2. MAIN DESIGN PARAMETERS OF A LNG PORT TERMINAL

2.1 LNG CARRIER SHIPS CHARACTERISTICS

The principal dimensions of six LNG carrier ships are given in Table 2.1. This data, provided by Gaz de France describes large ships currently in use or under construction. Two of these ships are MOSS type (the LNG is contained in spherical tanks) whereas the other four are membrane type ships (storage within the body of the ship). The latter type is the main one to be considered in the current project, according to Client's requirements, but the future terminal shall be designed in such a way it can also accommodate Moss type vessels likely to visit occasionally. Figure 2.1 illustrates various examples of existing MOSS type and membrane type ships, as well as some LNG receiving terminals.

From Table 2.1, the characteristics of the "design LNG carrier" have been established for the purpose of the present pre-feasibility analysis. This design ship includes all the most constraining data for each one of the parameters appearing in the table, in order to lead to the safe and broadly applicable conclusions and recommendations. These parameters will have to be refined and /or confirmed at a more advanced stage of study, during the engineering feasibility stage:

Cargo capacity:	138 000 - 160 000 m^3
DWT:	70 000 - 80 000 t
Displacement:	111 000 t.m.
LOA:	298 m
Breadth:	49 m
Depth:	27,5 m
Loaded draft:	11,7 m
Air draft:	60.63 m
Parallel mid body forward:	44 / 70 m
Parallel mid body aft:	58 / 95 m
Lateral windage :	6 700 m^2
End-on windage :	1 600 m^2

Table 2.1 – Principal dimensions of existing LNG Carrier Ships

	145 k / 4 x MRV	138 k / 5 x MRV	Alstom	138 k / 4 x GT	130 k / 5 x GT Edouard LD	65 k / 4 x GTLNG Lerici
Vessel Type	MOSS (sphere)	MOSS (sphere)	(Membrane)	(Membrane)	(Membrane)	(Membrane)
Length overall (m)	288.00	297.50	290.00	277.00	280.62	215.00
Beam (m)	49.00	45.75	45.00	43.40	41.60	33.90
Summer draft (m)	11.70	11.22	11.65	11.40	11.22	9.15
Ballast draft (m)	9.80	9.00	10.10	9.40	9.51	8.15
Depth (m)	26.80	25.50	26.20	26.00	27.50	21.26
Laden displacement (tons)	110 000	105 000	111 000	100 000	96 340	53 000
Height from BL (m)	62.80	69.63	51.00 (##)	52.95	49.29 (**)	54.00
Max. air draft (m) (#)	53.00	60.63	40.90	43.55	39.78 (**)	45.85
Manifold height Above BL (m)	32.40	29.50	30.80	30.80	31.30	25.75
Parallel mid body forward (m)	47.00	33.00 (*)	70.00	57.80	55.00	44.00
Parallel mid body aft (m)	80.00	98.00 (*)	95.00	73.70	58.00	60.00
Lateral windage (m^2)	8600	8091	6 700	6341	5113	3962
End-on windage (m^2)	2000	1633	N/A	1600	1330	1061

(*) with manifold located between tank 2 and 3
(**) modified for Boston Terminal condition (Aerial clearance 40,2 m under Tobin bridge)
(##) with radar mast folded to pass under Everett bridge.
Total height with mast unfolded: 59.40 m.
(#) corresponding to ballast draft

Source: Gaz de France

Figure 2.1 (a) – Photographs of LNG carrier vessels and terminals

Figure 2.1 (b) – Photographs of LNG carrier vessels and terminals

2.2 Design guidelines of a LNG Port Terminal

Design guidelines useful for the development of a LNG receiving maritime terminal have been published by various organizations that specialize in the transportation of petroleum products and / or navigation safety issues, namely:

SIGTTO – Society of International Gas Tanker and Terminal Operators Ltd:

- Site Selection and Design for LNG Ports and Jetties;

OCIMF – Oil Companies International Marine Forum:

- Prediction of Wind and Current Loads on VLCCs (Very Large Crude Carriers);
- Mooring Equipment Guidelines;

PIANC – Permanent International Association of Navigation Congresses:

- Design of Navigation channels;
- Big Tankers and their Reception;
- Dangerous Goods in Ports;

Transport Canada:

- TERMPOL review Process

Table 2.2 summarizes the most important recommendations about site selection, jetty layout, port equipment and operational procedures to be followed in the development and operation of a LNG receiving port terminal. At this pre-feasibility level of study, these recommendations are to be used as general guidelines to guide preliminary choices and as reminders of the various technical features, equipments and operation procedures that will have to be defined, verified and/or validated in further feasibility and final engineering studies.

