Environmental Assessment Certificate Application

LNG Canada Export Terminal

Section 10 – Accidents or Malfunctions

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10 ACCIDENTS OR MALFUNCTIONS

In over 40 years of LNG storage and terminal operations worldwide, there have been no significant offsite public injuries or property damage, and millions of tonnes of LNG have been transported, stored, and used without any serious public exposure. This excellent safety record is partially attributable to the fact that, although natural gas is flammable, LNG, as a liquid, is not flammable or explosive. In addition, there is a broad set of standards, codes, and regulations that apply to the LNG industry. Nonetheless, there is potential for accidents or malfunctions to occur during the course of Project activities. This section assesses the potential effects of Project-related accidents or malfunctions. For the purposes of this assessment, an “accident” is defined by the AIR as an unexpected event or unintended action that may result in an adverse environmental, social, economic, heritage, or human health effect, and a “malfunction” is defined by the AIR as the failure of a piece of equipment, a device, or a system to function normally, which can result in an adverse environmental or human health effect.

Section 10.1 outlines LNG Canada’s prevention and response practices and procedures including details regarding preventative safeguards and response capabilities that will be in place to reduce the likelihood and associated consequences of any events. Section 10.2 identifies credible worst-case scenarios on which the assessment focuses. A credible worst-case scenario is considered one whose likelihood of occurrence is remote, but not out of the realm of possibility, and where the effect could be significant. Section 10.2 also describes the methods used to assess the selected event. Sections 10.2.3 to 10.7 assess each scenario in detail, with Section 10.8 addressing the potential for cumulative effects.

10.1 Prevention and Response

LNG Canada is committed to conducting safe and environmentally responsible operations, and incident prevention and response planning is a primary priority in all aspects of operations. LNG Canada uses the Hazards and Effects Management Process (HEMP), which is a structured and systematic hazard analysis method involving the identification, assessment, and control of hazards, and the recovery from effects caused by an accident or malfunction (refer to Section 10.1.1.2). All four components (identification, assessment, control, and recovery) are essential for the development and implementation of appropriate controls to manage or avoid hazards or the potential effects of an accident or malfunction so that associated risks are “As Low as Reasonably Practical” (ALARP). These components are inherent in many existing HSSE processes and activities.

LNG Canada’s focus during design, construction, and operation is on the prevention or mitigation of hazards that might result in an incident. The ultimate goal is to put sufficient barriers or controls in place to reduce the potential for an incident.

In the unlikely event of an accident or malfunction, the focus shifts from prevention to response and recovery, with the goal to mitigate the incident so that the full potential effects or consequences of an incident are reduced to ALARP.

Increasing the number, type, and quality of preventative controls reduces the probability of an accident or malfunction occurring. Increasing the number and or quality of recovery measures should mitigate the consequences of potential incidents. Together these controls and measures reduce the overall probability and consequences of the incident, thereby reducing the residual risk.

10.1.1 Prevention of Accidents and Malfunctions

LNG Canada is committed to designing and building an LNG processing and storage facility and marine terminal that ensures ongoing safe and secure operations, as well as safe shipping in and out of Kitimat. The Project will be designed, constructed, and operated in accordance with the Liquefied Natural Gas Facility Regulation, under the BC *Oil and Gas Activities Act*, which prescribes that LNG facilities be designed, located, installed, and operated in accordance with the Canadian Standards Association (CSA) Standard Z276-11: Liquefied Natural Gas (LNG) – Production, Storage, and Handling (2011). Other regulations that could be relevant to the prevention of Project-related accidents and malfunctions include:

- *Canadian Environmental Protection Act* (CEPA)
- Spill Reporting Regulation under the BC *Environmental Management Act*
- Federal *Transportation of Dangerous Goods Act* and associated regulations
- *Canada Shipping Act, 2001*
- Pollution prevention provisions of the following federal acts:
  - *Fisheries Act* (section 36)
  - *Migratory Birds Convention Act*
- Fire prevention and response measures in the BC *Wildfire Act* and Wildfire Regulation, and
- The International Convention for the Prevention of Pollution from Ships (MARPOL)
  - Annex I: Regulations for the Prevention of Pollution by Oil
  - Annex II: Regulations for the Control of Pollution by Noxious Liquid Substances in Bulk.

10.1.1.1 LNG Canada's Health, Safety, Security, Environment, and Social Performance Control Framework

LNG Canada has adopted the Shell Health, Safety, Security, Environment and Social Performance (HSSE&SP) Control Framework.

LNG Canada is committed to the safe operation of the proposed facility and will work with the local community, Aboriginal Groups, the District of Kitimat, the OGC, Transport Canada, and emergency responders to ensure robust safety and emergency response plans are in place during construction and operation, as described below.

The LNG Canada HSSE&SP Control Framework includes:

- policy and commitment statement
- standards for health, security, safety, the environment, and social performance, and
- specific manuals.

The HSSE Policy requires that LNG Canada:

- have a systematic approach to HSSE management designed to ensure compliance with the law and to achieve continuous performance improvement
- set targets for improvement and measure, and apprise and report performance
- require contractors to manage HSSE in line with this policy, and
- include HSSE performance in the appraisal of staff and rewards.

The HSSE&SP Control Framework contains a series of manuals that detail the standards and procedures for the effective management of health, safety, security, and environmental hazards. These will be applied to LNG Canada operations.

10.1.1.2 LNG Canada's Health, Safety, Security, and Environment Commitment and Policy

LNG Canada's HSSE Commitment and Policy requires a systematic approach to the management of HSSE&SP. The HEMP is at the heart of HSSE risk management and involves:

- identification (systematic identification of hazards, threats, unwanted events, and their potential effects)
- assessment (assessment of the risks against screening criteria as found in the risk assessment matrix (RAM), taking into account the likelihood of unwanted events and the potential severity of the consequences regarding effects on people, assets, the environment, and reputation)
- control (implementation of suitable risk reduction measures to control or mitigate the hazard and its effects), and
- recovery (planning for recovery in the event of a loss of control leading to an undesired effect).

The HEMP will be implemented through all phases of the Project to manage HSSE effects (over the lifecycle of the activity) on people, the environment, assets, and company reputation. The steps of the HEMP process may overlap or may have to be carried out more than once.

The main objective of the HEMP activities is to demonstrate that hazards (and associated risks) have been identified, and where the hazard cannot be eliminated, that the risks are tolerable and have been managed to ALARP. The principle of ALARP is that HSSE risks are demonstrated to be both tolerable (within all legislative and other company and project requirements), and also further reduced as far as reasonably practicable. To reduce a risk to a level which is ALARP involves balancing reduction in risk against the time, trouble, difficulty, and cost of achieving it. This level presents the point, objectively assessed, at which the time, trouble, difficulty, and cost of further reduction measures become grossly disproportionate to the additional risk reduction achieved.

In the end, the HEMP analysis allows for assessment of the suitability of control and recovery measures and drives toward ensuring that the HSSE critical tasks identified for these measures are being managed by a clearly identified responsible job function.

In addition to the HEMP methods, LNG Canada will implement the following:

- Asset Integrity and Process Safety Management Manual. The management of hazards that can give rise to major accidents involving the release of potentially dangerous materials, release of energy, or both. Asset integrity means the ability of an asset to perform its intended function effectively while safeguarding life and environment. The manual describes components of the asset integrity and process safety management (AI-PSM) system and associated roles/responsibilities. The LNG Canada philosophy is that the Project is designed and built so that its risks are ALARP, it works within the operational limits (including the maintenance of the hardware barriers), and leaders play an important role in avoiding process safety incidents and must daily demonstrate visible and felt leadership in the field.
- Process Safety Design and Engineering Practices. This is adopted from Shell, and the practices are mandatory for new assets and modifications to existing assets. The design features are based on learnings from historical catastrophic events in the oil and gas industry.

10.1.2 Emergency Response Planning

An emergency response plan framework (ERPF) will be developed for the Project. The purpose of the ERPF is to provide a framework under which all aspects of Project emergency response will be managed including phase-specific (i.e., construction, operation) emergency response plans (ERPs). It will outline the approach that will be taken to guide the development, implementation, and ongoing management of specific ERPs over the Project life cycle. The ERP will outline incident levels, associated response levels and resourcing strategies for effective emergency response, and will be developed in the context of Project location, organizational structure, and access to local and regional services. Project contractors will be required to establish equivalent ERP's for contractor emergency response procedures. An important objective is to ensure clear communication during an emergency between all affected stakeholders, including LNG Canada, contractors, regional and local authorities and resources as well as potentially affected Aboriginal Groups and local communities. Accordingly, phase-specific ERPs will be shared with local emergency providers, potentially affected Aboriginal Groups and stakeholders as appropriate, with the goal of optimizing efficiency and coordination among stakeholders with respect to emergency response procedures.

As LNG is a substance listed in Schedule 1 of the Environmental Emergencies Regulations under CEPA and it will be stored onsite in a quantity greater than the threshold level of 4.5 tonnes, LNG Canada will be required for the operation phase of the Project to prepare, implement and test an environmental emergencies (E2) plan consistent with the requirements set out in the E2 regulations and related guidance, and comply with requirements related to notification of government related to these tasks. During the preparation of the E2 plan and as recommended by Environment Canada, LNG Canada intends to share information on the plan with potentially affected Aboriginal Groups and stakeholders, as well as local, provincial and federal emergency response authorities as appropriate to increase coordination, communication and efficiency with respect to planned emergency response procedures. The OGC (2004) also requires oil and gas operators to have a current ERP to "ensure a quick, effective and appropriate response to emergencies in order to protect the public, company, and contract personnel from fatalities and irreversible health effects and the environment from damage."

As part of the phase-specific ERP, Spill Response Plans will be developed as appropriate and in accordance with the Emergency Management Regulation under the *Oil and Gas Activities Act* to protect the environment, personnel, and the public in the event of a hazardous material spill or emergency scenario during construction and operation. Procedures for emergency shut-down, coordination of emergency response actions, potentially including evacuation if necessary, will be outlined in the plan. The plan will also provide details regarding emergency response training programs, and will list the locations and types of emergency equipment available to personnel.

10.2 Scope of Assessment

10.2.1 Potential Accidents and Malfunctions Scenarios

As specified in the AIR, the following accident or malfunction scenarios are assessed:

- spills of hazardous materials (not including LNG)
- loss of containment of LNG in the LNG processing and storage site
- emergency LNG facility shutdown
- explosion and fire
- marine vessel grounding, and
- marine vessel collisions (i.e., with the wharf, a non-tug assisted vessel, or a marine mammal) including loss of cargo, where applicable.

Credible worst-case scenarios are identified for each potential incident using a conservative approach based on professional experience.

10.2.2 Assessment Method

The assessment of potential effects of accidents and malfunctions considers all of the following steps as identified in the AIR:

- description of the potential event

  For each of the above scenarios, further description is provided in Sections 10.2.3 to 10.7. The range of potential scenarios that could result in the identified incident are discussed based on past experience of the study team and Project engineers, as well as results of available risk assessment documentation prepared to date by LNG Canada. While there are a range of potential scenarios leading for instance to a spill of hazardous materials, the focus is on identifying the worst case credible scenarios with the greatest potential for affecting VCs (e.g., largest potential source, material with the greatest potential for environmental effect, most sensitive location in relation to the VCs)

- method for assessing the potential risk of each event

  The likelihood of each worst case scenario occurring is discussed quantitatively where data are available, based on historic statistics. Otherwise, a qualitative approach is taken. The consequence or environmental effects are assessed using the methods further described below.

- definitions for each category of likelihood and consequence

  Likelihood is considered qualitatively, supported by historical statistics where available. Consequence is addressed for credible worst-case scenarios for each of the identified incidents, using definitions of significance of the residual environmental effects, as defined for each VC.

- assessment of the probability of the event occurring

  By their nature, accidents and malfunctions are not likely to occur (i.e., the likelihood of occurrence is low), and the extent and severity can vary depending on the event or incident. Where data are available, the probability of an event occurring is quantified based on scientific research and expressed using the convention of presenting probabilities as a percentage.

- identification of mitigation measures to reduce the likelihood of the event

  In addition to the prevention and response measures identified in Section 10.1, as applicable to the overall Project, the assessment of each of the identified events includes a list of specific measures (i.e., mitigation measures) for the incident being considered. These measures will reduce the likelihood and the potential severity of the event and are identified as a minimum. Additional or more detailed measures are likely to be identified as LNG

Canada progresses through their internal risk management procedures and permitting stage in consultation with regulators, potentially affected Aboriginal Groups and stakeholders.

- assessment of effects and/or consequences that may result from such events

  Spatial boundaries used in this assessment are scenario and VC-specific and encompass the total area over which the VCs may be affected. The residual effects of each scenario are discussed for those VCs where an interaction is likely if the scenario occurs (refer to Table 10.2-1). For clarity of presentation, where residual effects from accidents or malfunctions, are inter-related, they are addressed together. For example:

  - Air quality, GHG management, acoustic environment, and visual quality are presented under Atmospheric and Visual Environment.
  - Vegetation resources and wildlife resources are presented under Vegetation and Wildlife Resources.
  - Freshwater estuarine fish and fish habitat, and marine resources are presented as Marine Resources and Freshwater and Estuarine Fish and Fish Habitat".
  - If adverse effects occur to the marine transportation and use, adverse effects on economic conditions will also likely occur; therefore, the potential effects on these two VCs are discussed together.

- identification of emergency response measures to mitigate the effects and consequences

  The assessment of each of the scenarios includes consideration of response measures that are specific to the accident or malfunction being assessed.

- conclusions on the potential risk of the accident or malfunction, including determination of significance as required in section 19 (1)(a) and (b) of CEAA 2012

  Significance criteria are VC-specific and are the same as those defined for each of the VCs in Sections 5 to 9. A summary of residual effect characterizations is presented for each scenario. The descriptors used to characterize the scenario residual effects are the same as those used for each of the VCs in cases where the descriptors are relevant for both the Project effects assessment and for the accident or malfunction effects assessment. The risk of the accident or malfunction to a VC is determined based on the likelihood of occurrence and consequence to the VC. The likelihood of an accident or malfunction is low, unless indicated otherwise. The consequence is low if the VC is not likely to be significantly affected; it is high if the VC is likely to be significantly affected.

- a cumulative effects assessment

  This is required in section 19 (1)(a) of CEAA 2012 and consistent with CEAA's Operational Policy Statement titled "Assessing Cumulative Environmental Effects under the Canadian Environmental Assessment Act, 2012" (May 2013). Cumulative effects are addressed in Section 10.8, as required by CEAA 2012 (section 19[1]).

Table 10.2-1: Potential Interactions of Project Accidents and Malfunctions with Valued Components

Accidents and Malfunctions Scenario	Air Quality	Greenhouse Gas Management	Acoustic Environment	Vegetation Resources	Wildlife Resources	Freshwater and Estuarine Fish and Fish Habitat	Marine Resources	Surface Water Quality	Economic Conditions	Infrastructure and Services	Visual Quality	Marine Transportation and Use	Community Health and Wellbeing	Archaeological and Heritage Resources	Human Health
Spills of hazardous materials (facility-related)	✓			✓	✓	✓		✓			✓			✓	✓
Loss of containment of LNG (in the LNG Processing Area and Storage Site)	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓			✓
Emergency LNG facility shutdown	✓	✓	✓		✓						✓				✓
Explosion and/or fire	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓
Vessel grounding and collisions (and associated cargo release)[1]	✓	✓			✓	✓	✓		✓		✓	✓		✓	✓

NOTE:

[1] The two scenarios, marine vessel grounding and marine vessel collisions, have been consolidated because the interactions are the same

10.2.3 Potential Interactions with Valued Components

Potential interactions of a Project-specific accident or malfunction with each VC are summarized in Table 10.2-1. A check mark indicates that an interaction could occur, in which case it is assessed in the subsequent Sections 10.2.3 to 10.7.

