19 HUMAN AND ECOLOGICAL HEALTH

19.1 Introduction

Human and Ecological Health is a valued component (VC) because there is potential for the Project to change the chemical conditions of the environmental media (air, water, soil and sediment). Chemicals in the environment have potential to be transferred to human and ecological receptors, either from direct exposure to environmental media or through trophic transfer from the diet.

This assessment is based on a human health and ecological risk assessment (HHERA) approach. The HHERA evaluates the relationship between exposure to chemical stressors and potential effects on health. Project-related stressors include chemical emissions into the terrestrial, aquatic and atmospheric environments. The HHERA is not designed to evaluate non-chemical stressor such as noise and light. However, an evaluation of how non-chemical stressors may affect stress, annoyance and nuisance levels to nearby human and ecological receptors is provided in this assessment.

Potential effects to human and ecological health arising from accidents or malfunctions are addressed separately in this EIS/Application (see Section 22).

19.2 Scope of Assessment

The scope of this assessment includes the evaluation of human health and ecological health from exposures to chemical and non-chemical stressors. The assessment of human health and ecological health uses the analytical and modelling results from the assessment of other VCs including Air Quality (see Section 6), Acoustic Environment (see Section 8), Ambient Light (see Section 9), Vegetation and Wetland Resources (see Section 10), Terrestrial Wildlife and Marine Birds (see Section 11), Marine Resources (see Section 13). Underwater noise effects to marine mammals and fish are addressed in detail under the Marine Resources VC (see Section 13).

Other aspects of health such as Aboriginal health related to traditional and cultural practices, community health and well-being are discussed in Section 18 and Section 21. Worker health and safety is addressed through compliance with the *Pacific NorthWest LNG Health and Safety Management Framework* and applicable provincial and federal legislation.

19.2.1 Regulatory and Policy Setting

In British Columbia, public health is the responsibility of the BC Minister of Health in accordance with the *Public Health Act*. Health Canada's mandate includes the protection of human health from exposure to chemicals and noise. Health Canada provides guidance on human health risk assessments and evaluates human health issues for major projects regulated under the *Canadian Environmental Assessment Act* (CEAA). Ecological health is the responsibility of multiple regulatory institutions including the BC Ministry of Environment (BC MOE), Canadian Council of Ministers of the Environment (CCME), Environment Canada, and the Fisheries and Oceans Canada (DFO).

The following guidelines and objectives were considered for this assessment:

- Air Quality: BC MOE ambient air quality objectives (AAQO) and Health Canada national ambient air quality objectives (NAAQO)
- Water Quality: Health Canada, CCME and BC drinking water quality guidelines
- Soil Quality: CCME soil quality guidelines and the BC Contaminated Sites Regulations and US Environmental Protection Agency soil screening levels
- Sediment Quality: CCME and BC MOE sediment quality guidelines for the protection of aquatic life
- Marine Tissue: CCME tissue residue guidelines for the protection of mammalian and avian consumers of aquatic biota
- Noise Levels: BC Oil and Gas Commission Noise Control Best Practices Guideline.

Provincial and federal regulatory bodies provide objectives and guidelines for protecting the environment. BC MOE provides AAQOs, while Health Canada provides NAAQO. Air quality objectives are used to screen against potential health risks from inhalation of criteria air contaminants (CAC), which include particulate matter (PM), sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and carbon monoxide (CO). Air quality objectives are developed for the protection of the most sensitive receptor (usually humans). Human health based AAQOs were applied towards ecological health. There are uncertainties associated with applying human health standards to ecological health. However, it is important to recognize that there is insufficient science to accurately evaluate ecological health effects from the inhalation pathway. The assessment of ecological health from air contaminants is not typical of an ecological risk assessment. There are no applicable air quality guidelines that are protective of ecological health. The AAQOs for the protection of human health were applied as surrogate guidelines in lieu of any other appropriate air quality screening tool.

Additional conservative assumptions were made to address uncertainties with applying human health based AAQOs towards ecological health. In particular, the evaluation of air quality effects to ecological receptors used the maximum point of impingement (MPOI), which represents the maximum CAC concentrations within the assessment area. The assumption was made that wildlife populations would be continuously exposed to the maximum MPOI for the entire lifetime, rather than the annual average CAC concentrations, which are more realistic. Health Canada also provides health-based guidelines for ambient air quality concentrations of individual chemicals in their supplemental guidance to human health risk assessment (Health Canada 2009).

Drinking water quality guidelines provided by Health Canada and CCME are used to screen against potential chemical health risks to people consuming local stream water or well water, or coming in contact with water through various recreational water uses (e.g., boating, swimming, fishing). Ecological health risks linked to potential water quality degradation are screened using BC and CCME water quality guidelines for the protection of freshwater and/or marine aquatic life.

Soil quality guidelines for residential/parkland, industrial, commercial and agricultural use are provided by the CCME. The BC Contaminated Sites Regulation and US Environmental Protection Agency provide ecological soil screening levels to screen potential health risks to soil invertebrates, plants, wildlife or people following direct contact or ingestion of chemicals in soil.

Sediment quality guidelines from CCME and BC MOE were established to screen for potential health risks to aquatic benthic invertebrates, fish and algae following direct contact with sediment-based chemicals.

Dietary exposures of various contaminants of concern include metals, extractable petroleum hydrocarbons, polycyclic aromatic hydrocarbons (PAH), polychlorinated dibenzo-p-dioxins and polychlorinated dibenzo-p-furans (PCDD/F). Health Canada has calculated tolerable daily intakes for assessing potential human health risks. These are used in country foods risk assessments.

CCME and the US Environmental Protection Agency provide ecological toxicity reference values to assess chemical exposures to ecological receptors. Exposure pathways include ingestion and dermal exposures. Ingestion exposures include chemical uptake from food, water and soil associated with vegetation ingestion. Tissue body burdens are used to assess the chemical exposure from vegetation and prey items.

Dermal exposures include contact with environmental media such as water and soil. Dermal exposures also include sediment contact for aquatic wildlife such as fish, benthic invertebrates and aquatic plants. These exposure pathways are useful in evaluating ecological health risks from food chain transfer.

There are no provincial noise regulations in BC. The British Columbia Oil and Gas Commission (BC OGC) Noise Control Best Practices Guidelines (BC OGC 2009) were developed for controlling noise levels at operational gas production and processing facilities in Northeast British Columbia, to protect indoor residents. These guidelines are used to evaluate the potential for changes in noise levels that cause disturbance and annoyance to local residents during the operation of various projects. The guidelines compare predicted noise levels to both daytime and nighttime permissible sound limits, which are determined in consideration of site-specific parameters. Health Canada does not have a noise regulation and does not mandate specific noise limits. Instead, Health Canada's approach to noise assessment is based on a number of international standards and technical publications, and has provided an interim guidance document "Useful Information for Environmental Assessments" (Health Canada 2010c) in which they recommend the use of relevant available standards or regulations for the area of the proposed project. The BC OCG Noise Control Best Practice Guidelines will therefore be used for the assessment.

19.2.2 Influence of Consultation on the Assessment

Consultation with various stakeholders resulted in several changes to the scope of the HHERA. These changes include the addition of marine tissues in the assessment and modifications to the local assessment area (LAA).

Consultation with Aboriginal groups and the public identified dredging activities as a potential concern to people consuming locally harvested seafood. Local people are concerned that marine sediments at Lelu Island may contain PCDD/Fs from historical industrial activities. The physical disturbance of marine sediments from dredging activities could result in a sediment plume that could carry the sediment-bound PCDD/F into the water column along with the suspended sediment particles. Marine organisms such as fish and benthic organisms could come into contact with these suspended particles in the water column or on surface sediments as the particles resettle.

Local resource users were concerned this could adversely affect the quality of marine foods that people harvest for personal consumption or commercial resale. Concerns focused on a decommissioned kraft pulp and paper mill, which released PCDD/Fs into the marine waters of Porpoise Harbour. PCDD/Fs are still produced as a result of many combustion reactions and continue to be generated from smelting and waste incineration as byproducts. PCDD/Fs are chemically stable in the environment and partition into organic materials such as carbon-rich sediments and do not dissolve readily into the water column. Sediment-dwelling marine organisms such as Dungeness crabs, prawn and various clam species could uptake and bioaccumulate historically deposited PCDD/Fs in fat tissues, subsequently passing the chemicals to ecological receptors up the food chain or to people who consume these tissues.

Consultation with Aboriginal groups, the public, local residents and resource users also resulted in the expansion of the LAA to include the town of Prince Rupert. The original LAA was a 25 km x 25 km square area centered on Lelu Island. As a result of consultation, the LAA was expanded to a 30 km x 30 km square area centered on Lelu Island in order to include the city of Prince Rupert for the assessment of changes to human and ecological health. Guidelines for Air Quality Dispersion Modelling in British Columbia (BC MOE 2008) recommends that project effects representing 10% of the ambient air quality objective for the CACs should be captured within the 50 km x 50 km modelling domain for the regional assessment area (RAA).

19.2.3 Selection of Potential Effects

This section presents the selection of potential environmental effects that form the basis for the assessment of potential project-related changes to human health and ecological health from the degradation of environmental media. The selection of potential effects is based on the possible exposure pathways that receptors could be exposed to chemicals and non-chemical stressors. The identification of an exposure pathway alone does not indicate there will be a change to health risk, especially if health-based exposure thresholds are not exceeded. The potential effects include:

Changes to human health – Construction, operation and decommissioning of the Project will increase air emissions that could affect human health through inhalation. Dredging during construction could expose marine species to sediments containing historical deposits of chemicals. These chemicals could accumulate in the tissues of marine country food species and affect human health from the consumption of marine country foods. Changes to levels of noise and light may increase annoyance and disturbance levels to local people.

Changes to ecological health – Construction, operation and decommissioning of the Project will increase air emissions that could affect ecological health through inhalation. Dredging during construction could expose gilled and filter feeding marine species to suspended sediments containing historical deposits of chemicals. These chemicals could accumulate in the tissues and biomagnify up the food chain to higher level vertebrate predators such as marine mammals and birds. Changes to levels of noise and light may disturb or disorient marine and terrestrial wildlife.

19.2.4 Selection of Subcomponents and Measureable Parameters

The subcomponents selected to evaluate human and ecological health are the chemical aspects of the environment and levels of non-chemical stressors (see Table 19-1). These subcomponents facilitate the analysis of interactions between the Project and the potential effects to VCs.

Table 19-1: Valued Components and Subcomponents for Human Health and Ecological Health

Potential Effect to Valued Component	Subcomponent
Changes to human health	▪ Air quality ▪ Water quality ▪ Soil quality ▪ Sediment quality ▪ Quality of marine country foods ▪ Noise levels ▪ Light levels ▪ Electromagnetic Fields
Changes to ecological health	▪ Air quality ▪ Water quality ▪ Soil quality ▪ Sediment quality ▪ Noise levels ▪ Light levels ▪ Chemical uptake and trophic transfer to ecological receptors

Measurable parameters are used to evaluate the potential for chemicals to affect human and ecological health. The measurable parameters to evaluate changes in health risk to human receptors include the concentration ratio (CR), hazard quotient (HQ) and incremental lifetime cancer risk (ILCR). The risk quotient (RQ) is used to evaluate changes in health risk to ecological receptors (see Table 19-2).

Human and ecological receptors are continuously exposed to many different types of chemicals, each with a unique dose-response effect. The measurable parameters simplify the evaluation of multiple chemicals into a single measure of risk from different types of chemical exposures and health effects.

Table 19-2: Measurable Parameters for Human Health and Ecological Health

Potential Effect	Measurable Parameters	Rationale for Selection of Measurable Parameter
Changes to human health	▪ Concentration Ratio ▪ Hazard Quotient ▪ Incremental Lifetime Cancer Risk	▪ The CR evaluates non-cancer health risks from the inhalation of CACs or the ingestion of chemicals in water. ▪ The HQ evaluates non-cancer health risks from exposures to chemicals in food or direct skin exposure. ▪ The ILCR evaluates cancer risk from long-term inhalation, ingestion and skin exposures to carcinogens.

Potential Effect	Measurable Parameters	Rationale for Selection of Measurable Parameter
Changes to ecological health	▪ Risk Quotient (RQ)	▪ The RQ evaluates health risks to populations of ecological receptors from long-term ingestion and skin exposures to chemicals; or health risks to ecological communities based on chemical concentrations in exposure mediums.

19.2.5 Boundaries

19.2.5.1 Temporal Boundaries

The temporal boundaries for each project phase are:

- **Construction:** Q1 2015 – Q4 2018
- **Operations:** Q1 2019 – 2048+
- **Decommissioning:** 2048+

The operations phase begins in Q1 2019 with the completion of the first LNG train. The second LNG train will be constructed while the first train is in operation.

19.2.5.2 Spatial Boundaries

The spatial boundaries for the human health and ecological health assessment are depicted in Figure 19-1.

The spatial boundaries for the human health and ecological health assessment are based on the boundaries used for the Air Quality assessment (Section 6). The LAA and RAA for the Air Quality assessment are based on the Guidelines for Air Quality Dispersion Modelling in British Columbia (BC MOE 2008) combined with the predicted spatial extent of potential effects on Air Quality. The LAA is a 30 km x 30 km area centered on the facility and the RAA is a 50 km x 50 km area centered on the facility. This area incorporates modelling results from the air quality (see Section 6), acoustic environment (see Section 8) and ambient light (see Section 9) assessments.

Human Receptor Locations

Human receptor locations are sites where people are more likely to be located, or a location of interest that could be related to health effects (see Figure 19-1 and Appendix Q-1). These locations are used to assess potential health risks to human receptors from inhalation of CACs.

19.2.5.3 Administrative and Technical Boundaries

There are no administrative boundaries relevant to the scope of this assessment.

Technical boundaries include the availability of provincial and national objectives that are used in the assessment of human health and ecological health. For the assessment of human and ecological health, various provincial and federal regulating bodies provide guidelines applicable to environmental media (i.e., air, water, soil and sediment), and animal tissues that are consumed by people and predators (i.e., tissue residue guidelines). Criteria may be provided for various chemicals including CACs, metals, persistent organic pollutants and other organic and inorganic substances. In the absence of provincial or federal criteria, guidelines from other jurisdictions or internationally recognized organizations (i.e., World Health Organization) may be adopted for use as surrogate guidelines.

For the assessment of human health, provincial and federal guidelines are available for the anticipated types of chemical stressors that could affect human health. For non-chemical stressors, the evaluation of noise follows Health Canada's approach, which considers a variety of internationally recognized acoustic standards because there are no federally enforceable noise thresholds or standards (Health Canada 2010c). The evaluation of effects on ambient light uses the International Commission on Illumination maximum values for light spill and glare. The International Commission on Illumination is responsible for the international coordination of lighting and related technical standards. These are operational criteria used as surrogates because there are no recognized health-based guidelines for light effects.

For the assessment of ecological health, there are no applicable air quality guidelines that are protective of ecological health from chemical uptake. The AAQOs for the protection of human health were applied as surrogate guidelines in lieu of any other appropriate air quality screening tool. There are uncertainties associated with applying human health standards to ecological health. However, it is important to recognize that there is insufficient science to accurately evaluate ecological health effects from the inhalation pathway. The assessment of ecological health from air contaminants is not typical of an ecological risk assessment.

19.2.6 Residual Effects Description Criteria

The residual effects descriptions provide additional information to characterize potential residual effects for this VC (see Section 19.5).

Table 19-3: Characterization of Residual Effects on Human and Ecological Health

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Characterization of Residual Effects		
Context	Refers primarily to the current and future sensitivity and resilience of the VC to changes in health caused by the Project. Consideration of context draws heavily on the description of existing conditions of the VC, which reflect cumulative effects of other projects and activities that have been carried out, and especially information about the impact of natural and human-caused trends in the condition of the VC. (i.e., low, moderate or high resilience).	**Low resilience**—occurs in a fragile ecosystem with sensitive receptors and/or the level of baseline disturbance can be a contributing factor to changes in human and ecological health. **Moderate resilience**—occurs in a stable ecosystem and/or level of baseline disturbance not likely to contribute to change in human and ecological health. **High resilience**—occurs in a viable ecosystem and/or the level of baseline disturbance does not contribute to changes in human and ecological health.

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Magnitude	Refers to the expected size or severity of the residual effect. When evaluating magnitude of residual effects, considers the proportion of the VC affected within the spatial boundaries and the relative effect. (i.e., low, moderate, high).	**L**–Low—Complete exposure pathway to affect health risk, with exposures near or slightly above health-based guidelines. Residual effects offset by mitigation and management options. **M**–Moderate—Complete exposure pathway to affect health risk with exposures slightly above health-based guidelines. Residual effect will still persist with mitigation and management. **H**–High—Complete exposure pathway to affect health risk with exposures above health-based guidelines.
Extent	Refers to the spatial scale over which the residual effect is expected to occur. (i.e., within the PDA, LAA, or RAA)	**PDA**—Residual effects are restricted to the project development area. **LAA**—Residual effects are restricted within the LAA. **RAA**—Residual effects are restricted within the RAA.
Duration	The period of time an effect to health risk could be measurable	**ST**—Short-term residual effect lasting up to one month. **MT**—Medium-term residual effect lasting up to one year. **LT**—Long-term residual effect lasting more than one year. **P**—Permanent residual effect.
Reversibility	The likelihood that health status will return to baseline if exposure ceases	**R**—Changes to human or ecological health are reversible if the exposure ceases (e.g., temporary illness). **I**— Changes to human or ecological health are irreversible and will persist if exposure ceases (e.g., cancer effects).
Frequency	Refers to how often the residual effect occurs and is usually closely related to the frequency of the physical work or activity causing the residual effect. (i.e., single event, multiple irregular events, multiple regular events, continuous)	**S**—Residual effect occurs once. **MI**—Multiple irregular events – residual effect occurs more than once but at an unpredictable interval of time. **MR**—Multiple regular events – residual effect occurs more than once at a regular interval of time. **C**—Residual effect occurs continuously.
Likelihood of Residual Effects		
Likelihood	Refers to whether or not a residual effect is likely to occur.	**L** = Low likelihood of residual effects to health. **M** = Medium likelihood of residual effects to health. **H** = High likelihood of residual effects to health.

