B TECHNOLOGICAL RISK ASSESSMENT

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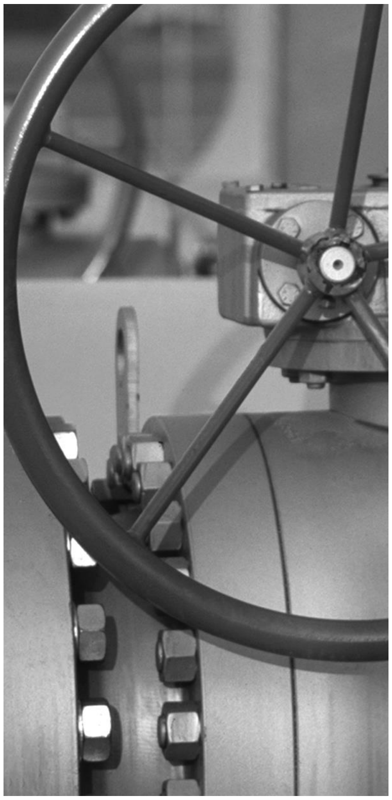

Bear Head LNG

A subsidiary company of Liquefied Natural Gas Limited

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01 | 04 | 2015

FINAL REPORT

622560-0001-T-4E-REP-000-0002

A subsidiary company of Liquefied Natural Gas Limited

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EXECUTIVE SUMMARY

The Bear Head LNG project consists of treating and liquefying natural gas to produce 8 million tonnes per annum (8 mtpa) of LNG (Liquefied Natural Gas). The facility will be built according the stringent requirements of the CSA Z276 Standard and the LNG Code of Practice. With the knowledge acquired through the years in the LNG industry, this modern facility will benefit from all the technological progress in the field of safety.

LNG, natural gas and refrigerants including methane, ethane, butane and ammonia will be the main hazardous materials at the plant. LNG will be stored in two tanks with an individual capacity of 180,000 m^3 approximately. These tanks will be single containment type with a second wall to maintain the insulation material. All piping in and out of the tanks will be through the top of the tanks. Natural gas will be transported by pipeline and there will be no storage at the plant. Refrigerants will be present mainly in the process, but will also be stored in small quantities at the plant in make-up cylinders and ISO containers.

The site is located within the Port Hawkesbury/Bear Head Industrial Park with land use designated for heavy industrial development, including petrochemical and marine facility activities. The main other tenants in the industrial park include an oil and gas trans-shipment terminal, a natural gas processing/fractionation plant and a coal fired electrical generating plant. These facilities are located at more than 2 km from the implementation site. Wind turbines are in operation at about 200 m from the north limit of the implementation site.

The population is mostly located in Port Hawkesbury, located at about 6 km north-west of the site. Across the Strait of Canso, the smaller town of Mulgrave is also located at about 6 km north-west of the site. The small community of Evanston is located 7 km north-east. The closest inhabitants are located on the other side of the Strait of Canso, along the coastal road (Marine Drive). A distance of approximately 2 km separates them from the site.

As required by the CSA Z276 Standard and the LNG Code of Practice, the site will include provisions to retain potential spilled LNG, flammable refrigerants and flammable liquids within the process, storage and transfer areas. As required by the standard and the code, each LNG storage tank will be surrounded by berms. The tank bermed area will have a capacity respecting the 110% minimum holding requirement. Furthermore, process and transfer areas will be drained to impoundment basins with capacities in accordance with the standard and the code. These impoundments will serve the liquefaction trains, the LNG rundown lines, the LNG transfer lines and the ship loading area.

The CSA Z276 Standard and the LNG Code of Practice specify setback and separation distances, as well as thermal and vapour dispersion exclusion zones. The project will be in compliance with all these requirements. One of the thermal exclusion zones slightly exceeds the property limit by approximately 100 m, but Bear Head LNG is currently completing negotiations to acquire the surrounding lands included in this exclusion zone. Some thermal exclusion zones exclude specific land uses around the plant site. However, these land uses are unlikely since the project area is all zoned industrial.

LNG tank impounding area fire could expose the non-involved tank and the process equipment to a radiant heat flux in excess of 30 kW/m^2, which is a maximum limit specified by LNG Code of Practice. Bear Head LNG will provide mitigation (most likely in the form of automated water spray or deluge systems) in order to achieve compliance with this requirement. Furthermore, the impoundments for the process and transfer area will be built in insulated concrete as a mitigation measure to meet the vapour dispersion exclusion zones.

As required by the CSA Z276 Standard, an evaluation of potential consequences in case of accidents was carried out to check the suitability of the plant site regarding the safety of the plant personnel and the surrounding public. The project being subject to the Environmental Emergency Regulations (under the Canadian Environmental Protection Act), this assessment followed the guidelines in risk management recommended by Environment Canada.

The evaluation of major and worst-case scenarios demonstrates that accidents involving the flammable mixed refrigerants (methane, ethane, butane) would have consequences limited to the site or its immediate surroundings. These accidents would have no consequences to the population.

A worst-case accidental release of ammonia was assessed with no mitigation measures in place and without considering the dispersion effect of the numerous air coolers close to the ammonia circuit. In case of weather conditions unfavourable to dispersion (low wind speed) and depending of the wind direction, few residents scattered along Marine Drive, on the other side of the Canso Strait, could experience adverse health effects if they are not protected. For the same scenario, the large population of Port Hawkesbury and Mulgrave would be exposed to much lower ammonia concentrations resulting only in temporary discomfort and irritation. These consequences are for worst-case scenarios only, which have a very low probability of occurrence. It is also to be noted that populations are located upwind of dominants wind directions and that low wind speed is not frequent because of the ocean proximity. For example, the specific low wind conditions blowing from BH facilities towards Marine Drive occur about 1% of the time. For most likely scenarios or if worst-case scenarios happened with more frequent weather conditions that are favourable to dispersion, all the population would not be affected. Protection measures specific to ammonia will be implemented at the plant to reduce potential consequences: leak detection systems, isolation and shut-down valves in the ammonia circuits, fixed deluge systems covering all potential ammonia release points. In addition, shelter-in-place will be planned in the emergency response plan. A more detailed analysis will be performed during detailed engineering to confirm the risk management measures or additional mitigation measures required to assure that the local population is not significantly impacted in the unlikely event of a major ammonia release.

Most major accidents involving a LNG release would have consequences limited to the plant site or its immediate surroundings, because all liquefaction trains and transfer area will be drained to impoundment basins, as requested by the CSA Z276 Standard and the LNG Code of Practice. This mitigation measure will greatly contribute to reduce the thermal radiations flux in case of LNG fire or the extent of a flammable vapour cloud if the released LNG vaporized without ignition.

An unmitigated major release from a storage tank with LNG covering all the bermed area could generate a more extended vapour cloud. In case of weather conditions unfavorable to dispersion, few residents scattered along Marine Drive could be exposed, but not the large population in Port Hawkesbury and Mulgrave. If this scenario occurred with the most frequent weather conditions that are more favourable to dispersion, no residents would be impacted. To assure that the local population is not significantly impacted in the unlikely event of a major LNG release from storage tanks, risk management measures or additional mitigation measures will be evaluated during detailed engineering.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF MAPS

Page

LIST OF APPENDICES

MEASUREMENT SYMBOLS

Quantity measured	Symbol	Unit
Time	s	Second
	min	Minute
	h	Hour
Length	m	Meter
	cm	Centimeter
	ft	Feet
	In	Inch
	mm	Millimeter
	km	Kilometer
Area	m^2	Square meter
	ft^2	Square feet
Volume	m^3	Cubic meter
Temperature	°C	Degree Celsius
Mass	kg	Kilogram
Pressure	kPa	Kilopascal
	kPag	Kilopascal (gauge – relative to atmospheric pressure)
Mass flow	kg/s	Kilogram per second
	mtpa	Million tonnes per annum
Volume Flow Rate (liquid)	m^3/h	Cubic meter per hour
Volume Flow Rate (gas)	m^3/h	Cubic meter per hour
Speed	m/s	Meters per second
Energy	BTU	British thermal unit
Power	BTU/h	British thermal unit per hour
	kW	Kilowatt
Heat Flux	kW/m^2	Kilowatt per square meter
	$Btu/h/ft^2$	British thermal unit per hour per square feet
Concentration	ppm	Parts per million
Multiplying prefix	M (million)	Mega (10^6)
	k (thousand)	Kilo (10^3)
	c	Centi (10^{-2})
	m	Milli (10^{-3})

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ACRONYMS

AEGL	Acute Exposure Guideline Levels
AGRU	Acid Gas Removal Unit
aMDEA	Activated Methyldiethanolamine
BOG	Boil-Off Gases
CRAIM	Council for Reducing Major Industrial Accidents
CSA	Canadian Standards Association
DIPPR	Design Institute for Physical Property
EN	European Norm
FEED	Front End Engineering Design
IMO	International Maritime Organization
INERIS	Institut national de l'environnement industriel et des risques (National Institute of Industrial Environment and Risks)
ISO	International Standards Association
LFL	Lower Flammable Limit
LNG	Liquefied Natural Gas
LP	Low Pressure
MR	Mixed Refrigerant
NFPA	National Fire Protection Association
NSBI	Nova Scotia Business Inc.
OSMR®	Optimized Single Mixed Refrigerant
PHAST	Process Hazards Analysis Software Tools
SOR	Statutory Orders and Regulations

1 INTRODUCTION

The Liquefied Natural Gas (LNG) facility in Cape Breton will be built according to the stringent requirements of the CSA Z276 Standard and the LNG Code of Practice of Nova Scotia. With the knowledge acquired through the years in the LNG industry, this modern facility will benefit from all the technological progress in the field of safety.

The purpose of this report is to examine potential hazards associated with the proposed Bear Head LNG Project. The hazards would arise from failure of facility components resulting from accidents or natural catastrophes. The effect of such events on the reliability and safety of the facility is evaluated in this report, and the procedures and design features proposed to reduce potential hazards are described.

This analysis is based on the Basis of Design, the Heat and Mass Balance, the Equipment List and other information contained in the Pre-FEED Documents issued on December 2014.

2 HAZARD IDENTIFICATION

2.1 Description of Hazardous Materials

The LNG facility consists of treating, liquefying and storing natural gas, which is a hazardous material in liquid and gaseous form. Other hazardous materials will be present at the plant, mainly refrigerants. Table 1 shows the quantities of the main hazardous materials that will be present at the Bear Head LNG plant.

2.1.1 LNG

LNG will be stored in two tanks with an individual capacity of 180,000 m^3 approximately. The LNG storage tanks will be single containment type, with an inner wall being of low-temperature 9% nickel stainless steel and the outer wall of carbon steel. The outer tank wall diameter will be approximately 78 m and the height at the top of the dome is approximately 55 m.

LNG is natural gas in its liquid state that has been cooled at atmospheric pressure to 161ºC below zero. LNG's principal hazards result from its cryogenic temperature and its flammable vapour.

LNG has the appearance of a colourless liquid. Although LNG vapour has no odour or colour, its low temperature causes condensation of water vapour in the air, forming a visible white cloud.

LNG has a density of approximately 424 kg/m^3, about half that of water. LNG releases or spills do not leave any residues and do not cause long-term environmental impacts like oil spills.

Table 1 Identification of the Hazardous Materials Present at the Plant

Materials	Source	Transportation	Storage
LNG	On-site production from feed gas	Export by LNG carrier.	Two (2) single containment tanks, about 180,000 m^3
Methane	Dry feed gas, BOG and LP fuel gas	None required. Methane will be taken directly from the gas supply on site.	None required.
Ethane	External	Delivery to site in high pressure cylinders contained in an ISO frame.	Cylinders.
N-butane	External	Delivery to site as liquid in pressurized ISO containers.	ISO container.
Anhydrous Ammonia	External	Delivery to site as liquid in pressurized ISO containers.	None required. Process inventory make-up delivered on site when required.
Nitrogen	Nitrogen generator and external.	Partly produced on site. High purity nitrogen delivered to site as liquid in pressurized ISO containers.	ISO containers for high purity nitrogen.
Methyldiethanolamin (aMDEA)	External	Delivery to site in drums.	One amine storage tank for each train.
Heavy Hydrocarbon Liquid	On-site production from feed gas	Sent outside by truck.	Two tanks.
Diesel	External	Delivery to site by fuel truck.	Steel storage tanks with impoundment.

LNG is nontoxic, but LNG vapour at high concentrations can displace oxygen, resulting in oxygen levels that are too low for safe human exposure, potentially causing asphyxiation if a person were to enter a high concentration area. Direct contact with LNG causes frostbite because of its cryogenic temperature.