In addition to these general guidelines, it is interesting to point out some technical and operational characteristics of the several existing LNG port facilities, namely Montoir-de-Bretagne (France) and Bonny (Nigeria), operated by Gaz de France and by Nigeria LNG respectively. These also provide useful guidelines for the purpose of the present study:

Montoir-de-Bretagne Terminal (France):

- Montoir is located on the Loire River, in a narrow navigation channel
- Operating limits and safety – (requirements are imposed by the local port authority):
  - Berthing during slack water only, with current ahead;
  - Under keel clearance: minimum 2 m;
  - Weather restrictions:

Visibility:	no turning in case of fog
Manoeuvering / Berthing:	wind speed less than 25 kn (46 km/h)
Suspension of cargo:	wind speed above 40 kn (74 km/h)
Resumption of cargo:	wind speed less than 40 kn (74 km/h)

  - Minimum distance between LNG vessel and other ship while in the channel (dredged to 12,4 m water depth):

    2 nautical miles ahead and behind, crossing forbidden.
    Clearance increased to 5 nautical miles while turning and berthing

  - Speed restriction for ships passing while LNG ship alongside berth: 8 kn
  - Maximum approach velocity for berthing: 0,15 m/ s

Bonny Terminal (Nigeria)

- Mooring equipment:
  - 5 mooring dolphins, each equipped with 3 hooks x 125 t capacity. Distance from berth line: 45 m;
  - 4 breasting dolphins: 2 equipped with 3 hooks x 125 t capacity + 2 equipped with 5 hooks x 125 t capacity;
- Tugs required (50 Tons Bollard Pull / each): berthing: 3 ; unberthing: 3

- Weather restrictions:

	wind speed	wave height / period
Berthing	< 25 kn	< 1,5 m / 9 s
Disconnection of arms	> 40 kn	> 1,5 m / 9 s
Unberthing	< 25 kn	< 1,5 m / 9 s

- Current restrictions for berthing / unberthing: < 1,2 kn

Table 2.2 - General Requirements for a LNG Receiving Port Terminal (SIGTTO)

The Port
Port Analysis
Speed restrictions for LNG carriers should be appropriate to limit grounding and collision damage
Approach Channels and Turning Basins
Navigable depths (for most LNG carriers) should generally not be less than 13 metres below the level of chart datum.
Under-keel clearances should be established in accordance with the sea-bed quality.
Channel width should be about five times the beam of the ship (approximately 250 metres).
Turning areas should have a minimum diameter of two to three times the ship's length (approximately 600 to 900 meters).
Short approach channels are preferable to long inshore routes which carry more numerous hazards.
Traffic separation schemes should be established in approach routes covering many miles.
Anchorages should be established at the port entrance and inshore, for the safe segregation of LNG carriers and to provided lay-by facilities in case, at the last moment, the berth proves unavailable.
Navigational Aids
Buoys to mark the width of navigable channels should be placed at suitable intervals.
Leading marks or lit beacons, to mark channel centrelines and to facilitate rounding channel bends, should be appropriately placed.
Electronic navigational aids, to support navigation under adverse weather conditions, are needed in most ports.
Lit navigational aids should be provided to allows ship movements at night.
Port Services
Tugs should be made available and three to four are normally required giving 140 tonnes total bollard pull. (Tugs may be required to meet LNG carriers farther offshore).
Mooring services are often required and these services should normally provide a minimum of two boats, each having at least 400 horsepower.
Escort services comprising fast patrol craft, to clear approach channels, turning areas, jetty, etc., should be provided in busy port areas.
Firefighting services comprising specially equipped craft or, one more suitably equipped tugs should be provided.

