accounted for the largest area of wetlands totalling 298.8 ha (76%) of all wetlands. Fens were the least common wetland class in the LSA at 4% of all wetlands. In total there are 399.6 ha in wetland polygons. All polygons with a greater than 20% wetland component were included in the wetland analysis. This results in the inclusion of 4.8 ha of terrestrial ecosystems in the wetland layer. These have been excluded from analysis numbers but are shown as wetlands on all maps.

Complete descriptions of the plant communities identified during baseline field work are included in Appendix 12-A. A list of all plant species recorded and wildlife sign noted during wetlands characterization fieldwork is included in Appendix 12-A. Use of wetlands by key wildlife species is in *Murray River Coal Project: 2010 to 2013 Wildlife Baseline Report* (Appendix 13-A). A brief description is provided below of the five federal wetland classes observed in the Murray River LSA.

Bogs are nutrient-poor, *Sphagnum*-dominated peatland ecosystems in which the rooting zones are isolated from mineral-enriched groundwater, soils are acidic, and few minerotrophic plant species occur (MacKenzie and Moran 2004a). Bogs may be treed or tree-less and are usually covered with *Sphagnum spp.* and ericaceous shrubs. Precipitation, fog, and snowmelt are the primary water sources. Precipitation does not usually contain dissolved minerals and is mildly acidic; subsequently bog waters are low in dissolved minerals and are acidic in nature. Bog water acidity is enhanced because of organic acids formed during the decomposition of peat (Warner and Rubec 1997).

Within the LSA, bogs including Black spruce – water sedge – peat-moss (Wb05), Tamarack – Water sedge – Fen moss (Wb06), Black spruce – soft-leaved sedge – peat-moss (Wb08), and Black spruce – common horsetail – peat-moss (Wb09) were observed. The vegetation in these bogs was generally dominated by carex species including *Carex aquatilis* and *Carex Disperma*. Herb, shrub and tree species include *Equisetum arvense, Ledum groenlandicum*, *Betula nana, Larix laricina* and *Picea* sp. The moss layer was dominated by *Sphagnum sp., Tomentypnum sp., Aulacomnium sp.*, and *Polytrichum sp.* The soils were humic or mesic sphagnum peat and the soil nutrient regime was poor to rich.

Fen wetlands are nutrient-medium peatland ecosystems, dominated by sedges and brown mosses, where mineral-bearing groundwater is within the rooting zone and minerotrophic plant species are common (MacKenzie and Moran 2004b). Fens can have fluctuating water tables and are often rich in dissolved minerals. Surface water flow can be direct, through channels, pools, and other open features that can often form characteristic surface patterns. The vegetation in fens is closely related to the depth and chemistry of groundwater. Shrubs occupy drier sites and minerotrophic graminoid vegetation (grass) is typically found in wetter sites (Warner and Rubec 1997).

One Wf04 fen association was observed within the LSA. The shrub layer was predominant at this site and was generally composed of *Salix barclayi.* There were a number of non-swamp indicator species such as *Picea sp*., *Oxycoccus oxycoccus*, and *Ledum groenlandicum*, indicating that this site may be transitioning to a bog or *Picea*-dominated swamp.

Marshes are permanently to seasonally flooded non-tidal mineral wetlands dominated by emergent grass-like vegetation (MacKenzie and Moran 2004b). Marshes are the most heavily used wetland type for most wetland-using wildlife species. They are typically eutrophic and support large standing crops of palatable vegetation, plankton, and aquatic invertebrates. They are the favoured wetland class for most waterfowl, amphibians, and semi-aquatic mammals because they provide good cover, open water, and food. Soils are typically mineral but can also have a well-decomposed organic surface tier (Warner and Rubec 1997; MacKenzie and Moran 2004). Marsh communities accounted for the majority of the wetland area and often existed in a complex with shallow open water and shrub and treed wetland and riparian areas. SOW.

One marsh type was observed in the LSA: Beaked sedge – water sedge (Wm01). Species diversity at these sites was low; vegetation was dominated by *Carex utriculata* or *C. aquatilis*. Some sites had shrubs and wetland adapted forbs such as *Equisetum arvense* and *Scirpus microcarpus*, occurring on margins and in transitional areas. All sites had an organic veneer over a poorly to imperfectly drained mineral soil.

Swamps are a nutrient-rich wetland ecosystems with significant groundwater inflow, periodic surface aeration, and elevated microsites supporting the growth of trees and tall (MacKenzie and Moran 2004b). Swamps generally have more than 30% tree or tall shrub cover. Soils are often gleyed mineral soils with a surface layer of anaerobically decomposed woody peat. In general, there are three physically different swamp communities: (1) shrub-thicket, (2) coniferous forest, and (3) hardwood (deciduous) swamps (Warner and Rubec 1997). Swamps have a more vertical structure than other wetland classes and support more diverse avifaunal assemblages (MacKenzie and Moran 2004). Furthermore, forested swamps typically have an open canopy that appears to be favoured by many bird and bat species (MacKenzie and Moran 2004; Lausen 2006).

Three swamp associations were observed in the LSA: Ws07, willow, and willow – sedge. The vegetation was diverse with an open overstorey canopy of *Picea sp*., *Alnus crispa*, and *Salix* sp dominant in the shrub layer; and a variety of species in the understorey including *Carex aquatilis, Equisetum fluvitile,*and *Calamagrostis canadensis.*

Shallow open water wetlands are ecosystems that are permanently flooded by still or slow-moving water and dominated by rooted and floating aquatic plants. Shallow open water wetlands are often the transition from bogs, fens, marshes, and swamps to permanent deep water bodies (i.e., sluggish streams and lakes; Warner and Rubec 1997; MacKenzie and Moran 2004). They are among the most important habitat for wildlife and fish because of vegetative cover and high prey densities (MacKenzie and Moran 2004). A variety of shallow open water ecosystems were observed throughout the LSA, including a submergent community, deep un-vegetated bog stream/pools, and flooded land.

Within the LSA, wetlands cover a small but important component of the landscape. They are the connection between wetter aquatic habitats and drier upland habitats. They contain processes specific to wetlands such as regulating flood waters, improving water quality, and offering semi-aquatic wildlife habitat. The primary wetland functions were identified for each wetland class (Table 12.5-3).

Table 12.5-3. Overview of General Wetland Functions[1]

Function Category	Value	Probable Services
Hydrology	• Flow moderation • Groundwater recharge • Erosion and shoreline protection • Climate regulation	• Replenishing groundwater supplies • Moderation of stormwater peaks • Climate moderation • Maintenance of water flow during drought • Reduced water velocity and removal of suspended sediments
Biochemical Cycling	• Water quality treatment • Carbon storage • Nutrient and organic export	• Atmospheric carbon sequestration • Natural water quality improvements • Reduction in excess nutrients
Habitat	• Biological productivity and diversity	• Production of harvestable species • Provision of biodiversity • Habitat for species at risk
Functional Diversity (ecological function)	• Assemblages of different wetland ecosystems that provide synergistic effects	• Multiple and diverse combinations of functions in wetland complexes including hydrology, biochemical, and habitat functions

[1] *Adapted from Hanson et al. (2008).*

Functional diversity has been included to account for the more varied combination of functions that are offered by complexes of different classes of wetlands. Some of this variety will be indicated by the spatial co-occurrences of different wetland ecosystems. Hydrological, biochemical, and habitat functions are provided at different levels by different wetlands. When wetlands occur as complexes, they offer a greater array of these functions. For example, bog and forested swamps can form wetland complexes. When this occurs, there is a greater potential for them to provide the biochemical functions of carbon storage associated with bogs and the higher nutrient cycling associated with the swamps. Hydrologic functioning would also be more diverse, and the limited flow moderation provided by bogs would be contrasted with the high flow moderation provided by swamps. Habitat function would also be enhanced as structural diversity would be greater. The resulting ecotones provide important habitat for animals such as forage, day bed sites on raised micro topography, escape cover, and perching sites. The open nature of bogs allows animals to thermoregulate during stressful weather conditions. For plant species, the transition from swamp to typical bog vegetation occurs along gradients determined by peat characteristics (input species, depth, pH, and state of decomposition), hydrology, light availability, nutrients, and microclimate. These variable conditions provide more habitat niches than occur in ecosystems where gradients are less varied.

Wetland class is an indication of which functions will be provided and how well a wetland will perform the various functions. Function by wetland class is shown in Table 12.5-4. Each of the five federal wetland classes and three of the functions are discussed below. Functional diversity (ecological function) is not described further in this section, as it is not specific to one wetland class.

Table 12.5-4. Summary of Functions and Values by Wetland Classes[1]

Wetland Class	Hydrological Function	Biochemical Function	Habitat Function
Bog	**Low** - Water flow moderation **Low/Moderate** - Groundwater recharge **Low** - Erosion protection **Low** - Climate regulation	**Low** - Water quality treatment **High** - Carbon storage **Moderate/High** - Nutrient and organic export	**Moderate/High** - Provides tall tree, shrub, and open area cover types for a variety of species
Fen	**Moderate** - Water flow moderation **Low** - Groundwater recharge **Low** - Erosion protection **Moderate** - Climate regulation	**Moderate/High** - Water quality treatment **Moderate/High** - Carbon storage **Moderate/High** - Nutrient and organic export	**Moderate/High** - Provides open area cover; provides early season vegetation for bears
Marsh	**Low/High** - Water flow moderation **Low/Moderate** - Groundwater recharge **Moderate/High** - Erosion protection **Moderate/High** - Climate regulation	**Moderate/High** - Water quality treatment **Moderate** - Carbon storage **Moderate/High** - Nutrient and organic export	**High** – Provides migratory bird habitat; the most important wetland class for providing habitat
Swamp	**Moderate to High** - Water flow moderation **Low** - Groundwater recharge **Moderate** - Erosion protection **Moderate** - Climate regulation	**Moderate/High** - Water quality treatment **Moderate/High** - Carbon storage **Low/Moderate** - Nutrient and organic export	**Highly Variable** – Provides cover habitat and moose forage; provides connectivity with freshwater aquatic systems such as rivers
Shallow Open Water	**Moderate/High** - Water flow moderation **Variable** - Groundwater recharge **Low** - Erosion protection **Low/Moderate** - Climate regulation	**Moderate/High** - Water quality treatment **Low** - Carbon storage **Low** - Nutrient and organic export	**Highly Variable** – Provides open water habitat for migratory birds, moose, and amphibians

[1] *Adapted from Hanson et al. (2008).*

12.5.3.1 Bog Wetland Function

Bog Hydrological Functions

The hydrological functions provided by bogs are generally low (Hanson et al. 2008). Water flow moderation, groundwater recharge, and reduction in shoreline erosion functions are often limited due to the lack of surface water flow into bogs. Because of the saturated soils found in bogs, they have limited capacity to slow down volume responses in lower systems during freshet and rainfall events. The exception to this is during dry summer months when water levels are low, allowing for recharge. Bogs generally occur in low energy environments and have little value in reducing erosion (Plate 12.5-1).

Plate 12.5-1. Wb06 bog at site 404.

Bog Biochemical Functions

Carbon storage is a key biochemical function provided by bogs. Due to low hydrodynamism, anoxic conditions, and low pH, decomposition rates are slow. This results in the accumulation of organic carbon in the forms of fibric, mesic, and humic peat. Disturbance of these sites can result in accelerated decomposition rates and reduction in their carbon storage function.

Bogs can be integral to nutrient and organic export as soluble organic matter can percolate through groundwater flow into adjacent ecosystems. The nutrient quality of this matter can be poor and the tannins and other associated leachates can alter nutrient cycling in adjacent ecosystems. Because of their isolated nature, bogs are less important in improving water quality than other wetland forms (Hanson et al. 2008). The low energy environment of bogs, anoxic conditions, and limited nutrient availability results in slow decomposition processes.

All wetland soils contain some concentration of metals. Metals may exist in wetland soils or vegetation and enter wetlands through surface water, groundwater flow, and aerial deposition. Wetlands can remove metals from surface and groundwater by binding metals to iron and aluminum ions via adsorption to clay surfaces or through carbonates precipitating as inorganic compounds. They can also form complexes with organic soils (Gambrell 1994).

Bog Habitat Functions

The unique environment provided by bogs creates habitat niches that can support a variety of rare or unusual plant species. They provide travel corridors and forage for a variety of species such as bears, ungulates, and wolves, depending on their position in the landscape. Bogs are often associated with shallow open water; invertebrates and amphibians may use these areas for various stages of their life cycles.

12.5.3.2 Fen Wetland Functions

Fen Hydrological Functions

The hydrological functions of fens are low to moderate (Hanson et al. 2008). For example, fens can provide some mitigation of local flooding but the value of this function is largely related to downstream flows and the potential impacts of changes to these flows. However, fens provide some mitigation for stream bed scouring, sediment loading, and temperature mitigation for cold-water species.

Fens provide a groundwater recharge capacity; however, the capacity is highly dependent on basin size, location in the watershed, substrate, and local groundwater gradients (Hanson et al. 2008). Smaller wetlands have a greater perimeter to volume ratio than larger wetlands and have been demonstrated to better support groundwater recharge than larger wetlands (Weller 1994).

Fen Biochemical Functions

The biochemical functions of fens are potentially high (Hanson et al. 2008). This potential is difficult to quantify because biochemical functions are influenced by the collapsed area left after the seam is mined and site-specific factors such as ambient temperature, local geology, base water chemistry, vegetation species, aspect, slope, drainage, etc. (Almas and Singh 2001; Brunham and Bendell 2010). It is generally accepted that fen ecosystems can improve water quality; actively facilitate nutrient storage, transformation, and transport; and store carbon (Mitsch and Gosselink 2000).

Fens, like other wetland classes, facilitate the nitrification/de-nitrification process (Reilly 1991; Gilliam 1994). Fens can be considered both carbon sinks and carbon sources depending on the wetland condition. This is determined by the stability of the ecosystem and by whether the system is developing (active peat accumulation and vegetation deposition), flooded (such as during extreme precipitation events), drained (through anthropomorphic disturbance), or in decline (drying out through natural successional processes).

Fen Habitat Functions

The habitat function of fens is related to their biological productivity (Hanson et al. 2008). The biological productivity of a fen can be attributed to a number of factors, including surrounding landscape type and use, stand age, complexity of landscape patterns, availability of specific habitat types for species of the area, uniqueness of habitat types available at various scales, and adjacency of habitat types. Collectively, fen wetlands are among the most floristically diverse of all wetland classes (Bedford and Godwin 2003). This increases habitat diversity and complexity and contributes to habitat function. In early spring, open sedge areas provide forage opportunities for grizzly bear and black bear. Treeless wetland areas adjacent to mature trees provide forage habitat for bat species throughout the growing season (Plate 12.5-2).

In spring and summer, emergent and submergent vegetation in open water areas provide browse for moose. Migratory bird species and signs of use are common, particularly where fens are in complexes with shallow open water.

Plate 12.5-2. Wf04 fen at site MW12.

12.5.3.3 Marsh Wetland Functions

Marsh Hydrological Functions

The hydrological function of marshes is greater than other wetland classes (Hanson et al. 2008). The hydrological function of marshes typically includes water flow moderation, groundwater recharge, and shoreline erosion protection. Marshes adjacent to surface water features, such as lakes, rivers, and creeks, receive a portion of their water during high water events. Marsh wetlands in these positions are extremely valuable for stormwater retention, mitigating channel alterations, stream bed scouring and sedimentation downstream that commonly occur during flood and high rainfall events. They can also be valuable for temperature mitigation for cold-water species using these areas.

Marsh Biochemical Functions

The biochemical function of marsh wetlands is classified as high but varies depending on local physical processes, interaction between root/bacteria assemblages, substrate, and oxidation (Hanson et al. 2008). Biochemical functionality can range among wetland complexes and temporally within a single wetland, depending on season and the processes indicated above. Marshes, like other wetland classes, facilitate the nitrification/de-nitrification process (Reilly 1991; Gilliam 1994) and are thus major contributors to the nitrogen cycle in the environment. Phosphorus absorption is facilitated through the deposition of suspended solids or dissolved phosphorus within wetlands. Floodplain marsh complexes tend to be important sites for phosphorus removal from the water column and improving water quality (Walbridge and Struthers 1993).

Marsh wetlands reduce sulphate to sulphide, which is either released to the atmosphere as hydrogen, methyl, and dimethyl sulphides or bound to wetland sediments as complexes of phosphates and metal ions (Mitsch and Gosselink 2000). These sulphides, when released to the atmosphere, can produce condensation nuclei and affect regional climates.

Marshes filter suspended solids in the water column when it comes into contact with wetland vegetation. Live and dead vegetation, leaves and stems, slow down the velocity of the water, allowing suspended solids to settle and thus removing potential pollutants from the water column (Johnston 1991). Marshes can be considered both carbon sinks and carbon sources depending on the wetland condition. This is determined by the stability of the ecosystem, the developmental stage of the ecosystem, and whether it is flooded (such as extended flooding during extreme precipitation events), drained (through anthropomorphic disturbance), or in decline (drying out through natural successional processes).

Marsh Habitat Functions

The habitat function of marsh wetlands is generally high but variable depending on site conditions (Hanson et al. 2008). Marshes are the most heavily used wetland class for most wetland-using wildlife species. They are typically eutrophic and support vigorous growth of vegetation and aquatic invertebrates. They are the favoured wetland class for most waterfowl, amphibians, and semi-aquatic mammals because they provide good cover, open water, and food (MacKenzie and Moran 2004b). Marsh and open water complexes provide opportunities for beaver habitation, which was observed within the local LSA (Plate 12.5-3).

Plate 12.5-3. Wm01 marsh at site MW19.

12.5.3.4 Swamp Wetland Functions

Swamp Hydrological Functions

The hydrological function of swamp wetlands is dependent on the wetland sub-form; it is low for mid-slope or tidal swamp wetlands, but generally high for riparian swamps (Hanson et al. 2008). Treed and shrubby riparian swamp wetlands slow the velocity of runoff and have the capacity to store water for extended periods (Plate 12.5-4).

Plate 12.5-4. Ws07 swamp at site MW05

Swamp Biochemical Functions

The biochemical functions of swamps can be similar to marsh wetlands; variable, but generally rate as quite high compared to other wetland classes and upland ecosystems with the variability arising from local physical processes, interaction between root/bacteria assemblages, substrate, and oxidation (Hanson et al. 2008). Swamps provide numerous biochemical functions such as nutrient and organic export and carbon storage and sequestration. For example, swamps facilitate the nitrification/ de-nitrification process (Reilly 1991; Gilliam 1994), while phosphorus absorption is facilitated through the deposition of suspended solids or dissolved phosphorus within swamp wetlands. This is likely to occur in riparian-associated swamp complexes (Walbridge and Struthers 1993).

Swamps are both carbon sinks and sources depending on the wetland condition, stability, and hydrodynamism. The high accumulation of organic matter and slow decomposition rates of vegetation that can occur in hydrologically stagnate forested swamps enable these swamps to sequester carbon at a relatively higher rate than many other wetland classes.

Riparian swamps have the capability to filter suspended solids in the water column as these solids come into contact with wetland vegetation. Vegetation and detritus slow down the velocity of the water, allowing settling of suspended solids and removal of potential pollutants from the water column (Johnston 1991).

Swamp Habitat Functions

Swamps are capable of producing mature forests and the associated complex vertical structure. This supports more diverse avifaunal assemblages than any other wetland classes (MacKenzie and Moran 2004b). Forested swamps can have an open canopy that appears to be favoured by many bird and bat species (MacKenzie and Moran 2004b; Lausen 2006). The habitat functions of swamp wetlands are considered moderate to high due to habitat diversity and structure. In winter, spring, and summer months, willow swamp complexes can provide moose with thermoregulation sites as well as foraging opportunities (Plate 12.5-4).

12.5.3.5 Shallow Open Water Wetland Functions

Shallow Open Water Hydrological Functions

The primary hydrological function of shallow open water wetlands is water storage within the landscape. Water is held for prolonged periods, extending into the drier summer months and providing a source of freshwater to adjacent ecosystems and wildlife during these periods. Generally, hydrological function of shallow open water wetlands is high (Hanson et al. 2008).

Shallow Open Water Biochemical Functions

Biochemical function is dependent on nutrient/sediment loading rates, flow through rates and volumes, retention time, wetland capacity, volume to surface area ratios, and productivity. As these wetlands are usually relatively small, shallow open water wetlands have a moderate capacity to remove sediments by allowing them to settle out in slower moving waters.

Shallow Open Water Habitat Functions

The habitat function of shallow open water wetlands is highly variable (Hanson et al. 2008) but is always limited to aquatic habitat. Their level of function is dependent on the availability of such habitat within the landscape and the presence of species that may use such habitat. These wetlands provide important open water habitat for migratory birds, mammals, and ungulates such as moose (Plates 12.5-5 and 12.5-6).

Plate 12.5-5. Submergent community at site MW01.

Plate 12.5-6. Western toads require ponds or shallow open water for breeding sites.

12.6 ESTABLISHING THE SCOPE OF THE EFFECTS ASSESSMENT FOR WETLANDS

Scoping is fundamental to focusing the Application/EIS on those issues where there is the greatest potential to cause adverse effects. The scoping process for the Application/EIS consisted of the following five key steps:

- *Step 1:* conducting a desk-based review of available scientific data, technical reports, and other Project examples to compile a list of potentially affected VCs in the vicinity of the Project;
- *Step 2:* carrying out detailed field baseline studies to fill information gaps and confirm presence/absence of VCs;
- *Step 3:* consideration of feedback from the EA Working Group on the proposed list of VCs included in the AIR and the EIS Guidelines;
- *Step 4:* definition of assessment boundaries for each VC; and
- *Step 5:* identification of key potential effects on VCs.

These steps are described in the following sections.

