DRAFT REVIEW ON

Canadian Environmental Assessment Agency Draft Environmental Assessment Report on Pacific Northwest LNG Project with specific reference to background literature on chemicals of potential concern, potential effects on human health, and effects of habitat loss to Pacific salmon.

Prepared for:

United Fishermen and Allied Workers' Union-UNIFOR
UFAWU-UNIFOR

Prepared by:

BioWest Environmental Research Consultants
Burnaby, BC
Canada V5G 1M7

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Dr. Chris Kennedy
Professor and Principal, BioWest

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1 copy – BioWest Environmental Research Consultants

EXECUTIVE SUMMARY

On behalf of United Fisheries and Allied Worker's Union-CAW (UFAWU-CAW-CAW), Biowest Environmental Research Consultants (BIOWEST), has conducted a literature review to evaluate the Draft Environmental Assessment Report of the Canadian Environmental Assessment Agency (CEAA) regarding the potential effects of chemicals of potential concern (COPCs) on human health, as well as potential effects in the project area on salmonid habitat as identified in the Pacific Northwest LNG Summary of the Environmental Impact Statement (EIS) and Environmental Assessment of Certificate Application. The review was conducted to inform the UFAWU-CAW-CAW of the potential impacts to human health and salmonid habitat that may occur following dredging and disposal of contaminated marine sediment resulting from the project and construction and operation of a liquefied natural gas (LNG) facility on Lelu Island in the Prince Rupert area of BC.

This review specifically addresses two areas of concern: 1) potential impacts of COPCs to human health through the consumption of contaminated seafood and land disposal of contaminated sediments on Lelu Island resulting from the marine dredging components of the project, and 2) the potential impacts of the project on salmonid habitat in the the Skeena River esturary, with special reference to the loss of wetlands, impacts on eelgrass beds, and potential reductions in nutrient inputs to the marine environment resulting from the industrialization of Lelu Island.

Identified COPCs included polycyclic aromatic hydrocarbons (PAH), polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzo-furans (PCDFs). The resuspension of contaminated sediment via dredging will occur, increasing the bioavailability of these chemicals to marine organisms. This will likely increase marine organism exposures, their potential accumulation and potential food web transfer. The propensity of PCDD/Fs to biomagnify in the food web is cause for concern for humans consuming contaminated marine organisms from the area. The observed sediment concentrations of PCDD/Fs and other contaminants, the potential for PCDD/F biomagnification, and the myriad of toxic effects in both human receptors suggest that there is potential health risks associated with the proposed dredging activities.

While it is indicated that the concentrations of PCDD/Fs measured in sediments and tissues in the area of the Project are widespread and a legacy of industrial operations in the area, these baseline estimates indicate the potential for unacceptable health risks associated with the consumption of marine country foods under current/baseline conditions. Given the predicted re-suspension of sediments during dredging, the resulting increased exposure of marine organisms to PCDD/Fs, and thus humans consuming these organisms, this is of particular concern. Although the duration is unknown, it is predicted that exposures to marine organisms will increase for some period, thus resulting in increased risk to humans consuming marine country foods.

The dumping of these sediments on land increases the potential for human receptors to be directly exposed to the sediments. It is recommended that a HHRA be conducted to evaluate the potential risks associated with such exposures. As discussed in subsequent sections of this report, standard HHRA methods would involve screening the available sediment data against environmental quality guidelines (e.g., CCME CEQG) or other benchmarks protective of human health.

This report also reviews the current literature to inform the UFAWU-CAW on the potential effects of the project on salmonid populations that use this area as a migration corridor and

nursery. Concerns have been expressed regarding the selection of Lelu Island as the preferred site location for the project as well as the proposed marine terminal to be built on Agnew Bank due to its proximity to important salmon rearing habitat in the Skeena watershed including the Skeena estuary and adjacent marine areas including Flora Bank.

Hundreds of millions of juvenile salmon travel through the Skeena River estuary as they migrate to sea. Estuaries act as critical nursery habitats and transition zones where juvenile salmon can grow rapidly and gradually adapt to the saltwater environment. They also provide refuge from predators due to high turbidity, estuarine vegetation (e.g. eelgrass and kelp beds), and riparian vegetation. Growth attained in the estuary can influence whether juvenile salmon survive to a reproductive age. Reports show that the area proposed for development support some of the highest abundances of some species of salmonids. Specifically, highest abundances of sockeye, Chinook, and coho salmon were captured in areas proposed for development.

The area between Lelu and Kitson Islands on Flora Bank in the Skeena estuary is recognized as one of the largest eelgrass beds in British Columbia and a region of high habitat value. The Flora Bank eelgrass bed is most likely limited to regions where the depth is shallow enough to allow good light penetration and activities related to the project may negatively affect the the growth of eelgrass in this area. Estuary eelgrass beds provide food, shelter from predators, and acclimation habitat for salmonids. The importance of Flora Bank to juvenile salmonids has been termed ‘critical’ and that Inverness Passage, Flora Bank and De Horsey Bank, in that order, are habitats of critical importance for the rearing of juvenile salmon in the Skeena estuary. The Skeena River plume plays an important role in controlling the growth of eelgrass on Flora Bank through changes in turbidity, suggesting that increases in sediment in the water column through anthropogenic activities may negatively affect the the growth of eelgrass on Flora Bank. In addition to this, energy and nutrients for juvenile salmon come from taxa associated with benthic and epibenthic environments of emergent marshes and other tidal wetland habitats or derive much of their energy from primary production in tidal wetlands, highlighting the vulnerability of salmon prey to the potential loss or degradation of estuarine wetlands and the terrestrial habitat of Lelu Island.

Concerns regarding the adequacy of the wetland compensation plan and its ability to mitigate for the loss of mature wetlands in the region are certainly justified. Although the CEAA considers the implementation of a follow-up program as necessary in order to determine the effectiveness of restored or created wetlands at fulfilling the wetland functions that they were meant to replace, little detail on the wetland compensation plan exist and it is unlikely that given the use and potential importance of this particular area in the Skeena estuary by salmonids, that any wetland restoration, enhancement or creation will compensate for the loss of such an important area to migrating juvenile salmonids. Maintaining the integrity and function of this estuarine habitat is important for supporting healthy and productive Skeena salmon populations.

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1.0 INTRODUCTION

On behalf of United Fisheries and Allied Worker's Union-CAW (UFAWU-CAW), Biowest Environmental Research Consultants (BIOWEST), has reviewed the Draft Environmental Assessment (EA) from the Canadian Environmental Assessment Agency (CEAA) on the Pacific Northwest LNG Project Environmental Impact Statement (EIS). Pacific NorthWest LNG Limited Partnership proposes to construct and operate the Pacific NorthWest LNG Project, a liquefied natural gas (LNG) facility on Lelu Island, within the District of Port Edward, BC. The Project would convert natural gas into LNG for export to Pacific Rim markets in Asia. At full build-out, the facility will receive approximately 3.2 billion standard cubic feet per day of pipeline grade natural gas, and produce up to 19.2 million tonnes per annum of LNG. The key components of the proposed Project include a natural gas reception system, gas pretreatment, three 6.4 million tonnes per annum natural gas liquefaction trains, three full containment 180,000 m^3 LNG storage tanks, a marine terminal and berths with a trestle, trestle control room, two LNG carrier berths, shipping LNG (between the terminal and Triple Island pilotage station), a materials off-loading facility (MOF), pioneer dock, bridge, and pipeline.

Following the public comment period on the EIS, the proponent revised its Project design to address comments raised by governments, Aboriginal groups, and the public in relation to marine issues, and to avoid and reduce environmental effects of the Project. Two key changes, confirmed in a Pacific NorthWest LNG Project Design Mitigation report (October 6, 2014) that have relevance to this report are:

First, a redesign of the marine terminal and relocating the berths to remove Project infrastructure on Flora Bank, eliminating the need for dredging on Agnew Bank and the associated disposal at sea of dredged sediment. Activities within the Materials Offloading Facility (MOF) and other construction will still occur and will now entail the production of approximately 200 000 m^3 of sediment and approximately 590 000 m^3 of rock for disposal. Construction, use, and decommissioning of a temporary pioneer dock will occur for the initial offloading of construction equipment until the MOF is built, construction of a two-lane bridge connecting Lelu Island to the mainland (including bridge footings in Lelu Slough), and construction and use of the MOF (pile driving, berthing of large roll-on, roll-off barges, and ships) will also occur. Construction of the marine terminal (suspension bridge and trestle from Lelu Island to beyond Agnew Bank, LNG loading infrastructure, and marine terminal berths will also entail the use of dredging activities and disturbance of the marine sediments in this area.

Second, disposal at sea was considered the preferred alternative for disposal of marine sediment from dredging, however, due to restrictions regarding disposal at sea, the proponent also assessed terrestrial disposal and determined the top 1 m of dredged marine sediment would be disposed of on Lelu Island. In this regard and with these changes to the amount of dredging activity and the disposal options, 8000 m^3 of dredged sediment (most contaminated fraction) would be piled and stored in a containment area on Lelu Island for draining.

This review has been conducted to inform the UFAWU-CAW regarding several conclusions made in the Draft EA of the CEAA with regards to the EIS and changes to the EIS (as noted above) of the proponent. Specifically, this report addresses two areas of concern 1) potential impacts of COPCs to human health through the consumption of contaminated seafood ('country foods') and land disposal of contaminated sediments on Lelu Island resulting from the marine dredging components of the project, and 2) the potential impacts of the project on salmonid populations in the the Skeena River esturary, with special reference to the loss of wetlands, impacts on eelgrass beds, and potential reductions in nutrient inputs to the marine environment resulting from the industrialization of Lelu Island.

The proposed Project will be located on Lelu Island in northwest British Columbia, Canada. Lelu Island and surrounding waters are federal lands and waters within the boundaries of the PRPA, 15 km southwest of the City of Prince Rupert, BC. In addition to human health concerns, this report reviews the current literature to inform the UFAWU-CAW on the potential effects to salmonid populations which use this migration and rearing corridor from the loss of wetlands and terrestrial habitat on and surrounding Lelu Island due to construction of this facility.

Existing data and information were obtained from a number of sources including the primary literature, electronic resources (e.g., websites), and publicly available reports. The review was guided by 3 topic areas posed in the February 10, 2016 *Proposed Statement of Work (SOW)* from Ms. Luanne Roth:

- Topic #1. Comment on the draft CEAA EA regarding MOF dredge and bridge foundation and pilings in the new design (construction phase and ongoing scouring) and their implications to the toxicology impacts pertaining to the dioxin and furan issue. Assess whether a human health risk assessment should be done prior to the MOF dredge and work on the foundation and pilings.
- Topic #2. Comment on the importance of the wetlands in the Lelu Island area with respect to the diet of salmon.
- Topic #3. Comment on whether mitigation to compensate for loss of Lelu wetlands would have to be in the area (unique features of area to salmon)

2.0 SUMMARY OF DREDGING AND ASSESSMENT ACTIVITIES

Pacific NorthWest LNG Limited Partnership (PNW LNG) is proposing to construct and operate a liquefied natural gas (LNG) facility within the District of Port Edward, British Columbia (BC). The marine components of the Project important to this review include: 1) a materials off-loading facility (MOF) and the approaches to the facility located on Porpoise Channel, and 2) limited dredging in changed portion of project with respect to the marine terminals, now located away from Agnew Bank and Flora Bank.