Port Procedures
Traffic control or VTS systems should be strictly enforced to ensure safe harbour manoeuvring between the pilot boarding area and the jetty.
Speed limits should be introduced in appropriate parts of the port approach, not only for the LNG carrier but also for other ships.
Pilotage services should be required to provide pilots of high quality and experience. Pilot boarding areas should be at a suitable distance offshore.
Ship movements by nearby ships, when the LNG carrier is pumping cargo, should be disallowed.
Pilots and tugs should be immediately available in case the LNG carrier has to leave the jetty in an emergency.
Port Operating Limits
Environmental limits for wind, waves, and visibility should be set for ship manoeuvres and these should ensure adequate safe margins are available under all operating conditions.
Weather limits for port closure should be established.
Weather Warnings
Forecasting for long range purposes should be provided to give warning of severe storms, such as typhoons and cyclones.
Forecasting for short range purposes, such as those required for local storms and squalls, should be made available.
THE JETTY
Jetty Location
Jetty location should be remote from populated areas and should also be well removed from other marine traffic and any port activity which may cause a hazard.
The maximum credible spill and its estimated gas-cloud range should be carefully established for the jetty area.
River bends and narrow channels should not be considered as appropriate positions for LNG carrier jetties.
Breakwaters should be constructed for jetty areas exposed to sea action, such as excessive waves and currents.
Restrictions, such as low bridges, should not feature in the jetty approach.
Ignitions sources should be excluded within a predetermined radius from the jetty manifold.

Jetty Layout
Mooring dolphin spacing – between the outermost dolphins – should not be less than the ship's length (approximately 290 metres).
Mooring dolphins should be situated about 50 metres inshore from the berthing face.
Mooring points should be suitably positioned, and have suitable strength for the environmental conditions.
Quick-release hooks should be provided at all mooring points.
Breasting dolphin spacing should be designed to ensure that the parallel body of the ship is properly supported.
Fendering for the dolphins, and for the berth face, should be to a suitable standard.
Jetty Equipment
Pipelines and pumps, etc., should be designed to provide a rapid port turn-round.
Emergency Release Systems (ERS) at the hard arms should be fitted in accordance with industry specifications. The ERS should be suited to both ship and shore by interlinking and a PERC should be fitted to each hard arm for emergency stoppage and quick release purposes.
Emergency shut-down valves should be fitted to both ship and shore pipelines and should form part of the ERS system.
Powered emergency release couplings (PERCs) with flanking quick-acting valves should be fitted to the hard arm as part of the ERS system.
Plugs both on ship and shore to carry all ESD and communication signals should be standardised.
Surge pressure control should be provided in LNG pipelines.
Communications equipment (telephone, hot-line and radios) should be provided for ship/shore use.
Load monitors, to show the mooring force in each mooring line, should be fitted to quick release hooks.
Gangways should be provided to give safe emergency access to or form the ship.
Basic Firefighting Facilities
Water curtain pumps and pipelines should be provided.
Fixed Dry Powder systems should be provided.
Gas detection monitors should be fitted at strategic locations.
Fireproof material should be used for the construction of hard arms (no aluminium)

Jetty Procedures
On shore jetty safety zones should be effectively policed while the ship is alongside thus providing control over visitors and vehicles.
Offshore safety zones should be effectively policed by a guard boat to limit the approach of small craft.
Passing ships, close to the jetty, should have their speed controlled by the harbour VTS system.
Communications procedures should be well established and tested.
Contingency plans should be available in written form.
Operating procedures should be available in written form.
A Port information/Regulation Booklet should be provided for passing operational advice to the ship.

(Note: Where figures are given they refer to LNG carriers of 135 000 m^3 capacity)

Ref: SIGTTO, Information Paper No. 14

2.3 Site selection guidelines from the 1979-80 Arctic Pilot project

The current project is in some ways a revised version of the "Arctic Pilot Project (APP)" that was submitted to public hearings under the jurisdiction of the Quebec Government "Bureau d'audiences publiques sur l'Environnement (BAPE)" in the early 1980s.

A description of that project is presented in full detail in a site selection study report, dated 1979, issued by the consulting firm André Marsan and Associates.

The BAPE public hearing report, issued in 1980, is a public document available at the following web address: http://www.bape.gouv.qc.ca/sections/rapports/tous/index.htm (select report no. 5-1).