19.2.7 Significance Thresholds for Residual Effects

Significance thresholds assess the potential change to human and ecological health. If there is an exceedance of a health-based guideline or criterion, an evaluation may be necessary to measure the health risk relative to the significance thresholds or the amount of change from baseline conditions. The significance thresholds for residual environmental effects on change in human and ecological health are presented in Table 19-4.

Table 19-4: Significance Thresholds for Residual Environmental Effects

Environmental Effect	Proposed Threshold
Changes to human health	The significance thresholds for measurable parameters are relative to the baseline level. **Concentration Ratios:** If the baseline CR for ***air inhalation*** is ***less than*** 1.0, the significance threshold is reached when: ▪ Predicted CR is greater than 1.0. If the baseline CR for air inhalation is ***greater than*** 1.0, the significance threshold is reached when: ▪ Predicted CR is greater than baseline CR + 0.2. **Hazard Quotients:** If the baseline HQ for ***food ingestion*** is ***less than*** 0.2, the significance threshold is reached when: ▪ Predicted HQ is greater than 0.2. If the baseline HQ for ***food ingestion*** is ***greater than*** 0.2, the significance threshold is reached when: ▪ Predicted HQ is greater than baseline HQ + 0.2. **Incremental Lifetime Cancer Risk:** An ILCR greater than 1 in 100,000 indicates the potential for cancer health risks, or: ▪ Predicted ILCR that is greater than 10^{-5}.
Changes to ecological health	The significance threshold for the RQ is 1, where the RQ is the ratio between predicted chemical concentrations divided by the health standard for each ecological species.

19.3 Baseline Conditions

This section describes the baseline conditions regarding human health, the subcomponents of human and ecological health (i.e., the quality of air, water, soil, sediment, food items and levels of noise and light) and traditional land use information. The baseline conditions provide a benchmark of the current health status in the region resulting from current and historical influences including social, economic, cultural and industrial factors.

19.3.1 Baseline Methods and Data Sources

Baseline conditions are based on multiple information sources including baseline technical data reports and available Aboriginal traditional knowledge. This information supports the evaluation of how project activities could affect human and ecological health. For example, baseline air quality conditions could be compared to modelled operational phase air quality or measured air quality from future monitoring activities.

19.3.2 Overview of Baseline Conditions

19.3.2.1 Traditional Land and Resource Use

Baseline conditions on the current use of lands and resources for traditional purposes are described in Section 21. This section summarizes key information relevant to the health assessment.

The spatial boundaries for the health assessment include areas that are important for traditional and recreational land and resource use. Traditional use is an important aspect of the perceived physical, psychological and cultural health of Aboriginal people. Traditional use activities such as the gathering and consumption of country foods are also important for nutritional health.

The health assessment RAA includes the traditional territories of the Metlakatla First Nation, Lax Kw'alaams First Nation, Gitxaala Nation, Kitselas First Nation and Kitsumkalum First Nation. Recreational land use by Aboriginal groups in the RAA includes hunting, trapping, guide outfitting, fishing, gathering vegetation and a variety of seasonal recreational activities. Many of these activities occur away from the urbanized areas of Prince Rupert and Port Edward and outside of the RAA.

Lelu Island is currently undeveloped with the majority of the island covered by wetlands and old forests. There are historical records of traditional use such as the gathering of traditional medicinal plants on Lelu Island. Areas adjacent to Lelu Island are also important for traditional use include the following waterways: Skeena and Ecstall River, Chatham Sound, Inverness Passage and Port Essington.

Terrestrial animals used by First Nations for food purposes include black-tailed deer, black bear and American marten. Freshwater and marine fish include salmon, herring, herring spawn, cod, halibut, sablefish, ground-fish, and eulachon. Marine invertebrates include clams, crabs, cockles, urchins, shrimps, sea cucumbers and geoducks. First Nations also hunt seals and sea lions and gather gull eggs. Vegetation collected for food, medicinal or cultural purposes include Devil's club, hellebore, cedar planks and bark, berries (salmonberries, blueberries, gooseberries, black crowberries, bog cranberries, huckleberries, salal berries), hemlock, amabilis fir, Pacific crab-apple, Sitka spruce, skunk cabbage and licorice fern.

19.3.2.2 Air Quality

The baseline conditions of air quality used in the air dispersion modelling are described in Section 6. Baseline maximum CAC concentrations among all human receptor locations are provided in Appendix Q-2. This section summarizes key information relevant to the health assessment.

Baseline air quality was modelled using available data from the emissions inventory of previous similar projects from the BC MOE Air Data Archive, which included Port Edward, Prince Rupert, and Kitimat, BC (BC MOE 2013). The baseline air quality represents the current conditions at sensitive receptor locations only (see Figure 19-1), considering existing point sources of industrial air emissions and local climate and meteorological conditions. Summary baseline concentrations are reported using the maximum concentrations of SO_2, NO_2, CO, and PM. Summary baseline concentrations are compared to BC AAQO for 1-hour, 8-hour, 24-hour maximum and the annual average concentrations when applicable (see Table 19-5).

Table 19-5: Baseline Maximum Air Quality at Human Receptor Locations

Criteria Air Contaminant	Averaging Period	Baseline Maximum Concentrations at Human Receptor Locations ($\mu g/m^3$)	Applicable AAQO[A] ($\mu g/m^3$)
SO_2	1-hour	31.4	450
	3-hour	18.4	375
	24-hour	7.3	150
	Annual	0.7	25
NO_2	1-hour	12.4	400
	24-hour	3.8	200
	Annual	0.3	60
CO	1-hour	7.8	14,300
	8-hour	4.1	5,500
PM_{10}	24-hour	6.6	50
$PM_{2.5}$	24-hour	3.7	25
	Annual	0.2	8

NOTES:
[A] BC AAQO or NAQQO

Under baseline conditions, there were no exceedances of any applicable AAQO for all CACs. The measurable parameter for air quality is the CR, which is the ratio of CAC concentrations and the applicable AAQO. None of the baseline maximum concentrations exceeded any applicable AAQOs (i.e., the baseline CR is below 1.0). The highest concentration of CAC relative to the most stringent objective was the 24-hour maximum $PM_{2.5}$, which reached up to 14.8% of the AAQO.

19.3.2.3 Drinking Water Quality

Port Edward sources its drinking water from Alwyn Lake, while Prince Rupert sources its drinking water from Woodworth Lake, with Shawatlan Lake as a secondary backup source. Drinking water quality is managed and monitored by the District of Port Edward and City of Prince Rupert.

Municipally treated drinking water in Port Edward and Prince Rupert is considered to be of good quality. Laboratory records from Prince Rupert municipal records for 2013 indicates no exceedances of BC Drinking Water Quality Guidelines for chemical constituents such as metals, inorganic ions and organics. Physical parameters such as water turbidity and colour were occasionally above guidelines. Guidelines for these parameters are based on aesthetics and not associated with any health risks.

Municipal records of raw water collected in all three lakes showed fluctuating pH levels that were regularly below the Health Canada and BC drinking water guideline range of 6.5 to 8.0. Drinking water guidelines for pH are not associated with any health risks. They are based on operational constraints related to long-term corrosion of pipes at low pH and scale deposits at high pH. Raw water from all three lakes tended to be slightly acidic on average (i.e., low pH). For example, the 2012 mean monthly minimum, mean and maximum pH values in Alwyn Lake were 6.1, 6.9 and 7.8.

19.3.2.4 Soil Quality

Soil quality on Lelu Island was analyzed as part of the Phase II Environmental Site Assessment and Baseline Assessment completed for the Project (Stantec 2013).

Soil samples were collected at 17 boreholes as well as at 12 additional locations. Borehole sites were focused on the northern region of Lelu Island and the mainland at the proposed bridge crossing. Surface soil samples were distributed throughout Lelu Island. Chemicals of potential concern were determined based on suspected historical, current or future activities conducted at specific locations throughout the site.

A total of 36 soil samples were submitted for analyses of petroleum hydrocarbons fraction 1 to 4 (PHC F1 – F4), benzene, toluene, ethyl benzene, xylenes (BTEX), PAHs, PCBs, pesticides and cyanides, as well as metals. The Index of Additive Cancer Risk (IACR) was also evaluated. This parameter is equivalent to a hazard index and takes into account the additive carcinogenicity of the PAH mixture. An IACR greater than 1 indicates possible incremental lifetime cancer risk based on drinking water exposures.

While the majority of the samples were below the CCME guidelines, there were a few exceptions at specific locations:

- Phenanthrene (5.5 %), arsenic (3%) 6, copper (8%), tin (3%) and zinc (8%). However, these samples were collected near a homestead so the concentrations are likely related to the presence of dilapidated boats, motors, small appliances and/or empty gasoline and oil containers.
- Ethyl benzene (3% of samples). Ethyl benzene is an additive in gasoline and found in plastics and paints. However, given the conditions at this particular site near the homestead, the presence of ethyl benzene are likely related to the materials found on the island since they are not detected on other parts of the island.

The IACR was greater than 1 for 33% of the samples. It is important to note that for PAHs analysis in some samples, the detection limit had to be raised higher than the applicable CCME guideline. The detection limits were raised because soil samples had high moisture content resulting from the area being composed of wetlands. High moisture content in the soils may interfere with the accuracy of laboratory analysis, resulting in an increase of the detection limit. Thus, even if no PAHs were measured in the affected soil samples, there is some uncertainty whether PAHs concentrations are below the CCME guideline or between the CCME guideline and the detection limit. Based on soil samples that were not affected by moisture content, the assumption was made that PAHs in the soils generally did not exceed the CCME guideline.

Overall, soil quality on Lelu Island was very good with localized areas with detectable organic contaminants related to an old homestead. No chemicals of potential concern were selected for evaluation based on the analysis of soils.

19.3.2.5 Marine Sediment Quality

The baseline conditions of marine sediment quality are described in Section 13 and Appendix L (Marine sediment and water quality). This section summarizes key information relevant to the health assessment.

There are two main dredging sites during the construction phase. The first location is the proposed site of the Materials Offloading Facility (MOF) in Porpoise Channel to the north of Lelu Island (see Figure 19-1). The second location is the proposed marine berth dredge area located approximately 2 km southwest of Lelu Island. Dredging at the MOF will include the removal of approximately 690,000 m^3 of dredge material to a depth of 12.5 m below chart datum and require an estimated 148 days to complete, based on dredging occurring 24 hours per day, 7 days a week. The marine berth dredge area will include the removal of approximately 7 million m^3 of dredge material to a depth of 15.6 m below chart datum and will require at least one year to complete.

Marine sediment samples were collected around Lelu Island, but focused on the MOF dredge area because the MOF is closer to Porpoise Harbour (4 km) than the marine berth dredge area (7 km). Porpoise Harbour is a historical disposal at sea site, which was the receiving environment for wastes generated by past industrial activities including the disposal of locally dredged materials (e.g., mud, silt and wood) and effluent from the kraft pulp and paper mill. In addition, the marine berth dredge area is situated in the open ocean on the southwest side of Lelu Island, which is more exposed.

Sediment samples were collected to establish a horizontal and vertical (area and depth) profile of chemicals contained in the sediment at the proposed MOF. Chemicals of potential concern include metals, polycyclic aromatic hydrocarbons (PAH), polychlorinated biphenyls (PCB), and polychlorinated dibenzo-p-dioxins and furans (PCDD/F) from historical human activities and naturally occurring events. Chemical concentrations are compared to CCME sediment quality guidelines for the protection of aquatic life and Canadian disposal at sea guidelines to address the disposal of dredged materials at the Brown Passage disposal at sea site.

The CCME interim sediment quality guidelines (ISQG), probable effects level (PEL) and Canadian disposal at sea criteria were used to screen against chemicals in the sediment. The PEL is an indicator that potential adverse effects could exist for aquatic life. disposal at sea criteria are used to screen sediments to help establish whether dredged materials could be suitable for disposal at sea.

A total of 82 sediment samples were collected at five different spatial depth profiles within the MOF. The depth profiling is necessary to establish chemical concentrations in the sediment for disposal at sea activities. The sample depth and number of samples include:

- 6 Intertidal surface grab samples (top 7.5 cm)
- 8 Subtidal surface grab samples (top 7.5 cm)
- 13 Surface core samples (0 – 1.5 m)
- 29 Mid core samples (1.5 – 5.5 m)
- 26 Deep core samples (5.5 – 12.0 m).

For metals, arsenic concentrations ranged from 1.74 to 12.8 mg/kg with an average concentration of 7.47 mg/kg. The concentration of arsenic was higher than the ISQG (7.24 mg/kg) in 45 of 82 samples, but was well below the PEL of 41.6 mg/kg. Arsenic concentrations that exceeded the ISQG occurred at all depth profiles from 0 to 12.0 m, suggesting natural concentrations.

Copper concentrations ranged from 11.0 to 40.7 mg/kg with an average concentration of 23.9 mg/kg. The concentration of copper was higher than the ISQG (18.7 mg/kg) in 56 of 82 samples, but was well below the PEL of 108.0 mg/kg. Copper concentrations that exceeded the ISQG occurred at all depth profiles from 0 to 12.0 m, suggesting natural concentrations. There were no exceedances of ISQG or PEL metal criteria for cadmium, chromium, lead, mercury and zinc from surface samples to a depth of 12.5 m.

For PAH concentrations, 78 of 82 sediment samples were below the laboratory detection limit. PAHs were only detected in three surface sediments to a maximum depth of 1.5 m. All core samples deeper than 1.5 m showed PAH concentrations below the detection limit. The total PAH concentration of all sediment samples were below the disposal at sea criteria, while one intertidal surface sample had concentrations of individual PAHs (i.e., benzo[a]pyrene, benz[a]anthracene and chrysene) above the CCME ISQG. No samples were above the CCME PEL for individual PAHs.

For PCB concentrations, 85 sediment samples were analyzed for nine PCB congeners. Concentrations of individual congeners were below the laboratory detection limits in all samples except one. In this sample, PCB-1254 was 0.059 mg/kg and total PCB in the sample was below the disposal at sea screening criteria (total PCB less than 0.1 mg/kg).

PCDD/Fs were analyzed in a subset of the 82 sediment samples. The initial sampling program in May to July 2013 included seven intertidal and five subtidal surface grabs and composite samples at 0-0.5 m and 0.5-1.0 m within two deep cores. The sampling program was expanded in October 2013 to include 24 samples from three pairs of cores to establish PCDD/F concentrations at 0.2 m intervals reaching depths of 1.0 to 1.4 m. Results were compared to the CCME ISQG (0.85 ng/kg TEQ) and PEL (21.5 ng/kg TEQ), which are protective of fish species since PCDD/Fs are toxic to vertebrates with negligible toxicity to invertebrates. There are no sediment guidelines for the protection of human health.

PCDD/Fs were detected in surface sediments up to a depth of 1.5 m. From 1.5 m to 12.0 m, all samples were below the laboratory detection limit for PCDD/Fs. The intertidal surface samples had measurable concentrations ranging from 0.4 to 0.90 ng/kg TEQ with only one sample exceeding the ISQG of 0.85 ng/kg TEQ. Subtidal and surface core PCDD/F concentrations ranged from 0.06 to 2.64 ng/kg TEQ. These concentrations are above the ISQG but below the PEL of 21.5 ng/kg TEQ. These concentrations are consistent to those reported for the Fairview Phase II Project (Stantec 2009).

As part of a data-sharing agreement with the PRGT Project, surface and 1.0 meter core sediments were collected to the southwest of Lelu Island, within 5 km of the marine berth dredge area. PCDD/F concentrations in these samples had an average of 0.11 ng TEQ/kg dw. Sediments near the marine berth contained PCDD/F concentrations that were only 5 to 23% of the amount in the MOF. Furthermore, most of the individual congeners of PCDD/Fs collected near the marine berth were below the detection limit achievable in the laboratory. The standard approach is to assume that a concentration of half the detection limit is present when considering non-detectable levels as a conservative step. When non-detectable congeners of PCDD/Fs were assumed to be zero, the average PCDD/F concentration in the sediments near the marine berth further decreased to 0.008 ng TEQ/kg dw.

The sediment quality guideline for PCDD/F is protective of benthic and epibenthic fish because of their close proximity to the sediment. The sediment guideline is not intended to be protective of other vertebrates (i.e., marine mammals and marine birds). The sediment guideline is also not protective of aquatic invertebrates because PCDD/Fs are relatively non-toxic to invertebrate life.

Overall, the sediments collected on Lelu Island contain levels of arsenic and copper that are assumed to be representative of natural levels in the region. PAHs were undetectable in most sampling areas and samples were all below the CCME PEL. PCBs were undetectable in all but one sample. PCDD/Fs were detected in sediments down to a depth of 1.5 m, with the highest concentrations in the surface sediment layers. All sediment concentrations were below the CCME PEL, above which, effects to aquatic life could occur. Marine sediment quality around Lelu Island would also meet the disposal at sea criteria.

19.3.2.6 Marine Tissue

A baseline survey of marine country foods was conducted due to concerns from First Nations and local residents about the potential for adverse chemical effects to marine biota (i.e., clams, crabs and prawns) and subsequent effects to humans consuming these tissues. Baseline marine tissue data was collected and analyzed to quantify existing PCDD/F concentrations in species that are harvested by First Nations and the general public.

PCDD/Fs are harmful to vertebrate species such as birds and mammals but are relatively non-toxic to invertebrates. Therefore, clams, crabs and prawn may accumulate PCDD/Fs in their tissues from their close interaction with sediments without adverse health effects, while predatory vertebrates and humans that consume these species may be exposed to PCDD/F levels that could cause harm.

There are no provincial or federal guidelines for PCDD/F concentrations in food. However, Health Canada recommends a dietary tolerable daily intake of 70 pg TEQ/kg bw/month, or 2.33 pg TEQ/kg bw/day (Health Canada 2005).

The PCDD/F concentrations in the tissues of marine organisms are screened against tissue residue guidelines for the protection of birds and mammals that consume aquatic biota. The tissue residue guidelines are intended to protect ecological health and are not applicable to human health effects.