12.6.1 Selecting Valued Components

Valued Components are selected to focus the Application/EIS on the issues of highest concern. Valued Components are specific attributes of the biophysical and socio-economic environments that have environmental, social, economic, heritage, or health significance. To be considered for assessment, a component must be of recognized importance to society, the local community, or the environmental system, and there must be a perceived likelihood that the VC will be affected by the proposed Project. Valued Components are scoped during consultation with key stakeholders, including Aboriginal communities and the EA Working Group. Consideration of certain VCs may also be a legislated requirement, or known to be a concern because of previous project experience.

A scoping exercise was conducted during the development of the draft AIR to explore potential Project interactions with candidate VCs, and to identify the key potential adverse effects associated with that interaction. The results of the scoping exercise were circulated for review by the EA Working Group. Feedback from that process and from additional comments received has been integrated into the EA.

Wetlands were identified as a VC as a result of the scoping process, along with the following sub-components:

- wetland extent; and
- wetland function.

12.6.1.1 Summary of Valued Components Selected for Assessment

Wetlands are regarded as important ecosystems within BC, Canada, and internationally, because they provide critical habitat for fish, birds, and other wildlife (Environment Canada 1991; Milko 1998; Hanson et al. 2008; BC MOE 2010). Many wildlife species in BC use wetland habitat at some point in their life cycle, and many red- and blue-listed species are wetland-dependent (BC MOE 2011).

Because of the value placed on wetlands by local communities and governments, they were selected for specific study within the LSA. Wetland extent and function were selected as VC sub-components because they represent aspects of wetlands that are measurable, valued by society, and respond differently to environmental effects. These sub-components include consideration of spatial distribution, wetland class, total area, and wetland processes. Wetland extent (location and size) was identified as reductions in wetland area results in an alteration of wetland functions, and there is a growing concern over the escalating rate of wetland loss in BC (BC MOE 2010). Wetland function was identified because the processes performed by wetlands have high potential of interactions with values and processes on the landscape such as habitat for critical wildlife species and modification of hydrological regimes. Federal wetland policy and environmental assessment guidelines also request that wetland functions be included in environmental assessments (Environment Canada 1991).

Wetlands play a key role in the maintenance of hydrologic cycles, wildlife habitat, nutrient cycling, water quality, biodiversity, and carbon sequestration. Wetlands also provide habitat for rare plants as well as plants of cultural and/or economic importance. They are unique assemblages from an ecological perspective, transitional communities between upland terrestrial communities and aquatic communities. The functions and ecological processes that occur in wetlands are vital to ecosystems and organisms at a much greater scale than their localized boundaries and limited extent suggests.

Valued Component sub-components were identified by integrating a number of important information sources including provincial and federal policy, scientific literature, and professional expertise (Table 12.6-1). A goal of the Application/EIS was to integrate TK/TU into Project development wherever possible. Although no direct feedback specific to wetlands was received from any of the Aboriginal groups during consultation, previous information has indicated that wetlands contribute to the economic, social, and cultural well-being of First Nation's citizens, because they contain or support culturally significant species such as moose, some migratory waterfowl, fish, and aquatic plants.

Table 12.6-1. Wetlands Valued Components Included in the Effects Assessment

Valued Components	Identified by*				Rationale for Inclusion
	AG	G	P/S	Other	
Wetlands (extent and function)	X	X			First Nations value wetlands and wetland-dependent species (Chapter 20). There is a growing concern over the escalating rate of wetland losses in BC (BC MOE 2011). Wetland extent often supports wetland function. Wetland extent is easily quantifiable and potential effects can be predicated directly through a footprint analysis. Federal policy is of no-net-loss to wetland function.

**AG = Aboriginal Group; G = Government; P/S = Public/Stakeholder*

No wetland-related VCs that were considered as candidates were excluded from the effects assessment.

12.6.2 Selecting Assessment Boundaries

Assessment boundaries define the maximum limit within which the effects assessment is conducted. They encompass the spatial and temporal extent within which the Project is expected to interact with the VCs. They also consider the constraints that may be placed on the assessment of those interactions due to political, social, and economic realities (administrative boundaries), and limitations in predicting or measuring changes (technical boundaries). The definition of these assessment boundaries is an integral part of the assessment of wetlands and encompasses possible direct, indirect, and induced Project effects on wetlands.

12.6.2.1 Spatial Boundaries

Mine Site Assessment Footprint

To assess Project-related impacts on wetlands, a Mine Site Assessment Footprint (the Assessment Footprint) was created around proposed infrastructure (Figure 12.6-1). It was created based upon expected locations of infrastructure while incorporating the possibility of changes in the final location of infrastructure. Within the Assessment Footprint, all wetlands are considered lost. Project caused effects outside this boundary are determined by the activity or type of infrastructure present.

Subsidence Footprint

To assess potential effects related with subsidence caused by longwall mining, polygons delineating the longwall mining panels were created in GIS. The polygons were drawn based on the mine plan, identifying the number of panels to be mined vertically. The final polygon boundaries indicate the location of all longwall mining areas and the number of panels to be mined vertically in each area. Based on recommendations, a 200 m buffer was applied to the external footprint to identify the potential extent of subsidence or horizontal displacement on the grounds surface (X-traction Science and Technology 2014). The Subsidence Footprint will be used to indicate where the effects of subsidence on wetlands may be greatest. This is based on the premise that the magnitude of subsidence increases proportionally with the number of panels mined vertically.

Local Study Area

The wetland LSA is 14,852 ha in extent and is defined by a buffer extending at least to the height of land or a 1 km buffer around the outer limits of the proposed infrastructure and the extent of underground mining (Figure 12.5-2). The boundary was expanded from the LSA defined in the *Murray River Coal Project: Wetland Ecosystem Baseline Studies* (Appendix 12-A) to include the extent of subsurface development associated with the Project. This was done to ensure potential changes related to subsidence could be assessed. Where appropriate, watershed height-of-land borders were used as these provide physical barriers to Project-related effects.

Regional Study Area

The Regional Study Area (RSA) is 2,276 km^2 and is the same RSA used in the *Murray River Coal Project: 2010 to 2012 Terrestrial Ecosystem and Vegetation Baseline Studies* (Rescan 2013; Figure 12.5-1).

Design of the RSA took into account the area that provides habitat for wildlife species that may come into contact with proposed Project infrastructure during the course of a season or a lifetime. Other ecological factors, such as height of land, were also considered when delineating boundaries. Project-specific wetland mapping was not done within the RSA, because the large size of the area and the footprint nature of Project effects, which precludes any effects from occurring great distances from the Project assessment footprint. However, regional wetland extent as identified through Predictive Ecosystem Mapping (PEM) was calculated. A total of 10,285 ha of wetlands were identified by PEM and are discussed in the *Murray River Coal Project: 2010 to 2012 Terrestrial Ecosystem and Vegetation Baseline Studies* (Rescan 2013).

12.6.2.2 Temporal Boundaries

- **Construction**: 3 years;
- **Operation**: 25-year run-of-mine life;
- **Decommissioning and Reclamation**: 3 years (includes project decommissioning, abandonment and reclamation activities, as well as temporary closure, and care and maintenance); and
- **Post Closure**: 30 years (includes ongoing reclamation activities and post-closure monitoring).

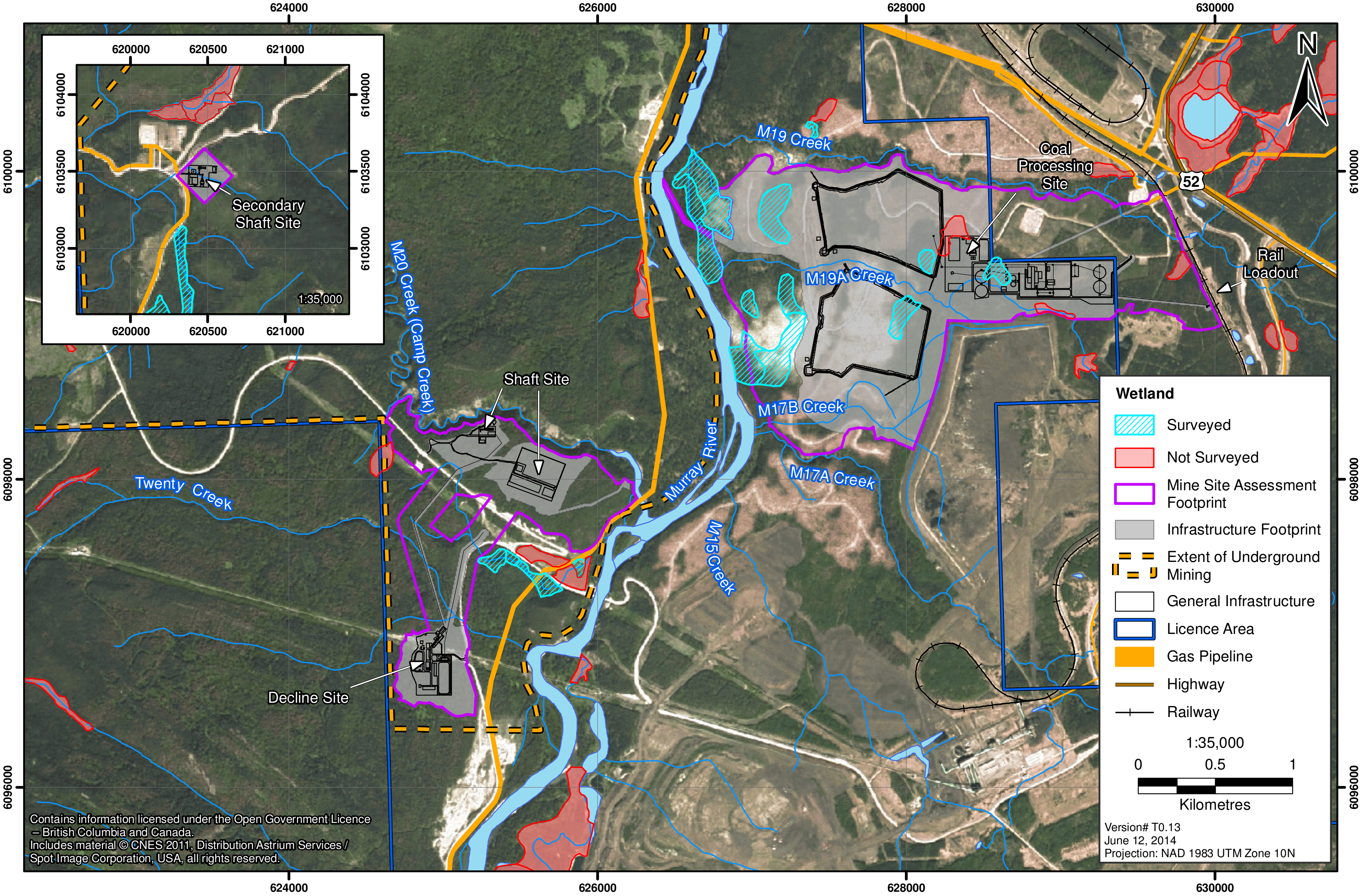
12.6.2.3 Administrative Boundaries

Administrative boundaries did not directly influence the assessment of wetlands.

12.6.2.4 Technical Boundaries

Technical boundaries did not directly influence the assessment of wetlands.

Figure 12.6-1
Assessment Footprint to Identify Potential Effects on Wetlands



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Projection: NAD 1983 UTM Zone 10N

12.6.3 Identifying Potential Effects on Wetlands

12.6.3.1 Summary of Potential Effects to be Assessed for Wetlands

Potential effects of the Project on wetlands follow one of two pathways: (1) Project component interaction with wetland extent and function resulting in a loss of extent and function; and (2) Project component interaction with one or more wetland functions resulting in an alteration of one or more wetland functions.

The effects on wetland extent that follow the first pathway are quantified through a footprint analysis of the Project infrastructure using GIS analysis. Project areas that do not affect wetlands are excluded from further effects assessment for the purposes of extent analysis.

A precautionary approach was used to identify effect on function where loss of extent occurs. It is assumed that current wetland function is at or near maximum unless otherwise identified. An effect on wetland extent will therefore result in an effect on wetland function of the same magnitude.

Effects on function that follow the second pathway have the potential to result in an alteration of wetland function. These effects are identified through a second footprint analysis that uses buffers to identify effects on function.

Effects on wetland function can be assessed using wetland functions characterized for each wetland class (Hanson et al. 2008). Other effects of the Project on wetland function can be identified by assessing proposed land uses adjacent to wetland communities and the possible effects on wetland function (wetland area within the buffers used to identify effects). This type of interaction may result in:

- alterations to wetland hydrological function through subsidence, ditch construction, culverts, watercourse crossing, or other types of alteration of flow;
- alterations to wetland biochemical function through subsidence, sedimentation, dustfall, site runoff, alteration of hydrology or point source discharge;
- alterations to wetland functional diversity through the introduction of invasive plant species, changes in ecosystem function related to subsidence, or loss of adjacent wetland areas; and
- alterations to wetland habitat function through subsidence, fragmentation, change of vegetation structure, or change of water quality or quantity.

12.6.3.2 Hydrologic Effects

Hydrological effects are difficult to measure, but the effects of excavation and activities such as ditching can have substantial upslope and downslope effects. Depending on soil conditions, ditch spacing of up to 300 m can alter wetland hydrology enough to make it suitable for tree growth (Skaggs et al. 2011).

Structures (buildings, roads, etc.) alter water movement through a variety of methods. The creation of impervious surfaces reduces infiltration rates into groundwater and changes the timing and quantity of water flow in wetlands (Azous and Horner 2010). Compaction of soil and loss of pore space can reduce infiltration rates and obstruct or reduce groundwater flow, depending on soil depth, porosity, and other characteristics that influence groundwater (Schack-Kirchner, Fenner, and Hildebrand 2007). Surface runoff water flow can also be increased by the removal of vegetation or routing of ditches (Ziemer and Lisle 1998). Ditches can also result in dewatering of wetlands by interrupting subsurface and surface water flow, allowing rapid water drainage and redirection. Ditches can also increase surface water flow to wetlands when water is directed in channels into wetlands and exceeds infiltration capacity. Both dewatering and impoundment can result in permanent shifts in vegetation communities and alteration of habitat types.

Changes in the timing and quantity of water entering wetlands will influence the functions that wetlands can provide (Mitsch and Gosselink 2000). Alterations to wetland functions will continue to occur as new hydrological regimes in affected wetlands become established. Possible changes to wetland functions may include alteration of habitat due to altered successional pathways, hydrodynamics, and hydrological connectivity; water quality treatment; and nutrient and organic export (Odland and del Moral 2002; Sheldon 2005).

Subsidence caused by underground resource extraction from oil and gas or longwall mining has been shown to alter hydrologic regimes (Morton, Bernier, and Barras 2006; NSW Department of Planning 2008; Hu and Xiao 2013). Changes in horizontal and vertical fracturing, ponding, and drainage patterns due to subsidence can have dramatic effects on wetland function and extent. Hydrologic effects due to subsidence are addressed in greater detail in Section 12.6.3.8.

12.6.3.3 Fragmentation Effects

Fragmentation affects upland habitat and wetland habitat through direct and indirect habitat alteration (Trombulak and Frissell 2000). The term *hyperfragmentation* has been used in reference to the effects on wetlands when typical upland fragmentation occurs in association with hydrological fragmentation and biotic changes that encompass many functions and processes (Trombulak and Frissell 2000). Fragmentation has multiple effects on wetland functions. Isolation of species has been found to reduce species richness and abundance for many taxonomic groups (Harris 1988). Organisms with limited dispersal are most affected (Brown, Smith, and Batzer 1997). However, even species with high dispersal abilities may experience small population decreases associated with the disruption of cover from land clearing (Lynch and Whigham 1984). Fragmentation can also impact the hydrological functions of wetlands by changing water flow into and out of wetlands, altering their connectivity and hydrodynamics (Sheldon 2005).

12.6.3.4 Edge Effects

While wetlands are themselves edges, they have microclimates with gradients moderated by the surrounding forest edges. Changing these edges has effects on these gradients. Most measurable physical environmental effects on vegetation associated with linear features such as roads appear not to extend beyond a distance of 100 m. Many of the changes associated with microclimate occur within one tree length of the dominant trees (Spittlehouse, Adams, and Winkler 2004). Most likely, the distance over which edge effects occur will be less in open (treeless) habitats such as wetlands but changes in amount of light, temperature, wind, other variables can affect wetland vegetation communities. Edges are also common sites for invasive species dispersal that may have dramatic effects on wetland communities.

12.6.3.5 Dust Effects

Dust can have various effects on the health of vegetation depending on the amount and frequency of dusting, the chemical properties of the dust, and the receptor plant species. In addition to blocking photosynthesis, respiration, and transpiration, dust can also cause physical injuries (Farmer 1993).

Cumulative impacts through long-term dust fall and sedimentation can result in a shift in vegetative communities and thus a shift or loss of biochemical and habitat functions. Dust impacts can be substantial in areas such as road sides where the traffic rate is high (Padgett et al. 2008). Wetlands provide natural funnels that facilitate the spread of dust and can be expected to experience greater dust dispersal than treed ecosystems.

The chemical effects of deposited dust often have greater impacts than the quantity of dust (Farmer 1993). Chemical effects can result from direct deposition on foliage or other tissues or through uptake through fine roots from the soil. Plant growth may be affected by dust-induced changes in soil pH, nutrient availability, radiation absorption, and leaf temperature and chemistry (Eller 1977; McCune 1991; Walker and Everett 1991; Farmer 1993; CEPA/FPAC Working Group on Air Quality Objectives and Guidelines 1998; Anthony 2001). Evergreen shrubs may experience greater cumulative dusting than deciduous shrubs as they retain leaves from year to year (Auerbach, Walker, and Walker 1997). Chemically active dusts that are alkaline, acidic, or bio-available will have the largest effects on vegetation, ecosystem, and biochemical pathways (Grantz, Garner, and Johnson 2003). Heavy metal concentrations and the amount of vehicle traffic are related and are observable 200 m or more from a road (Dale and Freedman 1982).

Soil pH may be altered by dust inputs. The effects of pH changes on wetlands can include loss of listed species, and alterations to functional diversity and habitat functions. The effects of pH change are species dependent. Species tolerant of high or low pH conditions will respond positively within a range of acidity levels, outside of which they will generally decline (Farmer 1990). As acidity increases, there is a general decrease in species diversity in lacustrine wetlands and a presumed loss of functional diversity (Farmer 1990). The effects of pH changes are more pronounced on invertebrates, amphibians, fish, and birds and include a general decrease in habitat quality associated with greater acidity (Sheldon 2005).

Biochemical functions are also susceptible to pH changes. In bog wetlands, pH changes can result in the release of heavy metals or reduced capacity to bind toxic metals; however, some contaminants can be more tightly held at low pH (Sheldon 2005).

12.6.3.6 Sedimentation and Waterborne Pollutant Effects

Sediment deposition to wetlands from roads can effect wetland function (Bilby, Sullivan, and Duncan 1989). Sloughing of road fill directly into wetlands can occur during and following construction activities. Additionally, maintenance activities such as grading and road repair have the potential to expose soils and cause sediment deposition in wetlands. Road use during the life of the mine will also result in sedimentation, and sediment rates are related to the volume of traffic (Bilby, Sullivan, and Duncan 1989). Vehicle size can also be an important determinant in dust production from roads.

Sediment accumulation in wetlands can cause shifts in wetland plant species composition and abundance by changing: nutrient concentrations; physical conditions that alter functional diversity (Tilman et al. 1997); biochemical functions such as nutrient export or carbon storage; or habitat quality for fish, invertebrates, amphibians, and other organisms by changing habitat depth (Sheldon 2005). Invasive plant species are often favoured over native plant species in cases where they tolerate disturbance or exposed soils offer favourable germination conditions (Pyke and Havens 1999). Sedimentation can also reduce the storage capacity of a wetland and reduce the ability of wetlands to ameliorate floods (Sheldon 2005). It is important to reduce sedimentation in wetlands as the effects are long-lasting and cannot be mitigated (Hagans, Weaver, and Madej 1986).

Changes in nutrient inputs associated with dust or burning of fossil fuels can have multiple effects on wetland functions. Enrichment with nitrogen (N) and other nutrients that are essential to plant growth can increase primary production and biomass, which can lead to changes in plant species community composition (Wetzel and Valk 1998). Low nutrient systems, such as bogs, are most sensitive to these additions and can experience floristic shifts that do not favour species adapted to low nutrient conditions (Moore et al. 1989). Increased biomass production may also result in reduction in water storage capacity and flood water reduction (Adamus et al. 1991).

The functions related to water quality may improve in moderately enriched wetlands, but with high levels of enrichment or eutrophication, algal blooms may occur and negatively affect water quality, plant species composition and diversity, and inhibit the ability of a wetland to reduce nitrogen levels through denitrification (Majora, Mayfielda, and Barkerb 1988; Ettema et al. 1998; Adamus, Danielson, and Gonyaw 2001). In nutrient poor systems, the addition of nutrients can change plant community structure, which in turn modifies wetland pH. This can alter adsorption of cations, resulting in the release of heavy metals or reduced capacity to bind toxic metals (Sheldon 2005).

Processing of toxic compounds by microbial communities in wetlands, especially metals and petroleum products, has been documented by numerous researchers (Nyman 1999; Sikora et al. 2000). The effects of toxic contaminants on wetland plant species is not well established (Sheldon 2005). However, the negative impacts on other wetland species including invertebrates, birds, and fish have been well established (Sheldon 2005).

Selenium is a major concern for coal mines as it has the potential to bio-accumulate in plant tissue and organisms such as benthic invertebrates, fish, water fowl, and other animals that feed in wetlands (Chapter 8 - Assessment of Surface Water and Aquatic Resources Effects).

12.6.3.7 Invasive Species Effects

Invasive species have the potential to negatively affect native plant and animal communities, especially where native biodiversity has been reduced by other impacts (Dukes 2002). The effects of invasive species on native diversity have been well documented, are growing in magnitude, and are the second greatest threat to listed species after habitat loss (Wilcove et al. 1998; Enserink 1999).

