Westmar

Consulting Engineers

Westmar Consultants Inc.

400 - 233 West 1st St.
North Vancouver, BC
Canada V7M 1B3

tel 604.985.6488 fax 604.985.2581

www.westmar.com

VIA E-MAIL

October 4, 2001

Teck Cominco Ltd.
PO Box 2000
Kimberley, BC
V1A 3E1

Project No.: 00282

Attention: Bruce Donald

Reference: Decommissioning of Dock Facilities at Polaris Mine
Little Cornwallis Island, Nunavut

Dear Sirs:

We are pleased to provide five bound copies of Revision 2 of our report on the above referenced work, in addition to a digital copy posted on our website.

If we can be of any further assistance or if you have any questions, do not hesitate to contact he undersigned.

Yours truly,

WESTMAR CONSULTANTS INC.

[Original Signed by Norman Allyn]

Norman Allyn, P.Eng.
Manager
Coastal Engineering

NFA/tmw
Encl.

011004NWB1POL Report for Decommissioning of Dock
- ILAE Part 1

TECK COMINCO LTD.

Report for:

Decommissioning of Dock Facilities at Polaris Mine
Little Cornwallis Island, Nunavut

REVISION 1

00282
October 2001

Westmar

TECK COMINCO LTD.

Report for:

Decommissioning of Dock Facilities at Polaris Mine
Little Cornwallis Island, Nunavut

REVISION 1

00282
October 2001

Westmar

TABLE OF CONTENTS

Executive Summary

Figure 1 in *Appendix A* shows the location of the Polaris Mine at the southwest end of Little Cornwallis Island in the Canadian High Arctic. The mine produces lead and zinc concentrates that are shipped out during a short shipping season when bulk carriers can safely navigate the ice infested waters.

The mine is nearing the end of its life, and is to be decommissioned and returned, as close as possible, to a natural condition. Westmar was retained by Teck Cominco Ltd. to examine concepts for decommissioning the dock and adjacent shoreline. Norman Allyn, P.Eng., Manager Coastal Engineering at Westmar, visited the site in August 2000. In September 2000, he met with the contractor that constructed the dock in 1980 and 1981.

The form and method of construction provided a cost-effective installation that was completed in a relatively short time frame, given the harsh environmental conditions. The facility included a sheet pile cell dock built from the ice in the winter, and a barge containing all of the process equipment that was set on a prepared base and incorporated into the shoreline.

This report reviews various options to decommission the dock facilities at the Polaris Mine operations. The report examines the main issues associated with each of three options considered, and recommends one of the options as the preferred method of decommissioning the dock facilities.

Prior to decommissioning, the following detailed design work will be required:

- Prepare accurate hydrographic surveys of the surrounding site.
- Incorporate the remedial excavation proposed in "Polaris Mine Decommissioning and Reclamation Plan" by Gartner Lee Ltd.
- Finalize the excavation plane through the dock to minimize the cut and fill volumes, within the ranges discussed in this report and based on remedial excavation requirements, while protecting the aquatic environment by minimizing erosion and sedimentation.
- Develop detailed procedures for the excavation process of the dock area to ensure protection of the aquatic environment during the process.

- Determine the gradations of the natural beach and fill materials to evaluate their rates of erosion.

- Assess the need to perform a thermodynamic analysis on the natural beach and fill materials, to determine the suitability of the proposed beach material to resist erosion based on the beneficial effect of permafrost.

The following three options were considered for decommissioning the dock facilities:

Option 1: Extract or cut-off the sheet piles under water and reinstate a beach profile that will minimize erosion.

Option 2: Encase the dock in rock.

Option 3: Leave the dock in place (do nothing).

Option 1 is the preferred option for the following reasons:

- It has minimal impact on the aquatic environment, as there is no work on the seabed.

- The flat slope will have minimal sedimentation rate due to the flat slope angle and the action of permafrost, both of which result in reduced erosion.

- It re-establishes a smooth shoreline similar to the original shoreline, and removes the dock as a projection of the beach into Crozier Strait.

The option will comprise the following activities:

- Excavate a trench on the back or east side of the dock, and cut-off the sheet piles at an elevation of about 1 m below lowest normal tide.

- Inspect for, and recover any refrigerant in the freezing pipes in the dock. Remove the freezing pipes.

- Spill contingency plans must be in place in case there is a spill of the refrigerant while recovering it to prevent potential contamination from reaching the ocean.

- Inspect soils for any evidence of refrigerant and excavate any contaminated soils.

- Remove the frozen fill in the interior of the cells by drilling, blasting and/or excavating. The deepest practical depth is about 3 m below lowest normal tide. When working near the water, the contractor shall use methods that prevent excavated fill from falling into the water, and the contractor shall dispose of all excavated material on land.

- Either remove the sheet piles completely or alternatively cut them off 2 to 3 m below the lowest normal tide at the front or west face of the dock. Taper up at the sides to achieve a sloping seabed of about 17.5H:1V which approximates the original beach slope below the high waterline.

- Remove the rock fill adjacent to the sheet piles.

- Re-grade the adjacent shoreline, and the fill on the land side of the dock to achieve the design beach slope.

- About 100,000 m^3 of fill will be removed from inside the cells and in the vicinity of the dock to achieve a smooth shoreline. The near surface material that is contaminated with concentrate dusts will be removed and disposed of in the mine (refer to Polaris Mine Decommissioning and Reclamation Plan). Underlying clean materials that are excavated will be utilized as fill at other areas of the site.

- The steel beams remaining from the original temporary dock located near Section Line 800N, as shown in *Drawing No. 00282-00-101* in *Appendix D*, will be removed or cut-off at ground level (see *Photograph Nos. 21 and 22* in *Appendix B*).

To achieve a cost-effective solution, contractors should be allowed to propose alternative methods of performing the work so that the best use is made of available equipment. However, no proposal will be considered that does not meet the requirements of Teck Cominco or fails to provide adequate protection to the aquatic environment.

Glossary

- D_{50}: The cubic dimension of the mean size rock by weight, such that 50% of the total weight of rock is comprised of pieces of rock smaller than the D_{50} size of rock.
- Fetch: The length of open water over which wind from a specific direction can generate waves.
- Peak Wave Period, T_P: The wave period of the most energetic waves in a wave train.
- Return Period: The average time period between events of a given or greater intensity.
- Significant Wave Height, H_S: The average height of the highest 33% of the waves in a wave train.
- Wave Height: The distance from trough to peak of a wave, measured vertically.
- Wave Period: The time for two successive wave crests to pass a given point.
- W_{50}: The weight of the mean size rock, such that 50% of the total weight of the rock is comprised of pieces of rock weighing less than the W_{50} weight of rock.

1 Introduction

1.1 General

Polaris Mine in the Canadian High Arctic is located at the southwest end of Little Cornwallis Island, as shown in *Figure 1* in *Appendix A*.

The lead and zinc ore is mined underground in permafrost, crushed and then transported by conveyor to the process barge, where it is processed into lead and zinc dry concentrates.

The concentrate is shipped to market during a short shipping season when bulk ore carriers can navigate to the deep sea dock through the ice infested waters. The MV Arctic, which is capable of breaking about 1.2 m thick sheet ice, is the first vessel in, and the last vessel out.

The mine is nearing the end of its life, and is to be decommissioned by returning it as close as possible to a natural condition. Westmar was retained by Teck Cominco Ltd. to examine the decommissioning of the dock and adjacent shoreline. Norman Allyn, P.Eng., Manager Coastal Engineering at Westmar, has extensive arctic marine experience, and is the project manager for this work. Mr. Allyn travelled to the site in August 2000, and met with the dock construction contractor in Montreal in September 2000.

This report addresses options for decommissioning the dock.

1.2 Description of Dock and Shoreline

The mine was constructed over a two year period in 1980 and 1981. The construction incorporated techniques that provided a fast and cost-effective installation. These included a sheet pile cell dock built from the ice in the winter, and a barge containing all of the process equipment that was set on a prepared base and incorporated into the shoreline. The facilities are described as follows.

1.2.1 Sheet Pile Cell Dock

The berth for the export of the concentrate on bulk carriers was constructed using steel sheet pile cells. Four cells, each about 26 m in diameter, were constructed by driving sheet piles through the ice in the early winter of 1981. The four cells were tied together by three inter-connecting arcs on the front face. The cells were filled with rock and overburden excavated from the barge dry dock. The front face of the cells forms a berth approximately 90 m long with a depth of about 13 m at low water.

1.2.2 Process Barge

The 31 m wide by 122 m long process barge was built in Quebec and towed to the site. A base was prepared in the dry dock, and upon arrival of the barge in mid August 1981, the dry dock was flooded by removing the closure berm.

The barge was floated into place on a high tide, and was ballasted down onto the prepared base. The entrance to the dry dock was filled in to form the shoreline adjacent to the northernmost cell of the dock. The location of the process barge is shown in *Drawing No. 00282-01-101* in *Appendix D*.