PCDD/Fs include over 100 chemically different substances with similar toxic effects, but at varying levels of potency. The Toxic Equivalency (TEQ) is a standardized measure of the total toxic potential from PCDD/F mixtures. Toxic Equivalency Factors (TEF) are the conversion factors used to convert PCDD/F concentrations into TEQ measurements. TEFs are available for vertebrate groups including mammals and birds because PCDD/Fs vary in their toxicity to these animal groups. Therefore, the same mixture of PCDD/F will have different degrees of toxic potency to mammals and birds.

The World Health Organization published mammalian TEF values in 1998 and updated values in 2005. However, the CCME tissue residue guideline has not been updated to reflect the 2005 TEF values. This report uses the more recent 2005 mammalian TEF values when calculating the TEQ, noting there may be minor differences between the 1998 and 2005 values. Analytical results and TEQs for birds and mammals are in Appendix Q-3.

In September 2013, samples of crab (*Metacapus magister*), clam (*Macoma sp., Mya arenaria*) and prawn (*Pandalus hypsinotus*) were collected within 3 km of the MOF based on the anticipated sediment plume distribution and the southern end of Lelu Island where the proposed natural gas feed pipeline would enter the facility. Samples were analyzed for all congener classes of PCDD/F. These samples include 16 crab muscle, 16 composites mixtures of *Macoma sp*. and *Mya arenaria*, and 8 prawn samples (see Table 19-6). The lower-bound and mid-point average concentration of PCDD/F are compared to the tissue residue guidelines to protect mammals and birds that consume aquatic biota. Standard guidance protocol assumes that non-detects contain half of the lowest detectable limit – defined as the mid-point concentration. The lower bound concentration assumes non-detects as zero. Comparing the lower-bound and mid-point averages may indicate the influence of non-detects on the mid-point average concentration.

Overall, average concentrations of PCDD/F measured in crabs, prawns and clams were below concentrations that would adversely affect mammals and birds that consume aquatic biota.

For mammalian consumers of aquatic biota (i.e., seals, otters), the average concentration of PCDD/Fs in the muscle tissues was 0.33 ng TEQ/kg wet weight (ww) compared to the tissue residue guideline of 0.71 ng TEQ/kg ww. When non-detects are assumed to be zero (lower-bound average), the concentration decreases to 0.04. This indicates that approximately 88 % of PCDD/Fs in the tissues result from assuming non-detects contain half of the detection limit.

For avian consumers of aquatic biota (i.e., gulls), the average concentration of PCDD/Fs in the muscle tissues was 0.59 ng TEQ/kg ww compared to the tissue residue guideline of 4.75 ng TEQ/kg ww. The lower-bound average was 0.13 ng TEQ/kg ww. This indicates that approximately 78 % of PCDD/Fs in the tissues result from assuming non-detects contain half the detection limit.

Table 19-6: Summary of PCDD/F Toxic Equivalency in Marine Tissues

Tissue Type	n	Toxic Equivalency (ng TEQ/kg wet weight)					
		WHO Mammal (2005)			WHO Avian (1998)		
		Tissue Residue Guideline	Lower-bound Average	Mid-point Average	Tissue Residue Guideline	Lower-bound Average	Mid-point Average
Marine country foods (i.e., crabs, prawns and clams)	40	0.71	0.04	0.33	4.75	0.13	0.59

It should be noted that between 1988 and 1995, high concentrations of PCDD/Fs in the marine environment resulted in shellfish harvesting restrictions around all Canadian pulp and paper mills including the areas of Prince Rupert and Port Edward (Hagen 1995). Studies of Dungeness crab near Port Edward and Prince Rupert indicated significant and substantial declines of PCDD/F concentrations in their tissues between 1987 and 1995 (Yunker and Cretney 1995). PCDD/F concentrations in crab hepatopancreas from Port Edward and Prince Rupert had measured concentrations of 1900 ng TEQ/kg ww in 1987, and steadily declined to 670 ng TEQ/kg ww in 1989, 260 ng TEQ/kg ww in 1990 and 53 ng TEQ/kg ww in 1993 (Yunker and Cretney 1995). In comparison, the baseline marine food tissues collected around Lelu Island had an average concentration of 0.33 ng TEQ/kg ww, which may be an overestimation due to the influence on the detection limits described earlier. This data supports the body of evidence indicating that the concentrations of PCDD/Fs in marine traditional and country foods has continued to improve since the harvesting ban related to PCDD/Fs had been lifted in 1995.

19.3.2.7 Marine Fish

The baseline conditions of the marine environment are described in Section 13 and Appendix M.

The marine environment surrounding the facility is characterized by nutrient-rich waters, which support a diverse assemblage of fish. A desktop review identified over 300 species of marine fish inhabiting the waters of the northeast Pacific Ocean (Hart 1988). However, only a portion of these species use marine habitats around Lelu Island for some or all of their lifespan.

Various fish species are relevant to the physical, psychological and cultural health and well-being of Aboriginal people and other land users. The waters around the project area support commercial, recreational and Aboriginal food, social and ceremonial fisheries. The key fish species used for these purposes include Pacific salmon, halibut, Pacific herring, rockfish, lingcod, sole, and eulachon. The most important commercial and recreational type of fish includes various flatfish species (Pleuronectidae).

19.3.2.8 Vegetation and Wetlands

The baseline conditions of vegetation and wetland resources are described in Section 10 and Appendix E. This section summarizes key information relevant to the health assessment.

Vegetation and wetlands play important roles in supporting a healthy ecosystem, providing food and shelter for wildlife. Vegetation is also gathered by First Nations and other land users for nutritional, medicinal and cultural purposes. The baseline conditions for vegetation and wetlands were evaluated using a variety of tools such as traditional ecological knowledge reports, relevant literature, publically available datasets, terrestrial ecosystem mapping and field surveys that were conducted on Lelu Island in August 2012 and May 2013.

First Nations regularly collect medicinal and food plants within the region. Tree species commonly harvested include hemlocks, amabilis fir, Pacific crabapple, Sitka spruce, western red cedar and yellow-cedar. Twenty-four shrub species were identified in the region including: Alaska blueberry, black crowberry, blueberries, bog cranberry, devil's club, juniper, Labrador tea, red huckleberry, salal and salmonberry. Harvested herbs the ferns include bunchberry, hellebore, skunk cabbage and licorice fern (Compton 1993; MacDonald 2005).

Lelu Island contains forested and wetland ecosystems. The forested unit is comprised of a mixture of western red cedar and western hemlock, often with a yellow cedar component. Understory shrub layers within this ecosystem were dominated by tree regeneration (mostly hemlock) and salal berries (Banner et al. 1993).

The wetland component is comprised of shore pine, yellow cedar, western cedar and goldthread bog forests. Shrub layers within this ecosystem are well developed and often characterized by dense stunted yellow and western red cedar as well as salal berries, Labrador tea, sweet gale, common juniper, tufted club-rush and hoary rock moss. Soils consist of saturated sphagnum peats (Banner et al. 1993). No vegetation species were identified on Lelu Island that were at risk under the Federal *Species at Risk Act*.

19.3.2.9 Terrestrial Wildlife and Marine Birds

The baseline conditions of terrestrial wildlife and marine bird resources are described in Section 11 and Appendix H. Baseline information on traditional ecological knowledge (TEK) and wildlife harvested by Aboriginal groups are described in detail in the assessment of Current Use of Land and Resources for Traditional Purposes (see Section 21).This section summarizes key information relevant to the health assessment.

Wildlife is an important ecological, cultural, economic and functional resource. The health status and species richness of wildlife is inherently linked to the perceived health and well-being of Aboriginal groups.

TEK information identified regional harvesting of terrestrial wildlife: marten, mink, otter, deer, moose, elk, mountain goat, fox, beaver, muskrat, squirrel, weasel, grey wolf and bears. Harvested bird species included ducks, geese, puffins, swans and the eggs of sea gulls.

The desktop review identified 359 species of terrestrial mammals, amphibians and birds in the Prince Rupert region (Radcliffe et al. 1994). Only a portion of those species are expected to use habitats available on Lelu Island, with 128 species documented during surveys on Kaien and Ridley islands. Mammals with the highest potential to occur near Lelu Island include moose, black-tailed deer, grey wolf, Pacific marten, American beaver and North American porcupine. Amphibians include northwestern salamander and rough-skinned newt. More than 104 terrestrial bird species have been observed in the Prince Rupert region with a portion of those expected to use habitats available on Lelu Island. These species include Pacific wren, American robin, hermit thrush, orange-crowned warbler and northwestern crow. Over 95 marine bird species have also been observed in the Prince Rupert region. Marine birds common to this region include glaucous-winged gull, mew gull, marbled murrelet, rhinoceros auklet and surf scoter.

There are 32 species of management concern that have the potential to use habitats on either Lelu Island or adjacent marine environments. Eighteen of these species have been detected on surveys of Kaien and Ridley islands. These include western toad, peregrine falcon *pealei* subspecies, great blue heron *fannini* subspecies, California gull, surf scoter, western grebe, double-crested cormorant, and pelagic cormorant *pelagicus* subspecies.

19.3.2.10 Noise Levels

The baseline conditions of the acoustic environment are described in Section 8 and Appendix D. This section summarizes key information relevant to the health assessment.

Noise is a non-chemical stressor that could affect the general health and well-being in human and ecological receptors. Exposure to noise may affect stress and annoyance levels. The effects of noise to humans and wildlife vary between individual receptors and within the same receptor. Noise factors such as magnitude, timing or frequency (i.e., single event, infrequent, continuous noise), pitch (i.e., high or low pitch), and time of day (i.e., daytime or nighttime) play a role in determining whether the noise may be stressful or annoying to a receptor. Noise levels were evaluated based on the BC Oil and Gas Commission's Noise Control Best Practices Guideline as recommended by Health Canada (BC OGC 2009; Health Canada 2010c).

Baseline noise levels were recorded in 2012 at eight locations near Lelu Island, with three on Ridley Island and five in Port Edward. These locations include the Port Edward Elementary School, residential dwellings and southern portions of Ridley Island that are close to Lelu Island. Ambient acoustics at these monitoring locations are the result of a combination of the natural environment and human activities. Naturally occurring noises include rain, wind, ocean waves and wildlife. Human activities include rail traffic, aircraft flyovers, local industry and traffic on local roads.

Baseline noise levels at all locations in the study were consistent with quiet rural environments. Ridley Island monitoring locations had a daytime maximum L_{90}(1) (i.e., the sound level that is exceeded 90% of an hour) range of 37 to 47 decibels. Nighttime maximum L_{90}(1) noise ranged from 33 to 46 decibels. These noise ranges are similar to sound levels in a quiet room.

Port Edward monitoring locations had a daytime maximum L_{90}(1) range of 41 to 73 dBA. These noise ranges are consistent with a quiet room to vehicle traffic travelling 60 km/h at a distance of 20 meters. Nighttime maximum L_{90}(1) ranged from 35 to 46 dBA.

19.3.2.11 Ambient Light Levels

Information on baseline light levels is described in Section 9.3. In Port Edward and Prince Rupert, municipal lighting and dockside facilities have luminaires that cast excessive glare and light spill on adjacent properties. Both towns are close to large areas where ambient light levels are extremely low.

Baseline levels of light in the night sky were recorded in 2013 at 17 locations surrounding the project area that represented urban, suburban, rural and natural areas. These locations include Prince Rupert, Port Edward, several locations along the railroad across from Lelu Island as well as along Ridley Island Road.

While data recorded for sky brightness was generally uniform, the readings show large variations between the levels of ambient light in urban and remote areas ranging from 0 to 88.85 Lux. Illuminance averaged 18.2 lux in urban and suburban areas, and 0.22 lux in remote and natural areas. Illuminance during a full moon is approximately 0.27 lux.

19.3.2.12 Electromagnetic Fields

Electromagnetic fields (EMF) are part of the spectrum of electromagnetic radiation, which extends from static electric and magnetic fields, through radiofrequency and infrared radiation, to X-rays. EMFs are generated from household electronic devices (e.g., cell phones, appliances, computers) and industrial machinery and infrastructure (e.g., wireless network towers, electric generators, transmission lines). Standards exist to limit exposure to EMF levels present in our environment. Guidelines are set by the International Commission on Non-Ionizing Radiation Protection, a non-government organization recognized by the World Health Organization. Exposure guidelines for electricity in the home are 5000 V/M for the electric field and 100 μT for the magnetic field.

In recent years, national authorities in different countries have conducted many measurements to investigate EMF levels in various living environments. None of these studies concluded that EMFs could result in adverse health effects (WHO 2013). Exposure to EMFs at levels present in urban environments or in the home do not cause detrimental health effects. Above a certain level, it has been postulated that EMFs might affect human health. However, there is no clear scientific evidence supporting this and additional research in this area is warranted (Health Canada 2012; WHO 2013).

The magnitude of an EMF diminishes rapidly with distance (inverse square of the distance from the source), with a safe distance ranging from 60 to 150 m from strong EMF sources such as transmission lines. Therefore, baseline levels of EMF on Lelu Island are limited to normal levels found in the natural environment since the island is not developed and there are no nearby transmission lines.

19.4 Project Interactions with Human and Ecological Health

Project activities and physical works that have the potential to change health risks to human and ecological receptors are ranked (see Table 19-7). The ranking system is based on the interaction of project activities with the subcomponents of health (i.e., the quality of air, soil, sediment and water). Based on past experience and professional judgment, if the resulting effect to the subcomponents of health can be managed to acceptable levels through standard operating and codified practices, the interaction is ranked as 1. A detailed rationale and justification is provided for the ranking, and no further assessment is warranted. If a project activity interacts with a subcomponent of health in a manner that could exceed acceptable standards without the implementation of mitigation measures, the interaction is ranked as 2. Interactions ranked 2 are assessed further in the HHERA.

Table 19-7: Potential Interactions between Project Activities and Human Health and Ecological Health

Project Activities and Physical Works	Potential Environmental Effects	
	Changes to Human Health Risk	Changes to Ecological Health Risk
Construction		
Site Preparation (land-based)	1	1
Onshore Construction	1	1
Vehicle Traffic	1	1
Dredging	2	2
Marine Construction	1	1
Waste Management and Disposal (liquid, solid, and hazardous)	1	1
Disposal at Sea	1	1
Operational Testing and Commissioning	1	1
Site Clean-Up and Reclamation	1	1
Operations		

Project Activities and Physical Works	Potential Environmental Effects	
	Changes to Human Health Risk	Changes to Ecological Health Risk
Operation of LNG Facility and Supporting Infrastructure on Lelu Island	2	2
Marine Terminal Use	2	2
Shipping	2	2
Waste Management and Disposal (liquid, solid, and hazardous)	1	1
Fish Habitat Compensation	0	0
Wetland Habitat Compensation	0	0
Decommissioning		
Dismantling Facility and Supporting Infrastructure	1	1
Dismantling of Marine Terminal	1	1
Waste Disposal	1	1
Site Clean-Up and Reclamation	1	1

0 = No interaction.

1 = Potential adverse effect requiring mitigation, but further consideration determines that any residual adverse effects will be eliminated or reduced to negligible levels by existing codified practices, proven effective mitigation measures, or best management practices (BMPs).

2 = Interaction may occur and the resulting environmental effect may exceed acceptable levels without implementation of project-specific mitigation. Further assessment is warranted.

19.4.1 Justification of Interaction Rankings

Project activities that could lead to changes to human and ecological health risk include land-based site preparation during the construction phase, and the operation of the proposed LNG facility and supporting infrastructure on Lelu Island.

These project activities could interact with subcomponents of health to change human and ecological health through the following pathways:

- The release of CACs from power generation, processing of feed gas, LNG carriers and small emissions from flare pilot light and support mobile land-based equipment could CAC concentrations in the air leading to health effects from inhalation.
- Dredging of sediments at the MOF and marine berth could change the chemical profile of sediments suspended in the water column and resettling on the benthic marine environment.
- The increase of noise levels during construction and operation of the Project could lead to higher annoyance levels to human receptors or stress ecological receptors.
- The increase of light levels during construction and operation of the Project could lead to higher nuisance levels to human receptors.

Interactions ranked as either a 0 or 1 do not require further assessment.

19.4.1.1 Electromagnetic Field Interaction Ranking

The interaction ranking between project activities and EMF during construction, operations and decommissioning is 0. Project activities are not expected to cause measureable changes in EMF during the various phases of the Project that will result in any health risks.

High voltage transmission lines are the major source of strong EMFs. The Project may connect to the municipal electric grid during the construction phase. However, the Project is not powered by the electric grid during operations and will not require high voltage transmission lines. The electricity from the generators used during the operation phase do not require the conversion of electric energy to a high voltage form for long distance transmission. The main source of EMF will be during operations from the electrical generators to power the facility. EMF from electrical generators would be highest in the immediate vicinity of the machinery and would decrease rapidly with distance (inverse square of the distance from the source).

There would be negligible potential for EMF levels affecting health to reach human or ecological receptors based on the low levels of EMF generated and the distance to residential areas or ecological habitat.

The effects of EMFs to human and ecological health are not assessed further.

19.4.1.2 Freshwater Quality Interaction Ranking

The interaction ranking between project activities and freshwater quality in all project phases is 1. Project activities are not expected to have direct impacts to sources of freshwater because project activities occur on Lelu Island and in marine waters. This represents an incomplete exposure pathway because there are no chemical effects to freshwater systems that could affect health risk.

An indirect effect to water quality could result from the deposition of acid-generating air emissions onto freshwater systems. Minor changes to water pH are not a health risk to human and ecological receptors. Baseline water quality of lakes used for municipal drinking indicated the existing pH range to be between 6.1 and 7.8.

There are no federal or provincial drinking water guidelines for pH based on human health effects. Health Canada provides a drinking water guideline for pH ranging from 6.5 to 8.5. The guideline is based on pH considerations for processes that are used to remove bacteria, viruses and other harmful components during water treatment. Health Canada does not provide health-based pH guidelines for drinking water because water pH is related to a variety of other parameters and it is not possible to determine a direct relationship with human health. The BC drinking water quality guideline for pH is based on operational constraints related to long-term corrosion of pipes at low pH and scale deposits at high pH. It is also important to note that humans regularly consume liquids ranging from highly acidic to moderately alkaline as part of a normal diet. Ecological receptors that are exposed to the natural pH range of freshwaters would experience negligible health risks from minor pH changes.