LNG vaporizes rapidly on contact with any surface that is at a temperature greater than the LNG itself. Vapour resulting from the vaporization of LNG has a specific gravity of 1.5 and initially behaves like a heavy gas, in that it spreads laterally and seeks the lowest points in the vicinity. As the cloud warms above -107°C, its density becomes lower than air, so it rises and rapidly disperses into the atmosphere. The distance that the vapour travels depends on many variables, including the release rate and duration, the wind velocity and direction, terrain characteristics, and atmospheric temperature and humidity.

The flammability characteristic of LNG vapours can be manifested as pool fires or jet fires in case of an immediate ignition or flash fires in case of a delayed ignition with concentrations within the range of the flammability limits (5 to 15 percent).

LNG itself is not explosive, but LNG vapour (mainly methane) can form an explosive mixture with air if its concentration is within the flammability range and the cloud is located in a confined or congested area.

When coming in contact with water, LNG vaporizes violently causing what is known as a *physical explosion* or *cold explosion.* There is no combustion in this explosion but rather a huge transfer of energy from the water to the LNG.

2.1.2 Natural Gas

A pipeline will be developed to transport feed gas to the Bear Head LNG facility. There will be no natural gas storage at the site.

Natural gas is odourless, colourless, non-corrosive, and non-toxic. Like all gases, natural gases at high levels of concentration can cause asphyxia. It is flammable with lower and upper flammability limits of 5% and 15%. A release can produce a jet fire in case of immediate release or a flash fire in case of delayed ignition. An explosion can occur only if the gas is at concentrations between the flammability limits and located in a confined or congested area.

Natural gas feed is expected to have approximately the following composition (base case): 90.94% methane, 5.12% ethane, 1.42% propane, 1.8% carbon dioxide, 0.4% nitrogen and 0.32% C4+.

2.1.3 Refrigerants

The liquefaction process will use anhydrous ammonia and a refrigerant mixture to provide the cooling.

Anhydrous ammonia is used as a liquefied or compressed gas. The ammonia refrigerant will be used to cool:

- The mixed refrigerant in the ammonia/MR pre-cooler;
- The inlet air for the gas turbines;
- The dry gas after exiting the mercury guard bed;
- The wet gas exiting the amine contactor.

The use of ammonia as the pre-cooling refrigerant makes the OSMR® (optimized single mixed refrigerant) technology more efficient than the other processes available to produce LNG. It also provides stable operation of the plant since it dampens the impact of variations in ambient air temperatures which would otherwise affect plant operation and capacity. The temperature of the ammonia refrigerant has been selected to optimize the overall performance of the plant.

Each LNG train will have a circulating ammonia inventory of approximately 50,000 kg. Ammonia will be delivered to the site with ISO containers only when process make-up is required. If de-inventory is required, truck tankers will be mobilized to the site to transport ammonia off site.

The mixed refrigerant system is a closed circuit with continuous pressure and composition monitoring. However, very low losses occur because of fugitive emissions and make-up is needed periodically. Methane and nitrogen will be sourced from on-site processes and materials, while ethane and butane will be sourced externally and delivered in cylinders and ISO containers.

Each LNG train has a circulating mixed refrigerant (MR) inventory of approximately 52,000 kg. A single MR stream made up of four components will be used. The mixed refrigerant is a blend of nitrogen, methane, ethane and butane.

2.1.3.1 Ammonia (anhydrous)

Ammonia is a colourless liquid that is very soluble in water. It reacts with water to form ammonium ions and hydroxide, which poses a threat to aquatic life due to its basicity.

Its odour is detectable between 1-5 ppm thresholds (Cawthon et al., 2009; Smeets et al., 2007). The main danger associated with ammonia is toxic gas inhalation. The ammonia gas is an irritant and corrosive when in contact with the skin, eyes and respiratory tract. It is classified as a Class 2.3 toxic gas, subsidiary Class 8, corrosive, under the Transportation of Dangerous Goods Act.

Ammonia is a slightly flammable gas, but difficult to ignite with a narrow range of flammability (16-25%). However, ammonia cannot sustain a flame by itself and requires an external source to maintain the combustion.

2.1.3.2 Methane

Methane is the main component of the natural gas, for which the properties were discussed in Section 2.1.2.

2.1.3.3 Ethane

Ethane is a colourless and odourless gas. Even if not toxic, ethane is an asphyxiant gas at high concentrations and can lead to drowsiness and nausea. Frostbites can result from contact with rapidly expanding gas near the point of release.

Ethane is flammable and air-vapour mixtures within confined or congested area can become explosives if the concentration of ethane is between 3 and 13%. The gas has a density comparable to air.

2.1.3.4 Butane

Butane is a colourless gas with a light odour of gasoline. Even if not toxic, butane is an asphyxiant gas at high concentrations. Contact with rapidly expanding gas near the point of release may cause frostbite.

In mixture with air at concentration between 1.6 and 8.5%, butane can become explosive if located within confined or congested area. Since the gas is heavier than air, it spreads laterally and remains on the ground before behaving neutrally when it becomes sufficiently diluted.

2.1.4 aMDEA (Activated Methyldiethanolamin)

The carbon dioxide contained in the natural gas feed must be removed as this would otherwise freeze in the main LNG exchanger (cold box). This removal will be performed with activated Methyldiethanolamin (aMDEA) used as a liquid absorbent at the Acid Gas Removal Unit (Amine Plant).

aMDEA is slightly toxic to aquatic fauna and biodegrades quickly. It is not flammable or combustible, but is toxic in case of ingestion and leads to mouth and throat burns. It can also lead to slight skin and eye irritation.

2.1.5 Diesel

Minimal diesel will be required on site for the following applications:

- A diesel engine generator for emergency power;
- For the facility fire systems diesel driven fire water pumps; and,
- LNG tank deluge systems will employ pumps driven by diesel engines.

Diesel will be stored in steel tanks with secondary containment.

2.1.6 Heavy Hydrocarbon Liquid

The feed natural gas may contain small amount of freezable aromatics components such as benzene and cyclohexane that need to be removed from the gas prior to the liquefaction. This will be achieved using a heavy hydrocarbon column. Heavy hydrocarbon liquids produced from the column will be sent to a debutanizer column in the natural gas liquids handling unit where C3-C4 will be recovered back to the process while stabilized condensate produced will be stored and trucked off site and sold.

2.1.7 Hydrogen Sulphide

The feed natural gas will contain traces of hydrogen sulfide that will be removed before the gas liquefaction at the amine plant. The removed hydrogen sulfide will be oxidized in sulfur dioxide at the thermal oxidizer. There will be no storage on site.

2.2 ACCIDENT HISTORY

The most significant accidents related to the industry of LNG are listed in various documents (CH-IV, 2012; INERIS, 2011; Woodward and Pitblado, 2010). They are summarized in the following sections with respect to the type of equipments used.

Pre-Treatment and Liquefaction Units

The accidents involving the pre-treatment and liquefaction units are documented in Appendix A. There are relatively few accidents for these process units.

Recently, in March 2014, an explosion occurred at the Williams Company liquefaction plant in the state of Washington, United States. In total, 5 workers were injured and 400 residents were evacuated. The plant suffered significant damages, mainly to the exterior wall of a tank. However, there was no leakage of LNG.

LNG Storage Tanks

The most significant accidents involving storage tanks are summarized in Appendix A. It should be noted that several of these accidents occurred several years ago and the technological advancements in regards to storage tanks, in terms of material, operational procedures and protection equipment, make it very unlikely that these accidents would occur today. Also, several of these events must be considered as work accidents during construction or maintenance work.

Feeding Pipeline, Loading Equipment, Flares

The accidents involving equipment are described in Appendix A. These accidents are relatively more frequent, but they also have relatively limited consequences. Among these accidents:

- 2 were due to a discharge by a disc or a valve rupture;
- 1 was due to a collision between a ship and the pier;
- 7 were due to physical shocks by work or vehicle engines.

Most of these accidents did not cause any leaks of LNG. In all cases, no injuries occurred.

3 SENSITIVE ELEMENTS IN THE SURROUNDING

The sensitive elements in the community are those which, because of their proximity, could be affected by potential accidents at the proposed plant. They include mainly the population and others industrial facilities.

The project is located in the Point Tupper area of Cape Breton, Richmond County, Nova Scotia. The population is mostly located in Port Hawkesbury, located at about 6 km north-west of the site. Across the Strait of Canso, the smaller town of Mulgrave is also located at about 6 km north-west of the site. The small community of Evanston is located 7 km north-east.

The closest inhabitants are located on the other side of the Strait of Canso, along the coastal road (Marine Drive). A minimal distance of about 2 km separates them from the site.

The site is located within the Port Hawkesbury/Bear Head Industrial Park, which is managed by Nova Scotia Business Inc. (NSBI), with land use designated for heavy industrial development, including petrochemical and marine facility activities.

The other tenants in the Point Tupper/Bear Head Industrial Park include:

- NuStar Terminals - An oil and gas trans-shipment terminal;
- ExxonMobil Canada - A natural gas processing/fractionation plant;
- Nova Scotia Power - A coal fired electrical generating plant.

Existing activities in the business park include wind power generation, industrial waste management facilities, coal storage and handling, transshipment terminals, storage of dangerous goods and management of bulk petrochemicals.

4 COMPLIANCE TO THE CSA Z276 STANDARD AND THE LNG CODE OF PRACTICE

The CSA Z276-15 Standard is the applicable Canadian standard for the production, storage and handling of LNG. The CSA Z276-15 Standard provides guidelines and requirements in order to ensure an acceptable level of safety for the population in the proximity of LNG facilities. The Gas Plant Facility Regulations in Nova Scotia incorporates by reference the current version of the CSA Z276 Standard.

The LNG Code of Practice is adopted pursuant to the Nova Scotia Energy Resources Conservation Acts. The LNG Code of Practice provides additional requirements and guidance for the design, construction, operation and abandonment of land-based LNG plants and the associated jetty and marine terminal to insure the protection of the public.

The CSA Z276-15 Standard is similar to other standards developed at the international level for the design, construction and operation of LNG facilities are the American standard, NFPA 59A (National Fire Protection Association) and the European standard, EN 1473:2007.

This following section presents the Bear Head LNG Facility's compliance with the above mentioned CSA Z276-15 Standard and LNG Code of Practice.

4.1 PLANT SITING PROVISIONS

The site will include provisions to retain potential spilled LNG, flammable refrigerants and flammable liquids within the process, storage and transfer areas, as required by the CSA Z276 Standard. The spill and leak control must minimize the possibility that an accidental discharge of LNG endangers adjoining property, waterways or important process equipment and structures.

4.1.1 LNG Storage Tanks

The two approximately 180,000 m^3 LNG storage tanks will be single containment type tanks, with second walls to maintain the insulation material. All piping in and out of the tanks will be through the top of the tanks. To comply with the requirement of the CSA Z276-15 Standard, the bermed area around each tank will have a minimum holding capacity corresponding to 110% of the tank maximum capacity.

4.1.2 Process and LNG Transfer Areas

In accordance with the LNG Code of Practice, impounding areas that serve only process or LNG transfer areas shall be sized to contain the largest total quantity of LNG or other flammable liquids that can be released from a single transfer line in 10 minutes. The LNG Code of Practice also mentions that in lieu of determining release rates by conducting a fluid dynamics analysis based on the actual pump characteristics, the release rate can be taken as 1.3 times the normal pumping rate. The following assumptions were used to size impoundments proposed for the Project:

- For LNG transfer from the two LNG liquefaction trains to the LNG storage tanks (LNG rundown lines), the design transfer rate is 1,422 m^3/h (711 m^3/h per train), which yields a volume equal to 308 m^3 considering a spill duration of 10 minute and 1.3 times the normal pumping rate;
- For LNG transfer from each LNG storage tank to the LNG carrier, the design transfer rate is 5,000 m^3/h via two pumps delivering LNG at a rate of 2,500 m^3/h per pump, which yields a volume equal to 1,084 m^3 considering a spill duration of 10 minutes and 1.3 times the normal pumping rate.

In consideration of the above, two impoundment basins will be provided to serve the LNG rundown lines and the liquefaction trains, one for each set of two trains. Each impoundment basin will have a capacity of approximately 308 m^3 (14 m wide and 7 m long).

Two other impoundment basins will be in place to serve the LNG transfer lines from the tanks to the LNG carrier. Each basin will be localized within the bermed area around each tank and will have a capacity of approximately 1,084 m^3 (10 m wide and 20 m long). A third impoundment basin with two times the previous capacity (2,167 m^3, 20 m wide and 20 m long) will serve the marine transfer system in the ship loading area, the design transfer rate being 10,000 m^3/h from the two tanks.

4.1.3 Minimum Setbacks and Separation Distances

Table 2 lists the siting criteria (other than thermal heat flux and vapour dispersion exclusion zones) that will be adhered to in locating equipment and systems at the Facility.