Interactions between the accident and malfunction scenarios and other potential VCs that were excluded from the Application are not expected except for land use under the explosion and/or fire scenario (Section 10.6.4.6) and odour under the spills of hazardous material (Section 10.3.4.1) and the explosion and/or fire (Section 10.6.4.1) scenarios.

10.3 Spills of Hazardous Materials (Facility-Related)

10.3.1 Scenario Description

Hazardous materials may include any item or chemical which poses a health or physical hazard and is a risk to public safety or is an environmental hazard in the event of an accident or malfunction. Although the likelihood of occurrence is low due to the range of standard prevention measures that should be in place with management of any hazardous materials, an accident or malfunction is possible during any stage of the Project. A range of hazardous materials will be either produced, transported, stored, or used onsite (e.g., condensate, propane, diesel fuel, lubricants, hydraulic fluids, compressed gases, form oil, paints and coatings, epoxies, glycol, cleaners, solvents, liquid asphalt/tars, and batteries).

Onsite storage or use of hazardous materials will comply with all relevant regulatory requirements, and secondary containment measures will make an uncontained spill unlikely. The most likely scenario is the spill of relatively small amounts of lubricating oils, fuels or other equipment fluids which may occur through refueling or leaks from machinery or valves. The volume of these spills is usually less than a few litres. Such spills are typically highly localized, limited to the required containment areas and bermed Project footprint, and readily cleaned up by onsite crews using standard equipment and materials. There is a very small potential for hazardous materials to enter the freshwater systems by direct discharge (e.g., gasoline or diesel leaks from maintenance vehicles travelling onsite). This is low risk because refuelling and maintenance areas will be located a minimum of 30 m from any water bodies or sensitive areas and proper equipment maintenance and inspection further limits the risk of leaks from equipment operating in proximity to any waterbodies.

While highly unlikely, the credible worst-case scenario for a facility-related hazardous material spill is related to a condensate spill, either due to a breach of a tank or equipment failure or leakage during loading operations from the tank to rail cars. Condensate will be stored in a fixed roof storage tank with a floating internal roof currently planned to be located at the northwest corner of the LNG processing and storage site. The tank capacity is estimated to be 10,000 m^3. The condensate loading system will be capable of loading up to approximately 20 rail cars daily at an approximate loading rate of 200 m^3/h to 400 m^3/h.

Note that the potential for loss of containment of LNG in the LNG processing area and storage site is discussed in Section 10.4. The potential for vessel collisions and groundings that could subsequently result in a hazardous material spill is discussed in Section 10.7.

10.3.2 Project Design Measures to Reduce Risk and Consequences

Hazardous or toxic liquid wastes are specified and regulated in the BC *Environmental Management Act* (2003) Hazardous Waste Regulation, and Schedule 1 of CEPA. Construction and operation discharges and wastes will be managed to ensure compliance with applicable policies and regulations.

Condensate storage tanks are designed and built in accordance with requirements outlined in BC regulations with respect to layout and spacing, potential seismic activity and site-specific environmental loads, such as snow, wind, and rainfall. In addition, the bunds (dykes), bunded areas, and site stormwater drainage systems will conform to BC regulatory requirements. Tank foundations will include a release prevention barrier (RPB) and leak detection system. Foam fire protection systems for the storage tanks will conform to BC regulatory requirements and the tanks will be equipped with automatic tank gauging and inventory monitoring systems together with level alarm instrumentation for tank overfill protection.

Condensate loading will only occur during the day light hours and the loading lines will be equipped with nitrogen to purge the loading arm free of product to avoid excessive drips. During loading of the railcars, there will be displacement vapours from the rail cars, which will be captured and sent to a vapour recovery unit. Venting of vapour from the railcars to the atmosphere will not be permitted under any circumstances.

Other Project design features aimed at hazardous material spill prevention and response include the following:

- All fuel storage facilities at the LNG processing and storage site will be registered with the BC Ministry of Environment in accordance with the Petroleum Storage and Distribution Facilities Storm Water Regulation under the *Environment Management Act*.
- Fuel and hazardous material storage tanks will be designed and operated as per the specifications of applicable acts, regulations, and codes, including secondary containment systems for above ground storage tanks. Storage of hazardous materials will not occur within a minimum of 30 m of water bodies or other sensitive habitats and the location of hazardous materials storage will be identified on a construction drawing to provide current information to workers present at the site.

- Bulk storage of hazardous materials that will be used in large volumes will be in above-ground, purposely built storage tanks with secondary containment as required. Materials requiring less substantial volumes will be stored in drums with secondary containment as required specifically for the product. Only those persons trained in safe materials handling practices will handle hazardous materials. Appropriate firefighting equipment shall be present at materials storage facilities.
- All hazardous materials will be inventoried and monitored, and the inventory will be updated as the Project progresses, to add or remove materials as required. Workers will be advised of the hazardous materials that will be used or be present during construction in accordance with the Canada-wide Workplace Hazardous Materials Information System (WHMIS) Regulations and the Occupational Health and Safety Regulation under the BC *Workers Compensation Act*.
- All transportation and handling of hazardous materials will be in accordance with the requirements of the *Transportation of Dangerous Goods Act* (TDG Act). All commercial vehicles will be inspected and evaluated to ensure compliance with the placard standards in the Act and Regulations. Appropriate documentation must be in place with commercial transporters in accordance with the materials being transported and the required transportation procedures.
- Mitigation measures will be in place to prevent small spills from occurring, such as regular maintenance and inspection of equipment, use of drip trays, and use of designated areas for refueling and maintenance that are a minimum of 30 m from any watercourses and sensitive habitat. Spill kits, including items such as absorbent pads and socks, specialized personal protective equipment and disposal bags or bins will be maintained onsite and employees will be trained in their use.
- Drainage systems will be in place for continuous oil contaminated water collection, accidently contaminated water collection, and collection of process effluent.

10.3.3 Response Measures

As described in Section 10.1, in the event of a hazardous material spill, LNG Canada would implement an Emergency Response Plan that includes a Spill Response Plan (Mitigation 10.1) to protect the environment, personnel, and the public. Specific procedures, in the event of a spill, will be detailed in the plan, and will address the following requirements:

- response action will take into account the risks associated with the spilled material
- spill response materials will be available onsite at all times, including absorbent material maintained on hand to facilitate the clean-up of spills in open areas
- in the event of a casualty, the first priority is the safety of personnel and to initiate actions which may prevent escalation of the incident and pollution

- immediate steps will be taken to control the spill including where possible, stopping the flow of the discharge
- response to spilled material of a hazardous nature will be carried out by trained, competent and properly equipped personnel
- under circumstances where identification of a spilled material is not confirmed (e.g., a spill from a container), the product shall be treated as a hazardous material spill, until the spilled material is identified and confirmed by the team
- the Material Safety Data Sheet (MSDS) will be consulted for properties of the spilled material that may require specialized response procedures
- action taken in the event of any spilled material will be in accordance with the Emergency Response Plan – Spill Management section, and
- action will include proper notification of personnel, regulatory agencies and potentially affected Aboriginal Groups and stakeholders as required in the Emergency Response Plan.

With respect to the condensate tank, the preferential flow path will be confirmed once siting of the tank is finalized. Emergency containment and recovery plans will be developed specific to the preferential flow path and potential flow rate including diagrams of the surrounding layout, topography, evacuation paths and drainage flow paths, ground and surface water resources, and sensitive ecological and protected areas. Included will be procedures to repair any secondary containment breach, conduct post-spill response investigation to evaluate the performance of spill management measures, and to collect post-response samples of soil and water as appropriate for testing.

10.3.4 Potential Residual Effects

A facility-related spill of hazardous materials is a credible worst-case scenario whose low likelihood of occurrence will be further reduced through implementation of the general prevention measures outlined in Section 10.1 and the specific Project design measures to reduce risk outlined in Section 10.3.2. The mitigation (prevention and response) measures outlined in Sections 10.1, 10.3.2 and 10.3.3 will also reduce the likelihood and severity of potential residual effects associated with a facility-related spill of hazardous materials.

10.3.4.1 Atmospheric and Visual Environment

An accidental event exposing light hydrocarbons (i.e., condensate or diesel) to the open air would release volatile organic compounds (VOC) into the atmosphere. The effect of such a spill on air quality would be localized (within 1 km) and brief (hours to days). The light hydrocarbons are non-toxic when adequately dispersed such that exposure would be limited, particularly if suitable protective clothing is worn. Depending on the volume of material spilled, odour may be detected in the immediate vicinity. If ignited, the burning of condensate will result in the release of products of incomplete combustion, including particulate matter and hydrocarbons, such as polycyclic aromatic hydrocarbons (PAHs). Clean-up of the site would employ haul trucks and earth moving equipment that would release particulate matter and combustion gases through fuel consumption and fugitive dust emissions. Changes in air quality due to a spill will be local in geographic extent, affecting only the immediate vicinity. Pollutant emissions from the clean-up will be sporadic in frequency and short in duration, and could also result in a temporary adverse effect on the visual environment. The likelihood of a spill is low and the volume of a potential spill is also expected to be low. The effects on the atmospheric and visual environment will cease once the clean-up is complete. Contaminant emissions are expected to be within all pertinent standards and guidelines at the property boundary. The risk of a condensate spill on the atmospheric and visual environment is low, of short duration, and reversible. As such, potential adverse residual effects are assessed as not significant.

10.3.4.2 Vegetation and Wildlife Resources

The magnitude and duration of any potential effects of a light hydrocarbons (i.e., condensate or diesel) spill on vegetation and wildlife resources would depend on the quantity spilled, the location of the spill, and the time of year in which the incident occurs. Condensate spilled into the environment is expected to mostly evaporate within a couple of days, and is not expected to bioaccumulate. It would have high acute toxicity during that period because it also contains the monoaromatic hydrocarbons (benzene, toluene, xylene) that are soluble and therefore toxic within aquatic environments.

While such a spill has the potential to interact with vegetation and wildlife resources, the residual effects are assessed as not significant as response procedures will be developed to contain and manage spilled product to a localized area and likely within the facility boundaries, thus limiting any potential interaction with vegetation and wildlife. Fuel storage tanks will not be located near important habitat for species of conservation concern, nor will they be located within 30 m of any watercourse or waterbody. Even if a large spill were to occur, it is unlikely to result in mortality or physical injury to wildlife or wildlife habitat such that population-level effects would occur.

Residual effects are predicted to be localized, short term, and reversible, and are assessed as not significant. Given the low probability of an extensive condensate or diesel spill occurring and the limited potential for any spilled material to interact with vegetation and wildlife resources, the risk of an effect is low.

10.3.4.3 Surface Water Quality and Freshwater and Estuarine Fish and Fish Habitat

In the unlikely event of a condensate spill, most material would be expected to evaporate within a couple of days (dependent on ambient temperatures). The potential pathway for a spill of condensate to enter nearby streams or rivers is very limited and the barriers and containment measures in place make the potential of a spill reaching the aquatic environment highly unlikely. While also unlikely, the greatest potential for interaction with the aquatic environment would be a spill of diesel fuel during construction activities. There will be onsite diesel storage tanks of approximately 1,000 m^3 to fuel construction equipment.

In the unlikely scenario that a spill of diesel were to reach the aquatic environment (e.g., the Kitimat River), freshwater quality would be adversely affected, and harm or mortality to fish and/or fish habitat could result. The geographic extent of the environmental effects would depend on the quantity spilled and would include areas downstream of the entry site, including the potential to affect the estuary and marine environment. Note that the effects of a hydrocarbon spill on the marine environment are fully addressed in Section 10.7. While toxic to aquatic organisms, diesel would evaporate or disperse rapidly into the water column (i.e., within 24 hours). Lytle and Peckarsky (2001) studied the effects of a diesel fuel spill of 26 500 L in a small trout stream in New York. Within 24 hours, the spill resulted in a fish kill estimated at 92% of total fish abundance of rainbow trout (*Oncorhynchus mykiss*), white sucker (*Catostomus commersoni*), blacknose dace (*Rhinichthys atratulus*), and darters (*Etheostoma* spp.). The study found that invertebrate densities at three locations below the spill site was significantly lower than reference sites and only returned to similar densities a year after the spill. The authors concluded that the diesel fuel spill significantly reduced the density of invertebrates (by 90%) and taxonomic richness (by 50%) at least 5.0 km downstream, with density recovering within a year. Species diversity continued to be low 15 months after the spill, suggesting that a longer period was required for full recovery.

Lee et al. (2001) assessed the fate of spilled hydrocarbons, which comprised a mixture of crude oil and straight-run condensate, following a pipeline rupture into the Rio Desaguadero in Bolivia. The spill affected over 400 km of riverbanks; however, findings showed that 46% of low density hydrocarbons (i.e., less than C15) evaporated within a six- to nine-week period. Macko et al. (1981) demonstrated in estuarine habitat that low density alkanes and aromatic hydrocarbon pollutants less than C13 are lost to evaporation within 24 hours, including naphthalene, methyl-napthalene, and substituted benzenes. Other factors responsible for the loss of low density hydrocarbons include dissolution, diffusion, adsorption, microbial degradation, photo-oxidation, and transport by winds, drainage, and currents (Macko et al. 1981).

Smaller streams can be more susceptible than larger streams and spills that occur during periods of low discharge can be more damaging to the aquatic food web. Fish may be more capable of evacuating affected areas, but smaller and more sedentary organisms (i.e., benthic invertebrates) could be subject to acute toxicity effects that could result in temporary declines in overall productivity of freshwater fish. The season of occurrence of a spill can also affect the rate of recovery of invertebrates.

The magnitude of the environmental effect of a spill is dependent on a number of variables, but should be localized due to standard spill response procedures. Based on existing knowledge, fish and invertebrate populations are expected to recover from a spill within several years depending on the size, location and timing of the spill. The residual effects from a condensate or diesel spill scenario should be localized and reversible over the short to medium term, and are therefore assessed as not significant. In addition, the likelihood of a condensate or diesel spill occurring is low given the controls and preventative measures that are required to be in place and the likelihood of a spill reaching the aquatic environment is remote given the required prevention, control and recovery measures. If spilled condensate or diesel were to reach the river, volumes are also expected to be low. Therefore, the risk of a worst-case spill for surface water quality and freshwater and estuarine fish and fish habitat is also low.

10.3.4.4 Archaeological Resources

A light hydrocarbons (i.e., condensate or diesel) l spill has the potential to adversely affect archaeological resources either due to the direct interaction of hydrocarbons with artefacts or as a result of ground disturbance associated with clean-up and response activities. Response procedures would include the need to avoid effects on any identified sites in the immediate vicinity of the facility. The likelihood of interacting with an undiscovered site in the immediate area of the facility is low.

Given the likely limited nature of a condensate or diesel spill in geographic extent and the low likelihood for the spill or associated response activities to interact with archaeological resources, the residual effects are assessed as not significant, and the associated risk to archaeological resources from a condensate spill is low.

10.3.4.5 Human Health

In the unlikely event of a light hydrocarbons (i.e., condensate or diesel) spill, most material will quickly volatilize and disperse into the atmosphere. Water spray or suppressing foam may be used to reduce potential vapors. The potential residual effects on human health should be limited to Project employees and contractors in the immediate vicinity of the spill. Personnel within this zone will be fully and appropriately trained in emergency response procedures and will be equipped with personal protective equipment (PPE) suitable to the site. As noted earlier, there is a very limited potential pathway for a spill of condensate to enter nearby streams or rivers. In the unlikely scenario that a spill of diesel were to reach the aquatic environment (e.g., the Kitimat River), freshwater quality would be adversely affected, and human health could be adversely affected by those that consume the contaminated water. Under such a situation, notification would be given to members of the public and potential resources users to avoid the area until such time as the area would be deemed safe.

The potential for adverse health risks to humans from a condensate or diesel spill would be mitigated through appropriate spill response management to limit the potential for exposure and longer-term human health effects. As a result, the residual effects on human health are assessed as not significant.