Based on the absence of human and ecological health effects from indirect changes to water pH and no pathway for dredged material to impact freshwater environments, no additional analysis is warranted.

19.4.1.3 Soil Quality Interaction Ranking

The interaction ranking between project activities and soil quality is 1. The type of chemical effects to soil quality includes indirect effects from the dry and wet deposition of air emissions onto surface soils. Project activities are not expected to change the chemical concentrations of metals and anthropogenic organic substances in the soil to the extent that human and ecological health could be affected. Deposition of air emissions could affect soil pH; however, there are no soil-based pH guidelines for health objectives. Changes in metal mobilization from reduced soil pH are unlikely. The expected changes to soil pH would be marginal relative to the magnitude of change required to cause leaching of metals bound to soils.

In addition, the project facilities proposed on Lelu Island will encompass the majority of the land. Human and ecological receptors would have very limited exposure to soil on Lelu Island during the lifespan of the Project.

Waste management activities associated with the disposal of liquid, solid and hazardous wastes are disposed at an off-site location in disposal or recycling facilities certified to handle such materials.

No additional analysis is warranted of this interaction.

19.4.1.4 Sediment Quality Interaction Ranking

The interaction ranking between project activities and sediment quality is 1 for human health and 2 for ecological health. Sediment quality refers specifically to the chemical constituents contained in the sediment. Dredging at the MOF and marine berth during construction is the primary activity that could affect sediment quality by physically disturbing sediments that contain historically deposited chemicals. Sediments are the ultimate environmental sink for many natural and anthropogenic chemicals.

Sediment plume modelling was conducted at the proposed MOF dredge site to evaluate the short-term and long-term distribution of disturbed sediments and to address public concerns regarding the impact to local sediments and seafood. Plume modelling of the dredging area by ASL Environmental Services predicted that up to 2 mm of sediment will re-settle in the majority of the surrounding area up to a radius of 3 km from the MOF (see Appendix N). Maximum sediment deposition could reach 11.3 mm within 500 m of the dredge site (excluding redeposition at the MOF where dredging occurs) in areas of low water current along Lelu Island. A plume dispersion model for the marine berth dredge area is currently unavailable. It is anticipated that the resulting plume range, concentration of suspended solids and subsequent sediment deposition upon completion of dredging activities will be greater. However, the effect on sediment chemistry would be similar to those in the MOF.

An exposure pathway to affect human health is unlikely and ranked as 1. Human receptors generally do not interact with marine benthic sediments. While human receptors may frequently use the marine environment for recreational uses such as fishing, kayaking or swimming, there would be minimal to no contact with deep ocean sediments in the dredging area. Exposure to suspended sediment particles in the water column would be short in duration and infrequent. PCDD/Fs also have poor solubility in the water column and uptake rates would be negligible given the short exposure duration and frequency.

An exposure pathway to affect ecological receptors is ranked as 2. An exposure pathway to affect ecological health could exist if chemical concentrations in deep sediment layers are higher than concentrations found in surface layers. Under this scenario, deep sediments containing higher concentrations of contaminants would settle over cleaner surface sediments. These concentrations must also be above ecological health-based criteria. Alternatively, if surface sediments contain higher chemical concentrations than the underlying layers, dredging would remove the surface sediments, exposing and disturbing relatively cleaner sediments. Under this scenario, chemical concentrations in the sediment could decrease or remain similar to existing conditions. There would be no potential for dredging to increase the chemical concentrations in the sediment from the physical disturbance.

The baseline study of marine sediments at the MOF indicate that historical deposits of chemical (i.e., PAH, PCB, PCDD/F) are primarily within the upper 1.5 m. PCDD/F concentrations were highest in the upper 0 to 0.2 m sediment layer with gradually decreasing concentrations to a depth of 1.5 m, based on sediment core intervals of 0.2 and 0.5 m. The underlying sediment from a depth of 1.5 m to 12.5 m is relatively free of PAH, PCBs and PCDD/Fs.

Literature information on the surface sediments in Chatham Sound indicates similar concentrations of PAHs, PCBs and PCDD/Fs in the region from Lelu Island to the Brown Passage disposal at sea site (DFO 2012). Therefore, the sediment plume resulting from dredging activities will contain similar or lower concentrations of anthropogenic chemicals than the existing surface sediments. There are no processes that could increase the concentration of chemicals in the sediment. This represents an incomplete exposure pathway at the dredge site because there are no expected concentration increases to the chemical in the sediment that could affect human and ecological health. Although no sediment plume model has been performed at the marine berth, the same assumptions are applicable as the sediment plume resulting from the dredging activities at the marine berth site will also contain similar or lower concentrations of anthropogenic chemicals than the existing surface sediments.

PCDD/Fs in the sediment were above the interim sediment quality guidelines to protect fish, but below the Probable Effects Level, above which adverse effects could exist. The concentration of PAHs, PCBs, and PCDD/Fs in disposed sediments will be further attenuated from volumetric mixing of the upper 1.5 m of sediment that contains these chemicals, and the underlying sediment to a depth of 12.5 m that are relatively free of these substances.

Project activity interactions with sediment quality represent an incomplete exposure pathway to human health and no further analysis is warranted. Interactions with ecological health for benthic marine species is a complete exposure pathway and assessed further.

19.4.1.5 Air Quality Interaction Ranking

The interaction ranking between project activities with air quality is ranked as 2. The changes to air quality and its impact to health risk will be assessed in greater detail in the effects assessment below.

The Project will release CACs during construction, operation and decommissioning phases. CACs include sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO) and particulate matter ($PM_{2.5}$ and PM_{10}). Sources of air emissions from project activities include point sources such as power generators, processing of feed gas, flare stacks and non-point source emissions such as LNG carriers, vehicle exhaust and support mobile land-based equipment. This represents a complete exposure pathway where receptors are directly exposed to CACs released from project activities. Greenhouse gases such as carbon dioxide are not included in the HHERA because they are not associated with adverse health effects under realistic exposure scenarios. This interaction is assessed further in Section 19.5.

19.4.1.6 Marine Country Foods, Chemical Uptake and Ecological Trophic Transfer Interaction Ranking

The interaction ranking between project activities with the quality of marine country foods is 2 for human health. The interaction ranking between project activities with ecological health is 2, based on the potential for increased chemical uptake from direct sediment contact and biomagnification up the food chain in marine ecological species.

Country foods are local animals, plants, and fungi that are harvested and consumed for nutritional or medicinal purposes by local people. Marine country foods include various crab, shrimp, shellfish, groundfish and pelagic fish species that are harvested by local residents of Port Edward and Prince Rupert, First Nations, recreational users and commercial harvesting industries. Consultation with First Nations and local land users indicate there is public concern regarding the project effects on marine sediment from dredging at the MOF and the marine berth sites, which could have subsequent effect on the tissue chemistry of marine organisms.

Although the concentration of PCDD/F in the sediments would not increase from dredging activities, the resulting sediment plume may result in an increased exposure to some marine organisms. Suspended sediments in the water column from the plume could contain PCDD/Fs which are exposed to the gills of marine organisms (i.e., fish, prawns and crabs) or collected by filter feeders (i.e., shellfish) and could affect ecological health. Humans who consume these organisms could be exposed to increased PCDD/F concentrations.

19.4.1.7 Noise Interaction Ranking

The noise effect for the activities related to the Project is ranked as 2 and are assessed in Section 19.5.

Project activities will generate noise during all phases. During construction, activities such as site preparation, onshore construction, dredging and marine construction may result in changes in noise levels. The duration of the construction phase is expected to be five years and will mostly occur during daytime. During operations, noise emission from the shipping, marine terminal use, LNG facility, power generation and other supporting infrastructure facilities may also result in changes to the existing acoustic environment. This phase is expected to have a minimum duration of 30 years. There will also be noise emission during decommissioning due to the dismantling of the marine terminal, facility and support infrastructure. However, noise emission during this phase will be much lower than during the construction phase. This interaction is assessed further in Section 19.5.

19.4.1.8 Light Interaction Ranking

Project activity interactions with light levels and its potential to affect nuisance levels is ranked as 2 and are assessed in Section 19.5.

Light is a non-chemical stressor that could affect general health and well-being in human and ecological receptors. Exposure to light may affect nuisance and annoyance levels in humans and also disorient ecological receptors that migrate or are physically attracted or repelled by light.

During the construction phase, activities such as terrestrial site preparation and construction of the LNG facility and supporting infrastructure on Lelu Island, operation of construction equipment, installation of bridges and roads, construction and use of the MOF and construction of the marine terminal have the potential to increase the level of ambient light. There is the potential that the exterior lighting associated with the project components described above will be visible to human and ecological receptors and might cause nuisance. Therefore, this interaction is assessed further in Section 19.5.

19.5 Effects Assessment

19.5.1 Analytical Methods

The HHERA assesses potential health effects from the inhalation of CACs from project air emissions. The concentration of CACs in the assessment area is based on air quality modelling (see Section 6) and local climate conditions. Marine tissues are evaluated based on the analytical data from collected crabs, prawns and crabs and professional judgment. Levels of noise and light were modelled and evaluated qualitatively because they do not cause health effects of a chemical nature. There are no provincial or federal health standards or criteria for noise and light.

19.5.1.1 Analytical Assessment Techniques

The HHERA uses a tiered approach to quantify measures of health risk to human and ecological receptors within the assessment boundaries. This approach begins with a screening level risk assessment that identifies the location of human and ecological receptors and the potential exposure pathways. The screening level risk assessment is based on the justification of interactions ranking (see Section 19.4). Chemical stressors associated with project activities are identified; followed by a description of potential exposure pathways where receptors could be exposed to chemical stressors. Lastly, the magnitude and nature of the exposures are evaluated for each receptor using conservative estimates.

The human health risk assessment and the ecological health risk assessment use conceptual site models (see Figure 19-2 for human health and see Figure 19-3 for ecological health) to establish plausible interaction pathways between project effects and human health or ecological health. For a risk to be plausible, three conditions must be met:

1. A stressor (i.e., hazardous chemical, noise or light) must be present.
2. A receptor (i.e., humans or ecological species) must be present.
3. An exposure pathway for the stressor to contact the receptor must be present.

While the presence of all three elements is required for a risk to be present, it does not imply there will be a health risk. An exposure to a stressor must be of sufficient magnitude and duration in order to elicit a biological effect. If exposure concentrations do not exceed applicable health-based standards, a full quantitative assessment of the potential health effects may be deemed unnecessary. An exceedance of a health-based standard does not necessarily imply significant health effects will occur because of the conservatism used in various steps of this assessment (air emissions inventory, modelling of worst case conditions and uncertainty (or safety) factors in deriving health-based standards). However, a quantitative evaluation may still be necessary to measure the health risk relative to significance thresholds or the amount of change to health risk from baseline conditions.

When potential health risks are identified, the HHERA evaluates the magnitude, likelihood, duration, frequency and reversibility of the health effect, and discusses potential health risks associated with the various exposure scenarios considered.

The HHERA follows the guidance provided by Health Canada (2004, 2009, 2010a, 2010b, 2010c, 2011), CCME (1996) and Environment Canada (2011).

Human Health

Potential project-related human health effects are based on the results of a screening level risk assessment. This incorporated the technical assessment results from other disciplines and Aboriginal traditional knowledge and land use information such as the marine species that are harvested for human consumption.

The screening phase of the HHERA considers how project-related changes to the quality of ambient air, marine country foods, water, soil and sediment have the potential to affect health. Levels of noise and light are also evaluated for the potential to cause annoyance or nuisance among receptors.

The selection of human receptor locations is based on satellite imagery of structures, available traditional knowledge information and public information regarding the locations of residences, businesses and government facilities. Human receptor locations are selected if the site is more likely to contain health-sensitive individuals compared to the general area. Such sites include schools, community centers, daycares, hospitals and long-term care facilities where infants, youths, elderly and those with pre-existing health conditions are typically present. Receptor locations also included residences close to project facilities, inhabited islands, industrial buildings, Aboriginal groups, and lakes that supply Port Edward and Prince Rupert with municipal drinking water. In rural areas with a sparse population, individual residences and structures were selected to provide a representative spatial distribution of sites within the RAA.

Human receptors include First Nations, people in towns and communities (e.g., Port Edward) and local land users (e.g., hunters, trappers and recreational users).

Based on the rankings for project interactions with human health, and the justifications of interaction rankings (see Section 19.4), pathways that are ranked as 1 are not further assessed for changes to human health. Pathways that are ranked as 2 are assessed in detail below.

Ecological Health

The conceptual model for the assessment of ecological health illustrates the interaction between project activities and the subcomponents of health. The conceptual model only identifies the plausible pathways where project-related chemical stressors could interact with ecological receptors and affect ecological health. The presence of a pathway does not imply that a risk to ecological health exists.

Based on the rankings for project interactions with ecological health, and the justifications of interaction rankings (see Section 19.4), pathways that are ranked 1 are not assessed further. Pathways that are ranked 2 are assessed in detail below.

19.5.1.2 Assumptions and the Conservative Approach

The assessment of human and ecological health makes assumptions to derive a realistic exposure scenario. These assumptions are:

- Human receptor locations are spatially representative of populated regions in the LAA for the effects assessment, and in the RAA for the cumulative effects assessment.
- Ecological receptors are present throughout the entire LAA for the effects assessment and in the RAA for the cumulative effects assessment.

The following conservative approaches are used in the assessment of human and ecological health:

- The air dispersion modelling is based on the worst-case scenario, which is the operation phase at full capacity.
- Air quality modelling results report the maximum concentration that could occur over one year based on the model input parameters. Maximum concentrations could occur infrequently, while the average concentration is representative of long-term exposures.
- The assessment of human and ecological health uses the most stringent of BC or national ambient air quality objectives.
- Health-based objectives and criteria have an inherent conservatism in their derivation (i.e., uncertainty factors) to address uncertainties on chemical interactions with human or ecological receptors.

19.5.2 Changes to Human Health

19.5.2.1 Potential Effects

Construction

CAC emissions to the environment are chemical stressor that could affect human health during project construction. CACs are emitted from vehicles construction and equipment. CACs have the potential to cause respiratory or inflammatory effects to human receptors, particularly to sensitive individuals such as infants, children, elderly and people with pre-existing respiratory or related medical conditions.

The sediment plume from dredging at the MOF and marine berth may result in an increased exposure to suspended sediment particles containing PCDD/Fs. Gilled and filter feeding marine organisms could absorb PCDD/Fs into the tissues from these particles. Changes to the PCDD/F concentrations in marine tissues could have indirect health effects to people who harvest crabs, clams, prawn and fish.

Non-chemical stressors include noise and light, which are generated from most activities during the construction phase. These activities could generate noise above permissible sound limits, which in turn could lead to the disturbance of local residents and increased levels of annoyance. Increased light levels during nighttime could affect nuisance levels of local residents.

Operations

CAC emissions to the environment are the primary chemical-related stressor that could affect human health. The tonnage of CACs released during operation would be greater than during construction because the LNG facility would be operating 24 hours per day, 365 days a year. The types of activities are also substantially different between construction and operations.

Occasional dredging acitvities may be necessary during the operation phase in order to maintain the depth of the channel over time. This repeat dredging would be infrequent and would only remove newly deposited sediments that are generally free of PCDD/Fs. The plume effect to marine organisms from this activity would be smaller in magnitude and duration compared to the construction phase. Subsequent indirect effects to people consuming these species as marine country foods would also be lower than in construction.

Noise and light levels during operations could affect annoyance levels of local residents, particularly during nighttime hours. There is a greater potential for noise effects during operations relative to construction because of the continuous operation of the facility for an estimated 30+-year period.

Decommissioning

During the decommissioning phase, changes to the environment will be similar to the construction phase. Atmospheric releases of CACs and levels of noise and light will be primarily from vehicles and machinery used to dismantle and recycle facility equipment. There will be no additional dredging activities or subsequent chemical effects to marine organisms. Decommissioning activities will be undertaken according to the legislation at the time, and are not considered further in this assessment.

19.5.2.2 Mitigation

The mitigation measures described in the related VC chapters will reduce the potential health effects to people. In particular, these mitigations will reduce or control the release of CACs, and changes in the acoustic environment and ambient light. These mitigations are considered to be effective in addressing the effects to their respective VC.

There are no additional mitigation measures recommended to protect human health because the mitigations from other VCs are intended to reduce adverse environmental effects to a level which does not adversely affect human health. Detailed mitigation measures can be found in the effects assessment for each discipline (see Air Quality [Section 6], Marine Resources [Section 13], Acoustic Environment [Section 8], and Ambient Light [Section 9]).

19.5.2.3 Characterization of Residual Effects

Air Quality Health Risks to Human Receptors

Details on the air quality assessment and modelling are included in Section 6.5 with results summarized below. Modelled CAC concentrations at sensitive human receptor locations are in Appendix Q-2.

The assessment screens potential health risks to sensitive individuals (the young, the old and those with pre-existing respiratory conditions). Resilience of individuals would be difficult to characterize without conducting site-specific studies of community health, which are beyond the scope of this risk assessment. Therefore, resilience is characterized as low, on the basis that air quality could affect sensitive human receptors.

Air Quality Health Risks (Construction)

The assessment of air quality health risks is based on the modelling results from the operation phase. Potential health risks from reduced air quality during the construction phase would be substantially lower in duration and magnitude because there would be no operating LNG facility and related facilities present. There were no exceedances of applicable AAQOs from the modelled operations phase. Consequently, no changes to human health are anticipated from air quality during construction.

The context considers the presence of sensitive human receptors within the assessment area and change to human health is characterized as having a low resilience. The magnitude of change is characterized as low because emissions during construction are lower than the operations phase, which met all applicable AAQOs. The geographic extent is characterized as being within the human health LAA since this is the area where human receptors are identified and assessed for project effects. The frequency of potential effects is characterized as multiple regular events and the duration is considered long term because active construction would only occur during daily between 7:00 am to 10:00 pm over a four year period. The potential changes are reversible because, after cessation of activities, changes in air quality would dissipate over time and the health risk associated with air quality would return to baseline conditions.