Table 2 Minimum Setbacks and Separation Distances

Criteria	Requirement	Code/Standard Reference
Minimum distance from the nearest edge of impounded liquid to a property line that can be built upon.	15 m minimum; Note: Applies to entire impoundment system, i.e. trenches, troughs, curbed areas and impoundment basin(s).	Section 5.2.3.7 of CSA Z276 Standard
Minimum distance from edge of impoundment or container drainage system to buildings and property lines.	0.7 times the container diameter, but not less than 30 m.	Table 3 of CSA Z276 Standard
Minimum distance between storage containers.	¼ of the sum of the diameters of adjacent containers.	Table 3 of CSA Z276 Standard
Minimum distance between process equipment containing LNG or flammable gases from sources of ignition, a property line that can be built upon, control rooms, offices, shops, and other occupied structures.	15 m minimum	Section 5.2.6.1 of CSA Z276 Standard
Minimum distance between LNG loading connections from uncontrolled sources of ignition, process areas, storage areas, control buildings, offices, shops, and other occupied or important plant structures.	15 m minimum	Section 5.2.7.2 of CSA Z276 Standard

4.2 THERMAL RADIATION EXCLUSION ZONE REQUIREMENTS

The CSA Z276-15 Standard requires that provisions shall be made to prevent radiant heat flux in case of LNG fire in an impoundment from exceeding the following limits:

- 5 kW/m^2 (1,600 Btu/h/ft^2) at a property line that can be built upon for ignition of a design spill;
- 5 kW/m^2 (1,600 Btu/h/ft^2) at the nearest point located outside the owner's property line that, at the time of plant siting, is used for outdoor assembly by groups of 50 or more persons for a fire over an impoundment;
- 9 kW/m^2 (3,000 Btu/h/ft^2) at the nearest point of the building or structure outside the owner's property line that is in existence at the time of plant siting and used for occupancies classified by NFPA 101 (Life Safety Code), as assembly, educational, health care, detention and correction or residential for a fire over an impounding area;
- 30 kW/m^2 (10,000 Btu/h/ft^2) at a property line that can be built upon for a fire over the impoundment.

The CSA Z276-15 Standard requires the following weather conditions for the calculation of the thermal heat flux exclusion distances:

- The wind speed producing the maximum exclusion distances shall be used except for wind speeds that occur less than 5 percent of the time based on recorded data for the area;
- The ambient temperature and relative humidity that produce the maximum exclusion distances shall be used except for values that occur less than five percent of the time based on recorded data for the area.

According to this requirement, the local weather data (Port Hawkesbury, 2010-2014) have been analyzed and the conditions mentioned in Table 3 have been selected for the thermal heat flux analysis.

Table 3 Thermal Heat Flux Weather Assumptions

Parameter	Value
Ambient temperature	-9^{o}C
Wind speed	9.2 m/s
Relative humidity	52%

The software PHAST has been used to calculate the thermal heat flux exclusion zones (see section 5.4 for a description of the software). This model meets the requirements of the CSA Z276 Standard.

Table 4 summarizes the thermal exclusion zones for the storage tanks with a LNG fire over all the impoundment area or LNG fire of a design spill. Table 5 summarizes the thermal exclusion zones for a LNG fire covering the impoundment serving the liquefaction trains and the transfer lines. Maps 1 and 2 illustrate these thermal exclusion zones on the Bear Head LNG Facility plot plan.

Table 4 Thermal Exclusion Zones for LNG Storage Tanks

Tank	Requirement	30 kW/m^2	9 kW/m^2	5 kW/m^2
Tank 1 (south-west)	Fire over the impoundment	359 m	561 m	702 m
	Fire of a design spill	na	na	88 m
Tank 2 (north-east)	Fire over the impoundment	366 m	572 m	716 m
	Fire of a design spill	na	na	88 m

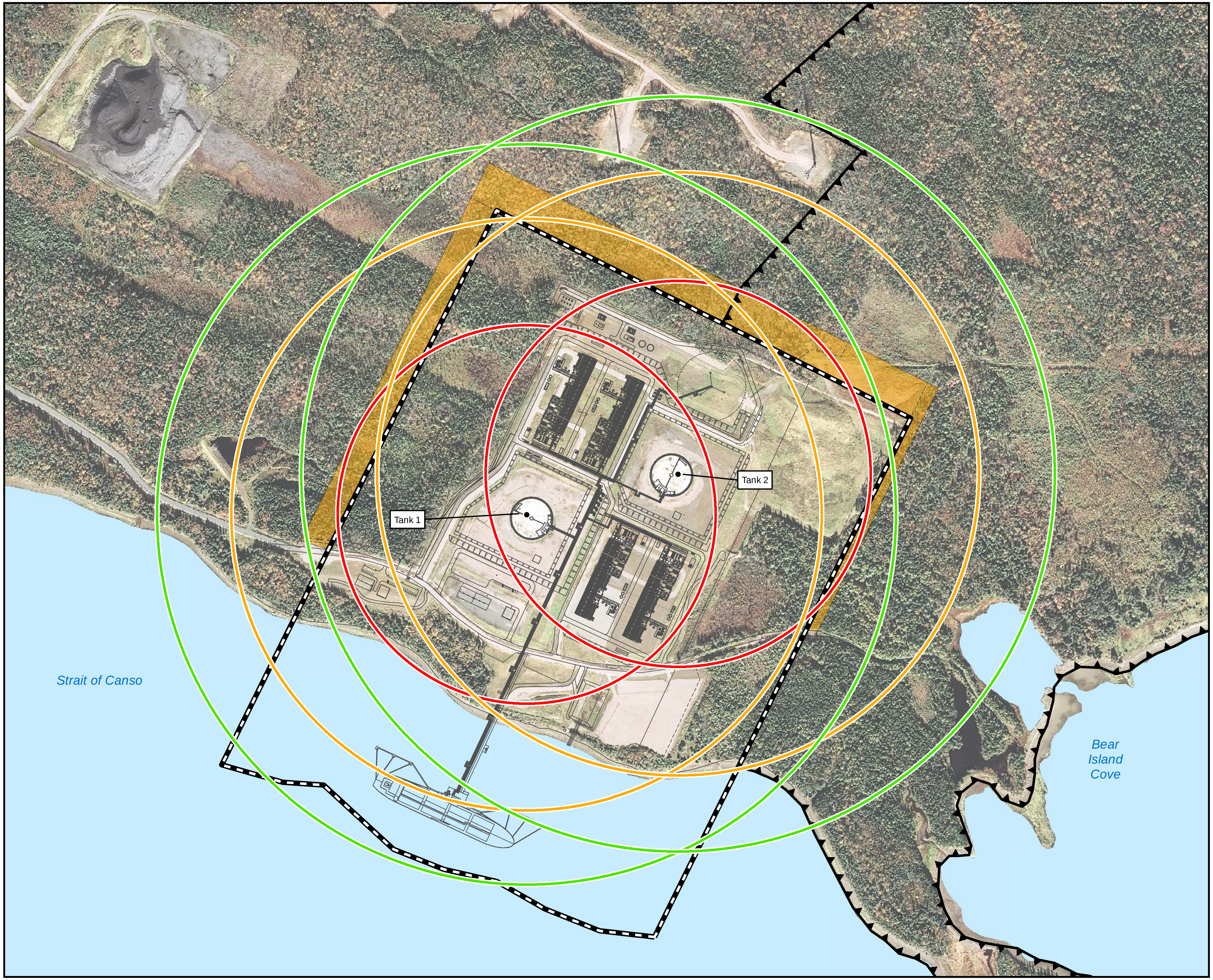
Table 5 Thermal Exclusion Zones for Liquefaction Train and Transfer Lines Impoundments

Impoundment	Requirement	30 kW/m^2	9 kW/m^2	5 kW/m^2
LNG rundown lines and liquefaction trains	Fire over the impoundment	34 m	53 m	60 m
LNG tank transfer lines	Fire over the impoundment	50 m	73 m	88 m
Ship loading area	Fire over the impoundment	65 m	98 m	120 m

To be in compliance with the requirements of CSA Z276 Standard, the radiant heat flux from any fully-involved LNG tank impounding area fire cannot exceed the 30 kW/m^2 at any onshore portion of the facility's property line. A review of Map 1 shows that this maximum slightly exceeds the property limit. However, Bear Head LNG is currently completing negotiations to acquire the surrounding lands included in this exclusion zone.

For the fully-involved tank impounding area fire, CSA Z276 Standard allows the 5 and 9 kW/m^2 thermal radiation exclusion zones to extend past the property line, but cannot exceed these levels for land uses described previously. A review of Map 1 shows that there is no such land uses inside these exclusion zones. The site therefore complies with this requirement. Furthermore, these land use limitations apply at the time of plant siting. The project area is all zoned industrial, so such development is unlikely.

Another requirement of CSA Z276 Standard is that a fire involving code-specified design spills specified cannot exceed the 5 kW/m^2 at a property line that can be built upon.



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Map 1

Thermal Exclusion Zones for LNG Storage Tanks

Legend

- Centroid of LNG Tank Containment Area
- Land Acquisition Zone
- Expansion Zone
- Bear Head Property Limit

Effect Distance

- 30 kW/m^2 (Tank 1: 359 m / Tank 2: 366 m)
- 9 kW/m^2 (Tank 1: 561 m / Tank 2: 572 m)
- 5 kW/m^2 (Tank 1: 702 m / Tank 2: 716 m)

N
W E
S

0 70 140 210 280
Metres

Map Parameters
Reference System: (ATS77)
Projection: Modified Transverse Mercator (MTM)
Zone: 4
Scale: 1:7,000
Project Numer: 622560
Date: March 11, 2015

Source :
- Service Nova Scotia and Municipal Relations, Access Nova Scotia, Nova Scotia Geomatics Centre.
- Topographic map, 2011, 1:10 000
- Plant Layout: LNGL, BH-SK-00-016-base2D.dwg (Update: December 12, 2014)

Filet Name: snc622560_rc_m1_risk_tank_11x17_pre01_150311.mxd

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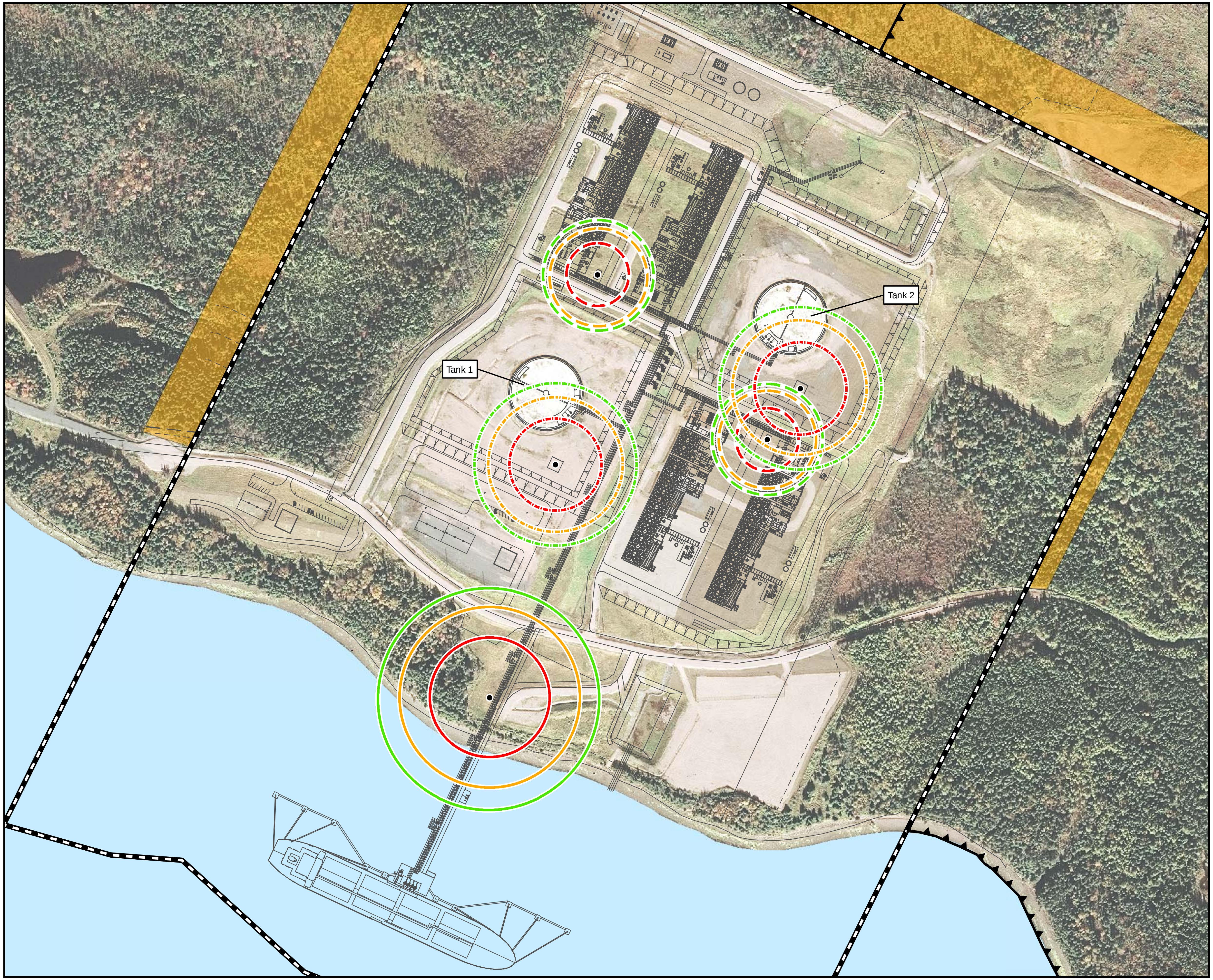

