SHIPPAGAN HARBOUR
CONDITION SURVEY
AND ASSESSMENT
WHARVES 401, 402, 403 & 404

for

Administration Portuaire de Shippagan Inc.

83, 15ème Rue, Shippagan, NB

De Curtis Engineering Limited

106 Willowlea Road
Carp, Ontario
K0A 1L0

Phone (613) 831-5072
Fax (613) 831-5841
Email info@decurtis.on.ca

2009-09-18

SHIPPAGAN HARBOUR
CONDITION SURVEY AND ASSESSMENT
WHARVES 401, 402, 403 & 404

Table of Contents

1. Introduction

Wharf facilities 401, 403 and 404 are the inside north, south and east walls of "jetty" structures which form the basin for the small craft fishing harbour, Shippagan Harbour, New Brunswick. The walls of wharves 401, 403 and 404 are comprised of anchored steel sheet piling. Wharf 402 is a marginal wharf structure forming the east side of the basin and is comprised of timber cribwork and a concrete cope wall. The deck surfaces behind the wharf walls are finished with cast-in-place concrete slabs on grade. Figure 1 is a site plan of Shippagan Harbour showing the location of wharf facilities 401, 402, 403 and 404.

Wharf facilities 401, 402, 403 and 404 have been in service for 36 years. Although the structures are presently serviceable, they are showing signs of extensive deterioration.

De Curtis Engineering Limited was retained by l'Administration Portuaire de Shippagan to undertake a condition survey and assessment of wharf facilities 401, 402 403 and 404 in Shippagan Harbour.

The principal objectives of the condition survey and assessment are to:

- Fully describe the present condition of the existing wharf facilities;
- Provide an assessment of the existing wharf structures, i.e., compare the structural capacity of the "new" and present condition of principal elements and ability of these elements to continue to provide their intended function;
- Estimate the remaining functional life of the existing facilities;
- Provide concepts for possible repairs to extend the life of the existing facilities;
- Provide concepts for reconstruction of the wharf facilities; and
- Provide preliminary cost estimates for repair and reconstruction concepts developed.

2. References

2.1 Condition Surveys

1) Guidelines for Inspection and Maintenance of Marine Facilities Public Works Canada and Transport Canada – 1984.

2) Inspection, Maintenance and Repair of Maritime Structures Exposed to Damage and Material Degradation Caused by a Salt Water Environment, Report of Working Group 17 – 2004 of the Maritime Navigation Commission, PIANC.

3) Underwater Investigations, Standard Practice, K. Childs Jr., ed., ASCE Manuals and Reports on Engineering Practice No. 101.

2.2 Assessment of Existing Structures

There are no specific codes or standards applicable to marine civil works in Canada. The assessment and evaluation of existing structures is based on various parts of the following codes, standards and guidelines:

4) The National Building Code of Canada

5) Canadian Foundation Engineering Manual 4th Edition, 2006

6) CSA Standard CAN/CSA S6-06, Canadian Highway Bridge Design Code

7) CSA Standard A23.3-04, Design of Concrete Structures

8) CSA Standard S16-01, Limit States Design of Steel Structures

9) CSA Standard O86-01 Engineering Design in Wood

10) Recommendations of the Committee for Waterfront Structures, Harbours and Waterways, EAU 1996

11) Coastal Engineering Manual, USACE, April 2002

12) Bridge Inspection Manual, Public Works and Government Services Canada (PWGSC), March, 2001.

3. Record Documents

The following documents were reviewed for structures information during the course of the study:

Item No.	Title/Description	Format
1	Harbour Improvements, Shippegan, NB, (1961) Plan and Details (sheet 1 of 2, C-728)	PDF Drawing
2	Harbour Improvements, Shippegan, NB, (1961) Plan and Details (sheet 2 of 2)	PDF Drawing
3	Wharf Repairs, Shippagan, (1990) North Wharf Plan of Site & Details (sheet 1 of 3, 658579)	PDF Drawing
4	Old North Wharf Reconstruction, Shippagan, NB, (2002) Site Plan (S2 of S9, 100321)	AUTOCAD Drawing
5	Harbour Improvements, Wharf and Fill Area Shippegan, (1972) General Finished Site Plan (sheet 1 of 9, 72623)	PDF Drawing
6	Harbour Improvements, Wharf and Fill Area Shippegan, (1972) Finish Grades & Drainage Layout (sheet 2 of 9)	PDF Drawing
7	Harbour Improvements, Wharf and Fill Area Shippegan, (1972) Sewer Line Layout (sheet 3 of 9)	PDF Drawing
8	Harbour Improvements, Wharf and Fill Area Shippegan, (1972) Catch Basin, Manhole, and Lateral Details (sheet 4 of 9)	PDF Drawing
9	Harbour Improvements, Wharf and Fill Area Shippegan, (1972) Cribwork Plan and Details (sheet 5 of 9)	PDF Drawing
10	Harbour Improvements, Wharf and Fill Area Shippegan, (1972) Cribwork And Concrete Sections And Details (sheet 6 of 9)	PDF Drawing
11	Harbour Improvements, Wharf and Fill Area Shippegan, (1972) Details (sheet 7 of 9)	PDF Drawing
12	Harbour Improvements, Wharf and Fill Area Shippegan, (1972) Steel Sheet Piling Details (sheet 6 of 9)	PDF Drawing
13	Harbour Improvements, Wharf and Fill Area Shippegan, (1972) Details (sheet 9 of 9)	PDF Drawing
14	ADMINISTRATION PORTUAIRE Shippagan Inspection Sous-Marine Quai 401 – 403 – 404 Projet # F4721-040019 (September 2004)	Printed Report
15	Phase II Environmental Site Investigation - Old North Wharf Parking Lot, Shippagan, New Brunswick Jacques Whitford Environment Limited, Fredericton, NB	Printed Sheets

Item No.	Title/Description	Format
	Project No. NBF13330-5 (Bore Hole Logs BH JW1 to BH JW4) (November 2001)	
16	Geotechnical Drilling For Old North Wharf AMEC Earth and Environmental Ltd., Moncton, NB Public Works and Government Services Canada, Shippagan, NB (March 2001, TV 21300)	Printed Report

4. Condition Survey

4.1 Team

The field work for the condition survey of wharf facilities 401, 402 403 and 404 was undertaken by personnel from De Curtis Engineering Limited (DEL).

The field inspection team included the following personnel:

- E. De Curtis, P. Eng.
- T. De Curtis, Senior Tech.

Ship to Shore Diving & Engineering Ltd. (STS) was engaged to assist with the subsurface inspection of the dock walls. The personnel employed by (STS) for the inspection included:

- D. Lewis, P. Eng., Dive Supervisor
- Julian Taylor, Diver
- Nathan McColeman, Diver
- Brent Lewis, Dive Tender

4.2 Survey Methodology

The methodology followed for conducting the condition survey of the wharf facilities is summarized as follows.

.1 Prior to the start of the field work, available record documents were reviewed in order to become familiar with the wharf facilities. A general arrangement plan of the site was prepared. Stations were located at 10 m intervals around the full perimeter of the wharf facilities as shown on the Key Plan, Figure 2.

.2 The field work was undertaken on June 21, 22, 23 and 24, 2009. For reference purposes and to facilitate recording of observations and measurements, each station and mid-point between stations was marked along the top edge and face of the wharf facilities as indicated on Figure 2

.3 The survey, except for the underwater observations, was conducted by the DEL project team members from the surface of the wharf and from a boat in front of the wharf. The condition of the exposed surface of the steel sheet piling along wharf facilities 401, 403 and 404 was observed and recorded in photographs, field notes and sketches. The exposed surface of the timber cribwork and concrete cope wall along wharf facility 402 was similarly inspected. A photographic record of the dock walls above water level is provided on a digital disk included with the report.

.4 The survey of the submerged section of the wharf walls was undertaken with the assistance of divers from STS. E. De Curtis and/or T. De Curtis were present during the entire underwater inspection. The dive team was equipped with video and voice

communication equipment which enabled the DEL personnel to view the condition of the submerged sections of the walls on a video monitor and to provide instructions to the divers when more detailed views of the wall or measurements were required. A video record of the complete subsurface survey is provided on a digital disk included with the report.

.5 For the underwater survey, the divers made two passes along each section of the wall, i.e., one near the bottom of the wall and a second pass just below still water level. When anomalies were noticed, the diver would move in for a closer look to determine if there were breaches and/or damage to the wall.

.6 At two locations along the steel sheet piling walls, the out-pan, the web and the in-pan sections of the walls were cleared of marine growth along the full height. The condition of the cleaned sections of the steel sheet piling was observed along the full height of the walls.

.7 Residual thickness measurements of the steel sheet piling were obtained at the two locations where the sheet piles had been cleaned. Approximately 36 measurements were taken at each location with most of the measurements concentrated near chart datum level. In the zone from 1.2 m above chart datum to -1.2 m below chart datum, the residual thicknesses of the in-pan, web and out-pan of the steel sheet pile sections were measured at 300 mm intervals. Above and below this zone measurements were obtained at approximately 1000 mm intervals.

.8 Along Wharf 402, the face of the submerged timber cribwork structures was tapped with a pointed steel hammer in order to determine the soundness of the existing timbers. The condition of fastening bolts visible on the face of the timber cribwork, was also examined by the divers. The divers closely observed conditions along the bottom of the cribwork to determine whether any scouring has occurred along the cribwork structure.

.9 Verticality of the wharf walls was measured at 17 locations using a 2000 mm long straight edge equipped with a digital level. The straight edge was held tight against the wall faces to take readings of the vertical alignment (percentage value). The verticality for a perfectly plumb wall is 0%. A positive value indicates that the wall is leaning inward (i.e., the bottom of the wall is further out towards the water than the top). A negative value indicates that the wall is leaning outward (i.e., the top of the wall is further out toward the water than the bottom).

.10 Sounding depths were measured at 5 m intervals around the full perimeter of the of wharf facilities 401, 402, 403 and 404. Depths shown on drawings are referenced to metres below chart datum (elevation 0.0 m).

.11 Damage, deterioration and any anomalies observed during the field survey above the water level and in the submerged sections of the wall were recorded in field books. All of the field information is shown on report figures (including plans, elevations, sections or details of the wharf structures).

.12 Analyses of the structure were undertaken upon completion of the field survey and review of record documents. The analyses and assessments of load capacity are based on the present condition of the various wharf elements as observed during the June 2009 field survey.

.13 Concepts for repair and reconstruction are based on preliminary designs of principal elements. Estimated costs for repair and reconstruction concepts are based on quantities of materials and work required for the developed concepts.

5. Existing Structures

5.1 Report Figures

5.1.1 General

The figures and drawings prepared for this report are based on the information contained in the record documents listed in Section 3 and from field measurements of the June 21, 22, 23 and 24, 2009 condition survey. Where possible, field measurements of the wharf components were taken to confirm the dimensions shown on record documents. However, such verifications were limited to components that are exposed and accessible from the surface or face of the structure.

5.1.2 Elevations

All elevations shown in the figures and drawings for this condition survey are referenced to chart datum.