1.3 Construction of Dock in 1981

The dock was built by Tower Arctic Ltd. A paper on the construction is attached in *Appendix E*.

Tower Arctic adopted the following construction procedure:

- The ice was first flooded and thickened to 3 m.
- A slot was cut in the ice using a double bladed chainsaw device called a "ditch witch".
- A curved steel pile driving guide was placed on the ice on the outside of the cells.
- The sheet piles were driven through about 3 m of silt to allow a minimal penetration into the underlying fractured limestone, using a vibro-hammer.
- Three small tie arcs, with a radius of 4.5 m, were installed along the front face, to connect the four cells as shown on *Drawing No. 00282-01-101* in *Appendix D*.
- The sheets were 24 m long, and were cut-off 4.6 m above water level, except for a section at the back, where they were cut-off lower to allow trucks to end dump fill into the cells.
- The ice in the interior of the cells was cut up and removed. Weak silts inside the cells were excavated from a portion of the seabed at the front of the cells, before filling.

- Fill was placed inside and along the back of the cells, using native gravel material excavated from the process barge dry dock. Mine rock was not used in the fill.

- Sheets of insulating styrofoam were placed between the fill and the sheet piles, on the front and sides of the dock where the sheets are exposed to the sun. The insulation was approximately 100 mm thick, 3 m long and 0.6 m wide.

- Work was completed in mid May 1981, when the ice started to deteriorate.

- The concrete cope beam and the bollards were installed in the summer.

- The intention was to install a refrigeration system to freeze the fill. However, using thermistors, it was determined that the natural progress of the freeze front was adequate and only part of the refrigeration system was installed. The freeze pipes are shown on *Bechtel Canada Limited Drawing No. 110-C-148, Rev. A*, "Dock Freezing Arrangement", which contains a hand-written note "All work on this drawing is cancelled, May12, 1981". The pipes shown have an outside diameter of 150 mm, are set in the fill to an elevation of about -10 m Plant Datum (PD), and are sealed with a blind flange 150 mm below the top surface of the fill. It is known that a number of the freeze pipes were installed and that the refrigeration plant operated for a brief period of time.

The shoreline on either side of the dock consists of fill and riprap rock slope protection, which is "faired in" to the original shoreline to the north of the dock between Stations 1700N and 1800N and south of the dock at approximately Station 800N as shown in *Drawing No. 00282-01-101* in *Appendix D*.

Cross-sections of the shoreline in the vicinity of the dock are shown in *Drawing Nos. 00282-01-102 to 00282-00-107* in *Appendix D*.

2 Design Criteria

The design criteria for ice coverage, wind and waves are developed in the following subsections. Supplementary information on datums, tide elevations and currents is provided in *Appendix C*.

2.1 Ice Coverage

Ice coverage is important in determining the open water to the south of Polaris, in McDougall Sound and Barrow Strait, for calculating waves that can be generated in this area under the action of winds from the south.

Information on ice coverage was obtained from the following references:

- Annual Arctic Ice Atlas, Canadian Ice Service, Environmental Canada, 2000.
- Ice Thickness Climatology, 1961 - 1990 Normals, Ice Centre, Ice Climatology Services, Ottawa, Ontario, 1992.
- Canadian Sea Ice Atlas from Microwave Remotely Sensed Imagery: July 1987 to June 1990, E. LeDrew, D. Barber, T. Agnew and D. Dunlop, 1992.
- Ice Atlas, Canadian Arctic Waterways, W.E Markham, 1981.
- Supplement to Ice Atlas, Canadian Arctic Waterways, W.E. Markham, 1984.

From these references, the following is noted:

- The average ice thickness at the end of the ice growth period in May/June is about 2.0 m.
- The average date on which melting degree days start to accumulate is about mid June.
- The average date on which break up of the ice occurs is mid August. *Figure 2* in *Appendix A* from the Ice Atlas, Canadian Arctic Waterways shows that by August 20th, the ice cover at Polaris has reduced to 8/10 or 80% ice coverage of the sea surface in a median year.

- The break up date is variable, and full open water does not occur in the average year. *Figures 3 and 4* in *Appendix A* from the Ice Atlas, Canadian Arctic Waterways, show that in the ice season with maximum ice, coverage is still 7/10 or 70% ice coverage of the sea surface at the end of August, and 10/10 or full ice coverage of the sea surface as early as September 10th.

- The average date of the beginning of the accumulation of freezing degree days is September 1st.

- The average date of the start of freeze up is mid September. *Figures 5 and 6* in *Appendix A* from the Ice Atlas, Canadian Arctic Waterways show that on September 17th, the cover is 2/10 or 20% ice coverage of the sea surface at Polaris in an average ice season, but increases to 9/10 or 90% ice coverage of the sea surface by September 24th.

- The freeze up date is variable, and can occur as late as early October. *Figure 7* in *Appendix A* from the Ice Atlas, Canadian Arctic Waterways shows open water at Polaris on October 8th.

The Ice Atlas by Markham is for 15 years of data, and indicates that in most years, the open water season is less than one month. From observations, the area does not completely clear of ice, with ice remaining in bays and along the coastline. It is considered that about once in 15 years the ice will clear to the extent that significant fetches for the generation of waves will occur, similar to the open water shown in *Figure 8* in *Appendix A*.

2.2 Wind

Wind data for Resolute was obtained from the Meteorological Service of Canada, Environment Canada, Toronto, Ontario. The wind data provided the monthly maximum wind speeds for the period of 1953 to 2000, of which there were 38 years of good data.

A Gumbel analysis of the data was performed to determine the extreme wind speed in the month of September, when open water could occur.

The design return period of 200 years was selected in consultation with Mr. Bruce Donald, P.Eng. of Teck Cominco Ltd. For a 1 in 15 year probability of achieving open water, the corresponding return period for wind is 13 years, to achieve a combined return period of 200 years.

For a return period of 13 years, the September wind speed is calculated as 23 m/s. This compares with the wind data provided in the National Building Code of Canada (NBCC) for Resolute, which gives the 1 in 10 year wind speed for all months as 28 m/s. The reason that the 13 year return period wind speed for September is lower than the 10 year return period wind speed is as follows:

- The 13 year return period wind speed is for the month of September only, and so is for a return period of 13 months at the time of year represented by the September wind data.

- The 10 year return period wind speed is for all twelve months of the year, and so is for a return period of 120 months.

The 1 in 200 year return period design hourly average wind speed, predicted for September is about 30 m/s. This compares with the wind data provided in the NBCC for Resolute, which gives the 1 in 100 year wind speed for all months as 34 m/s. The comparisons with the NBCC indicate that the predicted wind speeds for September are of an appropriate magnitude.

2.3 Waves

Wind-generated wave heights and periods are a function of wind speed, wind duration and fetch.

Fetch, represented by open water, is determined by ice coverage. It is assumed that the wind speed is independent of ice coverage, and so a joint probability study of wind speeds and ice coverage was carried out to predict the 200 year return period wave height. The combination of return periods on open water wind speed considered are shown in *Table 1* below:

TABLE 1: Combined Wind and Fetch for Design Return Period Event of 200 Years

Design Return Period for Waves	Return Period for Ice Coverage	Fetch	Return Period for Maximum Wind Speed	Maximum Hourly Average Wind Speed
200 years	15 years	100 km	13 years	23 m/s

Deep water design waves were predicted using the wave hindcasting technique in the US Army Corp of Engineers "Shore Protection Manual" (1984). The predicted design wave that will occur once in 200 years, including the effects of ice cover, shoaling and refraction is as follows:

- H_s: 3 m
- T_p: 9 sec

Where H_s is significant wave height and T_p is the peak wave period.

2.4 Rock Quality

Testing of three potential riprap materials, namely Limestone and Dolomite rock from the Little Red Dog Quarry (LRDQ), and Mine Rock, was performed by Levelton Engineering Ltd. and detailed results are attached in *Appendix F*. The results are summarized in *Table 2* below, and indicate that only the Limestone rock from the Little Red Dog Quarry is suitable for use as riprap for slope protection for the following reasons:

- The Limestone rock meets the specified results for all seven tests.
- The Dolomite rock does not meet the specified Freeze-Thaw result.
- The Mine rock does not meet the specified results for LA Abrasion, Magnesium Sulphate Soundness, Petrographic Examination or Freeze-Thaw.