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Map 2

Thermal Exclusion Zones for Impoundment Basins

Legend

- Impoundment Pit
- Land Acquisition Zone
- Expansion Zone
- Bear Head Property Limit

Effect Distance

Ship Loading Area

- 30 kW/m^2 (65 m)
- 9 kW/m^2 (98 m)
- 5 kW/m^2 (120 m)

LNG Transfer Lines

- 30 kW/m^2 (50 m)
- 9 kW/m^2 (73 m)
- 5 kW/m^2 (88 m)

LNG Rundown Lines and Liquefaction Trains

- 30 kW/m^2 (34 m)
- 9 kW/m^2 (53 m)
- 5 kW/m^2 (60 m)

N
W E
S

0 40 80 120 160

Metres

Map Parameters
Reference System: (ATS77)
Projection: Modified Transverse Mercator (MTM)
Zone: 4
Scale: 1:4,000
Project Numer: 622560
Date: March 12, 2015

Source :
- Service Nova Scotia and Municipal Relations, Access Nova Scotia, Nova Scotia Geomatics Centre.
- Topographic map, 2011, 1:10 000
- Plant Layout: LNGL, BH-SK-00-016-base2D.dwg (Update: December 12, 2014)

Filet Name: snc622560_rc_m2_risk_tank_11x17_pre01_150312.mxd

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This design spill, which is defined in the next section, would flow into the basin localized within the bermed area of each tank. As shown on Map 2, the 5 kW/m^2 level doesn't go beyond the property limit, so this case is in compliance with the requirement of the CSA Z276 Standard.

For the impoundments related to the liquefaction train and the transfer lines, all thermal exclusion zones remain inside the property limit, as shown on Map 2. The site therefore complies with this requirement.

4.3 OTHER THERMAL RADIATION REQUIREMENTS

The LNG Code of Practice requires that LNG containers and other process equipment shall be spaced such that the thermal radiation flux from a fire in an impoundment or drainage system does not exceed the following values:

- 30 kW/m^2 at the concrete outer surface of an adjacent storage tank;
- 15 kW/m^2 at the metal outer surface of an adjacent storage tank or the outer surfaces of process equipment.

Map 1 shows that an LNG tank impounding area fire could expose the non-involved tank and the process equipment to a radiant heat flux in excess of 30 kW/m^2. Bear Head LNG will provide mitigation (most likely in the form of water spray or deluge systems) in order to achieve compliance with the LNG Code of Practice.

The CSA Z276 Standard requires LNG tank impoundments to be located such that the radiant heat flux from a fire in the tank impounding area will not cause damage to an LNG ship sufficient to prevent the ship from leaving. The LNG Code of Practice requires the use of 15 kW/m^2 as the maximum allowable heat flux on the ship. Maps 1 and 2 show that, if an LNG fire were to occur in either LNG tank impounding area, the LNG ship would be exposed to a maximum of 9 kW/m^2. Thus, the layout is in compliance with the previous requirements.

4.4 VAPOUR DISPERSION EXCLUSION ZONE REQUIREMENTS

The CSA Z276-15 Standard requires that the distance from an LNG impounding area to the nearest property line that can be built upon shall be sufficient to accommodate vapour cloud dispersion from the design spill such that an average concentration of methane in air of 50% of the Lower Flammability Limit (LFL) does not extend beyond the property line.

The CSA Z276-15 Standard doesn't specify weather conditions for this requirement. However, the LNG Code of Practice and the NFPA 59A standard mention 2 m/s for the wind speed and Category F for the Pasquill-Gifford atmospheric stability for this requirement. These weather conditions are a combination of those which result in longer predicted downwind dispersion distances than other conditions at the site.

The local weather data (Port Hawkesbury, 2010-2014) have been analyzed and the wind speed and stability mentioned in Table 6 have been selected for the vapour dispersion analysis. Table 6 also includes specific requirements of the LNG Code of Practice for the relative humidity and the surface roughness. No temperature requirement is listed in the LNG Code of Practice and the NFPA 59A standard, so an average ambient temperature for the region has been used.

Table 6 Vapour Dispersion Weather Assumptions

Parameter	Value
Wind Speed	2 m/s (at reference height of 10 m)
Pasquill-Gifford Atmospheric Stability	F
Average Ambient Temperature	6°C
Relative Humidity	50%
Surface Roughness	0.03 m

The design spill to be used for the vapour dispersion analysis is specified in the CSA Z276 Standard. For an impoundment serving a single containment tank with over-the-top fill and withdrawal with no penetrations below the liquid level, as well as for an impoundment serving transfer or process equipments, the design spill is defined as the maximum flow of LNG from the largest branch connection, 60 mm (2-inch) or smaller, on the piping system. According to this requirement, a 60 mm design spill during 10 minutes and the process conditions for the each line have been used for the analysis.

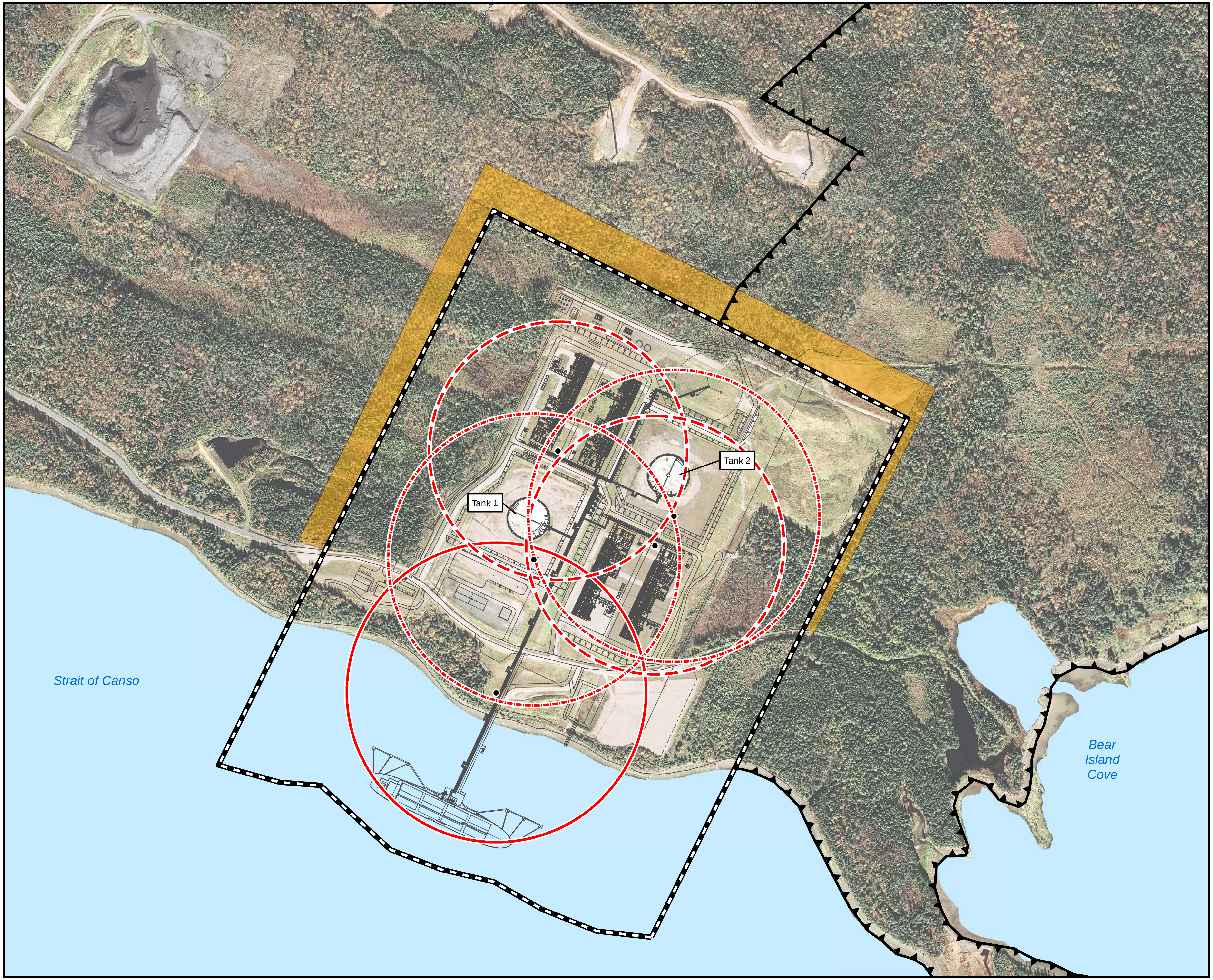
Neither the CSA Z276 Standard nor the Code of Practice list a specific dispersion model for the calculation of the vapour dispersion distances. However, both require that for continuous LNG releases, the LNG vaporization rate shall be determined using a detailed dynamic pool spreading and vaporization model. Therefore, the evaluation used the software PHAST to determine the pool source term evaporation rate and the vapour dispersion modelling from the impoundment basins (see section 5.4 for a description of the software).

Table 7 summarizes the vapour dispersion exclusion zone for the LNG impoundment basins. Map 3 illustrates the exclusion zones on the Bear Head LNG Facility plot plan.

Table 7 Vapour Dispersion Exclusion Zone

Impoundment	Distance to ½ LFL
LNG rundown lines and liquefaction trains	245 m
LNG tank transfer lines	277 m
Ship loading area	284 m

As shown on Map 3, the vapour cloud exclusion zones remain within the property lines of the facility, in accordance with CSA Z276 Standard requirements. It was assumed that impoundments will be built with insulated concrete. If this mitigation measure was not in place, the exclusion would exceed the property limit.



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Map 3

Vapour Dispersion Exclusion Zones

Legend

- Impoundment Pit
- Land Acquisition Zone
- Expansion Zone
- Bear Head Property Limit

Effect Distance

- ½ LFL (284 m) (LNG Ship Loading Area)
- ½ LFL (277 m) (LNG Transfer Lines)
- ½ LFL (245 m) (LNG Rundown Lines and Liquefaction Trains)

N S W E

0 70 140 210 280
Metres

Map Parameters
Reference System: (ATS77)
Projection: Modified Transverse Mercator (MTM)
Zone: 4
Scale: 1:7,000
Project Numer: 622560
Date: March 12, 2015

Source :
- Service Nova Scotia and Municipal Relations, Access Nova Scotia, Nova Scotia Geomatics Centre.
- Topographic map, 2011, 1:10 000
- Plant Layout: LNGL, BH-SK-00-016-base2D.dwg (Update: December 12, 2014)

Filet Name: snc622560_rc_m3_risk_tank_11x17_pre01_150312.mxd

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5 POTENTIAL CONSEQUENCES OF MAJOR ACCIDENTS

Although not an exclusion zone, Clause 5.1.1 of the CSA Z276 Standard states that the suitability of the plant site must take into account the other factors applicable to the specific site that have a bearing on the safety of plant personnel and the surrounding public. The review of such factors shall include an evaluation of potential incidents and safety measures incorporated in the design or operation of the facility. This requirement of the code is evaluated in this section.

The Environmental Emergency Regulations (SOR/2003-307 under the Canadian Environmental Protection Act) will be applicable to the project, which set out requirements for the preparation of emergency plans and reporting of accidental releases. The Environmental Emergency Regulations requirements are specific to the substances listed in Schedule 1. Methane, ethane, butane, LNG and ammonia are listed in Schedule 1 and quantities at the Bear Head plant will exceed the mass threshold levels.

Environment Canada recommends the following guidelines for the application of the regulation:

- Council for Reducing Major Industrial Accidents (CRAIM), 2007. Risk Management Guide for Major Industrial Accidents;
- Canadian Standard Association (CSA), 2003. Emergency Planning for Industry. CAN/CSA-Z731-03.

