APPENDIX I

Appendix I – Notes from Meetings

The notes from the meetings are presented in chronological order.

November 13, 2002 : Captain Réginald Corriveau

Early discussions with Capt. Reginald Corriveau, Superintendent, Escort and De-icing, Canadian Coat Guard, November 13, 2002:

- An ice patrol ship sails twice a week during the ice season, therefore, 2-3 ice charts are produced per week.
- Current ice conditions are now electronically available on line.
- Coast Guard has a ship-borne helicopter with the ice patrol.
- Any work on the ice (sampling, thickness measurements, is done by Environment Canada personnel, seconded to the Coast Guard each winter season.
- In some sections of the river, even icebreaking ships have occasional navigation difficulties because of the ice. It is not uncommon to have huge ice accumulations (20-25 ft) in the vicinity of an icebreaker.

December 16, 2002 : Professor Brian Morse

Early telephone discussions with Prof. Brian Morse, December 16, 2002:

- Ice observers do not to take photographs, in their normal duties.
- Ice ridging and rafting is likely to produce the most significant ice features of interest for design. Ice observers from the Coast Guard are not focused on this kind of information regarding general ice processes (circumstances of occurrence for piling, rafting, ridging, frequency, thickness of sheet, thickness of accumulation, degree of consolidation...). This should be discussed with them.
- For ice thickness, besides direct local measurement by boring, air-borne radar techniques (Fleet Technology) can be used to produce ice thickness profiles.

December 19, 2002 : Captain Réginald Corriveau

Introductory meeting in Quebec City with Capt. Reginald Corriveau, Canadian Coat Guard, December 19, 2002:

- Described area of interest, general objectives of the ice study. Ice season of significance is typically from Mid-January to end of March.
- Ice charts produced by the Coast Guard, and distributed by Environment Canada, are produced by hand from by on-board ice observers and the data is not geo-referenced. The Coast Guard therefore can make no representation

concerning accuracy of the charts. The Coast Guard will assume no responsibility and any data from the ice charts is provided as indicative only.

- The Coast Guard has been purchasing satellite imagery for ice in recent years. Therefore more objective and reliable data is available and can be examined, but ice charts are still prepared by hand, based on on-board observations.
- The focus in on ice conditions as they affect navigation and not on the mapping of ice features close to shore (grounded or land-fast ice).
- Ice thickness measurement are done systematically in Bécancour and Trois-Pistoles.
- It is suggested to consult ship captains and local harbor masters to get a feel for navigation conditions in the area. Local fishermen may also be a useful source of information, since they make holes in the ice throughout the winter.
- Correlation of temperature data (FDD) with extent/thickness of ground-fast ice should be possible. However, pertaining to ice conditions as they affect navigation, there are no simple climatic correlations since currents, tides and strong winds are all significant drivers of ice dynamics in the area of interest.
- An exposed mooring similar to the Ultramar loading dock is not common on the St-Lawrence River. (*Writer's comment: it is feasible at Ultramar because the river is very narrow near Quebec City, thus currents are very variable and of high velocity. In addition, the ice cover is actively and constantly managed to maintain the passage clear.*)
- All other ports along the River are sheltered. In the Estuary, wind conditions alone occasionally prevent ferries from safely docking at South shore harbors. When this occurs, they must return to the North shore. (*Writer's comment: dominant winds are from the North, West and North-West, thus 15 km plus fetch over water; the North coast is mountainous and therefore sheltered from these wind directions*.)
- Ice push can be very extreme once in 10 or 20 years: on Lake St-Pierre, a ship was pushed out of the channel from 35 to 15 ft of draft. When a major push occurs, moorings cannot maintain a ship on station.
- In March-April, problems come from large extents of shore-fast ice becoming dislodged in high tides/favorable winds. The ice can jam the river and then has to be broken up.
- The Coast Guard run a mathematical model of the river daily, and the data is starting to be used as an aid for operations on some sections of the river (mostly in the Gulf of St-Lawrence, not at our site). Denis Lefebvre (Institut Océanographique Maurice-Lamontagne (IML), Mont-Joli, 418-775-0568) should be contacted for data and modeling of currents.

December 19, 2002 : Professor Brian Morse

Introductory meeting with Prof. Brian Morse, December 19, 2002:

- Respective responsibilities and supervision roles were discussed.
- Met the two finishing students who will be assigned to work on the project: Olivier Kervella (Pouliot Pavilion at Laval University, 418-656-2131, ext. 4929;

residence 418-692-4427) will be dedicated to the work full time, and Julien Toquer will be 1-2 days per week.
- Coast Guard personnel can be very helpful in providing a general perspective on the situation, identifying engineering or navigation problems, commenting locations, commenting loading or operational scenarios, identifying solutions (e.g. advance warning of significant events…).
- It is suggested that the layout of proposed structures should be reviewed with experts familiar with conditions on the St-Lawrence River, including Yan Ropars, Public Works Canada, Quebec City, and other port design engineers.
- Consult Altas of currents, available from Canadian Hydrographic Services. People from the Oceanographic Intitute of Mont-Joli can help understand and interpret currents.
- It is suggested to interview as many ice observers, fishermen, icebreaker commanding officers (including retirees) as possible.
- Discussed some aspects of the methodology to extract quantitative statistics from ice charts and from other data. Useful items to gather would include : ice concentration values, extend of shore-fast ice, persistence (i.e. consecutive days of ice at a given concentration), extent of shore-fast floes breaking away between observations, correlation of concentrations with tidal cycle, correlation with water levels, climatologic data…

January, 2003 : Environment Canada - Canadian Ice Service

Obtaining ice charts from Environment Canada, Canadian Ice Service-Client Services, 373, Sussex Drive, Ottawa K1A 0H3, contact Robert Tessier/Maria MacLeod, 800-767-2885, 613-992-3073, fax 613-947-9160):

- Environment Canada keeps and distributes ice data. The consolidation and transcription of ice data to CD is on-going, but some data is still only available at the Coast Guard office, in Quebec City. Environment Canada will assist in obtaining the most complete data set possible.
- An initial data set has been ordered, which is to be received by January 13, 2003). The initial order includes:
    - Ice Summary and Analysis – Eastern Canadian Seaboard from 1964 to 1971.
    - Ice charts – St. Lawrence Estuary – from 1988 to 1992 (on CD).
    - Ice charts – St. Lawrence Estuary from 1994 to 2002 (on CD).
    - Historical ice thickness reports at station P35 (Gros Cacouna) and others, if available.
- More data will be ordered , as data gaps become apparent.