Some wetland types, such as marshes, fens, swamps and other wetlands with low canopy cover, are more susceptible to invasive species than forested wetlands (Detenbeck et al. 1999). Depending on the species involved and pre-existing conditions, wetlands can experience dramatic loss of biodiversity from 50 to 100% as a result of colonization by invasive plant species (Sheldon 2005). In BC, there are 163 species of plants identified as nuisance, noxious, or invasive (E-Flora BC 2012). These include species that have moderate to high effects on wetlands such as purple loosestrife (*Lyhtrum salicaria*), giant knotweed (*Polygonum sachalinense*), and canary reed grass (*Phalaris arundinaceae*; (Voller and McNay 2007).

Anthropogenic disturbances, particularly vegetation removal and site disturbance, are key determinants of colonization by invasive species (Detenbeck et al. 1999). Excessive nutrient input can provide the opportunity for fast growing species to invade wetlands and displace native species (Adamus, Danielson, and Gonyaw 2001). Hydrological disturbances such as ditches and culverts have also been associated with invasive species (Zedler and Kercher 2004), and sedimentation has been shown to increase rates of invasive colonization (Kercher and Zedler 2004). Roads, power lines and other linear features are key causes of increased rates of introduction (Trombulak and Frissell 2000). Roads provide three mechanisms that increase exotic species spread (Trombulak and Frissell 2000), namely by:

- providing habitat by altering conditions (hydrological regimes, soil disturbance, and light regimes);
- reducing competition from native species through removal or stress; and
- acting as corridors for dispersal by human or animal vectors.

Invasive plants are often found along road verges and other recently disturbed areas. Once established, they can decrease vegetation biodiversity, forest and range productivity, and ultimately reduce the overall efficacy of reclamation initiatives (Polster 2005b). Vehicles and machinery can carry plant propagules in their tires, undercarriages, or in mud on the vehicle, inadvertently transporting them to previously unaffected areas. In addition to roadside ditches and verges, forest edges are susceptible to the introduction of invasive species propagules from adjacent clearings (Murphy and Lovett-Doust 2004).

When colonization of wetlands occurs, hydrological, biochemical, habitat, and diversity functions can be affected. Some species have the ability to alter the physical nature of wetlands through infilling (high productivity or lower decomposition rates). It is speculated that this can reduce the topographic diversity of a wetland, reducing water volume and distribution and simplifying habitat complexity and species richness (Zedler and Kercher 2004). This can alter the hydrological functions of wetlands by changing the capacity to buffer flood waters (Zedler and Kercher 2004). Higher evapotranspiration rates can also affect wetland hydrological functions by reducing soil moisture and water levels (Ehrenfeld 2003). Invasive species tend to have higher biomass and net primary production than native species which alters biochemical functions (Ehrenfeld 2003). Invasive N fixing plants can dramatically alter N cycling, enriching sites or where plants are high N users, they may deplete soil N reserves (Ehrenfeld 2003). Changes in pH, which can affect pH sensitive wetlands such as bogs, are associated with invasive species colonization (Ehrenfeld 2003). Biodiversity and habitat loss associated with invasive species colonization has been confirmed by numerous studies, and species richness has been shown to be affected by competition for light resources and changes related to nutrient cycling (Richburg, Patterson, and Lowenstein 2001; Zedler and Kercher 2004). Negative impacts on bird, mammal, fish, and invertebrates have all been documented due to invasive species colonization (Benoit and Askins 1999; Weinstein and Balletto 1999; Fell et al. 2003).

12.6.3.8 Effects Due to Subsidence

The general term for changes observed at the ground surface caused by longwall mining is subsidence. The initial subsidence that occurs after mining, called active subsidence, accounts for 90 to 95% of all subsidence, and occurs rapidly within days to months after mining of panels is complete. Residual subsidence can continue over years after mining is completed as compaction of material in the gob (collapsed area left after the seam is mined) continues (Mehnert, Van Roosendaal, and Bauer 1992; L. Holla and Barclay 2000). However, residual subsidence changes are much smaller in magnitude (Bauer 2008).

Subsidence is caused by the removal of coal and the collapse of rock strata into the mined out areas. During longwall mining, coal is removed in panels that are between 150 to 400 m in width and can be 1 to 4 km long. Between each mined panel, chain pillars of coal 10-50 m in width are retained for safety and stability (NSW Department of Planning 2008). As mining proceeds along the working face of the coal seam, mechanical braces are used to support the roof. Once these are removed, the roof collapses into the the gob. This zone of collapse is called the *Caved Zone* and can extend from 3 to 10 times the mining height. Laminated bedrock layers tend to increase the caved zone as they pack densely when they collapse. The *Caved Zone* creates fractures in the zone above (the *Fractured Zone*), which depending on the nature of the rock, increases vertical permeability of the rock strata. The *Fractured Zone* can extend 30 to 60 times the thickness of the mined seam (Coe and Stowe 1984). Above this layer, in what is called the *Constrained Zone*, the rock strata in this zone will crack but as shear and tensional forces have decreased, cracking occurs primarily along horizontal planes, resulting in changes to horizontal permeability of water but limited changes in vertical permeability (L. Holla and Barclay 2000). The *Surface Zone* experiences vertical cracking and vertical permeability increases, albeit to limited depths (up to 15 metres; Coe and Stowe 1984). In complex topography, the S*urface Zone* can experience horizontal as well as vertical cracking and may experience uplift as well as subsidence. This description is based on homogenous structure of strata and will vary depending upon actual strata unit characteristics such as rock mass variations, geological discontinuities, bedding plane direction, mine layout, seam angle, and surface topography (NSW Department of Planning 2008).

The effects of longwall mining are not limited to directly above the mine panel but extend outward along the *angle of draw*. The *angle of draw* is a term used to describe where the limits of subsidence are expressed on the Surface Zone, and it may be 0.35 to 0.45 times the depth to the mined seam (Bauer 2008).

The heterogeneous nature of geological formations, topography, and other variables, can cause complex surface expressions of subsidence. Changes in surface topography can include: tilt, surficial cracking, horizontal as well as vertical changes in permeability, horizontal movement of rock strata, valley closure, and uplift of ground within subsided areas (upsidence).

Tilt occurs primarily along the edges of the areas of extraction and in areas where steep V-shaped valleys are incised, particularly within the angle of draw, which can cause increases in erosion and likelihood of slope failure or rockfall (Shea-Albin 1994). Tilting of wetlands can result in draining of some portions of wetlands and ponding in others, reducing wetland functions and diversity. Tilt can also result in increased scouring of wetlands and increased drainage (NSW Department of Planning 2008).

The effects of subsidence on the shallow groundwater are a consideration during longwall mining. While drawdowns of water into the *Caved* and *Fractured Zone* can lower water tables, this is often prevented by the *Constrained Zone* which has low permeability (Booth 2006). However changes in permeability in the *Surface Zone* due to fracturing can cause head drops. In areas of greater topographic relief, this can result in losses of shallow groundwater through cracks in aquitards (Booth 2006). An aquitards is a zone of low hydraulic conductivity that restricts flow to or from aquifers. They often occur in sufficiently thick soils with high clay contents that have lower conductivity than soils above them and the underlying aquifers (Cherry et al. 2004). Vertical fractures in aquitards or lenses that support perched water tables can result in continuing decreases in water availability in overlying strata and are the most common pathway of loss (Cherry et al. 2004; Booth 2006). Where these are sufficiently close to ground level, this could result in decreases in water availability to vegetation and changes in surface water expression. Recovery of hydraulic potential may never occur, take years or decades to recover, or recover relatively quickly. As an indicator of groundwater recover rates after subsidence, wells that draw from perched aquifers with aquitards that have been fractured have lower rates of recover (Werner and Hempel 1992). Rauch (1989) found that wells on flat ground recovered quickly, wells on steep slopes recovered slowly, springs originating on steep slopes did not recover, and where overburden thickness was less than half the panel width, wells did not significantly recover. Hutcheson et al. (2000) found that ridge tops were affected by longwall mining, and that the creation of aquitards due to mine collapse increased ridge top hydraulic connectivity with groundwater. The effects of longwall mining on groundwater are complex and heavily reflective of the hydrogeological setting and mine layout.

Changes in groundwater occur beyond the zone of subsidence or angle of draw. The extent of this change is determined by the hydraulic characteristics of the aquifer, and often is limited to a few hundred metres in extent due to the low permeability of strata (Booth 2006). However, the pathways that govern flow may be better indicators of the horizontal zone of influence than attempts to identify zones of influence determined by angles related to mining depth, height, and width (Hutcheson et al. 2000).

The effects of increased permeability can include loss of standing pools, ponding of water, adverse effects on water quality, and loss of surface and shallow groundwater flows to deeper horizons (NSW Department of Planning 2008). Formation of cracks in the ground surface can occur, especially in zones of tension located at the edge of subsidence (Bauer 2008). Cracks may be visible on rock outcrops, but are not detectable when covered by soil (McNally and Evans 2007). Losses of surface water have been reported in sandstone dominated bedrock due to cracks caused by subsidence from longwall mining (NSW Department of Planning 2008).

Ponding occurs when wetlands and ground sink below water tables and become inundated due to subsidence. In Louisiana this has been put forward as the principle cause behind historical wetland losses in the state (Morton, Bernier, and Barras 2006; Hu and Xiao 2013). Ponding can also occur when fractures in aquitards occur over aquifers with hydraulic head greater than the height of the ground surface (Cherry et al. 2004). Where ponding occurs, wetlands can become submerged and many of the biochemical and habitat functions they provide may be lost.

Primary productivity and growth rates can also be affected by subsidence. Negative effects on agricultural crop yields due to subsidence have been documented (Kundu and Ghose 1994). These may be caused by ground subsiding in areas with elevated water tables, ponding, or changes in surface water runoff. While the Project does not occur under agricultural lands, much of the area that will experience subsidence is forested and changes to productivity may occur. Productivity declines in wetlands could reduce habitat functions and functional diversity.

Lateral movement of rock from 20-60 mm may occur up 1.5 km from the edge of longwall mining panels, depending on site geology. This occurs as horizontal stress can remain in buried strata. After mining, these stresses can be released and are expressed particularly in gorges or V-shaped valleys. Valley closure can occur as this incised topography interrupts these horizontal stresses. The valley floors are then susceptible to uplift or upsidence (the uplifting of subsided ground; L Holla 1997). This can result in near surface fractures that affect surface water movement, quantity, and quality. Shearing and uplift in bedrock can create planes that can direct surface water into underground aquifers (NSW Department of Planning 2008). Changes in quality result from alterations in iron precipitates (McNally and Evans 2007) or increases in salinity (Hu et al. 1997; Giambastiani et al. 2007). Where wetlands occur downstream, these alterations in quality and quantity can have negative effects on wetland biochemical, hydrologic, habitat, and diversity functions as well as changes in extent.

While general mechanisms and effects of subsidence are known, predicting specific effects of subsidence on specific wetland extent or functions are problematic due to the complex interactions between subsidence, ground water flow, and geology in areas with variable topography and geology.

12.6.4 Footprint Analysis

A footprint analysis was used to identify which Project areas and which Project components interact with wetlands. This was done using the Assessment Footprint to represent the maximum extent of disturbance and the Subsidence Footprint, consisting of a 200 m buffer around the mine panels (Figure 12.8-6). Consideration of effects on wetland function included: subsidence, hydrological connectivity, fragmentation, edge effects, dustfall, sedimentation and water quality, and invasive species. The potential effects of Project components or activities on wetland extent or function are characterized in Table 12.6-2. Where Project/wetland interactions were identified during Construction, they were carried through to Post Closure. Reclamation will include wetlands; however, this is not expected until Decommissioning and Reclamation, so effects on wetlands are still identified through all Project phases. Although the effects analysis was done using the footprint for the maximum extent of disturbance, Project phases were used to identify when the effects were expected to start.

Table 12.6-2. Ranking Potential Effects on Wetlands

	Loss of Wetland Extent	Alteration of Wetland Function
Construction		
Underground Mine	L	L
Coal Processing Site	H	H
Shaft Site	L	M
Decline Site	L	M
Traffic and Transportation	L	M
Operation		
Underground Mine	L	L
Coal Processing Site	H	H
Shaft Site	L	M
Decline Site	L	M
Secondary Shaft Site	L	M
Traffic and Transportation	L	M
Subsidence Footprint	H	H
Decommissioning and Reclamation		
Underground Mine	L	L
Coal Processing Site	H	H
Shaft Site	L	L
Decline Site	L	L
Secondary Shaft Site	L	L
Traffic and Transportation	L	M
Subsidence Footprint	H	H
Post Closure		
Underground Mine	L	L
Coal Processing Site	L	L
Shaft Site	L	L
Decline Site	L	L
Secondary Shaft Site	L	L
Traffic and Transportation	L	L
Subsidence Footprint	H	H

Notes:

L	*Negligible to minor adverse effect expected; implementation of best practices, standard mitigation and management measures; no monitoring required, no further consideration warranted.*
M	*Potential moderate adverse effect requiring unique active management/monitoring/mitigation; warrants further consideration.*
H	*Key interaction resulting in potential significant major adverse effect or significant concern; warrants further consideration.*

12.7 EFFECTS ASSESSMENT AND MITIGATION FOR WETLANDS

12.7.1 Key Effects on Wetland Extent and Function

The project components that will affect wetland extent include development of the Coarse Coal Rejects Piles, Coal Processing Plant, and subsidence due to longwall mining. Within the Assessment Footprint, there are eight wetlands that occur within and one that overlaps the south eastern corner of the Coal Processing Site. While only four of these wetlands have spatial overlap with planned infrastructure, all are considered as lost where they overlap the Assessment Footprint as movement of infrastructure and construction related impacts within the Assessment Footprint are highly likely (Table 12.7-1).

Table 12.7-1. Wetland Buffer Guidelines

Environmental Feature	Reserve Zone	Management Zone	Total Buffer
Small Wetlands (< 5 ha)	10 m	20 m	30 m
Large Wetlands (> 5 ha)	10 m	30 m	40 m
Wetland Complexes	10 m	40 m	50 m

12.7.1.1 Loss of Extent

Wetland loss of extent has been determined using the Assessment Footprint. Where a wetland occurs within the footprint area or is bordered on three or more sides by the footprint, the wetland and its associated functions are considered lost.

12.7.1.2 Alteration of Function

Alteration of wetland function has been identified based on the proximity of wetlands to the Assessment Footprint and Project infrastructure. Wetland functions adjacent to these sites were deemed to be potentially altered; it is quite likely that they will remain unaffected where they are not:

- subject to subsidence;
- hydrologically connected to the lost areas;
- fragmented;
- subject to edge effect;
- subject to dust deposition;
- subject to sedimentation;
- subject to waterborne pollutants; or
- subject to the introduction of invasive wetland plant species.

Subsidence can affect wetland function by altering site hydrology through changes such as ponding or dewatering. To understand the amount and possible general effects of subsidence, modelling was completed by Xtraxtion Science and Technology (2014). Predictions of subsidence based on the current mine plan were completed on cross sections that were chosen to characterize subsidence based on the number of panels being mined vertically. The cross sections include areas with one to five panels being mined vertically and identified the associated predicted subsidence with increasing panel numbers. As effects are expected to increase in magnitude with number of panels mined, the Subsidence Footprint was used to identify wetlands according to the number of panels being mined beneath them.

The sources of potential alteration of wetland function by the Project include changes in wetland hydrological functions due to changes in surface and groundwater flow caused by subsidence or the development of the coarse coal rejects dumps in the Coal Processing Site.

Fragmentation and edge effects can alter wetland habitat functions. These alterations are not restricted to the time period in which they occur and may take decades to manifest as indicated by parameters such as species abundance and diversity, especially where species with low dispersal rates occur.

Wetlands are an endpoint receptor for air quality and surface water quality effects. Dust inputs from the Decline, Shaft, and Coal Processing Sites, and use of the roads could alter biochemical and habitat functions by changing pH and nutrient concentrations.

Seepage from the Coarse Coal Reject Piles containing selenium has the potential to impact fish and wildlife that feed in wetlands. Selenium levels are expected to exceed water quality guidelines (WQG) value of 2 micro-g/L (Nagpal and Howell 2001) in M19A Creek which flows into wetlands at the base of the Coal Processing Site. These wetlands may provide reducing conditions that favour the formation of organo-selenium compounds. These have been shown to bioaccumulate in fish and waterfowl from dietary sources (USEPA 1998); however, effects on vegetation are less of a concern. Bioaccumulation of selenium in fish and wildlife and is addressed in Chapters 9 and 13, respectively.

Sedimentation and contaminants related to clearing of project footprints can affect habitat, biochemical processes, and hydrological functions in wetlands by changing physical properties related to water storage and treatment. One of the most serious effects on wetland function is the introduction of invasive species, which can alter all wetland functions by changing abiotic and biotic processes.

Where wetlands are subject to any of these effects, the processes they modify and functions they perform will be altered. Wetlands with potentially altered wetland functions were identified using methods described in Section 12.8 using probability and consequence ratings that identified interactions between Project effects and wetland function.

12.7.2 Mitigation Measures for Wetlands

12.7.2.1 Mitigation Measures for Alteration of Wetland Functions

Implementing mitigation strategies will minimize alteration of wetland function. Avoiding wetland areas is the best way to limit potential effects. Mitigation measures will concentrate on reducing hydrological effects, habitat fragmentation, edge effects, dust deposition, sedimentation and water born pollutants, and invasive species effects on wetland functions that may be associated with the Project. Management plans relevant to mitigating effects on wetland functions include:

- Air Quality Management Plan – Section 24.2;
- Selenium Management Plan – Section 24.10;
- Subsidence Monitoring Plan – Section 24.15;
- Invasive Plant Management Plan – Section 24.11;
- Site Preparation and Soil Salvage – Section 24.4;
- Spill Response Plan – Section 24.18;
- Erosion and Sediment Control Plan – Section 24.5;
- Wildlife Plan – Section 24.12; and
- Metal Leaching and Acid Rock Drainage Plan – Section 24.7.

Although monitoring is not a mitigation measure, the information collected during monitoring will inform future development of appropriate adaptive management strategies for wetland management. Tools and practices to minimize Project effects on wetland function, as can be accomplished through the institution of environmental management plans, are discussed below.

Hydrological Effects

To reduce the effects of loss of hydrological connectivity, mitigation measures should follow recommendations in the Site Preparation and Soil Salvage (Section 24.4), Subsidence Monitoring Plan (Section 24.15). Site preparation and soil salvage measures will help restore soil hydrological characteristics in reclaimed areas through proper soil handling measures to reduce the potential of soil compaction. While these measures are important, due to the limited reclamation occurring in or adjacent to wetlands, no significant mitigating effects on a wetland hydrology are anticipated. The Subsidence Monitoring Plan is an important tool in identifying changes related to subsidence, but is not mitigation tool and was not considered in assessing significance.

Fragmentation Effects

Following recommendations in the Wildlife Plan (Section 24.12) will also help meet the target of minimizing loss of wetland functions related to fragmentation. Buffers retained to protect values such as high quality moose winter range, dens for bears, fisher, marten, and western toad will help reduce fragmentation of habitat. As these are not spatially defined, they were not considered in assessing significance.

Edge Effects

Wildlife and wildlife habitat areas that are located in or are associated with wetlands are to be protected by strategies identified in the Wildlife Plan (Section 24.12). Additional mitigation for edge effects can be found in the Invasive Plant Management Plan (Section 24.11).

If maintenance and operation activities must take place within sensitive periods, appropriate preconstruction and operation surveys are to be conducted to ensure minimal risk to wetland habitat associated with wildlife, birds, and amphibians. Sensitive periods, specific guidelines, and applicable legislation for species of concern are presented in the Wildlife Plan (Section 24.12). While these plans will reduce edge effects, the spatial effects of these plans are not defined and were not considered in assessing significance.

Dust Effects

Dustfall impacts will be partially mitigated through the: Air Quality and Dust Control Plan (Section 24.2) and Site Access Plan (Section 24.17) along all access corridors and work locations as required. Dust emissions from roads and other project infrastructure were assumed to be partially mitigated by watering, enclosed or covered stockpiles and conveyors, fog and sprinkler systems, and a wet deduster used with the coal dryer.

Sedimentation and Water Borne Pollutants Effects

To mitigate the effects of development on the biochemical and habitat functions of wetlands, the quality of any discharge will be thoroughly scrutinized through environmental monitoring. The two types of discharge are:

- point source (e.g., end of pipe or ditch discharge or seepage into a seepage collection pond); and
- non-point source (i.e., surface runoff).

Selenium contamination will be largely mitigated by the installation of geosynthetic liners under the Coarse Coal Reject Piles. Seepage quality will be monitored as part of the Selenium Management Plan (Section 24.10). Recommendations on mitigating the effects of sedimentation and pollutant on wetlands are included in the Erosion and Sediment Control Plan (Section 24.5).

Adverse effects of herbicide use, insecticide use, and road ploughing on wetland functions will be mitigated through the implementation of the Access Management Plan (Section 24.17) and the Invasive Plants Plan (Section 24.11).

The Spill Response Plan (Section 24.19) details measures intended to prevent and mitigate the effects of deleterious substances discharged into the environment. It also provides emergency response procedures should a spill occur. These measures were considered fully effective at reducing the probability and effects of a spill on wetlands.

Invasive Species

Implementation of the Invasive Plants Plan (Section 24.11) is integral to reducing the probability of introducing invasive species to wetlands. Avoiding introducing invasive species is central to circumventing costly measures required for their eradication to protect wetland functions.

The Operational Plan for invasive species will manage for the Northwest Invasive Plant Council of BC priority species throughout the Project area. A site-specific plan will be developed by the

Project's Environmental Manager through discussion (as needed) with the Invasive Plant Council, environmental scientists, and local governing agencies. The plan will draw upon the recent *Pest Management Plan for Invasive Alien Plants on Provincial Crown Lands in Central and Northern British Columbia* (BC MOFR 2010b), and the *Invasive Alien Plant Program: Reference Guide* (BC MOFR 2010a), which outline an Integrated Pest Management approach for invasive alien plants, under the authority of several partnering ministries.