Although the Arctic Pilot project presented important technical, social and economic differences with the current one, it also included some relevant similarities and therefore, many of the Commission's comments and recommendations can be used as guidelines for the development of the present LNG receiving terminal.

It should be noted that during the last two decades since 1980, the number of LNG terminal facilities around the world and the annual volume of LNG safely loaded, transported and unloaded have been largely increased. For all LNG related activities worldwide, accidents have been very rare and the industry has always had an excellent safety record. Moreover, the LNG industry has adopted rules and practices which are complied with worldwide and described in SIGTTO (previous section).

The most significant differences between the two project features are summarized in the following table. It should be noted that the current assessment covers only the items related to the port facilities.

Table 2.3 – Comparison of Main Project Features between 1979-80 and 2003 Studies – Port facilities

	Arctic Pilot Project (1980)	Current project
Origin of LNG products	Melville Island, in the Canadian Arctic	International markets, producing countries (Algeria, Bahamas, others)
LNG Carrier Ships	374 m in length, class 7 icebreakers	300 m in length, reinforced for ice navigation, but not icebreaker class.
Site selection	8 sites considered, among which: 2 on the north shore of the Saint Lawrence: - Sault-au-Cochon, - Cap aux Oies, and 6 on the south shore: - Pointe de la Martinière, - Pointe Saint Michel, - Pointe aux Orignaux, - Gros Cacouna, - Grande Île de Kamouraska, - Île Verte.	3 sites considered, from a review of the sites previously considered in 1980: - Ville Guay (some 3 km east of Pointe de la Martinière), - Pointe Saint Denis (some 3 km east of Pointe aux Orignaux), - Gros Cacouna (same as in 1980). All other sites were rejected before pre-feasibility assessment for economic or environmental reasons.
LNG delivery to terminal	Typically, 1 ship / 12 days Duration of calls: 18 to 22 hours Ship capacity: 140 000 m^3	Typically, 1 ship / 7 days Duration of calls: 18 to 22 hours Ship capacity: 160 000 m^3

The following table lists the various site selection criteria that were in use in the 1980 APP assessment, along with the corresponding criteria adapted to the current study. It must be kept in mind that the 1979-80 study included maritime and on-land facilities whereas this work is restricted to the port facilities only. It is also important to clearly state that the current study consists only of a pre-feasibility analysis whereas the 1979-80 site selection study was a feasibility analysis and therefore included a more thorough examination of the various criteria. The purpose of the present study is to give an overview of all the aspects pertinent to the selection of an implementation site for the port facilities. It aims at identifying major constraints for each proposed site and to justify site selection preferences without necessarily leading to final conclusions. It also aims at eliminating any unacceptable site, if any.

Table 2.4 – Comparison of Site Evaluation Criteria between 1979-80 and 2003 Studies

1979-80 Study (Arctic Pilot Project)	2003 Study	Remarks
TECHNICAL CRITERIA		
Bathymetric conditions:		
Distance to adequate water depth (8 fathoms)	Same, considering a 15 m water depth	Water depth considered in both studies are slightly different: 8 fathoms = 14,6 m
Dredging depth required (port construction and maintenance)	Same	Dredging is to be minimized
Navigation conditions:		
Minimum width of approach channel (2 x ship length)	Minimum width of channel is 5 x ship beam = 250 m	Current specification according to SIGTTO
Alignment of approach channel	Same	Not considered as a differentiating criterion in current study, since St. Lawrence Seaway is already used by 6 000 – 8 000 ships /yr
Presence of adequate turning basin (7 x ship length)	Same, considering 2 x ship length as turning basin diameter	Apply current specification according to SIGTTO. Note that use of tugboats is compulsory.
Presence of adequate anchoring area	Same	
Density of maritime traffic	Same	
Ice conditions	Same	
Current – direction / intensity	Same	
Ship transit time	Same	Not considered an important discriminating criterion in current study. However, length of pipeline to network connection is an important economic factor.