5.2 Services and Utilities

Although the assessment of underground services and utilities was not included in this mandate, it is noted that there are several service lines buried beneath the wharf deck surfaces. In some areas service lines are also located along the top of the deck adjacent to the curb. Buried services on the wharf structures include electrical service lines for power and lighting, water supply lines for potable water, supply lines for fire hydrants and salt water service lines.

There are several hoists and sheds housing the hoist drives along the perimeter of the wharf walls. The hoists and sheds are located immediately behind the timber curbs at the top of the steel sheet pile walls.

5.3 Geotechnical Conditions

No direct geotechnical data was available along the length of the wharf walls. Assumptions regarding geotechnical conditions were based on the information contained in the "as-built" drawings, and the descriptions and characteristics of the soils described in the two referenced reports *('Geotechnical Drilling For Old North Wharf*', AMEC, March 2001 and '*Phase II Environmental Site Investigation - …'*, Jacques Whitford, Nov. 2004).

5.4 Description of Existing Wharf Structures

5.4.1 Wharf 401

Wharf 401 is a jetty structure on the northeast side of the harbour basin. The structure is "L" shaped and set perpendicular to the marginal wharf (Wharf 402). The section perpendicular to the marginal wharf is approximately 122 m long and the paved surface along this section of the wharf is 16 m in width. The outer section is approximately 82 m long and 20 m wide with steel sheet piling walls on both sides of the structure.

Wharf 401 is comprised of anchored steel sheet piling and an armour protected slope along the seaward side of the perpendicular section of the wharf. The total length of steel sheet piling around the wharf perimeter is 307 m. The steel sheet piling extends the full height of the walls to the top of deck elevation.

The "as-built" drawings indicate that along the first 80 m of the perpendicular section of the wharf, the overburden layer above bedrock is very thin. To achieve the required toe stability, the lower end of the steel sheet piling is set in a trench excavated in the underlying bedrock (Figure 3). Along the remaining 42 m of the perpendicular leg of the wharf, the "as-built" drawings indicate that the overburden layer increases to a thickness of 4.6 m± (approximately). The steel sheet piling penetrates the full depth of the overburden layer. Information on the "as-built" drawings indicates that the sheet piling was to be driven to and set into the surface of the underlying bedrock (Figure 4). The top section of the steel sheet piling is supported by steel tie-rods placed at elevation 1.2 m above chart datum level. Along the full length of the perpendicular section of the wharf the tie-rods are secured to an anchor wall comprised of steel sheet piling located 9.14 m from the face of the wharf walls.

Along the outer section of the wharf, the "as-built" drawings indicate that the thickness of overburden materials increases. The drawings show the installed length of the steel sheet piling as 17 m±. The resulting pile penetration in the overburden below harbour bottom is in the order of 8 m on the harbour side and 6.5 m on the seaward side of the wharf (Figure 5). Along the outer section of the wharf the tie-rods connect the tops of the two parallel walls. The end of the outer section and a length of the sheet piling along the northeast corner of the structure are connected to steel sheet pile anchor walls similar to the perpendicular leg of the wharf.

The type and/ properties of the steel sheet piling used in Wharf 401 are not indicated on the "as-built" drawings. Tie-rods are shown on the "as-built" drawings as 70 mm bars upset to 89 mm diameter at the threaded ends. Steel properties are not indicated for the tie-rods.

The top surface of the wharf is finished with a concrete slab on grade. The curb around the full perimeter of the steel sheet piling is comprised of 250 mm by 250 mm treated timber bolted though150 mm timber chocks to the top plate over the steel sheet piling. A galvanized steel guide rail secured to timber posts is set along the top of the rubble mound slope at the seaward edge of the perpendicular leg of the wharf.

5.4.2 Wharf 402

Wharf 402 is a marginal wharf structure on the southwest face of the harbour basin. The wharf structure is about 147 m in length. The structure is comprised of ballasted timber cribwork and reinforced concrete cope wall. The timber cribwork extends from harbour bottom to elevation 0.91 m above chart datum. The concrete cope wall extends from the top of the crib to the top of the structure, elevation 3.96 m above chart datum.

The "as-built" drawings indicate that the cribwork structure is comprised of 6 units each 24.38 m long by 7.32 m wide, with bays measuring 3.05 m in the longitudinal direction

and 2.44 m in the transverse direction of the cribs. They are constructed with 250 mm by 250 mm treated timbers. The harbour face of the cribwork is "closed face" construction with intermediate filler pieces placed between the longitudinal members. Ballast floors in the cribwork are comprised of 150 mm by 200 mm timbers bearing on the bottom transverse members. The "as-built" drawings indicate that some of the bays in the cribwork units did not require ballast floors to be installed.

Notes on the "as-built" drawings require the cribwork structure to be "scribed" to harbour bottom. This indicates that there is little or no overburden material above hard bottom along this section of the harbour basin.

The cope wall is comprised of a 600 mm thick reinforced concrete base and a vertical reinforced concrete wall which tapers from 600 mm in thickness at the top of the base to 300 mm at the top of the structure. The base slab is 2.3 m wide.

The base slab bears directly on the transverse and front longitudinal timbers. At the location of the cribwork transverse walls the two vertical binder posts on the front face and two additional vertical posts located at approximately the mid-point of the concrete base, are extended above the cribwork level 300 m into the cope wall concrete base. A 22 mm diameter bar extends across the two posts. It is assumed that the extension of the vertical posts and 22 mm diameter bars were intended to provide a connection between the cope wall base slab and the cribwork structure.

At each bollard location, a 762 mm wide by a 1067 mm deep column is extended from the base slab and cast integrally with the wall stem.

Presently the concrete curb above the top of structure level is 500 mm in height. The curb was extended approximately 200 mm some time after initial construction.

The deck surface behind the cope wall is comprised of a cast-in-place concrete slab on grade.

A typical cross section of Wharf 402 is shown on Figure 6.

5.4.3 Wharf 403

Wharf 403 is located on the southwest face of the harbour basin. Wharf 403 is about 90 m long. The structure is comprised of steel sheet piling similar in construction to the steel sheet piling wall along the first 80 m section of Wharf 401. Like Wharf 401 the overburden layer above bedrock along Wharf 403 is very thin. The "as-built" drawings indicate that trenching of the bedrock is required to install the sheet piles.

The only apparent difference with Wharf 401 is the length of sheet piles below chart datum level for the anchor wall. Also at the location of the existing ice plant (Station 3.0± to Station 5.7±), the distance of the tie-rod anchor wall tapers from 9.14 m to approximately 5.5 m from the wharf face.

The deck surface behind the steel sheet piling wall is comprised of a cast-in-place concrete slab on grade. The curb along Wharf 403 is comprised of 250 mm by 250 mm

treated timber bolted though150 mm timber chocks to the top plate over the steel sheet piling.

The type and/or properties of the steel sheet piling used in Wharf 401 is not indicated on the "as-built" drawings. Tie-rods are shown on the "as-built" drawings as 70 mm bars upset to 89 mm diameter at the threaded ends. Steel properties are not indicated for the tie-rods.

A typical cross section of Wharf 403 is shown on Figure 7.

5.4.4 Wharf 404

Wharf 404 is the 'inside' wall of the structure that extends northward from the end of Wharf 403. Wharf 404 is approximately 42 m in length.

Wharf 404 is comprised of steel sheet piling similar in construction to the steel sheet piling wall along Wharf 403. The "as-built" drawings show a total penetration of the steel sheet piling along Wharf 404 of only 2.43 m below harbour bottom. The "as-built" drawings show no requirements regarding trenching of hard bottom. Borehole No. 6, located at the corner of Wharves 403 and 404 (from the report *Geotechnical Drilling For Old North Wharf,* AMEC, 2001), indicates that there is only a 2 m thick silty sand overburden layer encountered below harbour bottom above a fractured mudstone layer. At the junction with Wharf 403 the steel sheet piling is set approximately .4 m into hard bottom. There is no information regarding the hard bottom elevation along the remainder of Wharf 404.

The steel tie-rods are shown anchored on the inside face of an existing structure pre-dating the 1973 construction which is shown as being only 4.57 m from the face of the 1973 wall.

The deck surface behind the steel sheet piling along Wharf 404 is finished with new asphalt which was placed as part of the 2003 *Old North Wharf Reconstruction*. The curb along the top of the wall is comprised of Steel HSS 305x305. The steel curb along Wharf 404 was also replaced as part of the 2003 reconstruction.

The type and properties of the steel sheet piling used in Wharf 404 are not indicated on the "as-built" drawings. Tie-rods are shown on the "as-built" drawings as 70 mm bars upset to 89 mm diameter at the threaded ends. Steel properties are not indicated for the tie-rods.

A typical cross section of Wharf 404 is shown on Figure 8.

6. Observed Conditions

6.1 Wharf 401

6.1.1 Wharf Deck

Subsidence of the deck surface behind the sheet pile face is evident throughout Wharf 401. Photo 1 shows the subsidence of the deck slab (190 mm±) at the back face of the steel sheet piling at Station 1. It is clear that the subsidence of the deck occurred some time ago and is not a recent event. At some point the sheet piling was deliberately cut at the in-pan for drainage purposes. It can be seen that additional subsidence of the deck surface has occurred (50 mm±), since the hole was initially cut. Photo 2 shows differential settlement between adjacent sections of the concrete deck slab behind the sheet pile at Station 5.5. The magnitude of the deck subsidence that has occurred throughout Wharf 401 indicates that significant amounts of fill materials are being lost.

Photo 1 - Wharf Deck Subsidence (Station 1)

Photo 2 - Wharf Deck Subsidence (Station 5.5)

Photo 3 is a view of the top of the steel sheet piling wall taken from Station 0 looking eastward. The steel sheet pile wall is "bowed" at the top. Similarly Photo 4 shows outward bowing of the sheet pile wall between Stations 19 and 21 at the outer end of the "L" section of Wharf 401. Clearly at these locations, the top of the wall has moved outward. The outward movement of the wall also contributes to subsidence of the deck slab.

Photo 3 - Outward Bowing SSP Wall (Station 1)

Photo 4 - Outward Bowing of SSP Wall (Stations 19 to 21)

There are longitudinal cracks in the deck slab along the full length of the wharf. The cracks usually occur between the back face of the wall and the first longitudinal control joint in the deck pavement. Clearly, the cracks are due to the subsidence of the fill below and operation of heavy equipment in the area.

The most severely distressed section of the wharf deck occurs at the northeast corner of Wharf 401 between Stations 28 to 30. At this location a large cavity has been created beneath the deck slab. At the corner Station 29.3, the top of fill level is more than 1200 mm± below the underside of the deck slab. The cavity below the slab extends a considerable distance from the back face of the steel sheet piling. Photo 5 taken at Station 29 shows settlement of the bollard. At this location the top of fill level is approximately 200 mm below the underside of the deck slab. Photo 6 shows the wharf deck along Stations 29 to 30. The steel sheet piling has moved outward separating from the concrete deck slab. The deck slab is cracked.