The implementation of the invasive species management plan was considered to only partially mitigate invasive species effects due to the difficulty of controlling invasive species, especially areas where multiple road users are present and the potential for invasive species spread is greater.

12.7.2.2 Wetland Buffers

To support the maintenance of wetland function outside of Project footprints, reserve and management area buffers will be established around all wetlands. These buffers will be used to guide clearing activities during Construction and were selected following the BC Ministry of Forests and BC Ministry of Environment *Forest Practices Code Riparian Management Area Guidebook* (BC MOE and BC MOF 1995). The smallest reserve zone (10 m) proposed in the guidebook will be extended to all wetlands. This will provide protection of the vegetation, soil, and hydrological constituents of wetlands, which will maintain their extent and reduce impacts on function. Wetland management zones will be extended beyond the 10 m reserve zone to the distances detailed in Table 12.7-1. These buffers must be considered during tower/pole placement for construction of the proposed transmission lines.

Light activities, such as construction access, sediment, and erosion controls, and targeted vegetation clearing will be permitted within the wetland management zone; however, permanent features such as buildings and main roads will be located outside this zone wherever possible.

12.8 RESIDUAL EFFECTS ON WETLANDS

The footprint analysis determined that some wetlands will be lost and others are at high risk of alteration due to proximity to Project infrastructure. The majority of wetland loss of extent will occur within the Assessment Footprint where the coarse coal rejects will be stored.

Alteration of wetland functions is expected for wetlands below the Coarse Coal Rejects due to changes in hydrologic connectivity, edge effects, minor sedimentation and fragmentation. Residual effects are also anticipated for wetlands within the Subsidence Footprint.

While effects from dustfall are expected adjacent to the Shaft Site, most of the effects will occur east of the Coarse Coal Rejects and Coal Processing Plant. Mitigation measures such as following air quality management recommendations and adaptive management protocols, and implementing relevant management plans will help mitigate the potential for residual effects on wetland function.

The loss of wetland extent and alteration of functions were carried through as residual effect for the Project because it is expected that mitigation efforts will not return wetland function or extent to baseline levels after closure (Table 12.8-1).

Table 12.8-1. Summary of Residual Effects on Wetlands

Valued Component	Project Phase (timing of effect)	Project Component/ Physical Activity	Description of Cause-Effect[1]	Description of Mitigation Measure(s)	Description of Residual Effect
Wetland Extent	Construction to Post Closure	Coal Processing Site	Loss of Extent	None	Loss of wetlands
Wetland Function	Construction/ Operation	Coal Processing Site/ Shaft Site	Dust deposition	Air Quality and Dust Control Plan, and Site Access Plan	Alteration of biochemical, habitat, and hydrologic functions and functional diversity
	Construction/ Operation	Coal Processing Site/ Shaft Site, Decline Site	Hydrologic connectivity	Site Preparation and Soil Salvage Plan	Alteration of wetland hydrological, biochemical, functional diversity, and habitat functions
	Construction/ Operation	Coal Processing Site/ Shaft Site/Decline Site	Edge effect	Wetland buffers described in mitigation measures	Alteration of habitat function, functional diversity; greater potential for invasive species colonization
	Construction/ Operation	Coal Processing Site/ Shaft Site access roads/Decline Site access roads	Sedimentation/ water quality	Soil Management Plan, Selenium Plan, Aquatic Effects Monitoring Plan, Spill Response Plan, Site Access Management Plan, Invasive Plant Management Plan	
	Construction/ Operation	Coal Processing Site/ Shaft Site and access roads Roads/Access Roads/Secondary Shaft Site	Invasive species	Invasive Plant Management Plan	Greater potential for invasive species colonization
Wetland Extent and Wetland Function	Operation	Subsidence Footprint	Subsidence	None	Alteration of wetland hydrological, biochemical, functional diversity, and habitat functions
	Closure/ Post Closure	Subsidence Footprint	Subsidence	None	Alteration of wetland hydrological, biochemical, functional diversity, and habitat functions

[1] *"Cause-effect" refers to the relationship between the Project component/physical activity that is causing the change or effect in the condition of the VC.*

A risk-based approach to wetlands management in BC has been recommended to address the loss and damage to wetland functions (MacKenzie and Shaw 2000) and was employed to assess residual effects on wetland function for the Project. It informs management decision-making on risk reduction by providing a framework that allows for the identification of cause and effect. This approach has been employed in various fields from wildfire, flood, and ecological risk management (Blackwell et al. 2004) (Sayers, Hall, and Meadowcroft 2002). Risk is defined as the probability that an adverse event will occur multiplied by the consequences of an adverse event (Sayers, Hall, and Meadowcroft 2002). While the end result of risk assessment is an overall characterization of risk, it is helpful to also present both probability and consequence separately to assist in management decisions to reduce potential impacts. It provides a more transparent process to guide decision making (Figure 12.8-1).

To develop a risk-based approach to wetland assessment, a spatial model was developed in ArcGIS using the probability of Project components and activities affecting wetlands and the associated consequences to wetland functions. The purpose of the model is to identify where function is most likely to be affected (probability) and where wetlands with the highest values at risk occur (consequence). The output of the model is the calculation of risk, derived from probability and consequence ratings.

The model consists of four groups: risk, ratings (probability and consequence), components, and sub-components (these components and sub-components refer only to groupings within the model and not VC categories). Risk is calculated as probability multiplied by consequence. Knowledge of where and what project risks exist provides guidance on where active management is required. Probability and consequence are calculated using the components and subcomponents. Within subcomponents, criteria specific to each subcomponent are used to evaluate individual characteristics (Figure 12.8-2).

12.8.1 Probability and Consequence of Project Effects on Wetland Extent and Function

To calculate the probability rating, six components were assessed in the LSA: hydrological connectivity, fragmentation, edge effect, dust, sedimentation and water quality, and invasive species (Table 12.8-2; Figure 12.8-2). Subsidence is addressed separately in Section 12.8.5. Each of these six components′ contribution to the final probability rating was weighted as a percent (Table 12.8-2). Probability ratings were assigned to each subcomponent based upon either quantitative values from baseline data and modelling, where available, or qualitative values, determined through reviews of relevant literature, baseline information, or expert opinion. As an example, Table 12.8-3 shows the rating system used to identify the probability of fragmentation based upon infrastructure and the size of the fragments created (Table 12.8-3). The final subcomponent weighting for fragmentation is weighted as 15% of the total probability rating.

Consequence was assessed for five components including: rare/listed species or ecosystems, hydrological function, biochemical function, functional diversity (ecological function), and habitat function. All polygons with rare or red-listed species or ecosystems were given a final consequence rating of 10, the highest value possible (Table 12.8-4). This was to ensure they were set as a high priority and distinguishable from consequence ratings.

Figure 12.8-1

Probability and Consequence Assessment to Guide Risk Management Planning

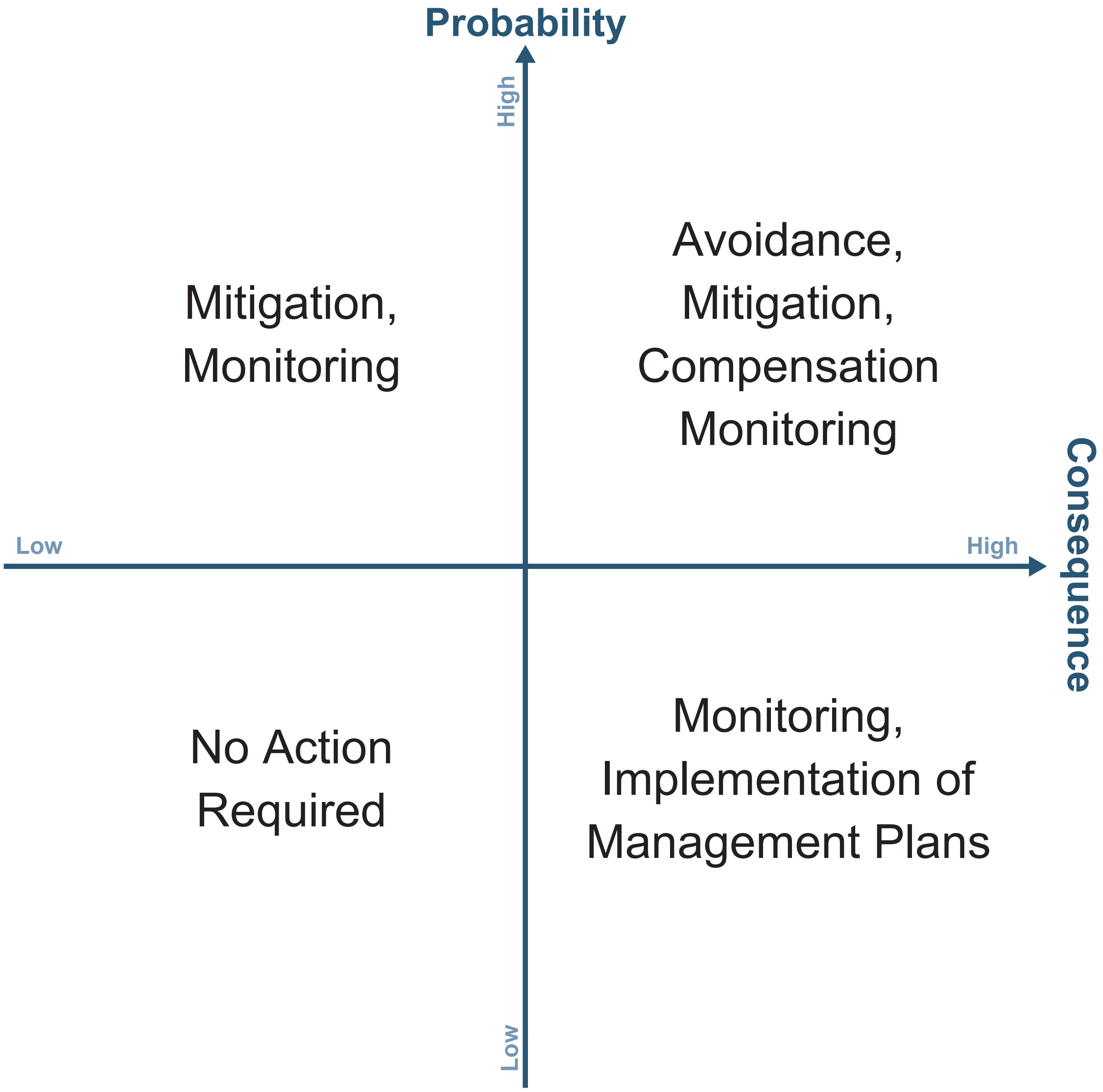


Figure 12.8-2

Probability and Consequence Model used to Evaluate Project Effects on Wetland Function

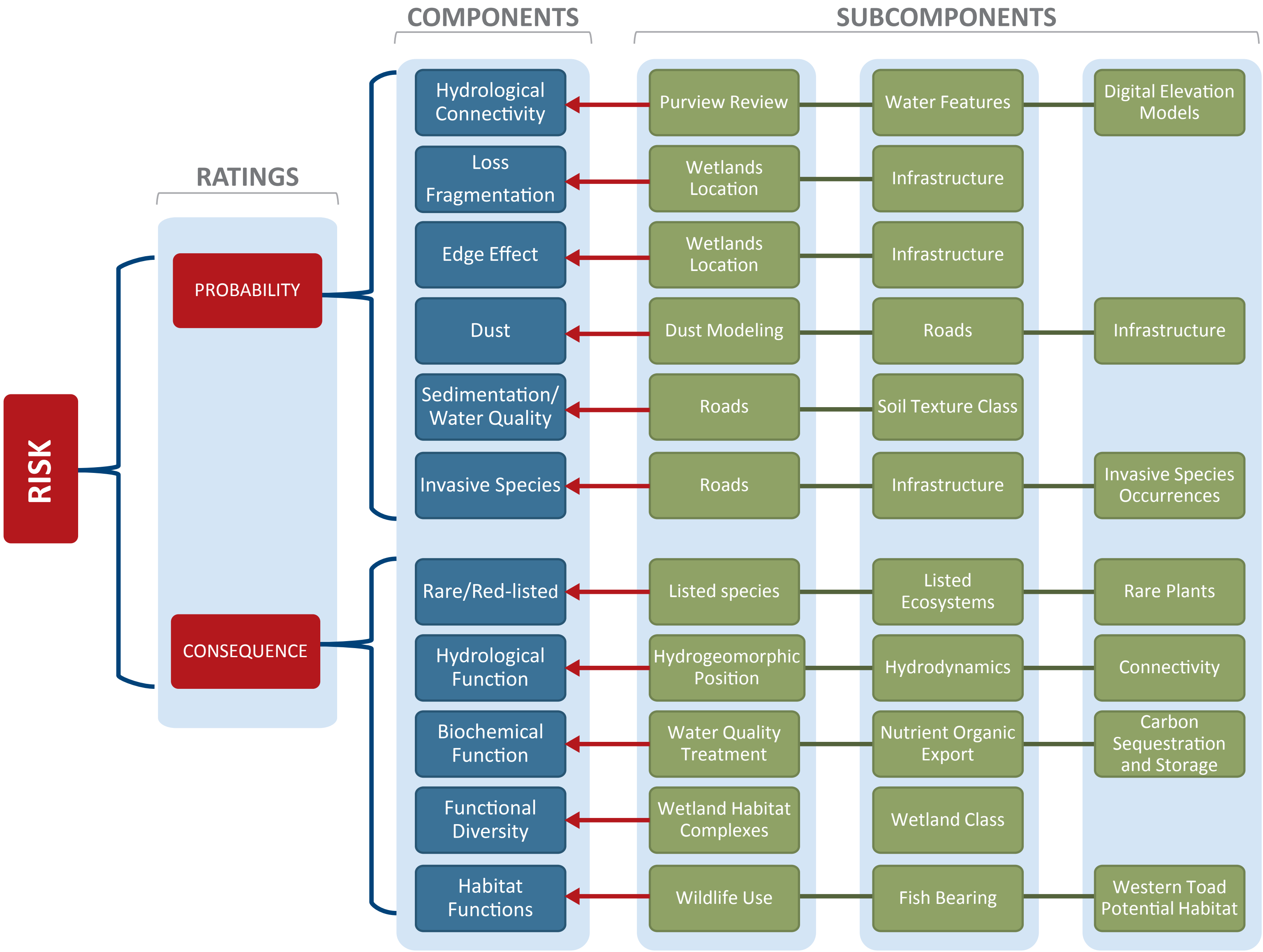


Table 12.8-2. Probability Ratings Table for Wetlands for the Project

Probability Rating		
Component	**Rating Weight**	**Subcomponent Contribution**
Loss of Wetland Extent (due to footprint overlap or fragmentation)		
Loss		100%
Alteration of Wetland Function		
Hydrological connectivity	0-10	25%
Fragmentation	0-10	15%
Edge Effects	0-10	15%
Dust Effects	0-10	15%
Sedimentation/water quality	0-10	15%
Exotic invasive species	0-10	15%
Total		**100%**

Table 12.8-3. Example of Probability Ratings Table for Project Fragmentation Effects

Fragmentation Effects-Probability				
Assessable Characteristic	**Data Source**	**Rating Criteria**	**Rating Weight**	**Subcomponent Weight**
Fragmentation Effects	Infrastructure footprint and wetlands mapping	Not fragmented	0	15%
		Fragment > 2 ha in size	2	
		Fragment 1-2 ha in size	7	
		Fragment < 1 ha in size	10	

Table 12.8-4. Consequence Ratings Table for Wetlands

Consequence Rating		
Component	**Rating Weight**	**Subcomponent Contribution**
Rare/Red-Listed Species or Ecosystems		
Rarity	10	100%
Functions		
Hydrological function	0-10	30%
Biochemical function	0-10	20%
Functional diversity	0-10	20%
Habitat function	0-10	30%
Total		**100%**

Each of the four remaining components' contribution to the final consequence rating was weighted as a percent (Table 12.8-4). Consequence ratings were assigned to each subcomponent based upon either quantitative values from baseline data or modelling where available or qualitative values that were determined through reviews of relevant literature, baseline information, or expert opinion. Components for consequence were derived from subcomponents, which are assessable or measurable parameters (Figure 12.8-2). The subcomponent ratings were based upon inputs from baseline reports, literature review, or expert opinion.

For example, Table 12.8-5 shows the characteristics used to evaluate habitat functions: wetland bird habitat use, based on wildlife baseline identification of bird preference by wetland class; fish presence, based on aquatics baseline sampling; and habitat values, based on wetland class as identified by Hanson (2008). Identification of potential western toad habitat was based on a review of all wetlands with components of shallow open water (SOW) or marsh. Each of these characteristics was broken down into a rating scale, which was then assigned a rating weight between 0 and 10 (confirmed western toad habitat is automatically assigned a high consequence rating as it is a listed species). The characteristics were then summed based on a subcomponent weight.

Table 12.8-5. Example of Consequence Ratings Table for Wetland Habitat Function

Habitat Functions - Consequence					
Assessable Characteristic	**Data Source**	**Unit**	**Rating Scale**	**Rating Weight**	**Subcomponent Weight**
Wetland bird habitat use	Wetland bird habitat preference (Appendix 13-A)	Wetland Class	Open water	10	20%
			Marsh	8	
			Shrub Swamp	6	
			Forested Swamp/ Bog/Fen	3	
Fish presence/ absence	Fish mapping (Appendix 9-A)	Species/Use	Fish Bearing	10	30%
			None	3	
General habitat by wetland class	Wetland mapping (Appendix 12-A)	Wetland Class	Marsh	10	30%
			Swamp/SOW	7	
			Fen	5	
			Bog	3	
Western toad (potential habitat)	Review of wetlands in Purview	Potential	High	10	20%
			Moderate	7	
			Low	3	

The final output is a spatial characterization of risk based on probability and consequence ratings for individual wetlands. In addition to the final risk database and map, maps are generated for each component and subcomponent based on their weightings. The map outputs follow the general model as shown in Figure 12.8-2. The individual components for probability and consequence and the model outputs specific to each component for the Project are discussed in greater detail below.

12.8.2 Probability of Effects

To assign the outputs for the components to classes (None, Low, Moderate, and High), Jenks natural breaks classification method was used in ArcGIS. Four classes were generally used. This classification approach attempts to reduce variance within classes while maximizing variation between classes. Some class boundaries were manually selected to ensure logical breaks were maintained.

12.8.2.1 Direct Loss of Extent and Fragmentation

To assess wetland loss, wetlands within the Assessment Footprint areas were assumed as having total loss of extent. This maximum extent of disturbance footprint represents the largest spatial extent of disturbance across all temporal boundaries. Areas potentially affected by the Project were identified in terms of the amount of anticipated disturbance. Generalized infrastructure were assigned a designation of "lost" to indicate that any wetlands within these areas will be completely removed and essentially replaced by infrastructure, at least for the duration of the Project.

Fragmentation was assessed where infrastructure occurred within 500 m of a wetland on one, two, three, or more sides of the wetland. For fragmented wetlands with Project infrastructure on three or more sides, loss of extent was assumed. For wetlands with less than three sides with adjacent infrastructure or where the isolated wetland fragments were less than 1 ha, alteration was rated as high probability of effects due to fragmentation. Fragments of 1 to 2 ha were rated moderate, and wetland fragments greater than 2 ha rated low for fragmentation.

The assumption in these cases is that wetland habitat, hydrological, functional diversity, and biochemical functions are all altered relative to their initial level of function, but the size of the remaining fragment affects the degree of alteration. The alterations in hydrological connectivity, plant and animal dispersal, biochemical pathways, and maintenance of habitat complexes all contribute to a general reduction in wetland functions.

Project-specific Effects

Wetland extent was assessed as lost in areas associated with the Assessment Footprint at the Coal Processing Site. Wetlands located in this area include nine Bogs, a Marsh with SOW (and a portion of a Marsh with SOW for the discharge pipe to Murray River), and a swamp with SOW. The total lost area is 28.5 ha (Table 12.8-6).

Table 12.8-6. Loss of Wetland Extent and Probability of Fragmentation Effects by Wetland Class

Loss	Wetland Class (Area in ha)					
Probability Class	Bog	Fen	Marsh	SOW	Swamp	Total (ha)
None	149.8	15.9	48.3	28.5	113.8	356.3
Low	2.7	0.0	0.0	1.4	5.8	9.9
Loss (of Extent)	26.2	0.0	1.1	0.7	0.5	28.5
Total (ha)	**178.7**	**15.9**	**49.4**	**30.6**	**120.1**	**394.7**[1]

[1] *This is the total area in all wetlands in the LSA.*

No mapped wetlands were identified with fragmentation on three or more sides; therefore, no loss of extent was identified due to fragmentation. No wetlands were identified as highly fragmented (fragments less than 1 ha; Table 12.8-6). No wetland fragments were 1 to 2 ha in size. Low ratings were assigned to 9.9 ha of wetland. These wetland areas were fragmented but fragments were greater than 2 ha in size and thus assessed as Low. The remainder of wetlands were assessed as being unaffected by fragmentation. Loss is shown in all of the probability tables for clarity.

12.8.2.2 Hydrological Connectivity Component

Hydrological connectivity inputs included TRIM water features, mapped wetlands, a Digital Elevation Model (DEM), and Project infrastructure. These were reviewed in ArcGIS using Purview to identify where Project infrastructure had the potential to affect wetland hydrology by interrupting or diverting subsurface or surface water flow to a wetland. The potential effects were assigned a value based on whether disruption in water flow to a wetland due to the Project infrastructure could occur and the severity of impairment. Wetlands 500 m or more from the Project Assessment Footprint were not evaluated. Wetlands upslope and downslope were assessed equally, as alterations of natural flow can result in dewatering or impoundment of wetlands.

Project-specific Effects

Hydrological connectivity was identified as unaffected in 348.2 ha of wetland and moderately affected in 18.1 ha of wetland, primarily swamps (Table 12.8-7). Loss is shown in each of the tables to provide clarity on the total effects. Most effects occurred below the coarse coal reject piles.