There is now one main dredging site that will operate during the construction phase of this project. This is at the proposed site of the MOF in Porpoise Channel to the north of Lelu Island. Dredging at the MOF will include the removal of approximately 690,000 m^3 of dredge material (rock and sediment) to a depth of 12.5 m below chart datum. Of the approximately 200,000 m^3 of dredged sediment, approximately 192 000 m^3 would be disposed at Brown Passage and the top 1 m of dredged sediment (most contaminated, approximately 8,000 m^3) would be disposed of on Lelu Island.

Changes in sediment or water quality that could lead to potential for toxicological concerns were assessed. Canada's Fisheries Act, 1985 (including June 12, 2012, amendments), and SARA, 2002, administered by Fisheries and Oceans Canada (DFO), are the primary laws providing protection for fish and fish habitat and marine mammals in the project boundaries. The Canadian Council of Ministers of the Environment (CCME) sediment and water quality guidelines (WQG) for protection of marine life were used to assess potential effects of contaminants in sediment and water. Changes in sediment or water quality was assessed by comparing baseline project-related chemical concentrations to CCME and BC water and sediment quality guidelines for the protection of marine life.

Physical and chemical characteristics of intertidal and subtidal sediment and water quality were identified through field studies to assess the potential for release of contaminants during dredging at the MOF and disposal of the sediment. Marine sediment samples were collected around Lelu Island, but focused on the MOF dredge area only. 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. Sediment was sampled from the proposed dredge area within the MOF and turning basin in May, July, and October 2013 at a variety of depths at 36 locations. Parameters of interest were polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), metals, dioxins and furans, particle size and total organic carbon.

The BC Ministry of Environment guidance was used to assess and manage contaminated sediments under the BC Contaminated Sites Regulation. For cadmium, lead, mercury, PCBs and PAHs, sediment quality was assessed in relation to the Disposal at Sea National Action List and the Canadian Council of Ministers of Environment (CCME) 2001 guidelines for the protection of aquatic life. These include Interim Sediment Quality Guidelines (ISQGs) and Probable Effects Levels (PELs). All other metals and polychlorinated dibenzo-dioxins (PCDDs) and polychlorinated dibenzo-furans (PCDFs) were assessed on the CCME ISQG and PEL. The BC working sediment guideline based on the National Status and Trends Program Approach (NSTPA) was used for nickel.

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 presumed naturally occurring events. Chemical concentrations were compared to CCME sediment quality guidelines for the protection of aquatic life.

3.0 CHEMICALS OF POTENTIAL CONCERN (COPCS)

Contaminant levels in sediment and water in the proposed project area have been affected by historical and current industrial activities such as a pulp mill which is no longer in operation, terminals and port facilities, fish processing facilities, a log dump, and from release of sanitary waste and storm water from developed areas. There are 3 areas of consideration with respect to present (baseline) and future sediment contamination and are: 1) the MOF dredge area, 2) the marine berth dredge area, and 3) the proposed loading site at Brown Passage.

Information on existing contaminant levels found in samples taken in the MOF dredge area include a total of 82 sediment samples were collected at five different spatial depth profiles within the MOF.

In summary, the PNW LNG report data shows that sediment characteristics within the MOF dredge area are typical of the Prince Rupert area and suggest that localized contaminant accumulations do not occur (these results are similar to those from other locations around Lelu Island and from the Fairview Phase II and Canpotex programs) and that widespread contamination of the area has occurred. PCDD/Fs were detected in sediments down to a depth of 1.5 m, with the highest concentrations in the surface sediment layers. Common dioxin sources include atmospheric releases from combustion, waste incineration, chemical manufacturing, petroleum refining, wood burning, metallurgical processes, vehicle emissions, historic pulp and paper mill effluents (CCME 2001). Dioxins and furans are most likely a legacy of historical discharges at the former Skeena Cellulose pulp and paper mill on Watson Island, about 3 km from the MOF. As well, sawmills, wood treatment facilities and chlorophenol-treated wood chip storage areas (Yunker et al. 2002), diesel emissions, coal combustion, municipal solid waste and other incineration stack emissions (Bright et al. 1999) may be contributors. These chemicals are of concern because they are taken up by biota and bioconcentrate and biomagnify in the food chain, which can lead to toxicological risks (mainly in fish, marine mammals, and humans).

Assuming the results of the sediment sampling program, as presented in the PNW LNG report, and related reports (e.g. Canpotex) are accurate, It is likely that the maximum concentrations of PCDD/Fs are not currently located at the immediate surface (0-0.1 m), and thus, many aquatic receptors are not currently being exposed to maximum concentrations. There is the potential that following dumping at the load site, that the sediments with the highest concentrations could be present at shallower depths than they are currently at the dredge site.

4.0 FATE OF DREDGE MATERIAL AND ENVIRONMENTAL PARTITIONING

Once a dredge occurs, sediment is transported and degraded according to numerous physical, chemical, and biological processes. The sediment characteristics (e.g. composition and size) will determine its environmental fate. Moreover, other factors such as location of the deposition and weather conditions (e.g. temperature, wind speed) will impact the distribution and fate of sediments. Dredging at the MOF is expected to occur using a clamshell dredge, which typically releases up to 1% of sediment due to bottom wake (disturbance of the sediment-water interface) from: capturing sediment in the clamshell bucket; release during closing; loss of sediments from the shovel while rising through the water column; draining during slewing and washing from descent through the water column; and debris captured in the dredge (Schroeder and Ziegler 2004). About half of the sediment release occurs at the bottom 5 m of the water column (Hayes et al. 2007). Dredging at the MOF will result in resuspension of marine sediment and potential for dispersal of contaminants from sediment.

Sediment plume modelling was conducted at the proposed MOF dredge site to evaluate the short- term and long-term distribution of disturbed sediments. Plume modelling of the dredging area by ASL Environmental Services predicted that up to 2 mm of sediment will resettle in the majority of the surrounding area up to a radius of 3 km from the MOF. 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.

Resuspension and erosion are influenced by bottom current velocity, potential for wave-induced currents, sediment grain size and cohesion. Wave-induced pore pressures can destabilise mounds resulting in large submarine slides occasionally exceeding a kilometre. Sediment dwelling biota, such as crabs, lobsters and fish, can colonize the mound and cause bio-erosion of the sediments. Extent of erosion may be self-limiting as fine-grained sediments are eroded away it leaves behind coarser sediments that are more resistant to erosion (Bray, 2008).

Transport and deposition depends largely upon size of the eroded materials and hydrodynamic processes in the area. High current, shallow areas allow for long-distance transport of the sediments. Depending on current regime it may be taken back towards the origin of dredged sediments (Bray, 2008).

5.0 BIOAVAILABILITY

Sediments within aquatic environments act as physical and biological repositories and can act as a sink for organic and inorganic contaminants (Zoumis, et al. 2001). Multiple physical (rate of mixing, rate of sedimentation, diffusion, resuspension), chemical (pH, equilibration time with sediment, dissolved organic content) and biological (biotransformation, behavior, diet) factors may influence the bioavailability of contaminants in sediment. In general, high hydrophobicity, lower polarity and larger organic contaminants such as PCDD/Fs have higher likelihood to adhere to sediments and sediment organic content (EPA 2000). Specifically, moderate to high levels of clay or organic carbon within sediments tend to adsorb dissolved contaminants, which can continue to be a source of contamination after the source is depleted (EPA 2000).

Organic pollutants may associate temporarily with particulate matter and establish a water–sediment equilibrium interface (Perelo 2010). Contaminants within the aquatic environment may be immobilized and accumulated, or possibly subjected to activation and transformation within sediments (Martinez-Jeronimo et al. 2008). According to Voie et al. (2002), organic pollutants such as PCBs and PCDDs are only available as a small fraction dissolved in water due to their hydrophobic nature. Intrinsic properties of these organic particles and the particulates suspended within the water column determine the partitioning between the dissolved phase and particulates (Voie et al. 2002). One major route of contaminant uptake in organisms is sediment ingestion (Lamoureux and Brownawell 1999). Organic contaminants dissolved in water are considered as another important exposure source by other authors (Schrap and Opperhuizen 1990). Uptake of dissolved hydrophobic chemicals is thought to occur through the gills or skin of aquatic organisms (Randall et al., 1998).

5.1 Bioaccumulation and biomagnification

Bioconcentration, bioaccumulation, and biomagnification cause body-burden levels of a chemical such as PCDD/Fs to far exceed ambient concentrations in aquatic environments. This may illicit adverse effects in affected environments despite a low environmental concentration of a chemical. Thus they are essential processes in assessing and understanding the impacts of low concentrations of PCDD/Fs. Table 1 contains known log K_{ow}, BCF, BAF, and BMF values for select common congeners of dioxins and furans.

Several studies have explored the bioaccumulation of PCDD/Fs in aquatic biota. Recently, Wan et al. (2010) conducted a study on two rivers that were subjected to heavy historical industrial use (Tittabawasee and Saginaw rivers). Addressing seven dioxin and ten furan compounds, 13 fish species (primary to tertiary consumers) were sampled. The results showed the extent of bioaccumulation to be species- and chemical-specific with all species showing a higher tendency to accumulate furans over dioxins (with regard to sum concentration of congener totals). Similar to previous studies, a positive correlation between tissue concentrations and lipid content/size of the specimen was also found (Kidd et al., 1998; Kidd et al., 2001), but a negative correlation between trophic level and chemical accumulation in tissues (Naito et al., 2003; Wan et al., 2005; Ruus et al., 2006).

Trophic dilution is not a characteristic of all dioxins and furans, rather it has been proposed to be a characteristic of particular congeners. Higher chlorinated congeners of dioxins and furans show generally less accumulation in higher trophic level organisms (Naito et al. 2003; Okumura et al. 2003; Wan et al. 2005; Ruus et al., 2006). This is reasoned to be due to reduced membrane permeability of the larger, highly chlorinated congeners (Naito et al. 2003; Okumura et al. 2003; Ruus et al. 2006) or higher metabolic transformation rates (Wan et al. 2005). Consequently, lower trophic level organisms tend to exhibit a congener profile similar to that of the pollution source whereas higher trophic level accumulation will show a preference for low chlorination congeners (Lyytikäinen et al. 2003; Okumura et al. 2003; Ruus et al. 2006).

Clearly, predicting whether a dioxin or furan congener will bioaccumulate and biomagnify should not be based solely on log K_{ow} values. While log K_{ow} provides evidence for how a chemical will partition between two phases it cannot account for actual accumulation in all organisms due complexity of chemical-organism interactions and inter-species differences. It is generally agreed that dioxins and furans are bioaccumulative (with many BCF values >5000), these studies highlight the importance of ecologically relevant values such as BCFs, BAFs, BMFs in assessing the environmental impacts of dioxins and furans.

5.2 Exposure pathways

Once released into the environment, ecological or human receptors can be exposed to PCDD/Fs through three possible pathways. These routes of exposure include direct contact with contaminated sediment, ingestion of contaminated sediment, and exposure to contaminated water or air (unlikely for PCDD/Fs).