TABLE 2: Rock Quality Test Results

Limestone	Requirement	Sample		
		Limestone	**Dolomite**	**Mine Rock**
LA Abrasion, 500 revolutions (ATM C535)	Not more than 30% loss.	17.1%	17.3%	44.8%
Durability Index (ASTM D3744)	No index less than 35.	92	82	71
Bulk Specific Gravity (saturated surface dry, ASTM C127)	Not less than 2.65.	2.74	2.63	3.76
Absorption (ASTM C127)	Not more than 2%.	0.985%	1.56%	1.72%
Petrographic Examination	Absence of weakness or materials that could result in significant stone alteration and reduction in durability.	Excellent	Good	Poor
Freeze-Thaw (CIRIA Special Publication 83, A2.4)	Not more than 0.5% weight loss.	0.03%	5.2%	0.7%

2.5 Slope Protection and Natural Beach Materials

2.5.1 Riprap Rock Size

The size of riprap rock was calculated using the Hudson Formula in the US Army Corps of Engineers "Shore Protection Manual", 1984. For the 200 year return period design wave (H_s = 3 m), nominal rock sizes required for protection of the shore at varying slopes are listed in *Table 3* below:

TABLE 3: Riprap Rock Size for 1 in 200 Year Design Event for Varying Slope

Slope	Nominal Rock Size D_{50} (mm)	Rock Mass W_{50} (kg)
2H:1V	1,200	4,580
3H:1V	1,000	2,650
4H:1V	920	2,070
5H:1V	850	1,630

Note: 1. D_{50} is the cubic dimension of the mean size of rock, by weight.
2. W_{50} is the weight of the mean size of rock.

A mean rock size of 300 mm has been produced from LRDQ and used for slope protection, as can be seen in *Photograph Nos. 11 and 14*. It is possible to increase the size of rock produced from LRDQ by the following means:

- Increase the drill spacing and adjust the blast pattern and the amount and type of explosives in the drill holes.

- Use a grizzly to separate out the fraction of smaller rock.

LRDQ is generally highly fractured, as can be seen in *Photograph No. 1* in *Appendix B*. The joint spacing in the quarry will limit the mean size to the range of 400 mm to 500 mm. This size of rock was achieved just south of the dock at Station 1300 N, as shown in *Photograph No. 13*.

It is apparent that the mean size of rock required, even for a slope as flat as 5H:1V, cannot be produced in any quantity on Little Cornwallis Island.

2.5.2 Effect of Permafrost on Stability of Riprap and Natural Beaches

The surface of the permafrost at the beach is subjected to freeze/thaw cycles as follows:

- During the winter months, the beaches will become completely frozen.
- During the short open water season, the surface layer of the permafrost will thaw, but this will be less in the tidal zone than in the interior of the island due to the cooling effect of the sea water, which is near the freezing point of sea water.

The freeze/thaw cycles will have a different effect on the larger riprap material than on a natural beach comprised of sands and gravels, as follows:

- The riprap rock has large voids that will thaw at break-up, as observed with the riprap at the site during the site visit by Mr. Norman Allyn on August 17 to19, 2000.
- The natural beach consists of a wide gradation of sand and gravel material. The voids between the larger fraction of gravel are filled with the finer fraction of the sands and gravels, and so will not thaw to as great an extent as a riprap slope.

The limited thawing of the natural beach material is the reason why the slopes made from the finer naturally occurring sands and gravels resist erosion and are stable under wave attack, even when set at a steep angle. Examples of this can be seen in *Photograph Nos. 23 and 24* in *Appendix B.*

The presence of permafrost allows naturally occurring sands and gravels to resist erosion much better than beaches in southern climates. This effect, combined with the short open water season, is likely the main reason that islands in the arctic have stable sand and gravel beaches that resist erosion under seemingly hostile environmental conditions.

3 Concepts for Decommissioning Shoreline and Dock

The dock will remain in service during the decommissioning of the mine to load vessels with material leaving the site. It will be one of the last structures to be decommissioned.

Several concepts were addressed and the following three options were reviewed in detail.

3.1 Option 1 - Remove Dock to 2 to 3 m Below Low Tide Leaving a Beach With a Low Slope

3.1.1 Overview

This option involves excavating the dock fill material from inside the cells and then removing/cutting off the sheet piles. The cross-section of Option 1 is shown in *Drawing No. 00282-01-104* in *Appendix D.* The remnants of the dock would be underwater where it will not present a hazard to small local vessel traffic.

The following work would be performed to complete Option 1:

- Excavate a trench on the east or back side of the dock, and cut-off the sheet piles at an elevation of about 1 m below lowest normal tide.
- Inspect for, and recover any refrigerant in the freezing pipes in the dock. Remove the freezing pipes.
- Inspect for and excavate any soils contaminated by refrigerant. This work will be done "in the dry".
- Spill contingency plans must be in place in case there is a spill of the refrigerant while recovering it to prevent potential contamination from reaching the ocean.
- Remove the frozen fill in the interior of the cells by drilling, blasting and/or excavating. The deepest practical depth is about 3 m below lowest normal tide. When working near the water, the contractor shall use methods that prevent excavated fill from falling into the water, and the contractor shall dispose of all excavated material on land.

- Either remove the sheet piles completely or alternatively cut them off 2 to 3 m below the lowest normal tide at the front or west face of the dock. Taper up at the sides to achieve a sloping seabed of about 17.5H:1V, which approximates the original beach slope below the high water line.

- Remove the soil adjacent to the sheet piles.

- Re-grade the adjacent shoreline, and the fill on the land side of the dock to achieve the design beach slope.

- About 100,000 m^3 of fill will be removed from inside the cells and in the vicinity of the dock to achieve a smooth shoreline. The near surface material that is contaminated with concentrate dusts will be removed and disposed of in the mine (refer to Polaris Mine Decommissioning and Reclamation Plan). Underlying clean materials that are excavated will be utilized as fill at other areas of the site.

- The steel beams remaining from the original temporary dock located near Section Line 800 N, as shown in *Drawing No. 00282-01-101* in *Appendix D*, will be removed or cut-off at ground level (see *Photograph Nos. 21 and 22* in *Appendix B*).

To achieve a cost-effective solution, contractors should be allowed to propose alternative methods of performing the work so that the best use is made of available equipment. However, no proposal will be considered that does not meet the requirements of Teck Cominco or fails to provide adequate protection to the aquatic environment.

Blasting techniques used to loosen fill material for excavation, or used to cut sheet piles, are to comply with the Department of Fisheries and Oceans (DFO) guidelines on blasting entitled “Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters”, current edition. A preliminary general blasting design is provided by Pacific Blasting in *Appendix H*, which demonstrates that blasting of frozen fill for excavation of fill from inside the sheet pile walls can be designed to meet the DFO guidelines. If blasting is to be used by the contractor to excavate material on the slope near the water to the north or south of the dock, similar calculations to those provided in *Appendix H* are to be performed to design blasts that meet DFO requirements. A detailed final blasting design will be submitted by the selected contractor for DFO approval.

3.1.2 Effect on the Shoreline

The condition of the shoreline was documented at 100 m intervals during the site visit by Mr. Allyn in August 2000. Photographs in *Appendix B* provide a visual condition record, and the cross-sections on the drawings in *Appendix D* show the existing and proposed shorelines. *Table 4* below summarizes the information provided in *Appendices B and D*.

TABLE 4: Details of Option 1 at 100 m Intervals Along the Shoreline

Station	Existing Shoreline and Dock	Shoreline After Decommissioning
1800 N	Natural beach gravel with a mean grain size of about 10 mm.	The natural beach will remain unchanged.
1700 N	The north end of the fill, with some pieces of rock up to 300 mm cubic size.	The bank will be trimmed landward from the mean water mark along a slope of about 17.5H:1V to high water, and then faired into the existing ground line over a total distance of about 20 m. Erosion and sedimentation is controlled by the flat slope and permafrost.
1600 N	Near the north end of the fill. The fill is not covered by riprap at this location, and has some pieces of rock up to 300 mm cubic size.	The bank will be trimmed landward from the mean water mark along a slope of about 17.5H:1V to high water, and then faired into the existing ground line over a total distance of about 25 m. Erosion and sedimentation is controlled by the flat slope and permafrost.
1500 N	The bank to the north of this location is not covered with riprap, while the bank between this location and the dock is covered with riprap with a mean size of about 300 mm cubic dimension.	The bank will be trimmed landward from the mean water mark along a slope of about 17.5H:1V to high water, and then faired into the existing ground line over a total distance of about 55 m. Erosion and sedimentation is controlled by the flat slope and permafrost.
1400 N	This section passes through the sheet pile cell dock and the Process Barge.	A plane sloping upward at 17.5H:1V from about 2 m below low water at the front of the dock, intersects the surface of the fill about 50 m west of the Process Barge. Erosion and sedimentation is controlled by the flat slope and permafrost.
1300 N	The bank at this location is covered with what is likely the largest possible size of riprap from Little Red Dog Quarry and observed on the shoreline, with a mean size of 400 mm to 500 mm.	The bank will be trimmed landward from the mean water mark along a slope of about 17.5H:1V, and faired to the existing ground line over a total distance of about 75 m. Erosion and sedimentation is controlled by the flat slope and permafrost.

