5.16 MARINE BENTHIC HABITAT ASSESSMENT

This section presents the results of the assessment of potential effects and cumulative effects on marine benthic habitat as a result of the construction, operation, and decommissioning of the Woodfibre Liquefied Natural Gas Project (Project). The processes used to select marine benthic habitat as a valued component (VC), assessment boundaries, and existing conditions relevant to marine benthic habitat are described. In addition, assessment findings, including evaluation of Project-related interactions and likely adverse effects, proposed approaches to mitigation, identification of likely residual and cumulative effects, and determination of adverse effects significance are presented. Monitoring and follow-up programs to be conducted with respect to marine benthic habitat are also described. This section should be read in conjunction with **Appendix 5.10-1 Marine Resources Baseline Study**. Other documents have informed this assessment section as well, and are presented below:

- **Appendix 5.10-2 Near-Field Mixing Simulation of Diffuser**
- **Appendix 5.10-3 Marine Thermal Analysis: Far-Field Modeling Report**
- **Appendix 5.10-4 Propellor Wash Assessment**
- **Appendix 5.10-5 Conceptual Design of Diffuser**
- **Appendix 5.16-1 Conceptual Design of the Water Intake**

The pathway for support of the marine benthic habitat VC assessment includes the following (refer to **Table 4-2 Component Linkages Matrix**):

- Section 5.6 Geotechnical and Natural Hazards
- Section 5.7 Site Contamination
- Section 5.10 Marine Water Quality
- Section 7.3 Marine Transport

The assessment in this section supports the following assessments:

- Section 5.12 Avifauna
- Section 5.18 Forage Fish and Other Fish
- Section 5.19 Marine Mammals
- Section 7.4 Land and Resource Use
- Section 7.6 Current Use of Lands and Resources for Traditional Purposes

5.16.1 Marine Benthic Habitat Scoping and Rationale

This section provides an overview of marine benthic habitat in the Project area and its regulatory setting with respect to marine benthic habitat, the rationale for the selection of marine benthic habitat as a VC, the spatial and temporal boundaries for marine benthic habitat with associated rationale, and the indicators that will be used to determine potential adverse effects to marine benthic habitat.

5.16.1.1 Overview and Regulatory Setting

Marine benthic habitat encompasses both marine sediments and benthic communities living near or within the seafloor in the intertidal and subtidal zones of the marine environment. Marine sediments provide the main substrate for benthic epifaunal (living above the seafloor) and infaunal (living in the seafloor) biological communities. Substrate type is one of the main physical factors that determine the composition of the associated marine communities. For instance, hard, rocky substrates provide sites for sessile animals such as barnacles and mussels to attach, which, in turn, can provide habitats for mobile animals. Soft-bottom substrates (e.g., sand, silt and clay) provide habitat for burrowing animals, such as clams. Both types of substrate can be utilized as spawning habitats by different species of benthic invertebrates and fishes.

Benthic processes are largely influenced by the sediment's physical and chemical properties such as substrate type, particle size composition, and levels of pollutants (i.e., trace metals and hydrocarbons). Particles of various types and sizes, notably the silt-clay fraction, can adsorb hydrocarbons and certain metals. Chemical constituents of sediments, such as nutrients (e.g., carbon, nitrogen, phosphorus), trace metals, and hydrocarbons, are incorporated into the benthic food chain, determining productivity and toxicity of the substrate, thus influencing growth of benthic organisms. The assessment endpoints for marine sediments are determined by their physical and chemical properties. The primary measurable physical property is particle size composition and the primary measureable chemical properties include concentrations of nutrients (i.e., total organic carbon), metals, hydrocarbons, dioxins and furans, and polychlorinated biphenyls, among others. These properties can be affected by historical or existing operations and activities, or future activities associated with the Project during both the construction and operation phases. Sediment quality may be affected through sediment re-suspension, siltation, or accidental release of chemicals.

Marine flora, especially eelgrass and kelp beds, provide important rearing habitat for juvenile fish, serving as a source of nutrients and organic matter. Eelgrass, a flowering plant found in intertidal and shallow subtidal zones of nearshore marine environments (Fonseca et al. 1998, Durance 2002), plays an important role in maintaining healthy coastal and estuary ecosystems, sustaining sediment stability, increasing biodiversity, and promoting species diversity (Davis et al. 1998, de Jong et al. 2000). Anadromous fish (such as chinook salmon), crabs, and molluscs use eelgrass for habitat (de Jong et al. 2000). Eelgrass serves as a breeding area and nursery for many species of socio-economic significance, including several fish and invertebrate species considered of commercial, recreational, and Aboriginal (CRA) importance (de Jong et al. 2000, Phillips 1984). Eelgrass is a primary source of food and shelter for finfish, shellfish, invertebrates, and migratory birds (Wright 2002).

Kelps (seaweeds) are important components of benthic habitats, often forming extensive three-dimensional habitats in coastal marine environments. Kelp ecosystems provide valuable socio-economic services to coastal marine environments, contributing to the productivity of marine ecosystems and serving as habitat for a diversity of fish and invertebrates, including species of CRA significance. Kelp species are also extracted for human consumption, pharmaceutical industries purposes, and to support commercial mariculture. Kelp beds, especially canopy-forming kelp species such as giant kelp (*Macrocystis integrifolia*) and bull kelp (*Nereocystis luetkeana*), function as physical barriers dampening ocean waves, thereby reducing coastal erosion. Kelp ecosystems are important to local coastal communities and support a wide range of activities such as SCUBA diving, kayaking, bird watching, and commercial and recreational fishing (Springer et al. 2006).

Marine fauna include benthic invertebrate species living on or in sediment or attached to hard substrates. Epifauna can be firmly attached to the substrate (sessile), relatively sedentary, or highly motile. Marine fauna are important components of coastal ecosystems, serving as the critical link between primary producers and other species in the food web, including fish and invertebrate species of ecological and CRA importance. Benthic communities provide many ecosystem services that help maintain good water and sediment quality. Bioturbation (mixing) of seafloor sediments by burrowing or feeding infauna has been shown to enhance degradation of some pollutants and promote the transfer of nutrients into the food web (Virginia Institute of Marine Science 2014). The assessment endpoints for benthos are density (abundance), taxonomic composition, and diversity of benthic communities. Effects to these communities can result from the installation of marine facilities, loss of habitat, changes in water and sediment quality, shading, and accidental release of toxic substances.

Northern abalone (*Haliotis kamtschatkana*), a species of marine gastropod, commonly occurs along exposed and semi-exposed rocky coastlines in British Columbia (BC), extending from Sitka Sound, Alaska, to Baja California. Abalone occurs in a wide range of habitats from sheltered bays to exposed coastlines, typically in patchy distributions on hard substrates in intertidal and shallow subtidal waters. In June 2003, Northern abalone was listed and protected as endangered under the *Species at Risk Act*, SC 2002, c. 29, (*SARA*) and the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2009). Northern abalone is not typically found in inlet waters and only small populations have been documented within the Strait of Georgia (Sloan and Farlinger 1987).

Federal and provincial regulations relevant to the marine benthic habitat VC include the *Fisheries Act*, RSC 1985, c. F-14, and *SARA*. A number of other conservation strategies and guidelines relevant to marine benthic habitat within Howe Sound include the following:

- Fisheries and Oceans Canada (DFO) *Pacific Region Cold-water Coral and Sponge Conservation Strategy (2010–2015)* (DFO n.d.) – provides guidance for the conservation of cold-water coral and sponge populations.

- *Fisheries Protection Policy Statement* (DFO 2013a) – provides guidance in support of changes made to the *Fisheries Act* in 2012.
- *Canadian Sediment Quality Guidelines for the Protection of Aquatic Life* (CCME 2014) – provides guidelines for the evaluation of adverse biological effects in aquatic systems.

Table 5.16-1 provides a summary of the federal and provincial regulatory and policy settings relevant to the marine benthic habitat VC. Other regulatory settings applicable to changes in water quality that may be relevant to marine benthic habitat are discussed in **Section 5.10 Marine Water Quality**, and include the *Migratory Birds Convention Act*, SC 1994, c.44, *Canadian Shipping Act, 2001*, SC 2001, c. 26, BC *Wildlife Act*, RSBC 1996, c. 488, BC *Environmental Management Act*, SBC 2003, c. 53 and BC water quality guidelines.

Table 5.16-1 Regulatory and Policy Settings for the Project Applicable to Marine Benthic Habitat

Legislation	Agency	Description and Application to the Project
Fisheries Act	DFO	• Section 35 – Prohibits any work, undertaking, or activity that results in serious harm to fish that are part of a CRA fishery, or to fish that support such a fishery. • Section 38(4) – Requires that any unauthorized serious harm to a CRA fishery be reported without delay.
Fisheries Act	Environment Canada	• Section 36 – Prohibits the deposit of a deleterious substance in waters frequented by fish. • Section 38(5) – Required that any unauthorized deposit of a deleterious substance in waters frequented by fish be reported without delay.
Species at Risk Act	DFO	• Protects Canadian indigenous species, subspecies, and distinct populations from becoming extirpated or extinct; provides for the recovery of endangered or threatened species; and encourages the management of other species to prevent them from becoming at-risk. • Section 32 – Prohibition against killing, harming, harassing, capturing, or taking an individual of a species listed as extirpated, endangered, or threatened. • Section 33 – Prohibition against damaging or destroying the residence of individuals of a species listed as extirpated, endangered, or threatened.

5.16.1.2 Selection of Valued Component

The selection of marine benthic habitat as a VC followed a selection process as set out in **Section 4.3 Issues Scoping and Selection of Valued Components** and described further in **Section 5.1 Environmental Background**. Marine benthic habitat includes two sub-components, as follows:

- **Marine sediment** – Provides the main substrate for benthic environment and habitat for marine flora and fauna. Benthic processes are largely influenced by sediment physical and chemical properties such as substrate type, particle size composition, level of nutrients, and concentrations of pollutants, such as trace metals and hydrocarbons.

- **Marine benthic communities** – Include benthic flora and fauna and are an important component of the coastal environment. Benthic flora are primary producers and, together with phytoplankton and some bacteria, form the base of the marine food chain. Benthic flora also provides a spawning substrate for marine fish species, such as herring. Benthic invertebrate infauna and epifauna, collectively referred as benthos, are represented by a great variety of organisms that belong to crustaceans, molluscs, worms, echinoderms, cnidarians and many other taxonomic groups. Benthos is a major food source for many species of fish, birds, and mammals. Conditions of benthic communities are a good indicator of the quality of the fisheries and aquatic habitat.

Potential effects from the Project on marine benthic habitat may include loss of habitat from shoreline modifications and installation of Project infrastructure (Project footprint), shading effect from the Project infrastructure, changes in water and sediment quality, and introduction of invasive species from ships' ballast water and hulls.

5.16.1.3 Indicators

The indicators used to assess the potential effects of the Project on marine benthic habitat are shown in **Table 5.16-2** and were identified using known anthropogenic threats to marine benthic habitat (e.g., fishing, industrial activity), scientific studies, and professional judgment.

Table 5.16-2 Indicators for Marine Benthic Habitat

Indicator	Rationale for Selection
Marine Sediment	
Change in sediment composition/contamination of marine sediment: • particle size composition • concentrations of metals, hydrocarbons and other pollutants	The indicators were selected to address potential Project-related adverse effects including: • effluent and other discharges may affect quality of sediment through changes in marine water quality • potential disturbance of seafloor sediments in the vicinity of effluent diffusers • re-suspension of marine sediments and potential contaminants associated with seafloor disturbance from pile-driving and propeller scour; land clearing and other construction, which may result in upland erosion and sediment/soil transport to the marine environment
Marine Benthic Communities (Marine Flora & Marine Fauna)	
Change in benthic community: • Density (abundance) • Taxonomic composition • Diversity	The indicators were selected to address potential Project-related adverse effects including: • direct loss of marine habitat within the Project footprint • shading from the Project infrastructure • thermal stress from heated effluent discharge • indirect effects through changes in marine water and sediment quality • introduction of non-native and invasive species from ship ballast

5.16.1.4 Assessment Boundaries

This section describes the spatial and temporal boundaries of the assessment of marine benthic habitat, as well as administrative or technical boundaries that may apply.