January, 2003 : Environment Canada - Meteorological Services

Obtaining climate data from Environment Canada, Meteorological Services, Montreal, 100, boul. Alexis-Nihon, 3rd floor, St-Laurent, contact Adrien Julien, (514-283-1112).

- Environment Canada has the following data sets:
    - Île Rouge, since 1984
    - Rivière-du-Loup, since 1990

    - Mont-Joli, since 1942
    - Quebec City, since 1942 or older
- The exact contents of each data set (parameters included, gaps…) is not readily available. The data is free, but time to gather it is chargeable at a fee.
- A Climatologic Map of the St-Lawrence is readily available and will be acquired.

January 15, 2003 : Captain Marc Harvey

Meeting with Capt. Marc Harvey, Traverse Rivière-du-Loup Saint-Siméon (199, rue Hayward, Rivière-du-Loup G5R 3Y8, 418-862-9545, fax 418-862-5382), January 15, 2003:

- Capt. Harvey has sailed 30 years on the St-Lawrence, including 15 at Rivière-du-Loup as captain on the ferryboat between Rivière-du-Loup and Saint-Siméon. He has been a senior captain for 15 years.
- A turbulence area is located close to l'Ile Verte because of the influence of the Saguenay River and Northwesterly winds that can reach 80 kt in Tadoussac.
- Southwesterly winds are dominant during summer.
- Operations are complicated with North and North-West winds because ice is pushed toward Rivière-du-Loup and the South coast of the Saint-Lawrence River.
- In his opinion, ice conditions were worse 15 years ago and ice period was beginning earlier (early December instead of mid or end December today).
- A powerful boat should not have any problem to navigate through ice during winter. In fact, new boats don't really have any problems reaching Québec City from the Saint-Lawrence Gulf.
- An ice free area raises some problems during winters. When the weather is cold enough and quite windy, waves produce freezing sprays, which can make maneuvers more difficult and operations more dangerous. Moreover open water is often associated with low visibility because of the fog ("fumée de mer").
- Current make the evacuation of ice easier. So coastal pack ice is narrower in areas exposed to strong currents, such as in the area of interest.
- Coastal pack ice can reach 10 miles width and ice pilling up between 2 and 5 meters thick. Such conditions are possible when Northwesterly wind blows about 25 kn and ice concentration is about 5/10 in the Saint-Lawrence River. However those conditions don't last and pack ice gets dislocated when the winds veer.
- Cacouna harbor is always navigable thanks to ice-breakers that come when boats cannot break ice by themselves, and because it is a place of ice-breakers crew change. Even if ice thickness can reach 1 meter, navigation in the harbor remains possible because ice is not under pressure. However winds can make it difficult to clear the ice.
- According to Captain Harvey, the longest floe that can drift could be 2 or 3 miles long with a speed equal to that of the current.
- In his opinion, between Kamouraska, Cacouna and Île Verte, Cacouna is the preferred site thanks to accessibility by two deep channels and because the fetch is shorter than at Ile Verte, where waves are high and strong. Cacouna is better protected from the Northeast.

- In his opinion, the zone along the South shore between Île Verte and Rimouski is to be avoided ("à proscrire", in his words) because of frequent dense ice under pressure, which can extend to isobath 30 m.
- New contacts :
  - M. Guy d'Aigle, Cacouna harbor master (862-6592).
  - Capt. Daniel Dionne, native from l'Ile Verte (862-6709).
  - Capt. Leopold Anctil, Kamouraska (492-1529)

  He also advices us contact the captain of the Trois-Pistoles ferryboat.

January 15, 2003 : Captain Leopold Anctil

Meeting in Kamouraska with retired Capt. Leopold Anctil, January 15, 2003:

- Capt. Anctil is now retired but has sailed on different ships on the Saint-Lawrence River. We understand that his experience is on smaller ships.
- Bad sailing conditions appear when a Northerly wind blows during 4-5 days.
- During a particular winter in the early 80's, he recalls that ice caused significant troubles for navigation, so that the journey by boat between Les Escoumins and Québec took 3 days, with the help of the Simon Fraser (not an icebreaker, but a Coast Guard service ship ("baliseur").
- He has no memory of ice pilling up near Kamouraska.
- New Contact :
  - Capt. Viel at Rivière-du-Loup.
- Finding statistics on boats that sail on the Saint-Lawrence could be convenient (tonnage, length…), so that it would be easier understand what people call "big boat" when they are interviewed.

January 14, 2003 : Patrice St-Amant

Call January 14, 2002: Patrice St-Amant, VP Operations, Société des Traversiers du Québec (STQ), 109 Dalhousie, Quebec, 418-643-2019:

- STQ operate 3 ferries in the area of interest:
  - Trois-Pistoles-Les Escoumins, seasonal, May to October
  - the Saguenay river crossing at Tadoussac, permanent link
- Other services by STQ include the Matane to Baie-Comeau ferry
- A private company operates the ferry from Rivière-du-Loup to St-Siméon, in seasonal, closed from early January to early April. Contact Captain Marc Harvey, Traverse Rivière-du-Loup Saint-Siméon, 199, rue Hayward, C.P. 172, Rivière-du-Loup, Quebec G5R 3Y8 (418-862-9545, fax 862-5382, res 418-862-8143)
- Suggests we contact retired Captain Marcel Desgagné, Île-aux-Coudres (418-438-2251)

January 16, 2003 : Guy Marmen

Call Les Pilotes du Bas Saint-Laurent, Mr. Marmen, President, 240 Dalhousie, Quebec, 418-692-0444. Message left January 16, 2003.