The potential consequences of major accidents or worst-case accidents, which are not already evaluated in the exclusion zone assessment, are analyzed in this section. According to CRAIM, the worst-case scenario is defined as the release of the largest quantity of a regulated substance from a single vessel or process line failure that results in the greatest distance to an endpoint. In broad terms, the distance to the endpoint is the distance a toxic vapour cloud, heat from a fire, or blast waves from an explosion will travel before dissipating to the point that serious injuries from short-term exposures will no longer occur. Alternate scenarios, more likely to occur, are also presented to provide the potential zones of intervention in relation with emergency planning.

5.1 METEOROLOGICAL CONDITIONS

Two sets of meteorological conditions were used to assess flammable or toxic cloud dispersion:

- Wind speed of 2 m/s and atmospheric stability F, conditions unfavourable to the dispersion and required in the CSA Z276 Standard and NS LNG code of practice to assess the LNG vapour dispersion;
- Wind speed of 3.5 m/s and atmospheric stability D, conditions more favourable to the dispersion and occurring more frequently.

The ambient temperature was set at 20^{o}C.

5.2 Threshold Levels

The threshold levels represent the limits above which effects on life and health could be observed within the exposed population. The thresholds used in this study to evaluate the risks to life and health correspond to the values recommended in the technological risk analysis guide (CRAIM, 2013).

For flammable substances, the zones related to the fatality effects were evaluated at the thresholds presented in Table 8. For thermal radiations and overpressure, these thresholds represent a probability of fatality on the order of 1%. The thresholds that were used to evaluate the maximum distances at which there are potential health effects are presented in Table 9.

Table 8 Thresholds Used to Evaluate Fatality Effects

Event	Threshold	Definition
Fire (thermal radiation)	13 kW/m^2	This threshold could entail a fatality after a 30-second exposure.
Explosion (overpressure)	13.8 kPa	This threshold applies to people inside a building and corresponds to moderate building damage. The fatalities are attributed to falling objects and to the partial destruction of walls and roofs. The threshold for people located outdoors is higher (100 kPa) and corresponds to fatality by direct effect.
Flash Fire	LFL	Maximum distance at which an ignition can occur.

Table 9 Thresholds Used to Evaluate Health Effects

Event	Threshold	Definition
Fire (thermal radiation)	5 kW/m^2	This threshold corresponds to possible second degree burn injuries after a 40-second exposure.
Explosion (overpressure)	6.9 kPa	This threshold corresponds to possible injuries caused by glass fragments or by falling objects.

The toxic effects of ammonia are based on the Acute Exposure Guideline Levels (AEGL), which have the following definitions:

- AEGL-3 is the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death.

- AEGL-2 is the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.
- AEGL-1 is the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic non sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.

AEGL levels for ammonia are summarized in Table 10. The AEGL levels and the averaging time used in the modelling were selected based on the maximum exposure time.

Table 10 Ammonia AEGL Levels

Level	Concentration (ppm)			
	10 min	30 min	60 min	4 h
AEGL3	2,700	1,600	1,100	550
AEGL2	220	220	160	110
AEGL1	30	30	30	30

5.3 SOFTWARE

The physical consequences of the accident scenarios were simulated with version 7.1 of the PHAST (Process Hazards Analysis Software Tools) software from the company DNV-GL. DNV-GL is a global leader in the field of risk safety, environmental assessment and accident consequence calculations. PHAST software has been rigorously validated and verified.

PHAST is an integrated software for the analysis of technological accident consequences using the following models: liquid, gaseous and biphasic discharges, jet and aerosol models, Gaussian dispersion, heavy and hybrid gases, pool formation and evaporation, thermal radiation for various types of fires, overpressure for various types of explosions.

The physico-chemical and thermodynamic properties of the products are included in PHAST and were taken from the DIPPR (Design Institute for Physical Property) databank of the American Institute of Chemical Engineering.

The Unified Dispersion Model used in PHAST has been reviewed by the US Department of Transportation's Pipeline and Hazardous Materials Safety Administration and approved for use in LNG siting applications.

5.4 MIXED REFRIGERANT

5.4.1 Scenario Description

Four major accidental release scenarios for mixed refrigerant stored or processed were analyzed. Tables 11 and 12 list the worst-case scenarios that could occur at the Bear Head LNG Facility. Operating conditions, such as pressure, temperature and release elevation used in the analysis are also presented in these tables. Since the piping will be located aboveground, each scenario was modelled as a horizontal release.

Table 11 Major Accidental Release Scenarios for Mixed Refrigerant (Storage)

Scenario	Line Size (cm)	Operating Temp (°C)	Operating Pressure (kPag)	Discharge Flow Rate (kg/s)	Elevation (m)
Ethane Storage – Rupture of Fill Hose	5	21	3,689	19.83	1
Butane Storage – Rupture of Fill Hose	5	21	1,800	57.57	1

Table 12 Major Accidental Release Scenarios for Mixed Refrigerant (Process)

Source	MR Composition	Operating Temp (°C)	Operating Pressure (kPag)	Process Flow Rate (kg/s)	Elevation (m)
Rupture of Process Pipe before Cold Box	nitrogen methane ethane butane	19	3,739	170.7	3
Rupture of Process Pipe before Compressor		-18.5	507	170.7	3

For the scenarios related to storage, the discharge rates correspond to a complete piping rupture and were calculated according to the operating temperatures and pressures. For the scenarios related to the process, the process flow rates were used as discharge rates.

5.4.2 Results for Jet Fire

The accidental release of a flammable refrigerant can form a jet fire. This outcome can occur if there is an immediate ignition.

Table 13 summarizes the resulting distances for each scenario. All scenarios do not impact the public. For process pipe scenario, these effect distances would have short duration because of the rapid decompression of the MR circuit in case of major leak.

Table 13 Releases of Mixed Refrigerant - Maximum Distances in Case of Jet Fires

Source	Jet Fire (thermal radiations)	
	13 kW/m^2	5 kW/m^2
Ethane Storage - Fill Hose	69 m	82 m
Butane Storage - Fill Hose	134 m	165 m
Process Pipe before Cold Box	142 m	184 m
Process Pipe before Compressor	142 m	184 m

5.4.3 Results for Flash Fire

Another possible outcome of these scenarios is the dispersion of the release refrigerant followed by a flash fire when the flammable cloud meets an ignition source at a certain distance from the emission point. An ignition is possible up to a distance reached by the LFL. If the fire flashes back to the release point, a jet fire can be the successive outcome.

The resulting distances for each scenario are shown in Table 14. All scenarios do not impact the public.

Table 14 Releases of Mixed Refrigerant - Maximum Distances in Case of Flash Fires

Source	Meteorological Conditions	Flash Fire (LFL)
Ethane Storage - Fill Hose	Wind speed 2 m/s; Stability F	46 m
	Wind speed 3.5 m/s; Stability D	47 m
Butane Storage - Fill Hose	Wind speed 2 m/s; Stability F	157 m
	Wind speed 3.5 m/s; Stability D	175 m
Process Pipe before Cold Box	Wind speed 2 m/s; Stability F	102 m
	Wind speed 3.5 m/s; Stability D	103 m
Process Pipe before Compressor	Wind speed 2 m/s; Stability F	125 m
	Wind speed 3.5 m/s; Stability D	127 m

5.4.4 Results for Explosion

A third possible outcome is an explosion if the following conditions are met:

- A part of the cloud is located in a confined/congested area;
- The confined/congested cloud has a concentration between the lower and upper flammable limits;
- The cloud meets an ignition source.

The liquefaction units are the only significant congested area at the plant or in the surrounding, where an explosion could occur.

Overpressure scenarios were modelled using the Multi-Energy method in the PHAST software. Furthermore, it was conservatively assumed that:

- The entire mass between the flammable limits from the release is within the confined/congested area;
- The confined/congested area has a maximum strength.

The results of all overpressure modelling scenarios are summarized in Table 15. All scenarios do not impact the public.

Table 15 Releases of Mixed Refrigerant - Maximum Distances in Case of Explosions

Source	Explosion (overpressure)	
	13.8 kPa	6.9 kPa
Ethane Storage - Fill Hose	80 m	140 m
Butane Storage - Fill Hose	127 m	279 m
Process Pipe before Cold Box	178 m	311 m
Process Pipe before Compressor	191 m	334 m

5.5 AMMONIA

5.5.1 Scenario Description

Dispersion modelling has been performed for ammonia, which will be used as a refrigerant at the Bear Head LNG facility. According to the recommendations of the risk assessment guidelines and the definition of the worst-case scenario:

- The selected scenario is related to the high pressure ammonia receiver, which is the process vessel with the maximum amount of ammonia;
- The scenario considers that the whole content is released in 10 minutes.

Table 16 summarizes the amount of ammonia, the operating pressure and temperature and the release elevation used in the scenario analysis. Since the vessel will be located aboveground, each scenario was modelled as a horizontal release.

Table 16 Major Accidental Release Scenario for Ammonia

Scenario	Amount of Ammonia (m^3)	Discharge Time (s)	Operating Temp (°C)	Operating Pressure (kPag)	Elevation (m)
Rupture of the Ammonia Receiver	15 (normal operation)	600	20	760	3

5.5.2 Results for Toxic Cloud Dispersion

For the scenario considering the ammonia receiver during normal operation, the resulting distances are shown in Table 17 and illustrated on Map 4. Based on this scenario, which has a very low probability of occurrence by definition, and if the accident occurs with weather conditions not favourable to dispersion (low wind speed and high atmospheric stability), the following observations are made:

- There is no possibility of fatality for the surrounding residents;
- The population at Port Hawkesbury and Mulgrave could experience concentrations well below the AEGL2 value, meaning it could experience not disabling and temporary discomfort and irritation effects;
- Few residents scattered along Marine Drive (between Steep Creek and Melford Point), on the other side of the Canso Strait, could experience concentrations slightly over the AEGL2 value but below the AEGL3 value, meaning that they could experience irreversible or other serious, long-lasting adverse health effects if they are not protected.

Table 17 Release from the Ammonia Receiver (inventory of 15 m^3) - Maximum Distances for Toxic Cloud

Source	Meteorological Conditions	Toxic Cloud Dispersion	
		AEGL3	AEGL2
Complete Release of the Ammonia Receiver	Wind speed 2 m/s; Stability F	417 m	3,074 m
	Wind speed 3.5 m/s; Stability D	283 m	902 m

For most frequent weather conditions (wind speed of 3.5 m/s and higher), there would have no consequences for the population. Because of the ocean proximity, low wind speed giving the largest distances is not frequent. Furthermore, populations are located upwind of the dominant winds coming from north-west, west and south-west. The few residents along Marine Drive could be affected with specific low wind conditions (speed and direction, stability F) occurring about 1% of the time.

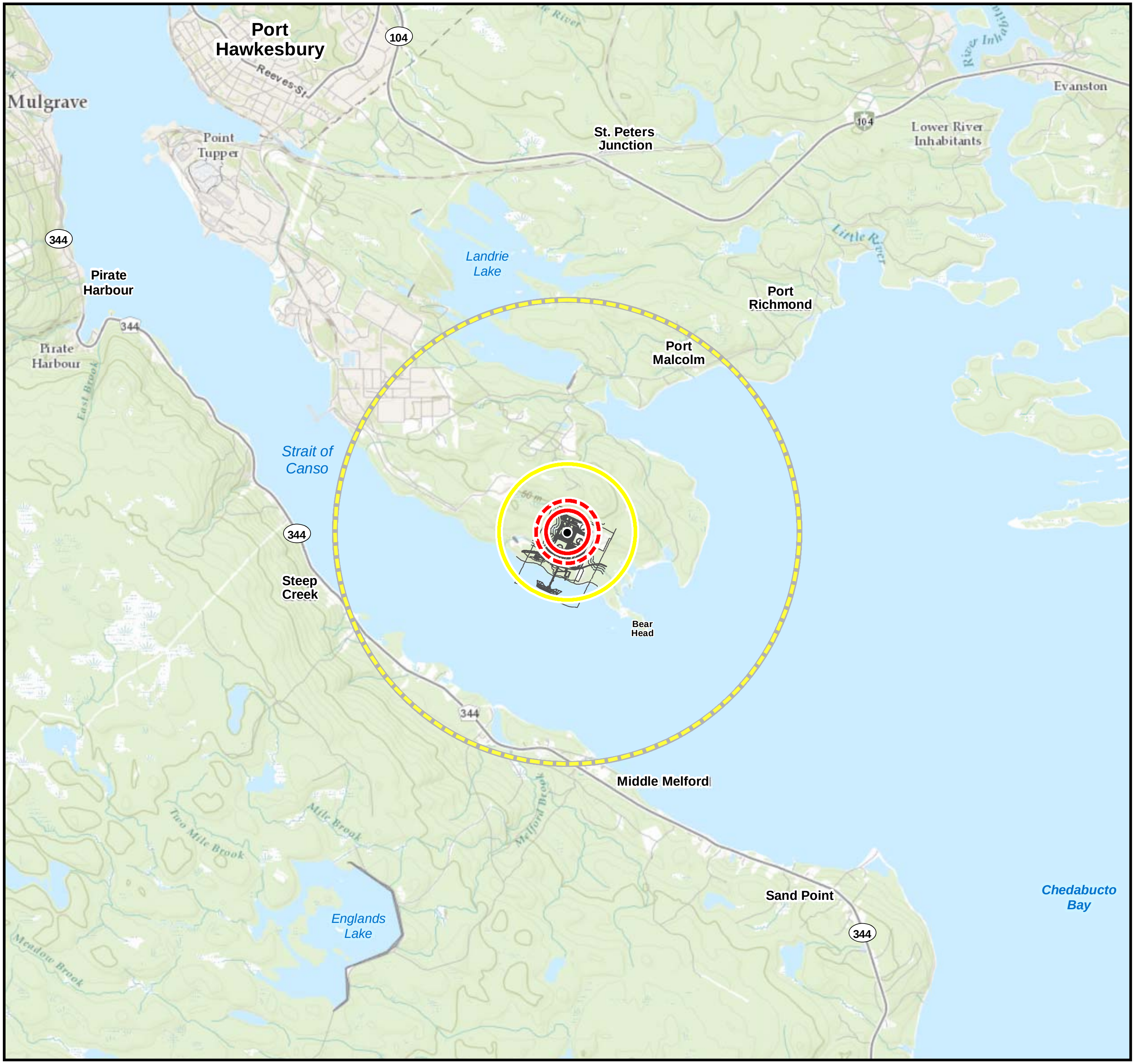
A potential design alternative would be to have two receivers instead of one, each of them containing 7.5 m^3 of ammonia during normal operation. In this case, the consequences of an ammonia release are shown in Table 18 and illustrated on Map 5. With this alternate design, the residents along Marine Drive would always be exposed to concentrations below the AEGL2 value.