10.3.4.6 Summary

A summary of residual effects resulting from a spill of hazardous materials (facility-related) is presented in Table 10.3-1 for those VCs where an interaction may occur. The more detailed VC-specific definitions for magnitude, geographic extent, duration, frequency, reversibility, and context are presented in Sections 5 to 9, and are used in cases where they are relevant for both the Project effects assessment and for the accident or malfunction effects assessment. Mitigation and emergency response measures are presented in Sections 10.3.2 and 10.3.3.

Table 10.3-1: Summary of Residual Effects – Spills of Hazardous Materials (Facility-related)

Valued Component	Residual Effects Rating Criteria						Likelihood of Residual Effect	Significance	Risk
	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Context			
Air Quality	M	LSA	ST	U	R	M	L	N	L
Vegetation Resources	L	PF	ST	U	R	L-H	L	N	L
Wildlife Resources	L	LSA	ST	U	R	L-M	L	N	L
Freshwater and Estuarine Fish and Fish Habitat	L-M	LSA	ST	U	R	M-H	L	N	L
Surface Water Quality	L-M	LSA	ST	U	R	L-M	L	N	L
Visual Quality	N	LSA	ST	U	R	M	L	N	L
Archaeological and Heritage Resources	N-L	PF	PT	U	I	D	L	N	L
Human Health	N	LSA	ST	U	R	H	L	N	L

KEY

MAGNITUDE:

N = Negligible
L = Low
M = Moderate
H = High

GEOGRAPHIC EXTENT:

PF = Project footprint
LSA = Local study area
RSA = Regional study area
P = Provincial—residual effect is within the provincial extent

DURATION:

ST = Short-term
MT= Medium-term
LT = Long-term
P = Permanent

FREQUENCY:

S = Single event
MI = Multiple irregular event
MR = Multiple regular event
C = Continuous
U = Unlikely: event is not likely to occur

REVERSIBILITY:

R = Reversible
I = Irreversible

CONTEXT:

L = Low resilience—low capacity for the VC to recover from a perturbation
M = Moderate resilience— moderate capacity for the VC to recover from a perturbation
H = High resilience—high capacity for the VC to recover from a perturbation
D = Disturbed
U = Undisturbed

SIGNIFICANCE:

S = Significant
N = Not Significant

LIKELIHOOD:

L = Low likelihood
M = Moderate likelihood
H = High likelihood

RISK:

The risk of the accident or malfunction to a VC is determined based on the likelihood of occurrence and consequence to the VC
L = Low risk—low likelihood and low consequence
M = Moderate risk—low likelihood and high consequence
H = High risk—high likelihood and high consequence

10.4 Loss of Containment of LNG in the LNG Processing Area and Storage Site, or Loading Lines

10.4.1 Scenario Description

The credible worst-case scenario for loss of containment of LNG would be a rupture in the loading arm or in the loading line immediately upstream of the LNG carrier loading arm emergency shutdown valves. While unlikely, given that the loading line is not operating under high pressure and is designed to allow for expansion and contraction of the pipe with temperature change, the worst case spill would involve a rupture at the terminal end. Emergency shutdown systems are integrated in the design to stop LNG flow in case of a malfunction, but in the highly unlikely situation that this shutdown system also fails, the LNG could continue to flow into the loading line for a short period of time. This would result in an LNG spill most probably into the marine environment or estuary environment surrounding the terminal. Given the nature of LNG (i.e., extremely cold liquid that is much lighter than water), any liquid that exits the loading line onto water would spread on the surface and would quickly or immediately vapourize.

LNG tanks will have a primary and secondary containment system, with the secondary containment system designed for isolation of leaks or spills from the primary containment tanks. Within the full containment tank design concept, during normal operation, liquid containment is provided by the inner tank and vapour containment is provided by a metallic liner that is attached to the inside of the concrete outer tank. In the extremely unlikely event of an inner tank failure, the outer tank provides secondary containment of the liquid and the vapour. The outer tank is made of prestressed concrete wall, a reinforced concrete bottom slab, and reinforced concrete dome roof.

The membrane tank, which is an alternative to full containment tanks, also provides double integrity with regard to liquid and vapour containment. However, the membrane is attached to the insulation material, which is in turn attached to the inner face of the outer prestressed concrete tank wall. Within the membrane tank concept, during normal operation, the membrane provides liquid and vapour containment. In the extremely unlikely event of failure of the membrane, the concrete secondary container includes corner protection and is capable of containing the liquid and of controlled venting of the vapour. The outer prestressed concrete tank also protects the insulation. In a similar manner to the full containment concept, a failure of the inner tank would not result in extensive vapour formation or fires.

For both LNG tank concepts, a liquid spill originating from the storage tank is not a credible scenario due to the secondary containment. Therefore, potentially larger LNG spills from facility storage tanks would be extremely unlikely; however, in such an event, a release of LNG from a storage tank would immediately vapourize.

The most credible type of release is the result of equipment or system leakage, such as a leaking valve seal or flange gasket. This type of release is typically small, visible and easily repaired by facility personnel. The tanks will be loaded through piping located at the top of the tank, thereby eliminating the possibility of pipe leaks or pipe/tank interface leaks at the bottom or sides. CSA Z-276-2011 contains design requirements that take seismic, wind, and weather factors into account, thereby reducing the potential for a significant LNG release resulting from an act of nature, such as a severe storm, ice storm, or earthquake. The tanks will be designed for the seismic rating of the region, and the tank profile will take into account the wind loads (both typical and maximum) for the region. The possibility of an LNG release caused by external events, such as a forest fire or adjacent industrial fire, is remote as the facility is built from non-combustible materials, mostly steel and concrete, and CSA Z-276-2011 requires siting of the facility in a way that contains vapour dispersion and thermal radiation within the boundaries of the facility. Therefore, critical components of the facility would not be susceptible to even large fires at the distances provided by the exclusion zones and facility boundaries. Furthermore, the facility will be equipped with an extensive firefighting system.

If a release were to occur, the liquid immediately warms up and converts back to a gas. Initially, the gas is colder and heavier than the air, so it freezes any water vapour in the air. This can temporarily create an icy fog, which can be a visual cue to alert trained employees of a release. As the gas continues to warm, it disperses into the atmosphere as a vapour cloud. LNG is not flammable or explosive in its liquid state. LNG vapours (its natural gas form) are only flammable within a limited range of concentration in the air. If the concentration of natural gas in the air is lower than 5% it cannot burn because of insufficient fuel. If the concentration of natural gas in the air is higher than 15% it cannot burn because there is insufficient oxygen. If ignition of the natural gas vapours occurs, the vapours do not burn rapidly like gasoline, but forms a slow burning flame that burns back to the source of the natural gas vapour, until the fire is extinguished or the fuel is exhausted. For ignition to occur when LNG vapour contacts a hot surface, the temperature of that surface must exceed 540°C. There would be no detonation type overpressures that will affect the general public beyond the boundary of the LNG facility.

LNG discharged to the marine or estuarine environment could result in several scenarios. The spill would initially spread across the water surface, potentially creating ice which would melt rapidly. The aquatic environment would return to normal with no residual trace of the incident. The LNG pool can vaporize rapidly (faster than an equal sized pool on land). If ignited, the natural gas cloud formation would burn back to the LNG pool. If LNG is spilled on metal surfaces, it can cause brittle fracture (carbon and low alloy steel). There is also potential for rapid phase transition (RPT) of LNG on contact with water resulting in localized physical pressure waves (without ignition or combustion), producing measurable overpressure. RPT occurs when enough LNG is spilled on the water at a high enough rate. Heat is transferred from the water to the LNG, causing the LNG to instantly convert from its liquid phase to its gaseous phase. A large amount of energy is released during this rapid transition between phases and physical explosion can result. Multiple RPTs of varying strengths can occur over the area of the release, the shock waves from each contributing to the initiation of others.

Further assessment of a fire or explosion from an LNG spill is provided in Section 10.6.

10.4.2 Project Design Measures to Reduce Risk and Consequences

The proposed facility will be designed and equipment selected to meet strict design codes and standards. Facilities will be designed to avoid contained spaces where LNG vapour could accumulate. CSA Z276-2011 requires that LNG storage systems be located far enough from the facility boundary to ensure that the radiant heat flux levels from fires and vapor concentration levels due to dispersion of flammable vapors do not exceed acceptable limits at the facility boundary. While these events could still have consequences for staff onsite, these personnel will be appropriately trained to react and respond to any such event.

Operational procedures will be prepared to ensure the transport, handling and process systems are operated within the design parameters and with the highest regard for safety. Employees will be trained in operational procedures and environmental emergency response procedures to ensure safe operation of LNG carrier loading and facility operation. Safety and operability of the transfer arm connection process and pier facilities will be enhanced by a quick connect/disconnect mooring system, hazard detection instruments, emergency and automatic shutdown systems, remote monitoring devices, competent and trained personnel, increased personnel attendance during LNG transfers and fire extinguishing equipment.

LNG storage tanks will be designed, constructed, and tested per relevant regulations/standards. Fire/leak detection and fire extinguishing equipment will be sited throughout the tank area to detect and mitigate potential leaks and fires. Specific design measures include:

- LNG tanks will have a primary and secondary containment system, with the primary containment to be designed for low temperatures and manufactured of nickel steel for full containment tanks and corrugated stainless steel for membrane tanks. The secondary containment system will be designed for isolation of leaks or spills from the primary containment tanks.
- Material selection for any piping and equipment exposed to cryogenic temperatures will follow international design standards.

Prevention of LNG spills will be enhanced by using safe, properly maintained equipment and competent trained staff. The probability of a spill will be further reduced through the use of standardized terminal procedures, in accordance with the Terminal Operations Manual to be developed. Procedures will be prepared and the workers will be trained to ensure LNG transfers are made safely.

Project design measures specific to LNG spills resulting from LNG carrier grounding or collisions are discussed in Section 10.7.2.

10.4.3 Response Measures

In the event of an LNG spill, the primary goal would be to protect human safety, and when safe to do so, contain the material at the source and keep it from moving offsite. Accordingly, LNG Canada would implement an Emergency Response Plan that includes a Spill Response Plan (Mitigation 10.1). The following procedures will be included in the Emergency Response Plan – Spill Response Plan section:

- notification of staff and persons with established response roles
- shutting valves and isolating and containing the release
- notifying appropriate regulatory agencies
- notifying potentially affected Aboriginal Groups and stakeholders, and
- reporting all incidents.

The LNG facility will be equipped with safe guarding instrumentation including process alarms, gas detection, and flame detection equipment. Control procedures would include use of remote activated deluge systems, fixed foam systems, and fire water monitors.

LNG evaporates rapidly, is odourless, colourless, and non-corrosive, and is non-toxic. No clean-up is expected to be necessary as a result of an LNG spill. If the freezing from an LNG spill results in adverse effects on terrestrial or marine habitats, appropriate restoration or compensation would be undertaken in consultation with regulators and potentially affected Aboriginal Groups.

10.4.4 Potential Residual Effects

Loss of containment of LNG is a credible worst-case scenario whose low likelihood of occurrence will be further reduced through implementation of the general prevention measures outlined in Section 10.1 and the specific Project design measures to reduce risk outlined in Section 10.4.2. The mitigation (prevention and response) measures outlined in Sections 10.1, 10.4.2 and 10.4.3 will also reduce the likelihood and severity of potential residual effects associated with a loss of LNG containment.

Adverse long-term residual effects from an LNG release are unlikely. Although cool LNG vapour initially clings to topography, upon warming the buoyancy of the methane gas will enhance dispersion to the atmosphere with no long-term hazardous effects. Clean-up of an LNG spill is not necessary because of its quick evaporative properties. Because LNG is non-toxic and leaves no residue after evaporation, adverse effects associated with an LNG release are minimal.

10.4.4.1 Atmospheric Environment and Visual Environment

Methane (the main constituent of LNG) is a greenhouse gas, but any vapours associated with a spill would be negligible in the context of overall provincial, national, and global GHG emissions. Therefore, residual effects on GHG management from an LNG release will be negligible. Air quality would be affected in the short term and locally (i.e., limited to the site) where methane concentrations exceed background conditions. Acoustic effects would only occur if the release resulted in ignition of the LNG or RPT, which in turn can result in localized explosions. Visual quality could be affected locally and for the short term in the event that conditions result in a vapour cloud.

The risk of an LNG release to GHG management, air quality, the acoustic environment, and visual quality is low because the likelihood of such a spill is low, the duration of the effect is short term, the extent is local, and the consequence is low.

10.4.4.2 Vegetation Resources and Wildlife Resources

Potential residual effects are limited to short-term hazards for flora and fauna in the immediate vicinity of an LNG release, from either the LNG loading line or an LNG storage tank.

In the event of a release from the LNG loading line, vegetation and wildlife within the estuary could be affected for the short period of time during water-vapour contact. LNG is not persistent and is not toxic to aquatic biota. As described in Section 10.4.1, surface water at the interface would initially freeze, but melt quickly, with no residual trace of LNG. Only wildlife and vegetation at the frozen interface would be potentially affected in this case. If ignited, the natural gas cloud formation would burn back to the LNG pool on the surface. Wildlife and vegetation at and near the interface would be potentially affected in this case. The potential for RPT and subsequent localized explosions is low as it is unlikely that enough LNG would be released from the LNG loading line to establish conditions for this to occur.

As LNG tanks are designed to incorporate secondary containment, it is highly unlikely that a large release would occur from a tank. In the event of an LNG release from a storage tank, the LNG facility is designed to contain any onsite incident within the fenced site and right-of-way. Within the vegetation and wetland environments near the Project footprint, short-term hazards to vegetation and wetland function from an LNG vapour cloud are assessed as not significant.

If a release results in a vapour cloud, any birds or wildlife within the vapour cloud may be harmed through asphyxiation, lung damage or freezing (Luketa-Hanlin 2006). The most vulnerable species to these events include birds that spend periods of their life history foraging within near shore areas or wildlife with reduced mobility, including amphibians. Given the localized nature of potential LNG spills, local populations are likely to sustain no long-term residual effects from an LNG release; therefore, residual effects are assessed to be not significant.

The risk of an LNG release to vegetation and wildlife resources is considered low given that the likelihood of such a release is low, the extent is local, the duration of the effect is short-term, and the consequence is low (i.e., the sustainability of the population within the RSA would not be affected (i.e., not significant effect).

10.4.4.3 Freshwater and Estuarine Fish and Fish Habitat and Marine Resources

For LNG spills in the estuarine or marine environments, it is possible that fish at the water surface and within a few hundred metres of a spill may be frozen or injured. An LNG spill may also reduce general short-term habitat quality in the immediate vicinity due to freezing. LNG is not persistent and is not toxic to aquatic biota. Once the LNG has vapourized and any associated ice melts, the environment will gradually return to normal with no residual trace of the incident. Marine mammals within the vapour cloud may be harmed through asphyxiation, but it is anticipated that marine mammals would likely avoid the affected area due to the decrease in temperature. Given the low number of individuals affected by such an event, it would not result in population level effects on fish and marine mammals. Residual effects on marine resources and estuarine fish are therefore assessed as not significant.

The risk of an LNG release to freshwater and estuarine fish and fish habitat, and to marine resources is low because the likelihood of such a release is low, the duration of the effect is short-term, the extent is local, and the consequence is low (i.e., not significant effect).

10.4.4.4 Economic Conditions and Marine Transportation and Use

A release could result in a temporary exclusion area where fishing, recreation, tourism, and commercial marine transportation might be prohibited. An exclusion zone would be of short duration and very small in comparison to the areas fished, or to those areas used for recreation or tourism; therefore, interference with fisheries would be limited, with no highly adverse residual economic effects. Thus, residual effects on marine transportation and use, and economic conditions are assessed as not significant.

