23 EFFECTS OF THE ENVIRONMENT ON THE PROJECT

An environmental assessment of a designated project must take into account a number of factors including any change to the designated project that may be caused by the environment (CEAA 2012).

The primary mitigation tools to prevent or reduce the severity of adverse environmental effects of the environment on the Project are sound engineering design and planning so that the facility systems can withstand routine and extreme physical environmental conditions. All engineering design must meet the standards set by the National Building Code of Canada (NBCC 2010) and the Canadian Standards Association (CSA 2011). It is expected that the facility will also be regulated by the BC Oil and Gas Commission (BC OGC) and will comply with BC OGC standards (including new LNG-specific regulations in early 2014). These standards form the basis for proper engineering design, which incorporate the effects of site-specific extreme physical environmental exposure. For example, engineering design must plan for high wind and storm effects and include material selection that inhibits corrosion.

The project infrastructure will consist of two main portions, the land and marine components. Land-based structures will be primarily affected by seismic events and meteorological conditions. Marine components will be affected by seismic events, meteorological and oceanographic conditions.

23.1 Physical Environmental Conditions Considered

The Project could be subject to the following environmental factors:

- Precipitation
- Fog and visibility
- Wind, tides and storms
- Seismic activity and tsunamis
- Climate change (changes in sea level rise, storm frequency and intensity).

Lelu Island is a flat low plain that has an elevation of approximately 35 m above sea level (masl) or lower. Island terrain is occupied by large expanses of muskeg that are predominantly underlain by granite. Lelu Island is undeveloped and covered with surficial peat and organic soils, which contain coarse roots and wood debris. Slope instability does not pose any risk to the Project because there are no hills within the property that could lead to a landslide. As a result, effects to the Project resulting from slope instability are considered unlikely and are not assessed further.

23.2 Spatial and Temporal Boundaries

The spatial boundaries for the assessment include all land and marine project components defined within the project development area (PDA). The temporal boundaries include the project construction and operations phases.

23.3 Significance Criteria

A significant effect of the environment on the Project would include an event that results in:

- A substantial delay in construction (e.g., more than one season), or
- A long-term interruption in service (e.g., loading LNG carriers), or
- Damage to infrastructure that compromises public safety, or
- Damage to infrastructure that would not be economically and technically feasible to repair.

23.4 Methods

Baseline climate conditions were determined from data representative of project site conditions. Data from the Prince Rupert Airport automated weather observing station (AWOS) (2007-2012) and Holland Rock station (2007-2013) were used to study the recent meteorology in the region. Historical Canadian Climate Normals (CCNS) were also extracted from the National Climate Data and Information Archive over the 30-year period of 1981 to 2010. The CCNS provide climate normal, averages and extremes trends based on available long-term data (typically 30-year datasets). A comprehensive analysis of climatic conditions including air temperature, precipitation, wind, and fog is provided in the Air Quality TDR (Appendix C). This information is combined with project-specific engineering design criteria to form the basis of this analysis.

Environmental factors that have the potential to affect the Project are assessed in the context of existing site conditions and project-specific mitigation measures proposed to avoid or reduce these potential adverse effects.

23.5 Environmental Effects Analysis and Mitigation

The design of all facility components considers potential effects of the environment on the Project, as required by the National Building Code of Canada (NBCC 2010) and the Canadian Standards Association document for LNG production, storage and handling (CSA Z276-11 2011). The application of standards for the Project is described in Section 2.1.2 (Project Design Standards and Policies).

23.5.1 Severe Precipitation

Precipitation data, over the 30-year period (1981 to 2010), was assessed from four Canadian Climate Normals stations closest to the project infrastructure. Data collected at the Prince Rupert Airport station was determined to be most representative of coastal site conditions. Historical records indicate September through to January are the wettest months of the year, while June and July are the driest.

At the Prince Rupert Airport station, the historical extreme daily rainfall (118.2 mm) was recorded during the month of September. Maximum daily rainfall events typically occur in September and October. During those months, the average monthly rainfall ranges from 266.3 mm to 373.4 mm. In winter, the clash between mild coastal air and colder air from the interior causes frequent changes in precipitation type between rain and snow. However, at sea level, the majority of the precipitation falls as rain even in December and January. The greatest snow depth on record (39.9 cm) was recorded in January. The most amount of snowfall is typically observed in December and January. During those months, the average monthly snowfall ranges from 22.8 cm to 25.6 cm.