Photo 5 - Wharf Deck Subsidence (Station 29)

The loss of fill materials at the northeast corner of Wharf 401 has created large cavities beneath the deck slab. The slab has to span across the cavities created by the loss of fill materials. As the deck slab was not intended to function as a "structural element", it is only a matter of time until collapse of this section of the deck slab occurs.

Temporary repairs should be implemented in this localized area to prevent further loss of materials. The electrical building Photo 7 is located in the immediate vicinity and continued loss of fill materials could cause damages to the building and electrical services.

Photo 6 - Wharf Deck (Stns 29 to 30)

Photo 7 - Electrical Control Building (Station 29)

In view of the subsidence that has occurred throughout the structure of Wharf 401, there could be other areas where cavities exist beneath the deck slab.

6.1.2 Steel Sheet Pile Wall

The "as-built" drawings of Wharf 401 do not indicate the type and/or characteristics of the steel sheet piles used in the construction of Wharf 401. Measurements of the width, depth and thickness of the web and flanges of steel sheet pile sections closely conform to the dimensions of the "ARBED" BZ IVNE" sheet pile sections. The thickness of the web and flanges were measured at accessible locations at the top of the wall where the piles have not been significantly affected by corrosion. The cross section dimensions of the "ARBED" BZ IVNE" steel sheet piles are shown on Figure 9.

The steel sheet piles above low water level generally remain in relatively good condition. From elevation 0.5 m± (approx.) to high tide level of elevation 2.0 m±, the steel sheet piles have a heavy rust coating on the surface but remain relatively smooth. There is no extensive scaling or pitting in this zone.

Photo 8 - Steel Sheet Pile Wall (Stations 11 to 12)

Above the high tide level the rust coating is heavier. There is some scaling and pitting throughout this zone. Photo 8 is a view of the wall between Stations 11 and 12 above water level and represents typical conditions along the wall from Stations 0 to 17.

From Stations 18 to 30.5 the steel sheet pile wall is coated with barnacles up to elevation 1.5 m±. The exposed surfaces in this zone are rusted but appear to be smooth with no heavy pitting or scaling. Above the barnacle encrusted section of the wall, the steel sheet pile surface are heavily pitted and scaled to within 0.6 m± from the top of the wall.

Pitting and scaling on the sheet pile surfaces is much more prominent along the walls of the seaward sides of the harbour basin. The upper 0.6 m± of the walls have a heavy rust coating but show less pitting and scaling. Photo 9 shows a section of the steel sheet pile wall at Station 29.5. This is the most severely corroded zone of the steel sheet pile walls in Wharf 401 that is visible above water level. This photo shows the perforation of the web at the corner steel sheet pile. It is also the area where a large cavity has formed beneath the concrete deck slab.

Photo 9 - Steel Sheet Pile Wall (Station 29.5)

Heavy marine growth and molluscs are attached to the submerged sections of the steel sheet pile walls. An orange colouring could be seen throughout the surface of the walls. Although the orange colouring was most prominent in a 0.6 m± band centred about low water level, it also appeared throughout the full height of the steel sheet piles.

The orange coloured areas are zones where a recently identified form of corrosion is occurring, i.e., *Microbiological Influenced Corrosion* (MIC). MIC is identified by a characteristic, poorly adherent orange corrosion product over a soupy black (iron sulphide rich) layer.

At Shippagan, the orange material and black soupy layer were easily removed by hand rubbing over the surface of affected steel. A shiny bright steel surface with extensive pitting was exposed at the cleaned areas.

Several zones were cleaned by the divers throughout the course of the survey of the submerged walls. In every case, shiny bright steel surfaces were exposed. The pitting was evident over the entire MIC affected surface. The average depth of pitting in the low

water zone ranged between 3 to 5 mm. The diameter of the pits ranged between 10 to 20 mm. In the submerged zone the average depth of pitting ranged between 1.5 to 3 mm. The diameter of pits appeared to be somewhat smaller than in the low water zone.

Photo 10shows MIC on the steel sheet pile surface as it appears before cleaning. Photo 11 shows the steel sheet pile surface after it has been wiped clean by the diver.

Photo 10 - MIC on SSP Surface Before Cleaning

Photo 11 - SSP Surface After MIC Has Been Cleaned

Close examination of the walls at the low water level indicates that the steel sheet piling is severely corroded in this zone. There is extensive perforation of the steel sheet piling along the full length of the walls.

Between Stations 0 to 4.5 on Wharf 401, the webs on almost every steel sheet pile are perforated. The perforations usually occur at the junction of the web and out-pan flanges of the piles. The perforations range from small holes, 25 mm in diameter to large holes 400 mm high by 250 mm (Station 2.65).

Between Stations 8 to 14, a total of 45 perforations were found in the webs of the steel sheet piles. Generally the perforations in this zone were in the range of 150 mm to 300 mm high by 75 mm to 150 mm wide. A large hole was found at Station 9.3 that was about 600 mm high by 300 mm wide.

Between Stations 16 to 24, almost every steel sheet pile is perforated. Again the perforations occur at the junctions of the webs and out-pan flanges.

The extent of perforation of the sheet pile walls described above is illustrated on Figure 10, Figure 11 and Figure 12.

At locations where perforations were observed, the thickness of the steel around the perforations was described by the divers as "paper thin". The divers also remarked that in many cases where perforation had not yet occurred, the steel surface felt paper thin.

In comparison with the observations contained in the diving report prepared for the Administration Portuaire de Shippagan in September 2004, perforation of the steel sheet piling currently appears to be much more extensive. During the current survey it was found that all of the steel sheet piling is perforated along sections of the walls from Stations 0 to 4.5 and Stations 16 to 24). Along Stations 8.5 to 14, at least 45 piles are perforated.

It is reasonable that the extent of perforation of the steel sheet piles in Wharf 401 has greatly increased within the past 5 years. Once perforation occurs, the sheet piling is subject to corrosion attack from both sides of the wall thereby greatly accelerating the corrosion.

6.1.3 Residual Thickness Measurements

Residual thickness measurements of the in-pan, web and out-pan of a steel sheet piling section were obtained at Station 17 using ultrasonic equipment.

The results of measurements are shown on Figure 13. The original thickness of the web and flanges of the ARBED IVNE section are also shown.

Figure 13 shows that at low water level the web has been perforated. The residual thickness of the out-pan flange is 6 mm±. Based on the thickness lost in the out-pan flange the average annual rate of corrosion at low water level is 0.22 mm/year. At elevation -3.5 m below chart datum the residual thickness of the web and out-pan flange is 8 mm± and 12 mm± respectively. The average rate of corrosion in the submerged section of the steel sheet piles is 0.06 mm/year. Both the rate for low water level corrosion and the rate for the submerged section of the steel sheet piling are in conformance with typical published rates contained in research literature.

Corrosion rates for pitted areas are much higher. Two methods are used to estimate the time required for perforations to occur in pitted areas. In the first method the time to develop perforations is calculated by subtracting 4 mm from the original thickness and dividing the remainder by the average annual corrosion rate. In the second method, it is assumed that the rate for "pitting" corrosion is approximately 150% that of the average

annual rate. For the web sections of the steel sheet piling (10 mm original thickness) these methods yield 27.3 and 30.3 years respectively for the time it takes for perforations to appear. The appearance of perforations in steel sheet piles reported in the 2004 report (after 31 years of service) is consistent with results predicted based on theoretical calculations.

Although no large piles of fill materials were observed at the bottom of the walls the subsidence of the deck slab along the wharf is probably due to a large part to the loss of fine materials due to the perforations in the sheet pile walls.

6.1.4 Vertical Alignment of Steel Sheet Pile Walls

Verticality measurements were obtained at 8 locations (Table 1) along Wharf 401 walls.

Table 1 Verticality Measurements Wharf 401

STATION	VERTICALITY*
1.7	-5.5%
6.5	-1.8%
11.5	0.2%
14.3	2.9%
18.0	2.6%
20.0	1.1%
23.5	1.8%
28.0	1.3%

** 0% indicates perfectly plumb wall, positive value means that the top of the wall leans inward, negative value means that the top of the wall leans outward*

Typically, specifications require sheet piles to be driven to within 1% and -1% vertical alignment. The worst location for vertical alignment of the wall occurs at Station 1.7. At this location the top of the wall is further out than the sheet piling at harbour bottom by more than 460 mm. The wall movement extends over a large zone. At Station 6.5 the wall is still leaning outwards. It is likely that in the zone commencing from Station 0 to Station 6.5 the anchor wall that the tie-rods are connected to has shifted and allowed movement of the steel sheet pile wall.

6.2 Wharf 403

6.2.1 Wharf Deck

As is the case for Wharf 401, subsidence of the deck surface behind the face of the structure occurs throughout Wharf 403. Photo 12 is taken from Station 9 looking westward. Photo 13 is a close up view of the deck surface behind the wall at Station 8. The subsidence of the deck slab at this location is around 250 mm. As was observed along Wharf 401, it is clear that the subsidence of the deck occurred some time ago and is not a recent event. The steel sheet piling was deliberately cut at the in-pan for drainage purposes. Additional subsidence of the deck surface has occurred (125 mm±) since the hole was initially cut. The magnitude of the deck subsidence that has occurred throughout Wharf 403 indicates that significant amounts of fill materials are being lost.

Photo 12 - Wharf Deck Subsidence (403)

Photo 13 - Wharf Deck Subsidence (Station 8)

Photo 14 shows outward bowing of the sheet pile wall between Stations 6.5 and 7.5. Clearly at these locations, the top of the wall has moved outward. The outward movement of the wall also contributes to subsidence of the deck slab.

Photo 14 - Outward Bowing SSP Wall (Stations 6.5 to 7.5)

There are cracks in the deck slab along the full length of Wharf 403. Some sections of the deck slab have been repaired with asphalt surfacing.

In view of the subsidence that has occurred throughout the structure there could be areas of Wharf 403 where cavities exist beneath the deck slab.

6.2.2 Steel Sheet Pile Wall

Measurements of the width, depth and thickness of the web and flanges of steel sheet pile sections along Wharf 403 confirm that the same steel sheet piling sections as Wharf 401 were used in the construction of Wharf 403 (Figure 9).

The condition of the wall above water level along Wharf 403 is similar to that described for Wharf 401. Above low water level the steel sheet piles generally remain in relatively good condition, i.e., relatively smooth with heavy rust coating from elevation 0.5 m to high tide level (elevation 2.0 m), heavier rust coating with some scaling and pitting above the high tide level. Photo 15 shows a section of the wall above water level between Stations 2 to 3.

Photo 15 - Steel Sheet Pile Wall Wharf 403 (Stations 2to 3)

Similar to Wharf 401, heavy marine growth and molluscs are attached to the submerged sections of the steel sheet pile walls along Wharf 403. Along this wharf, orange coloured MIC could also be seen over the whole surface of the submerged walls. Although MIC was most prominent in a 0.6 m band cantered about low water level, it was also present over the full height of the steel sheet piles.

MIC affected zones that were cleaned by divers along the walls of Wharf 403 showed the same characteristic shiny bright steel surface with extensive pitting as was observed along the Wharf 401 walls.