Station	Existing Shoreline and Dock	Shoreline After Decommissioning
1200 N	The bank between this location and the dock has been armoured with riprap in the last two years, while the shoreline south of this location has not and the gravel fill is generally unprotected from wave attack and is eroding.	The bank will be trimmed landward from the mean water mark along a slope of about 17.5H:1V to the existing ground line over a distance of about 60 m. Erosion and sedimentation is controlled by the flat slope and permafrost.
1100 N	The bank is exposed to wave action as much of the riprap has slipped down the bank.	The bank will be trimmed landward from the mean water mark along a slope of about 17.5H:1V to the existing ground line over a distance of about 50 m. Erosion and sedimentation is controlled by the flat slope and permafrost.
1000 N	Similar to Station 1100 N, the bank is exposed to wave action as much of the riprap has slipped down the bank.	The bank will be trimmed landward from the mean water mark along a slope of about 17.5H:1V to high water, and then faired into the existing ground line over a total distance of about 30 m. Erosion and sedimentation is controlled by the flat slope and permafrost.
900 N	This location is at the north end of the Temporary Dock, which was installed in 1980/81 to offload equipment at the site before the sheet pile cell dock was operational.	The bank will be trimmed landward from the mean water mark along a slope of about 17.5H:1V to high water, and then faired into the existing ground line over a total distance of about 30 m. Erosion and sedimentation is controlled by the flat slope and permafrost.
800 N	This location is at the south end of the temporary dock. There is riprap immediately to the north of this location, and natural beach to the south of this location.	This section will have some trimming over a total distance of about 30 m to fair in the shoreline. Erosion and sedimentation is controlled by the flat slope and permafrost.
700 N	Natural beach gravel with a mean grain size of about 10 mm, similar to Station 1800 N.	There is no excavation required at this location.

Note:
1. A detailed topographic survey is required to finalize the cross-sections and volumes for detailed design, tendering and construction.
2. Two additional sections are provided in the drawings in *Appendix D* in the vicinity of the dock, at Stations 1350 N and 1450 N.

The fill material inside the sheet pile cells is frozen, based on thermistor data provided in *Appendix I*. The fill was getting colder with time; for example, at a 10 m depth below the surface at the centre of the south cell, the following trend is extracted from the thermistor data in *Appendix I*:

- In January 1985 the temperature was about -2 degrees C.
- In November 1987 the temperature was about -4 degrees C.
- In August 1990 the temperature was about -6 degrees C.

At the side of the cells adjacent to the sea, the temperatures are just below -2 degrees C, based on the August 1990 thermistor data in *Appendix I*.

Once the fill is excavated to below sea level, the fill will gradually warm up to about -2 degrees C, the approximate temperature of the sea water. Over an extended period of time, the remaining fill will be eroded by ice, wave and current action, as follows:

- The sheet piles may be extracted or cut-off below low water.

- Cutting off the sheet piles below low water involves using mechanical means or shape charges to cut the steel sheets. Shape charges will require the use of a bubble curtain to meet DFO guidelines. The sheets would be cut-off about 2 to 3 m below low water along the front face of the cells, and at about 1 m below low water along the back side of the cells. The frozen fill will be excavated along a plane sloping up at about 17.5H:1V from the front face of the cells, and will be exposed to the sea along the excavation plane.

- Extracting the sheet piles will involve pulling the sheets out, possibly using the vibro hammer used during installation of the dock. The contractor will have to take into account possible tension in the steel in their method of pile extraction, as well as possible adhesion of frozen fill to the pile and the possibility that the piles were damaged during installation or operation. If the sheet piles are extracted along the front face of the cells, the fill will still be excavated to an elevation and slope as described above; however, in this case the fill will be directly exposed to sea water along the excavation plane as well as around the face where the sheet piles are extracted.

Regardless of whether the sheet piles are cut-off or are extracted, the frozen fill will erode very slowly, and is not expected to have an impact on seabed habitat.

The benefits of Option 1 are as follows:

- There is minimal impact on the aquatic environment, as there is no work on the seabed.
- The recontoured beach will be erosion resistant through the combination of a flat slope and the action of permafrost on the foreshore area of the beach, both of which result in reduced erosion.
- A smooth shoreline is re-established, similar to the original shoreline.
- The steel sheet pile cell dock is removed as a projection of the beach into Crozier Strait.

The disadvantages of Option 1 are as follows:

- Precautions to minimize sedimentation during the decommissioning is required.
- Work methods require removal of the freeze pipes to be completed prior to the area being flooded to eliminate the potential release of contaminants into the ocean.
- The dock structure left in place some distance below the waterline will eventually erode over an extended period of time, but due to the gradual nature of the process, will not degrade the aquatic environment.
- The forces of nature will re-shape and erode the beach, but this is anticipated to take place over a sufficiently long period of time to not cause sedimentation that would degrade the aquatic environment. The rate of erosion should not be significantly different from the original beach.

3.2 Option 2 - Encase the Dock in Rock

The option encases the dock in rock and extends the existing shoreline 95 m to the southwest, as shown in *Figure 9* in *Appendix A*.

This option presents the following issues:

- An area of about 50,000 sq. m of the seabed will be covered by rock, which has a significant impact on the existing aquatic environment.
- In the order of 450,000 cu. m of rock would be required.
- The size of rock required to withstand ice action and waves in the 1 in 200 year return period design storm is larger than the size of rock available in Little Red Dog Quarry. Larger rock is available from the mine, but it is of poor quality and will not stand up to the freeze/thaw cycles, as discussed in *Section 2.6*. Importing rock would be prohibitively expensive, and is not considered practical. This option would only be erosion resistant if 850 mm, durable rock were used for the slope of 5H:1V in the wave zone.

The benefits of Option 2 are as follows:

- The dock could be uncovered at some future date and reused.
- Deterioration of the dock by ice and wave action is prevented.

3.3 Option 3 - Leave the Dock in Place

The dock and some land based facilities could be donated to the Government of Canada or Nunavut, as a northern base for the icebreaker fleet or for research activities. At this time, the Government has not responded to this offer. However, the Government is in the process of divesting marine facilities, and probably would not accept responsibility to maintain the facility for the long term.

Wave action is focussed on the slope of the fill adjacent to the ends of the dock. This is due to waves reflecting off the vertical face of the cells, and combining with the waves impinging directly on the slope from deep water. As a result, the riprap on the slope at these locations would require continued maintenance to prevent loss of land behind and adjacent to the dock, and this is confirmed by the historical requirement to frequently re-armour these slopes.

Left without maintenance, the land surrounding the dock would gradually erode, and in combination with corrosion of the steel, would eventually result in the failure of the dock structure.

The benefits of Option 3 are as follows:

- This method is the low cost solution to decommissioning the dock.
- The dock would remain available for use by others in the short term.

The disadvantages of Option 3 are as follows:

- The dock would require maintenance or would degrade over time.
- The land adjacent to the dock would require maintenance or would be eroded by wave action over time.

Without a commitment of long term care and maintenance of the dock, this is not a viable option.

4 The Impact on the Aquatic Environment

The three options that were considered have the following impacts on the aquatic environment:

Option 1: Remove Dock 2 to 3 m Below Low Tide and Regrade Beach to a Low Slope:

- The construction of Option 1 will have very little impact on the aquatic environment, as it should be possible to perform the work without spilling any significant volumes of fill onto the seabed.
- Removal of the dock eliminates concerns of long term deterioration of the dock.
- Decommissioning the dock will be sequenced so the majority of the work is done on dry land.
- Removal of refrigerants will be done to protect the environment. If there is any evidence of refrigerants contaminating the soils, they will be excavated and disposed of in an approved manner.
- Gradual erosion of the shoreline is a natural occurrence. Developing a shoreline with a beach that provides a smooth shoreline and a slope similar to the surrounding natural features will ensure that erosion rates will proceed at a rate similar to the naturally occurring beaches.

Option 2: Encase the Dock in Rock:

- The additional rock will cover a large area of the seabed and will have a significant impact on the aquatic environment.
- A large volume of rock is required for this option.
- As the riprap on the island does not meet the design requirements of size or durability for long term life expectancy, this option will ultimately result in the dock being exposed to the effects of the ocean unless rock is brought in from off the island, which would be prohibitively expensive.

Option 3: Leave the Dock in Place:

- In the short term Option 3 will have very little impact on the seabed and the aquatic environment.
- In the long term, without maintenance, the land around the dock will deteriorate and fall onto the seabed. It is anticipated that this will occur slowly and will not have a significant effect on the aquatic environment.
- Finally, without maintenance the steel cells will corrode and lose support from the surrounding fill and gradually collapse. It is anticipated that this will occur slowly and will not have a significant effect on the aquatic environment.
- The dock facility would not remain functional in the long term without ongoing maintenance.

5 The Effect of Global Warming

Global warming will cause longer periods of open water and higher water levels resulting from the melting of glacial ice. The increase in the period of open water may result in increased wave action at the site, depending on the strength, duration and direction of the winds.