Table 12.8-7. Probability of Hydrological Connectivity Effects by Wetland Class

Hydrological Connectivity	Wetland Class (Area in ha)					
Probability Class	Bog	Fen	Marsh	SOW	Swamp	Total (ha)
None	149.8	15.9	45.8	26.8	109.9	348.2
Moderate	2.7	0.0	2.5	3.1	9.8	18.1
Loss	26.2	0.0	1.1	0.7	0.4	28.4
Total (ha)	**178.7**	**15.9**	**49.4**	**30.6**	**120.1**	**394.7**

12.8.2.3 Edge Effect Component

Edge effects were modelled using concentric 50 and 100 m buffers from the edge of the Assessment Footprint. Edge effects include, but are not limited to, potential changes in microclimate, structural diversity, biotic edge effects, invasive species colonization, increased sedimentation, and windthrow.

Project-specific Effects

Edge effects related to the Mine Site Assessment Footprint occur when it borders or intersects a wetland. There were 13.8 ha of high edge effect areas identified (Table 12.8-8). As only two buffers were used to model edge effect, only two classes were used: low and high.

Table 12.8-8. Total Area of Edge Effect by Wetland Class

Edge Effect	Wetland Class (Area in ha)					
Probability Class	Bog	Fen	Marsh	SOW	Swamp	Total (ha)
None	148.8	15.9	46.3	27.8	113.5	352.3
High	3.7	0.0	2.0	2.1	6.0	13.8
Loss	26.2	0.0	1.1	0.7	0.6	28.6
Total (ha)	**178.7**	**15.9**	**49.4**	**30.6**	**120.1**	**394.7**

12.8.2.4 Dust Component

Dust results are based on dust modelling detailed in the assessment of air quality in Appendix 6-B of Chapter 6. Total suspended sediments (TSP) were modeled based on concentration contours as described in Chapter 6.

Project-specific Effects

The dust fall extends approximately 1.3 km from the road, with the majority of exceedances to the east of the road due to the prevailing wind direction and exceeds 24-hour average TSP objectives (Chapter 6 - Air Quality and Greenhouse Gasses). The exceedances outside of the Assessment Footprints were from fugitive sources, primarily from road dust. The model has been run assuming no anthropogenic dust control; however, mitigation measures such as road watering would significantly reduce the amount of unpaved road dust. Other means of emission control are described in the Air Quality and Dust Control Plan (Section 24.2).

Dust has a high probability of altering wetland functions on 18.5 ha, a moderate probability on 10.2 ha and low probability on 24.6 ha of (Table 12.8-9).

Table 12.8-9. Probability of Dust Effects by Wetland Class

Dust Effects	Wetland Class (Area in ha)					
Probability Class	Bog	Fen	Marsh	SOW	Swamp	Total (ha)
None	113.6	15.9	41.6	25.1	116.6	312.8
Low	14.1	0.0	4.9	3.1	2.5	24.6
Moderate	7.2	0.0	1.4	1.6	0.0	10.2
High	17.6	0.0	0.4	0.1	0.4	18.5
Loss	26.2	0.0	1.1	0.7	0.6	28.6
Total (ha)	**178.7**	**15.9**	**49.4**	**30.6**	**120.1**	**394.7**

12.8.2.5 Sedimentation and Water Quality Component

Sedimentation was modelled using soil texture and buffers adjacent to the Assessment Footprint to calculate erosion potential, the assumption being that disturbance would occur close to the footprint edge. High ratings were assigned closer to edges where easily erodible and transportable soils occurred on slopes and deposition in a wetland was more probable.

Project-specific Effects

Sedimentation was identified as high probability in 0.3 ha and moderate probability in 1.5 ha of marsh, SOW, and swamp wetlands (Table 12.8-10). Most wetlands, 364.3 ha, were identified as having none to low probability of sedimentation effects.

Table 12.8-10. Probability of Sedimentation Effects by Wetland Class

Sedimentation Effects	Wetland Class (Area in ha)					
Probability Class	**Bog**	**Fen**	**Marsh**	**SOW**	**Swamp**	**Total (ha)**
None	152.5	15.9	47.7	29.2	119.0	364.3
Moderate	0.0	0.0	0.5	0.5	0.5	1.5
High	0.0	0.0	0.1	0.2	0.0	0.3
Loss	26.2	0.0	1.1	0.7	0.6	28.6
Total (ha)	**178.7**	**15.9**	**49.4**	**30.6**	**120.1**	**394.7**

12.8.2.6 Invasive Species Component

Invasive species were modelled using buffers on infrastructure and footprints. Where wetlands overlap the buffers, ratings were assigned from *low*, where no invasive species occur, to *high*, where invasive species are present and are species that can colonize wetlands. Wetlands within 100 m of infrastructure were still assigned a probability rating even in the absence of invasive species due to increased human access, which provides a vector for invasive species.

Project-specific Effects

Online database information from the Invasive Alien Plant Council of BC indicates that some invasive plants are found nearby including Scentless chamomile (*Matricaria perforate)*, Hound's-tongue (*Cynoglossum officinale)*, Canada thistle (*Cirsium arvense)*, Bull thistle (*Cirsium vulgare)*, Yellow hawkweed (*Hieracium pratense),* and Oxeye daisy (*Leucanthemum vulgare).*

This list does not include all the invasive plants that could be introduced into the Project area. Due to physical separation from roads and infrastructure most wetlands have no increased probability of invasive species occurring. Adjacent to the infrastructure, 13.8 ha of wetland were identified as being at moderate risk of invasive species colonization (Table 12.8-11).

Table 12.8-11. Probability of Invasive Species Effects by Wetland Class

Invasive Species	Wetland Class (Area in ha)					
Probability Class	**Bog**	**Fen**	**Marsh**	**SOW**	**Swamp**	**Total (ha)**
None	148.8	15.9	46.3	27.8	113.5	352.3
Moderate	3.7	0.0	2.0	2.1	6.0	13.8
Loss	26.2	0.0	1.1	0.7	0.6	28.6
Total (ha)	**178.7**	**15.9**	**49.4**	**30.6**	**120.1**	**394.7**

Probability was not rated high because the nearby invasive plant species favour mesic to dry sites and are not noted as highly invasive in wetlands. These wetlands were also assessed as moderate, because vectors such as trucks and other machinery for invasive species will come in contact with these wetlands during Construction.

12.8.2.7 *Probability of Adverse Effects on Wetlands*

The cumulative ratings for probability of effects on wetland extent and functions are shown in Figure 12.8-3 and Table 12.8-12. The maps are made by combining the individual contributions of each probability component. They are overlaid in GIS to create a resultant final probability map that shows total contribution.

Table 12.8-12. Probability of Effects on Wetland Function

Total Probability	Wetland Class (Area in ha)					
Probability Class	Bog	Fen	Marsh	SOW	Swamp	Total (ha)
None	109.7	15.9	38.9	21.8	106.5	292.8
Low	40.1	0.0	7.9	6.5	7.6	62.1
Moderate	2.7	0.0	1.5	1.6	5.4	11.2
Loss	26.2	0.0	1.1	0.7	0.6	28.6
Total (ha)	**178.7**	**15.9**	**49.4**	**30.6**	**120.1**	**394.7**

The combined probability of effect is greater directly adjacent to the Assessment Footprint especially adjacent to the Coarse Coal Reject piles as wetlands are located there and the most acute effects related to edge effect, hydrological change, fragmentation, dust deposition, and sedimentation/ water quality will occur here. Overall, there are no areas of high, 11.2 ha of moderate, and 62.11 ha of low probability of adverse effects on wetland functions. The Coal Processing Site will also result in the loss of 28.6 ha of wetland extent.

12.8.3 Consequence Analysis Components and Project-specific Ratings

12.8.3.1 *Rare and Red-listed Species or Ecosystems Component*

Wetlands with rare or red-listed species or wetlands that are red-listed ecosystems are assigned high consequence ratings (*Murray River Coal Project: Wetland Ecosystem Baseline Report (*Appendix 12-A); *Murray River Coal Project: 2010 to 2013 Wildlife Baseline Report* (Appendix 13-A), *Murray River Coal Project: 2010 to 2012 Ecosystem and Vegetation Baseline Report* (Appendix 11-A), This ensures that they are clearly identified so appropriate management measures can be developed. Western Toad are included in the rare and listed species model as this species breeds in wetlands, is a SARA Schedule 1 species, and was noted as the representative amphibian species VC for the wildlife effects assessment (Chapter 13). Blue-listed plant species and ecosystems that were identified are included in habitat consequence ratings not in the rare and red-listed species and ecosystem component. The rationale for this is based on the idea that red-listed species are at higher risk than blue listed species and as a result avoidance measures are more commonly required or prescribed for red-listed species and ecosystems than those that are blue-listed.

Project-specific Consequence Ratings

No rare or red-listed plant species or ecosystems were identified in wetlands.

Western toad were identified in 21.8 ha of wetlands, with the majority of occurrences in bogs (11.0 ha) and swamp wetlands (4.5 ha; Table 12.8-13; Appendix 13-A). No red-listed plant species or ecosystems were found in the mapped wetlands.

Table 12.8-13. Total Area of Wetlands with Identified Listed Species or Ecosystems by Wetland Class

Listed Species or Ecosystems	Wetland Class (Area in ha)					
Consequence Class	Bog	Fen	Marsh	SOW	Swamp	Total (ha)
Absent	167.7	15.9	45.4	28.3	115.6	372.9
Present	11.0	0.0	4.0	2.3	4.5	21.8
Total (ha)	**178.7**	**15.9**	**49.4**	**30.6**	**120.1**	**394.7**

12.8.3.2 Hydrological Function Component

Hydrological function values were assigned based upon wetland characteristics. Hydrogeomorphic position, hydrodynamics, and connectivity (streams or channels visible in Purview) were used as subcomponent inputs to assess hydrological function.

Project-specific Consequence Ratings

Hydrological function outputs identified 252.8 ha with low hydrological functioning, which was primarily in bogs and swamps (Table 12.8-14). Many of these were wetlands with low connectivity and were basins and hollows or seepage slopes. Most of the 59.7 ha of moderate consequence occurred in marsh and swamp wetlands. The 82.2 ha of wetlands rated as high consequence occurred primarily in swamps. However, a significant proportion of marsh and SOW wetlands were identified as having high hydrologic functions, and most of these wetlands were associated with creeks with mobile or dynamic classes of hydrodynamics.

Table 12.8-14. Total Area of Low, Moderate, and High Hydrologic Function by Wetland Class

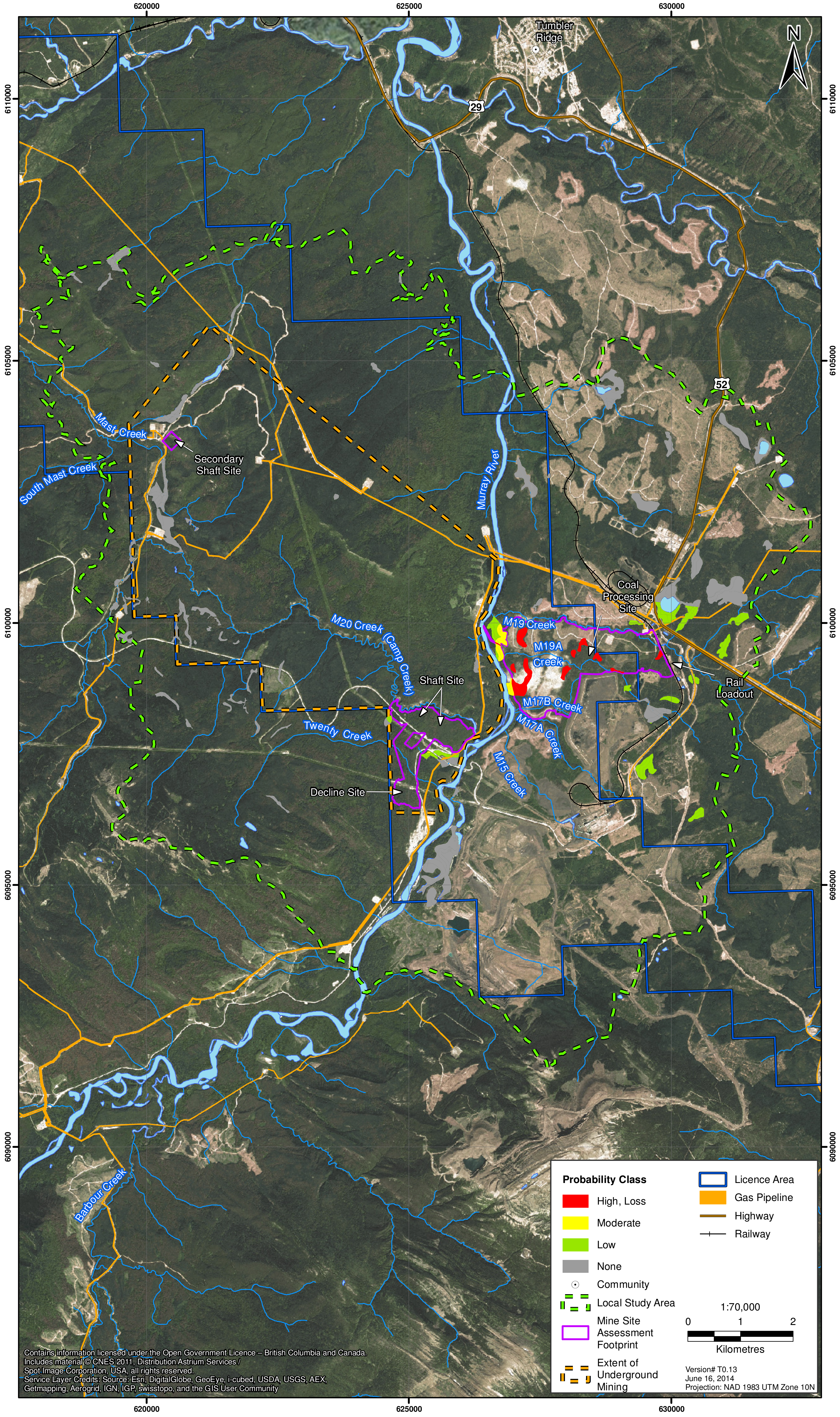
Hydrological Function	Wetland Class (Area in ha)					
Consequence Class	Bog	Fen	Marsh	SOW	Swamp	Total (ha)
Low	175.1	6.3	10.7	0.2	60.5	252.8
Moderate	3.3	9.6	13.5	6.9	26.4	59.7
High	0.3	0.0	25.2	23.5	33.2	82.2
Total (ha)	**178.7**	**15.9**	**49.4**	**30.6**	**120.1**	**394.7**

12.8.3.3 Biochemical Function Component

Biochemical function was calculated based on wetland classes as reported in the literature (Table 12.5-4; Hanson et al. 2008). Water quality treatment, nutrient organic export, and carbon sequestration for each wetland type were included as subcomponents in the assessment. For wetland polygons that included more than one wetland type, an area weighted average was calculated based upon the biochemical functions for each type.

Figure 12.8-3

Probability Component Ratings for Wetlands



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Version# T0.13
June 16, 2014
Projection: NAD 1983 UTM Zone 10N

Project-specific Consequence Ratings

The majority of mapped wetlands (231.2 ha) had moderate biochemical functions based on the functional assessment of water quality treatment, nutrient and organic export, and carbon sequestration. Most fens and swamps were identified as having high biochemical function, while bogs, marshes, and SOW were rated as moderate or low (Table 12.8-15).

Table 12.8-15. Total Area of Low, Moderate, and High Biochemical Function by Wetland Class

Biochemical Function	Wetland Class (Area in ha)					
Consequence Class	Bog	Fen	Marsh	SOW	Swamp	Total (ha)
Low	0.9	0.0	29.5	14.0	5.5	49.9
Moderate	177.2	1.2	18.6	10.4	23.8	231.2
High	0.6	14.7	1.3	6.2	90.8	113.6
Total (ha)	**178.7**	**15.9**	**49.4**	**30.6**	**120.1**	**394.7**

12.8.3.4 *Functional Diversity Component*

Loss of function in diverse ecological assemblages can have greater effect than loss of function in single community ecosystems (Tilman et al. 1997). Where multiple wetland classes were mapped either as deciles in a polygon or as distinct ecosystems with shared boundaries, functional diversity was assumed to increase with increasing number of wetland types. Wetlands with three or more ecological communities were rated as high, those with two communities were rated as moderate, and single wetlands were rated as low.

Project-specific Consequence Ratings

High ratings for functional diversity were calculated in 188.7 ha of wetlands, with bogs the most common (62.9 ha; Table 12.8-16). Swamps and marshes were also commonly found in complexes. Moderate ratings were attributed primarily to swamp and bog wetlands. Bogs were also the wetland class most associated with low ratings (87.2 ha).

Table 12.8-16. Total Area of Low, Moderate, and High Functional Diversity by Wetland Class

Functional Diversity	Wetland Class (Area in ha)					
Consequence Class	Bog	Fen	Marsh	SOW	Swamp	Total (ha)
Low	87.2	1.1	2.1	0.0	28.1	118.5
Moderate	28.6	5.2	3.9	6.0	43.8	87.5
High	62.9	9.6	43.4	24.6	48.2	188.7
Total (ha)	**178.7**	**15.9**	**49.4**	**30.6**	**120.1**	**394.7**

12.8.3.5 *Habitat Function Component*

To assess habitat functions, wetland bird habitat preferences based upon extrapolation from observations identified in the Wildlife Baseline Report (Appendix 13-A) were used. Fish presence or absence based on connectivity to fish-bearing waterbodies or field observations in the *Murray River Coal Project: 2012 to 2013 Fisheries Baseline Report* (Appendix 9-A). Western toad habitat was rated based on nearby areas where toads were identified (wildlife baseline; Appendix 13-A), wetland type, and the presence of shallow open water or ponds. Wetland class was also included as a parameter on which habitat function was assessed (Hanson et al. 2008). Wetlands identified in the wetlands baseline report (Appendix 12-A) as blue listed (Wb09 and Wb06) or wetlands with blue listed species identified in *Murray River Project: Species Accounts of Rare Plants and Lichens* (Appendix 11-D) and *Murray River Coal Project: 2010 to 2012 Ecosystem and Vegetation Baseline Report* (Appendix 11-A) were rated high for habitat value.

Project-specific Consequence Ratings

Wetlands rated as high for habitat function occurred mainly in swamp, marsh, SOW, and swamp wetlands (47.8 ha; Table 12.8-17). To clearly indicate how presence of fish or wetlands with highly suitable toad habitat affected ratings, these are indicated as High Fish and High Toad in the table. In total, 16.6 ha of wetlands were in part rated high due to these factors as well as bird and wetland class ratings.

Table 12.8-17. Total Area of Low, Moderate, and High Habitat Function by Wetland Class

Habitat Function	Wetland Class (Area in ha)					
Consequence Class	Bog	Fen	Marsh	SOW	Swamp	Total (ha)
Low	160.1	7.0	0.6	0.0	22.5	190.2
Moderate	12.8	8.9	25.0	13.4	80.0	140.1
High	0.0	0.0	19.8	14.8	13.2	47.8
High Fish	4.6	0.0	0.0	0.0	0.0	4.6
High Toad	1.2	0.0	4.0	2.4	4.4	12.0
Total (ha)	**178.7**	**15.9**	**49.4**	**30.6**	**120.1**	**394.7**

12.8.3.6 Consequence Ratings for Wetland Functions

The classes used for the consequence ratings, based on the components and subcomponents for wetland function are shown in Figure 12.8-2 and Table 12.8-18. The maps are made by combining the individual contributions of each of the components that are used to calculate consequence. They are overlaid in GIS to create a resultant final consequence map that shows the total contribution of each layer. As consequence is a measure of wetland function, not the potential impacts associated with the Project, the value associated with consequence is independent of the distance to Project infrastructure. There are 131.3 ha of wetlands that were rated as having high consequence related to wetland function, and 136.7 ha of wetlands that were rated as having moderate consequence (Table 12.8-18). There were 126.7 ha of wetlands rated with low consequence related to hydrological connectivity, biochemical functions, functional diversity, habitat functions, and rare or listed species or ecosystems.

Table 12.8-18. Consequence Rating of Wetland Functions by Wetland Class

Total Consequences	Wetland Class (Area in ha)					
Consequence Class	Bog	Fen	Marsh	SOW	Swamp	Total (ha)
Low	104.7	1.1	0.4	0.0	20.5	126.7
Moderate	62.6	7.1	19.9	1.2	45.9	136.7
High	11.4	7.7	29.1	29.4	53.7	131.3
Total (ha)	**178.7**	**15.9**	**49.4**	**30.6**	**120.1**	**394.7**

12.8.4 Final Risk Determination

As described in Section 12.8, risk is probability of an event occurring multiplied by the consequences of that event occurring. The total effect on wetland functions related to Project infrastructure and activities is shown in Figure 12.8-4. Probability and consequence maps were included in Figures 12.8-1 and 12.8-5 to clearly indicate the cause of the final risk rating. This is important as it provides guidance as to appropriate levels of management that should be considered. For example, a situation in which probability of altering wetland function is moderate but the consequences of this change are low might warrant monitoring or standard mitigation measures. In contrast, a situation in which probability is the same but consequences are high would warrant either avoidance, the consideration of special mitigation measures, or compensation.

Overall the residual risk to wetlands in high or loss classes as a result of the Project is 9% of all wetlands in the LSA or 37 ha (Figure 12.8-4 and Table 12.8-19). Residual risk is moderate for 11.1 ha (3%), low for 54.3 ha (14%), and risk was modelled as none for 293.3 ha (74%) of mapped wetlands. Risk ratings of none occur where no Project effects are anticipated to a wetland.