The risk of an LNG release on economic conditions, and marine transportation and use is low because the likelihood of such a release is low, the extent is local, the duration is short-term, and the consequence is low (i.e., not significant effect).

10.4.4.5 Human Health

Potential residual effects on human health are expected to be limited to Project staff and contractors in the immediate vicinity of the spill. Employees within this zone will be fully and appropriately trained in emergency prevention and response procedures. Once released from containment, the LNG will rapidly evaporate and disperse into the atmosphere. The main route of exposure to methane is through inhalation. At low concentrations methane is not toxic, but at higher concentrations has the potential to cause asphyxiation in confined spaces where it displaces oxygen. In situations where methane is released to the atmosphere from a loss of containment of LNG, methane would not be able to reach levels in outdoor air where asphyxiation would be a potential concern. Direct dermal contact with LNG may cause frostbite or potential mortality resulting from freezing. Potential direct effects from exposure to LNG would be limited to the area very close to the spill site, as the LNG would rapidly evaporate and disperse. The potential for adverse health risks to humans would be mitigated through appropriate spill response management to limit the potential for exposure and subsequent long-term effects. Thus, residual effects on human health are assessed as not significant.

10.4.4.6 Summary

A summary of residual effects resulting from a loss of containment of LNG in the processing area and storage site or loading lines is presented in Table 10.4-1 for those VCs where an interaction may occur. The more detailed VC-specific definitions for magnitude, geographic extent, duration, frequency, reversibility, and context are presented in Sections 5 to 9, and are used in cases where the descriptors are relevant for both the project effects assessment and for the accident or malfunction effects assessment. Mitigation and emergency response measures are presented in Sections 10.4.2 and 10.4.3.

Table 10.4-1: Summary of Residual Effects – Loss of Containment of LNG in the Processing Area and Storage Site or Loading Lines

Valued Component	Residual Effects Rating Criteria						Likelihood of Residual Effect	Significance	Risk
	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Context			
Air Quality	M	PF	ST	U	R	M	L	N	L
Greenhouse Gas Management	N	P	ST	U	R	D	L	N	L
Acoustic Environment	M	LSA	ST	U	R	M	L	N	L
Vegetation Resources	N	P	ST	U	R	L-H	L	N	L
Wildlife Resources	L	LSA	ST	U	R	L-M	L	N	L
Freshwater and Estuarine Fish and Fish Habitat	N	LSA	ST	U	R	M-H	L	N	L
Marine Resources	M	LSA	ST	U	R	L-H	L	N	L
Economic Conditions	L	LSA	ST	U	R	L-M	L	N	L
Visual Quality	N	LSA	ST	U	R	M	L	N	L
Marine Transportation and Use	L	LSA	ST	U	R	M	L	N	L
Human Health	N	LSA	ST	U	R	H	L	N	L

KEY

MAGNITUDE:

N = Negligible
L = Low
M = Moderate
H = High

GEOGRAPHIC EXTENT:

PF = Project footprint
LSA = Local study area
RSA = Regional study area
P = Provincial—residual effect is within the provincial extent

DURATION:

ST = Short-term
MT= Medium-term
LT = Long-term
P = Permanent

FREQUENCY:

S = Single event
MI = Multiple irregular event
MR = Multiple regular event
C = Continuous
U = Unlikely: event is not likely to occur

REVERSIBILITY:

R = Reversible
I = Irreversible

CONTEXT:

L = Low resilience—low capacity for the VC to recover from a perturbation
M = Moderate resilience— moderate capacity for the VC to recover from a perturbation
H = High resilience—high capacity for the VC to recover from a perturbation
D = Disturbed
U = Undisturbed

SIGNIFICANCE:

S = Significant
N = Not Significant

LIKELIHOOD:

L = Low likelihood
M = Moderate likelihood
H = High likelihood

RISK:

The risk of the accident or malfunction to a VC is determined based on the likelihood of occurrence and consequence to the VC
L = Low risk—low likelihood and low consequence
M = Moderate risk—low likelihood and high consequence
H = High risk—high likelihood and high consequence

10.5 Emergency LNG Facility Shutdown

10.5.1 Scenario Description

The worst-case credible scenario for an emergency LNG facility shutdown is a full shutdown of all production trains with associated flaring. While smaller shutdowns and flaring events are likely (though infrequent) over the life of the Project (e.g., commissioning, maintenance), this worst-case scenario is considered possible, but infrequent.

Skilled competent control room operators will follow shutdown procedures that quickly and in a controlled manner halt LNG production and set all respective systems to a safe standby mode, without the need for upset depressuring and flaring. The facility will also be designed with automated shutdown systems that will be triggered in this scenario. The LNG facility shutdown itself should not result in any environmental consequence beyond emissions from worst-case flaring.

During upset conditions, in the unlikely event it is required, the emergency relief system safely discharges vapours to flare for proper disposal.

Control philosophies, systems, emergency procedures and a shutdown hierarchy will be designed to provide a safe facility and to reduce the loss of inventory during process upsets. Total loss of electrical power for an extended period would be a possible cause for a shutdown of the LNG facility.

Trips are defined as fluctuations in normal operation or localized equipment failure. Such situations would cause brief periods of flaring until the equipment is taken off-line, or until the transient condition passes. These flaring events would likely have a smaller load than a total unit shutdown, and would be expected to be of short duration.

10.5.2 Project Design Measures to Reduce Risk and Consequences

The LNG facility will be designed according to the National Building Code of Canada, American Petroleum Institute recommended practices, CSA standards, American Society of Mechanical Engineers codes, American Concrete Institute standards, and others, as applicable. It will be designed to shut down in a failsafe manner due to serious upset conditions, protecting against high pressure, high and low temperatures and low flow conditions as necessary to ensure safe operations. Measures that will be in place to manage the risks and consequences of a shutdown scenario are:

- implementation of a distributed control system (DCS) and emergency shutdown (ESD) system which contain protection barriers (e.g., high and low temperature alarms, level and pressure controls, safeguarding trips, and emergency shutdown systems) to safely shut down equipment if required
- installation of detectors for combustible gas, fire, smoke, heat and manual call points

- implementation of a flare design with minimum destruction efficiency of 99.5%
- installation of continuously lit pilot lights on all flares
- use of skilled, competent personnel in LNG facility operations, and
- implementation of administrative controls, including safe work procedures, work permits, and an emergency response plan.

10.5.3 Response Measures

No other response or subsequent clean-up and restoration would be required, except in response to potential bird mortalities near the flare. LNG facility staff would report any bird mortalities to an environmental monitor, who would then report the event to Environment Canada or directly to Environment Canada, and to MFLRNO. The report would include information on species, location, and weather conditions.

10.5.4 Potential Residual Effects

An emergency LNG facility shutdown is a credible worst-case scenario whose low likelihood of occurrence will be further reduced through implementation of the general prevention measures outlined in Section 10.1 and the specific Project design measures to reduce risk outlined in Section 10.5.2. The mitigation (prevention and response) measures outlined in Sections 10.1, 10.5.2 and 10.5.3 will reduce the likelihood and severity of potential residual effects associated with an emergency shutdown of the LNG facility.

10.5.4.1 Atmospheric and Visual Environment

The shutdown and flaring scenario would result in a flame burning from one or more flare stacks, releasing air contaminants, including SO_2, NO_X, CO, PM, and GHGs.

The predicted air contaminant concentrations released from the Project site would be below the applicable ambient air quality objectives (refer to Table 5.2-1 in Section 5.2.2.1) and the GHG component would be negligible in the context of overall provincial and national GHG emissions. Emissions are not expected to have an effect on human health. The noise from an emergency flaring event would be audible outside the LNG facility; however, if it occurred, it would be short-term in duration. The light could cause some human and visual disturbance, particularly if an emergency flaring event occurred at night, but would be short-term. Photo 10.5-1 is a simulation of what an emergency flaring event associated with the Project would look like from MK Bay Marina. Residual effects on air quality, GHG management, the acoustic environment, and visual quality are assessed as not significant.

Photo 10.5-1: Example Emergency Flaring Event, as Viewed from MK Bay Marina

10.5.4.2 Wildlife Resources

Birds are attracted to artificial light, including flares, and could either be killed directly by flying into the flare, or ground themselves after being exhausted by circling the flare at night or during adverse weather conditions (Bourne 1979; Hope-Jones 1980; De Groot 1996). The sporadic nature of this interaction, and the rarity of major flaring scenarios occurring at night in conjunction with adverse weather conditions (that could cause birds to be oriented toward the flare), suggest that bird mortality would be a rare event.

The risk of a flaring event to wildlife resources is low because the likelihood of bird-flare interaction is low, and the consequence is low (i.e., not significant effect).

10.5.4.3 Human Health

Flaring activities would not be expected to represent a potential concern for human health. Flaring events would be expected to be burning LNG which is largely SO_2 free and thus, it is reasonable to expect that SO_2 concentrations beyond the fence line of the facility would meet the current human health-based air quality guidelines for SO_2. Similarly, NO_2 levels beyond the fence line are expected to meet the current human health-based air quality guidelines for NO_2. Given the expected short duration of flaring events (less than one hour), potential human health effects associated with flaring activities during emergency facility shutdowns are assessed as not significant.

10.5.4.4 Summary

A summary of residual effects resulting from an emergency LNG facility shutdown is presented in Table 10.5-1 for those VCs where an interaction may occur. The more detailed VC-specific definitions for magnitude, geographic extent, duration, frequency, reversibility, and context are presented in Sections 5 to 9, and are used in cases where the descriptors are relevant for both the project effects assessment and for the accident or malfunction effects assessment. Mitigation and emergency response measures are presented in Sections 10.5.2 and 10.5.3.

Table 10.5-1: Summary of Residual Effects – Emergency LNG Facility Shutdown

Valued Component	Residual Effects Rating Criteria						Likelihood of Residual Effect	Significance	Risk
	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Context			
Air Quality	L	LSA	ST	U	R	M	L	N	L
Greenhouse Gas Management	N	P	ST	U	R	D	L	N	L
Acoustic Environment	M	LSA	ST	U	R	M	L	N	L
Wildlife Resources	L	LSA	ST	U	R	L-M	L	N	L
Visual Quality	N	LSA	ST	U	R	M	L	N	L
Human Health	N	LSA	ST	U	R	H	L	N	L

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RISK:

The risk of the accident or malfunction to a VC is determined based on the likelihood of occurrence and consequence to the VC

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H = High risk—high likelihood and high consequence

10.6 Explosion and/or Fire

10.6.1 Scenario Description

The credible worst-case scenario for a fire or explosion is the uncontrolled release, with an associated ignition source, of gas phase materials that are stored or used within high pressure systems (e.g., gas feed system, refrigerant loop system, propane). Although a fire could also result from an LNG vapour cloud explosion, this scenario is more unlikely because LNG is stored and pumped under low pressure, meaning that an unintended release would be less likely than materials within higher pressure systems. The direct effects of both scenarios would likely be contained within the LNG facility.

LNG, as a liquid, is not explosive which helps explain why the LNG industry has an excellent safety record. In over 40 years of LNG storage and terminal operations worldwide, there have been no significant offsite public injuries or property damage. The physical and chemical properties of LNG itself enable hazards and risks to be easily defined and incorporated into technology and operational controls. The broad set of standards, codes, and regulations that now apply to the LNG industry also assist in maintaining a high safety record. The small number of serious accidents and fatalities that have occurred at onshore facilities, particularly in the early years of the industry, have led to improvements in design and the introduction of more stringent regulatory requirements. Millions of tonnes of LNG have also been transported, stored, and used in the past 40 years, without any serious public exposure.

Major fires or explosions at LNG facilities are rare. An explosion and fire in Ohio occurred in 1944 because of inappropriate material selection for LNG tanks (GIIGNL 2009), and in 2004 an explosion occurred in Algeria because of a steam boiler problem (the LNG Canada facility does not use steam boilers). In March of 2014, an explosion occurred at a LNG processing facility near the Columbia River in Plymouth, Washington, resulting in facility shut down, activation of emergency procedures and evacuation of personnel and neighbouring residents. Several employees were injured, but no fatalities occurred. The cause of the incident is under investigation.

This recent incident, while rare, confirms that a range of explosion or fire scenarios could possibly occur at the LNG facility, given the large volumes of flammable gases onsite. Natural gas is not flammable or explosive when in its liquid form (LNG) and as vapour has a narrow flammability range in air (5% to 15% by volume). At the same temperature, natural gas is lighter than air and mixes readily in the air when dispersed. This can result in dilution of the natural gas vapour cloud to below the lower flammable limit. If a natural gas vapour cloud in the flammability range were ignited, rapid combustion would occur. While the natural gas would not explode, it would burn back to the source of the spill and continue to burn at the point where the LNG was released, until the source was cut off or the fire extinguished. LNG does not explode because combustion propagates through slower heat transfer, rather than by supersonic shock.

Rapid phase transition, where LNG expands explosively into a vapour, can occur if LNG quickly absorbs heat from a water body. This can release large amounts of energy, but is generally localized.

It is possible, though unlikely, that a fire would extend beyond the boundaries of the LNG facility; fires and explosions could also be associated with an LNG carrier, but would be unlikely to lead to loss of containment on the LNG carrier. Over the history of commercial LNG shipping, there have been no fires or explosions concerning an LNG ship's containment system in port or at sea (GIIGNL 2012, Stantec 2014a). The most recent incident known to occur on an LNG ship was a fire in the engine room of the LNG carrier *Explorer*, which occurred on June 14, 2011 while the vessel was transiting off the coast of Mumbai, India. The fire was promptly extinguished by the ship's crew using portable fire extinguishers, but the ship lost propulsion and required tow assistance. The incident did not result in any casualties, injuries, or damage to the LNG containment system (World Maritime News 2014).

10.6.2 Project Design Measures to Reduce Risk and Consequences

Prevention of hydrocarbon release is the primary mitigation measure for natural gas explosion and fire, followed by control of ignition sources, gas detection, fire control and suppression and trained personnel. LNG containment and spill prevention is the central feature of Project design, and design standards for LNG facilities, including those specified by CSA, will be adhered to. Fire protection for all LNG facilities is included as part of the design and operation which must be in compliance with the CSA-Z276-11. The Code describes a number of specific requirements with regard to ESD systems, fire and leak control, fire protection water systems, fire extinguishing and other fire control equipment, security and personnel safety. The LNG facility design and operation will also adhere to internal standards established by LNG Canada, which in many cases exceed the referenced government and industry requirements.

Facilities will undergo frequent workplace safety assessments and necessary precautions will be taken to prevent fire hazards. Flammable waste will not be permitted to accumulate and will be contained and removed to a dedicated waste store. Smoking will not be permitted in the operational areas or around areas where flammable materials are stored or in use and would only be permitted in designated safe smoking areas, which will be clearly marked. Employees will be trained in emergency response procedures to ensure safe operation of loading and facility operation.

In addition to emergency shutdown and emergency depressurizing systems, fire prevention measures will include design of the processing facilities and overall facility layout to promote natural ventilation and dispersion of potential vapour clouds, and siting facilities at a safe distance. Additional fire prevention measures include:

- confinement or diversion measures, like curbs, dikes and trenches, at potential spill sources
- systems to prevent or limit releases (e.g., fire-safe valves, remote operable valves, minimum flanges, small bore connections, and minimal use of sight glasses for visual observation of liquid levels in pipes/vessels to reduce potential failure points)
- area classification guidelines and adequate distance between equipment to control possible ignition sources, and
- process control and instrument protective systems to provide early warning when normal process parameters are approaching their limits or automatic intervention when parameters exceeded.

In the event of a fire or explosion, CSA standard Z276-11 requires facilities to be located at sufficient distance to protect the public. Minimum distances from LNG tank impoundment areas to the nearest facility property line must be maintained to allow for sufficient vapour cloud dispersion to acceptable levels at the property line. CSA Z276-11 also specifies exclusion distances meant to prevent radiant heat flux (heat transfer) from a fire from exceeding specified thresholds at property lines and adjacent occupancies.