Bioaccumulative PCDD/Fs partition primarily into sediments in the marine environment and so aquatic-dependent wildlife species, and other organisms may be exposed to these chemicals through several pathways. For aquatic organisms, such as microbiota, aquatic algae, sediment-dwelling organisms (e.g. amphipods), and benthic fish (e.g. starry flounder), direct contact with contaminated sediment and/or contaminated pore water represents the most important route of exposure to toxic substances that partition into sediments. Direct contact with contaminated water or sediment can result in the uptake of these chemicals over the general organism body surface. However, ingestion of contaminated sediments can also represent an important exposure pathway for certain species [(e.g. organisms that process sediments to obtain food (e.g. polychaetes) and/or organisms that incidentally ingest sediments during feeding activities (e.g. benthic fish)]. Of the wildlife species that occur in the vicinity of the proposed dredge site, sediment-probing birds (e.g. sandpipers) and omnivorous mammals (e.g. raccoons) are the most likely to be exposed through this pathway.

For aquatic-dependent wildlife species, ingestion of contaminated prey species represents the principal route of exposure to bioaccumulative substances (biomagnification). The groups of wildlife species that are likely to be exposed to PCDD/Fs through this pathway include sediment-probing birds (e.g. sandpipers; black oyster catcher), carnivorous-wading birds (e.g. great-blue herons), piscivorus birds (e.g. belted kingfishers; osprey; double-crested cormorant), carnivorous birds (e.g. surf scoter; bald eagle), omnivorous mammals (e.g. raccoons), carnivorous mammals (e.g. river otters, mink), and piscivorus mammals (e.g. harbour seals; orcas).

Low water solubility of PCDD/F congeners make it unlikely that aquatic organisms and aquatic-dependent wildlife species will be exposed to these substances to any major degree through partitioning into the surface water. However, for some organisms, such as microbiota, aquatic algae, and aquatic invertebrates, or fish, direct contact with contaminated water (likely containing dredge particulates) in the water column may represent a route of exposure as these chemicals partition into surface water. This exposure route involves uptake through the general body surface or gills. This exposure pathway is likely to be important for benthic invertebrates and benthic fish due to desorption of PCDD/Fs from bottom sediments (i.e., through exposure to near-bottom water).

For aquatic-dependent wildlife species, ingestion of contaminated water represents a very minimal route of exposure to PCDD/Fs that partition into surface water. While virtually all aquatic-dependent wildlife species are exposed to toxic substances that partition into surface water, this pathway is likely to account for a minor proportion of the total exposure for most of these species.

Since PCDD/Fs are unlikely to partition into the surface microlayer (i.e. the layer of water that is present at the water-air interface), aquatic organisms and aquatic-dependent wildlife species, direct contact with the surface microlayer will not represent a likely route of exposure and will be of relatively minor importance under these circumstances.

The PNW LNG report states that '*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 statement is unlikely, as data indicate that the close sub-surface layer, but not the surface sediments may contain the highest PCDD/F concentrations. More importantly, is that resuspension of buried contaminated sediments may increase bioavailability over present conditions. In fact, the PNW LNG report contradicts itself and also states that '*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*'.

The PNW LNG report also states that '*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*' is not supported by current knowledge. The resuspension of contaminated sediment would make PCDD/Fs more bioavailable to many organisms, and could act as a new source of these contaminants to ecological receptors.

In this review, marine foods are described as local marine organisms that are harvested and consumed for nutritional or medicinal purposes by local people. Marine foods include various algae, 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. A described above, the concentrations of PCDD/F made bioavailable by resuspending and uncovering contaminated sediments may increase from dredging activities, and the resulting sediment plume may result in an increased exposure durations to many marine organisms. Suspended sediments in the water column from the plume could contain PCDD/Fs that could be taken up by a variety of marine organisms (e.g., fish, prawns and crabs, shellfish). These could be directly consumed by humans, exposing them to increased PCDD/F concentrations, or could be biomagnified through the food chain into other species consumed by humans.

6.0 HUMAN HEALTH CONSIDERATIONS

Volume 1, Section 19 of the *The Pacific Northwest LNG Summary of the Environmental Impact Statement and Environmental Assessment of Certificate Application* (Stantec, 2014) identifies human health as a valued component (VC) based on the potential for the Project 'to change the chemical conditions' in environmental media, and for the chemical in the environment to be transferred to human and ecological receptors, either directly through exposure to environmental media, or indirectly through the food chain. The report further indicates that there is the potential for human receptors in the area of the Project, in particular Aboriginal communities in the area of the Project, to be exposed to the chemicals from the Project via seafood consumption.

As discussed, the resuspension of contaminated sediment via dredging will occur, increasing the bioavailability of these chemicals to marine organisms. This will likely increase marine organism exposures, their potential accumulation and potential food web transfer. The propensity of PCDD/Fs to biomagnify in the food web is cause for concern for humans consuming contaminated marine organisms from the area. The potential effects of PCDD/Fs in humans include biochemical alterations, oxidative stress, endocrine disruption, reproductive and developmental effects, chloracne and cancer. The observed sediment concentrations of PCDD/Fs and other contaminants, the potential for PCDD/F biomagnification, and the myriad of toxic effects in both human receptors suggest that there is potential health risks associated with the proposed dredging activities. This is of particular concern based on the First Nations communities in the area because of their reliance on fish and shellfish (i.e., subsistence fishing).

The Pacific Northwest LNG Summary of the Environmental Impact Statement and Environmental Assessment of Certificate Application, Volume 1, Section 19 (Stantec, 2014) provided a qualitative assessment of such exposures, and concluded that there is the potential for a temporary increase in total suspended solids in the water column from dredging activities which could result in increased concentrations of dioxins and furans in the tissues of seafood items (i.e., marine country foods), leading to a potential increase the human health risk associated with the consumption of the marine country foods. It was, however, predicted that concentrations of dioxins and furans in sediment would ultimately decrease as a result of dredging, following the removal of surface sediments which contain the highest concentrations of PCDD/Fs. It was therefore predicted that overtime the dredging would result in a reduction to the concentrations of PCDD/Fs that marine organisms are exposed to, ultimately resulting decreased exposure and health risks to people consuming marine country foods from the area.

Baseline concentrations of PCDD/Fs were established in the tissues of three commonly consumed marine country food items (crabs, prawns and clams), with the measured concentrations used to predict human health risks associated with consumption of the seafood. The establishment of baseline conditions, and the prediction of baseline health risks, is essential in determining the impact of the Project. Baseline Hazard Quotients (i.e., human health risks) were estimated for human consumption of crabs, prawns, and clams for toddlers, children and adults; it is noted that according to Health Canada guidance (see below discussion), health risks should be estimated for various age groups including infants, toddlers, children, adolescents and adults. While it is considered reasonable to have excluded infants from the evaluation (as they are unlikely to consume seafood), it is not clear why adolescents were not included in the evaluation. Baseline additive health risks based on consuming all three species within the same day were also calculated by summing the Hazard Quotients for the three species for each age group. Details on receptor characteristics (e.g., seafood consumption rates) were not identified during the review. As is later discussed, based on the First Nations communities in the area, and their reliance on fish and shellfish (i.e., subsistence fishing), it is recommended that the seafood consumption rates used be reflective of their use. Based on the available information, it did not appear that tissue concentrations were determined for crab hepatopancreas, nor were exposures and associated risks estimated for consumption of this organ. Crab hepatopancreas is considered a delicacy, may be consumed, and is known to accumulate contaminants at a higher rate than the muscle tissues which are typically consumed.

The upper-bound additive baseline Hazard Quotients were predicted to be greater than 0.2, the Health Canada negligible risk level for threshold chemicals, for toddlers (0.30) and children (0.25), while the mid-bound additive baseline Hazard Quotient for these age groups were approaching 0.2 (0.17 and 0.14, respectively). While details are not provided, it is likely that these estimates were based on the upper and mid-bound concentrations of PCDDs/Fs measured in the tissue, as well as upper and mid-range estimates of consumption rates. Given the First Nations subsistence fishery in the area, it is considered likely that these estimates are most representative of their potential exposures and associated risks than the low-bound estimates. While it is indicated that the concentrations of PCDD/Fs measured in sediments and tissues in the area of the Project are widespread and a legacy of industrial operations in the area, these baseline estimates indicate the potential for unacceptable health risks associated with the consumption of marine country foods under current/baseline conditions. Given the predicted re-suspension of sediments during dredging, the resulting increased exposure of marine organisms to PCDD/Fs, and thus humans consuming these organisms, this is of particular concern. Although the duration is unknown, it is predicted that exposures to marine organisms will increase for some period, thus resulting in increased risk to humans consuming marine country foods.

As part of their Environmental Assessment (EA), the Canadian Environmental Assessment Agency reviewed *The Pacific Northwest LNG Summary of the Environmental Impact Statement and Environmental Assessment of Certificate Application* (Stantec, 2014) and proposed the following to address potential exposures and associated risks resulting from exposure to chemicals from the Project via seafood consumption:

- The Proponent shall develop, prior to construction, and implement in consultation with Aboriginal groups a follow-up program to verify that dredging of marine sediment at the Materials Offloading Facility does not result in increased risk to human health as a result of changes to marine country foods in Porpoise Channel. The follow-up program shall include:
    - Collecting legal-sized Dungeness crabs (*Metacarcinus magister*) and at least two other commonly-consumed species (including one prawn species and one groundfish species) in Porpoise Channel in three different sampling periods:
        - prior to the commencement of in-water construction activities;
        - immediately upon completion of dredging; and
        - one year following completion of dredging;
    - Conducting laboratory analysis of each animal's tissues, including the crab hepatopancreas, for concentrations of dioxins, furans, arsenic and copper for each sampling period; and
    - Reporting results of the monitoring to the Agency, Aboriginal groups and relevant federal and provincial authorities, as appropriate, within 90 days following the end of each sampling period. The results to be reported shall include:
        - all marine tissue contaminant concentrations from samples collected by the Proponent and the methodology for determining sample size;
        - a quantitative assessment of any changes in human health risk from consuming country foods in Porpoise Channel for all receptor age groups; and
        - updated recommendations on the quantity of marine country foods that can be safely consumed per week, using a hazard quotient of 0.2 to calculate the recommended maximum weekly intake. Updated recommended maximum weekly intakes shall take into account the additive risk from consuming multiple species in the same week.
- The Proponent shall implement additional mitigation measures if the results of the follow-up program referred to in condition 9.4 show that there is an increased risk to human

health from changes to marine country foods in Porpoise Channel resulting from the dredging of marine sediments.