The specific effects of global warming on the options considered are as follows:

- Larger rock sizes are required for any riprap options in order to maintain stability under the action of higher waves. This will further detract from options that utilize riprap as there are no quarries on the Island that could produce the required quantity of suitable rock.

- The increased water level will affect the height of the beach on the island. However, the beach has changed over time due to the rebound of the land from the last ice age, and it is not anticipated that it will have any effect on the present beach process.

From these considerations, it is not expected that global warming will have any significant impact on the preferred option presented herein, or on the conclusions of this report.

6 Recommendations

In developing the options, consideration was given to the prevailing ice, wind, waves, tides and currents, water elevations, and the availability of rock of sufficient quality and size. It is recommended that Option 1 for detailed design for decommissioning the dock, for the following reasons:

- Provides minimal impact on the aquatic environment.
- Removes all above water improvements, and provides adequate water depth for any small craft operating in the area.
- Restores the beach to a more natural slope at the waterline.
- Provides a smooth shoreline parallel to the original shoreline.

APPENDIX A

Figures

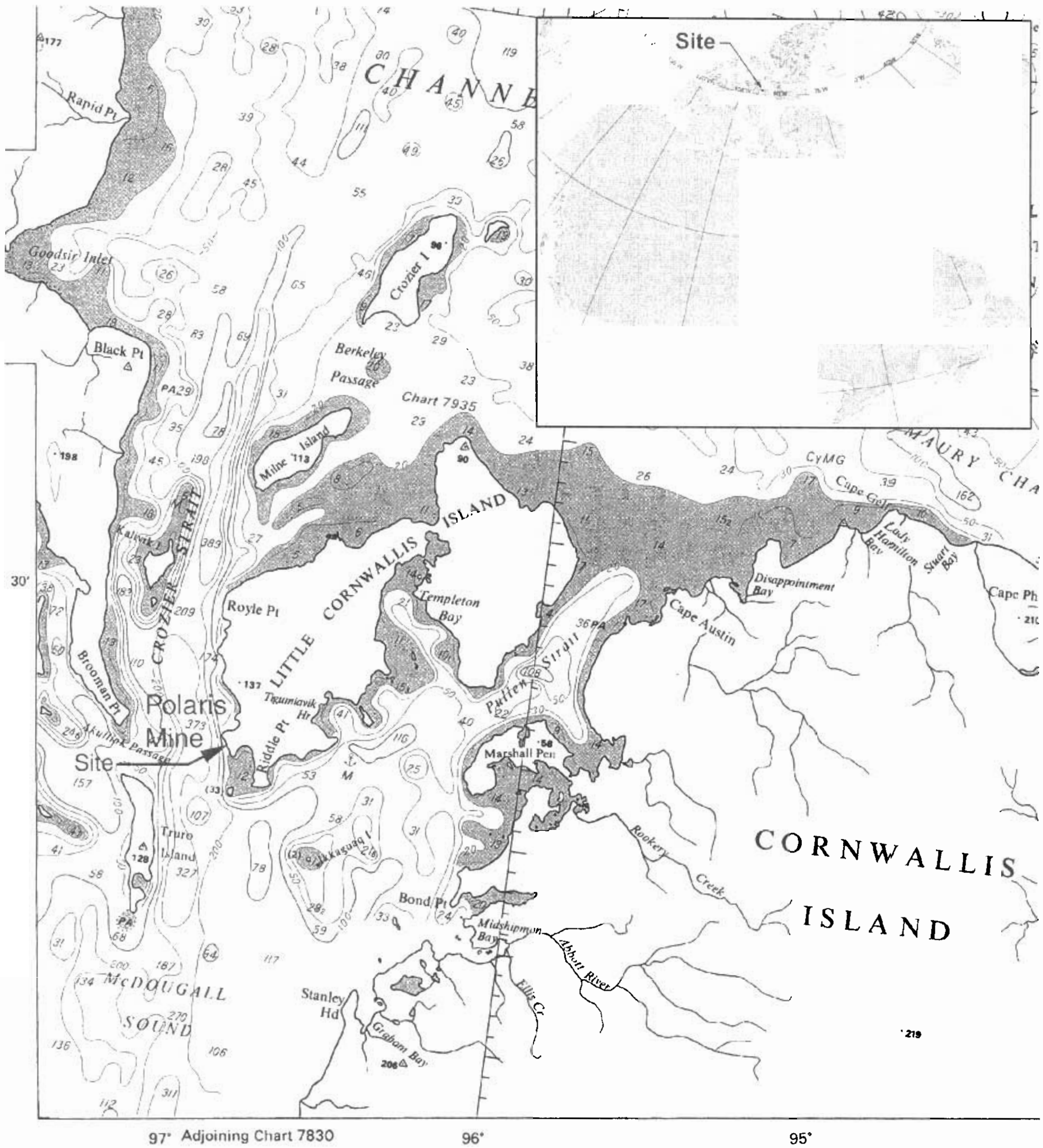

Figure 1: Site location (from Chart 7950, Canadian Hydrographic Service, 1985, depths in metres, Scale 1:500,000).

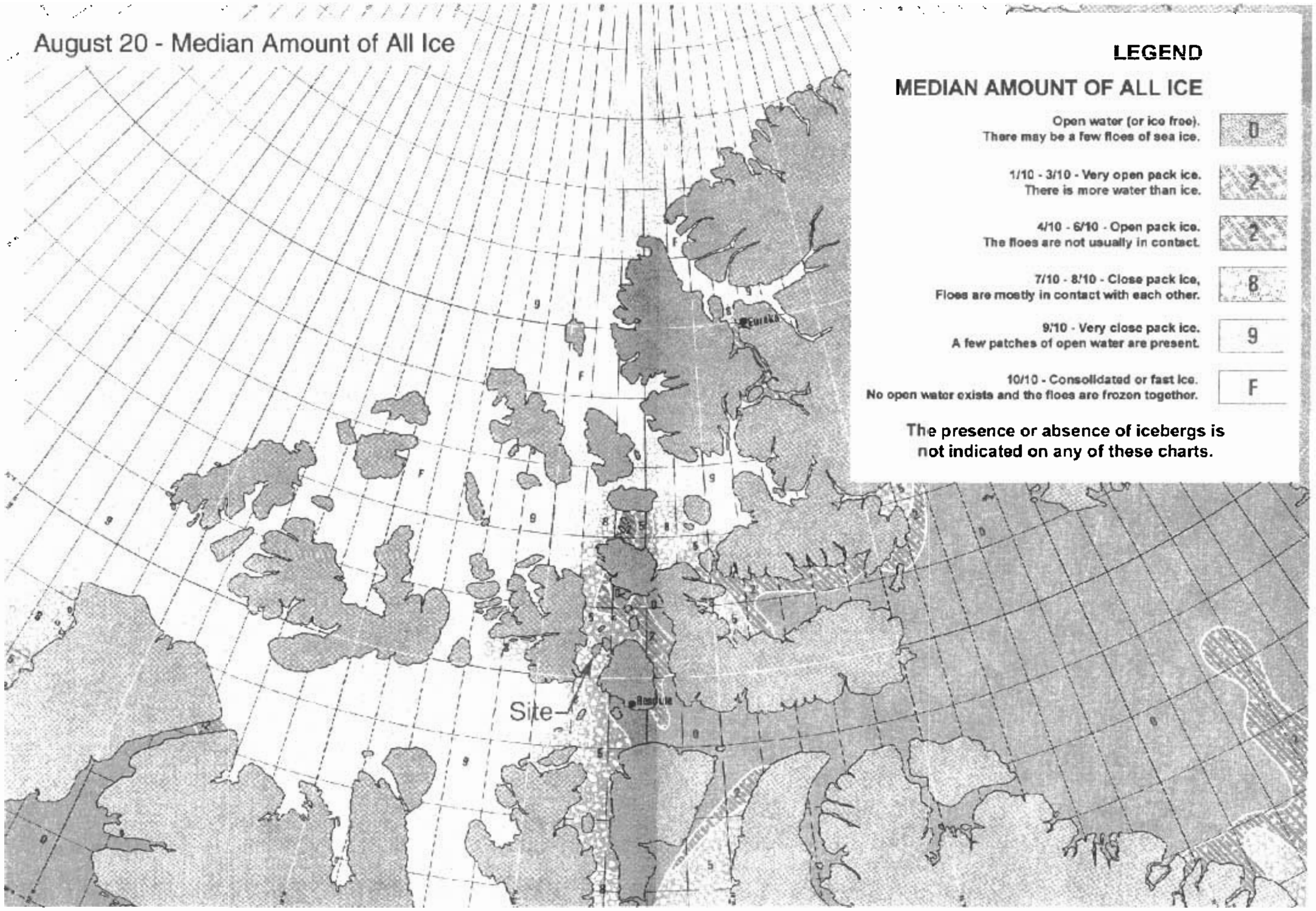

Figure 2: Median amount of all ice on August 20th, when break up of the ice occurs. The ice cover at Polaris is 8/10.