23.5.1.1 Potential Effects

Severe precipitation events can result in stoppages of outdoor work if they create unsafe working conditions (as determined by the project manager or site supervisor). All components of the facility will be designed to support the structural loadings created by extreme snow and freezing rain. Site runoff and drainage from project components will be designed in accordance with the National Building Code of Canada to handle extreme precipitation and sudden snowmelt. Construction may be halted during extreme weather events. If these conditions compromise a safe operation in any way, accident prevention measures would be taken, including the temporary suspension of operations.

23.5.1.2 Mitigation

The Project is designed to accommodate rainfall up to 126.4 mm in a single day, and 17.6 mm in one hour, with an expected frequency of occurrence of 1 in 10 years.

Project-specific mitigations include the following:

- Environmental management plans (EMPs) will be developed to include provisions for site drainage, sedimentation and erosion control. In the event of a severe rain event, the design would prevent risk to facility structures.
- Stormwater runoff from plant areas subject to oil contamination will be curbed or diked and collected by a segregated underground oily-water sewer system. This system will drain to an oil-water separator system for oil removal. Runoff water would then be treated through the Port Edward municipal waste water system.
- Runoff from other, non-curbed areas of the facility will be collected by perimeter ditches draining to a first flush basin, which would collect the initial runoff. The excess will be diverted to the clean runoff system.
- Clean runoff water will be collected by surface ditches for discharge to the ocean via pre-disturbance drainage pathways through the wetlands bordering the PDA.

23.5.2 Fog and Visibility

Fog is a reduction in visibility due to the suspension of very small water droplets or ice crystals in air. Historical visibility data from the Prince Rupert Airport station were analyzed over a 30-year period (1981-2010)(Air Quality TDR, Appendix C). Environment Canada (2013) defined fog as reducing visibility to 0.5 statute miles (0.8 km) or less. The annual average number of hours of fog is 188.6 hours per year based on data from 2007 to 2010 from the Prince Rupert Airport AWOS station. The most fog occurs from July to October, with a peak in August (31.8 hours per month).

23.5.2.1 Potential Effects

Effects of fog and reduced visibility can affect navigation safety and shipping schedules at the terminal.

23.5.2.2 Mitigation

LNG carriers will comply with all relevant international and Canadian regulations pertaining to conduct of navigation in reduced visibility, including standards of watch keeping and use of equipment such as radar, automatic identification systems and fog signals. The Marine

Communications and Traffic System (MCTS) will monitor LNG carrier movements in the Prince Rupert area. LNG carriers are accustomed to transit in fog and are equipped with the appropriate navigation equipment. LNG carriers underway within Chatham Sound will follow the direction of the MCTS during extreme weather events and reduce speed, as appropriate. LNG carriers would commence transit within the Prince Rupert area only if environmental limits for safe transit are not breached.

The PRPA area and its approaches is also subject to mandatory pilotage, which will further increase the safety associated with transit in fog and conditions of reduced visibility. This means each LNG carrier will be piloted between Triple Island and the marine terminal berths. The pilots would bring LNG carriers into the marine terminal only in safe weather conditions and in compliance with Terminal operations limits that will be set for wind and wave height.

23.5.3 Wind, Tides and Storms

Lelu Island is not sheltered from the oceanic influence of Chatham Sound. Surface level winds from the ocean areas are strongly influenced by the surrounding topography in the inland and island regions.

At the Holland Rock station (located 6 km southwest of Lelu Island), winds blow predominantly from the southeast. Wind speeds are moderate, with average speeds of 5.8 m/s (20.9 km/h) and maximum gust speed of 36.7 m/s (132 km/h) between January 2007 and June 2013. Calm winds (less than 0.5 m/s) occur about 1.1% of the time.

At the Prince Rupert Airport station (located on Digby Island, 14 km northwest of the Project), winds blow predominantly from the south-southeast or east. Wind speeds are moderate, with average speeds of 3.5 m/s (12.6 km/h) and maximum gust speed of 31.9 m/s (115 km/h) between January 2007 and May 2013. Calm winds (less than 0.5 m/s) occur about 7.2% of the time.