Given the lack of feasibility in predicting post dredging conditions, it is not possible to conduct a human health risk assessment (HHRA) to assess the impact of the Project on human health at this time. The recommended program is generally appropriate to address the seafood consumption pathway as it requires 1.) the collection of marine organism tissue samples, including crab hepatopancreas, post dredging, and 2.) the quantitative evaluation of human health risks associated with the seafood consumption pathway. Although generally appropriate, the following points are provided for consideration. Incorporation of the recommendations into the program would help to ensure that human health risks are adequately characterized:

- As stated, the objective of the program is to 'verify that dredging of marine sediment at the Materials Offloading Facility does not result in increased risk to human health as a result of changes to marine country foods in Porpoise Channel'. This objective in itself is not achievable. Given what is known regarding the concentrations of contaminants in sediments, the increased bioavailability associated with dredging the sediments, and the propensity of PCDD/Fs to biomagnify, it is likely that there will be increased risk to human health. Given that baseline risk estimates exceed Health Canada negligible risk levels, any level of increase in exposure/risk would be considered unacceptable.
- While it is recommended that the program be developed in consultation with Aboriginal groups, the expectations of the level of consultation is not specified. It is recommended that the consultation include a survey of the Aboriginal community to compile data on what marine species are most frequently consumed in the area, as well as the frequency of consumption and amount consumed for these species. This data could then be used to tailor the tissue sampling program (discussed in the next bullet), with upper-bound estimates of the reported consumption rates used to predict exposures and health risks associated with seafood consumption.
- The sampling of Dungeness crabs (including hepatopancreas) and at least two other commonly-consumed species from Porpoise Channel is appropriate and will allow for the assessment of potential human health risks associated with consumption of these organisms provided the sampling program is robust. The number of samples to be collected should be determined using statistical methods.
- The three sampling periods recommended may be appropriate; however, given that the baseline Hazard Quotients exceed the Health Canada negligible risk level, it may be prudent to include an additional sampling period. While the predicted increase in total suspended solids and therefore exposure to marine organisms will be highest during the dredging period, increase exposures are expected to last for some time, with PCDD/Fs accumulating overtime. Given that baseline Hazard Quotients already exceed acceptable levels, conducting an additional sampling program at 6 months post dredging could provide valuable information. Additionally, given the bioaccumulation/biomagnification potential of PCDD/Fs, if increased concentrations are observed 6 months and 1 year post dredging, further sampling should be considered until concentrations have stabilized.

The CEAA EA indicates that approximately 8000 m^3 of the upper 1 m of dredged sediment will be disposed of on Lelu Island; this is a change from the sediment disposal plan presented in The Pacific Northwest LNG Summary of the Environmental Impact Statement and Environmental Assessment of Certificate Application (Stantec, 2014) which indicated that all dredged sediment would be disposed of at sea, within Brown Passage. Based on the available data, the upper 1 m (up to 1.5 m) of sediments contain the highest concentrations of contaminants, including PCDD/Fs, copper, arsenic and PAHs. The potential impact of this change on human health has not been addressed.

It is indicated that peat and the 8,000 m^3 of dredged sediment would be piled and stored in a containment area on Lelu Island for draining, and that effluent would be captured, monitored, and treated if necessary before discharge into the marine environment. No additional details on the containment or treatment of the dredged sediments are provided.

The dumping of these sediments on land increases the potential for human receptors to be directly exposed to the sediments. It is recommended that a HHRA be conducted to evaluate the potential risks associated with such exposures. As discussed in subsequent sections of this report, standard HHRA methods would involve screening the available sediment data against environmental quality guidelines (e.g., CCME CEQG) or other benchmarks protective of human health. In the case of sediment, no such benchmarks are available, and the use of soil quality guidelines/benchmarks is not recommended as they may not adequately address sediment exposures. For example, given the fine grained nature of sediments, increased adherence to skin would occur during dermal exposures. It is therefore recommended that all contaminants measured in sediment be carried forward as chemicals of potential concern (COPCs) in a HHRA, and that receptor exposure to the COPCs and associated human health risks be predicted, and that the unique characteristics of the sediment be considered when predicting exposures and associated risks to the chemicals in the sediments.

In addition to the potential for human receptors (if present) to be directly exposed to the COPCs, there is the potential for the land dumping of sediments to further contribute to human exposures via seafood consumption. The PNW LNG report indicates that the soil in the area of Lelu Island is high in organic matter with a relatively low pH. The low pH has the potential to increase the leaching potential of the metals (i.e., arsenic and copper) in the sediments, and while this may be countered by increased adsorption to organic matter in the peat soils on the island, the end result is unknown and requires further consideration. Increased leaching would results in dissolution in groundwater, with subsequent transport to the adjacent marine environment, leading to marine organism exposure, and the potential for indirect exposure to humans consuming these organisms. Further, depending on the initial containment, and the end-placement of the sediment (i.e., it is assumed that eventually the sediment will be placed on land/will not be contained in perpetuity), there is the potential for the sediment to be eroded over time, with run off to the marine environment. This re-mobilization of sediments to the marine environment would result in additional exposure to marine organisms and therefore humans consuming marine country foods.

These transport mechanisms and potential exposures to human health require further consideration and should be addressed in a HHRA prior to undertaking the Project. Standard HHRA methods are discussed in subsequent sections of this report.

6.1 Human Health Risk Assessment Guidance and Methods

The Project will be primarily on Federal lands and thus, federal guidance and methods are applicable. Guidance published by federal agencies and specifically Health Canada's guidance on HHRA, should be used to complete an HHRA, including:

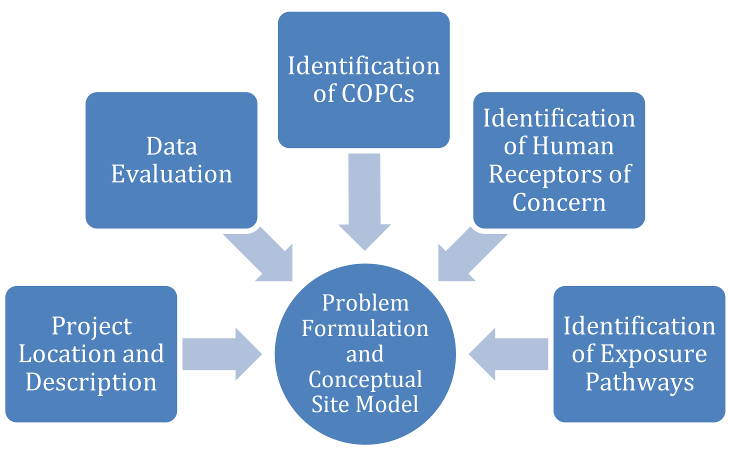
- Federal Contaminated Site Risk Assessment in Canada – Part V: Guidance on Complex Human Health Detailed Quantitative Risk Assessment. Version 1.0. September 2010. Contaminated Sites Division, Safe Environments Programme, Health Canada, Ottawa, Ontario (Health Canada, 2010a);

- Federal Contaminated Site Risk Assessment in Canada – Part II: Health Canada Toxicological Reference Values (TRVs) and Chemical-Specific Factors. Version 2.0. September 2010. Contaminated Sites Division, Safe Environments Programme, Health Canada, Ottawa, Ontario (Health Canada, 2010b); and
- Federal Contaminated Site Risk Assessment in Canada – Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA). Version 2.0. May 2012. Contaminated Sites Division, Safe Environments Programme, Health Canada, Ottawa, Ontario (Health Canada, 2012).

As indicated, because it is not possible to predict post-dredging tissue concentrations for marine country foods, it is not feasible to complete an HHRA evaluating the seafood consumption pathway at this time. The HHRA evaluating seafood consumption will be completed post-dredging, following the collection of tissue samples during the CEAA recommended sampling periods (e.g., immediately post-dredging, 1 year post dredging). The results of that HHRA will be compared to estimated baseline health risks to determine the impact of the Project.

Using the available sediment data representative of the upper 1 m of sediment that will be dredged and placed on Lelu Island, it is possible at this time to conduct an HHRA that evaluate the potential health risks to human receptors directly exposed to the sediments following placement on land. Direct exposure pathways include incidental ingestion of sediment, dermal contact with sediment, and inhalation of sediment particulate (i.e., dust generated from the sediments placed on land). The HHRA would consist of five main components, including the following:

- *Problem Formulation.* The Problem Formulation is the initial step of the HHRA and forms the basis of the assessment conducted in the remaining steps of the HHRA. A thorough Problem Formulation is essential to ensure that human health risks are appropriately characterized. The Problem Formulation would identify the chemicals of potential concern (COPCs) in the sediments that will be disposed of on land, the receptors that have the potential to be exposed to the COPCs (e.g., workers involved in the construction of the facility, workers at the future facility, Aboriginal people using the area), as well as the pathways by which these receptors have the potential to be exposed.



- **FIGURE 1: MAIN ELEMENTS OF THE PROBLEM FORMULATION**

- *Exposure Assessment.* The Exposure Assessment involves the estimation of the dose of each COPC that the receptors of concern have the potential to be exposed to. To estimate exposures, assumptions have to be made regarding the characteristics of the receptors exposed. As discussed earlier, the fine-grained nature of the sediments should be considered when predicting soil adherence to skin during dermal exposures.
- *Toxicity Assessment.* The Toxicity Assessment is the compilation of toxicity data on the potential adverse health effects for each of the COPCs, as well as TRVs for each of the COPCs. For non-carcinogenic chemicals, TRVs represent an exposure dose or air concentration below which no adverse effects are expected to occur. For carcinogenic chemicals, the TRV is presented as an upper bound of the increased cancer risk from a lifetime exposure either a specified air concentration or intake rate of to the chemical.
- *Risk Characterization.* In the Risk Characterization the doses estimated in the Exposure Assessment are compared to/combined with the TRVs identified in the Toxicity Assessment to estimate potential health risks associated with receptor exposure to the COPCs under the assumptions of the HHRA.
- *Uncertainty Analysis.* The Uncertainty Analysis is conducted to evaluate the sources of uncertainty inherent in the HHRA, as well as how the uncertainty will affect the results of the HHRA.

The HHRA should be conducted using a series of conservative assumptions to ensure that human health risks associated with the Project are not under predicted.

The completion of the HHRA evaluating the direct human exposure to the sediments to be disposed of on Lelu Island will determine whether or not additional mitigative measures are required to protect workers and other human receptors with the potential to spend time on the island. It is noted that the indirect exposures (i.e., contribution to marine organism exposure/subsequent human exposure) from the soils disposed of on Lelu Island will require evaluation as part of the post-dredging tissue sampling program and HHRA. As such, sampling of marine country foods from areas where groundwater discharge from the island and/or run-off is predicted to occur, requires consideration.

Although not presented in the application, in addition to predicting concentrations for comparison to benchmarks protective of aquatic organisms/fish, consideration must be given to the potential for the human health exposures. Although there is low potential for humans to be directly exposed to the sediments at the load site, as will be further discussed in subsequent sections of this report, PCDD/Fs bioaccumulate and biomagnify in the food chain, and thus, there is the potential for humans to be indirectly exposed to PCDD/Fs via consumption of fish and shellfish from the load site. This is of particular concern based on the First Nations communities in the area, and their reliance on fish and shellfish (i.e., subsistence fishing). Given the potential for increased bioavailability exposed during dumping of the dredgate at the load site, and the use of the area for subsistence fishing, further evaluation of human exposures via this pathway is recommended prior to approval of the application.

Estimation of human exposures and associated risks related to consumption of fish/shellfish from the area requires the completion of a human health risk assessment (HHRA); an HHRA would consider the bioaccumulation of PCDD/F in fish/shellfish, and subsequent consumption of fish/shellfish by local consumers, including First Nations subsistence consumers. The HHRA would then include the estimation of daily intakes of PCDD/F on an mg/kg bw/day basis, and the subsequent estimation of health risks to consumers. The WHO (2005) toxic equivalency factors (TEFs) for mammals and humans would be applied in the estimation of human health risks. Based on the conservatism and uncertainty in bioaccumulation and food chain models, the use of measured tissue concentrations (over modeled) is preferred. It is understood that tissue concentrations of crab, clams and prawns in the area of the dredge site were determined as part of the application; as previously discussed, based on the potential for increased bioavailability of PCDD/F during dumping at the load site, there is the potential that these concentrations underestimate concentrations at the load site. Furthermore, tissue concentrations were not determined for fish species.