Table 12.8-19. Wetland Risk Ratings Shown by Wetland Class

	Wetland Class (Area in ha)						% of Mapped Wetlands
Risk	Bog	Fen	Marsh	SOW	Swamp	Total (ha)	
None	109.7	15.9	38.8	21.8	106.1	292.3	74%
Low	40.1	0.0	6.5	4.4	3.3	54.3	14%
Moderate	2.7	0.0	1.5	2.2	4.7	11.1	3%
High	0.0	0.0	1.5	1.5	5.4	8.4	2%
Moderate Loss	8.4	0.0	0.0	0.0	0.0	8.4	2%
High, Loss	17.8	0.0	1.1	0.7	0.6	20.2	5%
Total (ha)	**178.7**	**15.9**	**49.4**	**30.6**	**120.1**	**394.7**	

12.8.5 Subsidence

Subsidence was not included in the risk model for several reasons. The primary reason is the uncertainty as to what the effects of subsidence on wetlands will be. Some effects could be beneficial while others could be negative. Monitoring of wetlands as mining proceeds is the recommended approach to identify specific effects at the site level. The secondary reason is to ensure clarity as to where the potential effects are anticipated. Most of the effects to wetlands are focussed around the Mine Site Assessment Footprint; subsidence occurs across the landscape and there is uncertainty as to how accurate subsidence estimates will be compared to actual subsidence and how subsidence will be expressed on a topographically and geographically complex landscape.

Hydrogeological models, particularly for shallow groundwater do not have sufficient resolution to predict how subsidence might affect hydrological regimes and wetlands. Responses to alterations in terrain could cause hydrological changes that vary from no change to ponding or draining of wetlands, depending on the amount of subsidence, change in slope, cracks in surficial layers, and alteration of perched water tables. Connectivity with ground water aquifers can increase or decrease depending on the nature of the aquitards and whether it is supporting aquifers or containing them.

Studies have shown unexpected results such as an increases in soil moisture in ridges due to increased connectivity to groundwater sources due to fractured aquitards, while wetlands and creeks have been dewatered in other cases (Hutcheson et al. 2000; Cherry et al. 2004). Effects are specific to the hydrogeological characteristics at a site level and require this level of detail to assess potential effects.

Wetland could be created or lost depending on the hydrologic changes that occur at each site. General trends may occur with the loss of bogs and fens due to ponding or drying and the creation of marshes and shallow open water. In short, wetlands may be created or lost. However, identifying the actual effects is not possible.

As specific effects cannot be determined for individual wetlands, wetland areas are summarized by the number of panels to be mined. Greater effects are expected in areas where more panels are mined.

Based on the mine plan, areas were grouped by the number of panels to be mined vertically. To capture possible subsidence effects outside panel margin, 100 m buffers were applied to account for the angle of draw. This buffer width was based on the approximate distance at which subsidence was less than 30 cm as shown in the modelling (X-traction Science and Technology 2014). The subsidence effects from none to very high were assigned to each of the areas that had been grouped by number of panels to be mined. Direction of panel development, timing of mining, and geotechnical considerations were not incorporated in this estimate.

In total, 44.4 ha of wetland (12.2 % of all wetlands in the LSA) fall within the Subsidence Footprint. None of these wetlands are affected by other Project activities. Table 12.8-20 shows the amount of wetland area associated with number of panels mined vertically. The majority of this occurs where two panels are being mined vertically (Figure 12.8-6). Alteration of hydrological regimes due to subsidence has the most potential to affect the 8.1 ha of bog habitats. Bogs are sensitive to changes in water level and bog extent may be lost or transition to another wetland type due to drying or inundation. Marsh, swamp, and SOW wetlands are more resilient to increases in water depth and may even increase in extent, depending on hydrological changes. However, decreases in water height or drying will result in losses of extent for these wetland types as well.

Table 12.8-20. Number of Panels Mined, Predicted Subsidence, and Wetland Class Affected and Area

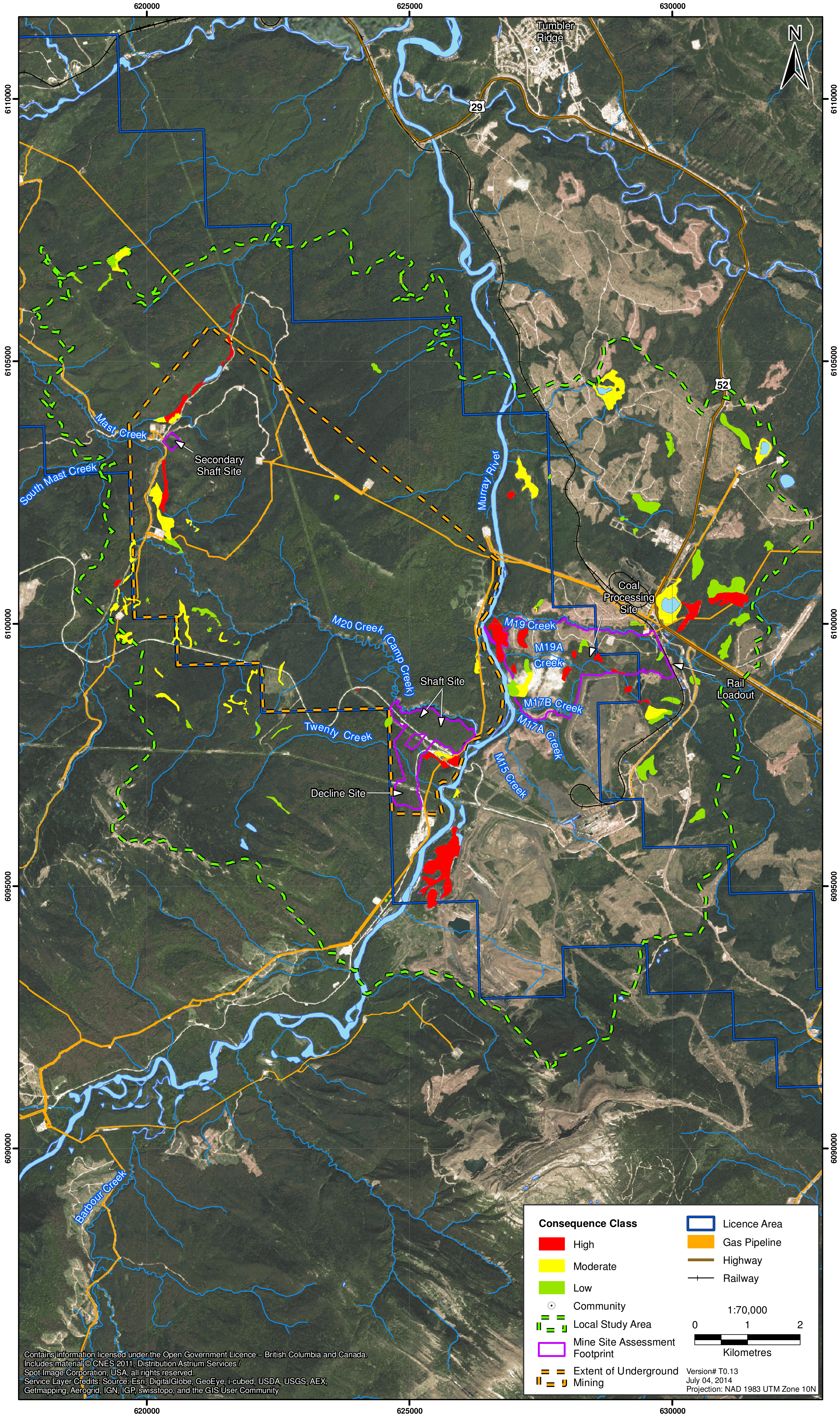
Number of Panels (vertically)	Wetland Class (Area in ha)					Total (ha)
	Bog	Marsh	SOW	Swamp	Fen	
0[1]	1.1	0.8	0.6	6.4	0.0	8.9
2	7.0	3.8	2.3	3.2	0.0	16.3
3	0.0	0.0	1.6	7.5	0.0	9.1
5	0.0	0.0	0.0	10.1	0.0	10.1
Total (ha)	**8.1**	**4.5**	**4.5**	**27.2**	**0.0**	**44.4**

[1] *This denotes the area within 100 m of the edge of mined panels where subsidence exists but decreases over distance.*

The expression of subsidence in areas of high relief is complex. Coupled with limited knowledge of detailed geologic formations, accurate predictions of how subsidence will be expressed on the ground surface are not possible.

Figure 12.8-4

Consequence Component Ratings for Wetlands



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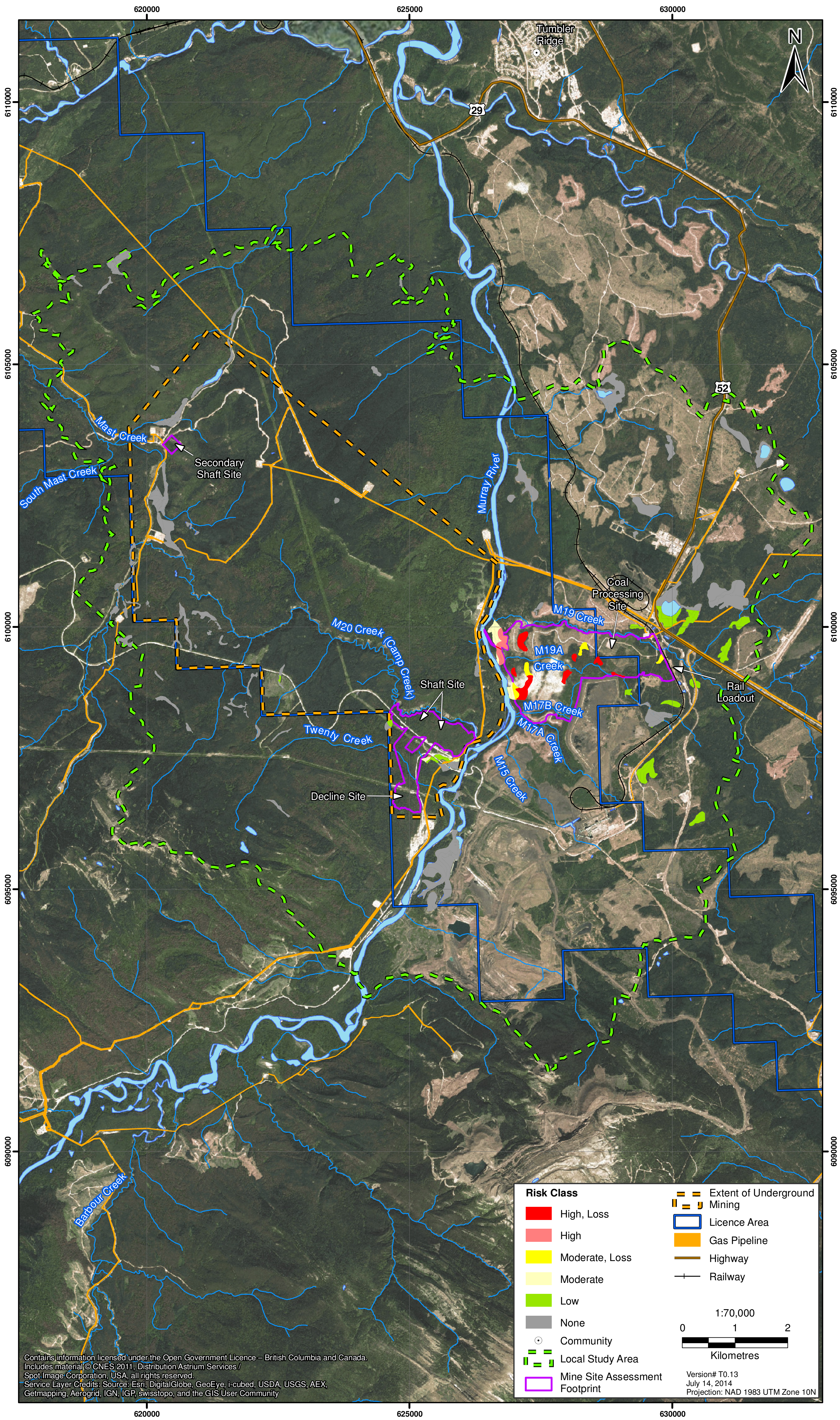
Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 12.8-5

Final Risk Ratings for Wetlands



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July 14, 2014
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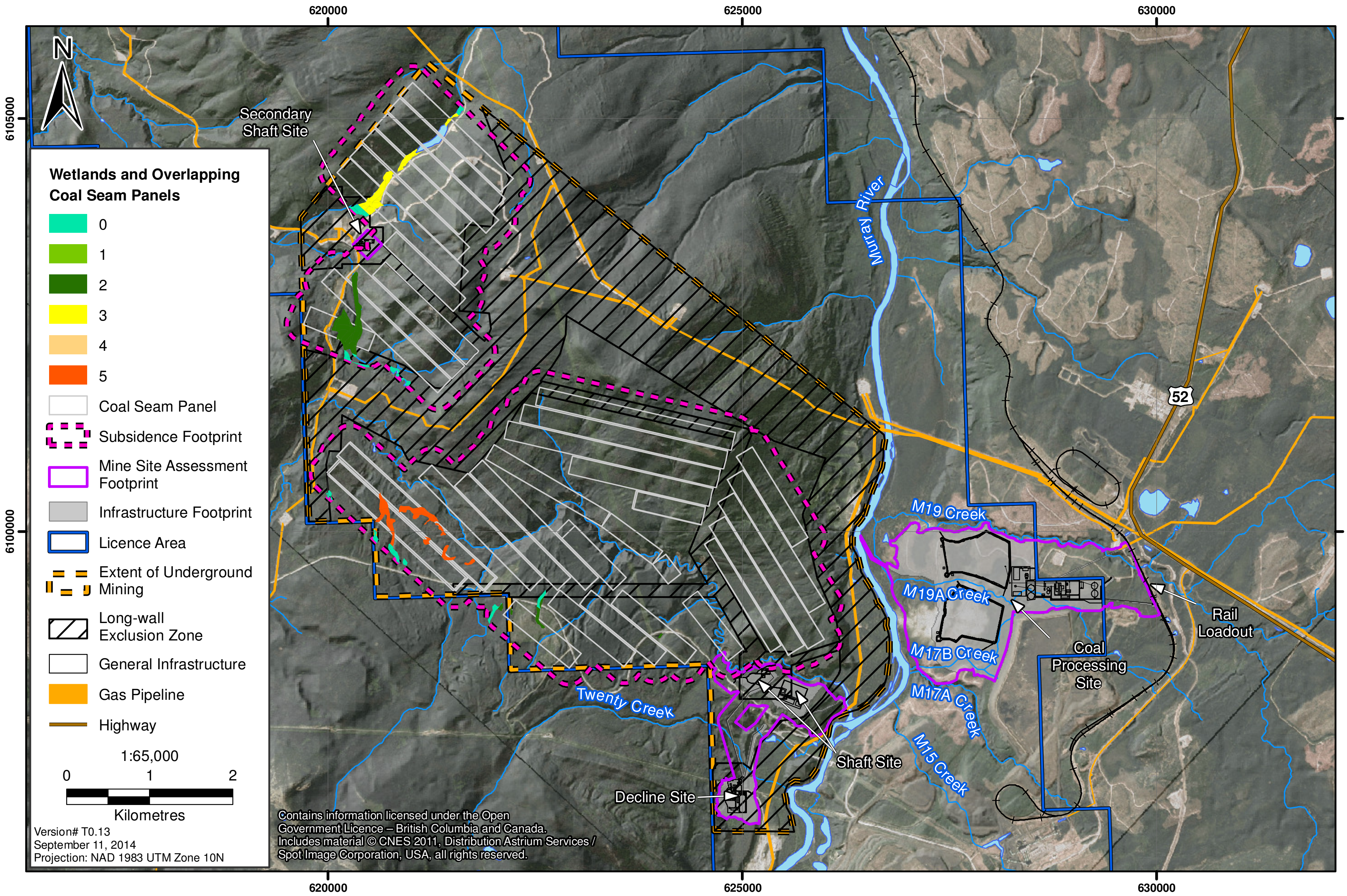
Figure 12.8-6

Wetlands in Relation to Various Magnitudes of Subsidence



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12.9 CHARACTERIZING RESIDUAL EFFECTS LIKELIHOOD, CONFIDENCE, AND SIGNIFICANCE ON WETLANDS

Although the risk to wetlands is generally low, there are predicted residual effects on wetland extent and function. Loss of wetlands will occur at the Coal Processing Site. Alteration of function will occur adjacent to this area as well as adjacent to the Shaft Site due to dust, sedimentation, hydrological changes, invasive species, edge effect, and fragmentation. In areas where subsidence will occur, wetland functions and possible extent will be altered.

12.9.1 Residual Effects Characterization for Wetland Extent and Function

The residual effects on wetland function are shown in Table 12.9-1 and characterized according to the criteria in Tables 12.9-2 and 12.9-3. Residual effects on wetland functions will occur where wetland extent or functions are altered by Project activities. These effects occur in four areas primarily: direct loss under Project footprints; alteration of function adjacent to footprints; dust deposition; and alteration or loss in areas of subsidence.

Table 12.9-1. Residual Effects on Wetland Function and Extent

	Wetland Class (Area in ha)						% of Mapped Wetlands in the LSA
Risk	Bog	Fen	Marsh	SOW	Swamp	Total (ha)	
None	101.6	15.9	34.3	17.3	78.9	248	63%
Low	40.1	0.0	6.5	4.4	3.3	54.3	14%
Moderate	2.7	0.0	1.5	2.2	4.7	11.1	3%
High	0.0	0.0	1.5	1.5	5.4	8.4	2%
Loss	26.2	0.0	1.1	0.7	0.6	28.6	7%
Subsidence	8.1	0.0	4.5	4.5	27.2	44.3	11%
Total (ha)	**178.7**	**15.9**	**49.4**	**30.6**	**120.1**	**394.7**	**100%**

Table 12.9-2. Magnitude Threshold for Wetlands Grouped by Risk Category

Area of Mapped Wetlands Grouped by Risk Category		Magnitude of Effect	Actual % of Mapped Wetlands
⬜	> 90% in None or Low. No detectable change from baseline conditions	Negligible	77%
🟩	Moderate + High ≤ 20% and High < 20%	Minor	0%
🟨	Moderate + High < 30% and > 20; and High ≤ 20%	Medium	23%
🟥	Moderate + High ≥ 30% or High > 20%	Major	0%

Magnitude was assessed in terms of the amount of area in the LSA affected in each risk class. Area affected by loss and subsidence was included with area in the High Risk class to determine magnitude.

Table 12.9-3. Definitions of Characterization Criteria for Residual Effects on Wetlands

Magnitude *How severe will the effect be?*	Duration *How long will the effect last?*	Frequency *How often will the effect occur?*	Geographic Extent (Physical/Biophysical) *How far will the effect reach?*	Reversibility *To what degree is the effect reversible?*	Resiliency *How resilient is the receiving environment or population? Will it be able to adapt to or absorb the change?*	Ecological Context *What is the current condition of the ecosystem and how commonly is it represented in the LSA?*	Likelihood *How likely is the effect to occur?*	Confidence Level *How certain is this analysis? Consider potential for error, confidence intervals, unknown variables, etc.*
Negligible: No or very little detectable change from baseline conditions. See Section 12.9-1 and Table 12.9-2 for classes.	**Short-term:** Effect lasts approximately 10 years or less.	**Once:** Effect is confined to one discrete period in time during the life of the Project.	**Local:** Effect extends less than 500 m from infrastructure or activity.	**Reversible Short-term:** Effect can be reversed relatively quickly.	**Low:** The receiving environment or population has a low resilience to imposed stresses and will not easily adapt to the effect.	**Low:** The receptor is considered to have little to no unique attributes or provision of functions is severely degraded.	**High:** It is highly likely that this effect will occur.	**High:** > 80% confidence. There is a good understanding of the cause-effect relationship and all necessary data are available for the Project area. There is a low degree of uncertainty and variation from the predicted effect is expected to be low.
Minor: Differs from the average value for baseline conditions to a small degree. See Section 12.9-1 and Table 12.9-2 for classes.	**Medium-term:** Effect lasts from 11 to 50 years.	**Sporadic:** Effect occurs at sporadic or intermittent intervals during any phase of the Project.	**Landscape:** Effect is limited to the LSA or one watershed.	**Reversible Long-term:** Within 20 years of Post Closure.	**Neutral:** The receiving environment or population has a neutral resilience to imposed stresses and may be able to respond and adapt to the effect.	**Neutral**: The receiving environment is considered to have some unique attributes and provides most functions that an undisturbed environment would provide.	**Medium:** This effect is likely, but may not occur.	**Medium:** 50 to 80% confidence. The cause-effect relationships are not fully understood, there are a number of unknown external variables, or data for the Project area are incomplete. There is a moderate degree of uncertainty; while results may vary, predictions are relatively confident.
Moderate: Differs substantially from the average value for baseline conditions and approaches the limits of natural variation. See Section 12.9-1 and Table 12.9-2 for classes.	**Long-term:** Effect lasts between 51 and 100 years.	**Regular:** Effect occurs on a regular basis during the life span of the Project.	**Regional:** Effect extends across the broader region (e.g., RSA, multiple watersheds, etc.).	**Irreversible:** An effect cannot be reversed (i.e., is permanent).	**High:** The receiving environment or population has a high natural resilience to imposed stresses, and can respond and adapt to the effect.	**High:** The receiving environment or population is uncommon and occurs in a natural state and provides functions at a maximum capacity	**Low:** This effect is unlikely but could occur.	**Low:** < 50% confidence. The cause-effect relationships are poorly understood, there are a number of unknown external variables, and data for the Project area are incomplete. High degree of uncertainty and final results may vary considerably.
Major: Differs substantially from baseline conditions, resulting in a detectable change beyond the range of natural variation. See Section 12.9-1 and Table 12.9-2 for classes.	**Far Future:** Effect lasts more than 101 years.	**Continuous:** Effect occurs constantly during the life of the Project.	**Beyond Regional:** Effect extends beyond the regional scale and may extend across or beyond the province.					