Regional shorelines generally experience two almost equal high tides and two low tides each day, called a semi-diurnal tide. The average and maximum tides are 4.9 and 7.7 m, respectively. At the berth, wave simulation results suggest the tide range reaches up to 7 m and is characterized by wave heights that exceed 0.15 m and 0.3 m about 50% and 10% of the time, respectively.

Wave data from two Ocean Data Acquisition System buoys located in Dixon Entrance and Hecate Strait indicate offshore waves at 1.5 m to 2 m wave height at the respective buoy locations. Long-period waves ranging between 8 seconds and 14 seconds are classified as swells. The data from these buoys suggest that the waves entering through the Dixon Entrance and Hecate Strait are mainly swells that are not locally generated or supported by the current wind.

23.5.3.1 Potential Effects

Wind and sea conditions can affect several aspects of shipping operations delaying pilot boarding or disembarking, docking, and cargo transfer.

High winds and heavy seas at low temperatures can cause freezing snow and spray conditions. Salt spray freezing results when the air temperature is below -1.8^{o}C, sea temperatures are below 6^{o}C and wind speeds are greater than 10 m/s.

LNG carriers can be affected by long period swells, for example in excess of 10 seconds. Wave heights, in themselves, are not an operating limit while the LNG carrier is moored at berth. Wave heights in excess of 1.5 m do however create an operating limit for the tugs that assist the LNG carriers, as they are substantially smaller and more sensitive to the height of a wave.

Overall, Lelu Island is not protected from waves or swells from Chatham Sound. The offshore project infrastructure (i.e., berth and trestle) has no protection from incoming Chatham Sound waves and swells. Extreme winds can produce high waves, dense blowing sea foam, heavy tumbling of the sea and poor visibility, all of which can make land and marine working conditions hazardous, and can result in temporary facility closures.

23.5.3.2 Mitigation

LNG carriers will undertake transit, maneuvering and berthing activities only within the environmental limits established specifically for the Project (see Table 23-1). Environmental limits include criteria for wind and significant wave height as applicable to each activity type.

Project-specific mitigations include the following:

- The berth will be designed to accommodate a significant wave height based on the upper 1st percentile mean wave height ($H_{1/100}$) for a 25-year return period.
- The Project will be designed to meet the extreme weather criteria identified in the National Building Code of Canada (NBCC 2010). If site conditions are more severe and require higher standards than NBCC, PNW LNG will design to more stringent requirements. (e.g., winds of 29 m/s).
- The top of the deck for the project berth platform will be between 13.5 and 21.3 m above Chart Datum. The design accounts for a high water level of 7.4 m, a potential sea level rise of 0.6 m over the 60-year design life, and a 100-year-return-period storm surge of 1.0 m.
- LNG carriers that do not have the capability to let go and retrieve their anchor because of ice formed on the LNG carrier deck or bow will be refused pilotage.
- Project-specific environmental limits will apply to LNG carrier activities (see Table 23-1)

Table 23-1: LNG Carrier Operating Environmental Limits

Activity Type	Environmental Limit	Ship Action
Pilot boarding/disembarking	Sustained wind ≥ 40 knots (20.6 m/s) or	Pilot transfer will be at the Master and pilot's discretion but may not be possible due to associated sea state
Transit	None	None
Maneuvering	Sustained wind ≥ 25 knots (12.9 m/s) or significant wave height ≥ 1.5m	Berthing delayed until environmental limits are met
Connect loading arms	Sustained wind ≥ 30 knots (15.4 m/s)	Delay connect
Cargo transfer	Sustained wind ≥ 30 knots (15.4 m/s)	Suspend cargo transfer
Cargo transfer	Sustained wind ≥ 35 knots (18.0 m/s)	Disconnect arms
At berth	Sustained wind ≥ 40 knots (20.6 m/s)	Consider leaving berth