Table 18 Release from an Ammonia Receiver (inventory of 7.5 m^3) - Maximum Distances for Toxic Cloud

Source	Meteorological Conditions	Toxic Cloud Dispersion	
		AEGL3	AEGL2
Complete Release of an Ammonia Receiver	Wind speed 2 m/s; Stability F	249 m	2,205 m
	Wind speed 3.5 m/s; Stability D	188 m	672 m

The above consequences are for worst-case scenarios only, which have a very low probability of occurrence. They were assessed with no mitigation measures in place. Especially when wind speed is low, the high upward air flow caused by the multiple air coolers within the trains could contribute to improve the dispersion of the ammonia and to reduce the maximum distances. This dispersion effect was not considered in the analysis.

A more detailed analysis will be performed during detailed engineering to optimize the design and to determine the risk management measures or the additional mitigation measures required to assure that ammonia concentration will stay at low concentrations, such that the local population is not significantly impacted in the unlikely event of a major ammonia release. These measures could include installation of additional equipment (such as water sprays), routine and preventive maintenance, shelter-in-place planned in emergency response plans, etc.



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Map 4

Consequences for the Complete Release of the Ammonia Receiver (15 m³)

- Ammonia Receiver

Effect Distance

- AEGL2 - 3.5 m/s - D (902 m)
- AEGL2 - 2 m/s - F (3,074 m)
- AEGL3 - 3.5 m/s - D (283 m)
- AEGL3 - 2 m/s - F (417 m)

N
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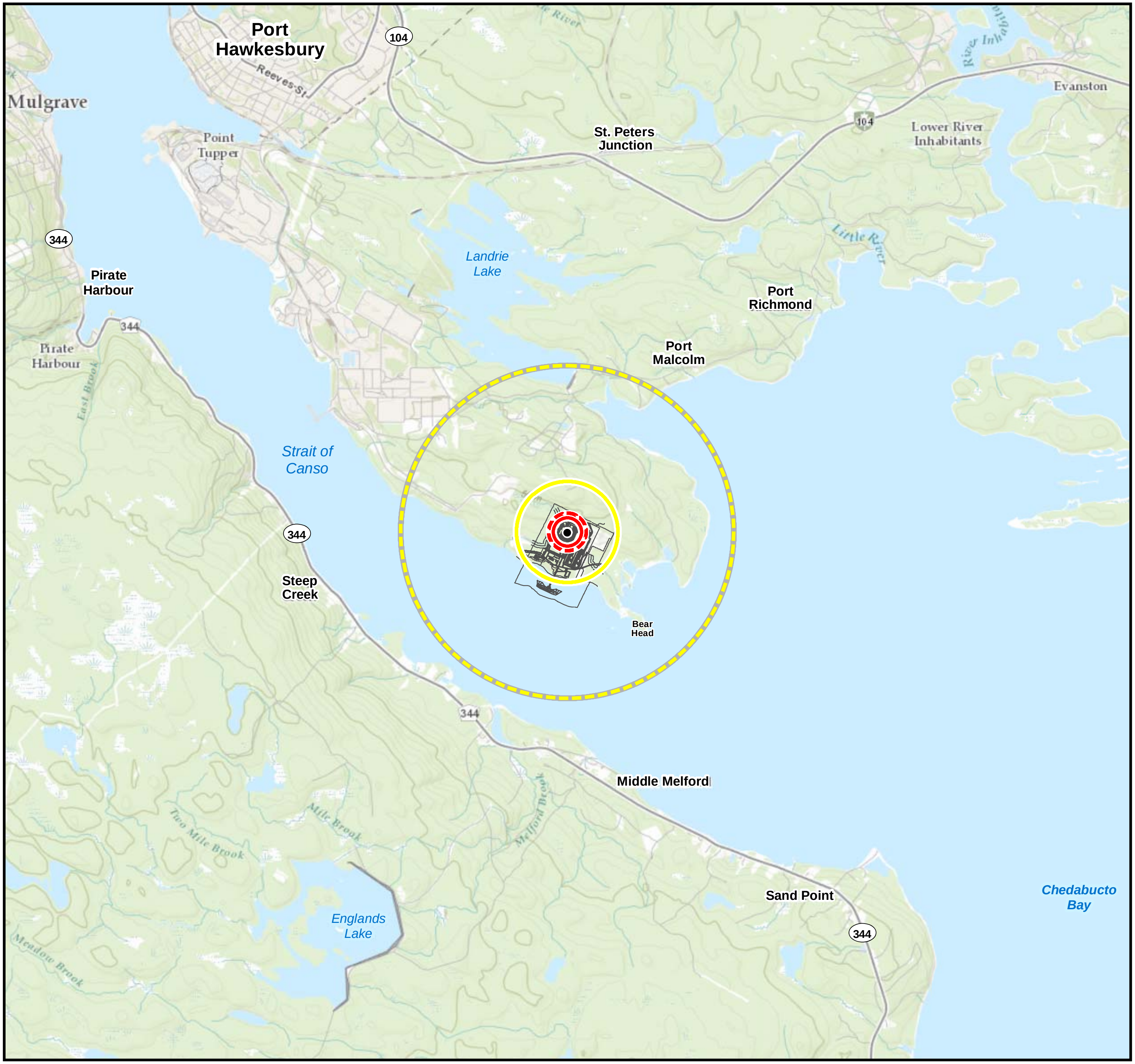
0 0,35 0,7 1,05 1,4 1,75
Kilometers

Map Parameters
Reference System: (ATS77)
Projection: Modified Transverse Mercator (MTM)
Zone: 4
Scale: 1:70,000
Project Numer: 622560
Date: March 31, 2015

Source :
- World Topo Map, courtesy of ESRI
- Plant Layout: LNGL, BH-SK-00-016-base2D.dwg (Update: December 12, 2014)

snc622560_rc_m4_risk_receiver_normal_let_pre01_150331.mxd



Map 5

Consequences for the Complete Release of the Ammonia Receiver (7.5 m³)

● Ammonia Receiver

Effect Distance

- AEGL2 - 3.5 m/s - D (672 m)
- AEGL2 - 2 m/s - F (2,205 m)
- AEGL3 - 3.5 m/s - D (188 m)
- AEGL3 - 2 m/s - F (249 m)

N
W E
S

0 0,35 0,7 1,05 1,4 1,75

Kilometers

Map Parameters
Reference System: (ATS77)
Projection: Modified Transverse Mercator (MTM)
Zone: 4
Scale: 1:70,000
Project Numer: 622560
Date: March 31, 2015

Source :
- World Topo Map, courtesy of ESRI
- Plant Layout: LNGL, BH-SK-00-016-base2D.dwg (Update: December 12, 2014)

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5.6 LNG Transfer Lines

5.6.1 Scenario Description

Two scenarios were assessed for the following main LNG transfer lines and transfer area:

- The LNG rundown lines from the liquefaction trains to the LNG storage tanks;
- The LNG transfer lines from the LNG storage tanks to the LNG carrier and the marine loading area.

The operating conditions of these lines are described in Table 19. Depending mainly of the operating pressure, the LNG released from these equipments can jet and flash or convey to the impoundment. The evaluated scenarios are 60 mm diameter leaks, corresponding to the design spill required by the CSA Z276 Standard.

Table 19 Operating Conditions of the Main LNG Lines and Transfer Area

Scenario	Line Size (cm)	Operating Temp (°C)	Operating Pressure (kPag)	Operating Flow Rate (m^3/h)	Elevation (m)
Liquefaction Rundown Lines	25	-152	749	1,422	3
LNG Transfer Lines and Marine Loading Area	76	-161	399	10,000	3

5.6.2 Results for LNG Jetting and Flashing

Two outcomes are possible: a jet fire if there is an immediate ignition of the released LNG, or a flash fire if there is a delayed ignition of the flammable cloud formed by the flashing and the dispersion of the released LNG. Table 20 summarizes the maximum distances evaluated for these scenarios. All scenarios do not impact the public.

Table 20 LNG Jetting and Flashing - Maximum Distances for Jet Fire and Flammable Cloud Dispersion

Scenario	Meteorological Conditions	Jet Fire		Vapour Dispersion
		13 kW/m^2	5 kW/m^2	LFL
Liquefaction Rundown Lines	Wind speed 2 m/s; Stability F	128 m	153 m	179 m
	Wind speed 3,5 m/s; Stability D			135 m
LNG Transfer Lines and Marine Loading Area	Wind speed 2 m/s; Stability F	118 m	142 m	132 m
	Wind speed 3,5 m/s; Stability D			112 m

5.6.3 Results for LNG Conveyed to Impoundment

Depending of the conditions, the LNG releases can be partly conveyed to the impoundments. The two possible outcomes are a pool fire if there is an immediate ignition of the released LNG, or a flash fire if there is a delayed ignition of the flammable cloud formed by the LNG evaporated from the impoundment. A flash fire could occur up to the distance corresponding to the LFL.

These scenarios correspond to those used for the evaluation of the exclusion zones. The results are summarized in Tables 5 and 7. All scenarios have no impact to the public.