In the PNW LNG report, the concentrations of PCDD/Fs reported for the sediment samples were calculated using the WHO 1998 toxic equivalency factors (TEFs) for fish; the estimated toxic equivalents (TEQs) were then compared to the CCME Interim Sediment Quality Guidelines (ISQGs) and Probable Effect Levels (PELs), guidelines that have been derived to be protective of aquatic receptors. The WHO (2005) TEFs for mammals and human have not been considered in the PNW LNG report. The application of the WHO (2005) TEFs to an abiotic medium, such as sediment, has limited toxicological significance. Furthermore, we are not aware of sediment guidelines/benchmarks for PCDD/F from Canadian agencies that have been derived to be protective of human health. The Oregon Department of Environmental Quality has derived a guideline for the protection of human consumers; the guideline is intended as a screening level value to determine the need for subsequent bioaccumulation modeling/testing (i.e., tissue sampling), and ranges from 0.0011 pg TEQ/g PCDD/F for subsistence consumers to 1.1 pg TEQ/g PCDD/F for the general population. Given the TEQs (based on the WHO, 1998 TEFs) reported in the PNW LNG report and the relationship between the WHO, 1998 and WHO, 2005, TEFs, it is anticipated that if the WHO, 2005 TEFs were applied to the sediment data included in the PNW LNG report, that concentrations would exceed the Oregon DEQ screening level for subsistence consumers by a minimum of three orders of magnitude. This further supports the recommendation for further assessment of potential human health risks prior to approval of the application.

7.0 SALMONID HABITAT

In addition to human health concerns, this report reviews the current literature to inform the UFAWU-CAW on the potential effects of the project on salmonid populations that use this area as a migration corridor and nursery. Concerns have been expressed regarding the selection of Lelu Island as the preferred site location for the project as well as the proposed marine terminal to be built on Agnew Bank due to its proximity to important salmon rearing habitat in the Skeena watershed including the Skeena estuary and adjacent marine areas including Flora Bank. Here, several specific potential impacts inadequately addressed in the CEAA EA are discussed, and include 1) area description in terms of salmon habitat, 2) use of the estuary, wetlands and eelgrass beds by Skeena salmon, 3) loss and impacts on salmonid habitat, 4) potential impacts of industrialization on salmon bioenergetics and survival, 5) importance and potential effects on Flora Bank and utilization by salmon.

7.1 Description of project site and biological importance

The proposed Project will be located on Lelu Island in northwest British Columbia, Canada. Lelu Island and surrounding waters are federal lands and waters within the boundaries of the PRPA, 15 km southwest of the City of Prince Rupert, BC, within the Skeena River estuary. Lelu Island is in the Hecate Lowland along the western margin of the Kitimat Ranges of the Coast Mountains of B.C. Lelu Island is a small island (219 ha) currently undeveloped and accessible only by water. Lelu Island has gentle topography, with a maximum elevation of 40 m. The soil in the area is high in organic matter, relatively low in pH, and limited in nitrogen. The soil is underlain by a variety of metamorphic rocks (predominately granite). The Lelu Island site is located within the Pacific Maritime ecozone and is occupied by large expanses of muskeg where drainage is poorly established. Dominant vegetation includes moderately productive forests (western red cedar and western hemlock) and forested and shrubby blanket bogs (western red cedar, yellow-cedar, western hemlock, and shore pine).

The proponent proposes to construct and operate the Project on Lelu Island. The Project area physically disturbed or occupied by the Project includes approximately 160 ha on Lelu Island, 0.3 ha on the mainland (bridge abutment and access road), 0.2 ha covered by the bridge crossing, approximately 90 ha offshore area covered by the marine terminal, and 8 ha offshore associated with the MOF. The total area of the Project development is approximately 260 ha. General site preparation within the terrestrial Project area, including site preparation for the LNG facility on Lelu Island, and site preparation for the bridge footings and road access on the mainland will result in the removal of terrestrial vegetation, wetlands, and watercourses (selected as valued components) on Lelu Island, and as outlined in the CEAA EA, these are the project's main potential environmental effects in relation to section 5 of CEAA 2012. The project would result in the removal of freshwater watercourses on Lelu Island. Other marine impacts important to salmon habitat include construction of a two-lane bridge connecting Lelu Island to the mainland, including bridge footings in Lelu Slough, construction and use of the MOF (pile driving, berthing of large roll-on, roll-off barges, and ships), as well as construction of the marine terminal (suspension bridge and trestle from Lelu Island to beyond Agnew Bank, LNG loading infrastructure, and marine terminal berths). The LNG Loading Marine Terminal would consist of a 2.7 km jetty that includes a 1.6 km clear-span suspension bridge and a 1.1 km conventional pipe pile trestle extending west from Lelu Island to the marine terminal berths beyond Agnew Bank.

7.2 Biology of project area

The marine habitats around Lelu Island are representative of marine ecosystems throughout the north coast of B.C. Key marine features on and around Lelu Island include rocky shorelines, soft sediment in protected bays and channels, and expansive shallow banks and mudflats. The District of Port Edward Official Community Plan identifies the Lelu Island shoreline as an environmentally sensitive area. Lelu Island is bordered by deep water to the northwest in Porpoise Harbour (up to 25 m) and to the southeast in Inverness Passage (about 15 m deep). The water is shallower west of Lelu Island along Flora and Agnew Banks. Flora Bank, immediately west of Lelu Island, is a large, flat, intertidal area of fine to medium sands with eelgrass beds that cover 10-15% of the 325 ha area seasonally. One unique biological characteristic of the Skeena River estuary are the size of the eelgrass beds on Flora Bank that are ecologically valuable to the region and provide important and crucial rearing habitat for annual out-migrating salmon stocks, originating predominantly from the Skeena River. Eelgrass is widely recognized as important nearshore habitat for juvenile and adult invertebrates (including Dungeness crab and *Pandalus* shrimp) and fish (DFO 1985). Eelgrass beds are restricted to the intertidal areas of Flora Bank because the high TSS influence of the Skeena River limits the photic zone, impairing subtidal plant growth (Faggetter 2009, 2013). Eelgrass beds can provide cover from predation, reduce local current regimes (allowing for settlement of organisms), and increase secondary productivity by adding to local habitat complexity and surface area.

Agnew Bank, to the northwest of Flora Bank, is a relatively flat subtidal area of much finer sediments with no eelgrass beds. At the southwest end of Flora Bank, the seabed drops off with a gradient of about 10 per cent changing from 5 m deep to 50 m deep in the more open waters of Chatham Sound. The Prince Rupert region experiences large semi-diurnal tides (two low and two high tides per day of different heights), with a relatively large tidal range of 7.4 m. Agnew Bank has relatively lower species diversity, with the main fauna consisting of sparsely distributed invertebrates, such as orange sea pens (Ptilosarcus *gurneyi), Pandalus* shrimp, tunicates, sponges, and various mollusc species.

Species found in the Project area, including Flora Bank and Agnew Bank, include Pacific herring, surf smelt, shiner perch, salmon, flounder, halibut, English sole, big skate, and invertebrates such as Dungeness crab, shrimp, cockles, butter clams, mussels, and littleneck clams. The most common marine mammals in Chatham Sound include humpback whale, northern resident and Bigg's killer whale, harbour porpoise, Dall's porpoise, Pacific white-sided dolphin, and harbour seal. Thirteen marine species (fish, invertebrates, and marine mammals) listed under the *Species at Risk Act* and six species designated by the Committee on the Status of Endangered Wildlife in Canada potentially occur in the vicinity of the Project.

Rocky subtidal areas support diverse seaweed communities, including numerous species of kelp. These plants provide food and shelter for mobile and sessile invertebrates and fish. Soft sediments rarely support seaweeds but provide suitable habitat for burrowing invertebrates, crabs (e.g., Dungeness, *Metacarcinus magister),* shrimp (Pandalus spp.) and flatfish (family Pleuronectidae).

7.3 Salmon

The Skeena River watershed encompasses an area of some 32,000 square kilometers and includes over 150 tributaries, most of which supports hundreds of populations of all six species of Pacific salmon: chinook (*Oncorhynchus tshawytscha*), coho (*O. kisutch*), pink (*O. gorbuscha*), chum (*O. keta*), steelhead (*O. mykiss*), and sockeye (*O. nerka*). The Skeena provides spawning and rearing habitat for over 50 genetically and geographically distinct populations of wild salmon, called Conservation Units.The Skeena River estuary is comprised of extensive mudflats and shallow intertidal passages that provide important nursery habitat for juvenile salmon. Hundreds of millions of juvenile salmon travel through the Skeena River estuary as they migrate to sea. Estuaries act as critical nursery habitats and transition zones where juvenile salmon can grow rapidly and gradually adapt to the saltwater environment. They also provide refuge from predators due to high turbidity, estuarine vegetation (e.g. eelgrass and kelp beds), and riparian vegetation. Growth attained in the estuary can influence whether juvenile salmon survive to a reproductive age.

Estuaries link freshwater and marine habitats for diadromous species such as Pacific salmon. Thus, estuaries may serve as bottlenecks during two transitions of salmon life history: first, in the spring when juvenile salmon leave freshwater rearing habitats and undertake their seaward migration, and then again in the summer and fall when adult salmon return to freshwater to spawn. Estuaries are staging areas and transition zones where juvenile salmonids physiologically adapt to saltwater environments (Heard, 1991) The early marine life history stages, including estuarine residence, are among the most critical life history stages for juvenile salmon (Kareiva et al. 2010) and the growth attained during this period can determine whether they survive to reproduce (Farley et al., 2007). Some species, such as pink, chum, and chinook salmon may remain in estuaries for weeks or months during their downstream migration (Kareiva et al., 2010). For large watersheds that contain several salmon species and potentially hundreds of locally adapted salmon populations, estuaries represent key migration bottlenecks that support high salmon biodiversity.

Carr-Harris et al. (2015) conducted a juvenile salmonid sampling program throughout the Skeena River estuary in 2007 and 2013. All species of juvenile salmonids were captured throughout the estuary in both years, and it was reported that areas proposed for development support some of the highest abundances of some species of salmonids. Specifically, the highest abundances of sockeye (both years), Chinook in 2007, and coho salmon in 2013 were captured in areas proposed for development. For example, juvenile sockeye salmon were 2-8 times more abundant in the proposed development areas. Genetic stock assignment demonstrated that the Chinook salmon and most of the sockeye salmon that were captured originated from throughout the Skeena watershed, while some sockeye salmon came from the Nass, Stikine, Southeast Alaska, and coastal systems on the northern and central coasts of British Columbia.

Maintaining the integrity and function of this estuarine habitat is important for supporting healthy and productive Skeena salmon populations. However, there is limited information on how long juvenile salmon spend in the Skeena River estuary, the extent of eelgrass and wetland habitat, and the availability of food for juvenile salmon. These knowledge gaps hinder the ability to both assess the status of estuarine habitats for Skeena salmon and employ strategies for protecting and mitigating effects on these important habitats from anthropogenic impacts such as the proposed project.

7.4 Wetlands

As outlined in the CEAA EA, the project's main potential environmental effects in relation to seciton 5 of CEAA 2012 include the removal of terrestrial vegetation, wetlands, and watercourses on Lelu Island. These were selected as valued components by the CEAA which focused its assessment on wetlands that include marshes, swamps, fens, bogs, and shallow open water as defined under the *Federal Policy on Wetland Conservation*. The proponent EIS also commented on the destruction of wetlands and noted that project construction would result in the loss of terrestrial vegetation and wetlands on Lelu Island.