If over 90% of the area occurs in none and low risk, the magnitude is negligible. The areas in wetlands modelled as high risk, lost, or subject to subsidence were summed. If the sum of these areas was greater or equal to 20% of the total wetland area in the LSA or moderate risk plus this sum was greater than or equal to 30% of the total mapped wetland area, magnitude was assessed as major (Table 12.9-2). If the sum of wetland area in moderate and high risk (including loss and subsidence) classes was less than 30% of the total mapped area and less than 20% of this was high, magnitude was assessed as moderate. If the sum of moderate and high risk was less than 20% and high risk was less than 20%, magnitude was assessed as minor.

The value of 30% is adapted from scientific research and reviews on ecological thresholds. Research has indicated that as total habitat declines both population size and the number of wildlife species decline (not necessarily in a linear relationship) and that thresholds for wildlife often occur somewhere between 30 and 70% of habitat loss, depending on the ecosystem and wildlife species of interest (Mace et al. 1996; Mace and Waller 1997; Mace 2004; Schwartz et al. 2006; Interagency Conservation Strategy Team 2007; Price, Holt, and Kremsater 2007).

The threshold value of 20% for high magnitude was selected based on the concept of maintaining ecosystem group representation. It has been suggested that poorly represented or rare ecosystems, such as wetlands, be offered greater protection (Bunnell et al. 2003; Wells et al. 2003).

Effects will be medium in magnitude as 20% of wetlands in the LSA were identified as being either lost, at high risk of alteration, or subject to subsidence (81.3 ha) but the sum of moderate and high was 23% which is less than the 30% limit shown in Table 12.9-2 that differentiates between medium and major magnitude.

To summarize, 20% of all the wetland area in the LSA was identified as being in lost or at high risk, 3% of wetland area was identified in the moderate risk class, and 77% were identified in low or none risk classes. The assessment of medium magnitude is conservative as it assumes that all wetlands that overlap with the Subsidence Footprint will have high risk. This is probably not the case, but as effects of subsidence are not known this is a conservative approach.

Lost areas under Project infrastructure, which are not anticipated to return to baseline conditions even after reclamation, account for 7% off all effects (Table 12.9-2). Where alteration of wetland functions will occur, the effects on function will be long-term, as wetland function can take decades to re-develop after disturbance (Trombulak and Frissell 2000). For example, there is the potential for functions to reach new equilibriums after subsidence has occurred. While these changes due to subsidence will occur relatively rapidly, restoration of biochemical function, habitat functions, and functional diversity to pre-effect conditions could take several decades or longer (Trombulak and Frissell 2000).

The frequency of disturbances such as sedimentation and dustfall due to Project activity and the effects on wetland function will be sporadic. The geographic extent of effects on wetlands is local in nature and confined to the LSA and generally, except in the cases of subsidence and dust, limited to the Decline, Shaft, and Coal Processing Sites. The effects on wetland functions are probably reversible in some areas over the long-term once hydrologic regimes are re-established and dust inputs reduced. Where subsidence has affected wetlands, new functional roles will establish over decades. However, there is uncertainty associated with how and what these altered functions will be, as wetlands have low resilience due to their susceptibility to disturbance. Physical, chemical, and biotic changes can have long-lasting effects on wetland function.

12.9.1.1 Significance of Residual Effects on Wetlands

Residual effects are expected on wetland extent and functions due to Project activities. These effects are considered to be not significant (moderate). As indicated in Table 12.9-2, 20% of mapped wetlands in the LSA are at high risk of being affected (81.3 ha) and 3% (11.1 ha) are at moderate risk; therefore, the magnitude of effect is major. The residual effects are local in extent, albeit long-term, and will approach the limits of natural variation at a landscape level scale (Table 12.9-4).

12.9.1.2 Characterization of Likelihood and Confidence for Residual Effects on Wetlands

After significance is determined, likelihood and confidence in the significance predictions are made.

To determine the potential for the Project to cause residual effects, the likelihood of a residual effect occurring can be expressed as a measure of probability. The likelihood of a residual effect does not influence the determination of significance, rather it influences the risk of an effect occurring. Likelihood has been considered here in keeping with the most recent guidance issued in September 2013 by the BC Environmental Assessment Office (BC EAO; 2013b): *Guidelines for the Selection of Valued Components and Assessment of Potential Effects.*

Likelihood criteria are provided in Table 12.9-3. Likelihood of residual effects to wetland extent and function is high after mitigation has been considered (Table 12.9-4). This is based on a risk model of the probability of residual effects on wetland function due to the Project and predictions of subsidence (X-traction Science and Technology 2014). Most wetlands have no or low probability of residual effects (77%); moderate residual effects are likely on 3% of wetlands; and high residual effects are expected on 20% of wetlands due to subsidence and loss.

Confidence, which can also be thought of as scientific uncertainty, is a measure of how well residual effects are understood. It includes a consideration of the acceptability of the data inputs and analytical methods used to predict and assess Project effects. The evaluation criteria of confidence and uncertainty for each residual effect is provided in Table 12.9-3.

As indicated in Table 12.9-4, overall there is a moderate degree of confidence in the outcomes of this assessment. The outputs from the probability and consequence model and final risk ratings from the model support provide high confidence in the characterization of adverse effects on wetland function. However, the confidence in the effects of subsidence is medium. While uncertainty exists in every prediction of future change, the approach used to assess the effects on wetland function was developed to incorporate quantitative data from baseline reports and literature reviews. The goals were to remove as much subjectivity from the assessment as possible and to increase certainty in the predictions of alteration of wetland functions, residual effects, and the determination of significance to ensure a robust, transparent, and defensible approach to the effects assessment of wetlands.

Table 12.9-4. Characterization of Residual Effects, Likelihood, Confidence, and Significance for Wetlands

	Residual Effects Characterization Criteria						Significance of Adverse Residual Effects	Likelihood and Confidence	
Residual Effects	Magnitude (*minor, moderate, major*)	Duration (*short, medium, long, far future*)	Frequency (*once, sporadic, regular, continuous*)	Geographic Extent (*local, landscape, regional, beyond regional*)	Reversibility (*reversible short-term; reversible long-term; irreversible*)	Ecological Context (*low, neutral, high*)	Not Significant (*minor, moderate*); Significant (*major*)	Likelihood (*low, medium, high*)	Confidence (*low, medium, high*)
Loss of wetland extent	Moderate	Far Future	Once	Local	Irreversible	High	Not significant (moderate)	High	High
Alteration of wetland function	Moderate	Long	Sporadic/ regular	Local	Long-term	High	Not significant (moderate)	High	High

12.10 SUMMARY OF RESIDUAL EFFECTS ASSESSMENT AND SIGNIFICANCE FOR WETLANDS

Alteration of wetland function is rated moderate in magnitude as determined by the criteria in Table 12.9-3. As shown in the probability and consequence model, 20% and 3% of wetlands in the LSA are in high (including loss, effects on function, and subsidence) and moderate risk, respectively (81.3 ha). The probability of effects on hydrological functions, biochemical functions, functional diversity, or habitat function will be minimized through adherence to the mitigation and management strategies described within the Management and Monitoring Plans (Chapter 24; Table 12.10-1).

Table 12.10-1. Summary of Residual Effects, Mitigation, and Significance on Wetlands

Residual Effects	Project Phase	Mitigation Measures	Significance
Loss of extent	Construction/ Operation	None	Not significant (moderate)
Alteration of function	Operation to Post Closure	Air Quality and Dust Control Plan, Access Management Plan, Erosion and Sediment Control Plan, Selenium Management Plan, Aquatic Effects Monitoring Plan, Spill Response Plan, and Invasive Plant Management Plan	Not Significant (moderate)

Alteration of wetland function is local in extent, as it occurs within the LSA. The use of weighted buffers to model effects of hydrological connectivity, fragmentation, edge effects, dust, sedimentation/water quality, and exotic invasive species was chosen to model Project effects on function, as effects generally decrease with increasing distance from the causal agent. The weighted buffers also facilitated the contribution of each effect to the final assessment of consequence, ensuring that minor effects were not over emphasized and potentially important effects were allotted appropriate weighting. Evaluation of subsidence used subsidence modelling results and the mine plan to determine areas that could be affected by subsidence. The actual effects of subsidence are unknown, but it is assumed that alteration of wetland functions will occur in response to changes in topography and shallow groundwater hydrology.

The loss of wetland extent is not reversible unless compensation or restoration is undertaken. The effects of alteration of wetland functions are generally reversible in the long-term (e.g., after Construction, Operation, and Decommissioning and Reclamation activities are complete), except where infrastructure is not reclaimed as continued use may alter adjacent ecosystems. Wetlands are sensitive to disturbance, have low resiliency compared to most upland ecosystems, and they recover more slowly in many cases. Implementing management plans to help ameliorate impacts during the life of the mine will help ensure successful restoration of wetland functions Post Closure.

It is expected that effects will not occur uniformly throughout the buffers used to model probability of function alteration. Uncertainty exists with respect to where and to what degree alteration of functions may occur. As a result, alteration of function may exceed or fall short of the chosen buffers or have a lesser or greater effect. However, the approach of selecting the buffer sizes and the weights assigned to each effect was precautionary to avoid underestimating the potential Project effects. As the effects of subsidence are also unknown, assuming that all wetlands that will experience subsidence will have high effects was precautionary. In summary, the potential residual effects of the proposed Murray River Project on wetlands are **not significant (moderate)**.

12.11 CUMULATIVE EFFECTS ASSESSMENT

12.11.1 Introduction

Cumulative effects are the result of a project-related effect interacting with the effects of other human actions (i.e., anthropogenic developments, projects, or activities) to produce a combined effect.

Cumulative effects are assessed in each of the assessment chapters, as required by the BC EAO (2013a). A synthesis of these sections is provided in Chapter 21, to address CEA Agency (2013) requirements.

The method for assessing cumulative effects generally follows the same steps as the Project-specific effects assessment: (1) scoping and identification of potential effects, (2) description of potential effects and mitigation measures, with subsequent identification of residual cumulative effects, and (3) identification and characterization of residual cumulative effects. However, because of the broader scope and greater uncertainties inherent in CEA (e.g., data limitations associated with some human actions, particularly future actions); there is greater dependency on qualitative methods and expert judgement. This framework for the CEA facilitates comparison between the two levels of assessment (project-specific and CEA) and between assessment categories, and is tailored to how much information is available.

12.11.2 Establishing the Scope of the Cumulative Effects Assessment

The following two criteria for the relevance of evidence pertaining to other human actions are considered in the scoping of the CEA:

1. A residual effect of the Project must be demonstrated to operate cumulatively with the effects of another human action.
2. The other human action must be known to have been carried out, or it must be probable (using best professional judgement) that it *will be* carried out.

The Application Information Requirements (BC EAO 2013a) state that only residual effects are carried forward from the Project-specific effects assessment into the CEA. Thus, the VCs used as focal points for the Project-specific environmental assessment, selected as described in Section 5.6.1, are also captured in the CEA. However, the assessment boundaries for the CEA are expanded in order to consider a broader scale of environmental concerns, as described in Sections 5.10.2.1 to 5.10.2.3.

The analysis for the Project determined that 20% (81.3 ha) of wetlands in the LSA will be at high risk of loss or of function alteration. The majority of the potential alteration is due to subsidence and loss. Effects on wetlands were carried through as a residual effect because it is expected that mitigation efforts will not return wetland function to baseline level.

12.11.2.1 Spatial Boundaries

The cumulative effects assessment spatial boundary is intended to encompass an area beyond which effects of the Project would not cumulatively interact with effects of other Projects. The RSA was selected as a suitable boundary to base the cumulative effects assessment on. It encompasses the regional setting for the Project and implicitly considers ecological factors, such as height of land in boundary delineation. The RSA also encompasses other relevant regionally important projects (Figure 12.11-1).

12.11.2.2 Temporal Boundaries

The temporal boundaries for the CEA go beyond the phases of the Project, beginning before major human actions were undertaken in the region, and extending into the future. While precisely forecasting which other human actions will occur at the end of the Project's Post Closure phase would be pure conjecture, an extrapolation of a likely future development scenario for the next several decades—based on information available today—is attempted. All projects considered in the cumulative effects assessment are shown in Table 12.11-1 according to these temporal periods.

The following temporal periods are evaluated as part of the CEA:

- **Past:** 1940 (to capture the early non-Aboriginal human activities in the region) to 2010 (when baseline studies at the Murray River Project began);
- **Present:** 2010 (from the start of the Project baseline studies) to 2014 (completion of the environmental assessment); and
- **Future:** temporal boundaries are stated in each assessment chapter, and vary according to the time estimated for VCs to recover to baseline conditions (taking into account natural cycles of ecosystem change).

The other human actions considered in the CEA (described in Section 5.10.5) fall into the following temporal categories:

- **Past** (closed) human actions;
- **Present** (continuing and active) human actions; and
- **Future** human actions, which may be:
  - **certain actions:** those actions that have received regulatory authorizations but are not as yet built or operating,
  - **reasonably foreseeable actions:** those actions that are currently in some stage of a regulatory authorization process, and for which a general concept is available from which potential cumulative effects may be anticipated, and
  - **hypothetical actions:** those actions that are conjectural but probable, based on best professional judgement of currently available information, including leases, licences, and extrapolations from historical development patterns; *the potential cumulative effects of such actions are discussed on a conceptual basis only in this CEA*.

Figure 12.11-1

Footprints used to Assess Cumulative Effects on Wetlands

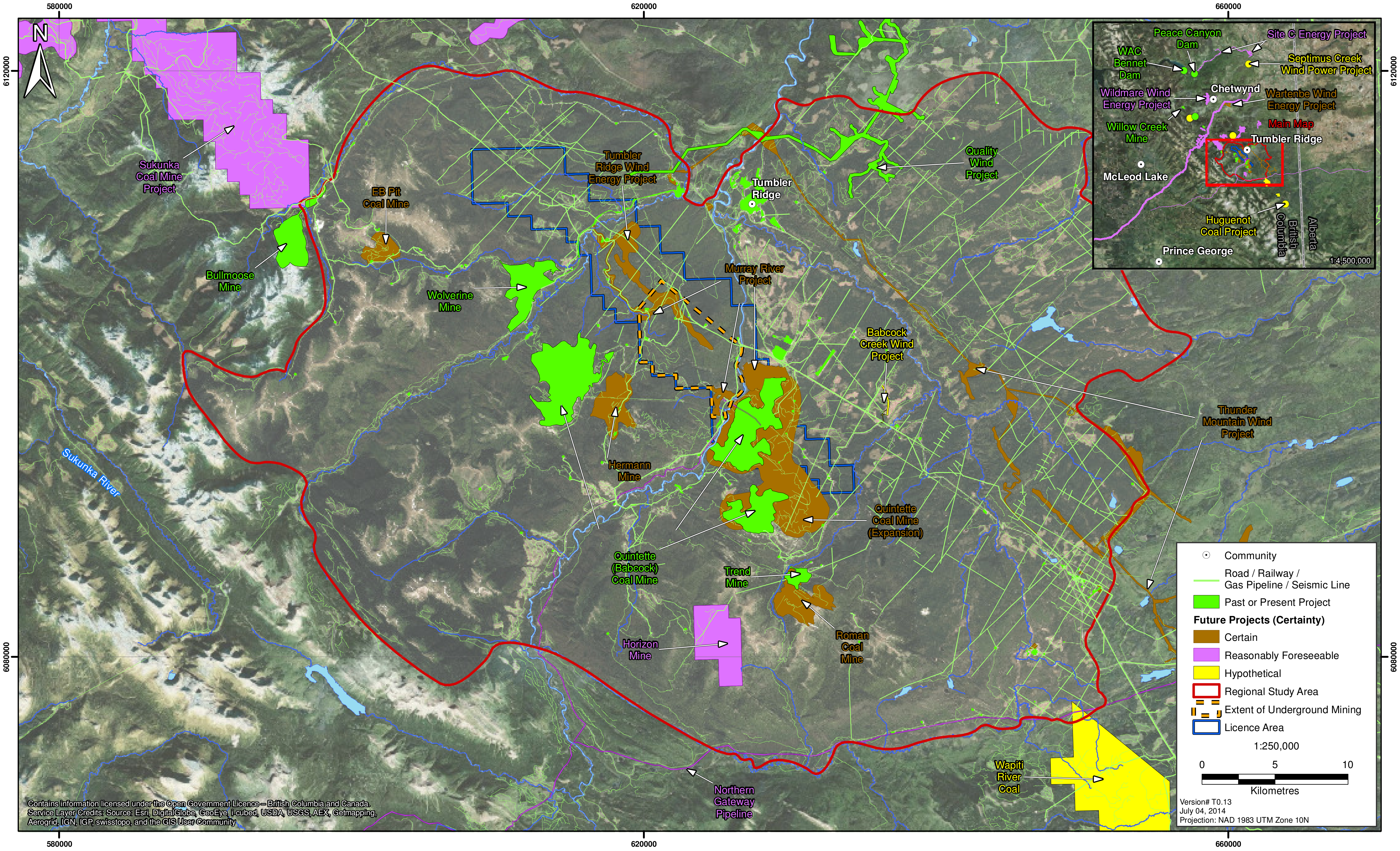

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Table 12.11-1. Potential for Residual Effects to Interact Cumulatively with Effects of Other Human Actions on Wetlands

Timeframe		Name of Action	Dates Active	Proponent (if applicable)	Cumulative Effects	Area Lost (ha) [Altered]	Comments
Past	Historical	Hasler Coal Mine	1941 - 1945	Hasler Creek Coal Company	-	0	No spatial overlap with the RSA
		Sukunka (Bullmoose) Mine	1972 – 1975	BP Exploration Canada Ltd.	N	10.2	Overlay mine footprints and calculate distribution of wetlands based on RSA PEM
	Recent	Bullmoose Mine	1983 – 2003	Teck Corporation	-	0	No spatial overlap with the RSA
		Dillon Coal Mine	2004 – 2007	Walter Energy / Western Coal	-	0	No spatial overlap with the RSA
		Quintette (Babcock) Mine	1983 - 2000	Teck Corporation	H	52.9 [12.5]	Source: EA historic TEM mapping
		Quintette (MESA Pit) Mine	1983 - 2000	Teck Corporation	H		Overlay mine footprints and calculate distribution of wetlands based on RSA PEM
		Willow Creek Mine	2000 - 2013	Walter Energy	-	0	No spatial overlap with the RSA
		Major Forest Licensees			☐	0	Riparian buffers used by forest companies adjacent to cut blocks
		Roads/Gravel Pits			H	Combined with present	Buffer roads and intersect with backdated RSA PEM
		Oil and Gas Footprints			H		Overlay O&G footprints and intersect with backdated RSA PEM
		Oil and Gas Seismic Lines			H		Buffer O&G seismic lines and intersect with backdated RSA PEM
Present		Brule Mine	2005 - 2016	Walter Energy	-		No spatial overlap with the RSA
		Trend Mine	2003 - 2016	Peace River Coal	M	5.2 [4.2]	Used PEM to identify potential historic wetland distribution
		Quality Wind Project	2013 - unknown	Capital Power	L	0.03	Source: EA
		Peace Canyon Dam	1980 – unknown	BC Hydro	-		No spatial overlap with the RSA

(continued)

Table 12.11-1. Potential for Residual Effects to Interact Cumulatively with Effects of Other Human Actions on Wetlands (continued)

Timeframe	Name of Action	Dates Active	Proponent (if applicable)	Cumulative Effects	Area Lost (ha) [Altered]	Comments
Present (*cont'd*)	Wolverine Mine (Perry Creek) and EB Pit	2004 - 2016	Walter Energy	M	52.1 [16.0]	Historic TEM Data from Wolverine Mine EA used to calculate wetland loss of extent. Where TEM data was absent, PEM was used to identify potential historic wetland distribution
	WAC Bennett Dam	1961 – unknown	BC Hydro	-		No spatial overlap with the RSA
	Major Forest Licensees			L		Riparian buffers used by forest companies adjacent to cut blocks
	Roads/ Oil and Gas Footprints/Seismic Lines			H	262.1 [1913.9]	Buffer roads and intersect with backdated RSA PEM. Overlay O&G footprints and intersect with backdated RSA PEM. Buffer O&G seismic lines and intersect with backdated RSA PEM
	Community of Tumbler Ridge			H	18.4 [4.1]	Used PEM to identify potential historic wetland distribution
	Tumbler Ridge Community Forest			L	0	Riparian buffers around wetlands used by community forest
Future Certain	Hermann Mine	2014 - 2025	Walter Energy	M	10.2	Source: EA
	Quintette Mine	2013 - 2025	Teck Corporation	M	1.3	Source: EA
	Roman Mine Project	2013 - 2024	Peace River Coal	M	5.4	Source: EA
	Thunder Mountain Wind Park	2014 – unknown	Aeolis Wind	M	1.5	Source: EA
	Tumbler Ridge Wind Project	2013 - unknown	Pattern Energy Group	M	13	Source: EA
	Wartenbe Wind Project	2014 - unknown	Avro Wind Energy Inc.	-	0	No spatial overlap with the RSA

(continued)

Table 12.11-1. Potential for Residual Effects to Interact Cumulatively with Effects of Other Human Actions on Wetlands (continued)

Timeframe		Name of Action	Dates Active	Proponent (if applicable)	Cumulative Effects	Area Lost (ha) [Altered]	Comments
Future (*cont'd*)	Certain (*cont'd*)	Major Forest Licensees			L	0	Riparian buffers used by forest companies adjacent to cut blocks
		Roads			H		No available data
		Oil and Gas Footprints			H		No available data
		Oil and Gas Sesimic Liness			M		No available data
		Tumbler Ridge Community Forest			L		Riparian buffers around wetlands used by community forest
	Reasonably Foreseeable	Echo Hill Mine	2015 - 2029	Hillsborough Resources Ltd.	-		No spatial overlap with the RSA
		Coastal Gaslink Project	2015 – 2048	TransCanada Pipelines	-		No spatial overlap with the RSA
		Horizon Mine	2015 - 2038	Peace River Coal	M	7.1	Source: EA
		Meikle Wind Energy Project	2015 – 2041	Meikle Wind Energy Partnership	-		No spatial overlap with the RSA
		Northern Gateway Pipeline	2016 – 2068	Enbridge Northern Gateway Pipelines	M	16.8	Footprint loss determined using PEM and identified pipeline route and ROW width. Area overlap with the RSA is 141.4 ha.
		Rocky Creek Energy Project	2015 – unknown	Rupert Peace Power Corporation	-		No spatial overlap with the RSA
		Site C Clean Energy Project	2015 – unknown	BC Hydro	-		No spatial overlap with the RSA
		Sukunka Coal Mine Project	2015 – 2038	Glencore	-		No spatial overlap of development with the RSA
		Sundance Wind Project	2015 - unknown	EDF Energies Nouvelles	-		No spatial overlap with the RSA
		Wildmare Wind Energy Project	2015 – unknown	Pattern Energy Group	-		No spatial overlap with the RSA

(continued)

Table 12.11-1. Potential for Residual Effects to Interact Cumulatively with Effects of Other Human Actions on Wetlands (completed)

Timeframe		Name of Action	Dates Active	Proponent (if applicable)	Cumulative Effects	Area Lost (ha) [Altered]	Comments
Future *(cont'd)*	Hypothetical	Babcock Creek Wind Project	Unknown	Babcock Ridge Wind Limited Partnership	N	0	This has a very small footprint about 400 m from closest wetland. Footprint is all in a clearcut.
		Belcourt Saxon Coal Project	Unknown	Xstrata Coal Canada Ltd.	-		No spatial overlap with the RSA
		Huguenot Mine	Unknown	Colonial Coal International	-		No spatial overlap with the RSA
		Moose Lake Wind Power	Unknown	Moose Lake Wind Power Corporation	-		No spatial overlap with the RSA
		Septimus Creek Wind Power Project	Unknown	Zero Emission Energy Developments	-		No spatial overlap with the RSA
		Suska Mine	Unknown	Xstrata Coal Canada Ltd.	-		No spatial overlap with the RSA
		Wapiti River Coal Project	Unknown	Canadian Dehua International Mines Group Inc.	L	29.0	PEM calculation; 83.4 ha extent overlap of the project boundary with the RSA. Many wetlands exist in this area.