Air Quality Health Risks (Operation)

A quantitative approach was used to evaluate the potential risk to human health from air quality during the operation phase, because there would be substantial air emissions expected from the project facilities operating 24 hours per day, 365 days per year for a minimum of 30 years. The air quality modelling results are the predicted maximum concentrations among all human receptor locations for where people may be located.

The modelled changes to air quality during operations shows that no CACs exceed applicable AAQOs at any time (see Table 19-8). This indicates that for the general population, there would be no changes to human health to people exposed to CACs in the air from project activities.

Table 19-8: Maximum Air Quality Concentrations at Human Receptor Locations during Operations

Criteria Air Contaminant	Averaging Period	Operations Maximum Concentrations at Receptor Locations ($\mu g/m^3$)	Applicable AAQO ($\mu g/m^3$)
SO_2	1-hour	25	450
	3-hour	20	375
	24-hour	7	150
	Annual	1	25
NO_2	1-hour	179	400
	24-hour	33	200
	Annual	2	60
CO	1-hour	160	14,300
	8-hour	58	5,500
PM_{10}	24-hour	13	50
$PM_{2.5}$	24-hour	8	25
	Annual	1	8

NOTES:
[A] BC AAQO or NAAQO

There could be adverse health effects to sensitive receptors such as infants, elderly or people with pre-existing respiratory conditions when CAC concentrations are below their respective criteria. Concentrations of SO_2 and CO were generally well below applicable AAQOs. Short-term concentrations of NO_2 only reached a maximum 1-hour concentration that was 45% of the AAQO. A time sensitivity analysis indicated that such concentrations are reached very infrequently and occurs less than 1% of the year, depending on local climate and wind conditions at the time.

The context considers the presence of sensitive human receptors in the assessment area, and change to human health is characterized as having a low resilience. The magnitude of change is characterized as low since the modelling results indicated no exceedance of health-based guidelines. The geographic extent is characterized as being within the human health LAA since this is the area in which human receptors were identified and assessed for project effects. The frequency of potential effects is characterized as continuous because the LNG facility would be operational 24 hours per day, 365 days per year. The duration is characterized as long-term because the operation phase will be at least 30 years in duration. The potential changes are characterized as reversible. After cessation of operational activities, air quality would improve and the health effects associated with the CACs at the modelled concentrations would be reversible.

Marine Country Food Consumption Health Risks to Human Receptors

Changes in the concentrations of PCDD/F in marine country foods with subsequent health risks to human receptors may occur during the construction phase as a result of the dredging activities and, to a lesser extent, during the operation phase. The potential for changes in PCDD/F concentrations in marine country foods to result in a risk for human health was evaluated using a qualitative approach based on professional judgment and knowledge of PCDD/F bioaccumulation and biomagnification in the marine environment.

The sediment baseline study indicated that PCDD/F concentrations are below the PEL that could indicate adverse effect to benthic and epibenthic fish. PCDD/Fs are also located in the upper 1.5 m of sediment, which will be removed during the initial dredging activities. The underlying sediment from a depth of 1.5 to 12.0 m does not contain detectable PCDD/Fs or other organic contaminants. The plume would contain PCDD/Fs from the initial disturbance of surface sediments. After the top 1.5 m has been removed, subsequent dredging and plumes would contain very low PCDD/F concentrations. Species of marine country foods would only experience temporary exposures to PCDD/Fs in the plume.

Organisms that interact with newly deposited sediment will not be exposed to higher chemical concentrations because the surface sediments currently contain the highest detectable PCDD/F concentrations. Dredging would expose sediments that do not contain any detectable PCDD/Fs and volumetric mixing would reduce the concentrations of PCDD/Fs in the resulting plume and settling sediment. Initial dredging activities may expose pelagic marine species to higher suspended solids which contain PCDD/Fs for a short period of time while the top 1.5 m for sediment material is being removed. These may enter the human food chain through dermal uptake through the gills or direct ingestion of sediment particles.

PCDD/F move through the various trophic levels via two processes. Bioaccumulation is the result of chemicals being absorbed from the environment and through the respiratory surface (e.g., gills) and/or the skin. Biomagnification refers to dietary absorption of a chemical resulting in significantly higher concentration in the predator compared to the prey (Gobas and Morrisson 2000).

PCDD/Fs are hydrophobic compounds that bind strongly to the organic content in sediments and do not readily dissolve in water for gill uptake (Black and McCarthy 1988). PCDD/Fs bound to sediment particles do not permeate the gill membrane when exposed to fish gills (Loonen et al. 1994) resulting in minimum bioaccumulation through this process. Another way fish could be affected by the resuspension of sediment is by ingestion. However, this would only represent a small amount compared to benthic marine biota that are continuously in contact with sediment.

Other factors also limit human exposure to PCDD/Fs in marine country foods. The Department of Fisheries and Oceans has issued a year-round long-term ban on the harvesting of all bivalve shellfish due to paralytic shellfish poisoning (red tide) in the region (Area 4) which includes the sediment plume range (Department of Fisheries and Oceans 2013). A year-round long-term ban also exists on the harvesting of crabs in Area 4-11 (see Figure 19-1), which encompasses Porpoise Harbour and Porpoise Channel to the westernmost point of Lelu Island (Department of Fisheries and Oceans 2013 and 2014).

These multiple lines of evidence and supporting conditions suggest that the overall potential for PCDD/Fs in marine country foods to increase in concentrations is negligible to low. Assuming that people continue to consume locally harvested marine country foods at the same rates and frequencies as they do currently, the change in HQ and ILCR associated the consumption of marine country foods is not expected to change substantially from existing baseline conditions.

Marine Country Food Consumption Health Risks (Construction)

The potential for changes to human health from the consumption of marine country foods is low. Concentrations of PCDD/F in surface sediments will not increase and absorption rates of PCDD/Fs from gill and ingestion exposures are minor pathways.

The context considers sensitive humans such as children who consume marine country foods and recognizes the toxic potency of PCDD/Fs. Changes to human health are characterized as having a low resilience. The magnitude of residual effects to humans is low, as no new sources of PCDD/F will be introduced in the environment. The geographical extent is within the LAA. The duration is characterized as long term over the four-year construction phase and the frequency is characterized as continuous as dredging will be 24 hours a day, 7 days a week for 148 days at the MOF and at least one year at the marine berth. The residual effects to human health from the consumption of marine country foods containing PCDD/Fs are reversible, as dredging-related effects will stop following cessation of dredging activities.

Marine Country Food Consumption Health Risks (Operation)

The potential for changes to human health from the consumption of marine country foods is low. There will be occasional dredging to maintain the channel depth as new sediments will deposit over time. However, these sediments are sourced from the Skeena River and surrounding environment and would not contain appreciable levels of PCDD/Fs.

The context considers sensitive humans such as children who consume marine country foods and recognizes the potency of PCDD/Fs. Changes to human health are characterized as having a low resilience. The magnitude of the residual effects is low as the extent of dredging activities will be significantly lower than the ones occurring during the construction phase. The geographical extent is within the LAA. The duration is characterized as long term and the frequency is characterized as multiple irregular events when dredging is necessary. The residual effects to human health from the consumption of marine country foods containing PCDD/Fs are reversible, as dredging-related effects will stop following cessation of dredging activities.

Noise Levels and Annoyance Risks to Human Receptors

Quantitative noise modelling results are provided in Section 8. For the assessment of the acoustic environment, the LAA and RAA include a 2 km and 5 km radius from the Project. The boundaries for the assessment of noise are within (i.e., smaller than) the boundaries for human health. This section evaluates the results of the noise modelling and the effect on human receptors within the specified spatial boundaries.

Changes to noise levels from project activities will occur primarily during daytime hours between 07:00 to 22:00 during the construction phase. Changes to noise levels during operations will be continuous for the lifespan of the Project. Eight noise sensitive human receptor locations were identified when considering the potential effects on human health. Those include the Port Edward Community School, residences within 1 km of the PDA, Kitson Island campsite, ICEC Terminals, Port Edward – commercial, and the Cannery Museum and Village. The measurable parameters assessed during modelling are daytime equivalent sound level (L_d), nighttime sound level (L_n), day-night equivalent sound level (L_{dn}) and the %HA.

Noise Levels and Annoyance Risks (Construction)

During construction, Port Edward residents closest to Lelu Island will experience the highest noise levels during daytime hours. The closest human receptor is a residence within 1 km of the project fence line and had the highest noise level among all receptors (Receptor 21, see Figure 19-1). The maximum L_d was 54.4 dBA, which was 9.4 dBA above baseline noise levels. The range of baseline and construction noise levels are equivalent to noise levels in a typical urban environment and meets Health Canada noise limits. The %HA when noise levels reach the maximum L_d of 54.4 dBA is 3.8%. This is well below the Health Canada recommended limit of 6.5%. There would be no changes to noise levels during nighttime hours.

The context considers existing noise conditions at sensitive receptor locations and changes to human annoyance levels are characterized as having a high resilience to noise effects. Although Lelu Island is currently undeveloped, Ridley Island is a hub of industrial and commercial activities and is adjacent to residential homes in Port Edward. Residents in this area would be accustomed to industrial noises. The magnitude of the noise effect to people is characterized as low because noise levels met Health Canada and BC OGC noise thresholds for construction activities. The geographical extent of noise effects extends into the RAA. The duration of noise effects is considered long term because the construction phase will last four years. The duration characterization follows Health Canada's guidance of using the Alberta Energy and Utilities Board Notice Control Directive 038 (Health Canada 2011c and AEUB 2007). The frequency of noise emission is characterized as multiple regular events, occurring at daytime hours. The potential stress and annoyance to humans is considered reversible almost immediately following cessation of activities.

Noise Levels and Annoyance Risks (Operation)

During operations, the highest noise levels would occur at the Port Edward commercial facilities (Receptor 30, see Figure 19-1). The maximum modelled noise level at this location is 47.9 dBA, which would occur continuously for the life of the Project. This noise level is equivalent to the lower spectrum of noises found in an urban environment. This noise level is lower than the construction phase and meets Health Canada's noise limits. The %HA when noise level reach the maximum L_d of 47.9 dBA is 1.7%.

The context considers existing noise conditions at sensitive receptor locations and changes to human annoyance levels are characterized as having a high resilience to noise effects. The commercial areas on the mainland across from Lelu Island are typically more tolerant to noise compared to residential dwellings. The magnitude of change is rated as low because the noise levels met Health Canada and BC OGC noise thresholds. The geographical extent of noise effects extends beyond the RAA. The duration of noise effects and the frequency of noise emission is considered long term and continuous, respectively, as the operation activities will occur 24 hours per day for a minimum of 30 years. Following cessation of activities, the effect of noise to human receptors is reversible.

Light Levels and Nuisance Risks to Human Receptors

Details on the light effects assessment are included in Section 9. For the assessment of light levels associated with the Project, the LAA is 8 km from the facility The RAA includes the portion of the view shed greater than 8 km from the Project. The boundaries for the assessment of light are within (i.e., smaller than) the boundaries for human health and ecological health.

Changes to light levels will occur during all phases of the project activities during daytime and nighttime. Nighttime lighting may be a nuisance to human receptors if stray light illuminates residential areas or enters residential homes. Daytime lighting is not considered a nuisance to people because ambient light will typically be brighter than any stray light generated from project activities.

The potential for changes in light levels to result in human nuisance was evaluated using a qualitative approach based on professional judgment and knowledge of lighting effects. The analysis of changes in ambient light focuses on the potential effects of the project infrastructure and activities on light spill, glare and sky glow.

Lighting effects that could cause a nuisance to human receptors would occur primarily in residential areas in Port Edward near Lelu Island. The areas located directly across from Lelu Island to the north and east are only sparsely populated.

Light Levels and Nuisance Risks (Construction)

A qualitative assessment of the potential effects of changes in ambient light (see Section 9) during construction phase indicates that, with mitigation, adverse effects will be avoided. Most construction activities occur during the daytime with limited nighttime lighting required. Nighttime lighting would be required for safety purposes. Lighting levels would be similar to municipal street lighting and pointed downward to avoid stray light effects. Direct light during daytime hours may be required during times of the year when daylight hours are short.

The context considers existing nighttime lighting from municipal lighting and vehicle traffic and changes to human nuisance levels are characterized as having a high resilience to light effects. There could be some light from the facility observed in Port Edward and east of Lelu Island. These areas will remain characteristic of a rural/sub rural and natural/rural environment. The magnitude of the residual effects to humans is therefore predicted to be low. The geographical extent is restricted to the light LAA. The duration is characterized as long term over the four year construction phase. The frequency of lighting effects to people is characterized as multiple regular events and effects to local residents will be limited to the nighttime. The light-related nuisance is reversible, immediately following cessation of lighting activities.

Light Levels and Nuisance Risks (Operation)

During operations, there is potential that the exterior lighting associated with some project components (e.g., storage tanks, flares) will be visible to receptors located in Port Edward and directly across from and to the north of Lelu Island due to the physical height of these components and the surrounding topography. Due to the positioning of the marine terminal component of the Project, for the most part, the exterior lighting associated with the terminal itself and the ships will likely not be visible to the residents living in Port Edward and to the east of Lelu Island.

The context considers existing nighttime lighting from municipal lighting and vehicle traffic and changes to human nuisance levels are characterized as having a high resilience to light effects. Although the plant lighting will be effectively controlled during nighttime, navigation, security and other required lighting will induce a change in ambient light. The magnitude of lighting effects to local residents is characterized as low. Even though there could be some light from the Project observed in Port Edward and east of Lelu Island, these areas will remain characteristic of a rural/sub-rural and natural/rural environment. The geographic extent of the lighting effect is restricted to the light LAA. The duration is characterized as long term, over the course of the project lifespan. The frequency is characterized as multiple regular events mainly occurring during the nighttime. The light-related nuisance is reversible immediately following cessation of lighting activity.

19.5.2.4 Likelihood

The likelihood of residual effects to human health from the emission of CACs is characterized as low for all project phases. The operations phase would generate the greatest tonnage of CACs annually compared to construction phase. CAC concentrations during operations were well below all health based air objectives and criteria. Healthy individuals in Port Edward and Prince Rupert would not experience any residual health effects from changes to air quality. The likelihood of residual health effects to sensitive receptors is not anticipated because the CAC concentrations during operations did not approach the most sensitive air quality objective at any time.

The likelihood of residual effects on the health of human receptors as a result of the consumption of marine country foods is characterized as low. Based on the current levels of PCDD/F in the environment and marine tissues with no potential to increase from project activities, people have a low likelihood of being exposed to these chemicals at a level which could affect human health.

The likelihood of residual effects from noise and light to human receptors is also characterized as low for all project phases. There are existing sources of industrial noise and lighting in the region that local people are accustomed to. The level of changes from noise is well within the %HA thresholds to affect people, while the anticipated increase in light would be similar to urbanized areas.

19.5.2.5 Determination of Significance of Residual Effects

The evaluation of exposure pathways, health-based guidelines and toxicological exposure limits characterizes the significance of residual effects to human health. If exposure concentrations do not exceed applicable health-based guidelines, significant residual effects to human health are unlikely. The following section characterizes the significance of residual effects to human health and the associated confidence level of the characterization.

Significance of Health Risk from Air Quality

The increase in CAC concentrations, during operations has a magnitude of negligible to low, remaining below 50% of all applicable AAQOs for air quality that are protective of human receptors. This indicates that there are no identified health risks even for the most sensitive individuals in the communities (e.g., children, infants, elderly, and those with pre-existing respiratory or cardio-vascular conditions). The air model used very conservative air quality predictions to evaluate the worst case scenario during operations phase, which would have the highest emission rates. The assessment of the operations phase is based on a comparison of the single highest maximum predicted point of impingement concentration for each CAC against its appropriate averaging period (e.g., 1-hour, 8-hour, or 24-hour).

Emission levels during the construction phase will be lower than those modelled for operations. Therefore, the construction air quality is expected to be better than that predicted and assessed with the air model. There is a high degree of confidence in the assessment, based on the quality of the emissions data and analytical techniques used. The residual effect of degraded air quality leading to human health risks during construction is not significant.

Significance of Health Risk from the Consumption of Marine Country Foods

There is minimal potential for dredging to increase the concentration of PCDD/Fs in the surface sediments with which marine country foods can interact. PCDD/F concentrations in the tissues of marine country foods are expected to remain at concentrations similar to baseline levels. Mitigation measures such as a safety zone; preventing access to the proximate dredging area would also reduce the potential for people to enter the plume area and harvest marine country foods. The residual effects of PCDD/F concentrations in marine country foods resulting in increased health risk in human receptors is rated as not significant during the construction and operation phases. Consumers of locally harvested marine country foods can continue to eat these foods during project activities without adverse health risks from PCDD/Fs.

Significance of Annoyance Risk from Noise

Ambient noise levels were quantitatively modelled and indicated no exceedance of noise thresholds based on negligible to low magnitude changes. The %HA from increased noise levels were within Health Canada’s acceptable limits. Mitigation measures are expected to attenuate noise levels that could reach residential areas in Port Edward.

The residual effect of noise to potentially disturb local people during operations is not significant.

Significance of Nuisance Risk from Light

The magnitude of changes in light levels that could reach residential areas is negligible to low, through the application of mitigation measures. Light effects are also not associated with health risk. The residual effect of light to cause a nuisance to local people during the operations phase is rated not significant.

Overall Significance of Residual Effects to Human Health

Overall, the residual effects on human health to people in Port Edward and Prince Rupert ,from the inhalation of CACs, ingestion of marine country foods and exposure to noise and light from the Project, are not significant.

19.5.2.6 Confidence and Risk

The quality and availability of baseline data and the quantitative modelling of air quality, noise levels and light levels for the project phases provides a high level of confidence that human health related to project activities will be protected for the reasonably foreseeable future.