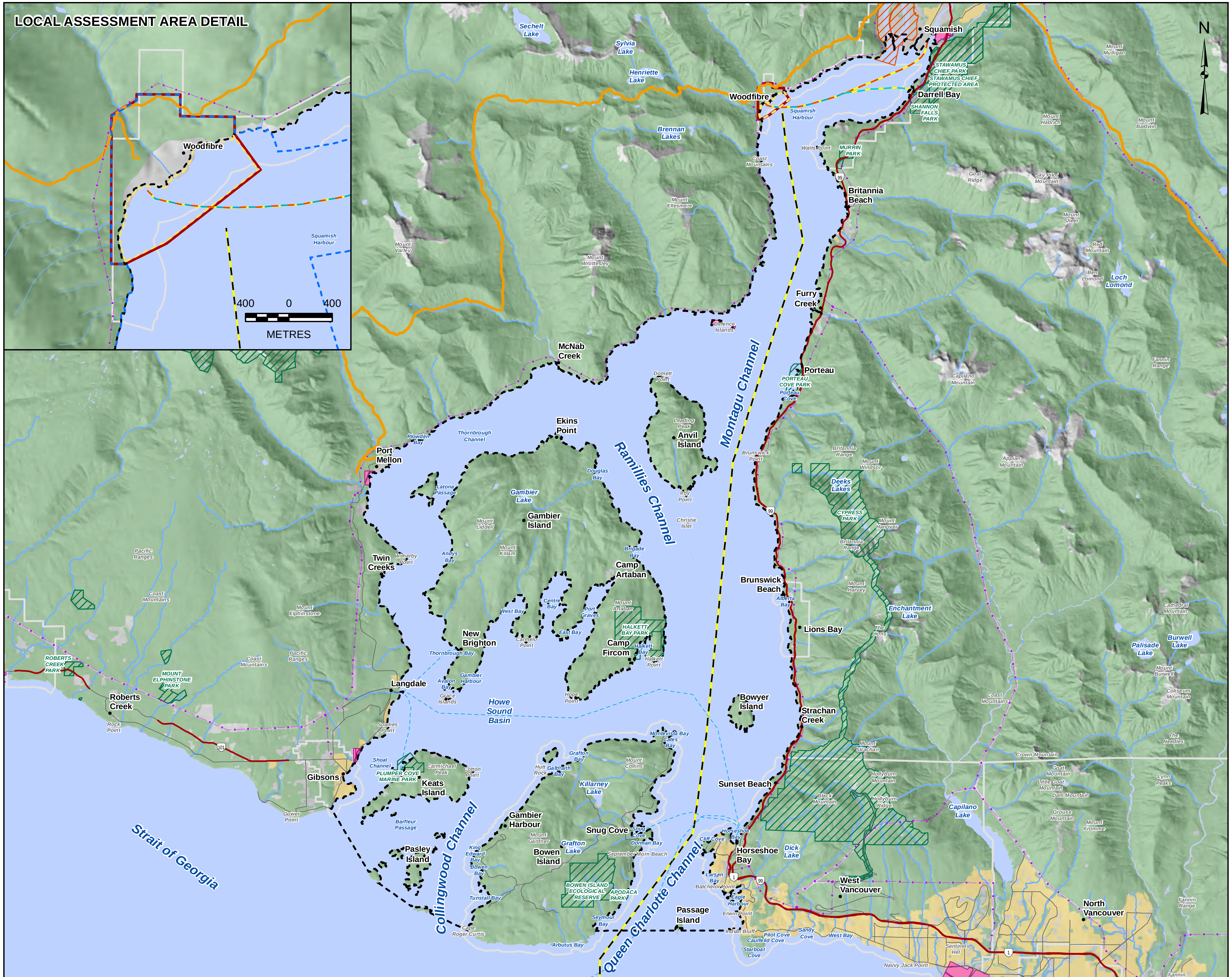
5.16.1.4.1 Spatial Boundaries

The local assessment area (LAA) and regional assessment area (RAA) for marine benthic habitat and subcomponents are defined in **Table 5.16-3** and shown in **Figure 5.16-1**. The LAA was established to encompass the area within which the Project is expected to interact with and potentially have a direct or indirect effect on marine benthic habitat. In determining LAA boundaries, consideration was given to the nature and characteristics of marine benthic habitat, its potential exposure to various influences, and the maximum extent of potential adverse effects on marine benthic habitat.

The RAA was established to provide a regional context for the assessment of Project-related effects. The RAA also encompasses the area within which the residual effects of the Project may overlap with the residual effects of other existing or reasonably foreseeable projects and activities.

Table 5.16-3 Spatial Boundary Definitions for Marine Benthic Habitat

Spatial Boundary (both subcomponents)	Description of Assessment Area
Local Assessment Area	The marine portion of the Project area
Regional Assessment Area	Howe Sound
Cumulative Effects Assessment Area	Same as RAA



LEGEND

- PROJECT AREA
- MARINE BENTHIC HABITAT LAA
- MARINE BENTHIC HABITAT RAA
- PARK / PROTECTED AREA
- SKEWLWIL'EM SQUAMISH ESTUARY
- FOREST AREA
- URBAN AREA
- INDIAN RESERVE
- MUNICIPAL BOUNDARY
- HIGHWAY
- ARTERIAL ROAD
- TRANSMISSION LINE (ELECTRIC)
- FORTISBC GAS PIPELINE
- PROPOSED SHIPPING ROUTE
- WORKER FERRY DIRECT ROUTE
- WATER TAXI DIRECT ROUTE
- BC FERRIES ROUTE
- WATERCOURSE

REFERENCE

PARKS/PROTECTED AREAS AND MUNICIPALITIES FROM GEOBC. GAS PIPELINE FROM ICIS. BASE DATA FROM CANVEC © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED. HILLSHADE PROVIDED BY GOVERNMENT OF BRITISH COLUMBIA.
PROJECTION: UTM ZONE 10 DATUM: NAD 83

SCALE

4 0 4

KILOMETRES

PROJECT

WOODFIBRE LNG LIMITED
WOODFIBRE, HOWE SOUND, B.C.

TITLE

MARINE BENTHIC HABITAT ASSESSMENT AREAS

Golder Associates

PROJECT NO. 13-1422-0006			PHASE No. 6000	
DESIGN	RF	11 Apr. 2014	SCALE: 1:165,000	REV. 0
GIS	DL	15 Oct. 2014	FIGURE 5.16-1	
CHECK	JS	16 Oct. 2014		
REVIEW	AK	16 Oct. 2014		

PATH: \\golder.gds\gal\Vancouver\CAD-GIS\VAN\2013\13-1422\13-1422-0006 - Woodfibre\Mapping\MXD\Marine Habitat\WOODFIBRE_MARINE_BENTHIC_HABITAT_FIGURE_5_16-1_Marine_Benthic_Habitat_Assessment_Areas.mxd Date: 10/16/2014 Time: 11:54:30 AM

5.16.1.4.2 Temporal Boundaries

Baseline studies to characterize existing conditions reflect the years 2013 and 2014. Studies predicting changes due to the Project were based on future conditions representing the construction, operation, and decommissioning phases. In order to describe the changes in the context of the future conditions related to marine benthic habitat, three temporal cases were considered: existing conditions, future conditions with the Project in place, and future conditions with the Project and other projects and activities.

The temporal characteristics of the marine benthic habitat VC are described in the existing conditions for this VC and relate to all seasons. Temporal characteristics are also considered in the identification of the potential effects, and in the proposed mitigation measures.

5.16.1.4.3 Administrative Boundaries

Administrative boundaries applicable to the marine benthic habitat VC include subareas 28-1 through 28-5 of Pacific Region Fisheries Management Area 28 (DFO 2013a). These five subareas encompass the boundaries for management or recreational fishing within the Project's RAA.

5.16.1.4.4 Technical Boundaries

Technical boundaries for the environmental assessment include adequacy of the data for understanding existing conditions and future changes unrelated to the Project; adequacy of the data for understanding of Project-related effects to complex systems that contain interactions across time and space; and knowledge of the effectiveness of design features and mitigation measures for avoiding effects. Factors that may affect the adequacy of the data include seasonal effects, which may not be fully captured by field surveys conducted for this assessment, as well as species presence, absence, or abundance for which the spatial or temporal scope of field surveys may not have fully captured the entire range of species distributions within the LAA.

5.16.2 Existing Conditions

This section presents the existing conditions for the marine benthic habitat VC in the LAA and RAA, and provides background information, as well as descriptions of desktop and field studies conducted to support this assessment.

5.16.2.1 Introduction

Benthic habitats play an important role in BC's ecology, economy, and society. This section describes existing marine benthic habitat conditions in the LAA and RAA to document existing conditions in the Project area, as well as compile regional information on marine benthic habitat through a review of available literature. See **Appendix 5.10-1 Marine Resources Baseline Study** for a full literature review and summary of existing conditions within the LAA and RAA.

5.16.2.2 Background Information

Marine benthic habitat in the Project area has been studied since at least 1979. Most of these studies address the effects from operation of the former Woodfibre Pulp and Paper Mill. These studies include the following:

- Woodfibre Pulp Mill Impact Assessment (Nelson 1979)
- Environmental Effects Monitoring by Hatfield Consultants (2004)
- Keystone Environmental Limited studies since 2006 for the Woodfibre Pulp and Paper Mill (Keystone 2014)[1]

In addition, various literature sources were reviewed to characterize the physical and biological attributes of Howe Sound. These sources included available grey literature and peer-reviewed scientific publications, governmental and non-governmental reports, environmental resource databases, and previous work completed for other projects in Howe Sound (see **Appendix 5.10-1 Marine Resources Baseline Study**).

Since the interactions of the effects associated with past and existing projects are not expected to change over time, these projects are considered through the documentation of the existing conditions for this VC. A summary of the projects, the effects of which are included in the existing conditions, is presented in **Table 4-7 Existing Conditions – Past and Existing Projects.** Projects and activities that are considered in the existing conditions for this VC include the Britannia Mine Remediation Project, Furry Creek Hydro Project, Howe Sound Pulp and Paper Corporation, Upper and Lower Mamquam Hydro Projects, McNair Creek Hydro Project, mineral activities, fishing, and backcountry and outdoor recreation activities.

5.16.2.3 Desktop and Field Studies

In 2013, Woodfibre LNG Limited (Proponent or WLNG) initiated environmental studies on marine benthic habitat and the two subcomponents to support Project planning and assessment, as well as future Project management. Building on available information, these studies were designed to address known data gaps. Desktop and field studies conducted with respect to marine benthic habitat are summarized in **Table 5.16-4**.

[1] Unpublished water and sediment quality data for the Woodfibre Pulp and Paper Mill, provided to Golder by Keystone Environmental Ltd. in 2014.

Table 5.16-4 Summary of Desktop and Field Studies Related to Marine Benthic Habitat

Study Name	Study Purpose
Baseline literature review	A desktop study to describe background conditions of marine benthic habitat in the RAA.
Marine baseline studies	Field studies to collect information on marine benthic habitat baseline conditions in the LAA and reference area. Field studies included collection of field samples for analysis of sediment quality and benthic invertebrates, and collection of intertidal and subtidal survey data.