January 16, 2003 : Captain François Gauthier

Meeting with Capt. François Gauthier, Société des Traversiers du Québec (STQ), rue du Porche, Quebec City, January 16, 2003:

- Capt. Gauthier has sailed 33 years on the St-Lawrence, some years as a pilot on the Lower St-Lawrence, and including 23 years as captain with the Canadian Coast Guard (CCG) and 2 years as captain of the Camille-Marcoux, the ferry between Matane and Baie-Comeau.
- The South channel, in the area of interest has little traffic, since if is not marked ("non balisé"). The South channel is not maintained in the winter. Only small boats sail there, and larger ones go there rarely (sometimes an older captain).
- There has been a marked reduction of traffic in the Cacouna sector.
- Capt. Gauthier recalls only 2 events in 25 years where navigation in the winter became very difficult, a rare combination of lasting cold, and unfavorable winds and tides. The delays do not last more than a couple of days, since the cold spell and/or persistent wind eventually subside.
- Problems occur when there is pressure built-up in the ice pack, due to wind and tides. As soon as the pressure is relieved, and that the ice moves again, navigation can returns to "normal"
- Actual dates can most likely be obtained by reviewing CCG data, who keep very good records, particularly in recent years (e.g. annual Review of Operational Program: we were shown the 2001-2 report; these can be obtained from the CCG; another CCG publications, Ice Navigation in Canadian Waters was also mentioned)
- There is a lot of current in the general area of interest, the North channel therefore requires very little ice breaking, and clearing occurs naturally. The shipping corridor mostly North of Île Rouge since ships have to stop at Les Escoumins for the pilot to embark or disembark. However many ships pass South of Île Rouge since the area is generally unobstructed by ice., i.e. the ice moves along freely.
- Access to the Port of Cacouna often does not require any assistance from icebreakers, but when requested (usually this is coordinated between the shipping agent and CCG), the entrance of the harbor is done routinely.
- The edge of the land-fast ice thickens with the shearing action of passing ice under pressure (under Westerly or Northwesterly winds which are predominant). The increase in thickness occurs mostly to the underside of the floating ice pack. Accumulations up to 20 ft deep are reported to have been observed at Matane. This forms a "conveyer" ("chariot", in the words of Capt. Gauthier). When the pressure increases, friction eventually stops the movement and a new active shearing zone forms further from the shore.
- This is when icebreaker intervention becomes necessary.
- Northeast of Île Verte, there is little ice but the ice edge from the South shore can extend out, exceptionally reaching the proposed site. It is noted that this site is quite far from shore, therefore more difficult to connect and access. Since there is a very large fetch and mostly open water, wave action and spray can be very brutal at this site. The area has tricky currents ("remous"). There

is a history of very violent storms at The Prince "haut fond" and at Île Rouge (retired lighthouse attendants could possibly be contacted, also wave estimates should be developed).
- The proposed site at Pointe du Diable does not appear problematic for traffic.
- Note bird sanctuaries and wetlands all along the South shore, particularly near Kamouraska and Île Verte. We should verify existing protection of these parks and wetlands. Conversely, Cacouna already has industrial activity.
- There is plenty room for stand-by, while waiting for dock access, if necessary, near La Malbaie and near the Saguenay.
- Large ice floes (pieces of shorefast ice becoming loose) can be a problem in constricted areas, upstream from Quebec City. Not an issue for navigation in the area of interest: problem floes will have been broken up before reaching the site; floes from the area can typically sail right through.
- CCG monitors shore-fast ice in problem areas, tracking ice thickness and reporting floes as they are observed. Statistics are probably available, but not for our area of interest.
- STQ is studying an upgrade of the Wharf at Rivière-du-Loup. Soils are poor and the dock structures need major rehabilitation.
- Check availability of site specific ice studies made by of for the CCG, (may include Cacouna).

January 16, 2003 : Roger Provost

Meeting with Roger Provost, Senior Ice Patrol Officer, Environment Canada, stationed and CCG Patrol office in Quebec City, January 16, 2003:

- 20 years at ice patrol, sailed in all areas of St-Lawrence, also in the arctic Will be on duty 7 days-a-week until January 23, returns February 11.
- Near Cap-aux Oies, Northern half of River has little ice. South of the area of interest, there is a lot of ice from Île-aux-Lièvres to Gros Cacouna
- The extent of the land-fast ice coincides with the shallow water area (shaded on bathymetric chart), does not exceed 5 m isobath
- Ice clearing of Cacouna harbor relatively is routine and easy; cannot recall any difficulties there
- Suggested contacts at Ottawa Ice Bureau:
  - Richard Chagnon (613-996-4390): ice climatology
  - Claude Dicaire 613-996-1599: ice and weather
- Ice thicknesses surveyed since 1982
- Brash ice (the type of ice seen on the River at Quebec City on the day of our meeting) does not consolidate, except in sustained winds. As soon as pressure disappears, accumulations break up easily as soon as a ship goes through.
- Has seen 20 foot grounded pile-ups at Matane
- Estimates largest floe in area of interest would be intermediate size (100-200 m). Thickness could reach 4-5 m (shore-fast ice can become quite thick because of jacking up from the tides: on January 15, 2003, we saw the Trois-Pistoles Ferry, stationed for the winter in the harbour, apparently jacked a couple of feet above the surrounding ice.

- Showed Radarsat images of River dated !4 January 2003. Flow patterns of the ice are very distinct, and follow the curves in the river and the protrusions from the shore. The open water at Cap-aux-Oies is evident. Noted also a zone of divergence at Cap-aux-Diable/Kamouraska, convergence, at Cacouna, packing along South shore in the entire area of interest.

January 16, 2003 : Professor Brian Morse

Meeting with Prof. Brian Morse, January 16, 2003:

- Professor Yvon Ouellet (2 offices down the corridor from Prof. Morse's) is the recognized expert for waves on the St-Lawrence, with or without the presence of ice.
- There are requirements imposed to the project by the Navigable Water Protection Act (Loi sur la protection des eaux navigables, LPEN); the law is administered by the CCG, and Reginald Corriveau will have a say at some point; it would be useful to check what makes life difficult or not for the CCG in a project like this, what information the CCG would require eventually in the approval process
- Respective responsibilities and supervision roles were discussed.

January 28, 2003 : Professors Yvon Ouellet and Brian Morse

Meeting with Professors Yvon Ouellet and Brian Morse, January 28, 2003:

- Paul Croteau indicates, from earlier discussions with Adrien Julien, meteorologist from Environment Canada, that meteorological data is available as follows:
    - Ile Rouge, since 1984
    - Rivière-du-Loup, since 1980,
    - Mont-Joli and Quebec, since approximately 1942
- Prof. Ouellet has wind data up to 1993. So they are available but have to be completed up to 2002. He has no data on temperature.
- He made synthetic wind charts for winds that blow on the St Lawrence thanks to correlations between data from ground stations and data from boats (mean hourly winds).
- Climatic data from l'Ile Rouge can give us better information and correlations than those from Rivière-du-Loup according to Prof. Ouellet. There is however a local tunnel effect from the Saguenay River gorge, which creates exceptionally high winds from the West. These would realistically represent the Ile Verte site, but would be conservative for the others.
- Data from synthetic stations V and VI can be used and processed (see attached listing and diagram, provided by Prof. Ouellet.
- If data older than those from the early 80's have to be used, he thinks that data from Mont-Joli is more representative for our sites than data from Québec. He also advised us checking if there are available data in St-Francois station (Ile d'Orléans).