Additional fire protection measures that will be incorporated during detailed design include:

- arranging the layout of equipment and materials to reduce the probability of fire escalation
- using fire-resistant construction materials
- designing control systems to remain operable under fire conditions
- designing control valves and depressurizing valves to remain operable (e.g., fail safe mode) in a fire emergency
- locating firefighting equipment at pre-determined, strategic locations in the process, storage and loading areas
- providing onsite storage of water in a volume sufficient for six hours of continuous firefighting, plus a secondary system to pump river water if required
- using an international shore/fire connection located near the gangway at the loading jetty, with appropriate tug boat connections for seawater back-up. It will therefore be possible for tug boats to connect to the fire water mains at the LNG jetty in the extreme and unforeseen case of fire water being unavailable from the fire water tanks.
- using a detection system that includes fire and gas detectors to immediately detect any release of hydrocarbon at the earliest stage of development.

In addition to potential fires and explosions at the terminal facility, fire and explosion could also potentially occur on an LNG carrier. Small fires and explosions in the engine room, on deck, or in the accommodation areas would be controlled by suitable fire detection systems and automatic firefighting, in addition to manual firefighting response by trained vessel staff. Most modern LNG carriers use the boil-off gas vapour from the LNG cargo tanks as fuel for ship power and propulsion, removing the need for operational venting of gas from the boil-off. Other modern LNG carriers are fitted with reliquefaction facilities on board to turn the boil-off gas vapour back to liquid, thereby also negating the operational need for venting. By eliminating the operational need to vent, the risk of fire or explosion is further reduced.

Other measures specific to explosions or fires on LNG carriers will include the following:

- LNG carriers are fully equipped with firefighting equipment, including large, dry chemical systems and sprinkler systems designed to contain a cargo system fire.
- Employees will receive the appropriate training on operational procedures and environmental emergency response procedures to ensure safe LNG carrier loading and LNG facility operation.

10.6.3 Response Measures

Any explosion or fire at the LNG facility would be responded to according to the Emergency Response Plan. An explosion or fire on an LNG carrier would be responded to according to the vessel's own emergency response plan; LNG Canada would provide assistance as and when required. Emergency response would scale to the severity of the explosion or fire.

A thorough investigation would be undertaken to identify the cause of fire or explosion and necessary repairs or changes in procedures would be implemented. Equipment affected by the fire or explosion would be inspected, retested, and replaced if required. Firefighting chemicals and debris would be cleaned up, where practical, to prevent entry into terrestrial or aquatic habitats.

10.6.4 Potential Residual Effects

A fire or explosion is a credible worst-case scenario whose low likelihood of occurrence will be further reduced through implementation of the general prevention measures outlined in Section 10.1 and the specific Project design measures to reduce risk outlined in Section 10.6.2. The mitigation (prevention and response) measures outlined in Sections 10.1, 10.6.2 and 10.6.3 will reduce the likelihood and severity of potential residual effects associated with a fire or explosion.

A fire or explosion would be confined to the Project footprint and associated safety zone, unless the accident or malfunction took place on an LNG carrier.

10.6.4.1 Atmospheric Environment and Visual Environment

A fire or explosion restricted to the combustion of natural gas in a worst-case scenario may result in emission of air contaminants, including SO_2, depending on gas composition. Air quality objectives, which are based on averaging times of at least one hour, are unlikely to be exceeded for such a short-term event. The additional potential combustion of a chemical such as a motor fuel or hydraulic oil would be only incrementally more serious because of the relatively small quantities of such materials at the Project site. Combustion of various hydrocarbon-based operational chemicals would generate primarily CO_2 and water vapour. Smoke and other particulate matter would reduce air quality for the duration of the fire, result in detectable odour, and reduce visibility in and around the site. Potential residual effects on air and visual quality would be short-term and reversible. Potential residual effects on the acoustic environment would be temporary and short term in duration. Thus, residual effects on air quality, GHG management, the acoustic environment, and visual quality are assessed to be not significant.

The risk of an explosion or fire to air quality, GHG management, the acoustic environment, and visual quality is low because the likelihood of such an event is low, and the consequences are insubstantial (i.e., effects would be not significant).

10.6.4.2 Vegetation Resources and Wildlife Resources

Flora and fauna may be affected as a result of this scenario; however, there will be no vegetation present in the LNG facility footprint. Tree thinning or clearing is also planned for select areas immediately surrounding the fenced and bermed portion of the LNG facility, which will reduce the risk of a fire spreading beyond the LNG facility boundary. Any lost vegetation is expected to regrow and continue to be managed (i.e., thinned, cleared, or trimmed) as needed for facility safety and security; therefore, residual effects on vegetation resources are assessed as not significant.

Wildlife and birds in close proximity to a fire or explosion could be injured or killed. The speed of the fire or explosion would affect the degree to which mobile species might be able to disperse from the area. The effects of a fire or explosion are likely to be confined to the Project footprint and surrounding safety zone; therefore, mortality or physical injuries from the fire or explosions should be localized and not have population level effects on wildlife or birds. A significant effect for SARA-listed bird species could occur if a fire were to spread outside the boundaries of the facility and affect adjoining habitat, although the likelihood of this occurring given the Project design and fire prevention and response measures is very low.

The risk of an explosion or fire to vegetation and wildlife resources is low because the likelihood of such an event is low, and the consequence is low (i.e., not significant effect). The risk of an explosion or fire to SARA-listed bird species is moderate because although the likelihood of such an event is low, the consequence could be high, depending on the time of year and extent of fire (i.e., significant effect).

10.6.4.3 Freshwater and Estuarine Fish and Fish Habitat and Marine Resources

In an LNG carrier fire or explosion, fish could be killed if the scenario resulted in a shockwave (such as a RPT). Marine mammals may be harmed by the shockwave, but RPT events are very localized and unlikely. The number of fish or marine mammals harmed as a result of an explosion or fire would not result in population level effects. Thus, residual effects on marine resources, and freshwater and estuarine fish and fish habitat are assessed as not significant.

The risk of an explosion or fire to freshwater and estuarine fish and marine resources is low because the likelihood of such an event is low, and the consequence is low (i.e., not significant effect).

10.6.4.4 Infrastructure and Services

A fire or explosion at the LNG facility may require support from external emergency response services. This has the potential to place increased strain on local infrastructure and services (e.g., firefighting and medical services). This would be short-lived and would not result in a persistent residual effect on local service delivery; therefore, residual effects on infrastructure and services are assessed as not significant.

The risk of an explosion or fire to infrastructure and services is low because the likelihood of such an event is low, and the consequence is low (i.e., not significant effect).

10.6.4.5 Economic Conditions and Marine Transportation and Use

A fire or explosion could affect local or regional marine transportation and use. While a fire or explosion on a vessel is a serious marine safety incident and would require investigation and follow-up actions, it would not result in increased economic costs to non-Project related transportation (i.e., it might temporarily delay other vessels in the immediate vicinity, but will have no long-term or regional consequences) or cause a reduction in the level of safety or service within Douglas Channel. Therefore, a ship-based fire is unlikely to affect marine navigation and safety. Consequently, potential residual effects on marine transportation and use, and subsequent effects on economic conditions are assessed as not significant. Depending on the extent and severity of a fire or explosion, significant effects on local economic conditions could result if LNG Canada-related business is interrupted over the long term.

The risk of an explosion or fire to marine transportation and use is low because the likelihood of such an event is low, and the consequence is low (i.e., not significant effect). The risk of an explosion or fire to economic conditions is moderate because although the likelihood of such an event is low, the consequence could be high (i.e., significant effect) depending on the severity of the event.

10.6.4.6 Community Health and Wellbeing

While worker safety is beyond the scope of this assessment, death or serious injury to workers from a fire or explosion would be expected to have residual effects on community health and wellbeing in those communities in which the workers and their families lived when the accident happened. Residual effects on the worker's family would be expected. Counselling and trauma support services might be required if a serious injury or death occurred, and depending on the severity of the event, could exceed existing capacity. Although such an event would not result in a persistent reduction of availability of services, residual effects on community health and wellbeing could be significant in the short term.

There is a low potential to adversely affect land use in the unlikely event that a fire or explosion extends beyond the Project footprint and associated safety zone. The credible worst case scenario includes only small areas of the safety zone, which extend beyond the LNG facility. Residual effects on land use would be limited to small areas and are assessed as not significant.

The risk of an explosion or fire to community health and wellbeing is moderate because although the likelihood of such an event is low, the consequence could be high (i.e., significant effect) depending on the severity of the event.

10.6.4.7 Archaeological and Heritage Resources

There is a low potential to adversely affect undocumented or unrecovered archaeological and heritage resources in the event of a fire or explosion. If undocumented or unrecovered resources were present on or near the ground surface in the area of a fire or explosion, the adverse effects on those resources could be significant. Archaeological and heritage resources that are deeply buried are more protected than those on or near the ground surface.

The risk of an explosion or fire to archaeological and heritage resources is moderate because although the likelihood of such an event is low, the consequence could be high (i.e., significant effect) depending on the severity of the event and potential location of undocumented resources.

10.6.4.8 Human Health

In the event of a fire or explosion, there could be injury and/or loss of human life for workers or responders, which would represent a significant effect. With respect to emissions, a fire or explosion would result in short-term releases of SO_2 and NO_2. In addition, the combustion of other hazardous materials such as motor fuels and hydraulic oils would result primarily in the release of CO_2, CO and water vapour. The potential effects on air quality associated with fires are expected to be minor due to the relatively small volumes of materials onsite. Short-term reductions in air quality and due to smoke and particulate matter could be expected to last for the duration of the fire resulting in inhalation concerns for people in the vicinity of the smoke plume. However, these effects would be short-term and reversible. Given the short duration and reversibility of the localized effects on air quality, the residual effects on human health resulting from emissions are assessed as not significant.

10.6.4.9 Summary

A summary of residual effects resulting from an explosion and/or fire is presented in Table 10.6-1 for those VCs where an interaction may occur. The more detailed VC-specific definitions for magnitude, geographic extent, duration, frequency, reversibility and context are presented in Sections 5 to 9, and are used in cases where the descriptors are relevant for both the project effects assessment and for the accident or malfunction effects assessment. Mitigation and emergency response measures are presented in Sections 10.6.2 and 10.6.3.

Table 10.6-1: Summary of Residual Effects – Explosion and/or Fire

Valued Component	Residual Effects Rating Criteria						Likelihood of Residual Effect	Significance	Risk
	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Context			
Air Quality	M	LSA	ST	U	R	M	L	N	L
Greenhouse Gas Management	L	P	ST	U	R	D	L	N	L
Acoustic Environment	M	LSA	ST	U	R	M	L	N	L
Vegetation Resources	L	LSA	ST	U	R	L-H	L	N	L
Wildlife Resources	L	LSA	ST	U	R	L-M	L	S*	M*
Freshwater and Estuarine Fish and Fish Habitat	L	LSA	ST	U	R	M-H	L	N	L
Marine Resources	L	LSA	ST	U	R	L-H	L	N	L
Economic Conditions	M	RSA	ST	U	R	L-M	L	N	L
Visual Quality	L	LSA	ST	U	R	M	L	N	L
Marine Transportation and Use	L	LSA	ST	U	R	M	L	N	L
Community Health and Wellbeing	M	RSA	ST	U	R	M-H	L	S	M
Archaeological and Heritage Resources	H	LSA	P	U	I	D	L	S	M
Human Health	L	LSA	ST	U	R	H	L	S	M

KEY

MAGNITUDE:
N = Negligible
L = Low
M = Moderate
H = High

GEOGRAPHIC EXTENT:
PF = Project footprint
LSA = Local study area
RSA = Regional study area
P = Provincial—residual effect is within the provincial extent

DURATION:
ST = Short-term
MT= Medium-term
LT = Long-term
P = Permanent

FREQUENCY:
S = Single event
MI = Multiple irregular event
MR = Multiple regular event
C = Continuous
U = Unlikely: event is not likely to occur

REVERSIBILITY:
R = Reversible
I = Irreversible

CONTEXT:
L = Low resilience—low capacity for the VC to recover from a perturbation
M = Moderate resilience—moderate capacity for the VC to recover from a perturbation
H = High resilience—high capacity for the VC to recover from a perturbation
D = Disturbed
U = Undisturbed

SIGNIFICANCE:
S = Significant
N = Not Significant

LIKELIHOOD:
L = Low likelihood
M = Moderate likelihood
H = High likelihood

RISK:
The risk of the accident or malfunction to a VC is determined based on the likelihood of occurrence and consequence to the VC
L = Low risk—low likelihood and low consequence
M = Moderate risk—low likelihood and high consequence
H = High risk—high likelihood and high consequence

NOTE:
* In specific consideration of SARA-listed bird species

10.7 Vessel Grounding or Collision

LNG will be transported overseas by using purpose-built LNG carriers. At full build-out, and depending upon the sizes employed, a fleet of approximately 30 LNG carriers will use the marine access route between Triple Island and the port of Kitimat for between 170 to 350 trips per year. The marine terminal will accommodate a range of LNG carrier sizes. The LNG carrier's passage to Kitimat will involve passage in confined waters with required pilotage for a total of approximately 295 km. Although the marine access route has a number of turns, it consists mainly of straight-course line sections and is wide and deep with only one charted shoal patch (Nanakwa Shoal). TERMPOL (Transport Canada) and PIANC (World Association for Waterborne Transport Infrastructure) recommend a minimum channel width of 7 to 10 times the ship's beam for a two way channel. Along the entire route, in all areas, there is well over 20 times the largest LNG carrier's beam available (current largest LNG carrier has a beam of 53.8m). The marine access route has been used successfully by the RTA and Methanex operations for their shipping for many years.

Marine transport of LNG by large vessels has a long record of safe operation. Since the first commercial LNG cargo shipped 50 years ago in 1964, there have been no collisions, fires, explosions or hull failures resulting in a loss of containment for LNG ships (GIIGNL 2012, Stantec 2014a). The impressive LNG marine shipping safety record is attributable to the inherently safe and robust design and construction of the vessels and their specialized cargo containment systems, comprehensive operational procedures, crew training, equipment maintenance planning, continuous technological improvements and effective industry standards and regulatory oversight by government. LNG is transported in double-hulled ships designed to prevent leakage or rupture in a collision or grounding. LNG is stored in special cargo tanks using either a metal membrane containment system supported and located within the ship's inner hull or special welded aluminum self-supporting spherical tanks that sit inside the ship's double hull. For membrane containment systems, a secondary barrier surrounds the primary barrier with insulation in between. Both types of containment systems have multiple gas sampling points that can detect trace amounts of methane (the main component of natural gas) in the event of even the smallest cargo tank leak.

Even with this impressive LNG carrier safety record, the potential for accidents to occur still exists even though it may be very unlikely. This would have various consequences for the receiving environment, depending on the circumstances and release of any hazardous materials (e.g., bunker fuel oil) or LNG cargo.

10.7.1 Scenario Descriptions

In considering potential vessel accident scenarios, four credible sub-scenarios form the basis for analysis: vessel grounding; vessel-to-vessel collision; vessel-to-marine terminal allision (an event where a vessel strikes a fixed object); and vessel-to-marine mammal collision. These are further discussed below.

10.7.1.1 Vessel Grounding

While unlikely, grounding is most likely to occur near the marine terminal, when an LNG carrier is in shallow waters and close to shore. Loss of directional stability (due to main engine malfunction or blackout) or tugboat controls, coupled with strong onshore winds and current changes, could result in low impact grounding. Grounding of an LNG carrier while travelling the marine access route is even more unlikely, given the presence of a professional crew lead by a master mariner and supported by two certified BC Coast Pilots, an escort tug during all transits and the use of specialized harbour tugs for vessel positioning at the marine terminal.