Similar to Wharf 401, the average depth of pitting observed in the low water zone ranged between 3 to 5 mm. The diameter of the pits ranged between 10 to 20 mm. For the submerged zone below the low water zone, the average depth of pitting ranged between 1.5 to 3 mm. The diameter of pits appeared to be somewhat smaller than in the low water zone.

Close examination of the walls at the low water level along Wharf 403 showed that the steel sheet piling is severely corroded in this zone. There is extensive perforation of the steel sheet piling along the full length of the walls.

Between Stations 3.5 to 5.5, a total of 5 holes were found in the webs of the steel sheet piles. Between Stations 5.5 to 8.5, a total of 15 perforations were found in the webs of the steel sheet piles. Generally perforations in these zones were in the range of 150 mm to 300 mm high by 75 mm to 125 mm wide. Holes about 450 mm high by 200 mm wide were found at Stations 5.3 and 6.

For safety reasons, the sheet pile wall between Stations 0 and 3.5 could not be observed by the divers as boats were using this section of the walls throughout the survey period. Two zones in this section of the wall were examined from the decks of boats moored there during a low water level. Photo 16 shows perforations of the steel sheet pile webs near Station 0. Photo 17 shows perforations of the sheet pile webs at Station 0.7. At least 6 perforations of the steel sheet pile webs are visible in this 7 m length of wall.

Photo 16 - Wharf 403 Steel Sheet pile Wall (Stationn 0)

Photo 17 - Wharf 403 Steel Sheet Pile Wall (Station

At locations where perforations were observed the thickness of the steel around the perforations were described by the divers as “paper thin”. The divers also remarked that in many cases where perforation had not yet occurred, the steel surface felt paper thin. At Station 6 the web of the steel sheet pile section was perforated while it was being cleaned with a pressure washer. Photo 18 shows the “paper” thin web adjacent to the perforated section of the pile at Station 6.

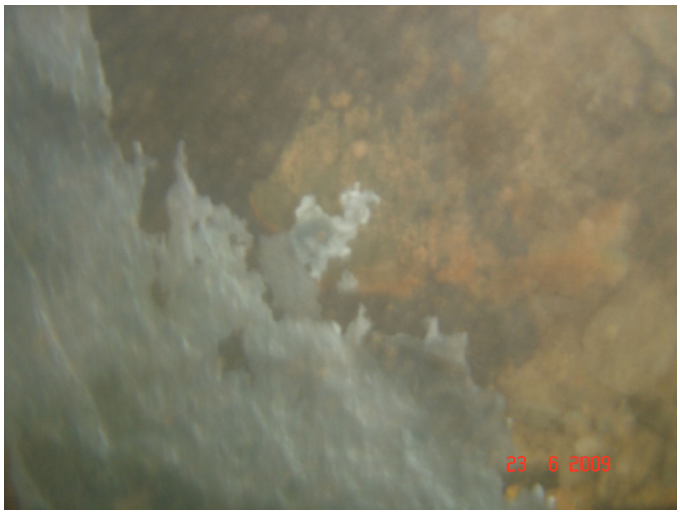


Photo 18 - Wharf 403 Steel Sheet Pile Web (Station 6)

As is the case with Wharf 401, the perforation of the steel sheet piling observed in the current survey along Wharf 403 appears to be more extensive than the magnitude of perforations reported in September 2004.

The extent of perforation of the sheet pile wall described above is illustrated on Figure 14.

6.2.3 Residual Thickness Measurements

Residual thickness measurements of the in-pan, web and out-pan of a steel sheet piling section were taken at Station 6 using ultrasonic equipment. The results of measurements are shown on Figure 15. The original thickness of the web and flanges of the ARBED IVNE section are also shown.

Figure 15 shows that the pattern of residual thickness measured at Station 6 on Wharf 403 is very similar to the pattern and residual thickness measurements at Station 17 on Wharf 401. The calculation for average annual corrosion rate at the low water zone and the submerged zone below the low water zone yield similar results (0.22 mm/year for the low water zone and 0.06 mm/year for the submerged zone). The theoretical calculation of the estimated time for perforations to occur would again be similar (in the order of 30 years). The results are reasonable since Wharves 401 and 403 were built in the same year using the same steel sheet piling sections.

Although no large piles of fill materials were observed at the bottom of the walls, the subsidence of the deck slab along the wharf is probably due to a large part to the loss of fine materials from the fill due to the perforations in the sheet pile walls.

6.2.4 Vertical Alignment of Steel Sheet Pile Walls

Verticality measurements were obtained at 5 locations (Table 2) along Wharf 401 walls.

Table 2 - Verticality Measurements Wharf 403

STATION	VERTICALITY*
2.2	0.4%
3.7	0.5%
5.2	-2.1%
6.7	-2.1%
8.3	0.1%

* *0% indicates perfectly plumb wall, positive value means that the top of the wall leans inward, negative value means that the top of the wall leans outward*

For the most part the wall alignment remains relatively vertical. At Stations 5.2 and 6.7 the top of the wall is further out than the sheet piling at harbour bottom by 175 mm±.

6.3 Wharf 404

6.3.1 Wharf Deck

The deck surface behind the steel sheet pile walls along Wharf 404 was replaced as part of the Old North Wharf reconstruction (2003). There are at least two zones along Wharf 404 where subsidence of the new asphalt surface and loss of fill materials has already occurred. Photo 19 shows the hole in the asphalt surface at Station 9.5. The top of the fill materials in this location is about 750 mm below the deck level. The cavity below the surface is 400 mm in width and extends 1200 mm along the wall. Photo 20 shows the deck surface at Station 12.5. Granular materials have been used to fill the cavity formed at this location.

Photo 19 - Wharf 404 Loss of Fill Materials (Station 9.5)

Photo 20 - Wharf 404 Loss of Fill Materials (Station 12.5)

The new steel HSS curb, concrete service centre and bollard base that were installed as part of the Old Wharf Reconstruction in 2003 remain in good condition.

6.3.2 Steel Sheet Pile Wall

The wall along Wharf 404 is an extension from Wharf 403. It was constructed at the same time as the sheet pile wall along Wharf 401 (1973). Field measurements of the width, depth and thickness of the web and flanges of the steel sheet piling confirm that the same ARBED BZIVNE section was used for the wall along Wharf 404 as was used for the walls along Wharves 401 and 403. It is therefore no surprise that the condition of the wall along Wharf 404 is similar to the condition of the walls along Wharves 401 and 403.

The steel sheet pile wall above low water level generally remains in relatively good condition: relatively smooth with heavy rust coating from elevation 0.5 m to high tide level (elevation 2.0 m); and heavier rust coating with some scaling and pitting above the high tide level. Photo 21 shows a section of the wall above water level between Stations 11.5 to 13.

Photo 21 - Wharf 404 SSP Wall (Stations 11.5 to 13)

Below low water level, conditions are again similar to conditions observed for the steel sheet pile walls along Wharves 401 and 403. The submerged section of the wall is covered with heavy marine growth and molluscs. MIC was observed throughout the surface of the wall but was most prominent in a 0.6 m± band centered about low water level.

Close examination of the walls at the low water level showed that the steel sheet piling along Wharf 404 is also severely corroded in this zone. Perforation of the steel sheet piling can be described as somewhat less extensive than conditions observed along the walls at Wharves 401 and 403.

Between Stations 9.5 to 12.5 on Wharf 404, a total of 14 holes were found in the webs of the steel sheet piles. Generally perforations in these zones were in the range of 100 mm to 200 mm high by 50 mm to 100 mm wide. Between Stations 12.2 to 12.5, the webs on both sides of the steel sheet pile out-pans are perforated. The extent of perforation of the sheet pile wall described above is illustrated on Figure 14.

The loss of materials through the perforations in the steel sheet pile wall has clearly resulted in the subsidence of the pavement and cavities that have been formed behind the wall.

The perforation of the steel sheet piling observed in the current survey along Wharf 404 appears to be more extensive than the magnitude of perforations reported in September 2004.

6.4 Tie-Rods Anchors Wharves 401, 403 and 404

Tie rod anchors at Wharves 401, 403 and 404 were not visually examined during the condition survey since it was deemed that excavation of pits to view their condition posed too many risks. The size of the required excavation pits is about 7 m long by 4.5 m wide. There are several service lines located beneath the deck slab. During the survey, there was a high level of commercial activity at the harbour.

The heads of the tie-bolts connecting the steel sheet piles to the steel channel walers behind the sheet piling face are visible along the full length of the walls in Wharves 401, 403 and 404. The tie-bolts are located at an elevation of 1.2 m above chart datum. As stated previously, the wall surfaces from about 0.5 m to high tide level (elevation 2.0 m±) have a heavy rust coating but remain relatively smooth. There is no extensive scaling or pitting in this zone. The tie-bolts are located at the mid point of this zone.

Like the steel sheet pile wall, there is no heavy scaling or pitting visible on the surface of the washer plates or heads of the tie-bolts. Except for surface rust, the tie-bolts and washer plates are in “like new” condition. The tie-rods are at the same elevation as the tie-bolts and are located behind the steel sheet pile face and buried in the fill materials. Although it was not confirmed by visual examination, it stands to reason that the tie-rods are in the same condition as the tie-bolt heads and washer plates visible on the outside surface of the wall.

6.5 Wharf 402

6.5.1 Wharf Deck

There are many longitudinal and transverse cracks in the section of concrete pavement which lies between the curb at the edge of the wharf and the first control joint in the deck surface along the full length of Wharf 402. The cracking is probably the result of subsidence of the fill materials below the cast-in-place deck slab.

The subsidence of fill materials along Wharf 402 is much less than the subsidence that is evident along Wharves 401 and 403.

6.5.2 Concrete Cope Wall

The curb along the top edge of the cope wall has been extended by 200 mm since the original construction. Some sections of the curb extension have been recently repaired. The section of the curb shown on Photo 22 is representative of the present condition of the curb along Wharf 402.

Photo 22 - Wharf 402 Concrete Curb (Station 1)

The cope wall face was examined from a boat operating in front of the wall. From the top of the cribwork level (elevation 0.91 m) to the top of hide tide level (elevation 2.0 m±), the surface is covered by light marine growth and some molluscs adhering to the concrete surface. Above high tide level, the surface is clean and generally clear of marine growth or molluscs. The concrete surface is relatively smooth without evidence of severe abrasion or other forms of deterioration. Deterioration of the concrete was observed at some locations along the base/ stem interface of the cope wall structure. The base and stem were likely cast as separate pours. The deterioration occurs at the “cold joint” between the two wall elements. The amount of deterioration observed is considered as relatively minor in view of the service life. Photo 23 shows deteriorated section of the concrete at the cold joint between the base and stem of the cope wall.

Photo 23 - Wharf 402 Concrete Deterioration at "Cold Joint" (Station 8.5)

There is evidence that there has also been differential movement between adjacent wall sections. At Station 6.1 adjacent cope wall sections at a construction joint are misaligned by approximately 75 mm at the top of deck level (Photo 24).