Functions provided by these wetlands include groundwater recharge and discharge, flow moderation, sediment stabilization, maintenance of water quality, carbon storage, and habitat for a variety of wildlife species. The proponent indicated it would prevent further wetland loss in the local assessment area by incorporating weed and invasive plant control measures during construction and operations, and designing and implementing drainage and erosion control techniques to maintain the local surface and groundwater hydrology. The proponent also proposed a 30 m vegetation buffer along the perimeter of Lelu Island that would further protect wetlands on the island. Even so, a total of 119.2 hectares of wetland out of the 154.3 hectares found in the local assessment area would be lost, resulting in the loss of wetland functions described below. This area represents 77 percent of the wetlands found in the local assessment area.

The Project is subject to the *Federal Policy on Wetland Conservation,* which has an objective of no net loss of wetland functions on federal lands and waters. The proponent considered effects on wetlands to be significant if they led to a net loss of any wetland functions. The CEAA concludes that the loss of wetlands will be compensated for: '*The Agency notes that prior to implementation of wetland compensation projects, there may be a moderate magnitude residual effect on wetland function that is short to medium-term in duration; however residual effects on wetlands would be negligible once compensation projects are fully developed'*. The proponent proposed implementing a wetland compensation plan with a ratio of 2:1 compensated areas for impacted areas and a five-year monitoring program for the restored or created wetlands. Based on advice from Environment and Climate Change Canada, the compensation plan would favor restoration over enhancement and enhancement over creation of wetlands. The proponent concluded that while the wetland functions would not return at the site where they were lost, the compensation plan would prevent net loss of wetland functions and, as such, the residual effects would not be significant.

Concerns regarding the adequacy of the wetland compensation plan and its ability to mitigate for the loss of mature wetlands in the region are certainly justified. Although the CEAA considers the implementation of a follow-up program as necessary in order to determine the effectiveness of restored or created wetlands at fulfilling the wetland functions that they were meant to replace, little detail on the wetland compensation plan exist and it is unlikely that given the use and potential importance of this particular area in the Skeena estuary, that any wetland restoration, enhancement or creation will compensate for the loss of such an important area to migrating juvenile salmonids. Additional and supporting information regarding this conclusion can be found in subsequent sections on the importance of this area, and in particular Flora Band to juvenile salmonids in the sections below.

7.5 Sediments and contamination

During construction at the Materials Offloading Facility, an area of approximately 54 000 m^2 would be cleared to a depth of 12.5 m, removing 790 000 m3 of material over a seven month period. Of the material to be removed, the proponent estimated that 192 000 m^3 would be sediment for disposal at sea and 8000 m^3 would be sediment for disposal on Lelu Island. Dredging at the MOF is expected to releases up to 1% of sediment due to bottom wake (Schroeder and Ziegler 2004) of which about half of the sediment release occurs at the bottom 5 m of the water column. Dredging at the MOF will result in resuspension of marine sediment and potential for dispersal of contaminants from sediment. Disturbance of the seabed sediment leading to higher total suspended solids concentrations in the water. The proponent found that total suspended solids concentrations would exceed the *Canadian Water Quality Guidelines for the Protection of Aquatic Life* for long-term exposures within 400 m of the MOF, primarily in deeper waters. The proponent concluded that, with mitigation measures, total suspended solids levels near active dredging areas could exceed the *Canadian Water Quality Guidelines for the Protection of Aquatic Life* for long-term exposure resulting in chronic effects, but would be unlikely to have acute effects. Sediment toxicity can occur in an acute manner as well as lead to chronic or longterm effects. It is difficult to predict the outcomes from increases in sediment exposure without concentration information.

In addition, the conclusion that outside of this area, including over Flora Bank, very little effect of increases in total suspended solids from the MOF is not justified. In addition to this, during operations at the marine berth, total suspended solids could exceed background levels on Flora Bank, which are typically low (5-10 mg/L) throughout the water column. Two-dimensional modelling by the proponent indicated that under certain conditions sediment could be resuspended by the wash of the tug propellers during maneuvering of LNG carriers resulting in total suspended solids levels in excess of the *Canadian Water Quality Guidelines for the Protection of Aquatic Life* for long-term exposure. This could result in eelgrass, invertebrates, fish and other organisms experiencing chronic effects from increased sediment and turbidity. The CEAA and Fisheries and Oceans Canada note that the proponent would need to modify the proposed construction activities to further mitigate effects of elevated total suspended solids outside of windows of least risk, that is, when fish are more likely to be using an area for sensitive life stages. With additional mitigation measures, exceedances of the guidelines are still likely, especially in deeper waters.

The proponent indicated that blasting, dredging, and disposal at sea could resuspend and relocate sediments that have detectable concentrations of dioxins and furans and polycyclic aromatic hydrocarbons as a result of previous industrial activity in Porpoise Harbour. Levels of dioxins and furans and some polycyclic aromatic hydrocarbons were highest in the upper 0.2 m of sediments. The proponent’s modelling indicated that disturbed sediments would not disperse far and would settle in areas with similar chemical composition within the immediate vicinity of the dredging area, with some additional sediment deposition expected to occur around the north coast of Lelu Island As such, the proponent concluded that there would be minimal risk of effects to fish in areas to the northeast and southwest, including Flora Bank. At the marine terminal berths, existing sediment could be resuspended from the ocean floor by the wash of tug propellers during the maneuvering of LNG carriers. The proponent expected that such resuspended sediments could be deposited on Flora Bank. These sediments would not accumulate, but be circulated by tidal currents, and therefore would not constitute serious harm to fish habitat.

According to the NRC (1997), environmental dredging is often used to minimize the spread of contaminants to the surrounding environment by removing sediment contaminated above certain levels. The resuspension of sediment via dredging can occur as dredge operations dislodge sediment particles which are dispersed into the water column (Bridges et al. 2008). The resuspended particulates may be redeposited or transported to other locations in the same water body (Bridges et al. 2008). Dissolution may occur with some contaminants into the water column and be made available for uptake by biota, an environmental exposure of some concern (Bridges et al. 2008). Several completed environmental dredging project field results indicate that post-dredging residual contaminant concentrations (expressed as contaminant concentration from surface sediments) are greater than pre-cleanup levels. Continuing or short-term risk at the site can occur as a result of this resuspension (Bridges et al. 2008). High concentrations of particulates and associated contaminants can also result from resuspension in the water column (Bridges et al. 2008).

The baseline study in the PNW LNG reports states that marine sediments at the MOF contain historical deposits of chemical (i.e., PAH, PCB, PCDD/F) that 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. Data from the Canpotex application for disposal at sea (Stantec 2014) indicate that the highest concentrations of PCDD/Fs in the sediments sampled occur in the top 0.1-0.2m, therefore chemical concentrations in deeper sediment layers are higher than concentrations found in surface layers. Under this scenario, deep sediments containing higher concentrations of contaminants will settle over less contaminated surface sediments. These concentrations are in some cases above ISQGs and lower than PELs. Dredging will remove the surface sediments, and potentially expose and disturb relatively cleaner sediments. Under this scenario, chemical concentrations in the sediment could potentially increase or remain similar to existing conditions. This information suggests that the dredging operations outlined in the application of sediments contaminated with PCDD/Fs may increase the bioavailability of these compounds at the dredge and loading sites and lead to increases in marine life exposures, their potential accumulation and effects, and potential food web transfer to humans consuming impacted seafood.

The CEAA recognizes that there is uncertainty as to the number and species of fish potentially affected by the changes in water quality, as well as the effectiveness of the proposed mitigation measures. They have identified a follow-up program to verify that effects would not be significant and determine the effectiveness of mitigation measures. However, a proposed water quality monitoring program, on-going fish abundance surveys, and monitoring program for total suspended solids, sediment erosion, and deposition will not mitigate effects if they are occurring but will simply document reductions in fish populations.

The 8,000 m^3 of dredged sediment containing higher levels of dioxins and furans and polycyclic aromatic hydrocarbons would be piled and stored in a containment area on Lelu Island for draining. The CEAA notes that any water discharges from the containment area on Lelu Island into the marine environment would be captured, monitored, and treated if necessary before discharge into the marine environment by the proponent, and would meet the applicable water quality guidelines and the requirements of the *Fisheries Act*, as well as being permitted by the Prince Rupert Port Authority. The conclusion by the CEAA that the effects to water quality from such discharges will not pose a risk to marine fish is not based on evidence, data, or risk assessment. For example, the possibility of treating PCDD/F containing effluent is unfeasable in this regard.

7.6 Flora Bank

Flora Bank is an intertidal, sand habitat dominated by eelgrass and a wide range of fish and invertebrate species. The area between Lelu and Kitson Islands on Flora Bank in the Skeena estuary is recognized as one of the largest eelgrass beds in British Columbia and a region of high habitat value. Flora Bank supports 50-60% of the eelgrass in the Skeena Estuary (Hoos, 1975) and is located within the "extended range" of eelgrass populations and is highly beneficial to the food chain. Decaying plants form a detritus base for consumption by benthic and planktonic invertebrates. It also acts a sediment stabilizer preventing drifting of sediments and it often provides a suitable environment for browsing invertebrates by virtue of its associated epiphytes. Relatively few studies have been done on the nature and extent of the eelgrass in this area. During August 1997, a survey of the area mapped habitats that included kelp and eelgrass beds, sandflats, and intertidal vegetation (http://www.oceanecology.ca/Flora_bank.htm). The amount of eelgrass present on Flora Bank during 1997 as estimated from the survey was approximately 0.80 km^2. Note that almost all of the reported eelgrass was located in the intertidal zone. Approximately 97% of the observed eelgrass was intertidal, and appeared to be *Zostera marina typica*. In recent surveys, very little eelgrass was observed in areas at a distance from the previously identified beds seems to suggest that the eelgrass has not been actively expanding since 1997.This suggests, given the high turbidity in the area of Flora Bank, eelgrass growing in the subtidal environment is likely light limited. Thus, the Flora Bank eelgrass bed is most likely limited to only those regions where the depth is shallow enough to allow good light penetration.

The Skeena River plume plays an important role in controlling the growth of eelgrass on Flora Bank through changes in turbidity, suggesting that increases in sediment in the water column through anthropogenic activities may negatively affect the the growth of eelgrass on Flora Bank. Eelgrass is very sensitive to changes in light, and it is not unusual to see impacts well outside the footprint of projects that may be causing sediment resuspension (US EPA). In the US, the EPA has designated eelgrass beds as ‘special aquatic sites’ pursuant to section 404(b)(1) of the Federal Clean Water Act, due to their important role in the marine ecosystem. They are subject to greater protection than other waters because of their significant contribution to the overall environment. Proponents are required to examine alternative sites where the proposed activity could be conducted without endangering the special aquatic site and use it instead or justify why the proposed activity can only be performed at or near the Special Aquatic Site. (OREVT1SAS.doc). To minimize impacts from construction vessels to eelgrass, the US EPA suggests that project proponents mark off the edge of the eelgrass meadows with buoys and implement no wake zones for construction vessels for 200 feet from the edge of any meadow.