23.5.4 Seismic Activity and Tsunamis

The west coast of Canada experiences higher than the national average seismic activity due to its location near some major plate tectonic boundaries. Near Vancouver Island, the Juan de Fuca Plate is currently moving eastward beneath the North American Plate (upon which most of Canada rests). Near Haida Gwaii, the Pacific Plate is moving northwest along the edge of the North American Plate. The Queen Charlotte Transform Fault (QCTF), which lies approximately 150 to 200 km west of the Project, takes up most of the movement, which is estimated at 49 mm/year (Bustin et al. 2007; Lay et al. 2013). It is possible that some of the movement is also convergent (with the Pacific Plate sliding beneath the North American) (Mazzotti et al. 2003). These movements cause ongoing small earthquakes, but rarely at magnitudes that are sufficient to cause damage to buildings and infrastructure in the immediate communities. Since it is not possible to predict when large earthquakes might occur, it is important that project proponents along the west coast of Canada be prepared for such events.

Several large earthquakes (greater than a magnitude 7 earthquake) have occurred since 1880. The main source of these earthquakes has been the QCTF, with the north-south trending QCTF causing a magnitude 8.1 strike-slip event in 1949 (Bostwick 1984). However, no tsunami event resulted from it (NGDC/WDC 2013).

On the north coast of BC, the largest recorded tsunami event occurred in 1975 near Bish Cove. The tsunami was triggered by a local submarine landslide in the Kitimat Inlet with a wave run-up (height of water onshore, above a sea level datum) of 8.5 m recorded across from the Douglas Channel. Between 1918 and 2012, there were 15 seismic events that generated tsunami events near Lelu Island. Five of those seismic events originated along the west coast of BC, and ten were transoceanic in origin (between 320 to 1,600 km off the BC coastline). The historical recorded maximum tsunami wave height was approximately 5 m in the immediate vicinity of Lelu Island and was the result of a local seismic event near Graham Island, BC (March 28, 1963).

If there is a locally-generated tsunami (within 320 km), the arrival time could occur in minutes, requiring an immediate organized response within a short time for facility shutdown, evacuation of LNG carriers and personnel from Lelu Island. For far-field transoceanic seismic events, a significant wave height of 1 m to 2 m at Lelu Island would be expected.

The two sources of tsunamis that might affect Lelu Island are the QCTF system and submarine (underwater) and subaerial (on the surface) landslide events. Existing observations and tsunami records (NGDC/WDC 2013, Conway et al. 2012) indicate the most likely source of a seismic event in the Prince Rupert area is submarine in nature; a tsunami resulting from a subaerial event is considered unlikely.

23.5.4.1 Potential Effects of Seismic Activity on the Project

An earthquake with a magnitude substantially greater than the design-based earthquake could result in damage to facility components that would not be able to be restored, either technically or economically. The berth would likely sustain the greatest damage from an earthquake. An earthquake could lead to strong ground shaking, permanent surface fault rupture, and liquefaction of sediments. Surface rupture occurs when movement on a fault deep within the earth breaks through to the surface, typically several tens of meters wide. Preliminary results from a seismic risk study undertaken by PNW LNG suggest this hazard is negligible.

Liquefaction is a dramatic loss of strength that can occur in saturated coarse-grained soils during seismic shaking and results from increased pore-water pressure and reduced effective stress. This could lead to settlement and/or damage to the infrastructure. Project liquefaction triggering hazard is negligible in onshore areas based on preliminary results. This hazard has been determined to be of greater concern with nearshore infrastructure. Areas shown to be susceptible to liquefaction are expected to be excavated.

Seismic motion may also cause subsidence or uplift in the area due to the relative movement of the tectonic plates. As most motion is taken up by the QCTF, it is unlikely that subsidence/uplift will be sufficient to affect the Project.

23.5.4.2 Mitigation for Seismic Activity

Project components will be designed to the applicable standards including the National Building Code of Canada (NBCC 2010) and the Canadian Standards Association document for LNG production, storage and handling (CSA Z276-11 2011). These design standards promote the integrity of the facility based on the level of risk for an earthquake in the region. The level of risk is expressed in terms of specific return periods (i.e., 1 in 475 years) of an earthquake event. During such events, facility services may be interrupted due to earthquake damage. An earthquake with a magnitude substantially greater than the design-based earthquake could result in damage to facility components that would not be able to be restored, either technically or economically. For that reason, design-based earthquake magnitude values are selected based on probability. It would therefore be very unlikely that the design-based earthquake would be exceeded during the life of the Project.