5.16.2.4 Description of Existing Conditions

5.16.2.4.1 Existing Conditions within the Regional Assessment Area

The Project area lies within a combined fjord embayment in Howe Sound and is located adjacent to the Strait of Georgia. The general area is situated within the northeast Pacific eco-region, which is characterized by soft sediment basins, rocky reefs, and bedrock outcroppings. Marine sediments in Howe Sound are a legacy of the glaciation history, which resulted in steep side slopes with shallow deposits over bedrock. The maximum depth of Howe Sound is approximately 280 m with a sill located near Anvil Island at approximately 70 m depth (Harding 1992). Howe Sound receives a significant amount of turbid, freshwater input from Squamish River, and to a lesser extent from the Fraser River. Discharge volumes vary depending on the season, with greatest discharges typically occurring in summer and fall associated with snow melt and the onset of the rainy season.

Numerous (696) marine species have been documented in Howe Sound, suggesting a marine community equivalent to the Strait of Georgia (Lamb et al. 2011). The steep, rocky walls of the outer exposed edges to Howe Sound host a benthic community of mostly attached or sessile epifauna and macrophytes. The intertidal area is fringed with barnacles, mussels, ochre stars (*Pisaster ochraceus*), small crabs, and rockweed (*Fucus gardneri*). Subtidal rock faces are encrusted with tunicates, bryozoans, cup coral, sponges, tubeworms, anemones (i.e., *Metridium* sp.), along with mobile organisms such as crabs, other sea stars, urchins, sea cucumbers, snails, nudibranchs, octopuses, and various fishes (McDaniel 1973, Harding 1992, Lamb et al. 2011). Refer to **Appendix 5.10-1 Marine Resources Baseline Study**.

Kelp (seaweed) coverage and abundance in Howe Sound is lower when compared to the Strait of Georgia (Lamb et al. 2011). Kelp is ecologically important as it provides important nursery habitat for several fish and benthic invertebrate species. Bull kelp (*Nereocystis luetkeana*) has only been identified at the southern entrance to Howe Sound, and giant kelp (*Macrocystis integrifolia*) is completely absent in this region. The fringed sea colander (*Agarum fibriatum*) is the most abundant and deepest-dwelling brown algae in the RAA, followed by *Laminaria* spp. (McDaniel 1973). Surveys of Gambier Island, Bowen Island, and surrounding islands in Howe Sound in 2012 and 2013 identified numerous occurrences of eelgrass in this RAA (Wright et al. 2013). Underwater video surveys conducted by Golder Associates Ltd. (Golder) in 2013 and 2014 did not capture any occurrences of eelgrass within the Project area (refer to **Appendix 5.10-1 Marine Resources Baseline Study**).

Several benthic invertebrate species support CRA fisheries within Howe Sound. Subtidal benthic invertebrates important for CRA fisheries include shrimp, prawn (i.e., spot prawn, *Pandalus platyceros*), and Dungeness crab (*Metcarcinus magister*) (McDaniel 1973, Harding 1992). Shallow, soft-bottom habitats supporting infauna such as clams are limited to river and stream deltas within Howe Sound where salinity is low. Both clams and oysters are historically important food sources for the Squamish First Nation, along with Dungeness crabs, octopus, sea cucumbers, urchins, chitons, mussels, and black turban snails (Kennedy 1976).

The predominant CRA shellfish fisheries in Howe Sound (PFA Area 28, subareas 1-5) are for spot prawn, shrimp, and crab. The commercial prawn and shrimp by trap fishery is one of the most valuable fisheries in the Pacific Region. Other significant shellfish fisheries in Howe Sound include for Dungeness crab by trap, and for pink (*Pandalus borealis*) and sidestripe shrimp (*Pandalopsis dispar*) by trawl. The majority of the BC shrimp trawl fleet consists of small vessels that harvest modest volumes of shrimp during day trips. Large trawl vessels are generally not active in the BC shrimp fishery. The crab by trap fishery, Area "I" (the Fraser River area) includes PFA Areas 28 and 29, and has trap limits and haul restrictions that are set based on fishery management objectives inside the area. With the exception of individual closures, the crab by trap fishery is open year-round (DFO 2013b).

Recreational and First Nations fisheries in Howe Sound are also focused predominantly on crab, shrimp, and prawn. Declines in salmon and rockfish stocks and the availability of fishing gear have resulted in more attention and effort in prawn and shrimp fishing in both recreational and Aboriginal fisheries (DFO 2013b). When fishing for prawn, the target species is spot prawn, but generally catch is accompanied by incidental catch of other shrimp species.

Benthic biodiversity is reduced at certain localized areas of anthropogenic activity, such as the former Woodfibre Pulp Mill, the inactive McNab Creek Log Dump, and the decommissioned Britannia Beach copper mine (McDaniel 1973, Harding 1992, Levings et al. 2004, Leys et al. 2004, Wright and Damborg 2006). Log booms have long-lasting effects on bottom-dwelling organisms as the accumulated wood debris remains for decades. McDaniel (1973) reports an absence of soft-sediment infauna, as well as the typical soft-bottom burrowing anemone and orange sea pen. Inversely, McDaniel reports an increase in the abundance of shipworm (*Bankia setacea*), which bores into logs and feeds on wood debris. Suspended organic matter in the water column and increased organic accumulation on the bottom, two by-products of historic pulp and paper mill discharge, similarly reduces the number of species. McDaniel (1973) reports fewer species and intermittent coverage of the typical rocky intertidal shore species assemblage (barnacles, mussels, and rockweed) at the former Woodfibre Pulp Mill.

Sensitive species known to or with potential to be present in the RAA include glass sponges and glass sponge reefs. Glass sponges (class Hexactinellida) are deep-sea organisms found typically at depths between 500 m and 3,000 m; however, glass sponges are also found at water depths shallower than 50 m in only four locations in the world. One of these locations is Howe Sound, where glass sponges grow in less than 100-m depth and have been documented as shallow as 18 m near Bowyer Island (Leys et al. 2004, McDaniel 1973, Dennison 2012). Glass sponges have also been documented in proximity to the Project site. Records of both live and dead specimens of reef-forming glass sponge species were observed at depths ranging from 38 m to 175 m near Woodfibre in 1984 (Leys et al. 2004); however, these glass sponge occurrences did not represent a fully intact glass sponge reef. Glass sponges near the Woodfibre site consisted of mostly dead specimens with only a single live solitary sponge observed shallower than 100 m; the closest living glass sponge reef was documented approximately 10 km to the southwest of the Project area at the mouth of the sill in Montagu Channel. Underwater video surveys conducted by Golder in 2013 and 2014, to depths reaching 55 m chart datum, did not capture any occurrences of glass sponges within the Project area (refer to **Appendix 5.10-1 Marine Resources Baseline Study**).

Changes in the physical or chemical composition of marine sediments can affect marine flora and fauna. High concentrations of polychlorinated dibenzodioxins (dioxins) and dibenzofurans (furans) have been documented in marine sediments and shellfish in Howe Sound, resulting in the closure of some recreational and commercial fisheries in the area. Fisheries for all bivalve molluscs are closed in Howe Sound, for example; however, fisheries for most other benthic invertebrate species have remained open or have re-opened with some restrictions. Since 1989, a marked decline in dioxin and furans has been observed in samples collected from marine sediment and crab tissue samples (Hatfield Consultants 2004).

5.16.2.4.2 Existing Conditions within the Local Assessment Area

This section presents descriptions of the existing conditions of marine sediment and benthic communities within the LAA.

5.16.2.4.2.1 Marine Sediment

Underwater video surveys within the Project area indicate substrates within the subtidal zone of the Project area consisting mostly of soft sediments with patches of cobble and boulder and in some areas a large amount of finer (<10 cm diameter) or coarser (>10cm diameter) wood debris (**Figure 5.16-2**). Large patches of hard substrate (e.g., bedrock, boulder) were found nearshore in the far northeast and southwest extents of the Project area. The area southwest of Mill Creek was dominated by soft sediments with generally low amounts of wood debris. A small patch of wood debris was observed adjacent to the outflow of Woodfibre Creek, which also contained a large amount of organic debris (e.g., leaf litter). Another similar patch of wood and organic debris was observed near the outflow of Mill Creek, though wood debris in this area extended to depths of approximately 40 m. The area northeast of Mill Creek was also dominated by soft sediments; however, large amounts of small and large wood debris were observed covering the seafloor in this area. Much of the small wood debris appeared to be remnants from previous industrial activity at the Woodfibre site, and created a thick cover of the seafloor at depths up to approximately 30 m. An area with abundant coarse woody debris, mostly in the form of large logs, was identified towards the northeast extent of the Project area, and extended to the deepest part of the survey. In general, the intertidal zone consisted primarily of boulder and bedrock substrate with very little soft sediment.

Sediment samples collected from the Woodfibre waterlot during previous studies exceeded the BC *Contaminated Sites Regulation* sediment quality criteria for multiple parameters at multiple sample sites (MOE 1996). The most notable exceedances were polycyclic aromatic hydrocarbons (PAH), copper, lead, and zinc. Concentrations of tri-butyl tin (TBT) exceeded Puget Sound Dredge Disposal analysis criteria in multiple samples. Total toxic equivalencies for dioxins and furans exceeded Canadian Council of Ministers of the Environment (CCME 2014) Canadian *Sediment Quality Guidelines for the Protection of Aquatic Life*. The Interim Sediment Quality Guideline (ISQG) of 0.85 micrograms per gram (µg/g) was exceeded for most samples analyzed, three of which also exceeded the CCME Probable Effects Limit (PEL) (i.e., 21.5 micrograms per gram (µg/g))[2].