Particular concern has been expressed over the loss of eelgrass beds and potential subsequent habitat loss for juvenile salmon, eulachon, and other fish species. The Canadian Groundfish Research and Conservation Society identified Flora Bank as important habitat for eulachon and groundfish species. Millions of salmon come down the Skeena, turn right through Inverness Channel and come across Flora Bank. This is where they are changing from living in freshwater to sea water; they are especially vulnerable and in need of shelter and food. The smoltification process takes a lot of energy and causes them to be less active. Estuary eelgrass beds provide both food and shelter from predators. The importance of Flora Bank to juvenile salmonids has been termed 'critical' and that Inverness Passage, Flora Bank and De Horsey Bank, in that order, are habitats of critical importance for the rearing of juvenile salmon (Higgins and Schouwenburg 1973).

Flora Bank was previously found to be among the most important early marine habitats for pink salmon from the Skeena watershed (Hoos, 1975). Pink salmon migrate to the estuary immediately upon hatching in May where they move out into shallow estuary channels, along the beaches and sandbanks of Flora and De Horsey banks (Hoos, 1975). Sockeye seaward migration takes place from April to June, peaking in mid-May. Upon reacing the etuary the majority stay right in the river mouth, or on Flora Bank near Kitson Island where they remain for a few weeks to a month (Hoos, 1975). Flora Bank is described as habitat of cirtical importance for the rearing of juvenile salmon by the Dept. of Environment Fisheries service. A biological assessment of fish utilization of the Skeena River estuary with a special reference to Port development in Prince Rupert concluded that 'the shallow estuarine areas between Porpoise Channel and the mouth of the Skeena River are of high biological significance as a fish (especially of juvenile salmon) rearing habitat (Higgins and Schouwenburg 1973).

The region with proposed development has been shown to contain the highest densities of coho, chinook, and sockeye salmon in a sampling program over several years (Carr-Harris et al. 2015). Consistently high abundances of salmon in this region suggest that this region contains important feeding and holding areas for outmigrating salmon smolts. These results are supported by previous research in the estuary, conducted in the 1950s (Manzer 1956) and 1970s (Higgins and Shouwenburg 1973) that found the areas currently proposed for development including the waters around Flora Bank and southeast Ridley Island to be critical habitat for juvenile salmonids (Hoos, 1975). Extensive eelgrass (*Zostera marina*) beds are known to exit on Flora Bank (Higgins and Schouwenberg, 1973). And it is here that the highest numbers of juvenile salmon are found. The Ridley Island shore, in contrast, produced relatively fewer captures. Higgins and Shouwenberg (1973) relate this distribution to the availability of amphipods, which they found only in the vicinity of Flora Bank. Kaczynski et al. (1973) have shown that for pink and chum salmon in Puget Sound, an onshore stage of development can be described in which both species feed mainly on epibenthic harpacticoid copepods and gammarid amphipods. Preliminary results reported by Higgins and Shouwenberg (1973) indicate that sockeye, coho and Chinook salmon consume amphipods and insect remains in the Flora Bank area.

These findings are not surprising as it is well known that estuaries are critical habitat for juvenile salmon (Heard, 1991; Beck et al., 2001), however, they contradict recent reports by the proponents consulting groups that did not report significant numbers of juvenile salmon in this area (Stantec Consulting 2011, 2013; AECOM, 2013). The most important capture sites for juvenile salmon were within 10 km of the northern entrance of the Skeena River, either within the development footprint, or in habitats where juvenile salmon would have to transit through the proposed developments to access. These migrants could be affected by habitat loss as a result of removal of foreshore habitat and dredging, reducing connectivity between freshwater and marine habitats following the installation of causeways and berths, and eventually the effects of pollution and propeller wash from tanker traffic. Cumulative degradation of estuarine habitats could erode the diversity, resilience, and productivity of salmon from the Skeena River and beyond (Bottom et al., 2009).

Construction of the Materials Offloading Facility in Porpoise Channel would permanently destroy 1830 m2 of eelgrass habitat. The proponent identified effects to the eelgrass habitat as serious harm given its use by juvenile salmonids, herring, surf smelt, sandlance, and crab. Hydrodynamic models indicated that changes to sediment erosion and/or deposition patterns would occur outside of the spatial limits of eelgrass beds on Flora Bank and that water current speeds around the infrastructure would be unlikely to increase in a manner that would affect fish. However, the suggestion that Flora Bank would be robust and stable following construction of the proposed structures with no evidence of divergent or run-away effects is unsubstantiated and not supported by data or evidence. Skeena Wild Conservation Trust submitted a report that detailed impacts of the Project on salmon habitat. This report reiterated the concerns expressed by First Nations about effects to Flora Bank from changes to the natural movement of sediments due to Project infrastructure.

The proponent identified 90 000 m2 of lower productivity habitats within five potential offsetting sites that could be modified to increase the productivity of fisheries. The potential enhancements to these habitats include the creation of eelgrass habitats, intertidal and subtidal reefs, and intertidal gravel and cobble benches. The enhanced habitats are expected to benefit a range of fish and marine plants including juvenile salmon, flatfish, forage fish, invertebrates, eelgrass, and kelp. For all fish habitat areas potentially affected by the Project, the proponent has proposed to offset effects that would be considered serious harm. Fisheries and Oceans Canada advised the Agency that the proponent appears to have adequately predicted impacts to fish and fish habitat, and has identified appropriate offsetting measures. Although the offsetting plan is not yet final, the Agency is satisfied that serious harm to fish habitat would be adequately managed by Fisheries and Oceans Canada under the requirements of any *Fisheries Act* authorizations. Evidence from the cited studies indicate that the estuary of the Skeena River in general, and the area proposed for development in particular, is an ecologically significant habitat that integrates diversity of all species of anadromous salmonids from the Skeena River and surrounding areas. High densities of juveniles are one characteristic of nursery habitats, and it is suggested that nursery habitats such as Flora Bank are specific areas within greater regions that may contribute disproportionately to adult recruitment (Beck et al., 2001). Due to the unique and critical character and importance of the Flora Bank area to juvenile salmonids, it is unclear how any offsets could mitigate the impact of the project.

7.7 Nutrients

The proponent considers an effect to food and nutrient content significant if it adversely affects nutrient and food supply in fish-bearing streams and estuarine/nearshore environments. The nearshore waters around Lelu Island are heavily influenced by the inputs from the nearby Nass and Skeena Rivers. Therefore, the proponent did not expect the loss of nutrient input into the estuarine areas from infilled watercourses on Lelu Island to have any measurable effect on the total nutrient content of waters surrounding the island. The proponent concluded that the residual effects on food and nutrient content would be not significant.

The proponent also stated that because the watershed area of Lelu Island is approximately 0.0032 percent of Skeena and Nass River watersheds, the loss of nutrient input into the estuarine areas from infilled watercourses on Lelu Island is not expected to have a measurable effect on water chemistry, including total nutrient content of waters surrounding the island.

According to the proponent, effects on vegetation would mainly occur as a result of land clearing during site preparation activities on Lelu Island. The Project would remove approximately 162 hectares of vegetation in the local assessment area. This represents 64 percent of the local assessment area, which covers 254 hectares. It has been suggested that the loss of wetlands adjacent to Flora Bank would decrease the food supply for juvenile salmon, and thereby reduce Skeena salmon production. Human modifications to the environment could potentially affect the foraging performance of juvenile fishes by altering the overall abundance of prey, the types of prey, or the intensity of competition for prey (e.g., Francis and Schindler 2009; Naiman et al. 2012; Toft et al. 2007), with population-level consequences.

The juvenile stage of many fishes is an important life history period when variation in foraging performance can affect survival and regulate population dynamics (Kennedy et al. 2008). Estuarine habitats are often highly productive foraging zones for juvenile salmon (Thorpe 1994) and estuarine residence can be a time of rapid growth for juvenile salmon prior to marine entry (Duffy et al. 2005). Because the amount and energy content of consumed prey affect juvenile salmon growth (Beauchamp 2009), high rates of prey (and energy) acquisition in the estuarine environment are critical (Levings 1994). Failure of juvenile fishes to acquire sufficient prey may result in death due to starvation (Kennedy et al. 2008), lengthen the period of vulnerability to size-dependent predation due to suppressed growth (Sogard 1997), force fish to adopt riskier behaviors to capture prey thereby increasing their vulnerability to predation (Biro et al. 2003), or drive fish to expend more energy to capture prey (Giacomini et al. 2013).

Energy flux between terrestrial and aquatic ecosystems is increasingly recognized as an important component of food webs across a diverse range of biomes (Polis et al. 2004). In the spring and summer, estuaries often support high densities and diversities of insects, benthic and planktonic crustaceans, and other invertebrates that are preyed upon by juvenile salmon; this high productivity coupled with high consumption rates contributes to rapid growth in these habitats (Wissmar and Simenstad 1988; Duffy et al. 2010). In one study with juvenile Chinook salmon, it was found that they consumed a diverse array of prey across nine Pacific Northwest estuaries. Dipterans (flies) and amphipods were the most frequently consumed taxa, accounting for five of the six most frequently consumed prey categories. Other consumed taxa included insects such as hemipterans (plant hoppers), coleopterans (beetles), and hymenopterans (wasps, bees, and ants), and crustaceans such as cumaceans, mysids, and copepods. Broadly, the stomach contents of juvenile Chinook salmon were dominated by insects and crustaceans, while annelid worms and other arthropods such as collembolans (springtails) and arachnids (spiders, mites) were less commonly consumed. Visualization of the diet data suggested that the contribution of crustaceans to salmon diets increased with increasing salinity, while the contribution of insects decreased.

Many of these taxa are associated with benthic and epibenthic environments of emergent marshes and other tidal wetland habitats (Simenstad et al. 2000) or derive much of their energy from primary production in tidal wetlands (Maier and Simenstad 2009), highlighting the vulnerability of juvenile salmon prey to loss or degradation of estuarine wetlands. Diking and development of wetlands could impact many of these invertebrate taxa by blocking access to habitats used on a regular basis (e.g., benthos and marsh plain) or by disrupting the transfer of energy from primary production in intertidal wetlands to invertebrates in other parts of estuaries. Importantly, wetland loss was also associated with the types of prey that salmon consumed. Ephemeropterans, trichopterans, and plecopterans were consumed more extensively in estuaries with the smallest proportional wetland losses. In freshwater ecosystems, these taxa are sensitive to human land use modification (e.g., Harding et al. 1998), and these results suggest they may also be sensitive to wetland loss and other human modifications to estuaries, at least in the low-salinity upper reaches of estuaries. Hymenopterans and collembolans were consumed more extensively in estuaries with greater wetland losses, which could indicate reduced availability of wetland associated prey and greater reliance on terrestrial prey that fall onto the water surface. Evidence that estuarine wetland loss may magnify the effect of conspecific density on juvenile Chinook salmon foraging performance and may alter the consumption of some invertebrate taxa.

In addition to wetland losses, loss of terrestrial vegetation may also affect the diet and energy consumption of juvenile salmonids. For example, in a study by Francis and Schindler (2006) lower riparian vegetation density on urban lakes resulted in a corresponding decrease in the terrestrial portion of fish diets suggesting that deforestation has direct effects on fish diets. At a broader geographical scale, a 2002 survey of 20 of 28 Pacific Northwest lakes demonstrated a decrease in riparian forest density with urban shoreline development resulting in a concomitant decrease in terrestrial insects in fish diets.