There is a high degree of confidence in the assessment based on the quality of the emissions data and analytical techniques used. AAQOs used to screen concentrations of CACs are derived from data intended to protect sensitive human receptors, which would also be protective of the general population.

There is a moderate degree of confidence in the assessment of marine country foods. Concentrations of PCDD/Fs in the sediment with which marine organisms interact are currently below health-based guidelines with negligible potential to increase in surface sediments from project activities. Dermal uptake of PCDD/Fs from sediment and water is comparatively small to dietary uptake and biomagnification. However, there remains some uncertainty regarding the change in physical dynamics of the potential sediment plume in the marine berth dredging site. While the sediment plume model indicates very localized sediment deposition around the MOF dredge site, the marine berth in the open ocean and more exposed with a larger dredge volume and longer duration. Confidence in the predictions of marine country food quality would be increased with the availability of plume modelling data in the marine berth.

There is a high degree of confidence in the acoustic assessment, based on the use of quantitative noise models, and the conservatism employed within the models in following guidance provided by BC OGC and Health Canada.

There is a high degree of confidence in the assessment based on the assessment of ambient light, and the mitigation measures recommended that would reduce stray light from reaching residential areas (i.e., maintain a tree line to the north and east of Lelu Island).

Since the confidence in this prediction is not low, no additional risk analysis has been conducted.

19.5.3 Changes to Ecological Health

19.5.3.1 Potential Effects

Construction

Atmospheric releases of CACs and fugitive dust are the primary chemical stressors that could affect ecological health. CACs are emitted from vehicles and construction equipment CACs have the potential to cause respiratory or inflammatory effects to sensitive ecological receptors.

The sediment plume from dredging is a new exposure pathway for gilled and filter feeding marine organisms that could absorb PCDD/Fs from particles of suspended solids. Changes to PCDD/F concentrations in marine tissues could progress in the food chain and affect higher trophic level marine mammals and marine birds.

Non-chemical stressors include noise and light, which are generated from most activities during the construction phase. Underwater noise effects to marine species during construction are discussed in the Marine Resources VC assessment (see Section 13). The potential for noise levels to affect ecological receptors is based on the evaluation of the potential effects of noise to people. Increased light levels, during nighttime could affect the behaviour of light-sensitive ecological species such as migrating marine birds or some species of fish that could be attracted or deterred by light. Nighttime construction activity will be limited to low noise activities. However, reduced daylight hours at certain times of the year will require additional lighting.

Operation

Atmospheric releases of CACs are the primary chemical stressors that could affect ecological health. The annual tonnage of CACs that would be released during operation would be greater than construction phase because the LNG facility would be operating 24 hours per day, 365 days a year. The types of project activities are also substantially different between construction and operations.

Occasional dredging activities may be necessary during the operation phase in order to maintain the depth of the channel over time. This repeat dredging would be infrequency and only removes newly deposited sediments that are generally free of PCDD/Fs. Any plume effect to marine organisms would be smaller in magnitude and duration compared to the construction phase. Subsequent effects to marine mammals and birds up the food chain would be lower than in construction.

Noise and light levels during operations could affect the behavior patterns of ecological receptors. There is a greater potential for noise and light effects during operations relative to construction because of the continuous operation of the facility for an estimated 30+-year period.

Decommissioning

During the decommissioning phase, changes to the environment will mostly be similar to the construction phase. Atmospheric releases of CACs and levels of noise and light will be primarily from vehicles and machinery used to dismantle and recycle facility equipment. There will be no additional dredging activities or subsequent chemical effects to marine organisms. Decommissioning activities will be undertaken according to the legislation at the time, and are not considered further in this assessment.

19.5.3.2 Mitigation

The mitigation measures presented in other relevant VC sections will reduce the potential health effects to ecological receptors. These mitigations act by reducing or controlling the release of CACs, noise and light. There are no additional mitigation measures recommended to protect ecological health. Detailed mitigation measures can be found in the effects assessment for each discipline (see the Air Quality assessment [Section 6], the Marine Resources assessment [Section 13], the Acoustic Environment assessment [Section 8], and Ambient Light assessment [Section 9]).

19.5.3.3 Characterization of Residual Effects

Air Quality Health Risks to Ecological Receptors

Details on the air quality assessment and modelling are included in Section 6.5.

The assessment screens potential health risks to ecological receptors within the entire LAA. A quantitative approach was used to evaluate the potential risk to ecological health from air quality during the operation phase, because there would be substantial air emissions expected from the project facilities operating 24 hours per day, 365 days per year for a minimum of 30 years. Potential changes to ecological health from air quality during the construction phase would be substantially lower in duration and magnitude than operations because there would be no operating LNG facility and related facilities present with different types of project activities occurring.

The summary of modelled air quality presents maximum CAC concentrations in the entire LAA over for the worst-case year. This area includes all of the sensitive receptor locations used in the human health assessment, recognizing ecological receptors exist throughout the LAA. Human health based AAQOs were applied towards ecological health. There are uncertainties associated with applying human health standards to ecological health. However, it is important to recognize that there is insufficient science to accurately evaluate ecological health effects from the inhalation pathway. There are no applicable air quality guidelines that are protective of ecological health. The AAQOs for the protection of human health were applied as surrogate guidelines in lieu of any other appropriate air quality screening tool.

Additional conservative assumptions were made to address uncertainties with applying human health based AAQOs towards ecological health. In particular, the evaluation of air quality effects to ecological receptors used the MPOI, which represents the maximum CAC concentrations within the assessment area. This assumption would mean that populations of ecological receptors would be present at the location where air quality was the poorest for their entire lifespan. Realistically, ecological receptors are mobile, and would be exposed to the annual average concentrations of CACs.

Air Quality Health Risks (Construction)

The assessment of air quality health effects to ecological receptors during construction indicates negligible health risks are present. There are no exceedances of applicable AAQOs from the modelled operations phase, and the construction phase would have substantially lower outputs of CACs and for a shorter duration of time.

The context of effects considers populations of ecological receptors and does not distinguish between individuals of a species that may be more sensitive. Therefore, the context is characterized as moderate, representing ecological populations in a relatively stable environment. The magnitude of change is characterized as low because there will be no exceedance of any applicable AAQOs during construction. The geographic extent is characterized as being within the LAA since this is the area within which there will be effects on air quality. The frequency of potential effects is characterized as multiple regular events and the duration is considered long term because active construction would primarily occur during the daytime over a 4-year period. The potential changes are reversible upon cessation of construction activities, with no lasting health effects to ecological receptors.

Air Quality Health Risks (Operations)

The assessment of the potential effects of air emissions on ecological health indicates no CACs would exceed applicable AAQOs and there would be no changes to ecological health. The 1-hour maximum concentration of NO_2 is 349.3 μg/m^3 and approached the maximum acceptable concentration of 400 μg/m^3. A time sensitivity analysis shows that this level of NO_2 occurs less than 1% of the time over the three year modelling period in the ocean environment near the Kinahan Islands. It is unlikely that infrequent acute exposures to such NO_2 concentrations below the AAQO could affect ecological health.

Table 19-9: Maximum Air Quality Concentrations in the LAA during Operations

Criteria Air Contaminant	Averaging Period	Operations Maximum Concentrations (μg/m^3)	Applicable AAQO[A] (μg/m^3)

SO_2	1-hour	50	450
	3-hour	26	375
	24-hour	7.7	150
	Annual	0.9	25
NO_2	1-hour	349	400
	24-hour	93	200
	Annual	3.8	60
CO	1-hour	303	14,300
	8-hour	142	5,500
PM_{10}	24-hour	32	50
$PM_{2.5}$	24-hour	10.1	25
	Annual	1.9	8

NOTES:
[A] BC AAQO or NAAQO

There are no exceedances of any applicable AAQOs for the assessed CACs for all modelled time frames and project phases in the LAA.

The context of effects considers populations of ecological receptors and does not distinguish between individuals of a species that may be more sensitive. Therefore, the context is characterized as moderate, representing ecological populations in a relatively stable environment. The magnitude of change is characterized as low since the modelling results indicated no exceedance of regulatory guidelines. The geographic extent is characterized as being within the LAA since this is the area within which there will be effects on air quality. The frequency of potential effects is characterized as continuous because the LNG facility would be operational 24 hours per day, 365 days per year. The duration is characterized as long-term because operations will continue for at least 30 years. The potential changes are characterized as reversible. After cessation of operational activities, air quality will improve and the health effects associated with the CACs at the modelled concentrations will be reversible.

Sediment Quality Health Risks to Marine Ecological Receptors

Changes in concentrations of PCDD/F in marine ecological receptors may occur during the construction phase from exposure to sediment plumes at the MOF and marine berth sites and during the operation phase to a lesser extent. The potential for changes in PCDD/F concentrations in marine organisms to result in a change to ecological health was evaluated using a qualitative approach based on professional judgment and knowledge of PCDD/F bioaccumulation and biomagnification in the marine environment.

The sediment baseline study indicated that PCDD/Fs concentrations are currently below the PEL; above which adverse effects to marine organisms may occur. Dredging will not increase these concentrations because there are no new inputs of PCDD/Fs and the underlying sediment does not contain these chemicals. Therefore, organisms that interact with newly deposited sediment will not be exposed to PCDD/F concentrations that are higher than existing baseline conditions. However, exposure to the sediment plume is a new exposure route where PCDD/Fs may absorb through the gills or be uptaken by filter feeding organisms that trap sediment particles. These organisms could be consumed by predatory marine mammals and birds where PCDD/Fs could biomagnify up the food chain and affect ecological health of higher vertebrates.

PCDD/F move through the various trophic levels via two processes. Bioaccumulation is the result of chemicals being absorbed from the environment and through the respiratory surface (e.g., gills) and/or the skin. Biomagnification refers to dietary absorption of a chemical resulting in significantly higher concentration in the predator compared to the prey (Gobas and Morrisson 2000).

PCDD/Fs are hydrophobic compounds that bind strongly to the organic content in sediments and do not readily dissolve in water for gill uptake (Black and McCarthy 1988). PCDD/Fs bound to sediment particles do not permeate the gill membrane when exposed to fish gills (Loonen et al. 1994) resulting in minimum bioaccumulation through this process. Filter feeding marine species such as shellfish could also be exposed though the ingestion of captured sediment particles. However, this would only represent a small amount compared to benthic marine biota that are continuously in contact with sediment.

PCDD/Fs from the diet are the primary exposure route for marine invertebrates. The baseline concentrations of PCDD/Fs in marine invertebrates are well below the tissue residue guidelines that are protective of marine mammals and marine birds. Furthermore, many of the individual congeners of PCDD/Fs were undetectable in tissue samples. When congeners were below the detection limit, a value of half the detection limit was assumed to be present in the tissues as a conservative estimate as indicated by the mid-point concentrations (see Appendix Q-3). When a concentration value of zero was substituted for congeners below the detection limit – as indicated by the lower bound concentrations (see Appendix Q-3), the tissue concentrations decreased an average of 90%. This suggests that approximately 90% of the measured PCDD/Fs in marine tissues are influenced by the assumption that PCDD/Fs are present in tissues when they are undetectable in the laboratory.

Based on the low baseline marine tissue concentrations of PCDD/Fs, the absence of additional PCDD/F input into the marine environment, the absence of project activities that could plausibly increase PCDD/Fs in surface sediments, the magnitude of residual effects on ecological health from sediment interaction is negligible during construction.

Sediment Quality Health Risks (Construction)

The potential for changes to ecological health from the direct exposure to sediment plumes and trophic uptake of PCDD/Fs is low. Suspended sediments in a plume would originate from benthic sediments that contain PCDD/Fs below marine health-based guidelines. Absorption rates of PCDD/F from gill and ingestion exposures are minor pathways.

The context considers the bioaccumulation potential of PCDD/Fs and recognizes the toxic potency of PCDD/Fs. Changes to ecological health are characterized as having a low resilience for vertebrates while having no direct impact to invertebrates due to the lack of toxic effects. The magnitude of the residual effects to ecological health is low because no new sources of PCDD/F will be introduced in the environment. The geographical extent is within the LAA. The duration is characterized as long term and the frequency of is characterized as continuous over the dredging period of 148 days at the

MOF and at least a year at the marine berth. The effects to ecological health are reversible as dredging-related sedimentation will stop following cessation of dredging activities.

Sediment Quality Health Risks (Operation)

During operations, there will be occasional dredging to maintain the channel depth as sediments will deposit over time. However, these sediments are sourced from the Skeena River and surrounding environment and would not contain appreciable levels of PCDD/Fs.

The context considers the bioaccumulation potential of PCDD/Fs and recognizes the toxic potency of PCDD/Fs. Changes to ecological health are characterized as having a low resilience for vertebrates while having no direct impact to invertebrates due to the lack of toxic effects. The magnitude of the residual effects to marine ecological receptors will be low because the extent of dredging activities will be much lower than the ones occurring during the construction phase. The geographical extent is within the LAA. The duration is characterized as long term and the frequency is characterized as multiple irregular events on an as-needed basis. Potential residual effects to ecological health are reversible following cessation of dredging activities.

Noise Effects to Ecological Receptors

Quantitative noise modelling results are provided in Section 8 (Acoustic Environment). This section evaluates the effects in ecological receptors as a result of terrestrial noise. Underwater noise effects on marine species during construction is discussed in the Marine Resources VC assessment (see Section 13).

For the assessment of the terrestrial acoustic environment, the LAA and RAA is 1.5 km and 5.0 km from the project fence line, respectively. The boundaries for the assessment of ambient noise are within (i.e., smaller than) the boundaries for ecological health. Additional information on potential noise-related effects on ecological species can also be found in the assessment of terrestrial wildlife and marine birds in Section 11.5 and marine life in Section 13.5 of the Application.

Noise disturbance may make adjacent habitats less suitable for terrestrial wildlife, fish, marine mammals and marine birds. Species with small home ranges and limited means of dispersal may seek refuge from noise. Large terrestrial mammals and adult birds (including marine birds) have greater mobility and are likely to avoid noise by leaving the area. As a result, these species may spend additional energy because of their altered movement patterns as well as because they might spend less time in preferred habitat. Noise disturbance can also cause adult birds to temporarily or permanently abandon their nests, potentially increasing mortality to eggs or offspring due to failed incubation or predation (Malt and Lank 2009).

There are no regulatory guidelines on ambient noise levels related to ecological health effects. Health Canada recommends that the AEUB protocols for industrial noise be adopted for noise effects to human health when possible (AEUB 2007; Health Canada 2010c). The AEUB notes that the typical range of industrial noise levels does not significantly affect the physiological and habitual patterns of animals over the long term. Animals may temporarily avoid an area due to noise until they become familiarized or acclimatized to the industrial noise (AEUB 2007).

The environmental code of practice for metal mines (Environment Canada 2012) recommends that ambient noise from mining operations and its effect on wildlife meet the objectives for residential areas. Noise level ranges from 85 to 108 dBA have been identified as a threshold for terrestrial mammals resulting in flight response, freezing or startle response (Weisenberg et al. 1996; Reimers and Colman 2006). At this level, wildlife habitat is considered disturbed due to the behavioral response. Bayne et al. (2008) and Habib et al. (2007) suggest that operational noise levels below 30 dBA, or beyond 1.5 km of the point source of noise, are unlikely to influence species presence and habitat use for some species. Birds can also be affected by ambient noise levels and it was shown that a reduction in the population density of birds occur at a threshold of 47 dBA (Reihjnen et al. 1996).

For ambient noise, eleven noise sensitive receptors are used to assess the potential effects on ecological health. These include the eight receptors from the human health investigation (Port Edward Community School, residences within 1 km of the Project Disturbance Area, Kitson Island campsite, ICEC Terminals, Port Edward – commercial, and the Cannery Museum and Village) as well as an additional two locations (Ridley Island and the west side of Kaien Island). The receptor locations provide spatial coverage on the general area where birds and terrestrial animals may live in urban areas. No noise receptor locations are located offshore. The daytime equivalent sound level (L_d) is the only measurable parameter generated during modelling that is relevant for the assessment of ecological health.

Noise Effects to Ecological Receptors (Construction)

Underwater noise effects to marine species during construction is discussed in the Marine Resources VC assessment (see Section 13).

During construction, the maximum modelled terrestrial noise level occurred at the residences near Lelu Island (Receptor 21, see Figure 19-1). The maximum L_d is 54.4 dBA, which is 9.4 dBA above baseline noise levels. The range of noise levels during construction is equivalent to noise levels in a typical urban environment. The baseline maximum noise levels in the area are already near the threshold that could reduce bird population density because Ridley Island is industrialized. For marine wildlife, the Ridley Island noise receptor location will be most relevant to harbor seals and sea lions (Receptor 37, see Figure 19-1). The maximum L_d is 36.4 dBA during daytime hours. This is well below the sensitive noise range of 40 to 50 dBA to affect harbor seals and sea lions.

The context of effects considers existing noise levels, which are typical of urban environments and characterized as having a high resilience to noise effects. Ecological receptors would be accustomed to the types of industrial noise near Lelu Island and Ridley Island. The magnitude of change is characterizes as low because noise levels are generally below the threshold to affect terrestrial and marine wildlife. The geographical extent of noise effects extends into the LAA. The duration of noise effects is long term because the construction phase will last four years. The frequency of noise effects is characterized as multiple regular events, occurring during daytime hours. Residual effects to ecological receptors are reversible almost immediately following cessation of activities.

Noise Effects to Ecological Receptors (Operations)

Underwater noise effects to marine species during construction is discussed in the Marine Resources VC assessment (see Section 13).

During operations, the maximum modelled noise levels of 47.9 dBA will occur at the Port Edward commercial facilities (Receptor 30, see Figure 19-1). This noise level is equivalent to the lower spectrum of noises found in urban environments and would occur continuously throughout the 30+ year lifespan of the Project. This level of noise is within Health Canada's permissible noise limits for human receptors, and terrestrial wildlife would be accustomed to similar types of industrial noises from existing industrial activities in Port Edward. The maximum modelled noise levels expected at Ridley Island are 36.3 dBA, which is well below the noise range that could affect marine life.