Photo 24 - Wharf 402 Cope Wall Misalignment (Station 6.1)

The face of the cope wall does not align perfectly with the face of the timber cribwork below. At the two ends of Wharf 402 the face of the cribwork projects out further than the face of the cope wall. At the northwest end of the structure, the cribwork projection is 50 mm at Station 0.0 increasing to a maximum of 200 mm at Station 2.0 and tapering back to become flush with the cope wall at Station 3.5. At the southeast end of Wharf 402, the cribwork is flush with the cope wall at Station 12.75 and tapers out to a maximum projection of 350 mm at the junction with Wharf 403. The misalignment of the cribwork and cope wall is probably due to construction issues. Photo 25 shows the projection of the cribwork face beyond the face of the cope wall at the southeast end of Wharf 402.

Photo 25 - Wharf 402 Projection of Cribwork Beyond Cope Wall (Station 14)

Verticality measurements were obtained at 4 locations (Table 3) along the concrete cope wall.

Table 3 - Verticality Measurements Wharf 402 Cope Wall

STATION	VERTICALITY*
2	0.0%
6.8	0.9%
10	0.3%
13.8	3.2%

** 0% indicates perfectly plumb wall, positive value means that the top of the wall leans inward, negative value means that the top of the wall leans outward*

The cope wall face is relatively vertical. The wall leans inwards at Station 13.8.

6.5.3 Timber Cribwork

The face of the cribwork below the cope wall is covered with heavy marine growth and molluscs.

Measurement of the distance between joints confirms the dimensions shown on the "as-built" drawings (i.e. the cribwork units are about 24 m in length). Measurements also confirm that the cribwork is constructed with 254 by 254 timbers. Joints between adjacent cribwork sections are in the order of 300 mm wide.

During the underwater inspection, the timbers were struck with a pointed hammer for the full height of the cribwork at random locations along the length of Wharf 402. Penetration of the tip of the hammer was observed to be less than 3 mm. The diver described the timbers as sound. Ends of transverse timbers on the face of the cribwork as well as ends of longitudinal timbers at cribwork joints were also struck with the pointed hammer. The cribwork timbers were sound at all the locations that were struck.

Closer examination of the timber elements was made along the full height of the cribwork at three locations along the wall, Stations 5, 5.5 and 6. At these locations the cribwork surface was cleaned by the diver using a pressure washer. In every case the timbers appeared sound without signs of deterioration or damage.

The timber elements from chart datum elevation to the underside of the concrete cope wall were examined from a boat operating in front of the structure. The timbers above chart datum level were also found to be sound without evidence of deterioration or damage. Photo 26 shows the horizontal cribwork timbers immediately below the concrete cope wall at Station 3.5.

Photo 26 - Wharf 402 Timber Cribwork (Station 3.5)

Damaged cribwork bolts were found all along the wharf in the upper 2 m section of the cribwork. The upper three to four bolts in the cribwork timbers have been sheared off. A damaged bolt can be seen in Photo 26. The bolts below the upper 2 m of the cribwork remain in good condition. Photo 27 shows the head of a bolt just below the sheared bolts at Station 5. The bolt remains in "like new" condition.

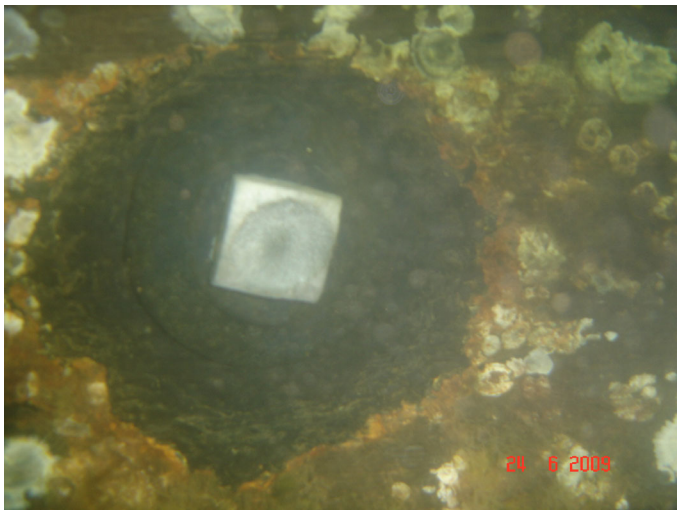


Photo 27 - Wharf 402 Typical Undamaged Cribwork Bolts (Station 5)

The cause of the damage is probably due to boats rubbing on the bolt heads as the rubber tire fenders do not keep the boat hulls away from the cribwork. For the most part, the cope wall and cribwork face are practically flush. In some areas the cribwork face actually projects beyond the cope wall face. Exacerbating the problem is the fact that the bolt heads and washers are not countersunk into the cribwork timbers and actually project from the cribwork face.

Observation along the bottom of the cribwork did not reveal any areas of scouring along the wharf.

Again, for safety reasons, the submerged cribwork wall between Stations 10 and 14.7 could not be observed by the divers as boats were using this section of the walls throughout the survey period.

6.6 Ladders

Generally the ladders in Wharves 401, 402, 403 and 404 are not in good condition. There are several ladders where rungs are broken or bent. At some locations, connection points have become detached from the wall.

The most serious safety problem with the ladders is in regard to their length. Along Wharves 401, 402, 403 and 404, in all cases the bottom rung of the ladders is approximately 0.9 m above chart datum elevation. Under the present circumstances it would be very difficult for a person to climb out of the water during the low water level period.

Future remedial works and/or reconstruction should include new ladders which will extend 0.6 m below chart datum elevation.

6.7 Soundings along Face of Walls (401, 402, 403 and 404)

Soundings were taken at 5 m intervals referenced to chart datum elevation and are shown on Figure 2. The soundings did not show any abrupt changes in harbour bottom elevations. The sounding depths are referenced to chart datum elevation.

7. Assessment

7.1 Wharves 401, 403 and 404

7.1.1 Steel Sheet Pile Walls

Extensive perforation of the steel sheet pile walls concentrated in the low water level zone was observed throughout the structures. Many large holes in the range of 150 mm to 300 mm in height by 50 mm to 150 mm in width exist throughout the perforated zone. Fill materials escaping through the holes in the wall have resulted in subsidence of the deck surface behind the face of the walls throughout the three structures.

Due to the extent of the perforations that exist, repair of these structures is not practicable. Furthermore, even if the sheet pile walls could be repaired at the low water level, the deterioration of the submerged sections of the steel sheet piling has reached the point where the strength of the walls is no longer adequate.

Analyses undertaken of various sections of the walls, based on assumed typical values for unit weights and angle of internal friction of fill and native overburden materials, show that the maximum bending moment in the steel sheet piles occurs from -3.5 m to -5.0 m below chart datum elevation. Table 4 is a comparison of the minimum section modulus at -3.5 m below chart datum elevation for the "new" condition and "present" corroded condition of the ARBED BZ IVNE sheet pile sections in Wharves 401, 403 and 404. Using the residual thickness of the sheet pile webs and flanges measured in the June 2009 survey, the calculated section modulus of the sheet piles at -3.5 m below chart datum elevation is only approximately 66% of the value listed for new sheet pile sections in the ARBED catalogue.

Table 4 - SSP PROPERTIES

SSP SECTION	New Condition Section Modulus $S_{min.}$	Present Condition Section Modulus $S_{min.}$
ARBED BZ IVNE	2050 x 10^3 mm^3/m	1355 x 10^3 mm^3/m

In the year that the contract documents for Wharves 401, 403 and 404 were issued (1972), design of steel sheet pile walls was based on "ALLOWABLE STRESS" principles. A maximum allowable stress of $0.66xF_y$ (yield strength of steel) was used for bending moment resistance. The resulting "FACTOR OF SAFETY" (FOS) for bending resistance at a bending stress of $0.66xF_y$ is equal to a value of 1.5. Assuming that the walls were designed using an allowable stress level of $.66xF_y$ in 1972, the stress level for the corroded piles at -3.5 m below chart datum elevation has increased to $1.0xF_y$. This means that the corresponding FOS has reached or is near 1.0. In other words, the wall has reached the point where it could yield under full soil and surcharge loading.

It would not be practical to pursue repairs for a wall in which the principal load resisting elements (steel sheet piling) has reached or is close to the point of yield from applied loads.

7.1.2 Steel Tie-Rod Anchors

Tie-rod anchors on the "as-built" drawings are shown as 70 mm bars upset to 89 mm diameter at the threaded ends. Typically, tie-rod anchors were made from structural quality steel. Information on the grade of steel for tie-rods is not provided on the record documents. At the time of construction, steel with F_y = 227.6 MPa was a common grade of material used for fabrication of tie-rods. Using this grade of steel and following requirements in CSA S16-01, the minimum capacity of the tie-rods is calculated to be T_r = 975.6 kN.

Analyses undertaken of various sections of the walls show that the steel tie-rod capacity is more than adequate for the calculated tension loads (based on assumed typical values for unit weights and angle of internal friction of fill and native overburden materials).

However, the tension capacity of the tie-rod anchorage system is limited by the soil anchor capacity that the steel tie-rods are connected to. The soil anchors consist of steel sheet piling driven through fill and overburden materials. In every case except Wharf 404, the anchor walls are located only 9.14 m from the face of the steel sheet pile walls. Figure 17 is a cross section through Wharf 401. The anchor wall is located in front of the theoretical soil failure plane. As such, the full theoretical passive resistance of the soil anchor cannot be developed. When soil anchors consist of elements driven though fill and overburden materials located in front of the theoretical failure plane, the capacity of the soil anchor is based on the bending resistance of such elements which achieve a point of fixity in the soil below the theoretical failure plane. For the steel sheet pile anchor walls in Wharves 401 and 403, calculations based on assumed typical values of soil unit weights and angle of friction indicate that the flexural capacity of the steel sheet pile anchors provides only 64.5% of the theoretical factored applied loads. The calculated FOS with respect to anchor capacity is approximately 0.97. At locations where the steel sheet pile toe is deeper in the overburden materials, the calculated factor of safety is even lower. It is emphasized these calculations are theoretical evaluations based on assumed values of soil properties. More precise evaluations would require detailed soils investigations. These calculations do indicate that the anchor capacity is very low with respect to applied loads.

In comparison with other similar steel sheet pile structures, the anchor walls for Wharves 401 and 403 are located considerably closer to the face of the wharf than what is considered normal practice.

The possible weakness in the soil anchors may explain why there are misalignments (top of the wall leans outward) in the wharf walls at several locations.

On the basis of these assessments, the existing tie-rods and tie-rod anchoring system do not appear to be capable of providing the required anchoring resistance. A new wall

should not simply be connected to the existing tie-rods and tie-rod anchoring system for lateral support.

7.2 Wharf 402

Wharf 402 can be described as a gravity structure comprised of a lower timber cribwork element and an upper concrete cope wall element. Examination of the cribwork during the condition survey undertaken in June of 2009 did not reveal any significant deterioration or damage. Some deterioration of the concrete cope wall has occurred since it was constructed. However, the deterioration is relatively minor and does not appear to impair the function of the cope wall.