In addition to the loss of wetlands and terrestrial vegetation, development such as shoreline armoring (hard structures such as seawalls or riprap bulkheads built to prevent coastal erosion) can also constitute a stressor for outmigrating juvenile salmon using nearshore habitats for foraging, physiological transition, and refuge from predators. One known effect of shoreline armoring is reduced aquatic-terrestrial connectivity (Heerhartz et al. 2014) resulting in decreased inputs of high-energy insect prey. Diet studies show that juvenile salmon consume fewer insects along armored shorelines (Toft et al. 2007), indicating a reduction in high quality prey. Decreased availability of these prey items may require juvenile salmon to increase their foraging efforts to meet their energy demands, essentially consuming higher quantities of lower-quality prey (Duffy et al. 2010). However, increased foraging effort may make these juveniles more conspicuous and susceptible to mortality from predators, as has been demonstrated in lakes (Biro et al. 2003). Predation mortality has been shown to have an influence on juvenile salmon survival in some estuarine systems (Miller et al. 2013). Shoreline armoring truncates the intertidal gradient resulting in increased water depths when the tide is high, especially where shoreline armoring extends well into the intertidal zone (Toft et al. 2007). Juvenile salmon along armored shorelines may be forced into deeper waters or other less-preferred habitats, where foraging comes at a higher energetic cost if potential prey items are more difficult to locate, and they may encounter increased predation risk (Duffy and Beauchamp 2008).

Increasing shoreline development, alteration of nearshore habitats, and loss of wetlands and terrestrial vegitation may be altering prey abundance, diversity, and adequate feeding opportunities. There are several mechanisms limiting survival (i.e., predation, prey resources) that may occur during and subsequent to this critical early marine life history stage through the impacts of the proposed project.

7.8 Smolt physiology and energetics

Altered somoregulatory mechanisms and energy metabolism are amongst he most important changes that accompany the smolting of migrating salmonids. The preadaptation to hypoosmotic regulation n fresh water, as expressed by elevated Na, K-ATPase activity in gills and better regulation of body water and ions in sea water, are well documented phenomena (for review, see Folmar and Dickhoff 1980). In fresh water, plasma and tissue chloride concentrations decrease and glomerular filtations rate andrine flow alter. The body energy stores, total bocy lipid and liver glycogen content decrease, and blood glucose conentration increases during smoltification (Wendt and Saunders 1973). These changes indicate that energy reserves are mobilized fo the metabolic needs of smoltification. Woo et al. 1978, suggested that the mobiliazation of lipid and glycogen reserves is required for the development of hypoosmoregulatory capacity.

Estuarine habitats are often highly productive foraging zones for juvenile salmon. (Thorpe 1994), providing them with transitional habitats for physiological adjustment before they move into higher-salinity nearshore waters.

Juvenile salmon and steelhead apparently depend on this area for two functions: acclimation to salt water, during which they must become accustomed to progressively higher salinities over a period of several days; and feeding on plankton and benthos, which must permit fast enough growth to minimize mortality from predation.

The development of salinity tolerance is obviously important to seaward migrants and has been the most widely studied physiological change that occurs during smolting. The mechanisms for increased hypoosmoregulatory ability include differentiation of the gill, gut, and kidney (McCormick and Saunders 1987). Increased gill Na^+, K^+-ATPase activity, number and size of gill chloride cells, and intestinal water permeability have been strongly linked to increased salinity tolerance during smolting (Boeuf 1993). Although parr can survive gradual acclimation to seawater, smolts can directly hypoosmoregulatory ability permits uninter-rupted feeding after seawater transfer, whereas nonsmolts experience high plasma ion concentrations and delayed feeding for several days (McCormick 1994). The increased salinity tolerance of smolts also permits decreased estuarine residence time (McCormick et al. 1985) and improved swimming performance in seawater (Jarvi 1989), both of which may reduce exposure to estuarine predators.

The embryos and larvae of all Pacific salmon are intolerant of sea water. The embyros of pink and chum salmon, which spawn in coastal stream mouths, have a greater tolerance to moderate salinity than those of coho, chinook, or sockeye, and can apparently withstand periods of inundation with dilute sea water. At the fry stage, pink and chum salmon are fully tolerant of seawater whereas the fry of coho, chinook and sockeye must remain in freshwater. Pink and chum salmon are therefore able to utilize small coastal streams for spawning, without regrad to habitat requirements for a one to three year freshwater residency. Chinook and sockeye are restricted to larger streams with abundant habitat, such as in systems with large lakes, and coho are known for their ability to seek out and thrive in extremely small and diverse kinds of habitat. It is in the seaward migration of juvenile salmon and steelhead smolts that estuaries (in the dynamic and biological sense) are of importance for salmon production. Seaward migration of coho, chinook, sockeye, and steelhead in the Skeena is closely associated with the spring freshet. During the freshet, discharge is at a maximum and consequently the size of the area of reduced salinity in the estuary is maximized. Studies on acclimation of young salmonids to sea water have shown that the fry of pink salmon are tolerant of seawater, whereas sockeye and coho smolts require an extended period, several days to a few weeks to gradually develop a tolerance for higher salinities as their osmoregulatory processes reverse. The demand for estuarine conditions may increase sustantially as salmon enhancement programs, now beginning in the Skeena tributaries, multiply the salmon populations migrating down the Skeena. Similarly, the estuary in the Skeena may not be fully utilized in most years, but under certain weather or Skeena discharge conditions, salmon production may depend entirely on areas such as Flora Bank for certain physical conditions. The diversity of habitat available for all phases of the life history is a major factor in salmon survival under adverse conditions.

Under normal conditions Flora Bank and shouldering Agnew Bank are uniqe and important habitat for the north turning Skeena River salmon smolts because they lie withing the 15% contour of freshwater, whereas nearby Ridley Island and Digby Island only have this beneficial level of freshwater during freshet. Of particular interest is the 15% freshwater contour. It is evident in the region of Flora Bank and Kitson Island during normal flow conditions and expands up the west coast of Digby Island during the high flows of the freshet. This transition area is probably of particular significance for young salmon: environments with salinity similar to that of the blood of salmon (isomotic) permit faster growths since less energy is spent on regulating internal water and salt levels than in either freshwater or sea water.

It is certain that not all areas within an estuary have the same fish productive capacity or biological significance. The data presented in this report show that the biological significance of this sub area within the Skeena estuary is very high. The potential impacts of construction and operation of the project on the fisheries resource in this area will not be compensated by offsets or wetland compensation due to the unique nature and characteristics of this unique habitat that is absolutely essential to the salmonid populations of the Skeena watershed.

8.0 SUMMARY AND CONCLUSIONS

This report evaluates the Draft EA Report of the CEAA regarding the potential effects of chemicals of potential concern (COPCs) on human health, as well as potential effects in the project area on salmonid habitat as identified in the Pacific Northwest LNG Summary of the EIS and Environmental Assessment of Certificate Application. The review was conducted to inform the UFAWU-CAW-CAW of the potential impacts to human health and salmonid habitat that may occur following dredging and disposal of contaminated marine sediment resulting from the project and due to construcion and operation of a liquefied natural gas (LNG) facility on Lelu Island in the Prince Rupert area of BC. This document was reviewed and the interpretations on the potential for effects in humans and on salmonid habitat in the project area were assessed. In addition, conclusions from an earlier report on the Pacific Northwest LNG Summary of the Environmental Impact Statement and Environmental Assessment of Certificate Application that continue to warrant attention are included in this summary.

- The assumption that As and Cu are background contamination and should not be considered COPCs is likely, however, a strict sampling program needs to be implemented to establish that the concentrations of these metals are background and natural;
- PAH, PCDDs and PCDFs are COPCs in the proposed operation areas;
- The mean concentration of PCDD/F in sediments in the most contaminated area near the proposed MOF is highest in the 0-0.5 m depth, and is as high as 2.64 ng/kg TEQ PCDD/F;
- Movement of contaminated sediment by dredging will uncover more contaminated sediments and may increase concentrations near the sediment surface in the loading area;
- The resuspension of contaminated sediment via dredging will occur, increasing the bioavailability of PCDDs and PCDFs to marine organisms. This will likely increase marine organism exposures, their potential accumulation and potential food web transfer;
- The potential effects of PCDD/F exposure may occur in several ecological receptors (e.g. microorganisms, algae, zooplankton, benthic invertebrates, invertebrates, fish, mammals and birds, as well as in humans;
- The observed sediment concentrations of PCDD/Fs and other contaminants, the potential for PCDD/F biomagnification, and the myriad of toxic effects in both human receptors suggest that there is potential health risks associated with the proposed dredging activities;
- Based on the First Nations communities in the area, and their reliance on fish and shellfish (i.e., subsistence fishing), it is recommended that the seafood consumption rates used be reflective of their use for calculating Hazard Quotients;

- Baseline estimates of Hazard Quotients indicate the potential for unacceptable health risks associated with the consumption of marine country foods under current/baseline conditions;
- The re-suspension of sediments during dredging may result in increased exposure of marine organisms to PCDD/Fs for some period resulting in increased risk to humans consuming marine country foods;
- Given the lack of feasibility in predicting post dredging conditions, it is not possible to conduct a human health risk assessment (HHRA) to assess the impact of the Project on human health at this time;
- Several recommendations are given to improve the program (to verify that dredging of marine sediment at the Materials Offloading Facility does not result in increased risk to human health) that would help to ensure that human health risks are adequately characterized;
- The dumping of contaminated sediments on land increases the potential for human receptors to be directly exposed to the sediments. It is recommended that a HHRA be conducted to evaluate the potential risks associated with such exposures;
- Salmonid sampling programs throughout the Skeena River estuary show that all species of juvenile salmonids are found in the project area, and that some of the highest abundances of some species of salmonids are found in areas proposed for development;
- Sensitive habitats including Flora Bank and dependent organisms (e.g. juvenile salmonids) are at particular risk from the proposed dredging operation;
- it is unlikely that given the use and potential importance of this particular area in the Skeena estuary, that any wetland restoration, enhancement or creation will compensate for the loss of such an important area to migrating juvenile salmonids;
- In order to mitigate the potential effects of proposed project activities on wildlife and in humans, alternatives to the application should be explored.

9.0 STATEMENT OF LIMITATIONS

This review has been prepared and the work referred to in this review has been undertaken by Biowest Research Consultants for the United Fishermen and Allied Workers' Union (UFAWU-CAW). It is intended for the sole and exclusive use of the UFAWU-CAW and its authorized agents for the purpose(s) set out in this review. Any use of, reliance on or decision made based on this report by any person other than UFAWU-CAW for any purpose, or by UFAWU-CAW for a purpose other than the purpose(s) set out in this review, is the sole responsibility of such other person or UFAWU-CAW. UFAWU-CAW and BIOWEST RESEARCH CONSULTANTS make no representation or warranty to any other person with regard to this review and the work referred to in this review and they accept no duty of care to any other person or any liability or responsibility whatsoever for any losses, expenses, damages, fines, penalties or other harm that may be suffered or incurred by any other person as a result of the use of, reliance on, any decision made or any action taken based on this review or the work referred to in this review.

This report has been prepared based on the UFAWU-CAW Statement of Work and the literature identified during the review. It is based on the literature specifically identified in the review at the time of the review. BIOWEST RESEARCH CONSULTANTS expresses no warranty with respect to the accuracy of the data reported in the literature.

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