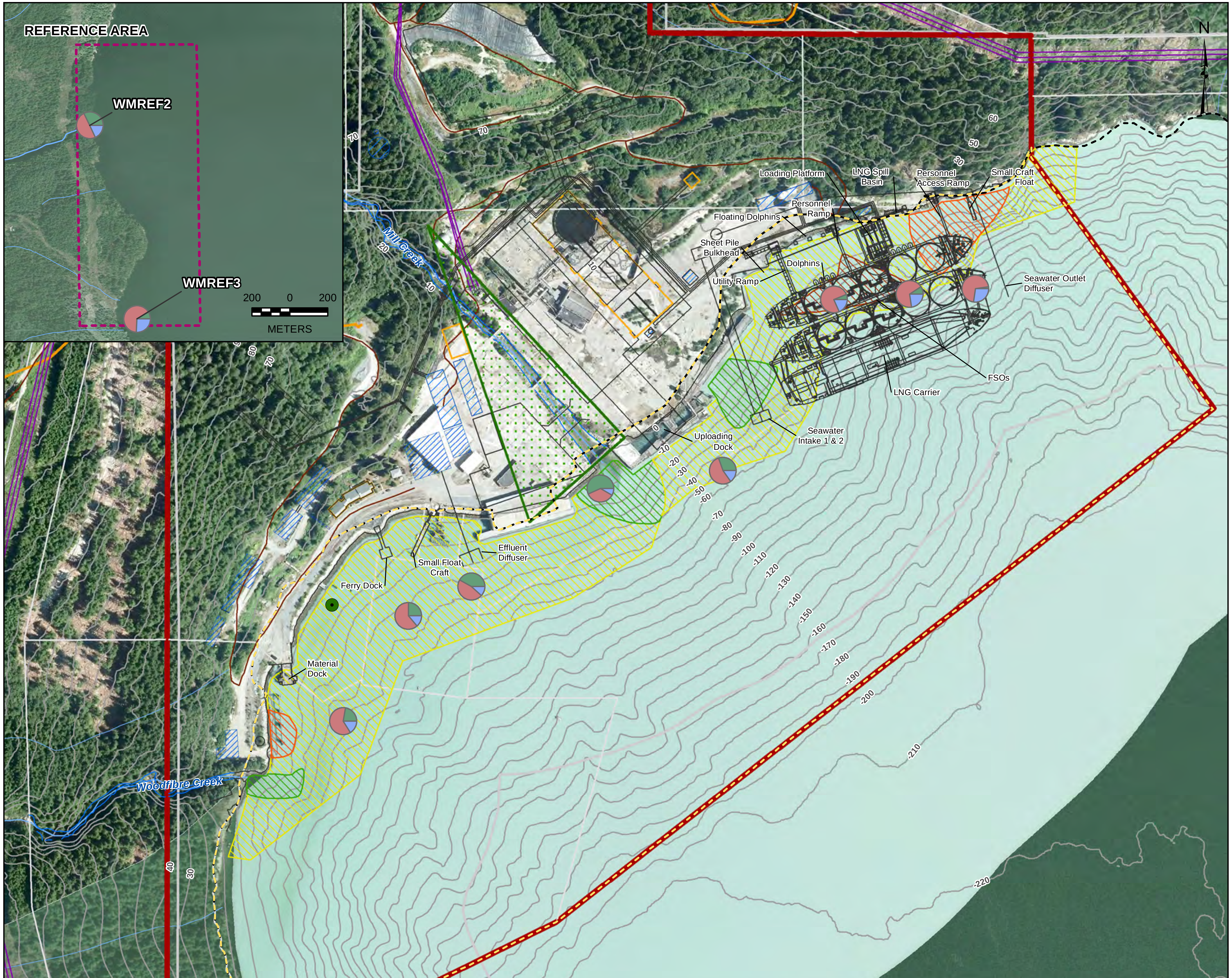
Results from analysis of marine sediments collected by Golder within the Project area in 2014 were consistent with previous studies in the Woodfibre waterlot. Sediments were predominantly silt with some sand, and samples contained a number of PAHs, dioxins, and furans in exceedance of CCME and BC Ministry of Environment (MOE 2006) sediment quality guidelines (refer to **Appendix 5.10-1 Marine Resources Baseline Study**). Sediments within the reference area were generally uncontaminated, with the exception of copper, while sediments in the Project area contained elevated PAHs (**Figure 53**, **Appendix 5.10-1 Marine Resources Baseline Study**). Concentrations of copper, zinc, arsenic, and cadmium in sediments from the Project area also exceeded CCME and MOE sediment quality guidelines. The ratio of simultaneously extracted metals (cadmium, copper, lead, mercury, nickel, and zinc) to acid volatile sulfide (SEM/AVS) showed that metals in sediment in the Project and reference areas were predominantly below bioavailable levels due to low metal solubility. Total toxic equivalencies for dioxins and furans exceeded CCME ISQG guidelines in each of the five samples analyzed, and dioxin and furan levels in two of the five samples exceeded the CCME PEL. High levels of PAHs and dioxins and furans in sediments within the Project area are most likely a legacy of the past pulp mill operations.

[2] Unpublished water and sediment quality data for the Woodfibre Pulp and Paper Mill, provided to Golder by Keystone Environmental Ltd. in 2014.

5.16.2.4.2.2 Marine Benthic Communities

Marine benthic communities identified in the LAA include a community within the subtidal zone that was generally associated with soft substrates (e.g., silt and sand), as well as a community within the intertidal zone that was generally associated with hard substrates (e.g., boulder and riprap). These biological communities are not mutually exclusive and may contain representative species from each of the benthic zones. In general, the intertidal zone contained a low diversity of benthic invertebrates and a greater amount of macroalgae compared to the subtidal zone. Several macroalgae taxa were present in the intertidal area, including green string lettuce (*Enteromorpha intestinalis*), rusty rock (*Hildenbrandia sp*.), rockweed (*Fucus gardneri*), green tuft (*Cladophora sp*.), and filamentous brown algae, with rockweed being the dominant taxa.

In general, the subtidal zone contained a low abundance and diversity of macroalgae and a greater abundance and diversity of benthic invertebrates. Trace amounts of kelp of the genus *Laminaria* spp were identified in the subtidal area during underwater video surveys of the Project area in 2013 and 2014 (**Figure 5.16-2**). No other kelp taxa were observed within the subtidal environment of the Project area. Benthic epifauna observed during underwater video surveys conducted by Golder in 2013 and 2014 included Dungeness crabs, tanner crabs, shrimps, squat lobsters, sea cucumbers, urchins, anemones, and seastars. No occurrences of northern abalone were documented within the LAA during 2013 and 2014 field surveys. Taxonomic analysis of benthic infaunal samples collected by Golder in 2014 revealed similar results to previous studies in Howe Sound. Lower benthic invertebrate density was observed in samples that contained higher proportions of wood debris. Generally, these samples were collected from locations within the existing Woodfibre log sort area. Benthic infauna communities were dominated by mobile and sedentary polychaete species at most stations, which had high silt and clay content while some shallow subtidal sandy stations had a high number of bivalves (clams and mussels). Samples collected at the mouth of Mill Creek had high proportions of insects within the benthos communities that are more common for low-salinity environments (refer to **Appendix 5.10-1 Marine Resources Baseline Study**).



LEGEND

- PROJECT AREA
- MARINE BENTHIC HABITAT LAA
- MARINE BENTHIC HABITAT RAA
- REFERENCE AREA
- SURVEY PARCELS
- SQUAMISH MUNICIPAL BOUNDARY
- NON - PROCESS FACILITIES
- LNG FACILITY
- GREEN ZONE
- PROJECT LAYOUT
- LIMITED ACCESS ROAD
- FORTISBC GAS PIPELINE
- TRANSMISSION LINE (ELECTRIC)
- WATERCOURSE
- CONTOUR AND BATHYMETRY (10m)
- *LAMINARIA* SP.

SUBTIDAL HABITAT FEATURE

- SOFT SUBSTRATE (SAND/SILT/COBBLE)
- HARD SUBSTRATE (BOULDER/RIP RAP)
- FINE WOOD DEBRIS
- COARSE WOOD DEBRIS

PARTICLE SIZE DISTRIBUTION (%)

- GRAVEL
- SAND
- SILT
- CLAY

REFERENCE

SUBTIDAL HABITAT DETERMINED BY GOLDER ASSOCIATED LTD PERSONNEL. BASE DATA FROM CANVEC © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED. TRANSMISSION LINES FROM ICIS. SITE PHOTO FROM MCELHENNEY AND SURROUNDING IMAGE PROVIDED BY THE GOVERNMENT OF BRITISH COLUMBIA.
PROJECTION: UTM ZONE 10 DATUM: NAD 83

SCALE

100 0 100
METRES

PROJECT
WOODFIBRE LNG LIMITED
WOODFIBRE, HOWE SOUND, B.C.

TITLE
SUBTIDAL HABITAT FEATURES AND PROPOSED PROJECT LAYOUT

Golder Associates

PROJECT NO. 13-1422-0006			PHASE No. 6000
DESIGN	JS	22 Aug. 2014	SCALE 1:5,000 REV. 0
GIS	DL	22 Aug. 2014	
CHECK	JS	16 Oct. 2014	
REVIEW	AK	16 Oct. 2014	

FIGURE 5.16-2

PATH: \\golder.gds\gal\Vancouver\CAD-GIS\VAN\2013\13-1422\13-1422-0006 - Woodfibre\Mapping\MXD\Marine Habitat\WOODFIBRE_MARINE_BENTHIC_HABITAT_FIGURE_5_16-2_Subtidal_Habitat_Features_and_Project_Layout.mxd Date: 10/16/2014 Time: 12:28:25 PM

5.16.3 Assessment of Project-related Effects

This section describes the methods for characterizing potential effects, the potential interactions between the Project activities and the marine benthic habitat, and mitigation measures to avoid and reduce potential interactions. Characterization of the residual effects and their significance is also presented in this section.

5.16.3.1 Assessment Methodology

In this section the potential residual effects of the Project are assessed with the methodology outlined in **Section 4.0 Environmental Assessment Methods**. Potential interactions between the Project activities and marine benthic habitat are also determined and described. In addition, interactions with an anticipated adverse effect on marine benthic habitat are evaluated, and mitigation measures to avoid or minimize potential interactions are provided. The residual effects and their significance are then presented for interactions that cannot be addressed through mitigation measures. Descriptions of residual effect characteristics and significance are also provided for marine benthic habitat.

5.16.3.1.1 Residual Effects Characterization

Definitions for ratings applied to residual effects criteria, developed with specific reference to marine benthic habitat, are presented in **Table 5.16-5**.

Table 5.16-5 Criteria Used to Characterize Residual Effects on Marine Benthic Habitat

Criteria	Description	Definition of Rating
Magnitude	Expected size or severity of the residual effect.	• **Negligible** – Project will result in no change in measured endpoint • **Low** – the incremental change in the relevant indicator will result in no measurable effect to marine benthic habitat, or will result in a minor measurable effect to marine benthic habitat • **Moderate** – the incremental change in the relevant indicator will result in a clearly defined change to marine benthic habitat but remains below a level of effect that could exceed the resilience and adaptability limits of the marine benthic habitat • **High** – the incremental change in the indicator is sufficiently large that it approaches or falls within the range of effects that could exceed the resilience and adaptability of the population
Geographic Extent	Spatial scale over which the residual effect is expected to occur	• **None** – no geographic extent • **Site-specific** – the incremental change in the indicator is confined to the Project area • **Local** – the incremental change in the indicator extends beyond the Project area into LAA • **Regional** – the incremental change in the indicator extends beyond the LAA into the RAA

Criteria	Description	Definition of Rating
Duration	Length of time over which the residual effect is expected to persist	• **Short-term** – the incremental change in the indicator continues to the end of the construction phase of the Project (approximately 1.5 years) • **Long-term** – the incremental change in the indicator continues to the end of the operation phase of the Project (approximately 25 years) • **Permanent** – the incremental change in the indicator is irreversible
Frequency	How often the residual effect is expected to occur	• **Infrequent** – the incremental change in the indicator is confined to a specific discrete event • **Frequent** – the incremental change in the indicator occurs intermittently over the life of the Project • **Continuous** – the incremental change in the indicator occurs continuously across the life of the Project
Reversibility	Whether or not the residual effect can be reversed once the physical work or activity causing the effect ceases	• **Fully reversible** –the incremental change in the indicator is reversible within a time period that can be identified when the Project no longer contributes to an adverse cumulative effect • **Partially reversible** – the incremental change in the indicator is partially reversible within a time period that can be identified when the Project no longer contributes to an adverse cumulative effect • **Irreversible** – the incremental change in the indicator is predicted to influence the VC indefinitely (duration is permanent or unknown)
Context	Primarily refers to the sensitivity and resilience of the VC to change caused by the Project	• **High resilience** – a high natural resilience to imposed stresses • **Moderate resilience** – a moderate natural resilience to imposed stresses • **Low resilience** – low natural resilience to imposed stresses

5.16.3.1.2 Definition of Significance

For VCs without legislated or regulated thresholds to define significance (e.g., amphibians), the BC Environmental Assessment Office (EAO) (2013) recommends using VC-specific factors such as population integrity to define significance. Consequently, significant effects would be considered likely for this VC if the population or meta-population is likely to not be self-sustaining or ecologically effective in the RAA as a result of project effects within the LAA. A VC is considered to be no longer self-sustaining where residual effects within the LAA are expected to place the abundance of a VC in the RAA, whether an open or closed population, on a declining trajectory that is not likely to recover or stabilize. Effects that are not significant could result in no change, stabilization at lower abundance, stabilization at higher abundance, or a temporary decline followed by recovery. Significant effects could result from either a decline to zero or apparent stabilization, but at a level that is sensitive to stochastic events, which could cause extirpation.