Project design will include earthquake engineering work in the form of a seismotectonic model, probabilistic seismic hazard analyses, development of design acceleration response spectra, and assessing the soil-liquefaction triggering hazard at Lelu Island. Primary modelling results will be used to characterize the various seismic sources that may affect the Project.

Design levels defined for this Project comply with the requirements of CSA Z276-11. A seismic hazard assessment for the PNW LNG includes three levels of ground motions:

- The Safe Shutdown Earthquake (SSE) event corresponds to probability level of exceedance of 2 percent in 50 years (about 1 in 2,475 years).
- The Operating Basis Earthquake (OBE) event corresponds to probability level of exceedance of 10 percent in 50 years (about 1 in 475 years).
- The Aftershock Level Earthquake event is defined as 50% of the SSE ground motion.

A return period of 1 in 2,475 years is used to evaluate the potential for liquefaction of LNG sediments underlying the tank terminal. Overall, liquefaction triggering hazard is negligible in the onshore areas. The potential for liquefaction has been identified over limited, isolated seams and thin strata (less than 1 m) encountered above the final grade of about 25 m. Soils identified to have the potential for liquefaction will be removed and replaced.

Seismic hazard analyses for marine components of the Project are currently underway. The marine terminal will incorporate pipe-pile supported trestle and berth structures. Piles will be driven through the sediments and anchored into the underlying bedrock. Both the trestle and berths will consist of cast in place concrete caps, pre-stressed precast girders, and cast-in-place deck slabs. An earthquake with horizontal peak ground acceleration of 0.18 g or above could lead to permanent lateral ground movement and alter the berth and trestle foundation. This could lead to settlement and/or damage to the infrastructure.

Project-specific mitigations include:

- Design levels defined for this Project will comply with the requirements of CSA Z276-11.
- Bridge design criteria will include collapse prevention for the 1 in 475 years earthquake event. Bridge design will comply with the BC Ministry of Forests, Lands and Natural Resources Operations Bridge Design, Construction Standards, Guidelines and Bulletins.

23.5.4.3 Potential Effects of Tsunami on the Project

The seismic activity of the region may also result in tsunami risk. Tsunamis can be generated by earthquakes, volcanic eruptions, landslides or submarine landslides (Fritz et al. 2001, Rogers et al. 2002). The largest tsunamis tend to be caused by earthquakes with offshore epicenters (Bobrowsky 2001). Effects associated with exposure to a tsunami event include mass-wasting and flooding, shoreline stability and erosion.

Lelu Island is exposed to waves from Chatham Sound. Kinahan islands may provide a partial barrier to large waves or swells coming from the west-northwest (only).

Tsunami run-ups of up to 20 m above sea level (asl) have been predicted for some parts of coastal BC (Bobrowsky 2001), but the historical recorded maximum tsunami wave height in the immediate vicinity of Lelu Island was approximately 5 m. Thus, a potential tsunami with a run-up of 5 m in height is considered for the Project. The potential effects of run-up caused by a tsunami on the project site would include mass wasting (i.e., landslides, debris flow), shoreline erosion and flooding, and possible damage to facility components.

23.5.4.4 Mitigation for Tsunamis

The design code for LNG facilities is currently included in the Canadian standard CSA Z276-11, which does not dictate any direct action regarding tsunami hazard and risk assessment. Emergency Response offices of BC indicate that the Cascadia subduction zone events do not need to be considered for coastal communities (Emergency Management BC 2008). However, Natural Resources Canada indicates that the tsunami hazard for BC (0 m to 15 m wave potential) utilizes an unpublished model of a Cascadia event (NRCAN 2013). Although the Canadian government does not provide direct mandate regarding tsunami hazard and risk, a full characterization of local sources and analyses of this hazard will be carried out to support project design engineering.

Design significant wave heights consider 100-year return periods, with significant wave height of 1.0 m. In the event of an earthquake that would generate a tsunami, or where a tsunami warning is issued, it is expected that facility components would be secured to the greatest extent possible and evacuated quickly.