The context considers existing noise conditions at sensitive receptor locations and changes to ecological health are characterized as having a high resilience to noise effects, because animal wildlife are known to adapt to urban development – known as synurbization (Luniak 2004). The modelled terrestrial noise levels are below the levels previously reported to disturb terrestrial mammals and marine birds (see Section 11.5). The magnitude is characterized as low to moderate because modelled noise levels are similar those seen in urban environments. Geographic extent for noise effects to ecological receptors is within the acoustic environment LAA. The duration of noise effects to ecological receptors is long term over the 30+ years of the operation phase. The frequency of noise effects to ecological receptors is continuous because the operation activities will occur 24 hours per day, every day. Noise residual effects to ecological receptors are reversible, following cessation of activities.

Light Effects to Ecological Receptors

Details on the light effects assessment are in Section 9.0. Light effects to terrestrial wildlife and marine birds are described in Section 11.0 of the Application. This section summarizes the results in those sections. The RAA includes the portion of the view shed greater than 8 km from the Project. The boundaries for the assessment of light are within (i.e., smaller than) the boundaries for human health and ecological health.

The potential effects of light changes on ecological health are mostly related to marine birds. Increased mortality to birds may result from nighttime lighting at the terminal, trestle, and berthed or anchored vessels. Artificial lighting can attract and disorient birds, causing them to collide with buildings, posts, or other lit structures (Section 11). This effect may be amplified during periods of higher bird use (i.e., during seasonal migrations when large numbers of birds are migrating along the coast), or during overcast or foggy conditions that intensify the dispersal of light (Merkel 2011; Rich and Longcore 2006).

Light Effects to Ecological Receptors (Construction)

A qualitative assessment of the potential effects of changes in ambient light (see Section 9) during construction phase indicate that, with mitigation, adverse effects will be avoided. Nighttime lighting would be required for safety purposes and directed at the ground. Direct light during daytime hours may be required during times of the year when daylight hours are short.

The context of lighting effects considers existing lighting that is typical of urbanized areas and changes to ecological health are characterized as having a high resilience to lighting effects. The type of nighttime lighting will be characteristic of a rural/sub-rural and natural/rural environment. The magnitude of the residual effects on ecological receptors is characterized as low and geographical extent is restricted to the LAA. The duration of lighting effects is long term based on the anticipated construction activities lasting four years, and the frequency of lighting effects is characterized as multiple regular events. The light-related residual effect is reversible following cessation of activities.

Light Effects to Ecological Receptors (Operation)

There is potential that the exterior lighting associated with some project components (e.g., storage tanks, flares. In addition, during visits by ships, vessel lighting will be visible from the western side of Kitson Island. Birds could be affected by sources of lighting at the LNG facility (including the pilot flare), marine terminal, trestle and berth and berthed or anchored vessels.

The context considers existing lighting that is comparable to urbanized areas and characterizes changes to ecological health from lighting as having a high resilience. Even though there could be some light from the facility observed in the various areas of concern, these areas will remain characteristic of a rural/sub rural and natural/rural environment. The magnitude of the residual effects to ecological health is therefore predicted to be low and geographically restricted to the LAA. The duration is characterized as long term over the 30+ years of operation. The frequency of lighting residual effects is multiple regular events and limited to the nighttime since ambient daytime light would be stronger than light used on-site. The light-related residual effect is reversible following cessation of activities.

19.5.3.4 Likelihood

The likelihood of residual effects to ecological health from the emission of CACs is characterized as low for all project phases. The assessment of ecological health is based on the comparison of CAC concentrations against applicable AAQOs for the protection of human health. However, it is important to recognize that there is insufficient science to accurately evaluate ecological health effects from the inhalation pathway. The AAQOs for the protection of human health were applied as surrogate guidelines in lieu of any other appropriate air quality screening tool. The ecological health assessment does not consider sensitive individuals in a wildlife population and ecological receptors are considered more resilient to the effects of air quality changes. Considering there are no exceedances of applicable AAQOs in the operations phase, the likelihood of residual effects to ecological health is low.

The likelihood of residual effects to ecological health from exposure to sediment plumes is characterized as low. Current levels of PCDD/Fs in sediment are below ecological health-based thresholds and the introduction of sediment into the water column is not a substantial pathway for PCDD/F absorption by marine ecological species. Subsequent biomagnification effects in the food chain to marine vertebrates will not change the status of ecological health.

The likelihood of residual effects to ecological health from noise and light is also characterized as low. There are existing sources of industrial noise and light near the Project, to which ecological receptors have been accustomed. The expected changes to noise and light levels are similar to those found in urbanized environments, which are not considered detrimental to wildlife. Levels of terrestrial noise are below threshold known to affect marine mammals.

19.5.3.5 Determination of Significance of Residual Effects

The evaluation of exposure pathways, health-based guidelines and toxicological exposure limits characterizes the significance of residual effects to ecological health. If exposure concentrations do not exceed applicable health-based guidelines, significant residual effects to ecological health are unlikely. The following section characterizes the significance of residual effects to human health and the associated confidence level of the characterization.

Significance of Ecological Health Risk from Air Quality

The modelling results show no exceedances of applicable AAQOs for any project phase.

While these objectives are intended for the protection of sensitive human receptors, they are applied to ecological receptors, while assuming that wildlife would be exposed to the MPOI concentrations at all times. Wildlife may also reduce their exposure to CACs by relocating to preferred habitat away from the facility.

The air model uses very conservative air quality predictions to evaluate the worst-case scenario during operations phase, which will have the highest emission rates. The assessment of the operations phase is based on a comparison of the single highest maximum predicted point of impingement concentration for each CAC against its appropriate averaging period (e.g., 1-hour, 8-hour, or 24-hour). Emission levels during the construction phase is expected to be lower than those predicted for the operations phase; residual effects during both construction and operations are not significant.

Because there are no exceedances of any applicable AAQOs for all project phases modelled, the potential change to ecological health from the inhalation of CACs is considered not significant to ecological populations.

Significance of Ecological Health Risk from Trophic Uptake

There is minimal potential for surface sediments to increase in concentrations of PCDD/Fs because the highest concentrations are already in the surface layers, which decrease in concentration with depth. Dredging would mix surface sediment layers with the underlying layers with lower PCDD/F levels. The pathway where PCDD/Fs increase in marine biota from interactions with sediment, and subsequent biomagnification of PCDD/Fs of higher trophic organisms from the diet is minor. This is also based on low bioavailability of PCDD/Fs to organisms when exposed to sediment plumes and the absence of PCDD/F inputs to the environment from project activities. The residual effects on health risks to ecological health, from direct exposure to sediment plumes containing PCDD/Fs or subsequent trophic uptake by marine vertebrates, are not significant for all project phases.

Significance of Ecological Health Risk from Noise

The residual effect of ambient noise to potentially disturb ecological receptors during the construction and operation phase is rated as not significant. Noise conditions that do not pose a concern for local people will typically not affect local wildlife. The AEUB notes that the typical range of industrial noise levels does not significantly affect the physiological and habitual patterns of animals over the long term. Animals may temporarily avoid an area due to noise until they become familiarized or acclimatized to the industrial noise (AEUB 2007).

Significance of Ecological Health Risk from Light

The residual effect of light to potentially disturb ecological receptors during the construction and operation phase is rated as not significant. Lighting levels are expected to be similar to urbanized areas during all project phases. The significant development in Port Edward and Prince Rupert would not constitute a substantial change in urban lighting scenarios and wildlife would be able to acclimatize to changes in light quickly.

Light effects are also not associated with health risk, but may be associated with disturbance stress and disorientation of ecological receptors.

Overall Significance of Residual Effects to Ecological Health

Overall, there residual effects on ecological health, from the inhalation of CACs, trophic uptake of PCDD/Fs in the food chain and exposure to noise and light from the Project, are not significant.

19.5.3.6 Confidence and Risk

The quality and availability of baseline data, and the quantitative modelling of air quality, noise levels and light levels provides a high level of confidence that ecological health related to project activities will be protected for the reasonably foreseeable future.

For air quality, there is a high degree of confidence in the assessment based on quality of the emissions data and analytical techniques used. The AAQOs applied to ecological health are intended to protect the most sensitive human receptor. There are uncertainties associated with applying human health standards to ecological health. However, it is important to recognize that there is insufficient science to accurately evaluate ecological health effects from the inhalation pathway. The assessment of ecological health from air contaminants is not typical of an ecological risk assessment. The AAQOs for the protection of human health were applied as surrogate guidelines in lieu of any other appropriate air quality screening tool.

Conservative assumptions were also used which increase the confidence of the predictions. In particular, ecological receptors are assessed based on wildlife populations or communities, rather than individual animals, which may have individual sensitivities. Ecological receptors were also assumed to reside at the MPOI and be exposed to the maximum concentrations of CACs for their entire lifetime.

There is a high degree of confidence in the assessment of marine tissues based on the minor contribution of PCDD/F absorption through gills and direct ingestion and that sediment concentrations are well below ecological health-based thresholds. Dredging would physically remove PCDD/Fs bound to surface sediments in the MOF and marine berth areas, and the underlying sediments would only contain PCDD/Fs from disturbed sediments that have resettled. With less than 2 mm of sediment settling in the surrounding plume area, sediment quality as it relates to PCDD/Fs would substantially improve because the current conditions indicate PCDD/Fs exist to a depth of 1.5 m.

There is a high degree of confidence in the acoustic assessment, based on the use of quantitative noise models, and the conservatism employed within the models in following guidance provided by BC OGC and Health Canada.

There is a high degree of confidence in the assessment based on the assessment of ambient light, and the mitigation measures recommended that would almost eliminate direct stray light from reaching residential areas (i.e., maintain a tree line to the north and east of Lelu Island).

Since the confidence in these predictions is not low, no additional risk analysis has been conducted.

19.5.4 Summary of Residual Effects

The modelled air quality indicated that concentrations of CACs will remain well below the regulatory thresholds for human health effects. Residual effects to ecological health are not significant, bearing in mind the uncertainties associated with applying AAQOs for human health towards ecological health and the conservative assumptions regarding wildlife exposures. For example, ecological receptors are assumed to be exposed to the MPOI concentrations of CACs for their entire lifetime, which is highly conservative. There will be no adverse residual effects to ecological health from the inhalation of CACs.

Residual effects to human and ecological health from PCDD/F concentrations in marine tissues are not significant. The Project will not introduce additional PCDD/Fs into the environment and existing levels in the sediment and marine tissues are below applicable health-based guidelines. Dredging in the MOF and marine berth areas will remove the majority of surface sediments containing PCDD/Fs while exposing underlying clean sediments.

The characterization of residual effects in Table 19-10 does not reflect the assessment of noise and light because they are not chemical stressors associated with health risk in the HHERA. However, the effects of noise and light are still characterized in their respective sections.

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Table 19-10: Summary of Residual Health Effects on Human and Ecological Health

Potential Residual Environmental Effects	Mitigation/Compensation Measures	Residual Environmental Effects Characteristics						Likelihood	Significance	Confidence	Follow-up and Monitoring
		Context	Magnitude	Extent	Duration	Reversibility	Frequency				
Change in Human Health											
Construction	See Section 6.0 - Air Quality	L	L	LAA	LT	R	C	L	N	M	None
Operation	See Section 8.0 - Acoustic Environment	L	L	LAA	LT	R	C	L	N	H	
Decommissioning	See Section 9.0 - Ambient Light	L	L	LAA	LT	R	MR	L	N	H	
Residual effects for all Phases	See Section 13.0 – Marine Resources	L	L	LAA	LT	R	C	L	N	H	
Changes in Ecological Health											
Construction	See Section 6.0 - Air Quality	M	L	LAA	LT	R	C	L	N	H	None
Operation	See Section 8.0 - Acoustic Environment	M	L	LAA	LT	R	C	L	N	H	
Decommissioning	See Section 9.0 - Ambient Light	M	L	LAA	LT	R	MR	L	N	H	
Residual effects for all Phases	See Section 13.0 – Marine Resources	M	L	LAA	LT	R	C	L	N	H	

KEY **CONTEXT:** **L** = Low resilience - occurs in a fragile ecosystem with sensitive receptors and/or the level of baseline disturbance can be a contributing factor to changes in human and ecological health. **M** = Moderate resilience - occurs in a stable ecosystem and/or level of baseline disturbance not likely to contribute to change in human and ecological health. **H** = High resilience - occurs in a viable ecosystem and/or the level of baseline disturbance does not contribute to changes in human and ecological health.	**MAGNITUDE:** **L** = Low - Complete exposure pathway to affect health risk, with exposures near or slightly above health-based guidelines. Residual effects offset by mitigation and management options. **M** = Med - Complete exposure pathway to affect health risk with exposures slightly above health-based guidelines. Residual effect will still persist with mitigation and management. **H** = High - Complete exposure pathway to affect health risk with exposures above health-based guidelines. **EXTENT:** **PDA** = project development area - Residual effects are restricted to the project development area. **LAA** = local assessment area - Residual effects are restricted within the LAA. **RAA** = regional assessment area - Residual effects are restricted within the LAA.	**DURATION:** **ST** = Short term - Short-term residual effect lasting up to one month. **MT** = Medium term - Medium-term residual effect lasting up to one year. **LT** = Long term - Long-term residual effect lasting more than one year. **P** = Permanent - Permanent residual effect. **REVERSIBILITY:** **R** = Reversible - Changes to human or ecological health are reversible if the exposure ceases (i.e., temporary illness). **I** = Irreversible – Changes to human or ecological health are irreversible and will persist if exposure ceases (i.e., cancer effects).			**FREQUENCY:** **O** = Effect occurs once. **MI** = Multiple irregular events - residual effect occurs more than once but at an unpredictable interval of time. **MR** = Multiple regular events - residual effect occurs more than once at a regular interval of time. **C** = Residual effect occurs continuously. **LIKELIHOOD OF RESIDUAL EFFECTS:** **L** = Low likelihood of residual effects to health. **M** = Medium likelihood of residual effects to health. **H** = High likelihood of residual effects to health.

19.6 Cumulative Effects

19.6.1 Context for Cumulative Effects

A cumulative effects assessment is required to determine if project-related health effects could interact with regional sources of chemical stressors that could result in significant cumulative effects. Chemical stressors associated with the Project are primarily related to air emissions of CACs. The cumulative effects assessment examines existing and reasonably foreseeable sources of CACs to evaluate the potential for cumulative effects to human health and ecological health.

Marine tissue is not evaluated for cumulative effects. The Prince Rupert Gas Transmission Project could have overlapping sediment plume ranges because the natural gas pipeline entering from the south of Lelu Island will require some dredging during its construction. The volume of dredged material necessary to construct the pipeline will be substantially lower (less than 1%) compared to the volume of dredged material for the MOF and marine berth construction. Dredging on the southern end of Lelu Island would be shorter in duration and further from the decommissioned kraft pulp and paper mill, which is the primary source of historical PCDD/Fs in the local environment.

Noise and light are not evaluated for cumulative effects because these are not chemical stressors that affect physical health. The evaluation of the acoustic environment (see Section 8) and ambient light (see Section 9) provide a technical evaluation of cumulative noise and light levels and are not addressed here.

19.6.2 Cumulative Effects Assessment

The cumulative effects assessment follows a two-step process to determine the potential for cumulative effects on to human health and ecological health. In conducting the cumulative effects assessment, the residual effects arising from interactions that scored either a 1 or a 2 in Table 19-7 are considered. The first step consists of two questions:

- Is there a project residual environmental effect?
- Does the project residual environmental effect overlap spatially and temporally with those of other past, present or reasonably foreseeable future projects?

Where the answers to both of these two questions are affirmative, a check in Table 19-11 indicates that there is potential for the Project to contribute to cumulative effects to human health and ecological health. Potential contribution of these project effects to cumulative effects is assessed below. The second step consists of one question:

- Is there a reasonable expectation that the contribution (i.e., addition) of the Project's residual effects would cause a change in cumulative environmental effects that could affect the quality or sustainability of the VC?

Where the answer to this question is affirmative, additional assessment of the potential cumulative effects is described below.

Table 19-11: Potential Cumulative Effects on Human Health and Ecological Health

Other Projects and Activities with Potential for Cumulative Environmental Effects	Potential Cumulative Environmental Effects	
	Changes to human health	Changes to ecological health
Atlin Terminal		
Canpotex Potash Export Terminal	✓	✓
CN Rail Line	✓	✓
Douglas Channel LNG		
Enbridge Northern Gateway Project		
Fairview Container Terminal Phase I	✓	✓
Fairview Container Terminal Phase II	✓	✓
Kitimat LNG Terminal Phase II		
LNG Canada Project		
Mount McDonald Wind Power Project		
NaiKun Wind Energy Project		
Northland Cruise Terminal	✓	✓
Odin Seafood		
Pinnacle Pellet Inc.		
Prince Rupert LNG Facility	✓	✓
Prince Rupert Gas Transmission Project	✓	✓
Prince Rupert Ferry Terminal	✓	✓
Prince Rupert Industrial Park		
Prince Rupert Grain Limited	✓	✓
Ridley Island Log Sort		
Ridley Terminals Inc.	✓	✓
Rio Tinto Alcan Aluminum Smelter and Modernization Project		
WatCo Pulp Mill		
Westcoast Connector Gas Transmission Project		

NOTES:
✓ **=** Those 'other projects and activities' whose effects are likely to interact cumulatively with the Project's residual effects.

The cumulative effects assessment identifies the projects that have the potential to generate CACs that could affect human health and ecological health within the RAA.

19.6.2.1 Air Quality Effects to Human and Ecological Health

Human receptor locations within the RAA were used because these are the locations where people will be present. For ecological health, AAQOs are applied which are protective of the most sensitive human receptor. The uncertainties associated with using this approach are previously described and are also applicable to this scenario.

Conservative assumptions are made to increase the confidence of the predictions. In particular, ecological receptors are assessed based on wildlife populations or communities, rather than individual animals, which may have individual sensitivities.

While ecological receptors exist throughout the RAA, the projects included in the cumulative effects assessment are near Prince Rupert and Port Edward. Therefore, human receptor locations are more appropriate for evaluating cumulative effects due to their proximity to Lelu Island and other facilities included in the cumulative effects assessment.