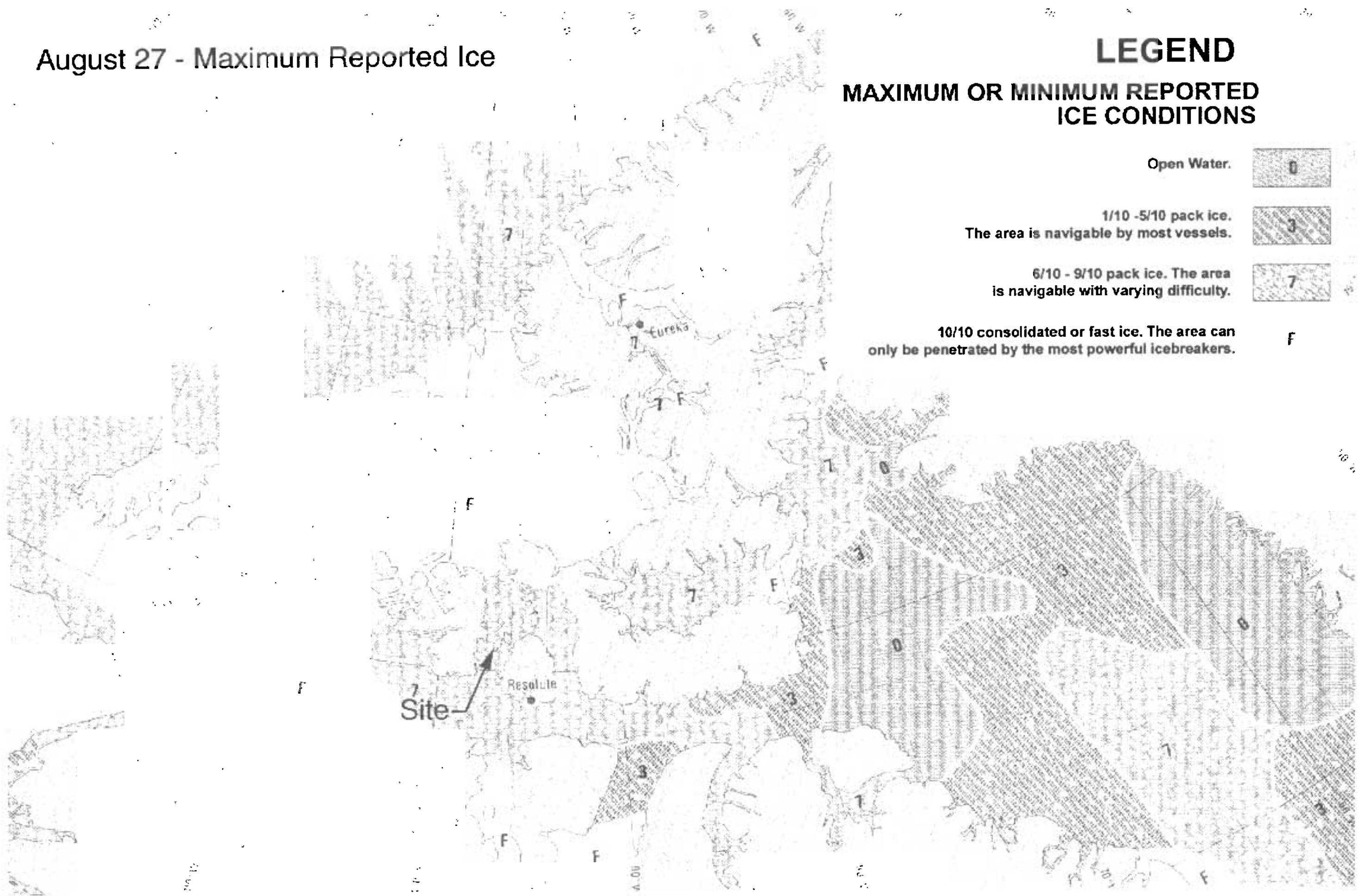

Figure 3: Maximum reported ice conditions on August 27th, when 7/10 ice cover is present at Polaris.

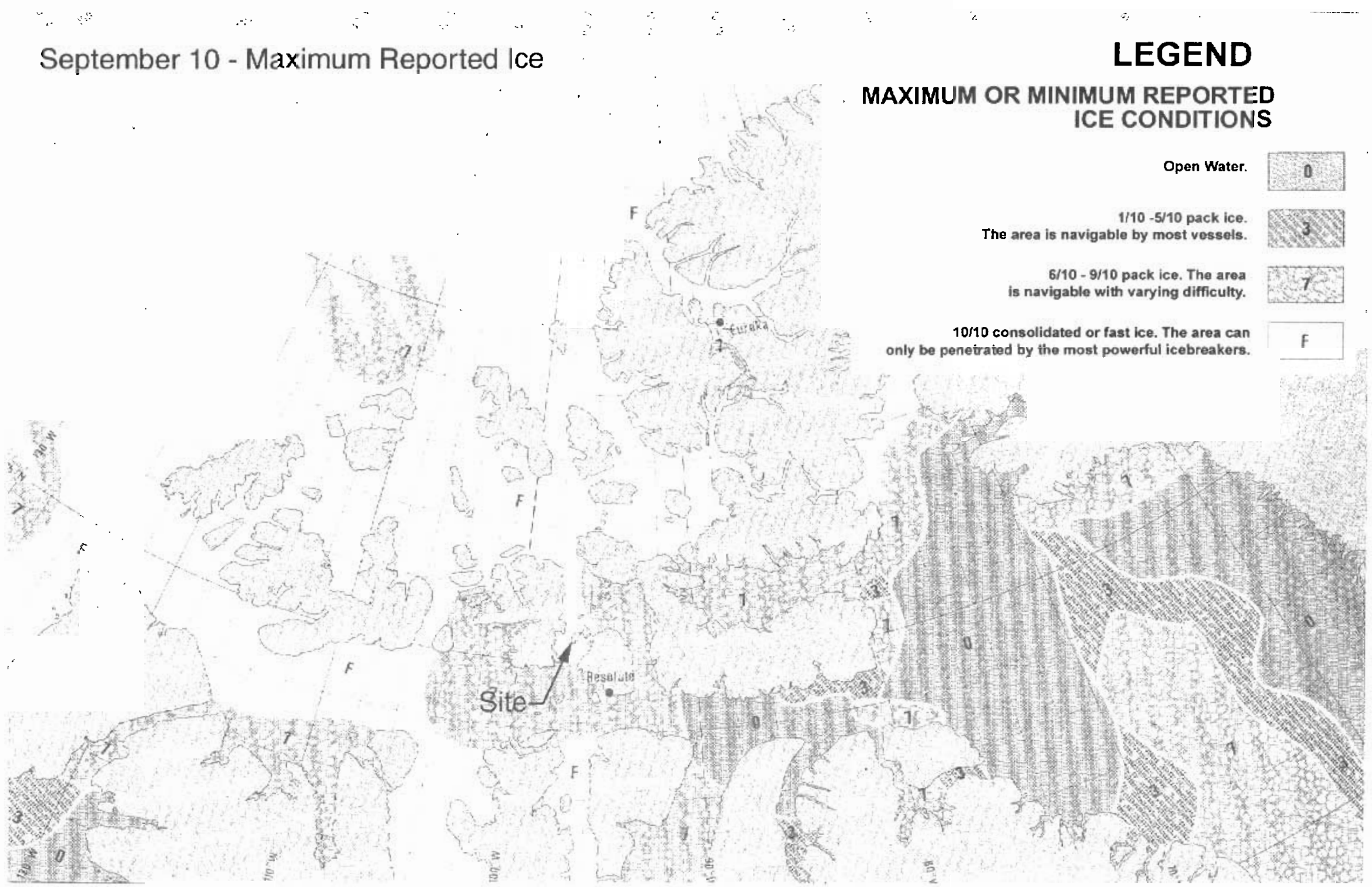

Figure 4: Maximum reported ice conditions on September 10th, when 10/10 ice coverage is present at Polaris.