10.7.1.2 Vessel-to-Vessel Collision

The credible worst-case scenario for vessel-to-vessel collision assumes a non-tug assisted vessel collides with the side of the current largest LNG carrier, resulting in extensive hull damage to both vessels and the release of LNG and fuel. This LNG carrier is considered because it is up to 345 m in length with draft of about 12-14 m, and capacity of up to 266,000 m^3 of LNG product. In addition to LNG and fuel spills from the LNG carrier (see Section 10.2), a spill of up to 2,500 m^3 of marine diesel from the other unescorted vessel could also occur.

Since each LNG carrier will carry a professional qualified crew lead by a master mariner (captain), with the guidance of two certified BC Coast Pilots, modern navigational equipment and aids, and have the assistance of an escort tug, a high-intensity collision of an LNG carrier with another ocean-going vessel is very unlikely to occur. Since LNG carriers are double-hulled and LNG containment is isolated, hull breach would require a high-intensity impact penetrating the outer hull, ballast tanks/void spaces, inner hull, and finally, the cargo tank containment system itself. While possible, this scenario is highly unlikely.

10.7.1.3 Vessel Allision with the Marine Terminal

Maneuvering of each LNG carrier in and out of the marine terminal berth has the possibility of resulting in an allision with the supporting marine terminal infrastructure. Loss of directional stability (due to main engine malfunction or blackout) or poor tugboat control, coupled with strong onshore winds and current changes, could result in a low-impact allision. LNG carriers will be maneuvered in and out of the terminal by experienced Captains and licensed BC Coast Pilots (i.e., unrestricted pilots with a minimum of seven years of experience). Since maneuverability of an LNG carrier is reduced at low speeds, maneuvering will be strictly controlled by up to four assist tugs capable of moving and holding the LNG carrier in and out of the berth.

Since an incident of this type has never resulted in an LNG cargo containment breach, the worst-case scenario can only be assessed theoretically. In the very unlikely event of an LNG carrier allision with the marine terminal, there is a remote chance for penetration of an LNG carrier's double-hull which may release marine diesel or LNG into the marine environment. In addition, a high-intensity allision could also rupture the LNG loading or circulation arms depending on location of impact. During periods in between carrier loadings, only small amounts of LNG will be circulated through the loading lines to keep them cool. The magnitude of a potential spill from the loading lines during this period is very small and would not contribute meaningfully to potential effects in this scenario.

10.7.1.4 Collision with a Marine Mammal

There is potential for a Project-related vessel to collide with a marine mammal. At full build-out, up to 350 LNG carrier transits to the marine terminal could take place annually. During construction, ship traffic volumes may be sporadic with periods of high activity. On average, shipping traffic volumes during construction and operation are expected to be similar (approximately one vessel per day visiting the marine terminal). The slower speeds in areas of high marine mammal density (maximum speed of 10 knots or approximately 18 km/h) planned for the vessels along the marine access route during periods of high marine mammal densities should give sufficient time for marine mammals to avoid the vessels and increasing the encounter distance between a whale and the vessel and therefore reducing the likelihood of a collision (Gende et al. 2011), and reducing the probability of a severe collision (Vanderlaan and Taggart 2007). As a result, the likelihood of marine mammal strikes is low. The LNG carrier will also have an enhanced look-out bridge team during transits in the channels.

10.7.1.5 Credible Worst-Case Scenario

For the vessel grounding, vessel-to-vessel collision, and vessel-to-marine terminal allision (collision between a ship and a stationary object), the credible worst-case scenario is a hull breach and containment failure of one LNG tank and one fuel tank. Although it is more likely that a vessel will use diesel for fuel, as opposed to bunker fuel, it is possible that some vessels will have bunker fuel on board. This could result in a spill of up to 53,200 m^3 of LNG and this scenario has been carried forward for the purposes of the assessment. Project-related vessels (e.g., LNG carriers, escort tugs) will comply with the International Maritime Organization (2010) requirement for protected fuel tanks individually not exceeding 2,500 m^3. Although fuel tanks may be much smaller than this, this volume is used for the purpose of this assessment as a maximum capacity of fuel to be conservative. Accidental release of the bunker fuel could only occur following a substantial rupture of the vessel hull and failure of fuel tank protection measures, including any tank liners. Spills could also result from accidents or malfunctions associated with tugs or construction-related vessels that support the LNG Canada marine activities. However, because these smaller vessels carry smaller fuel volumes, the potential effect of a spill would also be smaller and therefore does not constitute a credible worst-case scenario.

The magnitude of environmental effects associated with a spill depends on the nature of the product spilled, the volume, location, and timing of the spill, as well as the efficiency of response measures. LNG has a specific gravity of about 0.45 (making it float on water). If released, the LNG will rapidly vaporize by absorbing heat from contact with warm surfaces and the atmosphere. Ice formed as a result of exposure to LNG may form a scab over the hull fracture and potentially reduce or fully close the hull opening. Without an ignition point, the methane vapour will mix with air and disperse into the atmosphere until the exposed LNG is plugged or the tank is emptied. If the vapour cloud is ignited, it will burn back to the source and continue to burn at the source until the cargo tank is empty or the fire is extinguished. If confined, LNG will not explode but, upon warming and turning into vapour, will simply burn (see Section 10.4 and Section 10.6). If the spill rate is high, the heat released during rapid phase transition may lead to a localized explosion (see Section 10.4 and Section 10.6).

When fuel oil (Bunker C) is spilled in the marine environment, only 5% to 10% is expected to evaporate within the first hours of a spill (NOAA 2014). Because of the density and viscosity of fuel oil, it is not expected to disperse into the water column or form slicks, but is more likely to break up into patches and tarballs that can be carried long distances, making them difficult to detect. The specific gravity of fuel oil can vary and consequently oil spilled in the marine environment can float, be suspended in the water column or sink, where the latter circumstance can result in subsurface tarballs (NOAA 2014). With rapid response, most of the fuel oil can be effectively recovered using skimmers and vacuum pumps. Oil that reaches the shoreline tends to remain on the surface, allowing for effective shoreline cleanup if conducted before the oil weathers (NOAA 2014).

Diesel oil is a light, refined petroleum fuel and when spilled on water, most of the oil will quickly spread to a thin film and evaporate or naturally disperse within a few days or less (NOAA 2014). Due to its low viscosity, it is readily dispersed into the water column, forming small droplets that are carried and kept in suspension by the currents, unless they emulsify or mix with suspended particulate matter and sink to the bottom. Due to its properties, there is seldom any oil on the surface for responders to recover. If spills reach the shoreline, diesel will penetrate porous sediments, but also be washed off by wave action, generally negating the need for shoreline cleanup (NOAA 2014). Diesel oil is readily and completely degraded by naturally occurring microbes, under time frames of one to two months (NOAA 2014).

10.7.2 LNG Carrier Design Measures to Reduce Risk and Consequences

Risks and consequences associated with grounding or collisions of an LNG carrier, as described in 10.7.1, will be reduced through a combination of rigorous vessel design measures and marine traffic management practices.

LNG carriers will adhere to the Vessel Pollution and Dangerous Chemicals Regulations under the *Canada Shipping Act, 2001*, specifically the need for a response organization and an oil pollution prevention plan.

Every LNG carrier built after July 1, 1986 must conform to the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IMO 1993), otherwise known as the IGC Code. The code provides an international standard for the safe transport of bulk LNG and other substances by prescribing specific design and construction standards for ships and their auxiliary equipment. This includes LNG carrier cargo containment system requirements regarding the primary and secondary barriers. The code also prescribes loading limits, the cargo tank venting system, and fire protection and extinguishing requirements.

Since LNG carriers are double-hulled, any hull breach would require a high-intensity impact penetrating the outer hull, ballast tanks/void spaces, inner hull, and finally, the cargo containment system itself (composed of an inner and outer containment barrier and associated insulation in a membrane type). Even if LNG containment is compromised, it is even less likely that more than one LNG tank would be compromised at the same time. Thus, the credible worst case scenario considered an LNG spill from a single tank (up to 53,200 m^3).

LNG carriers servicing the Project will require certification under the International Association of Classification Societies (IACS). Certification under IACS will further contribute to maritime safety and regulation through technical support, compliance verification and research and development. LNG carrier crews and operators are provided with an international standard training which includes vessel-specific emergency response protocols. The vessel's officers responsible for cargo operations must have specialized gas carrier training.

The insulation space between the two containment barriers will include sensors programmed to detect minute amounts of methane (the main component of natural gas), used to indicate a possible leak of LNG. This technology will ensure containment breaches are identified and addressed immediately.

LNG carriers using the marine access route will have a professional crew, led by an experienced master mariner (captain) and supported by two licensed BC Coast Pilots for the entire passage, both inbound and outbound. The Pacific Pilotage Authority (PPA) is a not-for-profit crown corporation responsible for providing experienced marine pilots to vessels subject to compulsory pilotage in the Pacific Pilotage

Regulations (2009), under the *Pilotage Act* (2011). The unique characteristics of the Canadian pilotage system include independent focus on public interest, rigorous pilot licensing standards, responsiveness to the unique regional requirements, and government, public and industry stakeholder accountability. LNG carrier crews and operators will also have a high standard of training which includes vessel-specific emergency response protocols. There are currently no anchorages available for large vessels at the head of Douglas Channel. Arrival times for LNG carriers at or near the Triple Island pilotage station will be managed so that berths are available upon arrival at the marine terminal, eliminating any need for waiting in the channel of the harbor.

LNG carriers will travel at average speeds of 8 to 14 knots, which will be determined based on the judgment of an experienced ship captain and the local advice from the BC Coast Pilots on board and will be subject to the necessity to ensure navigational safety at all times and taking into consideration location and marine mammal presence. In areas of high whale density between the northern end of Campania Island and the southern end of Hawkesbury Island, LNG carriers will travel at average speeds of 8 to 10 knots from July through October (recognizing periods of high use by marine mammals) (Mitigation 10.2). LNG carriers also have automatic identification system (AIS) equipment fitted and call-in procedures to the Marine Communications and Traffic System located in Prince Rupert. This will help reduce the risk for collisions and groundings. Each LNG carrier is also fitted with standard equipment and navigational safety aids to prevent collisions with other vessels including radars, navigation lights, shapes, sound-signaling devices, marine VHF radios, compasses, electronic charts, and emergency steering.

Each LNG carrier will be accompanied by assist escort tugs during transit of the marine access route and four harbour tugs while maneuvering and on standby at the marine terminal. LNG carriers will be teamed with escort tugs capable of assisting and holding each LNG carrier well away from the shallow waters and shores in the case of engine or steering failure.

Reducing the potential of marine mammal-vessel collisions will primarily rely on vessel speed restrictions as the most effective method to reduce the probability of striking marine mammals as well as the probability of a fatal collision (e.g., Vanderlaan and Taggart 2007; Wiley et al. 2011). Transiting at slower speeds will also increase the ability for avoidance maneuvers if an animal were to surface in front of or near a vessel. LNG carriers' crew and the BC Coast Pilots will remain vigilant and use VHF marine radio communications to broadcast marine mammal presence in local area.

10.7.3 Response Measures

The Canadian Coast Guard and Transport Canada have jurisdiction over emergency response procedures for a vessel involved in a collision away from the marine terminal. Although emergency response for such an incident is outside of LNG Canada's purview, LNG Canada will require that vessels servicing the Project have their own emergency response plan in place that meets or exceeds LNG Canada's safety standards for such accidents and would assist as and when required. In the event of a grounding or collision, mitigation measures would focus on human safety, fuel and LNG spill source containment, fire and explosion prevention or protection, and reducing associated effects. Emergency response is the obligation of the operator of each respective LNG carrier servicing the marine terminal.

Although the primary response responsibility is with the LNG carrier operator, LNG Canada will initiate its own best management practices within its jurisdictional authority. This may include notification of appropriate regulatory agencies, Aboriginal Groups, and stakeholders that would be affected by grounding and subsequent spills. An LNG spill response would follow the vessel's emergency response plan, with assistance from LNG Canada as appropriate. In the event that an LNG spill results in a fire or explosion, the response will be as described in Section 10.6.

Response to a fuel spill would be guided by the Emergency Response Plan. For spills in the marine environment, response procedures (depending on the nature, volume and conditions at the time of the spill) could include natural dispersion, mechanical containment and recovery through the use of booms and its subsequent removal using sorbents, skimmers, and other mechanical recovery devices and techniques, and shoreline clean-up as required.

Marine and auxiliary equipment spill response will be supported by a Transport Canada certified Response Organization such as Western Canada Marine Response Corporation (WCMRC). The WCMRC North Coast operations are located in Kitimat and Prince Rupert, allowing for a regional response on short notice. All clean-up and restoration activities would be approved by the appropriate regulatory agencies.

Project-related vessel collisions with marine mammals will be reported to the Marine Mammal Response Program under Fisheries and Oceans Canada. This program works with partners to track and respond to marine mammal entanglements, strandings, vessel strikes, contaminated animals, and other threats. Personnel working on Project-related marine activities will be required to observe, document and report any incidents of vessel strikes to the 24-hour hotline.

10.7.4 Potential Residual Effects

A vessel grounding or collision is a credible worst-case scenario with a low likelihood of occurrence that will be further reduced through implementation of the general prevention measures outlined in Section 10.1 and the specific Project design measures to reduce risk outlined in Section 10.7.2. The mitigation (prevention and response) measures outlined in Sections 10.1, 10.7.2 and 10.7.3 will reduce the likelihood and severity of potential residual effects associated with a vessel incident.

Potential residual effects from a vessel grounding or collision with another vessel or marine terminal primarily relate to effects from fuel spills and LNG spills, with potential for interaction with a number of VCs including air quality, GHG management, wildlife resources, freshwater and estuarine fish and fish habitat, marine resources, economic conditions, marine transportation and use, archaeological and heritage resources and human health.

Design measures for risk and consequence reduction are part of the terminal design and operation, and any planned emergency response and clean-up methods would be expected to occur immediately following the accident and would be expected to reduce the dispersal of hazardous materials through marine and terrestrial habitats.

10.7.4.1 Atmospheric Environment and Visual Environment

Air quality in the immediate area could be adversely affected in the event of either a fuel spill or LNG spill. A spill of bunker fuel oil, on land or in water, will result in the release of light hydrocarbons into air through volatilization. The effect of a bunker fuel spill on air quality will be localized (within 1 km) and brief (hours to days). Emissions from a spill will disperse quickly into the atmosphere, limiting the potential for human health effects. Facility staff and spill responders will have appropriate PPE to further reduce potential effects of hydrocarbon emissions. The effects of a diesel fuel spill would be similar, with evaporation of spilled fuel occurring at a faster rate.

If ignited, the burning of spilled bunker fuel will result in the release of products of incomplete combustion including particulate matter and hydrocarbons, such as PAHs, with resulting effects on air quality and visual quality. The effect of a bunker fuel fire on air quality will be localized (within 1 km) and brief (hours to days). The products of incomplete combustion are non-toxic when adequately dispersed in the atmosphere such that exposure to direct emissions in the vicinity of the fire should be limited; or PPE is worn.

Because any adverse effects on air quality and greenhouse gas emissions would be temporary, reversible, and limited in geographic extent, the residual effects are assessed as not significant. In addition, the likelihood of any vessel collision or grounding resulting in a loss of containment of fuel is very unlikely, and therefore the risk of a bunker or diesel fuel spill is low for these VCs.

The duration of residual effects from an LNG spill into the marine environment would be considerably shorter than for fuel spills. The vapour cloud would consist mostly of LNG facility-processed methane with minimal amounts of ethane and heavier hydrocarbons. Air emissions would disperse relatively quickly without any serious effects on air or visual quality. There would be a negligible contribution to the overall Canada and BC total greenhouse gas emissions. Thus, residual effects on air quality, visual quality, and GHG management are assessed to be not significant.