The level of each residual effect has been rated as negligible, not significant, or significant, as follows:

Negligible (N)	Negligible effect is defined, for the purposes of this assessment, as a residual effect with negligible consequence or low probability of occurrence. The incremental change to the indicator from an effect of negligible significance is not measureable. Negligible effects are not carried forward to the residual effects characterization or significance section, or to the cumulative effects assessment.
Not significant (NS)	Effects determined to be not significant are those that are greater than negligible that do not meet the definition of significant. Effects that are not significant are carried forward to the cumulative effects assessment.
Significant (S)	Significant effects are defined, for the purposes of this assessment, as residual effects that are predicted to exceed the resilience and adaptability limits of the marine benthic habitat and result in a marine benthic community that is not self-sustaining or ecologically effective. Significant effects are carried forward to the cumulative effects assessment.

Likelihood refers to whether or not a residual effect is likely to occur. This may be influenced by a variety of factors, such as the likelihood of a causal disturbance occurring or the likelihood of mitigation being successful (EAO 2013). The basis for likelihood is assessed using appropriate qualitative or quantitative terms with applicable descriptions for how a conclusion was reached. Likelihood determinations for the Project have been assessed in terms of a residual effect occurring being likely or not likely, as follows:

- **Likely –** likely that the adverse residual effect will occur
- **Not likely –** not likely that the adverse residual effect will occur

The level of confidence for each predicted effect is discussed to characterize the level of uncertainty associated with both the significance and likelihood determinations. Level of confidence is typically based on expert judgement and is characterized as low, medium, or high. Confidence in the assessment of environmental significance is related to the following elements:

- adequacy of baseline data for understanding current conditions and future changes unrelated to the Project (e.g., extent of future developments, climate change, catastrophic events)
- model inputs (e.g., noise modeling)
- understanding of potential Project-related effects on complex ecosystems that contain interactions across different scales of time and space
- knowledge of the effectiveness of the environmental design features and mitigation for reducing or removing effects (e.g., re-vegetation of wildlife habitat)

Ecosystems are complex and are characterized by interactions across multiple scales, nonlinearity, self-organization, and emergent properties (Boyce 1992, Holling 1992, Levin 1998, Wu and Marceau 2002). These characteristics can confound our understanding of ecosystem processes and limit the accuracy of predictions about the effects of development on marine benthic habitat. To be scientifically defensible, residual effects predictions must be tempered with uncertainty associated with the data and knowledge of the ecosystem. To reduce uncertainty associated with changes in habitat quantity, conservative estimates related to the development footprint of the Project area were applied to calculate the area of habitat directly affected by the Project.

Development activities will directly and indirectly affect marine benthic habitat; however, over the long term, the lack of comprehensive monitoring studies documenting the resilience of marine benthic habitat to development, the effectiveness of mitigation, and the time required to reverse these effects creates uncertainty surrounding the degree to which some effects may occur and in the effectiveness of mitigation techniques for marine benthic habitat.

5.16.3.2 Potential Interactions of the Project and Proposed Mitigation

Potential interactions between Project activities and the marine benthic habitat subcomponents, and mitigation measures proposed to avoid or minimize the interactions are presented in the following sections.

5.16.3.2.1 Potential Interactions

Potential interactions between Project activities and marine benthic habitat during the construction, operation, and decommissioning of the Project components are identified in **Table 5.16-6**. The following criteria have been used to indicate the degree of the effect from the interaction between marine benthic habitat and each activity:

- No interaction is predicted.
- Minor interaction is predicted, i.e., an adverse effect may result from an interaction, but standard measures to avoid or minimize the potential effect are available and well understood to be effective, and any residual effects are negligible.
- Carried forward means that interactions may result in an adverse effect and have been carried forward into the cumulative effects assessment.

A rationale for the assessment of interactions rated as minor and carried forward is presented in **Table 5.16-6**. Interactions with potential effects rated as carried forward are discussed in **Sections 5.16.3.2.2** and **5.16.3.2.3**.

Effects from potential emergency situations, accidents and marine spills are addressed in **Section 11.0 Accidents and Malfunctions**. Accordingly, these effects are not considered further within this section.

Table 5.16-6 Potential for Interactions between Project-related Activities and Marine Benthic Habitat

Project Activities and Physical Works	Valued Component Interaction		Nature of Interaction and Rationale for Interaction Rating
	Marine Sediments	Marine Benthic Communities	
Construction Phase			
All Project construction activities and works	See below	See below	
Transportation of construction crews to the Project area via crew boat or ferry, transportation of materials and supplies to the Project area via barge, and emergency transportation via helicopter	No interaction predicted	No interaction predicted	No interaction with marine benthic habitat
Site clearing	Minor interaction	Minor interaction	Potential changes to marine water quality are addressed in **Section 5.10**
Blasting where required to accommodate Project infrastructure	Minor interaction	Minor interaction	Potential changes to marine water quality are addressed in **Section 5.10**
Demolition of infrastructure not required for Project	Minor interaction	Minor interaction	Potential changes to marine water quality are addressed in **Section 5.10**
Upgrades to existing buildings and infrastructure, including site administration and safety facilities	No interaction predicted	No interaction predicted	No interaction with marine benthic habitat
Installation of stormwater and erosion and sediment control measures	No interaction predicted	No interaction predicted	No interaction with marine benthic habitat
Construction of Mill Creek water intake, pipeline and water storage tank	No interaction predicted	No interaction predicted	No interaction with marine benthic habitat
Installation of batch plant	No interaction predicted	No interaction predicted	No interaction with marine benthic habitat
Upgrading and construction of onsite roads	Minor interaction	Minor interaction	Potential changes to marine water quality are addressed in **Section 5.10**
Construction and upgrading of small craft floats	Carried forward	Carried forward	Loss of habitat due to Project works Potential changes to marine water quality are addressed in **Section 5.10**
Waste material disposal at permitted offsite and onsite landfills	Minor interaction	Minor interaction	Potential changes to marine water quality are addressed in **Section 5.10**
Construction of electrical substations and transformers and cables and powerlines	No interaction predicted	No interaction predicted	No interaction with marine benthic habitat
Construction of land-based civil works, including foundation excavation, cast-in-place concrete, and structures	Minor interaction	Minor interaction	Potential changes to marine water quality are addressed in **Section 5.10**

Project Activities and Physical Works	Valued Component Interaction		Nature of Interaction and Rationale for Interaction Rating
	Marine Sediments	**Marine Benthic Communities**	
Construction of the foundation uploading dock for land-based LNG facility, including natural gas piping; transfer of the LNG facility to its foundation	Minor interaction	Minor interaction	Potential changes to marine water quality are addressed in **Section 5.10**
Construction of FSO jetty, including pile driving and shoreline modifications to accommodate structural infrastructure, including possible dredging, and permanent mooring of FSO	Carried forward	Carried forward	Loss of habitat due to Project works Potential changes to marine water quality are addressed in **Section 5.10**
Connection of utilities (e.g., electrical, controls, gas, water) to LNG facility and FSO	No interaction predicted	No interaction predicted	No interaction with marine benthic habitat
Installation of seawater cooling system, including inlet and outlet structures	Carried forward	Carried forward	Loss of habitat due to placement of structures on the sea floor Potential changes to marine water quality are addressed in **Section 5.10**
Re-vegetation of areas of the Green Zone	No interaction predicted	No interaction predicted	No interaction with marine benthic habitat
Operation Phase			
All Project operation activities and works	See below	See below	
Commissioning of equipment for startup	No interaction predicted	No interaction predicted	No interaction with marine benthic habitat
Delivery of natural gas via piping from the from the FortisBC natural gas metering station to the LNG facility	No interaction predicted	No interaction predicted	No interaction with marine benthic habitat
Pre-treatment and liquefaction of natural gas at the LNG facility	Carried forward	Carried forward	Impingement and entrainment at intake Potential changes to marine water quality are addressed in **Section 5.10**
Storage and offloading of LNG at the FSO	No interaction predicted	Carried forward	Potential shading of marine benthic habitat
Mooring of LNG carriers at the FSO for LNG transfer	Minor interaction	Minor interaction	Potential changes to marine water quality are addressed in **Section 5.10**
Shipping within Howe Sound (approximately 40 LNG carriers per year) in established shipping lanes	No interaction predicted	No interaction predicted	No interaction with marine benthic habitat
Patrolling of Control Zone around LNG facility, FSO, and LNG carriers	No interaction predicted	No interaction predicted	No interaction with marine benthic habitat
Extraction of water from Mill Creek	No interaction predicted	No interaction predicted	No interaction with marine benthic habitat
Supporting infrastructure: transport of employees through private passenger ferry terminal, transport of supplies using barges, site administration and safety facilities and emergency transportation via helicopter	No interaction predicted	No interaction predicted	No interaction with marine benthic habitat

Project Activities and Physical Works	Valued Component Interaction		Nature of Interaction and Rationale for Interaction Rating
	Marine Sediments	Marine Benthic Communities	
Decommissioning Phase			
All Project decommissioning activities	See below	See below	
Dismantling of equipment and buildings that will not continue to serve a purpose	Minor interaction	Minor interaction	Potential erosion and sediment transport
Removal of LNG facility and FSO from the Project area	No interaction predicted	No interaction predicted	No interaction with marine benthic habitat

5.16.3.2.2 Potential Effects for Marine Sediment

Potential interactions between Project activities and the marine sediment subcomponent during the construction, operation, and decommissioning of the Project are described below.

Section 5.6 Geotechnical and Natural Hazards concludes that, with the mitigation measures in place, Project-related changes to geotechnical and natural hazards including marine slope stability are expected to be low to very low during all Project phases. Accordingly, effects to sediment quality as a result of changes from natural hazards and geotechnical hazards are not considered in this section.

Section 5.10 Marine Water Quality concludes that, with the mitigation measures in place, Project-related changes to marine water quality are unlikely to exceed water quality guidelines. Accordingly, effects to marine sediment quality as a result of changes to marine water quality are not anticipated, however, for completeness, potential effects in marine sediment quality from changes to marine water quality are also considered herein in relation to the benthic habitat VC.

Construction Phase

Potential change in sediment quality due to site erosion and sediment transport

Increased soil erosion and sediment transport associated with demolition and construction activities on land may result in increased sediment load in marine water. These interactions may result in changes in the physical and chemical composition of sediments by increasing the concentration of particles with finer grain size (silt-clay). Decrease in grain size of sediments correlates with an increase in concentration of metals and organic matter. Metals tend to accumulate more in finer sediment (Goldberg 1954, Krauskopf 1956, Thorne and Nickless 1981) primarily through adsorption and cation exchange due to the larger surface areas of fine particles (Jones and Bowser 1978). Sediments with higher organic content tend to concentrate more trace metals that form physical (adsorption) and chemical bonds with organic molecules (Goldberg 1954, Krauskopf 1956, Kononova 1966). Increase in organic content may induce anoxic conditions in sediment (Libes 1992).

In addition, soil erosion and storm water runoff could transport contaminants of potential concern into the marine environment. Particulates and potential contaminants entrained in runoff could accumulate in marine sediments.

Potential change in sediment quality due to seabed disturbance and contamination during marine construction

Physical disturbance to the seabed from pile driving, placement of intake, outfall, and diffuser pipes on the seafloor and other marine-related construction operations may result in sediment re-suspension in the water column.

Limited pocket dredging may be required during the construction phase. As described in **Section 2.2.7.1.1 Ancillary Activities**, this pocket dredging will consist primarily of the removal of historic wood waste from beneath Project foundations because the material is not suitable for construction. A detailed sediment investigation and risk-based remediation program was undertaken to address effects from existing sediment contamination, and a COC was issued on December 22, 2014 for the Woodfibre property waterlot (sediment). Details regarding the COC and the work conducted in support of the COC is summarized in **Section 5.7 Site Contamination**. The removal of historic wood waste will be conducted in accordance with the conditions of the COC and is likely to have a positive effect on sediment quality; accordingly, this potential effect is not considered further within the Application.