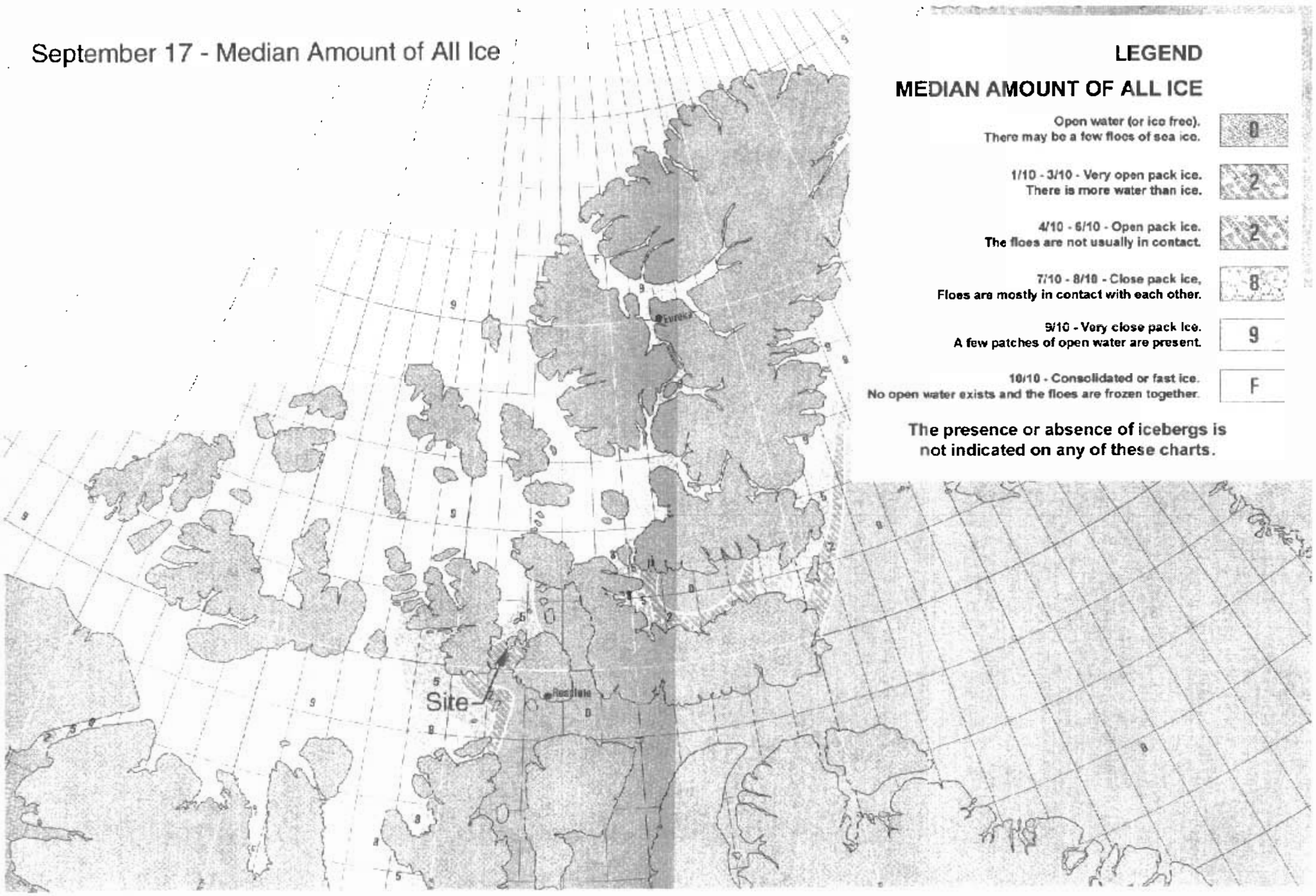

Figure 5: Median amount of all ice on September 17th, when freeze up starts. The ice cover is 2/10 at Polaris.

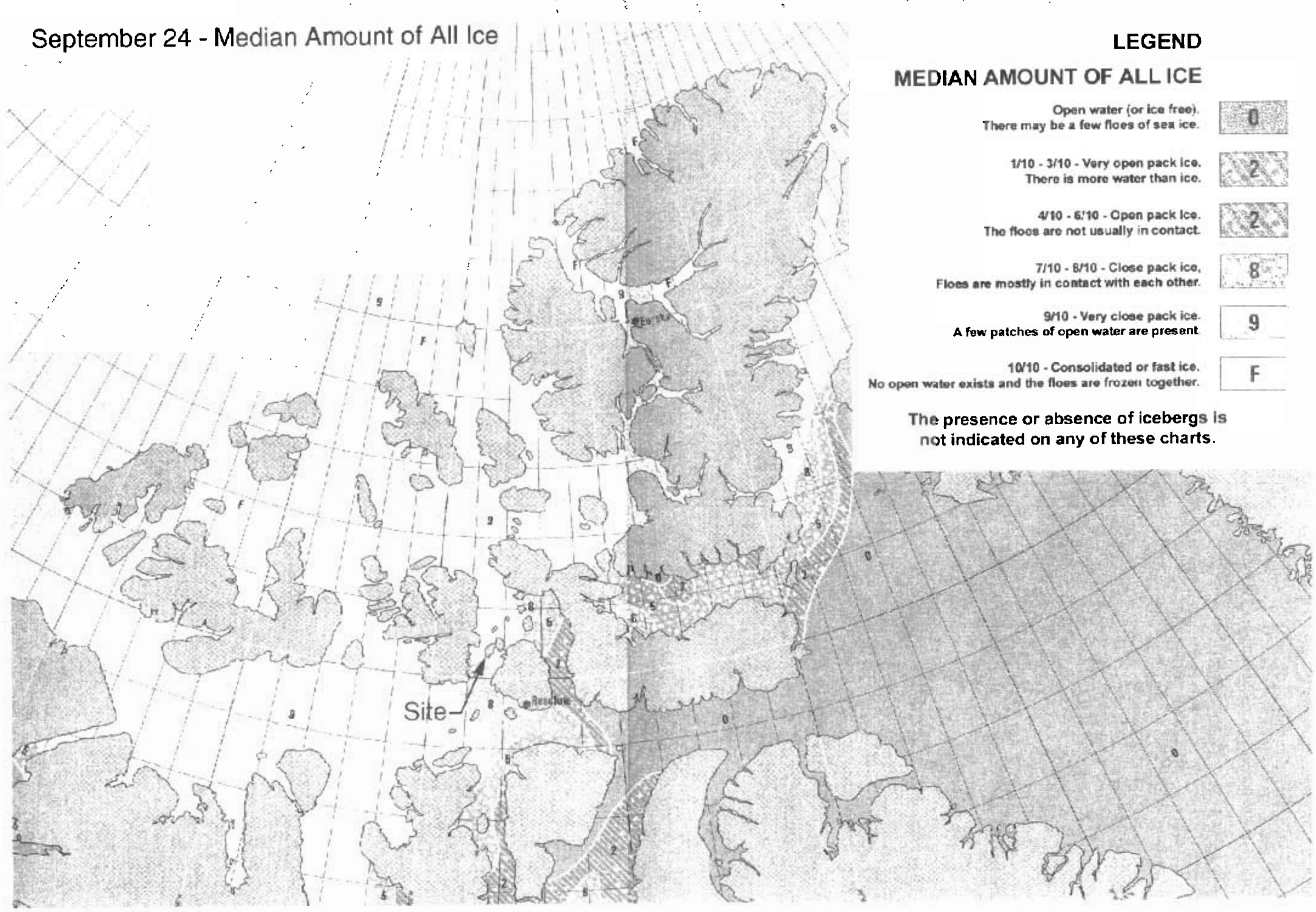

Figure 6: Median amount of all ice on September 24th. The ice cover is 9/10 at Polaris.