Project-specific mitigations include the following:

- Tsunami risk on marine facilities, bridge and other project components will be mitigated by adapting a 5.0 m (tsunami), 0.6 m (sea level rise due to climate change), and 1.0 m (safety margin) above mean se level rise.

23.5.5 Climate Change

Increasing concentrations of greenhouse gases in the atmosphere are predicted to enhance global climate change (IPCC 1990, 1995, 2001, 2007, 2013). Climate models and scenarios suggest that the climate in BC and the north coast will continue to change during the 21st century in the following ways, for example:

- Average annual temperature in BC may increase by 1ºC to 4ºC per century; however, changes on the North Coast will be moderated by the Pacific Ocean.
- Average annual precipitation may increase by 10% to 20% in the next century. Coupled with the increase in temperature, the north coast may receive more precipitation as rain, and less precipitation as snow.
- Wind speed and direction are expected to change; however, global circulation models are not able to accurately predict the changes in regional wind speed and direction. Some global effects have been studied (Wuebbles and Hayhoe 2003). This may alter existing patterns of atmospheric dispersion of air contaminants.

A change in sea level on the BC coast is the result of three distinct forces:

- BC's west coast land is still rebounding from the glacial loading during the last ice age (isostatic forces).
- BC's west coast is also down-warping due to tectonic plate movements (tectonic forces).
- The oceans are expanding due to warming and growing in volume due to glacial melt.

Increased temperatures may also contribute to a sea level rise. The IPCC (2013) estimated the global sea level rise to between 0.26 m to 0.82 m by 2100, depending on the scenario considered. Other atmospheric changes relating to climate change may include increased storm intensity and other changes relevant to coastal stability such as surface winds, ocean waves, storm surges, and ice conditions (Forbes et al. 1997).

23.5.5.1 Potential Effects

The effect of potential climate change on the Project was assessed qualitatively following guidelines from the CEA Agency (CEA Agency 2003).

The sensitivity of the Project to predicted climate change is ranked (see Table 23-2). The following rankings assess the effect of climate change on the Project:

- The construction phase is ranked as nil to low because changes in weather conditions are likely to only affect construction activities and transportation of materials modestly in the period between approval and completion of construction.
- The operations are assessed at nil to low. An increase in sea level and winds may affect both the jetty and the land-based infrastructure. An increase in storms may introduce

weather delays in LNG carrier berthing and loading. This risk is assessed as low. For all other parameters, sensitivity is ranked as nil. Increases in temperature and precipitation will not have an effect on project activities. The Project will be constructed to meet extreme weather criteria following the National Building Code and is not sensitive to direct climate changes.

- The decommissioning phase is ranked as nil to low, based on the eventual removal or partial removal of infrastructure, and nature and success of revegetation activities at the site, and climate conditions at that time.

Table 23-2: Project Sensitivities to Direct and Indirect Climate Influences

Climate Parameter	Project Phase		
	Construction	Operations	Decommissioning
Direct			
Mean temperature	Nil	Nil	Nil
Extreme temperature	Nil	Nil	Nil
Mean rainfall	Nil	Nil	Nil
Mean snowfall	Nil	Nil	Nil
Extreme precipitation	Nil	Nil	Nil
Extreme winds	Low	Low	Low
Indirect			
Sea level increases	Nil	Low	Nil
Extreme weather events	Low	Low	Low

23.5.5.2 Mitigation

The design of the structures incorporates an adequate factor of safety to address changes in weather severity during the lifetime of the Project, including storms and sea level rise resulting from climate change.

Project-specific mitigations include the following:

- Offshore infrastructure will be designed to accommodate a conservative sea level rise of 0.6 m, based on a 60-year design life.

23.6 Significance of Effects of Environment on the Project

A significant effect of the environment on the Project would be a substantial delay in construction, long-term interruption in services, or damage to infrastructure that is economically or technically unfeasible to repair, or compromises public safety. Since the Project will be designed to prevent or reduce the severity of adverse environmental effects of the environment, the likelihood of an adverse effect on the Project is low. Based on a consideration of the various mitigation strategies applied through design criteria and the Environmental Management Plan, it is concluded that potential adverse effects of the environment on the Project will be not significant.

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