Potential change in sediment quality due to removal of existing creosote (wood) pilings

Removal of existing creosote pilings during the construction phase of the Project may cause creosote release from the pilings and into the marine environment. Creosote is a distillate of coal tar, up to 80% of which comprises PAHs (Hutton and Samis 2000). Creosote in the sediment surrounding the pilings may also be suspended during removal. This release of creosote may indirectly affect marine sediments through a change in water quality, resulting in deposition of PAHs in sediments.

5.16.3.2.3 Potential Effects for Marine Benthic Communities

Construction Phase

Potential effect on marine benthic communities due to seabed disturbance

Physical disturbance to the seabed from sediment re-suspension and deposition and increased particulate load in the surface water could increase suspended sediments in the water column. Effects on marine benthic communities from the changes in marine sediments as outlined in **Section 5.16.3.2.2** include smothering, contaminant dispersion, increased turbidity, and total suspended solids (TSS). These effects are described in more detail in the following sections.

Marine benthic communities may be exposed to smothering and toxic effects of suspended sediments and chemical pollutants through the same pathways identified in **Section 5.10 Marine Water Quality** (i.e., site clearing, blasting, demolition of infrastructure, upgrading and construction of onsite roads, construction and upgrading of small craft floats, waste material disposal at permitted offsite and onsite landfills, construction of land-based civil works, construction of the foundation and uploading dock for land-based LNG facility, construction of FSO jetty, and installation of the seawater cooling system). Sensitive benthic species that are particularly vulnerable to smothering effects include glass sponges and other filter-feeding benthic species. Glass sponges (class Hexactinellida) are a group of filter-feeding organisms, which can form large sponge reefs that provide habitat for other marine invertebrate and fish species (Leys et al. 2004). Increased levels of sedimentation can result in smothering of glass sponges, which reduces their filtering capabilities and limits their ability to feed and grow (Leys et al. 2004). Glass sponges were not identified within the vicinity of the Project during underwater video surveys and have not been identified within the LAA (refer to **Appendix 5.10-1 Marine Resources Baseline Study**). Glass sponges are known to occur within the RAA and have been previously noted adjacent to the Project area; however, sediment re-suspension from Project activities is expected to be localized and is unlikely to affect glass sponges outside the Project area. Increased sedimentation may also reduce the filtering capabilities of other bivalves such as clams and mussels (Wilber and Clarke 2001).

Seabed disturbance and increased particulate load in the surface water will result in an increase of suspended sediments in the water column. In water, pollutants are mainly adsorbed onto small particles (Chapman 1992). Suspended particulates contain significantly more trace metals than are found in dissolved phase (Horowitz 1985). Once settled on the sea floor, these metals become included in the food chain. In addition, increase of suspended sediment load in the water will change the physical composition of sediment by increasing concentration of particles with finer grain size (silt-clay).

The effects of increased turbidity and TSS during the construction phase may also result in a disruption of feeding by visual predators (Berg and Northcote 1985) or create a shading effect that will disrupt photosynthesis by algae (Bilotta and Brazier 2008, CCME 2014). Potential shading effects are discussed in greater detail in the following sections.

Potential change in habitat quality from removal of existing creosote (wood) pilings

Creosote, comprising up to 80% PAHs, may be suspended during pile removal, which can have adverse effects on marine benthic communities. PAH compounds share common properties but are highly variable in terms of their toxicity (Eisler 1987). For example, low-molecular-weight PAH compounds exhibit acute toxicity to some organisms, with toxicity increasing as alkyl substitution increases (Van Luik 1984); however, they are considered non-carcinogenic. Conversely, high-molecular weight compounds are less toxic but can be carcinogenic, mutagenic, or teratogenic to a wide variety of organisms (Moore and Ramamoorthy 1984, Eisler 1987, Environmenta Canada 1994). Although PAHs are rapidly bio-accumulated, they can also be quickly metabolized and eliminated from most organisms (e.g., forage fish, birds) (Eisler 1987).

Potential direct loss of habitat from construction and demolition of infrastructure

The marine footprint of the Project is restricted to the proposed nearshore marine facilities, including the loading platform, shore moorings, mooring dolphins supporting the floating storage and offloading unit (FSO), the FSO utility ramp, personnel access ramp, and ferry dock. In addition to these facilities, submerged pipes will be placed on the seafloor for the cooling water intake and outfall pipes, and the effluent diffuser and the structures themselves may be supported by pilings (**Figure 5.16-2**). The marine facilities and the intake, outfall, and diffuser pipes are designed in a way that will minimize their environmental impact. The proposed marine structures to be constructed will occupy a total approximate footprint of 3,856 m^2 on the seafloor within a low-productivity benthic habitat (**Table 5.16-7**).

Table 5.16-7 Summary of Number and Diameter of Piles to be Installed in the Marine Environment

Construction Component	Number of Piles	Approximate Diameter of Piles (m)	Approximate Surface Area of Seafloor Disturbance (m^2)
Loading Platform	48	1.07	43
Floating Dolphins to Support FSO Mooring System	8	2.0	25
Additional Shore Moorings (pending results of dynamic mooring analysis)	18	1.0	14
FSO Utility Ramp and Personnel Access Ramp	18	0.81	9
Ferry Dock	4	2.0	13
Cooling Water Intake	4	1.0	1,734
Cooling Water Discharge Diffuser	–	–	1,157
Effluent Diffuser	–	–	861
Total	–	–	3,856

Notes: Approximate area of seawater intake and outlet diffuser, and effluent diffuser approximated from ARC-GIS shape files of AMEC Conceptual Layout Drawing Number 176258-29000-DD10-SKT-9030 REV B. Number and diameter of piles for seawater intake were taken from Conceptual Design of Water Intake Woodfibre LNG Technical Memorandum (refer to **Appendix 5.10-1 Marine Resources Baseline Study**). Conservative assumptions made regarding pile number and diameter for construction of ferry dock based on design requirements.

Operation Phase

Potential direct loss of habitat from shading of marine vegetation

Installation of marine facilities along the Project foreshore has the potential to create some shading effect on intertidal and subtidal vegetation. The effects of marine shading will last for the duration that the marine facilities are in place. Marine facilities that have the potential to result in shading of marine communities include the loading platform, FSO, FSO utility ramp, personnel access ramps, small-craft float, uploading dock, and ferry dock. Combined, these marine facilities could create potential shading on the seafloor (**Table 5.16-8**).

Table 5.16-8 Summary of Area and Duration of Shading Effect Created by Marine Facilities to be Constructed in the Marine Environment

Construction Component	Approximate Surface Area of Shading Impact (m^2)	Duration of Potential Impact
Loading Platform	2,565	Long term
FSO Mooring System (including Dolphins)	24,955	Long term
FSO Utility Ramp	574	Long term
Personnel Access Ramps	950	Long term
Small Craft Float	366	Short term
Uploading Dock	1,328	Long term
Ferry Dock	275	Long term
Total	31,013	–

Notes: Approximate area of each construction activity approximated from ARC-GIS shape files of AMEC Conceptual Layout Drawing Number 176258-29000-DD10-SKT-9030 REV B.

Although the construction components listed above will create a shading effect on the seafloor, they will be constructed over areas on which no marine vegetation has been observed. Several of the structures, including the FSO, will be constructed in deep waters (>30 m) and are not expected to result in any significant shading effect on marine vegetation. As a result, no significant loss of benthic communities is likely to result from the shading effect created by the installation and operation of marine facilities.

Potential mortality from impingement and entrainment at water intake

Both juvenile and adult benthic invertebrates are susceptible to impingement and entrainment at water intakes, thereby causing direct or indirect mortality. Impingement is when an organism is trapped against an intake screen and entrainment is the capture of small organisms, mostly larvae, within water that is drawn into the seawater cooling system. Without mitigation measures to minimize the effects of impingement and entrainment, adverse effects on marine benthic habitat will occur. Mortality rates due to impingement and entrainment vary by species and are difficult to quantify. For the purposes of this assessment it is assumed that mortality rates of organisms that become impinged or entrained will equal 100%.

The magnitude of the effect of mortality due to impingement and entrainment depends on a number of key factors:

- flow-through velocity of the intake
- proximity of the intake to spawning grounds and other sensitive habitat
- distance between the intake and the seafloor
- screen size of the intake
- antifouling properties of the intake screen
- abundance and life history of benthic invertebrate adults and larvae in the vicinity of the intake

Direct mortality may occur when benthic invertebrates are trapped against intake screens, causing physical abrasion and suffocation (Fedorenko 1991). Indirect mortality may occur when benthic invertebrates experience physical abrasion and due to physical damage are then susceptible to disease or increased predation.

Larvae that are small enough to pass through the intake screen and become entrained in the intake flow will most likely experience mortality (Federenko 1991). Mortality due to entrainment can affect a wide range of benthic invertebrate size classes, and depends on the mesh size of the intake screen and the life history of the benthic species at risk of entrainment. For example, Dungeness crabs juveniles off the west coast of southern Washington generally tend to move into subtidal habitats at sizes larger than 25 millimeters (mm) carapace width (Armstrong et al. 1989). Smaller-size classes tend to be restricted to intertidal areas or shallow subtidal areas with greater habitat complexity (i.e., eelgrass beds, areas with high macrophyte cover). Intake screens with mesh sizes smaller than 25 mm would restrict Dungeness crab juveniles from becoming entrained but would still allow larvae and smaller juveniles to become impinged.

Mortality of adult and juvenile benthic invertebrates that become impinged, and of benthic invertebrate larvae that become entrained, could adversely affect benthic invertebrate density, taxonomic composition, and diversity. The majority of benthic invertebrates produce a large number of eggs, of which only a few survive to become adults (Obrebski 1979). Other stressors such as predation and competition for settlement create a naturally high rate of larval mortality in most species. The larval pool that supplies a particular benthic area is also generally regional in context in comparison to the local benthic community. As a result, adverse effects on larvae will be spread amongst a greater area within which a larger larval pool exists to aid in population recovery. Benthic invertebrate communities are also highly resilient to stresses that affect larval mortality, and have been known to respond by increasing spawning frequency and production based on changes to the adult benthic community (Obrebski 1979).

Potential introduction of invasive species from ballast water exchange during shipping

Introduction of exotic marine species (including pathogens) from ship ballast water exchange during shipping events can affect native marine species. Discharge of ballast water during commercial shipping operations has the potential to introduce exotic species to the marine environment and disrupt natural marine benthic communities by altering the abundance, diversity, and distribution of native marine species (Butman and Carlton 1995, Carlton 1999). Possible introduced species include bacteria and other microbes, microalgae, and aquatic plant and animal species in ballast water or sediment transferred from ship ballast tanks. Exotic invasive species are those species whose rapid establishment and spread can adversely affect ecosystems, and dramatically alter local habitats, making them unsuitable for native species. Invasive species can also have effects on the abundance of native species, due to predation or competition for habitat and food resources.

If re-ballasting is required to facilitate safe cargo operations, it is possible that ballast water may be discharged by one or more of the shipping vessels during the Project. Effective mitigation strategies are required early in Project planning phase to address the potential introduction, spread, and effects of exotic invasive species to the marine environment.

5.16.3.2.4 Proposed Measures to Mitigate Project-related Effects

Mitigation measures are proposed to avoid, minimize, control, or restore onsite conditions or offset potential adverse environmental effects to marine sediment and marine benthic communities. Mitigation measures are any practical means, whether used alone or in combination, to avoid, minimize, or control the potential adverse effects. These measures are described below and summarized in **Table 5.16-9**. For ease of reference, each of the mitigation measures described has a unique identification number (unless the measure is being incorporated into the Project design or outlined in another section of this EA, in which case it is described in the other section).