- It would be useful to interview Denis Lefebvre in order to understand what parameters are used in the so-called Ice Severity Index ("indice de sévérité"), which appears as an output to the mathematical model.
- According to Prof. Morse, it is difficult to determine how much time it takes for a floe to go from Québec to Cacouna for instance. Because of currents and tidal conditions, the flow fluctuates: for example, it is said that a piece of ice passes under the Québec Bridge 7 to 9 times (no particular source…folkloric).
- Prof. Ouellet will provide results of his data processing. Wind roses will be supplied for the months of January, February and March, and for all three.

January 28, 2003 : Captain Réginald Corriveau

Meeting with Capt. Reginald Corriveau, Superintendent Icebreaking Program, Escort And Flood Control (Fisheries and Oceans, Coast Guard), 101 boul. Champlain, Québec Qc G1K 7Y7 (418-648-5620), January 28, 2003

- There have been 2 major problems due to ice this winter, but it was in areas located South of our sites.
- Capt. Corriveau has provided a written report of ice observations made between January 14 and January 27, 2003, specifically at the three sites of interest, Cap au Diable, Cacouna and Île Verte. Some data are unavailable (Cap au Diable) because of weather conditions when observations were made (snow storm, fog…).
- When ice thickness ranges 15 to 30 cm and is under pressure, an icebreaker is normally required to help ships navigate through ice.
- Big boats are radar monitored as soon as they enter the Gulf of St-Lawrence.
- The ice cover becomes grounded between l'Ile Verte and the shore, and it happens that there are no currents in this place at low tide.
- The ice mathematical model is not totally reliable and is in continuous improvement. In fact, results are highly depends upon initial data, which are forecast (winds, temperature…). Therefore, model results often diverge from ground observations.
- When sustained Northwesterly winds blow between 35 and 40 knots, a heavy icebreaker must be deployed in Matane (further downstream, on South shore), to substitute the light icebreaker usually based there, because ice is pushed towards this shore of the Saint-Lawrence.
- The "Société des traversiers" could show us the logbook of the ferry located in the study area if we are authorized. Watch officer registers strength and speed of winds and currents when the boat crosses the river. So the last 5-6 years of measurements should be available. The main advantage of this is they are actual measurements, not forecasts.
- In his opinion, climatic data from Mont-Joly is more representative than data from l'Ile Rouge. In fact, winds blowing on the Saguenay River influence data collected on l'Ile Rouge, as shown by the Radarsat image taken on January 28 (see attached print). Otherwise, data collected in Matane can be used because 90% of winds blowing there are the same along the shore.
- The wider the River is, the longer the fetch, and, as a consequence, the higher the ice pressure.

- It has already happened that boats could not dock in Cacouna harbor because of ice and winds (35-50 knots). Moreover this harbor is not protected from winds even in summer and 2 or 3 tugs are often requested. It is the same in Sept-Iles, event if the harbor is wind protected, 2 tugs are requested to dock boats of 100 000 tons.
- During winter, 2 pilots from les Escoumins must embark and guide large vessels.
- Brash ice is usually not a problem for navigation. However, when brash consolidates because of cold temperatures, bad navigation conditions can appear.
- Pilotage costs (based on usage, required upstream from Les Escoumins) and dredging costs (shared between users) are substantial.
- It is rare, even in Quebec, that a ship cannot dock because of ice problems. In the wider and windier estuary, ships cannot dock occasionally, due to the wind.
- Even in the summer, a 100 000 DWT ship will require 2 to 3 tugs for docking, every time.
- Contacts:
    - Michel Demers, Protection of Navigable Waters, Canadian Coast Guard, 101 Champlain, Quebec, (418-648-5403) to discuss permitting process

January 28, 2003 : Captain Germain Tremblay

Interview with Captain Germain Tremblay, icebreaker "Desgroseiller", Section , Quebec Harbour, boul. Champlainat l'Anse-aux-Foulons, Québec Qc (on board ship: 563-3195, home: 681-3337), January 28, 2003.

- Conditions in closed harbours of the south shore, Matane and Cacouna are, in his words, "horrible". It is due to strong Northwesterly winds and the presence of shearing zones at the ice edge ("chariots"). This forms a barrier at the entrance of the harbours that makes icebreaker maneuvers very difficult. In his opinion, closed harbours on the South shore should be avoided.
- Discussing the Ultramar terminal, he notes the difficulties of the site and the size limited maneuverability of the large oil tankers. The fact that there has not been a serious accident associated with marine operations at the site is a tribute to the fine piloting system on the St-Lawrence.
- Boats have to arrive at Ultramar at the end of the rising tide in order to have plenty of water for in the shallowest portion of the channel, just downstream from Québec. Docking is always done with the bow facing the current at the start of the ebb tide. Assistance by tugs (which are based at the Québec harbor) is always required for large vessels (80 000 DWT plus). Those operations are long and can be very dangerous if any mechanical failure should occur because the Saint-Lawrence is very narrow.
- Ferries sometimes cannot dock at Matane because of strong tides and currents, more particularly during ebb-tides.
- The area North of Ile Verte is quite ice-free, but is very exposed to Northeasterly storms, which are frequent during autumn. During such storms, waves can reach many meters high (5-6), and when it is cold enough freezing

sprays can appear. Docking is tricky with Westerly winds. During storms, first year ice (thickness > 30 cm) can be pushed in from the Gulf and ice accumulates on moorings.