The risk of a fuel or LNG spill or release into the marine environment to air quality, GHG management, the acoustic environment, and visual quality is low because the likelihood of such an event is low, and the consequence is low (i.e., not significant effect).

10.7.4.2 Wildlife Resources

The effects of oil spills to wildlife are well established for seabirds (Burger and Fry 1993, Jenssen 1994, Carter and Kuletz 1995) and marine furbearing mammals (NOAA 2004). Bunker oil is known to be persistent (Lee et al. 2003) and can be transported hundreds of kilometres (NOAA 2004), whereas LNG and diesel cannot. Accordingly, this assessment is limited to the potential effects of a bunker oil spill.

Spilled oil may affect wildlife by ingestion and thereby affecting physiology, reproductive performance and suppressing the immune response system (Burger and Fry 1993; Environment Canada, 2014); by coating feathers or fur and thus impeding thermoregulation (Jenssen 1994); or by altering intertidal community structure (Kingston 2002). PAHs from oil are known to bioaccumulate in zooplankton (Almeda et al. 2013) and thus enter the marine food web; however, there is little evidence of biomagnification with trophic levels (Environment Canada 2014). The degree or magnitude of the effect to wildlife depends upon season and location. A spill occurring during a seasonal congregation (e.g., bird migration staging, winter congregations) or near sensitive habitat (marine mammal haulout locations, salt marshes) can have a greater effect than one occurring during a period when the area is not used as heavily or in deep water. There is little relationship between the size of the spill (volume spilled) and seabird mortality (Kingston 2002, Burger and Fry 1993) indicating that even small spills can result in a measureable detrimental response by local wildlife, although Kingston (2002) points out that environmental recovery may be relatively swift (i.e., within 2-10 years). In general, those species more intimately associated with the water surface are affected the most; for example, shorebirds are less affected than waterfowl and marine birds, although shorebirds may suffer chronic and sub-lethal effects from feeding in the contaminated intertidal (NOAA 2004).

Of the 11 key wildlife species identified for the LSA, harlequin duck, marbled murrelet, double-crested cormorant, common goldeneye, and glaucous-winged gull are most likely to be affected by a spill of bunker oil. In particular, Carter and Kuletz (1995) identify the marbled murrelet as being highly sensitive and having the highest mortality rate among seabirds in response to oil spills. The western sandpiper and the black oystercatcher, both birds which use the intertidal extensively, are also at risk for indirect impacts.

The distribution of oil and effect of a spill of bunker oil along the marine access route will depend upon spill volume, climatic and oceanographic conditions at time of spill, as well as season. Heavy oils, such as bunker, are problematic in terms of clean up due to difficulty in detecting extent and boundaries of spill, distribution of oil within three-dimensional water column (as opposed to light oils which float), effort and expense of keeping the vessel clean to avoid further contamination outside of spill location, and often a need for heated storage tanks to keep the oil sufficiently liquid for pumping (Ansell et al., 2001). Conventional dispersants are ineffective on heavy oil. Ansell et al. (2001) maintain that oil which has sunk in open water is likely unrecoverable.

Exposure to hydrocarbons frequently leads to hypothermia and deaths of affected marine birds (French–McCay 2009). Although some may survive these immediate effects, long-term physiological changes may eventually result in lower reproductive rates or premature death. Sublethal effects of hydrocarbons ingested by marine birds may affect their reproductive rates or survival rates. Sublethal effects may persist for a number of years, depending upon generation times of affected species and the persistence of any spilled hydrocarbons. Most marine birds are relatively long-lived. Adult marine birds foraging offshore to provision their young may become oiled and bring hydrocarbons on their plumage back to the nest to contaminate their eggs or nestlings, causing embryo or nestling mortality (Leighton 1993). The factors influencing the long-term effects of a spill on a bird population can include the circumstances of the spill event (acute or chronic exposure, location of spill, time of year) and health of bird populations (Burger 1993; Wiese and Robertson 2004).

Although a bunker fuel spill could result in mortality of marine birds at the individual level, these environmental effects are predicted to be reversible at the population level and therefore not significant. However, there is potential for mortality of SARA-listed bird species to be harmed or killed from oiling, particularly species vulnerable to oiling, such as marbled murrelet, resulting in the potential for a significant adverse effect. The risk of a bunker oil spill to SARA-listed bird species is therefore moderate because although the likelihood of such a spill is low, the consequence could be high, depending on the time of year and extent of the release (i.e., significant effect).

In the event of a LNG release, birds or wildlife within the vapour cloud may be harmed through asphyxiation and lung damage (Luketa-Hanlin 2006) or freezing. The most vulnerable species to these events include birds that spend periods of their life history foraging within near shore areas or wildlife with reduced mobility. Given the localized nature of potential LNG spills, populations should sustain no long-term residual effects from an LNG release; therefore, residual effects are assessed as not significant.

With the exception of a hazardous materials spill as described above, the risk of a vessel collision or grounding to wildlife resources is low because the likelihood of such an event is low, the potential for interaction of grounded vessels with wildlife resources is low, and the consequence is low (i.e., no significant effect).

10.7.4.3 Marine Resources and Freshwater and Estuarine Fish and Fish Habitat

Spills of either diesel or bunker oil from LNG carriers and support vessels could adversely affect the quality of marine, estuarine and freshwater fish habitat, Such spills could also cause direct or indirect localized mortality of associated flora and fauna. Potential effects of both of these scenarios are discussed together below.

Fish, invertebrates, and vegetation that come in direct contact with diesel fuel may be killed. Potential residual effects on eulachon or salmon populations would be increased if a spill were to occur during spawning migrations or seaward out-migrations. Crabs, shellfish, and eulachon can be tainted from diesel spills in shallow and near-shore areas. These organisms bioaccumulate diesel fuel, but crabs and shellfish will effectively eliminate it (i.e., filter it out), usually over a period of several weeks after exposure (NOAA 2006). The high lipid content of eulachon may make it more susceptible to absorption of lipophilic organic contaminants (Higgins et al. 1987), such as those associated with petroleum products. As a consequence, it could take longer for the species to eliminate any ingested hydrocarbons due to a spill; however, there is a reduced likelihood of diesel exposure to adult eulachon because of its predominantly marine life cycle. Eulachon is only present in estuarine and freshwater habitats for a short period during annual spawning migrations at the end of its life cycle, which historically occur over several weeks in late winter (late February to early March) on the Kitimat River (McPhail 2007).

Due to the high viscosity of bunker oil there is a relatively low risk of it contaminating adult finfish (Yender et al. 2002). However, given the propensity of heavy fuel oil to sink and strand in fish spawning areas, the release of bunker oil presents a long-term toxicity risk to developing fish embryos because of the sustained release of PAHs from the oil to interstitial waters (Hatlen et al. 2010, Martin et al. 2014). Recent research by Martin et al. (2014) showed that modern heavy fuel oil like bunker C was in fact consistently more toxic to rainbow trout (*Oncorhynchus mykiss*) than crude oil, regardless of exposure method. The most important factors that would determine the degree of adverse effects of a bunker oil spill on estuarine or freshwater fish habitat quality or availability would be the extent of sediment contamination and oiling on the vegetation (NOAA 2014). Plants can survive partial oiling; although, if most or all of the vegetation is coated in heavy oil, the roots often survive if the substrate is not heavily oiled.

With respect to marine mammals, vapours released by oil spills are likely the most immediate threat to marine mammal health (Gubbay and Earll 2000). Marine mammals may inhale volatile hydrocarbons that vaporize from the surface of spilled oil when breathing at the water surface. This can result in lethargy and intoxication, and irritate or damage soft tissues such as the mucus membranes of the eyes and airway (Englehardt 1983; Gubbay and Earll 2000). Medium to long-term effects on marine mammals can occur if they ingest oil by eating contaminated prey or if they feed in an area of a spill. Baleen whales are especially vulnerable because they ingest large volumes of water during feeding, which can result in oil coating their baleen resulting in reduced filtering capacity (Englehardt 1983). All mammals can digest and metabolize some oil. While the oil is not usually bioaccummulated in mammals, some amount can be absorbed and cause toxic effects (LGL Limited 2000).

Studies suggest that some cetaceans can detect oil spills; however, they may or may not consistently avoid contact with various oil types (St. Aubin et al. 1985; Smultea and Würsig 1995). Some evidence exists that dolphins attempt to reduce contact with surface oil by decreasing their respiration rate and increasing dive duration (Smultea and Würsig 1995). Even if cetaceans actively avoid slicks, continued exposure through feeding on oiled prey may occur. The long-term health effects on cetaceans of external exposure, bioaccumulation, or ingestion of oil-contaminated food remain poorly studied (Gubbay and Earll 2000).

Cetaceans are highly mobile and carry energy reserves that reflect their seasonal or “pulsed” feeding activities. Short-term exclusion from a particular area due to a spill would likely have no measurable residual effect on populations, since none of the marine mammal species are restricted by range to the marine resources shipping RSA and are likely able to move to other areas.

Residual effects of a diesel spill on estuarine fish and fish habitat and on marine resources are not expected to have population-level effects because diesel spills are expected to disperse and degrade fairly rapidly. Further, the likelihood of such a spill is low, any potential interaction with the VC would be of short duration, and there is a low likelihood of causing harm to any endangered or threatened species. As a result, residual effects on these VCs are assessed as not significant.

Adverse effects of bunker oil are generated primarily through coating of marine animals, smothering of intertidal invertebrates or fish, and long-term sediment contamination (NOAA 2014). Bunker oil, which is grouped under the same type as heavy crude oil (NOAA 2014), can also cause sickness, stranding, or mortality in whales and dolphins (Geraci 1990).

Bunker oil spills are difficult to clean-up if not caught very early and can form tarballs that can be difficult to detect visually or with remote sensing techniques (NOAA 2014). A bunker spill could have residual adverse effects on estuarine fish (due to chronic embryonic or larval effects) and fish habitat and intertidal species. Similarly, residual chronic effects could be observed in marine mammals directly exposed to the heavy oil. However, the likelihood of a bunker oil spill affecting the population viability of cetaceans or pinnipeds is expected to be low, given that the volume of bunker oil that would be carried by the LNG carriers and a credible worst-case scenario is one involving a spill of 2,500 m^3. Therefore, adverse effects on marine fish, estuarine fish, and marine mammals are likely to be not significant. Depending on the location and timing of a spill, there could be harm to threatened or endangered species, resulting in a significant effect.

The risk of a bunker oil spill to freshwater and estuarine fish and fish habitat and non-listed marine mammals is low because the likelihood of such a spill and the consequence are both low (i.e., not significant effect).

In the event of an LNG spill, it is possible that fish within a few hundred metres of the spill may freeze or be injured at the water surface. An LNG spill may also temporarily reduce general habitat quality in the immediate vicinity. LNG is not persistent and is not toxic to aquatic biota. Once any ice (from the initially -160°C LNG) melts, the environment will return to normal with no residual trace of the incident. Any marine mammals transiting through the vapour cloud may be harmed or killed through freezing or asphyxiation (see Section 10.4.4). Residual effects on fish and fish habitat are assessed as not significant.

No long-term residual effects from an LNG release resulting from a collision or grounding are expected. The buoyancy of the vapour will enhance vapour cloud dispersion to the atmosphere with no long-term hazardous residual effects. Unlike a petroleum-based oil spill, an LNG spill does not require environmental clean-up.

An explosion or fire from the spilled LNG would have effects as outlined in Section 10.5.4.

Collision of an LNG carrier or other support vessels with marine mammals may cause injury and potential mortality to the marine mammal. The likelihood of such an event depends on the distribution, abundance, and behavioural characteristics of the marine mammal species, as well as the relative increase of LNG carrier activity (and supporting vessels) associated with the Project, compared to existing vessel activity. With reductions in LNG carrier speeds, the probability of a lethal or severe injury is reduced.

As of 2013, the International Whaling Commission has recorded 1,073 ship strike incidents worldwide, including historic (early 1900s) and recent events (Ritter and Panigada 2013). A review of ship strike data by Jensen and Silber (2003) found tankers were involved in 6% of strikes. Collisions between vessels and whales commonly involve large baleen whales, such as fin whales and humpback whales (e.g., Jensen and Silber 2003; Laist et al. 2001; Neilson et al. 2012). A summary of whale-vessel collisions in Alaskan waters from 1978 to 2011 by Neilson et al. (2012) reported that over 80% of collisions were with humpback whales, with 18% of those reported as fatal. Toothed whales and pinnipeds are less frequently involved in collisions, probably due to their smaller size and agility (Laist et al. 2001). Collisions between vessels and 18 different small cetacean species have been reported worldwide (Van Waerebeek et al. 2007), including 10 collisions with killer whales in BC waters (Williams and O'Hara 2009).

In 2013, DFO reported humpback whales as the most frequently struck species in BC according to reports from the BC Marine Mammal Response Network. Vessel strikes on toothed whales, such as killer whales, are less likely, and most commonly occur due to small vessels traveling at high speeds (DFO 2013).

It is rare for a pinniped to be struck by a vessel; from 1973 to 2012, DFO's Marine Mammal Incident Database has only one recorded strike involving a Steller sea lion. There have been a few reported cases of harbour seal strikes, though none witnessed. Data obtained from BC Marine Mammal Incident Database is collected on a voluntary basis and the accuracy of data could be limited by several factors including: unknown reporting compliance following a strike; unknown sinking frequency of struck animals (and the determination of pre or post mortem strike); limited capacity for re-sighting reported carcasses or injured mammals; and inconclusive cause of death determinations at advanced stages of decomposition.

The probability of marine mammal vessel strike and the severity of injury to the marine mammal as a result of a collision depend on:

- position of the marine mammal relative to the direction of the vessel's travel
- time the marine mammal spends in waters along a designated route
- speed, bridge team look-out, size, and type of vessel, and
- species of mammal.

Research suggests the probability of vessel-marine mammal collisions are more likely in geographic bottlenecks, such as narrow straits or confined inlets or passageways (Williams and O'Hara 2009). The encounter distance between a vessel and a marine mammal also decreases with increased vessel speed (Gende et al. 2011).

The probability and severity of a strike also increases with vessel speed (Jensen and Silber 2003; Vanderlaan et al. 2008). Whales are more likely to suffer lethal injuries from vessel collisions when vessels travel at speeds greater than 13 knots (Jensen and Silber 2003; Laist et al. 2001).

Within the marine resources shipping RSA, humpback whales, which are listed as threatened under SARA, may be the most vulnerable marine mammal species with respect to vessel collisions. Predictive modelling results suggest humpback whales are the most abundant large whale species with peak abundance in August (Stantec Consulting Ltd. 2014b) primarily within Squally Channel. Historically, they also have high numbers of reported vessel collisions (e.g., Neilson et al. 2012).

The probability of a strike is directly related to vessel speed. Kite-Powell et al. (2007) modeled the likelihood of a ship strike given a right whale swimming into the path of the large vessel for a range of vessel speeds. The likelihood of a ship strike by a large vessel traveling at a speed of 25 knots is above 50%; at 12 to 13 knots, approximately 35%; at 10 knots, approximately 30%; and at 8 knots, approximately 28%. Larger marine mammals, calves and resting whales have a higher likelihood of being struck, whereas smaller marine mammals are less likely to be struck (Laist et al. 2001). If a vessel strike of a marine mammal occurs, the probability of lethal injury is approximately 50% at a speed of 12 knots, and reduces to approximately 30% at 10 knots and approximately 15% at 8 knots (Vanderlaan and Taggart 2007). Based on the likelihood of striking a whale (Kite-Powell et al. 2007) and the probability of a ship strike being lethal (Vanderlaan and Taggart 2007), it is estimated the probabilities of lethal strike on a marine mammal directly in the path at speeds of 8 knots to 14 knots are approximately 4% to 20%; at 8 knots to 10 knots (in areas of high whale density, see Section 10.6.2), the probability is approximately 4% to 9%. These low probabilities indicate that population-level effects on marine mammals are unlikely to occur; however, as there is the potential for physical injury or mortality to SARA-listed species, the significance is conservatively rated as significant.