Assessment for sliding and overturning stability were undertaken for the structure as a whole, i.e. global stability of cribwork and cope wall combined and for the upper cope wall element alone. The analyses were based on assumed values of unit weights and angle of internal friction for cribwork fill and back fill materials. Results of the global stability analyses are summarized in Table 5. The analyses indicate that the factors of safety with respect to sliding and overturning for global stability are well above minimum recommended values.

Table 5 - Global Stability Factors of Safety

	Factors of Safety Analyses Results*	Factors of Safety Recommended Minimum
Sliding	1.7	1.5
Overturning	3.8	3.0

* *Results include 10kN/mhorizontal bollard load acting 300 mm above the deck*

The cope wall element was analyzed only for overturning factor of safety. The "as-built" drawings show that four 250 mm by 250 mm vertical timbers project about 300 mm into the concrete base of the cope wall. (there are two verticals immediately behind the front face and two verticals at the midpoint of the cribwork cell pockets at 3.05 m centre to centre). The timbers are bolted to the horizontal elements of the cribwork. These timbers provide the "sliding" resistance for the cope wall section.

Results for overturning stability of the cope wall section are shown on Table 6.

Table 6 - Global Stability Factors of Safety

	Factors of Safety Analyses Results*	Factors of Safety Recommended Minimum
Overturning	1.67	3.0

* *Results include 10kN/mhorizontal bollard load acting 300 mm above the deck*

The overturning factor of safety for the cope wall section is somewhat low. However, this FOS value applies to high water condition, full surcharge on the deck immediately

behind the cope wall and a horizontal bollard pull of 10kN/m acting 300 mm above the deck level. In view of the fact that the wall has been in service for more than 36 years and still remains relatively vertical without signs of serious distress the overturning, stability of the cope wall is considered adequate.

Based on the surface and subsurface examination of the timber cribwork structure, examination of the cope wall and deck surface behind the structure face and assessments of stability undertaken, Wharf 402 remains serviceable although some minor repair/maintenance will be required.

The minor repair/ maintenance work includes: removal of the cracked and broken sections of the concrete curb and top of cope wall sections and repair with new concrete; removal and replacement of broken sections of the concrete deck immediately behind the cope wall; repair of deteriorated areas at the base slab/ stem interface; and installation of new larger rubber tire fenders that will keep the boat hulls from rubbing on the cribwork face.

There is some concern with the sheared bolts that were found along the top section of the cribwork just below the underside of the cope wall base. These bolts serve to tie longitudinal face timbers to the cribwork structure. However, not all of the bolts along the upper section of the cribwork are broken and due to the “screening” effect of the cope wall base, horizontal pressure from fill materials on the inside of the cribwork face is very low. There is no evidence of the longitudinal face timbers separating from the crib. At the same time there is no sure way of determining whether or not the face timbers will separate from the cribwork structure and allow spillage of the fill materials sometime in the future. A program of regular annual inspection (above water and submerged sections) of Wharf 402 should be implemented to ensure that the cribwork structure remains functional at the location of the sheared bolts.

8. Assessment of Remaining Useful Life

8.1 Wharves 401, 403 and 404

The assessment of remaining useful life following the methodology in Public Works Canada and Transport Canada, *"Guidelines, Inspection and Maintenance, Marine Facilities"*, indicates that the steel sheet piling walls in Wharves 401, 403 and 404 have already surpassed the theoretical useful life as predicted by empirical calculations (29.3 years predicted life versus 36 years actual life).

Assessments of the remaining useful life based on the load carrying capacity also show that the steel sheet piling has reached the end of its useful life. At low water level the steel sheet piling is extensively perforated resulting in loss of fill materials behind the walls. The FOS (remaining pile capacity/theoretical applied loads) is at approximately 1 in the submerged zone at the location of maximum bending stress. The theoretical calculations indicate that the steel sheet pile walls could yield under full soil and surcharge loading.

8.2 Wharf 402

Assessment of the remaining useful life following the methodology in Public Works Canada and Transport Canada, *"Guidelines, Inspection and Maintenance, Marine Facilities"*, indicates that Wharf 402 (comprised of a concrete cope wall and timber cribwork structure) has also already surpassed the theoretical useful life as predicted by empirical calculations (20.3 years predicted life for the cribwork and 16.75 years predicted life for the cope wall versus 36 years actual life).

The condition of the cribwork and cope wall observed during the June 2009 survey do not support the results obtained above. Although some repair/ maintenance of the cope wall will be required, Wharf 402 has not reached the end of its functional life. Based on the conditions observed and satisfactory results obtained for stability analyses, Wharf 402 can be expected to remain functional for at least 15 more years.

This estimate of remaining functional life is valid provided that:

- Future commercial activities along Wharf 402 will continue similar to the present operations, i.e. loading and size of vessels will remain the same;
- Repair/ Maintenance of the concrete cope wall is undertaken in the near future;
- New larger tire fenders are installed that will prevent the vessel hulls from rubbing on the cribwork surface; and
- A program of regular annual inspection of Wharf 402 above and below water level will be implemented to verify that the longitudinal face timbers are not separating from the cribwork structure.

It must be remembered that, in this condition survey, it was only possible to observe the dock walls of Wharf 402 visible from the top of the structure and from the front face.

The possibility exists that in some cases buried components of the structure may require repair and/or replacement sooner than the predicted estimated remaining life of the dock wall structure. The probability that such repairs may be required and the extent of the repairs required is impossible to quantify.

9. Proposed Repairs and/or Reconstruction

9.1 Wharves 401, 403 and 404

There is extensive perforation at the low water level of the steel sheet piling in Wharves 401, 403 and 404. Furthermore, deterioration of the submerged section of the steel sheet piling has reached the point where it can no longer provide the required resistance for soil and surcharge loading. Repair of the sheet pile walls is not practical. Complete reconstruction of the walls using new materials is required.

Three principal options have been investigated for reconstruction of Wharves 401, 403 and 404. The new wall systems in these options are: an "HZ" wall; a steel pipe pile/sheet pile combination wall; and a "Berlin" wall. All of the options involve constructing a new bulkhead wall approximately 1.5 m in front of the existing walls. A plan layout of the new walls is shown on Figure 18.

The new bulkhead walls have been developed based on the design criteria listed below in Table 7.

Table 7 - Design Criteria

Deck Live Loads	- 25 kPa superimposed uniformly distributed live load or wheel loading from CL 625 truck as per *CAN/CSA S6-06 Canadian Highway Bridge Design Code*
Bollards	- 20 tonne capacity
Dredged Depth	- minimum -4.5 m below chart datum elevation inside the basin and -7.0 m at the harbour entrance and northeast wall

Details for the proposed new walls are discussed in the following.

9.1.1 Option 1 - New "HZ" Wall System

In Option 1, the new wall is comprised of steel "H" king piles with intermediate steel sheet pile sections similar in construction to the new bulkhead walls used for the 2003 reconstruction of the Old North Wharf. Figure 19 shows a plan of the "HZ" wall.

Along the walls where the depth of overburden above bedrock is insufficient to develop the required toe resistance, the king piles are driven 5 m into the "mudstone" layer. The intermediate sheet pile sections are driven 1 m into the mudstone layer. A typical cross section of the new wall is shown on Figure 20.

Although no direct geotechnical data was available along the length of the wharf walls it is assumed that conditions will be similar to conditions encountered for the Old North Wharf reconstruction undertaken in 2003. That is, it will be possible to drive the "king" piles to achieve the necessary toe penetration.

At the outer end of Wharf 401, the king piles and intermediate steel sheet piles are driven to sufficient depth in the overburden materials to develop the required toe capacity. Driving shoes would be installed on all king piles to avoid damage from hard driving conditions that will be encountered. A typical cross section along the outer end of Wharf 401 is shown on Figure 21. The exact penetration required for king piles and intermediate steel sheet piles would be based on results of geotechnical investigations.

New steel tie-rods and pre-cast concrete anchor blocks are used for anchorage of the new walls along Wharves 401 and 403 (Figure 20). At the outer end of Wharf 401 the tie-rods extend across the full width of the new structure connecting the two opposing walls (Figure 21). The installation of new tie-rods requires removal of the top section of the existing wharf and replacement of fill materials and deck surfacing. Services would also have to be removed and re-installed.

Along Wharf 404, the existing tie-rods are used for anchoring the new wall by adding a new reinforced concrete waler behind the existing steel sheet pile wall. A typical cross section of the proposed construction for Wharf 404 is shown on Figure 22.

Along Wharf 403, the section of wall located in front of the ice house is anchored with tie-rods connected to vertical pipe piles installed just in front of the old anchor wall. The new steel pipe anchor piles are advanced into the mudstone below the existing fill materials. The cross section of the new steel pipe anchor piles and advancement into the mudstone layer is designed to provide the resistance required for anchorage of the new wall. A typical cross section of this section of Wharf 403 is shown on Figure 23.

The top section of the new walls along the full length of Wharves 401, 403 and 404 is finished with a reinforced concrete cope wall.

9.1.2 Option 2 - New Steel Pipe Pile/Sheet Pile Combination Wall

In Option 2, the new wall is comprised of steel pipe piles with intermediate steel sheet pile sections. The concept is similar to Option 1. Basically, the steel pipe piles serves as the king piles replacing the steel “H” king piles in Option 1. Figure 24 shows a plan of the proposed steel pipe pile/sheet pile combination wall.

All other aspects of the new construction in Option 2, such as the deck slab, tie-rod anchorage system, concrete coping at the top of the wall, electrical and mechanical services is similar to the details described for Option 1.

The advantages in using a steel pipe pile/sheet pile combination wall lessen the risks involved in achieving the necessary pile toe penetration. That is, using pipe sections for the “king” piles allows drilling inside of the pipe to facilitate advancement of the toe should difficult driving conditions be encountered.

9.1.3 Option 3 - New Berlin Wall

The Berlin wall in Option 3 is again an anchored bulkhead structure. The wall is comprised of steel king piles with intermediate pre-cast concrete panels spanning between the king piles. Figure 25 shows a part plan of the proposed Berlin wall.

The concept in Option 3 is similar to both Option 1 (HZ wall system) and Option 2 (steel pipe pile/sheet pile combination wall). However, the Berlin wall is comprised of both concrete and steel elements whereas the walls in Options 1 and 2 are comprised solely of steel elements.

The Berlin wall is suitable for locations where the surface of underlying bedrock is close to harbour bottom. Based on the information contained in record documents, reconstruction using Berlin walls may be possible along Wharves 402, 403, 404 and the first 80 m long section of Wharf 401. The exact penetration required for king piles and excavation required for seating the intermediate pre-cast concrete panels would be based on results of geotechnical investigations. Along the remainder of the walls in Wharf 401, where bedrock is too far below harbour bottom, an HZ wall system similar to the concept described for Option 1 is used.

The steel king piles for the Berlin wall are set with tremie concrete into sockets drilled into the bedrock, as opposed to being driven to the required penetration. The accuracy of installation is more important for this type of structure in order to ensure the proper fit of the pre-cast concrete panels.

All other aspects of the new construction in Option 3 are similar to the details described for Options 1 and 2 (e.g., deck slab, tie-rod anchorage system, concrete coping at the top of the wall, and electrical and mechanical services).