1979-80 Study (Arctic Pilot Project)	2003 Study	Remarks
Physical site characteristics:		
Necessity for length of underwater pipeline	Not applicable	This criterion was used in the 1979-80 study since two of the potential sites were located on islands (Kamouraska, Île Verte)
Pipeline length to network connection	Not directly applicable	Although not a criterion to decide the location of the maritime facilities, must be considered in the overall financial assessment of the project.
Land suitability for pipelining	Not applicable in current study	Not considered as an important discriminating criterion in current study
Land access to site	Same	
Topography of site	Same	
Length of cryogenic line	Same	Related to layout of terminal and length of access jetty
PUBLIC SAFETY CRITERIA		
Population densities:		
Density of population within a 2 km radius	To be determined	In current project, a risk assessment study is to be carried out at feasibility stage
Density of population within a 6 km radius	To be determined	In current project, a risk assessment study is to be carried out at feasibility stage
Other conditions:		
Frequency of calm wind periods	Same	
Distance of settlements located downwind	Same	
Topography (presence or absence of escarpment affecting atmospheric dispersion)	Same	Effect of escarpment unknown at current stage. To be evaluated at feasibility stage within dispersion study.

1979-80 Study (Arctic Pilot Project)	2003 Study	Remarks
ENVIRONMENTAL CRITERIA		
Biological factors:		
Presence of or proximity to spawning grounds, nesting areas or bird refuges	Same	
Diversity and abundance of benthos, fish or birds	Same	
Diversity of intertidal and coastal habitat	Same	
Extent of intertidal flats	Same	
Shoreline woodland quality	Same	
Land use factors:		
Presence or proximity to housing (permanent houses or cottages)	Same	
Agricultural (Class A agricultural potential)	Not directly applicable to maritime facilities site selection	
Presence or proximity to recreational facilities (camping, etc)	Not directly applicable to maritime facilities site selection	
Cultural, archeological or historic values	Not directly applicable to maritime facilities site selection	
Fisheries	Same	
Potential of shorelines for recreation	Same	
Compatibility with development plans	Same	Development plan of the Port of Quebec was issued after APP studies were completed.

1979-80 Study (Arctic Pilot Project)	2003 Study	Remarks
SOCIO-ECONOMIC CRITERIA		
Project compatibility with regional development trends	Same	Regional plans were issued and/or updated after APP studies were completed.
Site access (proximity of highway, railway, dock or port)	Not directly applicable to maritime facilities site selection	
Accomodation capacity, within 10-25 km radius of site	Not directly applicable to maritime facilities site selection	
Access to service centres from site	Not directly applicable to maritime facilities site selection	
Proximity and availability of manpower	Not directly applicable to maritime facilities site selection	
Anticipated public attitudes to project	Same	

2.4 SERVICE LEVEL OF MARINE TERMINAL

The accessibility of the LNG marine terminal will be determined by weather and hydrodynamic conditions, i.e. tidal currents, wind, waves, ice, visibility. According to Gaz de France's indications specific to this study, the acceptable down time of the terminal should not exceed 5%, corresponding to 18 days per year. The following conditions are mentioned as preliminary guidelines to establish down time level:

- Wave height: 2 m while alongside (arms connection / disconnection + mooring) and berthing / unberthing (also depending on tug efficiency);
- Wind: 25 kn for berthing / unberthing (could be more depending on direction);
- Visibility: 1 nautical mile;
- Ice: to be determined by Port Authority and Pilots.

2.5 TERMPOL REVIEW PROCESS

The "TERMPOL Review Process (TRP)" refers to a technical review process of marine terminal systems and transhipment sites under Canadian jurisdiction.

(http://www.tc.gc.ca/marinesafety/tp/tp743/def_and_acro.htm)

Transport Canada Marine Safety is responsible for the administration of national and international laws designed to ensure the safe operation, navigation, design and maintenance of ships, protection of life and property and prevention of ship source pollution. Fisheries and Oceans Canada is also involved in this process and its responsibility is to ensure the safe and environmentally responsible use of Canada's waters, support understanding and management of oceans resources, facilitate the use of Canadian waters for shipping, recreation and fishing, and provide marine expertise in support of Canada's domestic and international interests.

The TRP applies to:

- the specialized equipment and procedures necessary at proposed bulk oil, chemical, liquefied gas terminals and any other cargoes which may be identified by Transport Canada, Marine Safety (TCMS);
- proposed transhipment facilities for these substances; and
- any proposed changes to existing terminals or designated transhipment sites or facilities for these substances.