- Current is strong near Cacouna, and stronger during ebb than during flood tide. Cacouna is better protected from Northeasterly winds.
- Kamouraska is also better protected from storms than l'Ile Verte, there are regular currents for clearing the ice but, as for Ile Verte, the site is quite far from the shore.
- Capt Tremblay notes that there are no existing transit-transport infrastructures close to any of the sites included in the study. In fact for any mechanical failure on a ship, a road is necessary to bring spare equipment on board.
- As another potential site, he pointed out Pointe-de-la-Martinière near Quebec, where ice is not a problem and because it is already an industrial area belonging to the Port Authority of Quebec. Ross Gaudreau, should be able to answer our questions.
- Moreover tugs are based in Quebec, close to Pointe-de-la-Martinière. Therefore, these operations would be more affordable.
- The available draft is always at least 12.5 m in the channel leading to Quebec. The site is also well protected from storms and has fairly constant currents.
- If this site, close to Quebec City is further considered, he recommends limiting the draft to 11.5 m.
- According to him, Matane, Rimouski and Cacouna will never expand because of climatic and navigation conditions.
- New container transport vessels have drafts smaller than 12.5 m but are wider than 50 m.

February 19, 2003 : Guy Marmen

Meeting with Captain Guy Marmen, Corporation des Pilotes du Bas Saint-Laurent (C.P.B.S.L) , February 19, 2003.

- Guy Marmen was reelected as chairman of this corporation for the second time. Each mandate lasts 1 year and can't be renewed more than 3 times. At this time, there are 77 pilots who work between Quebec and Les Escoumins.
- Some sandbars are located abreast of Cap au Diable.
- The depth increases quickly at Pointe de la Martinière, unlike Pointe Saint-Vallier where the depth is quite shallow for big vessels. Moreover, this potential site is further from the shore than the one close to Pointe de la Martinière.
- Thanks to the bifurcation of the river in Pointe du Bout de L'Ile (Ile d'Orleans), there are strong currents near Pointe-de-la-Martinière that free the St-Lawrence from ice. Nevertheless large extents of land-fast ice can develop, particularly under sustained Northeasterly winds. However, the ice build-up in the shear zone ("chariot") is not large.
- Some pilots have often said that Pointe-de-la-Martinière could be a good site for container ships because of the proximity of the main highway (Autoroute 20) and the railway.
- Check location of 4 potable water intakes for Quebec City, which are located near l'Ile d'Orleans.

- Ultramar has increased its production at the refinery in the last 6 months so the monthly frequency of large (157 000 ton) ships has increased from 3 or 4 , to 7 or 8. Tankers with a draught up to 15.5 meters load or unload oil at this wharf but the tidal window in which they can pass the North Channel in Quebec is, of course, restricted in time. Indeed this window lasts only between 1.5 and 2 hours after the end of flood tide. Smaller vessels with 12.5 meters draught or less can navigate practically anytime. In fact ships must keep a under-keel clearance of at least 1.5 m above the bottom of the channel in the winter (1 m in the summer). At MLLW (mean lower low water), water depth is 12.5 m. So pilots use tide tables and a network of tide gauges in order to establish the time window. Tide gauges must be used in real-time because of differences between forecasts and reality that can reach 1 m (storm surges, effect of ice, atmospheric pressure). Now, new kinds of ships, with same tonnage, are built: they are wider (55 m instead of 52) with a smaller draught (0.5 m less).
- The costs for dredging the north channel are shared by the Port of Quebec, the Port of Montreal, Ultramar, and shipping companies.
- During winter, 3 tugs are generally used for docking at Ultramar. Two of them are along the boat and the other one is posted near the upstream protective dolphin in order to deflect ice from the wharf. A tug is also often requested to break land-fast ice that can sometimes reach the dolphins. In fact, with proper timing of tidal currents (ebb tide will clear the ice) tugs are strong enough for clearing the docking area. Icebreakers are never required.
- An anchorage site is located near Pointe au Pic where the depth is about 36 m.
- During winter ice movements are fast and strong. So in experience, he has memory of an oil tanker that was close to strand because its anchor had yielded. In fact it's a good anchorage area except with the combination of ice and strong winds. However with Northeasterly winds blowing more tan 24 hours, this area becomes ice free.
- There is no traffic in the South Channel during winter, and hardly ever in the summer, except small boats.
- Guy Marmen recalled an earlier marine terminal project at Grande-Ile.
- Last year, 36 ships docked in Cacouna, instead of 100 before. This is due to a decrease in wood exports and increased loading capacity of boats. This Port handles wood, fertilizer and scrap.
- Cacouna is accessible all winter long thanks to icebreakers and favorable currents. Nevertheless it sometimes happens that ships arrivals are delayed of 1 or 2 days when weather conditions are too bad and winds from the Saguenay River push ice toward there.
- Most of the time, the site close to Ile Verte is ice-free due to the convergence of strong currents. It is an often-used area for vessels anchorage when they are waiting for pilots from les Escoumins to come on board. If there was a terminal there, caution should be exercised during approach maneuvers. The berthed ship would also be subjected to strong swells (1-1.5 m).
- Regardless of the site chosen, tugs would be required every time a ship arrives or departs. Tugs would have to come from Quebec in the winter because the tugs based at LaBaie, up the Saguenay River, do not operate in the winter, due to of their propulsive mode, which does not work in ice.

March 5, 2003 : Site visit at Sainte-Flavie

On the way to Mont-Joli on March 5, 2003, quick visit of sites from the shore, but visibility was very poor.

However, the weather cleared as we were approaching Mont-Joli. We made a very interesting observation of a remarkable pressure ridge.

- The ridge is located approximately 150-200 m from the shoreline and parallel to the shore, at Sainte-Flavie. Good photographic records were taken. Scientists at IML indicated that this ridge had been there for several weeks.
- The ridge is about 150 m long, and the sail reaches a maximum of 3 m. The blocks forming the ridge are typically 30-40 cm thick.
- At Sainte-Flavie, the St. Lawrence is about 50 km wide (twice as much as the width at Île Verte). Therefore wind fetches for Northwesterly winds (which have formed this ridge) are considerably longer. Our sites being much further upstream, where the river is much narrower, therefore the likelihood of a ridge of this scale is reduced. As a matter of fact, no ridging of this importance was observed or reported in any of our previous visits and interviews, for the sites under study.

March 5, 2003 : Dr. François Saucier, François Roy

Meeting with François Saucier and François Roy at l'Institut Maurice Lamontagne (IML), Mont-Joli on March 5, 2003.