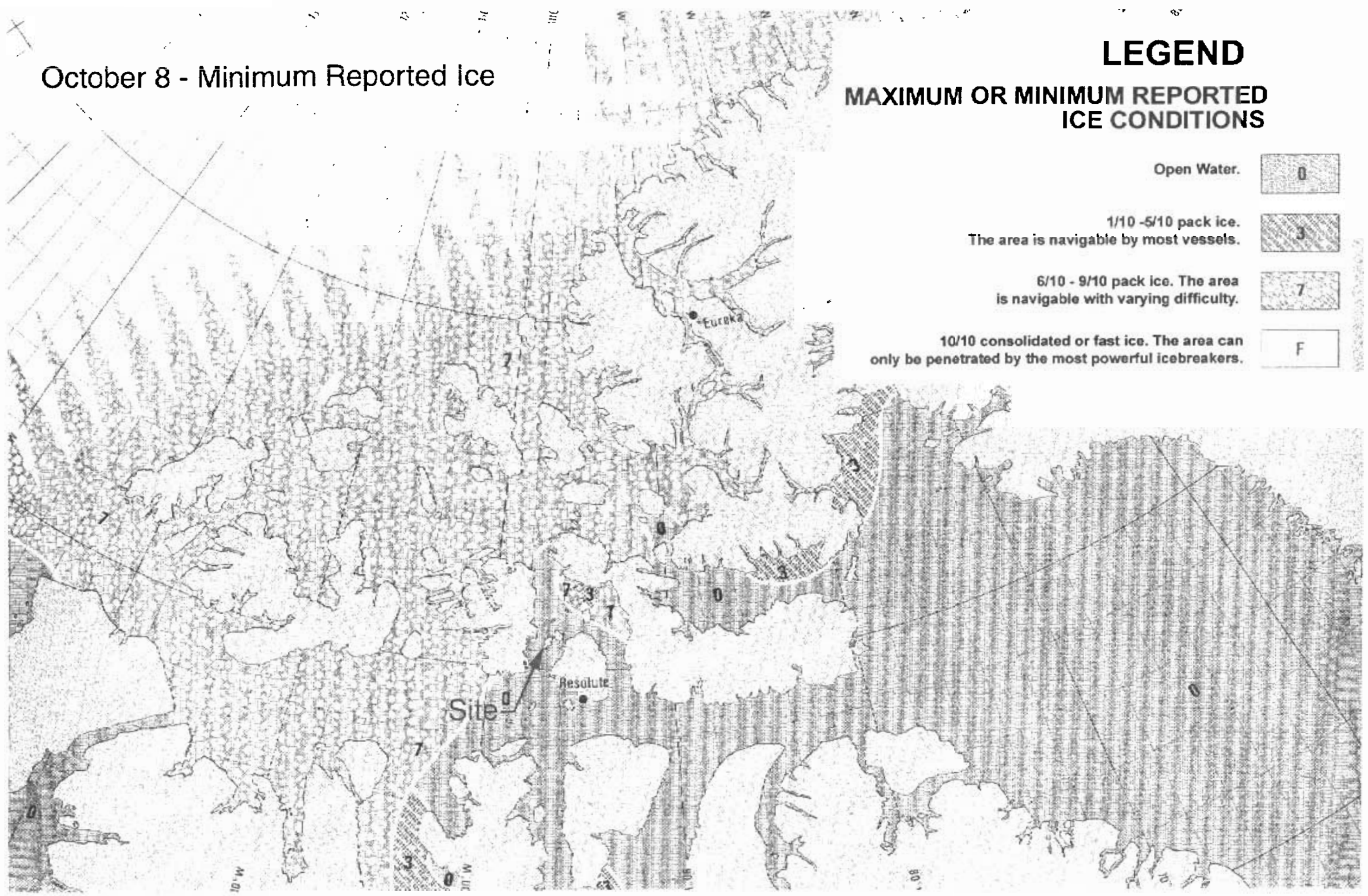

Figure 7: Minimum reported ice conditions on October 8th, when there is open water at Polaris.

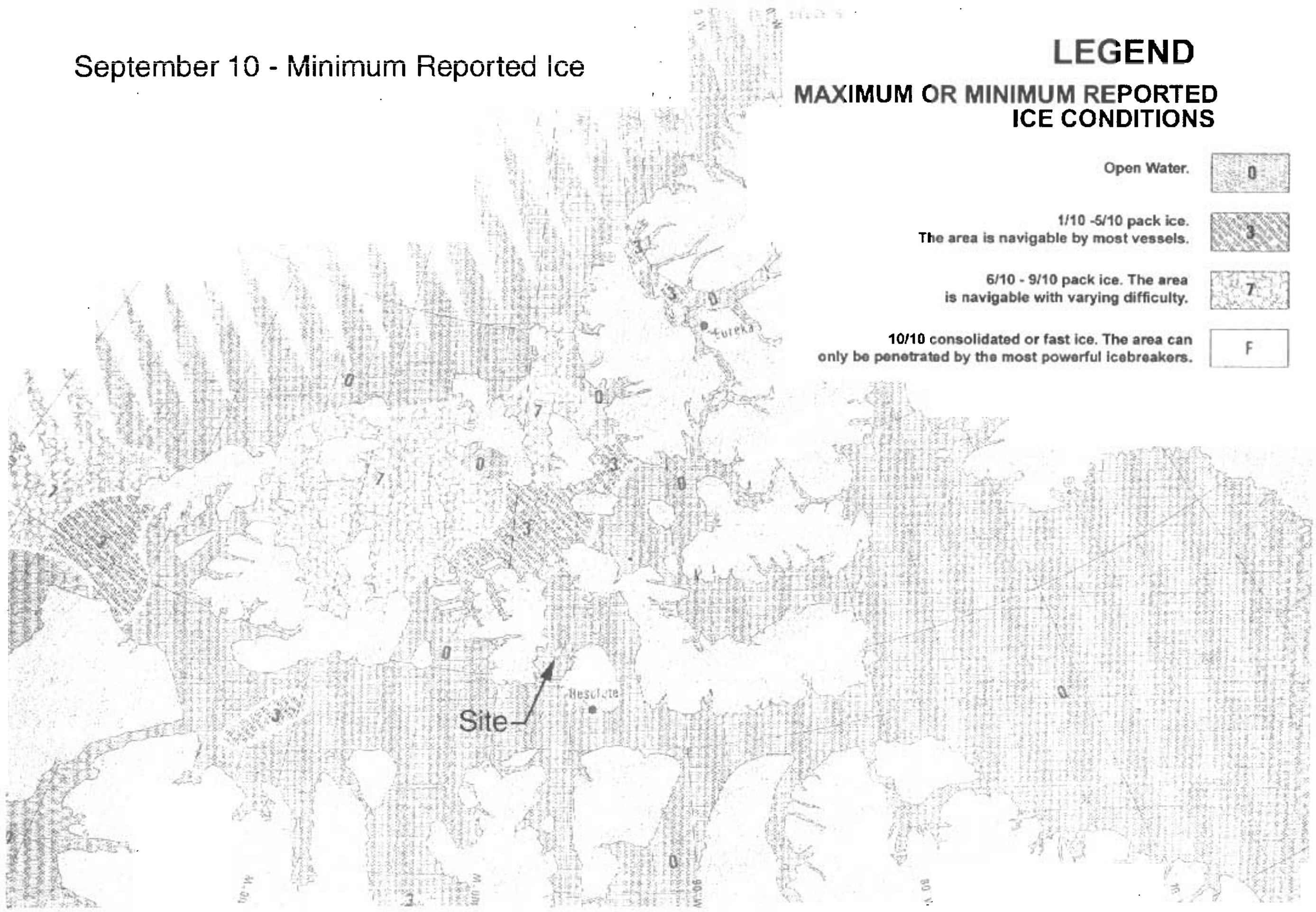

Figure 8: Minimum reported ice conditions on September 10th, when maximum open water is present.

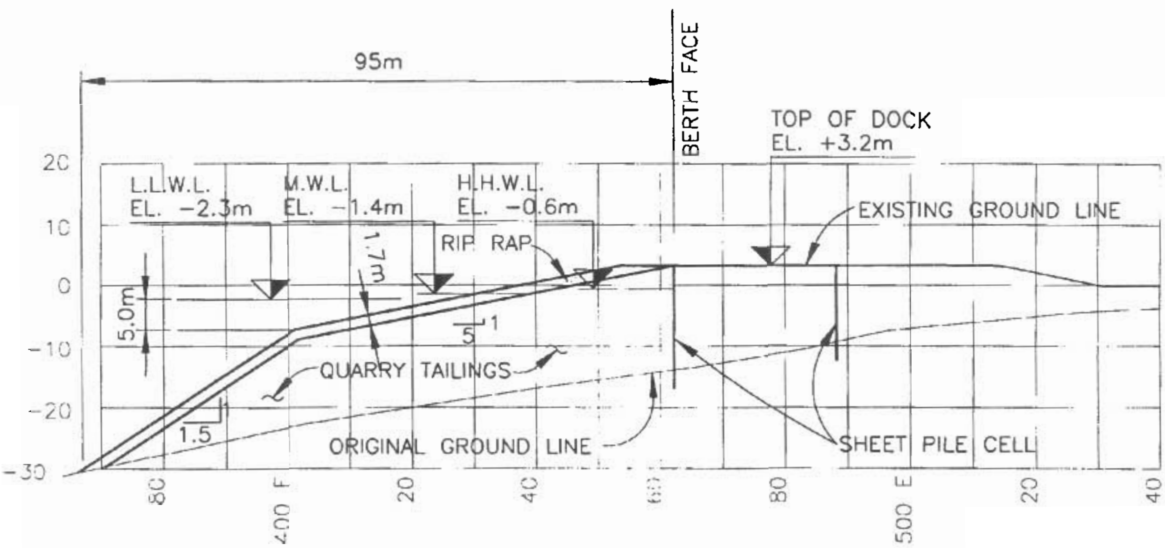

Figure 9: Cross-section through dock at Station 1400 N showing Option 2, to encase dock in rock (Scale 1:1,000).

APPENDIX B

Photographs

Photograph No. 1: Quarry face in Little Red Dog Quarry (August 17, 2000).

Photograph No. 2: View of shoreline to north of dock, from north end of dock (August 17, 2000).

Photograph No. 3: View of area between dock and process barge (August 18, 2000).

Photograph No. 4: View of shoreline to south of dock, from the deck of the vessel "Federal Baffin" (August 17, 2000).

Photograph No. 5: View of shoreline looking north at Station 1800 N. The beach is natural at this location, and is comprised of gravel with a mean size of about 10 mm (August 19, 2000).