Notes:

\- *No spatial or temporal overlap.*

N *No interaction anticipated.*

L *Negligible to minor adverse effect expected; implementation of best practices, standard mitigation and management measures; no monitoring required, no further consideration warranted.*

M *Potential moderate adverse effect requiring unique active management/monitoring/mitigation; warrants further consideration.*

H *Key interaction resulting in potential significant major adverse effect or significant concern; warrants further consideration.*

12.11.2.3 Identification of Potential Cumulative Effects

Residual effects carried forward from the Project-specific assessment are considered in combination with the residual effects of past, present, and future human actions, where some spatial and temporal overlap occurs. Unless there is a spatial overlap, temporal overlap is considered irrelevant.

A review of the interaction between potential effects of the Project and effects of other projects and activities on wetlands was undertaken. The results are presented in an impact matrix, as shown in Table 12.11-1. If there is no spatial and temporal overlap between the residual effects of the Project and those of another human action, the relevant cell is marked with a dash (-). Where there is spatial and temporal overlap, but no interaction is anticipated, the cell is marked with gray (■) and a rationale as to why no interaction is predicted is given in the table. If there is overlap, and an interaction is anticipated, the cell is marked with green (🟩), yellow (🟨), or red (🟥), as summarized in the footnotes to Table 12.11-1.

As in the Project-specific effects assessment, only potential adverse effects ranked as moderate or major (yellow or red) before active application of mitigation measures are carried forward in the CEA.

An initial list of past, present, and future human actions to be considered in the CEA was developed as part of the Murray River Land Use Baseline Report via desk-based review of existing information and field research conducted between 2010 and 2014 (Appendix 16-A; *Murray River Coal Project: 2013 Non-traditional Land and Resource Use Baseline Report*) for a detailed description of this methodology). For the purposes of the CEA, this list was augmented with information on past historic mining operations retrieved from the BC Ministry of Energy, Mines, and Natural Gas, information on current and future hydroelectric projects from BC Hydro, FortisBC, and Columbia Power Corporation, and information on future actions from the BC EAO and the BC Ministry of Forests, Lands, and Natural Resource Operations.

Information was found to be deficient for many of the historic land uses in the RSA. To supplement the desk based information, interpretation of available spot imagery was used to identify disturbance footprints in the RSA using ArcMap. While the imagery comes from multiple years (2005, 2008, and 2009) and has 250 cm pixel resolution, it was sufficient to provide a base from which to identify and delineate anthropogenic disturbances in the RSA. To avoid duplication of existing data, only disturbances that were not well recorded in available spatial datasets were delineated. Existing road shapes were used, although in some areas new roads were digitized as line features in ArcMap as they were not present in existing datasets. The main disturbance footprints digitized as polygons in ArcMap included the community of Tumbler Ridge, mine sites, gas wells (historic and currently active), seismic lines, gravel pits, airstrips, railways, pipelines, hydro lines and other disturbances that result in the removal or alteration of vegetation. Where existing data was available and accurate, these were used. Due to the relatively coarse scale of the imagery, some errors in attributing the cause of the disturbance may have occurred. Identifying differences between older gas well footprints and gravel pits was difficult to determine is some cases. This, however, does not affect the use of this data for determining cumulative anthropogenic impacts in the RSA; it only reduces the accuracy of determining the land use that resulted in the effect.

12.11.3 Description of Potential Cumulative Effects and Mitigation

12.11.3.1 Analytical Approach

To evaluate the effects of human activity on wetlands in the RSA, ecological mapping of pre-disturbance wetland distributions is required on historic airphotos. However, the cost of historic TEM mapping the entire RSA is prohibitive. To create a pre-disturbance map of ecosystems, an approach was adopted to back-date the predictive ecosystem mapping for the RSA.

To accomplish this, a moving window filter was used to fill the barren values in the PEM that were associated with anthropogenic footprints. All barren cells associated with infrastructure footprints (excluding barren cells in the alpine BEC zones) were set to 0 and removed. Then a raster calculator was used to create a 20 × 20 pixel moving window around each barren cell. The barren cell was replaced with the ecosystem type which occurs most frequently within the specified moving window. The window samples the raster cells adjacent to the barren cells and then populates them based on the neighbouring raster cells. As the barren raster cell footprints are small, this provides a reasonable approximation of pre-existing ecosystems.

As barren cells are calculated for naturally occurring features (rock outcrops and other un-vegetated areas), the barren cells that the moving filter was applied to were identified in the PEM by using the digitized disturbance footprints. Linear and other small features like roads, wells, or other small footprints were back-dated using the moving window. Large footprints associated with mines, development such as the community of Tumbler Ridge, or other infrastructure could not be back dated using the moving window method.

To fill these larger holes, historic TEM data was used where available from other projects. However, for many older projects, no PEM or TEM data exists. To identify cumulative losses for these areas, the area of the Biogeoclimatic (BEC) subzones and variants in each footprint was calculated. Then the distribution of site series for each BEC unit in the RSA was calculated and these distributions were assigned to the footprints that had not BEC data to approximate pre-disturbance ecosystems distributions in the footprints.

To calculate cumulative loss for projects that occurred in the past to present, the digitized disturbance footprints were overlaid on the back-dated PEM. The footprints were then clipped out of the PEM and assumed as lost. For mine footprints and other polygonal features, loss was determined by polygon size. For linear features, buffers were applied. A 10 m buffer was applied to roads and 4 m buffers were applied to seismic lines to account for footprints.

Alteration of function was calculated using 100 m buffers of all polygons and roads to account for changes in hydrology, dust inputs, increased potential for invasive species, fragmentation, and edge effects. Seismic lines were not buffered due to their narrow footprints and lack of anticipated edge effects, dust, and fragmentation.

To determine alteration of function and loss of wetland extent due to future projects, environmental assessments on the BC EAO's website were reviewed for information regarding effects on wetlands and are included in Table 12.11-1.

The table identifies the rationale for inclusion or exclusion in the cumulative effects assessment and summarizes the source of the data used for the assessment. For most projects that occurred in the past to present, these were calculated using the back-dated PEM and the methods described in Section 12.11.1.5. For future projects, environmental assessments were retrieved from the BC EAO website and reviewed. To assess the Northern Gateway Pipeline and Wapiti River Coal Project, the proposed footprints for these projects were overlaid with the backdated PEM and wetland loss was calculated. Figure 12.11-1 shows the footprints of all the potential projects assessed for cumulative effects on wetlands.

12.11.3.2 *Cumulative Effects on Wetlands and Mitigation Measures*

The calculation of loss and alteration due to past and present footprints has no mitigation applied. As the footprints are existing, measures such as avoidance or implementation of buffers are accounted for. Mitigation measures along roads such as dust control or invasive species control were not considered as these are not generally used in most areas. No altered wetland function was identified in the environmental assessments that were reviewed, and it is assumed that mitigation measures have been applied in these projects and account for this. The lost areas of wetland extent identified in the environmental assessments are also assumed to have had all mitigation measures applied, and therefore these effects are all considered residual.

The Project will affect wetland extent and function as will other projects in the region (Table 12.11-1; Figure 12.11-1). The cumulative effects on wetland extent will be limited to the Mine Site Assessment Footprint areas and the areas where subsidence is predicted for the Murray River Coal Project. A residual cumulative effect on the loss of wetland extent and alteration of function is expected due to nibbling and additive losses in the region. The total loss of wetland extent for all projects is 803 ha, and when Murray River Coal Project is included, this increases by 28.6 ha to 832 ha, which accounts for 7.9% of wetlands in the RSA. Alteration of wetland function is anticipated on 1,950 ha (18.6%; Table 12.11-2). Including the Project, this increases to 2,014 ha which accounts for 19.2% of all wetlands in the RSA. Alteration of function is primarily associated with roads and other linear features. In total, 2,846 ha or 27.1% of wetlands in the RSA will be affected by development through either loss or alteration.

12.11.3.3 *Cumulative Residual Effects for Wetlands*

There are predicted residual effects on wetlands that remain after the implementation of all mitigation measures (Tables 12.11-2 and 12.11-3).

12.11.4 Characterization of Residual Effects Confidence, Likelihood, and Significance

The characterization of residual effects was completed by comparing predicted cumulative effects against thresholds, standards, trends, or objectives relevant to wetlands, as defined in Table 12.11-4.

Effects will be moderate magnitude as 27.1% of wetlands in the RSA were identified as being either lost or altered from baseline conditions (Table 12.11-2). To assess magnitude using Table 12.9-2, loss was assumed to be the high risk category and alteration was assumed to be moderate risk. There are two thresholds in Table 12.9-2 that indicate high magnitude. Magnitude is high if high risk (loss in this case) is greater than 20%, or if high risk plus medium risk (alteration) exceeds 30%.

The amount of lost extent is 7.9% off all wetlands which is less than the value 20% in Table 12.9-2. Alteration was calculated as 19.2% of wetland area in the RSA. When alteration of wetland functions is combined with lost wetland extent, total affected wetland area is 27.1%, which is less than the 30% threshold for high magnitude. This does not account for residual effects that may occur due to future oil and gas exploration, road construction, or other unforeseen projects or those lacking sufficient data to predict future effects. While this is considered moderate magnitude, the cumulative effects are close to differing substantially from baseline conditions and exceeding the threshold for high magnitude.

Geographic extent is considered regional.. Duration of effects is considered long-term as most footprints will not be restored in the medium term. Increasing road density, as deactivation is not commonly practiced, is also an example of how these effects can be expected to continue into the future.

The frequency of effect is sporadic and most effects are considered reversible in the long-term. Wetlands are relatively rare and unique ecosystems on the landscape and their context as receptor is rated high. The probability of cumulative effects is high for most of the projects assessed and confidence is high.

12.11.4.1 Significance of Cumulative Residual Effects on Wetlands

The evaluation of significance was completed by comparing predicted residual cumulative effects against thresholds, standards, trends, or objectives relevant to wetlands, as defined below.

- **Not significant**: Residual effects have low or moderate magnitude, local to regional geographic extent, short- or medium-term duration, could occur at any frequency, and are reversible in either the short- or long-term. The effects on the receptor VC (e.g., at a species or local population level) are either indistinguishable from background conditions (i.e., occur within the range of natural variation as influenced by physical, chemical, and biological processes), or distinguishable at the individual level. Land and resource management plan objectives will likely be met, but some management objectives may be impaired. There is a medium to high level of confidence in the analyses. Follow-up monitoring of these effects may be required if the magnitude is medium.
- **Significant**: Residual effects have high magnitude, regional or beyond regional geographic extent, long-term or far future duration, and occur at all frequencies. Residual effects on receptor VCs are consequential (i.e., structural and functional changes in populations, communities, and ecosystems are predicted) and are irreversible. The ability to meet land and resource management plan objectives is impaired. Confidence in the conclusions can be high, medium, or low.

The cumulative effects of the proposed Project and the other projects assessed as part of the cumulative effects assessment are not significant (Table 12.11-5). Magnitude was moderate but close to the threshold for high magnitude. The residual effects are regional in extent and long-term. The effects of alteration are reversible (where loss is not the effect), and over the long-term wetlands will reach new stases and recover from alteration.

Table 12.11-2. Area Summary of Residual Cumulative Past to Future Effects on Wetlands

			Past/Present Activities (ha)								
Cumulative Effect	RSA Area (ha)	Total Wetlands in RSA (ha)	Wolverine Mine (Perry Creek) and EB Pit	Community of Tumbler Ridge	Trend Mine	Sukunka (Bullmoose) Total	Quintette Mines Total	Roads/ Oil and Gas Footprints/Seismic Lines	Quality Wind Project	Total Past/Present	% Wetlands
Altered			16.0	4.1	4.2	-	12.5	1,913.9	-	1,950.7	18.6%
Lost			52.1	18.4	5.2	10.2	52.9	262.1	0.3	401.4	3.8%
Total Altered and Lost	**227,616**	**10,488**	**68.1**	**22.5**	**9.4**	**10.2**	**65.4**	**2,176.0**	**0.3**	**2,352.1**	**22.4%**

	Future Activities (ha)													
	Certain					Reasonably Foreseeable		Hypothetical		Past to Future Total				
Cumulative Effect	Hermann Mine	Quintette Mine	Roman Mine Project	Thunder Mountain Wind Park	Tumbler Ridge Wind Project	Horizon Mine	Northern Gateway Pipeline	Wapiti Coal	Total Future	Total Past to Future (ha)	% Wetlands	Murray River Coal (ha)	Total Past to Future with Murray River (ha)	% Total Past to Future with Murray River
Altered	-	-	-	-	-	-	-	-	-	1,950.7	18.6%	63.8	2,014.5	19.2%
Lost	10.2	1.3	5.4	1.5	13.0	7.1	16.8	29.0	401.7	803.1	7.7%	28.6	831.7	7.9%
Total Altered and Lost	**10.2**	**1.3**	**5.4**	**1.5**	**13.0**	**7.1**	**16.8**	**29.0**	**401.7**	**2,753.8**	**26.3%**	**92.4**	**2,846.2**	**27.1%**

Table 12.11-3. Summary of Residual Cumulative Effects on Wetlands

Valued Component	Murray River Activity	Other Human Action Activity	Description of Potential Cumulative Effect	Description of Mitigation Measure(s)	Description of Residual Cumulative Effect
Wetlands	Footprint Construction/ Subsidence	Footprints for roads, oil and gas wells, railways, hydro lines, seismic lines, mines, wind projects, pipeline's, railways, Community of Tumbler Ridge	Construction footprints – loss of extent and function; Alteration of function due to sedimentation, hydrological changes, invasive species, fragmentation, edge effects, and dust	Avoidance of wetlands, best management practices, sediment control measures, dust control, invasive species control	Nibbling and additive loss of wetlands and their functions

Table 12.11-4. Summary of Residual Cumulative Effects Descriptor Definitions

Criteria	Descriptor	Definition
Magnitude	Low	Minimal or no change from baseline conditions.
	Moderate	Measurable change from baseline conditions, but below or equal to guidelines or thresholds.
	High	Measurable change from baseline conditions and exceeding guidelines or thresholds.
Geographic Extent	Local	Effect restricted to the Project footprint.
	Landscape/Watershed	Effect extends beyond Project footprint but within RSA.
	Regional	Effect extends throughout RSA.
	Beyond Regional	Effect extends across province or further.
Duration	Short-term	Effect lasts 0 to 5 years.
	Medium-term	Effect lasts 6 to 25 years.
	Long-term	Effect lasts 26 to 50 years.
	Far Future	Effect lasts more than 50 years.
Frequency	Once	Effect occurs once.
	Sporadic	Effect occurs intermittently.
	Regular	Effect occurs on a regular basis.
	Continuous	Effect occurs constantly.
Reversibility	Reversible Short-term	Effect can be reversed immediately or quickly.
	Reversible Long-term	Effect can be reversed after many years.
	Irreversible	Effect is permanent.
Context	Low	VC is considered to have little or no unique attributes.
	Neutral	VC is considered to have some unique attributes.
	High	High: the receptor is considered to be unique.
Significance	Not Significant (Minor)	Effect on the VC is indistinguishable from background conditions.
	Not Significant (Moderate)	Effect on the VC may be distinguishable from background conditions, and may impair land and resource management plan objectives.
	Significant (Major)	Effect on the VC is consequential in terms of structural and functional changes; land and resource management plan objectives are impaired.
Probability	Low	Effect is unlikely but could occur.
	Medium	Effect is likely, but may not occur.
	High	Effect is highly likely to occur.
Confidence	Low	<50% confidence.
	Medium	50 to 80% confidence.
	High	>80% confidence.

Table 12.11-5. Characterization of Residual Effects, Significance, Confidence and Likelihood

	Cumulative Residual Effects Characterization Criteria								
Cumulative Residual Effects	**Magnitude** (*low, moderate, high*)	**Duration** (*short-term, medium-term, long-term, far future*)	**Frequency** (*once, sporadic, regular, continuous*)	**Geographic Extent** (*local, landscape, regional, beyond regional*)	**Reversibility** (*reversible short-term, reversible long-term, irreversible*)	**Ecological Context** (*low, neutral, high*)	**Likelihood** (*low, medium, high*)	**Significance of Adverse Cumulative Residual Effects** (*not significant, significant*)	**Confidence** (*low, medium, high*)
Wetland extent loss and alteration of function	Moderate	Far future	Once/ Sporadic/ Regular	Regional	Reversible long-term	High	High	Not Significant	High

12.11.4.2 Confidence of Cumulative Residual Effects on Wetlands

Confidence is considered to be high given the methods used to identify past, present, and future effects on wetlands. There is uncertainty as to precisely where and to what degree alteration of wetland functions may occur, as the effects will not occur uniformly in the areas used to estimate effects on wetland function. As a result, alteration of function may exceed or fall short of the chosen buffers or have a lesser or greater effect.

12.12 EFFECTS ASSESSMENT CONCLUSIONS FOR WETLANDS

Alteration of wetland function is rated moderate in magnitude as determined by the criteria in Table 12.9-3. As shown in the probability and consequence model, 20% and 3% of wetlands in the LSA are in high (including loss, effects on function, and subsidence) and moderate risk respectively (81.3 ha). The probability of effects on hydrological functions, biochemical functions, functional diversity, or habitat function will be minimized through adherence to the mitigation and management strategies described within the Management and Monitoring Plans (Chapter 27).

Alteration of wetland function is local in extent, as it occurs within the LSA. The use of weighted buffers to model effects of hydrological connectivity, fragmentation, edge effects, dust, sedimentation/water quality, and exotic invasive species was chosen to model Project effects on function, as effects generally decrease with increasing distance from the causal agent. The weighted buffers also facilitated the contribution of each effect to the final assessment of consequence, ensuring that minor effects were not over emphasized and potentially important effects were allotted appropriate weighting. Evaluation of subsidence used subsidence modelling results and the mine plan to determine areas that could be affected by subsidence. The actual site-specific effects of subsidence are unknown, but it is assumed that alteration of wetland functions will occur in response to changes in topography and shallow groundwater hydrology.

The loss of wetland extent is not reversible unless compensation or restoration is undertaken. The effects of alteration of wetland functions are generally reversible in the long-term (e.g., after Decommissioning and Reclamation activities are complete), except where infrastructure is not reclaimed as continued use may alter adjacent ecosystems. Wetlands are sensitive to disturbance, have low resiliency compared to most upland ecosystems, and they recover more slowly in many cases. Implementing management plans to help ameliorate impacts during the life of the mine will help ensure successful restoration of wetland functions Post Closure.

It is expected that effects will not occur uniformly throughout the buffers used to model probability of function alteration. Uncertainty exists with respect to where and to what degree alteration of functions may occur. As a result, alteration of function may exceed or fall short of the chosen buffers or have a lesser or greater effect. However, the approach of selecting the buffer sizes and the weights assigned to each effect was precautionary to avoid underestimating the potential Project effects. As the effects of subsidence are also unknown, assuming that all wetlands that will experience subsidence will have high effects was precautionary. In summary, the potential residual effects of the proposed Murray River Project on wetlands are **not significant (moderate;** Table 12.12-1).

Table 12.12-1. Summary of Project and Cumulative Residual Effects, Mitigation, and Significance for Wetlands

			Significance of Residual Effects	
Residual Effects	Project Phase	Mitigation Measures	Project	Cumulative
Wetland extent loss and alteration of function	Construction to Post Closure	Wetland buffers, best management practices, soil management, selenium management, spill response, dust control, invasive plant measures	Not significant (moderate)	Not significant (moderate)

Cumulative effects for the Project and projects within the RSA were assessed. A residual cumulative effect on the loss of wetland extent and alteration of function is expected due to additive losses in the region. This effect is expected to be not significant, because the loss and alteration of wetlands associated with the projects in the RSA is expected to be of moderate magnitude, far future in duration, occur at multiple frequencies, be regional in extent, only reversible in the long-term, and the likelihood of occurrence and confidence are high. In summary, the potential cumulative effects of the proposed Murray River Coal Project and other projects in the area on wetland extent and function are considered to be **not significant (moderate;** Table 12.12-1).

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