- The "Charlevoix corridor", a valley on the North shore, perpendicular to the St. Lawrence, causes Northwesterly winds to be amplified in the area of the study. This local amplification is similar to the so-called "cannon effect" ("coup de canon"), the local amplification at the mouth of the Saguenay, as recorded at Île Rouge.
- According to François Saucier, the choice of building a harbor in Cacouna was not random and this site can be in fact the most appropriate in the area. The site is somewhat shielded by the islands.
- Currents are stronger in the North channel than in the South channel. Moreover, bed currents are stronger than surface currents during rising-tide. It is the opposite during ebb-tide.
- There is a divergence of currents during rising-tide in Kamouraska. Ice accumulations can appear when 2 or 3 days-long storms with Northeasterly winds stronger than currents occur. With such conditions, ice becomes stationary at Kamouraska and the pack could become under pressure.
- According to estimates computed at IML, the average ice production in the Gulf and the St Lawrence River is about 60 km^3 on a 250 000 km^2, which represents an average thickness of 24 cm on the surface. We have estimates from 1963 to present. The maximum ice production can be twofold than the previous one, that means about 120 km^3. The method used to calculate has changed. Until 1997, the unit cell of the grid was 1° longitude on 0.5° latitude

(roughly 50 x 50 km) and the ice concentration used was updated once a week. Since then, the unit cell is 5 x 5 km and ice concentrations are updated every 3 days. Moreover, the use of the observation satellite Radasat (1997) has improved reliability of ice concentration data. A quick analysis of ice production has shown a correlation between it and characterization of winters with day-degrees. It is noted that the return period for cold winters about 20 years.

- The average St-Lawrence discharge is 12 000 m^3/s while it is 1 300 m^3/s for the Saguenay. But discharges due to tidal flow are far most important. For instance, the flow out of the Saguenay during ebb-tide reaches 70 000 m^3/s.
- A simple estimate of ice drift can be obtained by assuming free drift of an ice block drift. The free drift velocity vector is obtained by adding the surface currents vector with 2.5% of the surface wind vector.
- François Saucier raised the issue that if contaminants are released at the site close to l'Ile Verte, it would be impossible to collect them because of strong diverging currents there. Therefore, this site would not be considered favourably in an environmental review (he was obviouswly thinking of an oil development, not gas). Cacouna is not located in this very strong "evacuation corridor", which is readily visible on the tidal current charts.
- Besides the "cannon effect" of the Saguenay, which greatly amplifies Northwesterly winds, the "coup de boeuf", caused by Northeasterly winds, was described, as pertinent to the Île Verte site. Sustained Northeasterly winds produce severe waves because of the very long fetch. There are severe waves in this area even in the winter, because the area is most often ice free. During ebb tide, these high waves are held up downstream, because of the strong currents opposing wave propagation. Despite high winds, the water surface remains quiet during ebb-tide, but 20-30 min before slack tide, the area is rapidly invaded by extreme, breaking waves, creating literally "columns of water". This condition is very dangerous for small boats and many casual navigators and fishers have drowned in the area.
- Commenting on the Kamouraska site, François Saucier mentioned that a lot of ice can accumulate upstream, particularly during Northeasterly winds, so there could be some packing of ice, particularly near the South shore, in the area. Compared to Kamouraska, Île Verte and Cacouna, have less ice, but more wind and waves.
- For ice modeling, the large scale yield strength of pack ice is taken as $p^* = 27 * 10^3\ N/m^2$.
- For an ice block, an average free-drift between Quebec and Cacouna can be taken as 4 or 5 day, and between Tadoussac and Matane 5 or 6 days.
- In the absence of wind, ice trajectories follow isobaths. However, any amount of wind will cause deviations.
- The ice-model has been in day-to-day use since 1997.

March 6, 2003 : Aerial reconnaissance of the sites

Flight over sites under study, morning of March 6, 2003. Passengers on board include Prof. Brian Morse, Paul Croteau and Olivier Kervella. Weather clear and sunny. Good photographic records are taken, which are commented in a separate memo.

April 3, 2003 : Marcelin Papillon

Meeting with Marcelin Papillon, Manager of the Technical Service Division, Transport Canada, Marine Safety, Quebec Region, at the Champlain Harbour Station, 901 Cap Diamant St., Quebec City, Qc, G1K 4K1 (418-648-4166) on April 3, 2003.

- M. Papillon has already sailed on 60 000 tons DWT LNG ships between Spain and Algeria.
- Some years ago, a LNG project, including storage facilities in a natural cavern, was envisaged in Varennes on the South shore of the St Lawrence, south of Quebec. LNG transport ships with cargo capacity ranging between 60 000 and 125 000 m^3 could have docked there. However, the project, designated *Soligas*, was blocked following the public hearings held by the B.A.P.E (Bureau d'Audiences Publiques sur l'Environnement) because of environmental concerns associated with storage of gas in caverns.
- LNG transport ships must have on board a team of engineering experts, including a specialist in natural gas.
- If storage of LNG is required, cryogenic facilities have to be built close to the wharf.
- The basic code recognized in Canada for LNG transport vessels is the International Maritime Organization (IMO) "Code for the construction and equipment of ships carrying liquefied gas in bulk". We were also referred to the:
    - TP R-009, (Transport Publication R-009),
    - TP 743: Termpol Process Review 2001, and
    - Arctic Shipping Pollution Prevention Regulations, Chapter 353 of Arctic Waters Pollution Prevention Act (AWPPA) no 1.
- There are no LNG cargo ships with Canadian owners.
- M. Papillon is in charge of ship inspections. He directs a staff of 8-10 persons, including mechanical, electrical engineers and naval architects. They are responsible for making sure ships built in Quebec are constructed in accordance with regulations. His staff will issue an Inspection Certificate ("Certificat d'Inspection"), which allows the owner to purchase insurance. Since last year, Transport Canada can also delegate this inspection function to one of five (5) private Classification Societies, recognized by Transport Canada, including Bureau Véritas, American Bureau of Shipping, Lloyd's Register of Shipping, Det Norske Veritas...).
- According to the AWPPA, the ocean north of the 60th parallel is divided into zones for ice classification. Corresponding classes of the various Classification Societies are given in the AWPPA.
- For navigation on the St Lawrence, AWPPA and Transport Canada have no ice class requirement. However, Transport Canada recommends that the vessel should have a "minimal" ice class, for example Lloyd's ice class 3.
- If the boat was built in a foreign country, it must have all certificates required by the International Maritime Organization (IMO) to enter Canadian territorial waters, namely the *Certificate of Construction* and *Certificate of fitness for the carriage of liquefied gases in bulk...).*

- Any vessel must report its intention to enter Canadian waters at least 96 hours before reaching Cabot Strait.