9.1.4 Feasibility of Re-Using Existing Tie-Rods for Anchorage of New Walls

Except for Wharf 404, re-use of existing tie-rods to anchor the new walls does not appear to provide a significant cost savings.

A new wall cannot simply be connected to the existing tie-rods and tie-rod anchoring system for lateral support. Although the existing tie-rod elements have sufficient tension capacity, the steel sheet pile anchor walls are located within the theoretical soil failure plane and cannot provide the required anchorage capacity.

The existing tie-rod anchors can be re-used in a new wall provided that they are extended and connected to a new soil anchor located a sufficient distance from the face of the new wall.

Figure 26 is a cross section which illustrates how the existing tie-rod anchors could be re-used for anchorage of new walls.

Although the tie-rod elements can be re-used, the possible savings that could be realized are not significant. The excavation required for making the connection to the existing tie-rods at both ends and to install the new concrete anchor blocks leaves only a small portion of the wharf fill intact. Also, the spacing of tie-rods for the new walls (centre to centre of king piles) does not exactly match the spacing of the existing tie-rods. This means that a “transfer” waler is required in order to connect the new wall to the existing tie-rods which will increase costs for the new walls.

In view of the fact that potential savings are not significant, there are no advantages to re-using the existing tie-rod elements.

9.2 Wharf 402

The options investigated for Wharf 402 include: complete reconstruction with a new wall in front of the existing structure (Option 1 - "HZ wall system, Option 2 - steel pipe pile/ sheet pile combination wall and Option 3 – Berlin wall) and a shorter term repair solution (Option 4).

Details for the proposed new walls are discussed in the following.

9.2.1 Option 1 - New "HZ" Wall

Reconstruction of Wharf 402 using a new "HZ" wall system is similar to the "HZ" solution described for Wharves 401, 403 and 404.

A new wall is installed approximately 1.5 in front of the existing wharf face. The deck surface and fill materials behind the wharf would be removed to allow installation of new tie-rods and tie-rod anchor blocks. Existing services would have to be removed and replaced.

A cross section of the proposed reconstruction for wharf 402 is shown on Figure 27.

9.2.2 Option 2 - New Steel Pipe Pile/Sheet Pile Combination Wall

The proposed reconstruction in Option 2 is identical to Option 1 except that a steel pipe pile/ sheet pile combination wall is used instead of the "HZ" wall system.

9.2.3 Option 3 - New Berlin Wall

The proposed reconstruction in Option 3 is identical to Options 1 and 2 except that a Berlin wall is used instead of the "HZ" wall system or steel pipe pile/ sheet pile combination wall.

9.2.4 Option 4 - Repair/Modification of Existing Cope Wall

In Option 4, damaged sections of the deck slab immediately adjacent to the wharf face and the upper section of the cope wall are removed and repaired with new concrete. Localized deteriorated areas of the concrete cope wall face such as the cold joint between the base and stem of the cope wall are cleaned, chipped to sound surface and patched with new concrete.

The existing tire fenders are removed and new thicker tires that will increase the stand off distance between the hull of moored boats, and the timber cribwork below the cope wall are installed. All existing ladders are removed and new ladders that extend 0.6 m below chart datum elevation, i.e. two full rungs are added.

It is estimated that these repairs will remain effective for at least 15 years.

A typical cross section of the repairs for Option 4 is illustrated in Figure 28.

9.3 Theoretical Useful Life

For all steel elements in Option 1 and 2 walls a minimum steel thickness of 12.7 mm is used. Assuming a minimum steel thickness of 12.7 mm and using the corrosion rate determined on the basis of the existing steel sheet piling, the calculated theoretical useful life for a new structure is in the order of 40 years.

For Option 3 a minimum thickness of 12.7 mm is also used for the web and flanges of the steel king piles. Assuming that proper quality control measures are followed, a theoretical useful life of the intermediate concrete panels of at least 40 years can be achieved.

9.4 Cathodic Protection

The theoretical useful life for new steel structures (Options 1 and 2) can be extended by the installation of a cathodic protection system, i.e. impressed current. The cathodic protection system will prevent corrosion of the steel sheet piling which lies below the low water level. Protection of the steel sheet piling above low water level will require placement of a cover layer of concrete over the steel surface from the top of the structure to -1.2 m below chart datum elevation.

For steel sheet piling elements in a wall with cathodic protection and a concrete cover layer over the upper section of the walls, a theoretical life of at least 75 years is achievable provided that the system is properly designed and maintained throughout its service life.

The theoretical useful life of a Berlin wall structure can also be extended by cathodic protection, i.e. sacrificial anodes attached to the king piles. The upper section of the king piles can be protected by a factory applied “epoxy” coating.

10. Estimated Costs

The estimated total project costs for the reconstruction and repair options investigated for Wharves 401, 402, 403 and 404 are shown in Table 8. The estimated total project costs for full reconstruction options investigated are shown in Table 9. Summaries of the estimated costs for principal elements of the work are contained in Appendix A.

Table 8 - Estimated Total Project Costs for Reconstrucxtion and Repair

STRUCTURE	RECONSTRUCTION/REPAIR OPTION	AMOUNT
Wharf 401	Option 1 - New HZ Wall System	$ 8,091,667
Wharf 403	Option 1 - New HZ Wall System	$ 2,611,265
Wharf 404	Option 1 - New HZ Wall System	$ 850,500
	Total Wharves 401, 403 and 404	$ 11,553,432
Wharf 402	Option 4 - Repairs to Existing Cope Wall	$ 199,448
	Total Wharves 401, 402, 403 and 404	$ 11,752,880
Wharf 401	Option 2 - Steel Pipe Pile/Sheet Pile Combination Wall	$ 8,239,410
Wharf 403	Option 2 - Steel Pipe Pile/Sheet Pile Combination Wall	$ 2,550,155
Wharf 404	Option 2 - Steel Pipe Pile/Sheet Pile Combination Wall	$ 895,431
	Total Wharves 401, 403 and 404	$ 11,684,996
Wharf 402	Option 4 - Repairs to Existing Cope Wall	$ 199,448
	Total Wharves 401, 402, 403 and 404	$ 11,884,444
Wharf 401	Option 3 - New Berlin Wall and HZ Wall System	$ 7,832,983
Wharf 403	Option 3 - New Berlin Wall	$ 2,152,978
Wharf 404	Option 3 - New Berlin Wall	$ 760,757
	Total Wharves 401, 403 and 404	$ 10,746,718
Wharf 402	Option 4 - Repairs to Existing Cope Wall	$ 199,448
	Total Wharves 401, 402, 403 and 404	$ 10,946,165

Estimated construction costs in this report are based: on quantities of material derived from the conceptual designs of the reconstruction and/or repair options discussed in the previous sections; budget prices received from material suppliers; and unit prices for labour and materials for similar marine works in Atlantic Canada.

Development, refinement and possible changes to requirements for final design documents may impact on costs. As such, the presented costs should only be considered as providing a class “C” level of confidence.

The total project costs include a contingency amount equal to 15% of the total construction cost to account for unforeseen items. An amount of 16% of the total construction cost is also added to account for project management, engineering design and site supervision. The estimates do not contain any amounts related to requirements arising from environmental assessments.

Table 9 - Estimated Total Project Costs for Full Reconstruction

STRUCTURE	RECONSTRUCTION OPTION	AMOUNT
Wharf 401	Option 1 - New HZ Wall System	$ 8,091,667
Wharf 403	Option 1 - New HZ Wall System	$ 2,611,265
Wharf 404	Option 1 - New HZ Wall System	$ 850,500
	Total Wharves 401, 403 and 404	$ 11,553,432
Wharf 402	Option 1 - New HZ Wall System	$ 3,922,193
	Total Wharves 401, 402, 403 and 404	$ 15,475,626
Wharf 401	Option 2 - Steel Pipe Pile/Sheet Pile Combination Wall	$ 8,239,410
Wharf 403	Option 2 - Steel Pipe Pile/Sheet Pile Combination Wall	$ 2,550,155
Wharf 404	Option 2 - Steel Pipe Pile/Sheet Pile Combination Wall	$ 895,431
	Total Wharves 401, 403 and 404	$ 11,684,996
Wharf 402	Option 2 - Steel Pipe Pile/Sheet Pile Combination Wall	$ 3,951,150
	Total Wharves 401, 402, 403 and 404	$ 15,636,146
Wharf 401	Option 3 - New Berlin Wall and HZ Wall System	$ 7,832,983
Wharf 403	Option 3 - New Berlin Wall	$ 2,152,978
Wharf 404	Option 3 - New Berlin Wall	$ 760,757
	Total Wharves 401, 403 and 404	$ 10,746,718
Wharf 402	Option 3 - New Berlin Wall	$ 3,454,814
	Total Wharves 401, 402, 403 and 404	$ 14,201,532

Installation of cathodic protection systems will add to the capital cost of the proposed new structures. For Options 1 and 2 installation of “impressed current” cathodic protection and the addition of a concrete cover layer on the upper sections of the steel sheet pile walls will add approximately $ 3550/m for the HZ walls and $ 3960/m for the steel pipe pile/sheet walls. For Option 3, the additional cost for epoxy coating the steel king piles and initial installation of sacrificial anodes is approximately $ 700/m of wall. Note the sacrificial anodes will have to be replaced every 15 years at a cost of about $ 400/m of wall. The estimated total additional costs are shown in Table 10.

Cathodic protection systems will also result in additional annual maintenance costs (inspection, adjustments and repairs).

Table 10 - Additional Costs For Cathodic Protection

STRUCTURE	RECONSTRUCTION OPTION	AMOUNT
Wharf 401	Option 1 New HZ Wall System	$ 1,088,287
Wharf 403	Option 1 New HZ Wall System	$ 522,804
Wharf 402	Option 1 New HZ Wall System	$ 320,084
Wharf 404	Option 1 New HZ Wall System	$ 149,373
	Total Wharves 401, 402, 403 and 404	$ 2,080,548
STRUCTURE	**RECONSTRUCTION OPTION**	**AMOUNT**
Wharf 401	Option 2 Steel Pipe Pile/Sheet Pile Combination Wall	$ 1,216,376
Wharf 403	Option 2 Steel Pipe Pile/Sheet Pile Combination Wall	$ 584,337
Wharf 402	Option 2 Steel Pipe Pile/Sheet Pile Combination Wall	$ 357,758
Wharf 404	Option 2 Steel Pipe Pile/Sheet Pile Combination Wall	$ 166,954
	Total Wharves 401, 402, 403 and 404	$ 2,325,425
STRUCTURE	**RECONSTRUCTION/REPAIR OPTION**	**AMOUNT**
Wharf 401	Option 3 New Berlin Wall and HZ Wall System	$ 860,287
Wharf 403	Option 3 New Berlin Wall	$ 61,355
Wharf 402	Option 3 New Berlin Wall	$ 102,900
Wharf 404	Option 3 New Berlin Wall	$ 29,400
	Total Wharves 401, 402, 403 and 404	$ 1,053,682

11. Summary & Recommendations *(résumé et recommandations)*

11.1 Wharves *(Quais)* 401, 403 and 404

1) Wharf facilities 401, 403 and 404 are comprised of anchored steel sheet piling. The structures have been in service for 36 years. Assessments of remaining useful life indicate that the steel sheet piling walls in Wharves 401, 403 and 404 have already surpassed the theoretical useful life as predicted by empirical and analytical calculations.