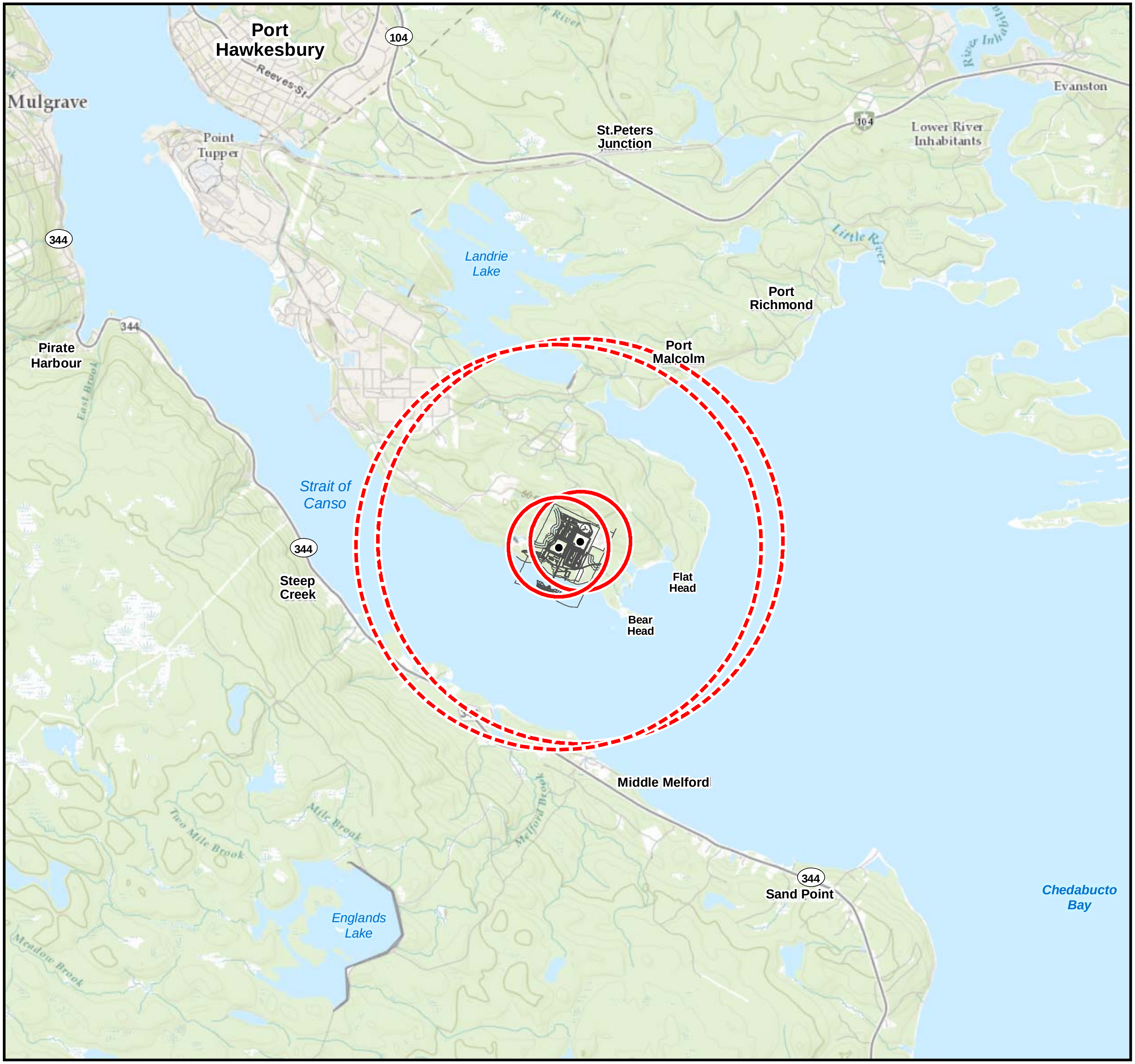
5.7 LNG Tanks

In addition to the scenarios evaluated for the determination of the exclusion zones, an additional scenario was assessed for the LNG tank. This scenario assumes a major LNG spill from one tank with LNG filling the bermed area. The outcome could be a flash fire following the delayed ignition of the flammable cloud formed by evaporated LNG. Table 21 summarizes the maximum distances that can be expected for this scenario. The results are also shown on Map 6.

Table 21 Major LNG Spill from a Tank - Maximum Distances Flammable Cloud Dispersion

Scenario	Meteorological Conditions	LFL
Major LNG Spill from a Tank	Wind speed 2 m/s; Stability F	2,684 m
	Wind speed 3.5 m/s; Stability D	660 m

To assure that the local population is not significantly impacted in the unlikely event of a major LNG release from storage tanks, risk management measures or additional mitigation measures will be evaluated during detailed engineering. The possible mitigation measures are: reconfiguration of the geometry of the bermed area, insulation in the bottom of the bermed area, water curtain, and vapour fences.



BearHead LNG
A subsidiary company of Liquefied Natural Gas Limited

Map 6

Consequences for a Major LNG Spill from a Tank

● Tank

Effect Distance

- LFL - 3,5 m/s - D (660 m)
- LFL - 2 m/s - F (2,684 m)

N
W E
S

0 0,35 0,7 1,05 1,4 1,75
Kilometers

Map Parameters
Reference System: (ATS77)
Projection: Modified Transverse Mercator (MTM)
Zone: 4
Scale: 1:70,000
Project Number: 622560
Date: March 31, 2015

Source :
- World Topo Map, courtesy of ESRI
- Plant Layout: LNGL, BH-SK-00-016-base2D.dwg (Update: December 12, 2014)

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6 ACCIDENT PREVENTION AND FACILITIES SAFETY MEASURES

6.1 PROTECTIVE EQUIPMENT

In addition to intrinsic security characteristics, there will be many protection equipment put in place to eliminate or mitigate the risks of accidents.

Equipment will be designed and selected to increase overall system safety and to protect the public from a potential system failure resulting from accidents or natural catastrophes.

General – Entire facility

- Equipment for fire protection such as gas detectors, flame detectors, smoke detectors, fire extinguishers, high expansion foam systems, fire monitors, sprinklers and deluge systems, alarm points, safety showers/eye wash stations and hose reels.
- Diesel-fuel emergency generator (to maintain the essential functions in case of power outage, such as the boil-off gas system).
- Emergency shutdown valve for the gas feed pipeline.
- Fail safe shutdown systems.
- Depressurizing systems connected to the flare.
- Alarm system.
- System to control ignition sources.
- Redundancy of measurement and control systems, when required.
- Walls and fire protection measures.
- Perimeter fences and access gates.

LNG storage tanks

- Single containment tanks surrounded by bermed area, designed to meet the CSA Z276 Standard.
- LNG impoundment pits designed and sized according the CSA Z276 Standard to allow the vapourization of LNG in a safe area.
- Pipelines connected to tanks through the roofs (no side penetration).
- Submerged LNG pumps in the tanks.
- Emergency stop valves on the main pipelines connected to the tanks.
- Gas detection system for wall and floor insulation space.

- Flare system for emergencies, discharging in safe area.
- LNG vapour recovery system (boil-off gas).
- Level indicators with alarms for high level.
- Pressure and temperature indicators.
- Protection against overpressure (overpressure valve connected to the flare).
- Protection against depressurization (vacuum breaker).
- Protection against rollover.

Refrigerant Tanks

- Depressurization system connected to the flare.
- Level, pressure and temperature indicators.

Ammonia Systems

- Hazard Detection and Mitigation Systems (HDMSs) as an independent, stand-alone, high integrity system to continuously monitor for hazardous situations in the facility, including ammonia releases, local leak detection systems and safety integrated shutdown systems to remotely isolate leak points.
- Active mitigations including isolation and shut-down, coupled with high integrity, fixed deluge systems covering all potential ammonia release points.

Process Units

- Automatic emergency stop valves at various locations in the process.
- Flare system for emergency gas evacuation.
- Pressure relief valves connected to a closed drainage system.
- Flammable gas detectors.
- Electrical equipment suitable for hazardous atmospheres in high-risk areas.
- LNG impoundment pit designed and sized according the CSA 276 Standard to allow the vapourization of LNG in a safe area.
- Impoundment basin to contain amine spills.
- Ship loading area.
- Isolating valves and purge valves.
- Quick connect fittings.

6.2 RISK MANAGEMENT PLAN

A Project Design and Construction Risk Management Plan framework will be developed and implemented jointly between the Project Owner and its engineering, procurement, and construction contractor. The framework will focus on identifying, classifying, assessing, and prioritizing risks, as well as planning, and creating mitigation strategies for handling the identified risks.

Risk management procedures will be developed by the engineering, procurement, and construction contractor and will be implemented during the design phase of the Project. The procedures, that will continue to be used throughout the construction and commissioning phases, will cover the following topics:

- Understanding risk;
- Risk management approaches;
- Risk management definitions;
- Risk management process;
- Definition of risk and related topics;
- Personal approach to risk;
- Types of risks;
- Risk factors;
- Risks in a construction project environment.

6.3 CONTENT OF THE RISK MANAGEMENT PLAN

Risk management planning is an important aspect of the Risk Management Plan because it sets the tone for the rest of risk management activities. Planning focuses on who, what, where, and when aspects of risk management. The Risk Management Plan will include policies and procedures for the following:

- Understanding the project environment and project objectives;
- Planning requirements for risk management processes;
- Risk management planning process;
- Schedule and schedule related risk management;
- Quality assessment and quality control;
- Cost risk;
- Change management.

Risk Identification Process

Risk identification is an interactive process and will involve key stakeholders. Topics to be covered in the Risk Management Plan will include the following:

- Risk identification;
- Approaches to risk identification, which will include qualitative and quantitative risk assessment techniques;
- Risk statement and developing a risk register;
- Types of risk and risk categories;
- Practical issues related to risk identification.

Strategies for Handling Risks/Risk Response Planning

The Risk Management Plan will describe the tools used to develop strategies including the following items:

- Steps for developing risk response;
- Information/documentation required to prepare for risk response planning;
- Tools for generating risk response options;
- Strategies for risk response planning;
- Risk response options evaluation;
- Risk response planning deliverables.

Managing Project Risks (Risk Monitoring and Control)

The Risk Management Plan will describe the mechanisms that will be used to manage project risks throughout the Project's design and construction life cycle. Such mechanisms will include the following:

- Definition and risk management cycle;
- Risk monitoring and control activities;
- Risk documentation;
- Risk communication;
- Risk monitoring and control tools.

Bear Head will conduct business in a manner to protect the safety and health of its employees, its customers, its neighbours, the public, and others involved in its operations. The Project will be designed and operated to meet or exceed applicable safety standards using a systematic approach to identifying and managing health, safety, and environmental risks.

6.4 Approach to Risk Management and Loss Prevention

Bear Head's approach for the Project is to minimize the probability of safety incidents and malfunctions, and minimize the effects of such incidents should they occur. Consistent adherence to this approach will be observed throughout the design, construction, and operation phases of the Project. Identifying potential hazards and malfunctions is the first action required in this approach. This practice has been considered in the preliminary design of the Project as described in this Risk Assessment Report.

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APPENDIX A

Accident History Related to LNG Facilities

Appendix A Accident History Related to LNG Facilities

Table A.1 Accidents related to liquefaction facilities

Date	Location	Facility	Description	Consequences	Causes
January 1972	Montreal, Canada	Liquefaction and peak shaving plant	An explosion occurred in the control room due to a back flow of natural gas from the compressor to the nitrogen line. Nitrogen was supplied to the compressor as a seal gas during defrosting operations. The valves on the nitrogen line that were kept open during defrosting operation were not closed after completing the operation. Natural gas entered the nitrogen line and vented into the control room through the pneumatically controlled instruments operating with nitrogen. LNG was not involved in this incident.	Explosion; No LNG involved.	Valves were kept open by mistake during defrosting operation.
April 1983	Bontang, Indonesia	Liquefaction and export facility	The main liquefaction column (large vertical, spiral wound, heat exchanger) in Train B ruptured due to over-pressurization caused by a blind flange left in a flare line during start-up. All the pressure protection systems were connected to this line. The exchanger experienced pressures three times its design pressure before rupturing. Debris were projected some 50 meters away and killed three workers. The ensuing fire was extinguished in about 30 minutes. This incident occurred during dry-out and purging of the exchanger with warm natural gas before introducing any LNG into the system. LNG was not involved or spilled.	Explosion and fire; No LNG involved.	Maintenance error.
August 1985	Pinson, Alabama, USA	LNG peak shaving facility	The welds on an 8¼ inch by 12 inch “patch plate” on a small aluminum vessel (3 feet in diameter by 7 feet tall) failed when the vessel was receiving LNG from the liquefaction cold box. The plate was propelled into a building that contained the control room, boiler room and offices. Some of the windows in the control room were blown inward and natural gas escaping from the failed vessel entered the building and ignited.	Projection of debris; Gas explosion; Six employees were injured.	Failure of a patch plate on an aluminum vessel.
August 2003	Bintulu, Malaysia	Liquefaction and export Facility	A major fire occurred in the exhaust system of the propane compressor gas turbine. A crack had developed in the regeneration gas coil, which lead to the presence of natural gas in a waste heat recovery unit (WHRU). Simultaneously to the leak, a defect in the turbine was drawing air into the WHRU. The natural gas mixed with the air inside the WHRU (that was still at a very high temperature) exploded when it reached its lower flammability limit and auto ignition temperature. The incident caused damage to the WHRU ducting, to the hot oil coils, to the compressors and the compressor building. No injury occurred to the personnel. The incident involved natural gas in an auxiliary system for one of the major pieces of the refrigeration system. It did not directly involve LNG or any part of the cryogenic systems.	Fire; Material damages, but no one injured; No LNG involved.	Defect in the turbine and air infiltration; Crack in the regeneration gas coil.

Date	Location	Facility	Description	Consequences	Causes
2004	Skikda, Algeria	Liquefaction facility	An explosion occurred late afternoon in a petrochemical port complex, located on the coast and containing 6 gas and hydrocarbon units. The accident took place in the LNG unit, following an explosion of a high pressure boiler that was producing vapor. Under the violent explosion, the nearby flammable substances tanks were damaged as well: the leaks that resulted caused the spread of the fire to different housings and new explosions. The blast of the explosion, which extended to a radius of 10 km, broke the windows of buildings and shops in the neighbourhood. The record indicates 23 victims among the employees, 9 others were lost and 74 people were injured. The material damages were estimated to $800M US, other units in the complex did not seem to be damaged. However, 3 of the 6 liquefaction units were destroyed.	Fire and explosion by domino effects 23 employees dead; 9 employees lost, 74 people injured.	Explosion of a high pressure boiler.
2014	Washington State, USA	Liquefaction facility	Explosion in the pressurized equipments designed to remove carbon dioxide.	Significant damages, 5 workers injured, residents evacuated.	Investigation in progress.