Table 19-12: Maximum Predicted Concentrations at Human Receptor Locations for the CEA Case

Criteria Air Contaminant	Averaging Period	CEA Maximum Predicted Concentrations at Human Receptor Locations (µg/m^3)	Applicable AAQO[A] (µg/m^3)
SO_2	1-hour	98	450
	3-hour	60	375
	24-hour	31	150
	Annual	2	25
NO_2	1-hour	239	400
	24-hour	64	200
	Annual	6	60
CO	1-hour	207	14,300
	8-hour	94	5,500
PM_{10}	24-hour	13	50
$PM_{2.5}$	24-hour	8	25
	Annual	1	8

NOTES:
[A] BC AAQO or NAAQO

Maximum concentrations of CACs at human receptor locations for the cumulative effects assessment indicate that there will be no exceedances of any applicable AAQO (see Table 19-12). Acute and chronic concentrations for SO_2, CO and particulate matter do not exceed 35% of any applicable guidelines. While the cumulative effects assessment concentration of NO_2 is substantially greater than baseline and operation scenarios, it is well below applicable health based guidelines. The 1-hour maximum concentration of NO_2 and other similar concentrations occur on Digby Island and Ridley Island (Receptors 35, 42 and 5, see Figure 19-1). Maximum CAC concentrations at all receptor locations are listed in Appendix Q-2.

19.6.2.2 Sediment Quality Effects to Ecological Health

The PRGT Project will construct a pipeline from northeastern BC to the facilities on Lelu Island to transport natural gas. The construction of this pipeline includes options for a land and marine route to Lelu Island. If a marine option is selected as the route, pipeline construction will require some dredging and trenching along the southwestern region of Lelu Island within 5 km radius of the marine berth. The cumulative effect of this dredging is discussed qualitatively based on professional judgment.

Overall, the potential for cumulative effects from both projects is negligible. This is based on multiple lines of evidence gathered through the data-sharing agreement between the PRGT and PNW Projects:

1. The PNW Project will dredge approximately 7,000,000 m^3 of material at the marine berth over at least one year, and 690,000 m^3 of material at the MOF over 5 months. In comparison, dredging for the PRGT Project will dredge approximately 20,000 m^3 of material over 10 days. The magnitude and duration of these activities between the two projects are substantially different.
2. An overlap of the sediment plumes from the PNW Project marine berth and the PRGT Project pipeline dredging may occur if dredging activities happen concurrently. There is no anticipated overlap of plumes from the MOF based on the modelled plume range. If the plumes overlap spatially and temporally, the duration of such overlap would be approximately 10 days. Based on the sediment plume model at the MOF, suspended sediments from dredging re-deposit to the benthic environment within several days.
3. The sediment quality (defined as PCDD/F concentrations) southwest of Lelu Island that was collected for the PRGT Project is significantly lower in PCDD/Fs compared to sediments in the MOF. Subtidal sediments collected at the MOF had a concentration range of 0.06 – 2.64 ng TEQ/kg dw. The sediments collected for the PRGT Project had a concentration range of 0.07 – 0.23 ng TEQ/kg dw and did not exceed the CCME ISQG (0.85 ng TEQ/kg dw) or PEL (21.5 ng TEQ/kg dw) in any samples. A sediment plume from the PRGT Project would contain comparatively better quality sediments.
4. Additional sediment quality will be collected for the marine berth, but the expectation is that sediments in the marine berth dredging area will be similar in quality to those collected for the PRGT Project due to the marine berth being in the open ocean and further away from the decommissioned pulp and paper mill compared to the MOF.

Based on these factors, the potential for cumulative effects to sediment quality and subsequent effects to vertebrate marine life is negligible and considered not significant.

19.6.2.3 Marine Country Food and Trophic Transfer Effects to Human and Ecological Health

The potential for cumulative effects to marine country food and human health, or trophic transfer to ecological health is based on the cumulative effects to sediment quality discussed in the previous section.

While the PRGT Project may include dredging and trenching near the marine berth, the magnitude and duration of these activities is comparatively minor to the PNW Project. As discussed in the previous section, cumulative effects to marine vertebrate life are not expected. Similarly, biomagnification effects from dredging at the MOF, marine berth and PRGT Project right-of-way are also not expected to occur. The process of biomagnification generally takes years, with older and larger animals showing higher PCDD/F concentrations in their tissues compared to younger and smaller animals of the same species.

Not only will the 10-day dredging at the PRGT Project right-of-way be insufficient in duration and magnitude to affect marine country food and trophic transfer, but also the quality of sediment is also better as this location because it is further away from the decommissioned pulp and paper mill near Porpoise Harbour.

19.6.2.4 Summary of Cumulative Effects

There are no exceedances of any health based AAQO under the cumulative effects assessment. No changes to human health are expected from cumulative effects to air quality. Subsequently, no changes to ecological health are expected.

19.7 Follow-up and Monitoring

No follow-up and monitoring specific to Human and Ecological Health is required.

19.8 Conclusion

The HHERA relies primarily on the conclusions in the assessments for air quality (see Section 6), acoustic environment (see Section 8) and ambient light (see Section 9). The HHERA predicts that there are not significant residual effects on human and ecological receptors from the Project. There will also be no cumulative health risks to human and ecological receptors from this Project, in combination with other projects, within the RAA.

19.9 References

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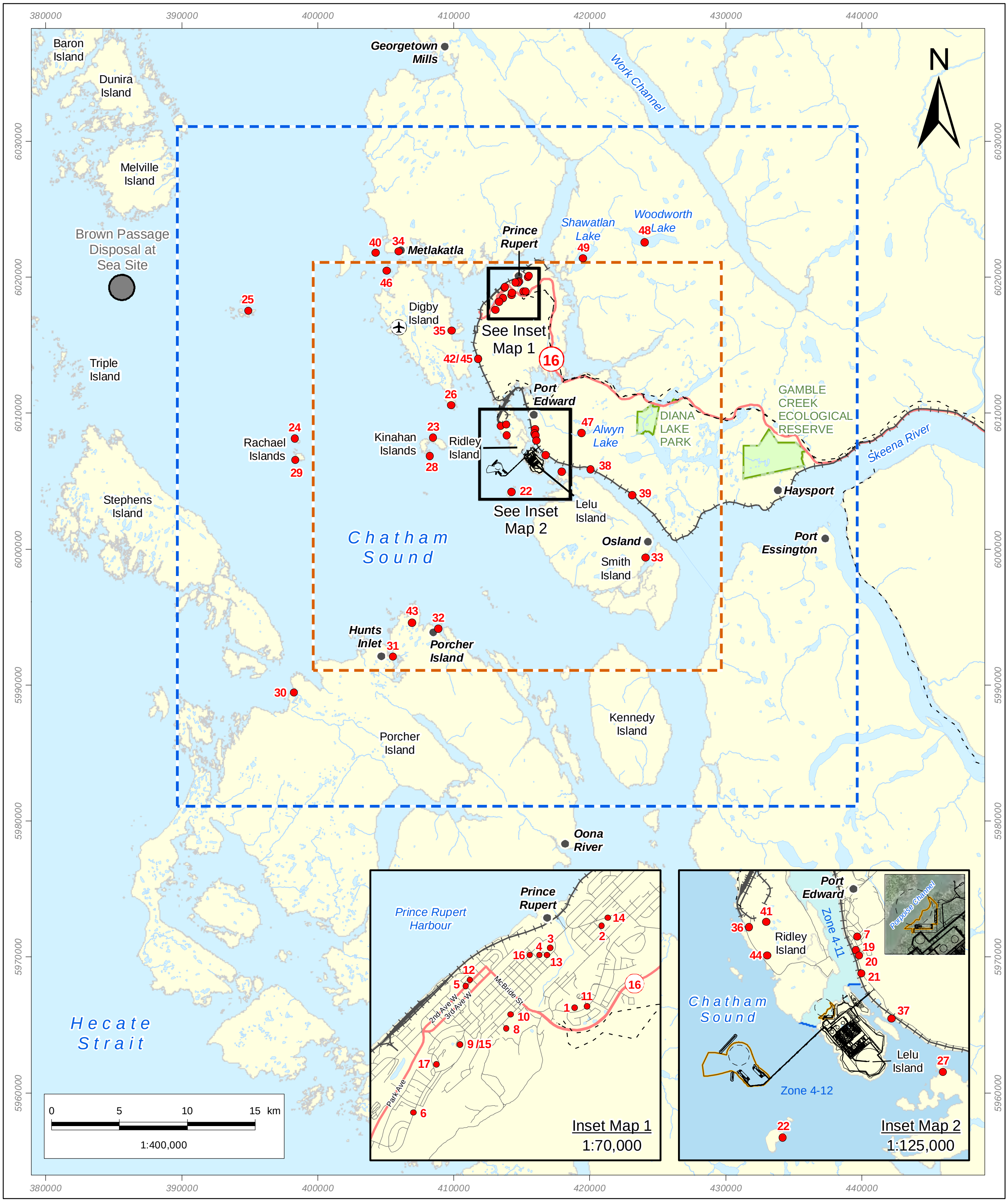
19.10 Figures

Please see the following pages.



Human Receptor Location	Airport	Protected Area
Disposal at Sea Location	City or Town	Waterbody
Dredging Boundary	Electrical Power Transmission Line	**Fisheries and Oceans Fishing Area**
Local Assessment Area for HHERA	Highway	Zone 4-11
Regional Assessment Area for HHERA	Railway	Zone 4-12
Project Component	Secondary Road	
Turning Basin	Watercourse	

Pacific NorthWest LNG

Assessment Areas and Human Receptor Locations for the HHERA

Sources: Government of British Columbia; Prince Rupert Port Authority; Government of Canada, Natural Resources Canada, Centre for Topographic Information; Progress Energy Canada Ltd; WorldView-2 Imagery. Imagery date: 2011.

Although there is no reason to believe that there are any errors associated with the data used to generate this product or in the product itself, users of these data are advised that errors in the data may be present.

DATE: 11-FEB-14
FIGURE ID: 123110537-301
DRAWN BY: K. POLL

PROJECTION: UTM - ZONE 9
DATUM: NAD 83
CHECKED BY: R. LEE

PREPARED BY: Stantec

PREPARED FOR: Pacific NorthWest LNG

FIGURE NO: **19-1**

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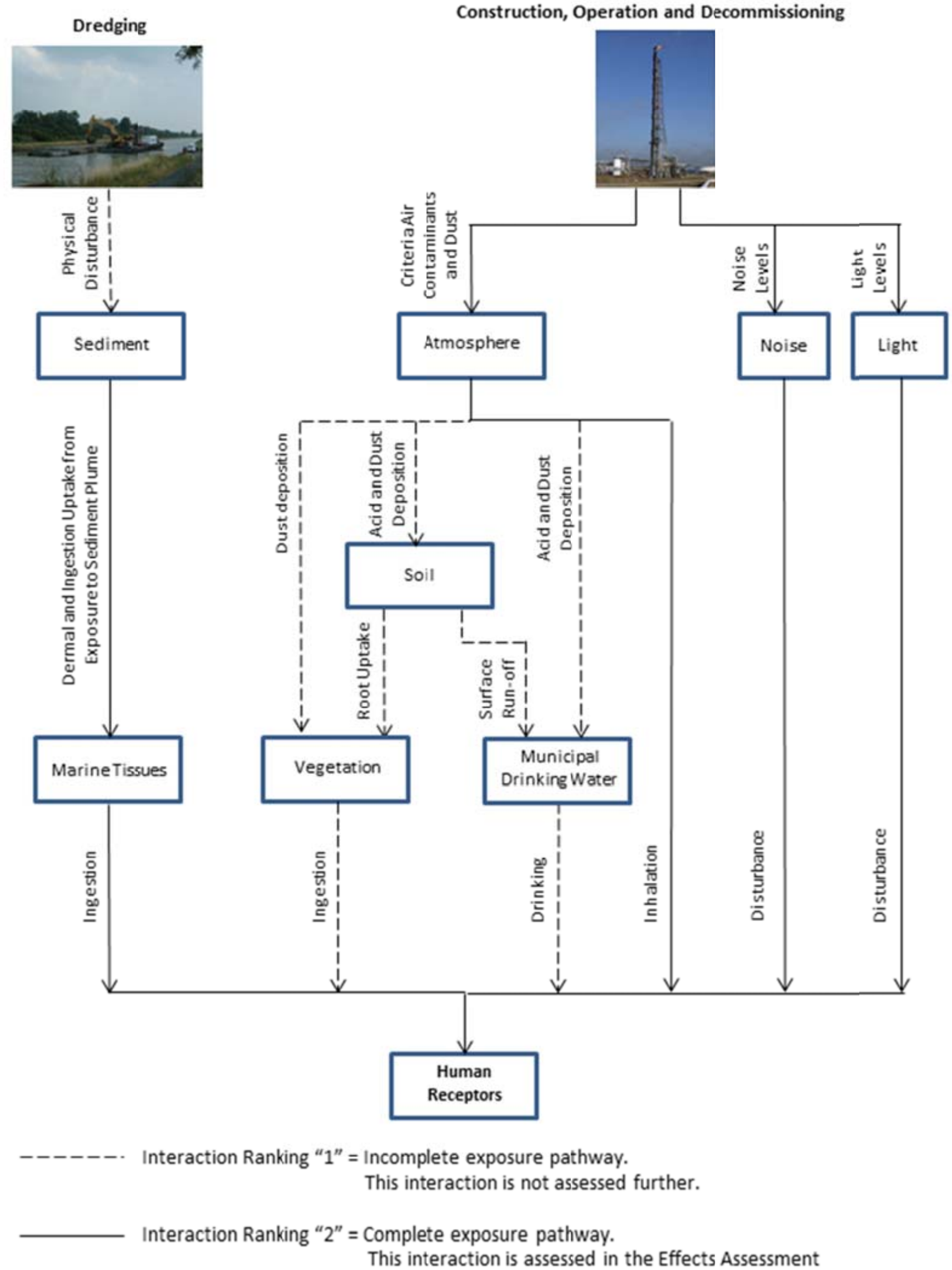


Pacific NorthWest LNG

Human Health Conceptual Model

PREPARED BY:

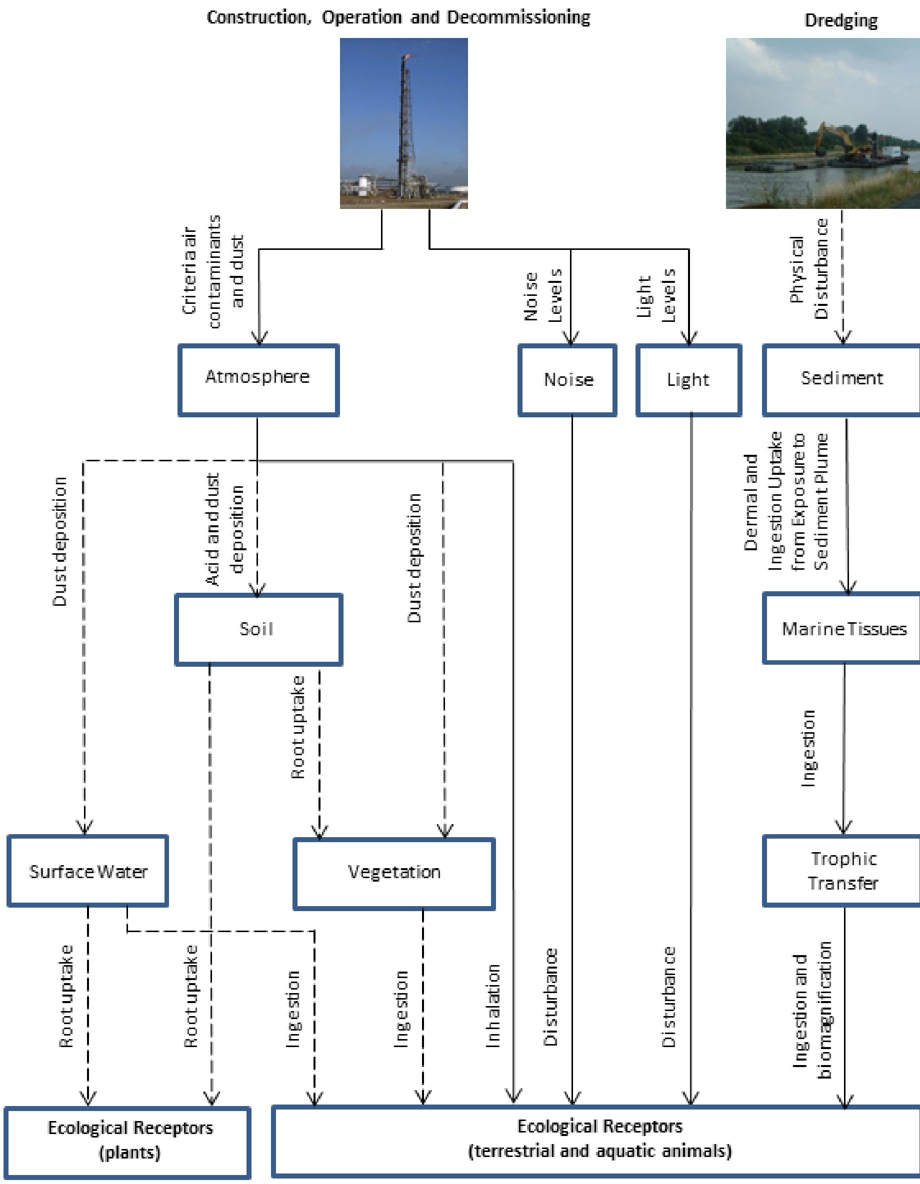
Stantec

PREPARED FOR:

Pacific NorthWest LNG

FIGURE NO:

19-2



------- Interaction Ranking "1" = Incomplete exposure pathway.
This interaction is not assessed further.

——— Interaction Ranking "2" = Complete exposure pathway.
This interaction is assessed in the Effects Assessment

Pacific NorthWest LNG

Ecological Health Conceptual Model

PREPARED BY:

Stantec

PREPARED FOR:

Pacific NorthWest LNG

FIGURE NO:

19-3