April 10 and 16, 2003 : Richard Chagnon

Telephone conversation on April 10 and meeting in Ottawa on April 16, 2003, with Richard Chagnon, Archive Manager, Canadian Ice Service, Environment Canada, Ottawa (800-767-2885):

- Environment Canada has issued two editions of an Atlas of ice conditions, which includes conditions for Eastern Canada. The first Atlas was based on regional charts from 1959 to 1974, the latest one, in 2002, based on 1971 to 2000 charts. The atlas contains for each week of the ice season, a series of maps showing average conditions: frequency of the presence of ice, ice coverage in percentage, distribution of ice concentrations (i.e. % of 1/10, 2/10…concentrations), distribution ice types, and median ice thickness in the presence of ice.
- The Atlas gives "normal" conditions. Therefore, this is not the ideal product for this study, where we are interested in assessing extremes as well.
- Regional charts are drawn at a large scale, to include all of Atlantic Canada, including the Coast of Labrador. They are useful for studying conditions in the Gulf, but do not show much detail in the estuary.
- Regional charts are prepared once a week. In earlier years, the data was obtained mostly from the daily charts (same scale as the Regional). Daily charts are archived on microfilm.
- River ice charts are only available since 1980. Therefore, we have the complete records.
- Historical charts, drawn at a large scale than Regional charts, cover years 1959 to 1974. Regional charts cover years 1968 to present. Both can be downloaded from the web site free of charge.
- Currently, Regional charts are compiled from a variety of sources, including the detailed River ice charts and Gulf charts prepared by the Coast Guard, satellite imagery, etc.
- A computerized data base exists containing historical ice condition maps on a weekly basis. The outline of the ice zones on the maps are stored in vector form. Numerical parameters describing weekly historical ice characteristics can be extracted from these maps at any given location, defined by coordinates, or averaged over an area. A site specific data base of this kind, which would give weekly historical data, could be extracted for several key areas in the Gulf, or for a specific zone in the estuary. A numerical database could be ordered from Environment Canada in order to extract statistics other than mean conditions and extreme values. However, the limitations of the data, particularly the fact that observations are not available all the time (due to lack of visibility…) should be kept in mind.
- Seasonal weather and ice condition reports are prepared in May of each year by the Ice Service.

Several hours were spend looking through many years of the printed copy of Regional and Historical Charts for the East Coast. Although the maps extend up to Quebec City, the scale is such that ice conditions cannot be distinguished between specific terminal sites in the estuary. However, they do give a good description of large scale conditions in the Gulf.

Because it is limited to average conditions, the Atlas is not directly useful to predict frequencies or scenarios of adverse navigation conditions due to ice in the Gulf. However, this could be studied further using numerical databases which can be extracted quite readily from the computerized maps.

May 8, 2003 : Roger Provost

Telephone conversation on May 8, to set up meeting on May 26, to review the 2003 ice season and some images.

Discussed what had happened in 1984, the only year, according to CCG Annual Reports, where the channel was closed to winter navigation, for 4 days. From our study of the data, nothing was apparent from ice charts available, and 1984 was a normal year in terms of temperatures. Mr. Provost remembered well that somewhere around March 20-25, persistent winds blowing from the NE had stopped the ice… and the navigation, south of Île d'Orléans,

We later verified that winds has indeed remained from the NE quadrant for 10 consecutive days from March 13 to 23. From an analysis of the data at Quebec, only 4 similar sequences occurred in the last 50 years, but only once during the ice season.

May 8, 2003 : Thomas Brown

Telephone conversation on May 10 to discuss ice forces on the piers of the Northumberland Strait Crossing:

- Prof. Brown participated in the development of design ice forces with a remarkable group of Canadian experts in ice mechanics and structural engineering.
- A series of papers have been published, explaining the development of the design criteria, which was based on probabilistic analyses, taking into account the statistical distribution of all meaningful variables influencing the maximum ice loading. Ice load is controlled by the failure of an ice ridge. Since the piers have a conical apron at water level, the ridge fails by upward bending against the cone.
- Driving forces are not limiting at the site, so peak forces are produced by failing ridges. The Bridge seen 1000 km of ice in a typical year (we estimated 600 km for our sites ion the St. Lawrence). From statistics, the Bridge receives an estimated 5 000 impacts/year from ridges.
- Maximum annual force estimated in the design studies was 8 MN, 100-year force was 16 MN. The corresponding load factor used with the 100-year force is 1.83.
- Monitoring of ice force measurements in on-going. In 6-7 years of results, the average annual maximum force has been found to be 4 MN, so the design estimate is quite conservative.

- The reasons for this overestimation of force have not been clearly determined yet, but Brown believes that the consolidated core of the ridge (by re-freezing of pieces of broken ice) has a smaller strength than estimated from data from sound ice sheets, because it is not homogeneous.
- The largest impact recorded on the Crossing was is fact due to a huge "batture" floe (many km by many km) hitting at high velocity, an event that was monitored visually. The maximum force was 6 MN. The dimensions of the floe have not been worked out from the images but will be. Prof. Brown believes the average thickness was "1 m plus", and pieces up to 2 m thick are included.
- He believes we should consider a reduces strength for "batture" ice, perhaps 1 MPa instead of the usual 1.5 MPa specified by the codes for sound sheets of ice.

May 16, 2003 : Gary Timco

Telephone conversation on May 16, 2003, with Gary Timco, National Research Council of Canada (NRCC), Ottawa (613-993-6673):