Mitigation measures that will be implemented to avoid or minimize changes in marine water quality, and which are described in detail in **Section 5.10 Marine Water Quality**, are implicitly included in this assessment despite not being explicitly listed.

Project Design

At the Project site, during maneuvering to and from the FSO, the LNG carriers will be assisted by tugboats, and therefore will not use their own propellers, or will use them at a considerable slower speed. In addition, the tugs will have smaller draft and smaller propellers. The resulting stress on the seafloor at the berth will be considerably lower than if the LNG carriers were moving at a transit speed. Water depth at the LNG berth is between 50 m and 100 m, which is a sufficient depth to allow jets produced by ship propellers to dissipate through the water column before reaching the seafloor. Therefore, the seabed disturbance caused by ship propellers (i.e., propeller wash) will most likely be negligible. More detail on the propeller wash effect is presented in **Section 5.10 Marine Water Quality**.

The barge ramp will replace an existing barge ramp already located on the property. Use of piles rather than fill to support the marine structures will significantly reduce the marine footprint of the Project. The installation of steel piles will create additional hard substrate for colonization of sessile benthic invertebrates, which may result in a net positive effect on marine benthic communities over the lifespan of the Project.

The FSO, loading platform, utility and personnel access ramps, seawater intake, and small-craft float will be installed in the existing log sort area, an area historically affected by pulp and paper mill and log sort operations; this area is of relatively low-quality benthic habitat. No eelgrass or high-density growth areas of other macrophytes (e.g., kelp beds) have been observed within the Project footprint. Benthic invertebrate communities (epifauna and infauna) in this area of proposed construction are depressed in terms of density and diversity in comparison to the other habitat zones and the reference area.

The following design measures are recommended to mitigate effects associated with entrainment or impingement:

- The intake will be located in deep water (greater than 25-m depth), below the photic zone; consequently, effects to marine vegetation (macroalgae) are not likely.
- The intake will be located 2 m above the seafloor to reduce the potential for entrainment or impingement of benthic fauna.
- The intake will contain a screen with mesh size no larger than 4.75 mm to prevent entrainment of adult and juvenile benthic invertebrates.
- The intake will contain a maximum approaching velocity of 3.0 cm/s for a stationary screen or 12.0 cm/s for a self-cleaning screen.
- The intake screen will contain a minimum of 50% open screen area as a percentage of the total screen area to maintain average through-screen velocity.

The intake will be sited away from subtidal rock reefs containing significant abundances of macrophytes that provide nursery habitat for juvenile fish and benthic invertebrates. Entrainment of plankton and larvae will potentially occur as a result of the water intake demands for the LNG cooling process. The implementation of mitigation and environmental design features will further reduce entrainment and impingement associated with the intake. As a result, measurable changes in the distribution of native marine species relative to baseline conditions are not likely.

Woodfibre LNG Limited will mitigate direct habitat loss from construction and demolition of infrastructure with the following Project design measures:

- Structures will be placed in marine areas of low habitat quality (i.e., low species diversity and abundance).
- Where possible, construction and infrastructure installation will employ methods that minimize the Project footprint and seafloor disturbance.

M5.10-1 – Marine Works Management Plan

Woodfibre LNG Limited will prepare and implement a Marine Works Management Plan to minimize sediment disturbance during construction and prevent discharge or runoff containing high TSS, concrete wash water and fuel from entering the marine environment. The plan will contain (but not be limited to) the following measures:

- All construction operations will be monitored by a qualified Environmental Monitor who will be onsite during the high risk construction and demolition activities to determine whether the works are resulting in any adverse effects on marine environment. Frequency of monitoring will be detailed in a monitoring plan. Any adverse effects will be reported to DFO by WLNG.

- Marine works will be conducted during the least risk fisheries work window specified by DFO for the region if practical. If the work window cannot be followed, additional mitigation measures including the advice provided by DFO (Measures to Avoid Causing Harm to Fish and Fish Habitat (2013b)) will be implemented. The work window for Howe Sound is currently August 16 - January 31 (DFO 2014).
- Work activities will cease, and DFO will be contacted, if aggregations of herring (e.g., herring spawn) and salmonids (e.g., smolts) are observed within the work area.
- Marine works will be avoided during weather conditions that may increase sediment suspension.
- All works will be conducted in a manner to prevent the discharge or introduction, either direct or indirect, of soil, sediment or sediment laden water, turbid water or any other deleterious substance into the marine environment. All discharges from construction activities shall meet BC water quality guidelines (MOE 2009).
- Construction materials, excavation wastes, overburden, sediment, or other substances potentially deleterious to marine life shall be disposed of off-site in accordance with regulatory requirements, or placed in such a manner by the contractor, to prevent their entry into the marine environment.
- The contractor shall follow *Best Management Practices for Pile Driving and Related Operations* (BCMPDCA and DFO 2003).
- Vessels and other equipment involved in pile driving and construction activities will be positioned in a manner that will prevent damage to the seafloor and shoreline.
- Where required, turbidity monitoring will be implemented during all pile drilling/driving activities, to determine that turbidity levels in the marine environment do not exceed established water quality regulatory criteria during Project works.
- The following water quality criteria will be applied based on BC water quality guildlines (MOE 2009) with regards to discharge or introduction of sediment or sediment- laden water in the marine environment:
    - Turbidity:
        - change from background of 2 NTU when the background level is less than 8 NTU
        - change from background of 5 NTU when background is 8-50 NTU
        - change from background of 10% when background is more than 50 NTU
    - TSS:
        - change from background of 5 mg/L when background is less than 25 mg/L
        - change from background of 10 mg/L when background is 25-100 mg/L
        - change from background of 10% when background is more than 100 mg/L
- If the criteria outlined above is exceeded as a result of Project activities, these works or activities will be halted until measures that will result in compliance with the criteria outlined above are put in place.
- Where the sediment control criteria cannot be practically met, the work areas and activities contributing to these conditions will be isolated from tidal and flowing waters. This may include use of silt curtains and other silt control measures.

- For dredging activities the following mitigation measures will be followed:
    - Prior to dredging, the perimeter of the dredge area will be identified, so that work occurs within the confines of the Project area. Tools such as real-time kinematic positioning controls (e.g., differential GPS) may be used to assist in positioning.
    - Employ sediment containment and water filtering devices on the barge to meet the TSS and turbidity criteria outlined above. This may require containment and treatment of barge dewatering effluent that exceeds the criteria.
    - Water quality monitoring will be implemented during dredging works to verify that the turbidity and TSS criteria are being met and enable management decisions to be made in the event that the performance criteria are not met.
    - The contract specifications will include operational controls to minimize disturbance of substrates (e.g., making additional dredge passes rather than dragging a bucket or beam to level the dredge surface, not stockpiling material underwater, controlling the rate of ascent and descent of the bucket).
    - The dredged material barge will not be overloaded beyond the top of the side rails to minimize loss of dredged material from the barge and to prevent barge listing or instability.
    - The barge will not come to rest on the seafloor (no grounding) (spuds may be used to anchor the brege).

M5.10-3 – Minimize the Effects of Creosote Pile Removal

Woodfibre LNG Limited will prepare and implement creosote pile removal mitigation measures as part of the CEMP, including the following measures:

- A reasonable attempt should be made to remove the entire creosote-treated pile.
- Piles will be removed by a slow, steady pull to minimize disturbance of seafloor habitats and to avoid bringing creosote-contaminated sediments to the surface. If the pile breaks off below the biologically-active zone in the sediment, it may not be advisable to dredge the remainder out, depending on the sensitivity of the habitat at the site.
- Used/decommissioned piles will be disposed of on land in an appropriate waste management facility (Hutton and Samis 2000).
- Work will follow procedures outlined in DFO's *Guidelines to Protect Fish and Fish Habitat from Treated Wood Used in Aquatic Environments in the Pacific Region* (Hutton and Samis 2000).
- A sediment containment system (e.g., silt curtains) will be installed as appropriate during piling removal to prevent the dispersion of suspended sediments.
- Creosote piling removal will be conducted during the least risk fisheries work window specified by DFO for the region, unless unless a self-assessment determines that the work will not cause serious harm to fish or their habitat.

M5.16-1 – Minimize Marine Shading

Woodfibre LNG Limited will employ the following measures to minimize shading associated with the installation of marine structures:

- Where possible, ramps and gangways used to access floating facilities will be installed at an elevation of at least 2 m above the highest high-water mark to allow ambient light to reach the seafloor.
- Where possible, docks, ramps, and gangways will be surfaced with aluminum grating (or other light permeable material), allowing ambient light to reach the benthic communities below.

No significant loss or disruption of marine benthic habitat is expected from shading caused by installation of marine structures.

M5.16-2 – Ballast Water Management Plan

Woodfibre LNG Limited will comply or require its contractors to comply with all legislated shipping requirements, including those related to the management of ballast water:

- *Ballast Water Control and Management Regulations* (Government of Canada 2011) under the *Canada Shipping Act*, SC 2001, c. 26
- International Maritime Organization Resolution A. 868(20): *Guidelines for the Control and Management of Ships Ballast Water to Minimize the Transfer of Harmful Aquatic Organisms and Pathogens*, in particular section 7.1 (IMO 2004)
- Model Ballast Water Management Plan developed by the International Chamber of Shipping and the International Association of Independent Tanker Owners (IMO 2004)
- Regulation B-1 of the International Maritime Organization's Regulations for the Control and Management of Ships' Ballast Water and Sediments (IMO 2004)
- Part B of the Annex to Resolution MEPC.127 (53), *Guidelines for Ballast Water Management and Development of Ballast Water Management Plans* (IMO 2004)

Table 5.16-9 summarizes the potential effects on marine benthic habitat and the proposed management plans developed to mitigate those effects.

Table 5.16-9 Summary of Potential Effects and Mitigations for Marine Benthic Habitat

Summary of Potential Effect	Project Design Measure / Mitigation	Mitigation Number
Construction Phase		
Potential change in sediment quality from removal of existing creosote (wood) pilings	Minimize the effects of creosote pile removal	M5.10-3
Remobilization of legacy contaminants from the sea bottom from ship propeller scour	Project design (placement of Project works)	Project design
Potential change in habitat quality from removal of existing creosote (wood) pilings	Minimize the effects of creosote pile removal	M5.10-3
Potential direct loss of habitat from construction and demolition of infrastructure	Project design (placement of Project works)	Project design
	Mitigate direct habitat lost from construction and demolition of infrastructure	Project design
Operation Phase		
Potential direct loss of habitat from shading of marine vegetation	Project design	Project design
	Minimize marine shading	M5.16-1
Potential mortality from impingement at water intake	Project design	Project design
Potential remobilization of legacy contaminants from the sea bottom from ship propeller scour	Project design	Project design
Potential introduction of invasive species from ballast water exchange during shipping	Ballast Water Management Plan	M5.16-2

5.16.3.3 Residual Effects and Effects Characteristics for Marine Benthic Habitat

With the implementation of the mitigation measures identified above, the potential residual effects of the Project are likely to be negligible. Further rationale for the assessment and a description in terms of the effects characteristics for marine benthic habitat are provided below. To prevent redundancy, effects characteristics are described for marine benthic habitat as a whole without repetition for each subcomponent (marine sediments and marine benthic communities). Potential residual effects for each subcomponent are summarized in **Table 5.16-10** and **Table 5.16-11**.

Potential change in sediment /habitat quality from removal of existing creosote (wood) pilings

Removal of creosote-treated wood piles is not anticipated to adversely affect marine benthic habitat. The residual effect from this potential interaction is further characterized in **Table 5.16-10** and **Table 5.16-11**. After the application of the mitigation measures outlined in **Section 5.16.3.2.4** above, the adverse residual effects from this activity are likely to be negligible.