Useful guidelines for channel, manoeuvring and anchorage design are proposed in Appendix 2 of the TRP presentation document issued by Transport Canada. These are summarized in the following paragraphs 2.5.1 to 2.5.5.

2.5.1 Channels

- The cross-sectional geometry and alignment of a ship channel are site-specific matters. Moreover, in those instances where tidal stream or current directions are not invariably axial to the direction of the ship channel, the design ship's dimensions must be of primary consideration. This is particularly so where the ship channel changes directions.
- Channel width should be established in accordance with good engineering practice. In determining the width of one-way channels consideration should be given to allowances for the beam and manoeuvrability of the largest design ship, accuracy of position-fixing equipment, bank suction, tidal stream, current, wind, shallow water, operating speeds,

hardness of banks, length of the channel and whether overtaking will occur. In addition to the above, the width of two-way channels should include a separation zone between the inbound and outbound lanes. Where bends occur in a channel, the radii of the curvature must be compatible with the design ship's manoeuvring characteristics, taking into account the depth of water available in the bend. Channels should be widened in bends, and adequate transition zones provided between sections of channel having different widths, according to good engineering practice. Similarly, good channel design practice dictates avoidance of "S" curves, provision of adequate straight sections before, after and between bends, consideration of the navigator's sight distance in a bend, and avoidance of sudden large changes in water depth in channels. Adverse conditions of visibility, wind, current, wave dynamics or large turns may necessitate speed restrictions or tug escort / assistance.

- Anchorages and emergency containment areas should be located as close as is practicable to the channels they serve. The bottom in anchorage areas should provide a good holding ground. The area should provide the maximum practicable protection.

- In one-way channels where the design ship's maximum breadth is not a primary consideration, the minimum channel width should be at least four times the design ship's breadth allowing for the draught of the design vessel. In two-way channels where the design ship's maximum breadth is not a primary consideration, the minimum channel width should be increased to at least seven times the design ship's breadth, again allowing for the draught of the design vessel.

- For a distance of at least five times the length of the design ship from the marine terminal berth, the channel bank on the terminal side should be maintained at an angle not exceeding ten degrees (10°) from the direction of the alignment of the bank face. Where this requirement cannot be met, as in the case of finger piers, tug assistance will be required to bring the design ship in line with the berth face before the final approach.

2.5.2 Clearances

- Except where appropriate calculations have been made, every ship when manoeuvring should have an underkeel clearance not less than fifteen percent (15%) of the deepest draught at that time (see section 3.6 of the TERMPOL Studies and Surveys).

- Special consideration should be given to identifying any physical limitations along the route, especially power transmission lines and the effect of ice in further reducing the air height of those lines.

2.5.3 Minimum Distance Between the berth and the Center of the Channel

- In those instances where the proposed marine terminal's ship berth is in close proximity to a frequently used ship channel, careful consideration should be given to the minimum distance requirement between the berth and the centerline of the ship channel. This is a site specific consideration and should exceed six times (6X) the design ship's beam.

2.5.4 Turning Basin

- There should be at least one area in the vicinity of the terminal where the design ship in any displacement condition, aided by bow and stern tugs, may be brought to a stop and maneuvered so as to obtain the required heading. The minimum depth in the turning basin, or in at least one turning basin where more than one is provided, should be equal to the maximum draught of the ship plus 10% to 15% of such draught or as required to be computed in accordance with the Special Underkeel Clearance Survey (see section 3.6 of the TERMPOL Surveys and Studies). The permissible area of the turning basin should be such as to completely contain a turning circle clear of structures with a diameter equal to two and a half times (2.5X) the overall length of the design ship. If local conditions are favourable and subject to the proposed docking and undocking procedures being acceptable, the turning circle described may be reduced to a minimum of two times (2X) the overall length of the design ship.

2.5.5 Anchorages

- Anchorages and emergency containment areas should be located as close as is practicable to the channels they serve and relate to site-specific conditions. The bottom in anchorage areas should provide a good holding ground. The depth should be not less than the maximum draught of the design ship plus 15% and not more than 100 meters. The radius of each anchorage berth should be not less than one half nautical mile.