- Gary Timco is one of the leading research engineers on the subject of ice forces against structures. I had contacted him to have suggestions of recent papers on the topic, and a general discussion for update.
- The NRCC has assembled an ice load database, from many well documented multi-year full scale experiments, from which data is gradually being analysed and results published. The data comes from bridge piers and lighthouses (freshwater ice), and for offshore platforms (sea ice). Timco has sent me two recent papers focused on slender members (up to 4 m in diameter). Data on larger structures are from very wide platforms in the arctic (typical 100m), where ice conditions are very extreme, compared to our case. The data for slender structures is therefore felt to be more applicable.
- There is not any data for the specific size of interest (approx. 30 m). A series of lighthouses of that size are being monitored in Sweden as part of a European Union Program. Results are still proprietary and will become available over time.
- If there is an interest and if it is possible to arrange for access to the property, NRCC would consider instrumenting a suitable structure, for example one of the dolphins at the Ultramar terminal, using load panels, as part of its long-term research program.
- The current NRCC approach is basically empirical. Because conditions at breakup vary greatly from year to year, and produce just about any value of load, there is a great deal of scatter in the data. Timco's approach is to look for the obvious trends. In essence, for the "slender" structures discussed in the paper, the shape (cylindrical, pointed, cylindrical…) does not seem to matter much, but there is a clear correlation between force and ice thickness. Computation of ice loads is far from being an exact science…
- For the basic ice sheet impact, the classic indentation formula used in the bridge code, is just as good as any. For the thicker batture floe, there is a lot more uncertainty, due to the statistical nature of an encounter, the variations in thickness, size, ice properties. Guidance from the experience of icebreakers (sources of batture floes, typical sizes, how much force to break or deviate,

nature of the failure mechanism, splitting…), and from load measurements on ice booms (see Brian Morse) should be sought.
- Dan Masterson, now with Sandwell might be able to trace the original load calculations for the Ultramar terminal, or to reach his former Fenco colleague Hans Kivisild.

May 20, 2003 : Dan Masterson

Telephone conversation on May 20, 2003, with Dan Masterson, Sandwell, Calgary (403-237-8035):

- Masterson was with Fenco at the time the Ultramar terminal was designed and built. Loads were developed by Hans Kivisild, who has recently passed away. I mentioned an article in Oilweek, November 15, 1971, which gave the earthquake loads but not the ice loads…
- In Gary's opinion, the sheet ice case would have the primary ice load scenario considered by Hans, "after considerable mathematical complications". It is unlikely that the batture floe would have been considered, because it was never discussed.
- Splitting of the floe is a plausible mechanism, which would produce much smaller loads than crushing. The non uniform nature of the batture floe would make it susceptible to fracture along planes of weakness.
- In the arctic research conducted in the 1980s, Canmar-Dome had a lot of expectations for reduced loads due to splitting in large floes. In the Arctic conditions, the concern was with large multi-year floes. The non-saline ice of multi-year floes is typically much more competent and confined (because of thickness and size of the floe) than the irregular ice from batture floes. Hence, loads from a crushing failure are very severe. Apparently, some crushing is always present, so the splitting mechanism may be considered as a means if reducing probabilities of extreme impact loads.
- Masterson commented on the Confederation bridge work: the actual measured loads are much smaller than anticipated, but, "the designers had no data". In our case, a correct assessment of the batture impact problem requires good statistics on sizes, some thickness measurements and some means of estimating the large-scale physical properties of batture ice.

May 20, 2003 : Yvon Morin

Telephone conversation with Yvon Morin, Manager, Harbour and Coastal Engineering, Public Works and Governmental Services Canada, Hull (819 856-4061)

- Yvon Morin is an experienced design engineer for port and harbour structures, now a manager of Engineering.
- Although much progress has been made on sea ice, we agreed that there have not been major changes in the methods for computing ice loads for designing marine structures in freshwater ice. 1984 state-of the art reports prepared for Public

works Canada and Transport Canada (DNV, 1984; Fenco, 1984) are still quite current.

- In the St. Lawrence estuary, ice conditions must be well understood to design a facility with good winter performance. However, ice loads are generally not a controlling factor for most marine structures. For the type of wide caissons under consideration, an impact by a large floe would be the critical ice condition, but its probability is low.

May 26, 2003 : Roger Provost

Meeting on May 26, to set up meeting on May 20, to review the 2003 ice season and some images.

- According to Roger Provost, who is writing the Coast Guard's 2003 review of de-icing operations, 2003 was a colder than average year for climate, but a normal year, for ice conditions in the estuary.
- The winds were favourable all winter, and this kept the ice moving well in the estuary despite the large quantities of ice produced in the river. There was quite a bit of congestion in the Gulf of St. Lawrence, particularly at Cabot Strait, which is an unusual (normally congestion occurs at Anticosti). Some delays in shipping were experienced as a result of ice conditions in the Gulf.
- An additional favourable factor for 2003 was the relatively small amount of snow and snow storms. Snow causes the water to cool rapidly, therefore increasing the volume of ice produced. In addition, snow sticks to the hull, modifying its hydrodynamic properties, causing the ship loose speed. 2003 would have been difficult for navigation between Montreal and Quebec had it not been for the small amount of snow. In 1993, there was a lot of snow, which contributed to miserable ice conditions.
- Discussing large floes or *battures*, which, in the area, can reach a typical maximum of 1 to 3 kilometers, we distinguish two types:
    - floes of uniform fast ice (or sheet ice floes) are strong and competent (except in warm spring temperatures), and their thickness is that measured by the surveys, typically 60 to 80 cm: a typical example is the *batture* at Donnacona which comes loose at the end of February, during high tides and westerly winds;
    - floes formed from agglomerated brash and broken ice are very difficult to penetrate when under pressure because of their considerable thickness, reaching 4-5 metres; however, as soon as the pressure is releases, for example in a widening of the river when a bottleneck is passed, then they tend to break-up easily, because they contain a lot of voids and are poorly consolidated, with zones with pieces poorly frozen together.
- The Quebec bridges are the narrow point in the river and are susceptible to jamming. An ice jam can not only obstruct navigation, but also hold back water and cause flooding upstream (prior to 1980, jams could affect the water level up to Montreal). Therefore, the area is monitored carefully, with two patrols a day during the heavy ice season.
- For ice, all the sites under study are feasible: ice is in small pieces at the "South" sites of Ultramar, Pointe-de-la-Martinière and Pointe-Saint-Vallier and generally

flows well. There is only one occurrence of blocked navigation in 1984, therefore delays due to ice are improbable. Delays have occurred at Les Escoumins, where the pilot change takes place, during Northeasterly winds. There are also occasional delays in the Gulf.

- Satellite imagery for the month of February 2003 was reviewed. The higher concentration of ice near the south shore is clearly noticeable. But there is little else to comment except for the Strait of Cabot which was more interesting.
- Because of the lower water levels in the river system, tides are felt further upstream that usual, so has the potential of making things more difficult at the Trois-Rivières bridge. Despite this, there were not any particular problems in 2003 at Lac Saint-Pierre, which is normally the most difficult location.
- The 2003 Review of Operations Report will be available in the Fall.