Table A.2 Accidents related to storage tanks

Date	Location	Equipment	Description	Consequences	Causes
1944	Cleveland, Ohio, USA	LNG storage tank Peak shaving facility	A crack had developed on the wall of a cryogenic tank with 4,540 m^3 of liquefied natural gas. The inner tank was made of 3.5% nickel steel with stone wool insulation. The cloud ignited rapidly and exploded. A huge fire occurred and spread to another tank which in turn exploded. In total, 12 ha of facilities were destroyed and approximately 2,900 t of gas were burned. 136 people were dead, 300 were injured, 80 houses were destroyed and 10 plants were severely damaged. The damages are evaluated to $8M US.	Fire and explosion; Victims among the population, 126 deaths and 300 people injured.	Tank construction material not adapted to cryogenic conditions, causing the crack in the inner shell.
1965	Canvey Island, UK	LNG storage tank LNG gasification terminal	A small amount of LNG spilled from a tank during maintenance. The spill ignited and a nearby worker was seriously burned.	1 person seriously burned.	Maintenance; Spill from a tank and vapor ignition.
1968	Portland, Oregon, USA	Unfinished LNG storage tank Peak shaving facility	4 workers inside an unfinished LNG storage tank were killed when natural gas from a pipeline being pressure tested inadvertently entered the tank as a result of improper isolation, and then ignited causing an explosion. The LNG tank was 120 feet in diameter with a 100-foot shell height and a capacity of 176,000 barrels.	Natural gas explosion; 4 deaths; LNG was not present.	Construction; Improper isolation of a tank's feeding line.
1971	La Spezia, Italy	LNG storage tank Rollover	The LNG carrier Esso Brega had been in the harbor for about a month before its expected unloading. The storage tank was supposed to be filled with "heavy" LNG. 18 hours after the tank was filled, the tank developed a sudden increase in pressure caused by LNG vapor. These vapors were discharged from the safety valves and vents for few hours. The roof of the tank was slightly damaged. The LNG vapors were not ignited. The phenomenon that caused this accident is called "roll-over".	Atmospheric discharge of LNG for few hours without ignition; Slight damage to the roof of the tank.	Mixing of two layers of LNG with different densities in the storage tanks during the loading
1973	Staten Island, New York, USA	LNG storage tanks in repair	In 1973, an industrial accident occurred at a LNG terminal in Staten Island, New York, when the tank was taken out of service for repairs. 40 workers inside the tank were killed when the vapor of the vacuum cleaners ignited, leading to the collapse of the tank's concrete dome. Although the accident occurred in an LNG facility, the authorities in charge of the investigation concluded that the accident was a construction accident, not related to the tank's usage.	Explosion leading to the collapse of the dome; 40 deaths; No LNG present.	Maintenance; Emission of flammable vapor from cleaning products.

Date	Location	Equipment	Description	Consequences	Causes
1977	Arzew, Algeria	LNG storage tank	A worker on the site was sprayed with LNG, which escaped from a ruptured valve body on top of a storage tank. This worker was frozen to death. Approximately 1,500 to 2,000 m^3 of LNG were released without the ignition of vapors. The construction material of the valve body was cast aluminum. The best practice is to provide valves made with stainless steel.	1 worker killed.	Leak of LNG following the failure of a valve body in cast aluminum.
1978	Das Island, U.A.E.	LNG storage tank	A failure of a LNG pipeline connection at the bottom of a tank led to a spill inside the LNG tank containment. The liquid flow was stopped by closing the internal valve designed for just such an emergency. A large vapor cloud formed without ignition. No injuries were identified.	No injuries.	Spill of LNG with cloud formation.
1979	Columbia gas terminal, Cove Point, Maryland, USA	LNG Pump	In 1979, a worker was killed and others were seriously injured at the Cove Point LNG terminal, in Maryland. LNG had leaked through an inadequately tightened LNG pump electrical penetration seal and passed through an underground conduit to the substation 60 m away, where the vapors were ignited. The confined vapors increased the pressure of the substation, resulting in an explosion. The substation was not equipped with gas detector, which is the standard in the buildings nowadays.	Vapors explosion; 1 worker killed.	Leak at the pump seal.
1980	Le Havre, France	LNG storage tank	In the late 1980's, a bottom valve in one of the three storage LNG tanks from the 1960's remained open during closing test. After draining the tank, the investigation showed that the closing device was separated from its axis due to the loosening of a bolt.	Undetermined	A bottom valve remained open due to technical failure.
1997	Manchester, UK	LNG storage tank	In a gas deposit, a discharge of approximately 19.7 tons of natural gas occurred from an LNG tank. Works were in progress to install a densitometer on the tank's roof, on an existing opening (diameter: 400mm) which corresponded to an old relief valve. A device that would stop the leak was inserted manually in the feeding line. However, the decision to not proceed with this manipulation before the pressure is reduced to a minimum of 7 to 8 mbar was taken. The cause of the accident comes from the implementation of a single isolating device (of "balloon" type) to allow the cold cutting work as designed according to the usual standards. The failure of this equipment, which caused the leak, may have several origins: fatigue of the balloon on the welds, overpressure of the balloon, impacts on the shavings due to cutting.	Gas leak; No one injured.	Poor work manipulation and equipment failure.

Date	Location	Equipment	Description	Consequences	Causes
2009	Tangguh, Indonesia	LNG Liquefaction and export Facility	A leak occurred at the manifold on the LNG storage tank platform when the LNG was being pumped from the storage tank. As a result, LNG hit the carbon steel tank roof causing cracks and methane gas to leak out in several places. It was speculated that the leak was the result of incorrect torque being applied to various flange bolts and incorrect pipe spring hanger settings during the cool-down process. The facilities had only been in operation for a short time and this may have been the initial cooling down of the tank pump discharge piping.	LNG leak on the tank roof; Cracks and leak of methane gas.	Torque incorrectly applied to various flange bolts and incorrect pipe spring hanger settings during the cool-down process.
Sept. 2011	Rotterdam, Netherlands	LNG import terminal	During maintenance works on one of the jetties of Gate terminal, a small amount of natural gas was released. This caused a visible white cloud at the jetty. The condensation of air humidity following the contact with the cold gas caused this cloud. In coordination with the authorities of the port, ship movements were stopped for a while in the immediate surroundings of the terminal. The release of gas was stopped and ship movements resumed shortly afterwards.	Leak of LNG.	During maintenance works.

Table A.3 Accidents related to pipelines, loading equipments and flares

Date	Location	Equipment	Description	Consequences	Causes
1973	Canvey Island UK	Unloaded ship	During the unloading phase of a ship, a 100mm rupture disc broke on an unloading line of 350mm. The LNG was released in a nearby dyke where water was present due to a previous storm. 3 explosions were heard, but the only damage is a broken window in an adjacent building.	Discharge of LNG; Rapid phase transition; No one injured.	Failure of a rupture disc.
June 1980	Terminal	LNG Crane/ pipe	The crane damaged an empty 10" LNG aluminum pipe, No product leakage were signaled.	No leak because the piping was empty.	Aggression by work equipment.
July 1980	Terminal	LNG / gas Crane/ pipe	In a LNG terminal, a crane hit and shoved an aerial duct of high pressure gas without causing any leak.	No leak.	Aggression by work equipment.
May 1981	Terminal	LNG Crane/ pipe	In a LNG terminal, during the construction phase, a crane was moved without lowering its boom and severely damaged an LNG pipe rack, bending the pipes. The pipes were empty, thus there was no leak. The circulation plan of the work equipments was revised.	No leak because the piping was empty.	Construction; Aggression by work equipment.
May 1982	Terminal NC	LNG Collision Ship/ Jetty	In a LNG terminal, an 800t ship collided with a jetty, damaging its structure, crushing the water pipes and deforming an unloading pipe which was not used at the moment of the accident. Nonetheless, gas leakages were detected at the flanges of the pipe.	No leak because the pipe was empty.	Collision; Ship/ Jetty.
Oct. 1985	Terminal	LNG Crane/ pipe	A crane was pressed to poor quality soil and tumbled on the LNG pipes. Only the insulations of the pipes were damaged and no leak occurred.	No leak.	Aggression by work equipment.
1988	Everett, Massachusetts, USA	Pipeline LNG import terminal	Approximately 30,000 gallons of LNG were spilled through "blown" flange gaskets during an interruption in LNG transfer. The cause was later determined to be "condensation induced water hammer." The spill was contained in a small area, as designed. The still night prevented the movement of the vapor cloud from the immediate area. No one was injured and no damage occurred beyond the blown gasket. Operating procedures, both manual and automatic, were modified as a result.	LNG spill through the blown gaskets.	Condensation in the pipeline.
Nov. 1991	Terminal	LNG Crane/ pipe	A crane was moved without lowering its boom and damaged a LNG pipe rack.	No leak.	Aggression by work equipment.

Date	Location	Equipment	Description	Consequences	Causes
Oct. 1995	Terminal	LNG Power shovel/pipe	In a LNG terminal, a power shovel operator was digging without supervision and stopped after detecting a hard point. He damaged the pipes (scratching) without causing any leak. The incident was due to a supervision and procedure failure.	No leak.	Aggression by work equipment; Procedure shortcoming.
Dec. 1992	Baltimore, Maryland, USA	LNG terminal LNG peakshaving station	A LNG pressure relief valve was triggered in the proximity of one of the three LNG storage tanks and was released in the impoundment of the LNG tanks for 10 hours. The quantity of spilled LNG is estimated to be over 3,000 m^3 in the impoundment. Some of the LNG leak impacted the tank, causing some cracks in the outer walls of the steel tank. The tank was out of service and repaired. No injuries occurred.	Discharge of LNG No one injured.	Release of a pressure relief valve.
1993	Bontang, Indonesia	Transfer line Liquefaction terminal	A LNG leak occurred on a transfer line. The LNG entered the sewage system for oil recovery and created a rapid phase transition (RPT) which caused an over pressure and damaged the sewage lines. The vapors were not ignited, but the sewage network was destroyed.	No LNG leak No one injured.	Initial cause unknown RPT following LNG and sewage contact.
Oct. 1998	Terminal	LNG Dumper/ pipe	A dumper hit the 22” unloading line located on a metallic rack above highly circulated public lane, which led the stripping of electrical cables and damaged the metallic structure without causing any LNG leak.	No leak.	Aggression by vehicle.
1998	Montoir de Bretagne, France	Flare LNG terminal	In a LNG terminal, during the resumption of operations following maintenance work, an incident related to the flare occurred. Two valves connecting the low pressure gas system to the evaporation gas system remained open, causing the presence of liquefied gas in the flare and a 50m high flame. The situation was under controlled in 30 minutes after the decompression of the concerned gas systems. The procedures for shut down, operation resumption or degraded situation scenario were established or completed.	Presence of LNG at the flare and jet fire; No injuries.	Maintenance work.
Sept. 2000	Savannah, Georgia, USA	Unloading equipment LNG import terminal	A 580 feet ship lost control in the Savannah River and crashed into the LNG unloading pier. There was no LNG in the facility at the moment of the accident. The ship suffered a 40 feet gash in its hull. The point of impact at the terminal was the LNG unloading platform. The LNG facility experienced significant damage.	Material damage on the ship and on the unloading station; No leak.	Control loss of the ship.

Date	Location	Equipment	Description	Consequences	Causes
2003	Fos sur Mer, France	Flare LNG terminal	At the end of the day, during the unloading of ship, an explosion occurred at a LNG terminal containing 3 tanks connected to a network of flares. The terminal was shut for maintenance, the discharge of the LNG remained authorized with the view of activities resumption. The explosion occurred inside the terminal flare's structure, projecting the foot door to the space on the control room, causing some material damages in it: break of windows, dusts and debris inside the room. The control room remained operational and was not evacuated. The gas discharged was interrupted (ship at the pier, liquid loading arm disconnected, vapor gas connecting maintained). The torch stopped functioning. The evaporations at the terminal, evaluated at 4,000 Nm^3/h, were released in atmosphere while waiting for the repair of the flare or the reinjection of the evaporated gas in the network. According to the operator, the cold cloud remained located in the proximity of the vents (5m in diameter and 35 m above the tanks). The visible cloud includes the ignition area. At the source of the accident, the absence of non-return flow device on the drainage trap of the gazostatic seal at the top of the flare allowed the gas migration and the creation of an explosive atmosphere in the flare structure and the accumulation of cold gas at the low point.	Explosion at the bottom of the flare; Gas discharge in the atmosphere; Limited material damage; No one injured.	Lack of protection equipment; Occurred during the maintenance work.

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