The risk of a vessel collision with marine mammals is moderate because the likelihood of such an event is low, and the consequence is high (i.e., significant effect for species at risk).

10.7.4.4 Economic Conditions and Marine Transportation and Use

A scenario resulting in economic effects due to loss of access to fishing grounds during key harvesting times, gear damage, increased expenses or changes in marketability or market value, could result in substantial effects to commercial, recreational, and Aboriginal fisheries. For example, a 265 m^3 bunker oil and marine diesel spill near Coos Bay, Oregon, resulted in a 21-day closure for bivalve harvest (Gilroy 2000, Mauseth and Challenger 2001). Additionally, marine transportation and use could be adversely affected by clean-up activities following a large spill. Vessels within the Canadian West Coast area might be required to avoid areas where the spill occurred, resulting in delays or re-routings, which could result in substantial economic consequences if delays are persistent (e.g., on fisheries, shoreline harvesting, eco-tourism, guided angling).

A bunker oil spill could result in substantial economic effects on commercial, recreational, and Aboriginal fisheries. For example, a spill of bunker oil could restrict access to fishing grounds (e.g., fishers are not likely to be allowed to fish in the immediate and surrounding areas with oil present), damage gear (e.g., soak into netting or cover lines), increase operational expenses (e.g., vessels might be required to travel further to unaffected areas), or reduce the value or marketability of the target species (e.g., through real or perceived perceptions of contamination), depending on the location and time of year.

The uptake of oil and PAHs by exposed fish poses a potential threat to human consumers and affects the marketability of catches. However, even when results demonstrate safe exposure levels for consumption and closed areas are reopened for fishing, market perceptions of poor product quality (e.g., tainting) can persist, thereby prolonging effects for fishers. Reduced demand for seafood that is perceived to be tainted can also lead to depressed market prices. As demonstrated in the Gulf of Mexico following the Deepwater Horizon Oil Spill, lack of consumer confidence in seafood quality and in the validity of government testing methods can have effects that persist beyond the period of actual effects. Even after federal and state testing showed Gulf seafood to be safe to eat, sales remained depressed due to lack of consumer confidence (National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling n.d.).

One or a combination of these mechanisms may act to cause substantial economic losses for commercial, recreational, and Aboriginal fishermen. Similar mechanisms might lead to adverse effects on recreation and tourism and the use of marinas and moorage facilities. In the event of a spill of bunker oil from a vessel, significant adverse residual effects on economic conditions and marine transportation and use could result. The risk of a bunker oil spill is moderate because although the likelihood of such a spill is low, the consequence could be high (i.e., significant effect) for effects on economic conditions and marine transportation and use.

The credible worst-case diesel fuel spill scenario is not expected to cause significant economic consequences because the area that the spill might affect, and the duration of the associated clean-up are not expected to cover areas large enough or be of a duration long enough to cause significant residual effects on marine transportation and use. Any perceived issues of taint and reduced marketability of seafood is also unlikely, because the visible effects of the spill would be limited both temporally and spatially in comparison to a bunker oil spill. Similarly, a diesel fuel spill is not expected to cause significant adverse residual effects on recreation or tourism opportunities. A spill of 2,500 m^3 of diesel is not expected to restrict access to, cause gear damage great enough, or alter seafood perceptions such that significant adverse economic effects occur. The residual effects of such a spill are expected to be moderate in magnitude, medium-term in duration, and reversible. Consequently, the residual effects of a credible worst-case diesel fuel spill on marine transportation and use and economic conditions are predicted to be not significant.

Vessel groundings or collisions may have potential economic effects if short-term exclusion zones (which are expected to be relatively small) are imposed at the site of the collision. Commercial, recreational, and Aboriginal fisheries may be temporarily and locally affected, but are expected to have access to alternative fishing sites. As a result, residual effects on marine transportation and use and on economic conditions are expected to be not significant. The effects of a fuel spill are discussed above. Therefore, the risk of a vessel collision or grounding on economic conditions and marine transportation and use is low because the likelihood of such an event is low, and the consequence is low (i.e., not significant effect).

10.7.4.5 Archaeological and Heritage Resources

A diesel fuel spill or a bunker oil spill to the marine environment has the potential to adversely affect inter-tidal and coastal archaeological and heritage resources. No control studies have been conducted to examine the effects of petroleum hydrocarbons on archaeological deposits. However, the relationship between the physico-chemical properties of sediments and the degradation or preservation of different archaeological materials is known (Davidison and Wilson 2006) and potential effects of hydrocarbon contamination can be predicted.

Known or potential effects are:

- Introduction of hydrocarbons will contaminate organic materials, effectively rendering the most common approach to dating archaeological sites (radiocarbon dating) ineffective.
- Petroleum hydrocarbons are phytotoxic to plants at relatively low concentrations (Adam and Duncan 1999). Changes to plant biomass may result in increased erosion of archaeological sites.
- changes in biological and chemical properties of sediments can affect the preservation of archaeological materials, which preserve or degrade under varying conditions.

Petroleum hydrocarbons have been shown to affect microbial activity, some elemental concentrations, and soil acidity (Obire and Nwaubeta 2002), which all affect preservation rates. This may be especially problematic at coastal shell midden sites. In shell middens, natural soil acidity has been neutralized because of the presence of abundant marine shells, resulting in the preservation of artifacts made of bone and antler, as well as animal and human skeletal remains. The introduction of hydrocarbons is expected to negatively affect the preservation of these organic archaeological materials.

The effect of petroleum hydrocarbon contamination on archaeological resources can be expected to vary based on the local physico-chemical properties of the sediments and the type of archaeological materials present within the site or sites in question. For these reasons, adverse residual effects on archaeological and heritage resources from a spill may be significant.

The risk of a diesel fuel or bunker oil spill on archaeological and heritage resources is moderate because although the likelihood of such a spill is low, the consequence could be high (i.e., significant effect).

If a vessel grounding were to occur directly into an inter-tidal or coastal archaeological or heritage site with sufficient energy, the resource would likely be damaged; such an event, although highly unlikely to occur, could result in residual adverse significant effects on archaeological or heritage resources.

The risk of a vessel grounding on archaeological and heritage resources is moderate. Although the likelihood of a vessel grounding in general is very low, and the likelihood of a vessel grounding in a location where archaeological or heritage resources are present is even lower, the potential consequence could be high (i.e., significant effect) if a vessel grounding did occur in such a way as to cause damage or destruction to archaeological or heritage resources.

10.7.4.6 Human Health

Human health risks associated with food-chain exposures to spills of diesel fuel in the marine environment primarily result from the ingestion of contaminated seafood (e.g., fish and shellfish). Seafood contamination can result from exposure to the fraction of oil dissolved in the water column, dispersed oil droplets, or oil coating the organism. As a result of its physical properties (i.e., low viscosity and specific gravity), diesel fuel spreads rapidly into thin slicks that are readily dispersed by natural processes. Although diesel fuel usually floats on the surface with much of the product evaporating, it can sink to the bottom if it emulsifies or mixes with suspended particulate matter. Consequently, diesel fuel spills to the marine environment can result in moderate to high risk of seafood contamination via exposure to diesel fuel's relatively high concentration of low molecular weight, water soluble PAHs, and dispersed droplets (Yender et al. 2002). However, diesel fuel products have a relatively low proportion of high molecular weight PAHs, and are therefore less likely to accumulate in tissues and persist for long periods (Meador et al. 1995). Thus, residual effects on human health are expected to be not significant.

Human health risks associated with food-chain exposures to spills of bunker oil (i.e., bunker fuel) in the marine environment also result from the ingestion of contaminated seafood (e.g., fish and shellfish). As a result of its physical properties (i.e., high viscosity and specific gravity), bunker oil does not readily disperse or mix in the water column, but may sink in seawater if it emulsifies or mixes with suspended particulate matter. Consequently, bunker oil spills to the marine environment are likely to result in low risk of finfish contamination and moderate to high risk to benthic species (e.g., shellfish) (Yender et al. 2002). Additionally, where bunker oil strands on shorelines or accumulates on the intertidal or subtidal bottom, slow rates of weathering could result in its becoming a chronic source of contamination to benthic species (Yender et al. 2002).

As a result of their relative persistence and carcinogenicity, high molecular weight PAHs in spilled oil are typically of greatest concern with regards to human health effects (Yender et al. 2002). Refined heavy oils such as bunker oil have a greater proportion of high molecular weight PAHs, which are more likely to accumulate in tissues and persist for longer periods compared to low molecular weight PAHs (Meador et al. 1995). In addition, although finfish and some crustaceans metabolize and eliminate PAHs rapidly, some shellfish such as bivalve mollusks have a limited capacity to metabolize PAHs and are more likely to accumulate high molecular weight PAHs in tissues (CalEPA 2013; Yender et al. 2002). As a result, body burdens in shellfish, especially bivalves, tend to persist longer than for seafood items exposed in the water column (e.g., finfish).

Previous oil spills (e.g., T/V Sea Empress, T/V Braer, T/B North Cape, M/V Kure, M/V New Carissa, T/V Exxon Valdez) documenting the duration of body burdens on various seafood items show that PAH concentrations in wild finfish decrease rapidly and reach “background” concentrations within 1-2 months after a spill, whereas body burdens in caged finfish can persist longer (e.g., up to five months) (see references in Yender et al. 2002). For crustaceans, such as crabs, the amount of time before body burdens reach “background” concentrations after a spill vary with species behaviour. However, in general, the longest seafood closures associated with oil spills are for bivalves, which can take many months to greater than a year to eliminate PAH body burdens to background concentrations (CalEPA 2013; Brodberg et al. 2007; Yender et al. 2002; Law et al. 1997).

A spill of bunker oil to the marine environment would result in the immediate issuance of a fisheries advisory warning members of the public not to consume fish or seafood from the affected area until further notice. Monitoring of PAH concentrations in finfish and crustacean tissues would be employed to determine when PAH levels had returned to levels where finfish and crustaceans would be considered safe for human consumption. This use of fisheries advisories and the associated monitoring of PAH levels in fish and shellfish tissue would mean that there would be no significant exposure to human consumers of seafood and no significant residual effects.

10.7.4.7 Summary

A summary of residual effects resulting from a vessel collision or grounding is presented in Table 10.7-1 for those VCs where an interaction may occur. The more detailed VC-specific definitions for magnitude, geographic extent, duration, frequency, reversibility, and context are presented in Sections 5 to 9, and are used in cases where the descriptors are relevant for both the project effects assessment and for the accident or malfunction effects assessment. Mitigation and emergency response measures are presented in Sections 10.7.2 and 10.7.3.

Table 10.7-1: Summary of Residual Effects – Vessel Collision and/or Grounding

Valued Component	Residual Effects Rating Criteria						Likelihood of Residual Effect	Significance	Risk
	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Context			
Air Quality	M	LSA	ST	U	R	M	L	N	L
Greenhouse Gas Management	L	P	ST	U	R	D	L	N	L
Wildlife Resources	M	RSA	ST	U	R	L-M	L	S*	M*
Freshwater and Estuarine Fish and Fish Habitat	M	RSA	ST	U	R	M-H	L	N	L
Marine Resources	M	RSA	ST	U	R	L-H	L	S*	M*
Economic Conditions	L	LSA	ST	U	R	L-M	L	N	L
Visual Quality	L	RSA	ST	U	R	M	L	N	L
Marine Transportation and Use	M	RSA	ST	U	R	M	L	S	M
Archaeological and Heritage Resources	H	LSA	P	U	I	D	L	S	M
Human Health	L	LSA	ST	U	R	H	L	N	L

KEY

MAGNITUDE:

N = Negligible

L = Low

M = Moderate

H = High

GEOGRAPHIC EXTENT:

PF = Project footprint

LSA = Local study area

RSA = Regional study area

P = Provincial—residual effect is within the provincial extent

DURATION:

ST = Short-term

MT= Medium-term

LT = Long-term

P = Permanent

FREQUENCY:

S = Single event

MI = Multiple irregular event

MR = Multiple regular event

C = Continuous

U = Unlikely: event is not likely to occur

REVERSIBILITY:

R = Reversible

I = Irreversible

CONTEXT:

L = Low resilience—low capacity for the VC to recover from a perturbation

M = Moderate resilience—moderate capacity for the VC to recover from a perturbation

H = High resilience—high capacity for the VC to recover from a perturbation

D = Disturbed

U = Undisturbed

SIGNIFICANCE:

S = Significant

N = Not Significant

LIKELIHOOD:

L = Low likelihood

M = Moderate likelihood

H = High likelihood

RISK:

The risk of the accident or malfunction to a VC is determined based on the likelihood of occurrence and consequence to the VC

L = Low risk—low likelihood and low consequence

M = Moderate risk—low likelihood and high consequence

H = High risk—high likelihood and high consequence

NOTE:

* In specific consideration of SARA-listed species

10.8 Cumulative Effects of Accidents or Malfunctions

CEAA's Operational Policy Statement titled "*Assessing Cumulative Environmental Effects under the Canadian Environmental Assessment Act, 2012*" (May 2013) requires that "the environmental effects of accidents and malfunctions must be considered in the assessment of cumulative environmental effects if they are likely to result from the designated project in combination with other physical activities that have been or will be carried out."

Effects from small accidental spills of hazardous materials (smaller but potentially more frequent than the credible worst-case spill scenarios outlined previously) could result in likely cumulative effects with other accidents or malfunctions, or with other projects and activities. However, spill response and cleanup for small accidental spills will be implemented immediately, with the objective to eliminate any residual effects from such spills, thus avoiding cumulative effects. In the event this is not completely effective, any small residual cumulative effects from such spills would be remediated at Project closure; therefore, cumulative effects from these spills are expected to be not significant.

The increase in number of vessels in the marine shipping RSA could result in cumulative effects on marine mammals due to vessel-marine mammal collisions. Currently, up to 348 vessels per year (including ferries and cruise ships but not including smaller commercial vessels, recreational boats or fishing vessels) travel within the marine shipping RSA; 88 of these travel within Douglas Channel and Kitimat Arm (resulting in 176 transits). Likely over the next decade, the marine access route could see an additional 791 large vessels (1,582 large vessel transits) annually from reasonably foreseeable projects (including LNG Canada). This would result in an increase from the current 0.5 transits per day in Douglas Channel and Kitimat Arm to 4.3 transits per day, an increase of approximately eight times over current vessel traffic. Vessel strikes with marine mammals may therefore increase with the proposed increase in cumulative vessel traffic in the marine shipping RSA. Project mitigations include a reduction in vessel speeds in areas of high marine mammal densities within the confined channels of the marine access route (i.e., between the northern end of Campania Island and the southern end of Hawkesbury Island). Other proposed projects will have similar mitigations (i.e. Enbridge Northern Gateway 2010). Reduced vessel speeds reduce the probability of a marine mammal-vessel strike and the probability of a lethal injury as a result of a vessel strike (see Section 10.7.4.3 for a detailed description). Cumulative effects are conservatively rated as significant because of the potential for injury or mortality of a SARA-listed species if a collision were to occur, although there is a low likelihood of population-level effects on marine mammals. The risk of a vessel collision with marine mammals is moderate because the likelihood of such an event is low, and the consequence is high (i.e., significant effect for species at risk).

With respect to the other potential accidents or malfunction scenarios discussed in the preceding sections, these events are not likely to occur, and therefore effects from the scenarios are also unlikely to occur. This is in large part due to the emphasis LNG Canada places on the safe design of its Project, the historical safety record of both the industry and companies involved, and the implementation of a proven Project risk management framework as further detailed in Section 10.1, which will serve to further manage any hazards or risks associated with the Project. Accordingly, cumulative environmental effects of the other accidents and malfunction scenarios addressed in Sections 10.3 to 10.7 are not likely, and therefore are not considered further.