Potential direct loss of habitat from construction and demolition of infrastructure

Use of piles rather than fill to support the marine structures will significantly reduce the marine footprint of the Project. In addition, the barge ramp will replace an existing barge ramp already located on the property. The installation of steel piles will also create additional hard substrate for colonization of sessile benthic invertebrates, which is likely to result in a positive rather than adverse effect on marine benthic communities over the lifespan of the Project. Further, the FSO, loading platform, utility and personnel access ramps, and cooling water intake will be installed in the existing log sort area. The benthic habitat in this area has been historically impacted by pulp and paper mill and log sort operations and is of relatively low quality. The sea floor in the vicinity of the log sort is covered with a thick mat of bark and wood debris; sediments have high silt-clay content and elevated concentrations of trace metals, PAHs, and dioxins and furans. Marine vegetation in the areas where marine facilities will be constructed is mainly limited to the intertidal area and also limited to green string lettuce (*Enteromorpha intestinalis*), rusty rock (*Hildenbrandia sp*.), rockweed (*Fucus gardneri*), green tuft (*Cladophora sp*.), and filamentous brown algae. No eelgrass or high-density growth areas of other macrophytes (e.g., kelp beds) have been observed in the subtidal zone, and benthic invertebrate communities (epifauna and infauna) are depressed in terms of density and diversity in comparison with the other habitat zones and the reference area (refer to **Appendix 5.10-1 Marine Resources Baseline Study**). The barge ramp is also located in the area impacted by the log sort. Consequently the Project's proposed upgrades are not likely to result in a loss of benthic habitat and therefore no adverse effects are likely. The overall significance of the effect is considered negligible.

A detailed sediment investigation has been undertaken and risk-based remediation program proposed, which will mitigate residual effects from potential pocket dredging. Consequently pocket dredging is not likely to result in residual adverse effects on benthic habitat. Details regarding the program are provided in **Section 5.7 Site Contamination**.

Potential direct loss of habitat from shading of marine vegetation

Marine vegetation in the areas where marine facilities will be constructed is sparse. *Fucus* sp. and other intertidal macrophytes were restricted to hard substrates in the intertidal zone, typically on riprap armouring along the shoreline. Installation of gangways and ramps above the high-water mark will reduce the effect of shading, especially intertidal vegetation, which was more abundant within the Project footprint than subtidal vegetation. Increase of the height of pile-supported structures is a known practice to increase intensity of light and decrease the shading area (Witherspoon 1994). As a result, following this mitigation the Project is not likely to result in residual adverse effects from shading and the overall significance of the effect is considered to be negligible.

Potential mortality from impingement and entrainment at water intake

Operation of the seawater intake during pre-treatment and liquefaction of natural gas at the LNG facility is likely to result in some direct mortality to benthic invertebrate adults and larvae as a result of impingement and entrainment. Mitigation measures will minimize the overall effect on marine benthic communities. Placement of the intake 2 m above the seafloor will limit the effect on bottom-dwelling benthic invertebrate adults and larvae. Siting of the intake away from spawning grounds and ecologically important areas (i.e. rocky reefs with high macrophyte cover) will limit the effects on sensitive life stages of benthic invertebrates. Design criteria to limit the screen size and flow-through velocity of the intake will minimize the number of organisms that may become entrained. Considering the small proportion of benthic invertebrate adults and larvae that may be affected within the Project area compared with the larger community size within the larger RAA, which will aid in replenishing the affected benthic community, the magnitude of the effect is expected to be low.

The geographical extent of the effect extends to the RAA as larvae have potential to be dispersed over a wide area. The anticipated mortality effects are likely to be long term and continuous, and are expected to occur throughout the operation phase of the Project. Anticipated mortality effects are likely to be fully reversible due to high resilience within the marine benthic community to similar types of stress and loss of larvae. Although it is likely that there will be a residual adverse effect from this activity, due to the low magnitude of the effect and high resiliency of the marine benthic community, the Project is not likely to result in a significant adverse residual effect and the overall significance of the effect is considered negligible.

Potential change in benthic habitat associated with remobilization of legacy contaminants from the sea bottom from ship propeller scour

Characterization of the residual effects of ship propeller scour is provided in detail in **Section 5.10 Marine Water Quality**. From that analysis it is not likely that any seabed disturbance will be caused by ship propellers (propeller wash). Consequently this activity is not likely to result in significant residual adverse effects to benthic habitat. This potential interaction is further characterized in **Table 5.16-10** and **Table 5.16-11**.

Potential introduction of invasive species from ballast water exchange during shipping

Discharge of ballast water during commercial shipping operations has the potential to introduce exotic invasive species to the marine environment and disrupt natural marine benthic communities by altering the abundance, diversity, and distribution of native marine species. A Ballast Water Management Plan will be developed to mitigate the potential introduction of invasive species to the LAA and RAA through ballast water. After the implementation of the mitigation measures described in **Section 5.16.3.2.4** above Project activities are not likely to result in adverse changes to the physical and chemical composition of sediments or the density, taxonomic abundance, or diversity of marine benthic communities. The overall significance of the effect is considered negligible.

Consequently, these activities are also not likely to result significant adverse residual effects on benthic communities. Potential adverse residual effects on marine benthic habitat (sediment and marine benthic communities) are further characterized in **Table 5.16-10** and **Table 5.16-11**.

Table 5.16-10 Summary of Effects Characteristics and Significance for Marine Sediments

Potential Adverse Residual Effect	Contributing Project Activity or Physical Works	Mitigation #	Proposed Mitigation Measures	Residual Effects Characterization (see Notes for details)							
				Magnitude	Geographic Extent	Duration/ Frequency	Reversibility	Ecological Context	Level of Effect	Likelihood	Confidence
Construction Phase											
Potential change in sediment quality due to seabed disturbance and contamination during marine construction	• Pile driving • Installation of outfall and intake pipes • Installation of intake and diffuser	M5.10-1	Marine Works Management Plan	LM	LAA	ST/IF	PR	MR	N	NL	H
Potential change in sediment quality from removal of existing creosote (wood) pilings	Piling removal	M5.10-3	Minimize the effects of creosote pile removal	LM	LAA	LT/IF	PR	MR	N	NL	H
Operation Phase											
Remobilization of legacy contaminants from the sea bottom caused by ship propeller scour	Vessel operations	Project design	Project design	LM	LAA	LT/IF	PR	MR	N	NL	H

Notes:
Magnitude: NM = negligible, LM = low magnitude, MM = moderate magnitude, HM = high magnitude
Geographic extent: No = none, site = Project area, LAA = Local Assessment Area, RAA= Regional Assessment Area
Duration: LT = long term, ST = short term, P = permanent
Frequency: C = continuous, F = frequent, IF = infrequent
Reversibility: FR = fully reversible, PR = partially reversible, I = irreversible
Ecological Context: HR = high resilience, MR = moderate resilience, LR = low resilience
Likelihood: L = likely, NL = not likely
Level of Effect: N = negligible, NS = not-significant, S = significant
Confidence: L = low, M = medium, H = high

Table 5.16-11 Summary of Effects Characteristics and Significance for Marine Benthic Communities

Potential Adverse Residual Effect	Contributing Project Activity or Physical Works	Mitigation #	Proposed Mitigation Measures	Cumulative Residual Effects Characterization							
				Magnitude	Geographic Extent	Duration/ Frequency	Reversibility	Ecological Context	Level of Effect	Likelihood	Confidence
Construction Phase											
Potential change in habitat quality from removal of existing creosote (wood) pilings	Piling removal	M5.10-3	Minimize the effects of creosote pile removal	LM	LAA	LT/IF	PR	MR	N	NL	H
Potential direct loss of habitat from construction and demolition of infrastructure	Installation of marine infrastructure including pilings, outfall and intake pipes, and intake and diffuser	Project design	Project design	LM	LAA	LT/IF	FR	MR	N	NL	H
Operation Phase											
Potential direct loss of habitat from shading of marine vegetation	Shading from marine infrastructure	Project design M5.16-1	Project design Measures to minimize marine shading	LM	LAA	LT/ CF	FR	HR	N	NL	H
Mortality from impingement and entrainment in seawater intake	Pre-treatment and liquefaction of natural gas at the LNG facility	Project design	Project design	LM	RAA	LT/ CF	FR	HR	N	NL	H

Potential Adverse Residual Effect	Contributing Project Activity or Physical Works	Mitigation #	Proposed Mitigation Measures	Cumulative Residual Effects Characterization							
				Magnitude	Geographic Extent	Duration/ Frequency	Reversibility	Ecological Context	Level of Effect	Likelihood	Confidence
Re-suspension of legacy contaminants from the sea bottom from ship propeller scour	Vessel operations	Project design	Project design	LM	LAA	LT/IF	PR	MR	N	NL	H
Potential introduction of invasive species from ballast water exchange during shipping	Vessel operations	M5.16-2	Ballast Water Management Plan	LM	RAA	P/IF	I	MR	N	NL	H

Notes:
Magnitude: NM = negligible, LM = low magnitude, MM = moderate magnitude, HM = high magnitude
Geographic extent: No = none, site = Project area, LAA = local, RAA= regional
Duration: LT = long term, ST = short term, P = permanent
Frequency: C = continuous, F = frequent, IF = infrequent
Reversibility: FR = fully reversible, PR = partially reversible, I = irreversible
Ecological Context: HR = high resilience, MR = moderate resilience, LR = low resilience
Likelihood: L = likely, NL = not likely
Level of Effect: N = negligible, NS = not-significant, S = significant
Confidence: L = low, M = medium, H = high

5.16.4 Marine Benthic Habitat Cumulative Effects Assessment

Cumulative effects result from interactions between Project-related residual effects and incremental effects of all other certain and reasonably foreseeable projects and activities. The effects of other projects and activities that have been carried out (past and present projects) are reflected by the existing conditions as reported in **Section 5.16.2.4 Description of Existing Conditions**. Regarding future conditions with the Project, as described above the Project will likely not result in any residual adverse effects or will result in negligible residual adverse effects. Consequently, the Project is not likely to interact cumulatively with other reasonably foreseeable projects and activities and cumulative effects are not discussed further in this environmental assessment.

5.16.5 Summary of Residual Project-related Effects and Residual Cumulative Environmental Effects

Potential residual effects of the Project include changes to marine benthic habitat quality, marine benthic habitat quantity, and mortality from impingement and entrainment in the seawater intake. Residual effects for these potential interactions are not likely to result from the Project. Residual cumulative effects due to interactions with other certain and reasonably foreseeable projects and activities are also not likely to occur.

No changes to marine benthic habitat are likely to occur on federal or trans-boundary lands. No federal permits or approvals are anticipated for marine benthic habitat for this Project to proceed.

5.16.6 Monitoring and Follow-up Programs

Environmental monitoring plans will be developed and implemented to support effective mitigation measures. Monitoring will consist of two main components: operation or compliance monitoring and effects monitoring. Operation monitoring will occur during all phases of Project activities as a part of the Project mitigation plans and practices. Operation monitoring will include monitoring of Project emissions, effluents, discharges and footprints, and assessment of Proponent and contractor environmental performance using specifically developed performance indicators and benchmarks. Where possible, an adaptive management approach will be used to modify management plans as needed based on the results of the monitoring program.

The effects monitoring will include periodic studies of sediment quality and benthic communities. The studies will be conducted at the Project study area (receiving environment) and a reference area. The monitoring plan will establish timelines for each monitoring activity (e.g., five years for post-construction monitoring). Monitoring data will be assessed against Project-specific guidelines and baseline (pre-Project) data. Project-specific guidelines, particularly for water and sediment quality, will be developed based on Canadian and BC guidelines for the protection of aquatic life and background concentrations.

5.16.7 References

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