   Les quais 401, 403 et 404 sont composés de rideaux de palplanches d'acier ancrés. Les ouvrages sont en service depuis 36 ans. Les évaluations de durée de vie utile indiquent que les palplanches d'acier des quais 401, 403 et 404 ont déjà excédé théoriquement leur vie utile comme l'indiquent les calculs empiriques et analytiques.

2) The steel sheet piling in Wharves 401, 403 and 404 is extensively perforated at chart datum level along the full length of the walls. Perforation of the steel sheet piling currently appears to be much more extensive in comparison with the observations contained in the diving report prepared for the Administration Portuaire de Shippagan in September 2004.

   Le rideau de palplanches d'acier des quais 401, 403 et 404 sont excessivement perforés au niveau du zéro des cartes sur la totalité de la longueur des murs. La perforation du rideau de palplanches semble beaucoup plus étendue à comparer aux observations du rapport de plongée préparé par l'Administration portuaire de Shippagan en septembre 2004.

3) Due to the extensive perforation at the low water level, repair of the steel sheet piling walls is not practicable. Furthermore, even if the steel sheet piling could be repaired at the low water level, calculations in the zone of maximum bending indicate that the deterioration of the steel sheet piling has reached the point where the strength of the walls is no longer adequate.

   En raison de la perforation excessive au niveau de mer basse, il n'est pas pratique d'effectuer des réparations au rideau de palplanches d'acier. De plus, même si le rideau de palplanches pouvait être réparé au niveau de mer basse, les calculs dans la partie la plus pliée indiquent que la détérioration a atteint un point où la résistance des murs n'est plus adéquate.

4) Deterioration of principal elements has reached the point where complete reconstruction of the facilities is required.

   La détérioration des principaux éléments a atteint un point où la reconstruction complète des installations est nécessaire.

5) The northeast corner of Wharf 401 requires immediate attention. The loss of fill materials at the northeast corner of Wharf 401 has created large cavities beneath the deck slab. The slab spans across the cavities created by the loss of fill materials. As

the deck slab was not intended to function as a "structural element", it is only a matter of time until collapse of this section of the deck slab occurs. Temporary repairs should be implemented in this area to prevent further loss of materials. Failure of the deck could cause damages to the electrical building and associated electrical services lines.

Le coin nord-est du quai 401 nécessite une attention immédiate. La perte de matériau de remblai du coin nord-est du quai 401 a laissé de larges cavités sous la dalle du tablier. La dalle s'étend sur les cavités laissées par la perte de matériau de remblai. Comme la dalle du tablier n'est pas conçue pour être un "élément structural", ce n'est qu'une question de temps avant que cette partie du tablier ne s'affaisse. Il faudrait effectuer des réparations temporaires dans cette partie pour prévenir la parte d'autre matériau. L'affaissement du tablier pourrait provoquer d'autres dommages à l'abri électrique et aux lignes d'alimentation en électricité.

6) Reconstruction of Wharves 401, 403 and 404 will involve the installation of new anchored walls placed approximately 1.5 m in front of the old walls.

La reconstruction des quais 401, 403 et 404 nécessitera l'installation de nouveaux murs ancrés placés à environ 1,5 mètre devant les anciens murs.

7) Due to deficiencies in the existing anchor wall, re-use of the existing tie-rod anchoring system is not recommended except for the new wall along Wharf 404. New tie-rods and anchor blocks are required along Wharves 401 and 403.

En raison des faiblesses du mur d'ancrage actuel, il n'est pas recommandé de réutiliser le système de tiges de fixation d'ancrage sauf pour le nouveau mur le long du quai 404. De nouvelles tiges d'ancrage et de nouveaux blocs d'ancrage seront nécessaires le long des quais 401 et 403.

8) Three possible solutions have been developed for reconstruction of the walls. Option 1 involves construction of an "HZ" wall system (H-pile "king" piles with intermediate steel sheet piles). Option 2 involves construction of a steel pipe pile/sheet pile combination wall (steel pipe "king" piles with intermediate steel sheet piles). Option 3 involves construction of a Berlin wall (steel king piles with intermediate pre-cast concrete panels spanning between king piles). All of the options provide the same level of service for permissible loading, design dredged depth and expected service life.

Trois options possibles ont été élaborées pour la reconstruction des murs. L'Option 1 implique la construction d'un système de mur en "HZ" (poutres principales en H avec palplanches d'acier intermédiaires). L'Option 2 implique la construction d'une combinaison de mur de tuyaux d'acier et de palplanches d'acier (poutres principales en tuyaux d'acier et palplanches d'acier intermédiaires). L'Option 3 implique la construction du mur berlinois (poutres d'acier et panneaux de béton préfabriqués s'étendant entre les poutres principales). Toutes les options assurent le même niveau de service pour les charges permissibles, la profondeur draguée et l'espérance de durée de vie.

9) If geotechnical investigations confirm that competent bedrock is close to the existing harbour bottom, Option 3 – New Berlin Wall is the least expensive solution. For reconstruction of the walls in Wharves 401, 403 and 404 and repair of Wharf 402, the estimated cost for Option 3 is approximately $ 800,000 and $ 900,000 less than Options 1 and 2 respectively.

   Si les reconnaissances géotechniques confirment la présence d'une assise rocheuse solide près du fond marin existant, l'Option 3, le nouveau mur berlinois représente la solution la moins coûteuse. Pour la reconstruction des murs des quais 401, 403 et 404 et les réparations au quai 402, les coûts de l'Option 3 sont d'environ 800,000$ et 900,000$ de moins que les Options 1 et 2 respectivement.

10) Options 1 or 2 can be implemented if conditions are not appropriate for Berlin wall construction. If geotechnical investigations confirm that conditions along Wharves 401, 403 and 404 are similar to the conditions encountered for the Old North Wharf reconstruction undertaken in 2003, installation of an "HZ" wall system (Option 1) is recommended. If geotechnical investigations indicate that driving piles into the underlying bedrock/mudstone layers will be more difficult, a steel pipe pile/sheet pile combination wall is recommended. Using pipe sections for the "king" piles allows drilling inside of the pipe to facilitate advancement of the pile toe.

    Les Options 1 ou 2 peuvent être réalisées si les conditions ne sont pas appropriées pour la construction du mur berlinois. Si les reconnaissances géotechniques confirment que les conditions le long des quais 401, 403 et 404 sont similaires à celles rencontrées lors de la reconstruction du quai nord entreprise en 2003, l'installation d'un système de mur en "HZ" (Option 1) est recommandée. Si les reconnaissances géotechniques indiquent que l'enfoncement des poutres dans l'assise rocheuse/les couches de mudstone sera plus difficile, alors la combinaison tuyaux d'acier/palplanches d'acier est recommandée. Le fait d'utiliser des sections de tuyaux en guise de poutres principales permet le perçage à l'intérieur du tuyau pour faciliter l'enfoncement de l'extrémité de la poutre.

11) A minimum steel thickness of 12.7 mm is recommended for all wall elements (H-piles, pipe piles and steel sheet piles). A minimum steel thickness of 12.7 mm will provide a service life of at least 40 years for the new structures.

    Il est recommandé d'utiliser de l'acier d'épaisseur minimale de 12,7 mm pour tous les éléments (poutres H, tuyaux et palplanches d'acier). Cette épaisseur de 12,7 mm assurera une vie utile d'au moins 40 ans pour les nouveaux ouvrages.

12) For Options 1 and 2, the service life of the structures can be extended to at least 75 years if cathodic protection is installed and a cover layer of concrete is placed over the steel surface from the top of the structure to -1.2 m below chart datum elevation. For Option 3, the service life of the structure can be extended if sacrificial anodes are installed on all king piles and replaced every 15 years (approx.) and the king pile surfaces are treated with a factory applied epoxy coating.

Pour les Options 1 et 2, la durée de service des ouvrages peut être prolongée jusqu'à au moins 75 ans si une protection cathodique est installée et une couche de béton est posée sur la surface d'acier du sommet de la structure jusqu'à -1,2m sous l'élévation du zéro des cartes. Pour l'Option 3, la durée de service de l'ouvrage peut être prolongée si des anodes sacrificielles sont installées sur toutes les poutres principales à tous les 15 ans (environ) et si la surface des poutres principales est traitée avec une couche d'époxy appliquée en usine.

13) The additional cost for cathodic protection (impressed current) including a concrete cover layer over the upper section of the steel sheet pile walls is approximately $ 3,550/m with an "HZ" wall system (Option 1) and $ 3,960/m with a steel pipe pile/sheet pile combination wall (Option 2). The additional cost for cathodic protection of the Berlin wall (Option 3) using sacrificial anodes is approximately $ 700/m of wall. The sacrificial anodes would have to be replaced every 15 years at a cost of about $ 400/m of wall.

Le coût supplémentaire de la protection cathodique (courant appliqué) incluant une couche protectrice de béton sur la partie supérieure des murs de palplanches d'acier est d'environ 3,550$/m pour un système mural en "HZ" (Option 1) et de 3,960$/m pour la combinaison tuyau d'acier/palplanche d'acier (Option 2). Le coût supplémentaire de la protection cathodique du mur berlinois (Option 3) avec des anodes sacrificielles est d'environ 700$/m de mur. Les anodes sacrificielles devront être remplacées tous les 15 ans au coût d'environ 400$/m de mur.

11.2 Wharf *(Quai)* 402

1) Wharf facility 402 is comprised of ballasted timber cribwork and reinforced concrete cope wall. This structure has also been in service for 36 years. Results of empirical assessments indicate that Wharf 402 has already surpassed its theoretical useful life. However, the observed condition of the cribwork and cope wall does not support the empirical assessments.

Le quai 402 est composé d'un ouvrage en caisson de bois lesté et renforcé d'un mur de couronnement de béton. Cet ouvrage est également en service depuis 36 ans. Les résultats des évaluations empiriques indiquent que le quai 402 a déjà excédé théoriquement sa durée de vie utile. Toutefois, l'état observé du caisson de bois et du mur de couronnement ne coïncide pas avec les évaluations empiriques.

2) Although some repair/ maintenance of the cope wall is required, Wharf 402 has not reached the end of its functional life. Based on the observed conditions and satisfactory results of stability analyses, Wharf 402 can be expected to remain functional for at least 15 more years.

Bien que certaines réparations et un certain entretien du mur de couronnement soient nécessaires, le quai 402 n'a pas atteint sa fin de vie utile. D'après les conditions observées et les résultats satisfaisants des analyses de stabilité, le quai 402 peut demeurer fonctionnel pour au moins les 15 prochaines années.

3) The repair/ maintenance work for the cope wall includes: removal and repair of the cracked and broken sections of the concrete curb and top of cope wall; removal and replacement of broken sections of the concrete deck immediately behind the cope wall; repair of deteriorated areas at the base slab/ stem interface; and installation of new larger rubber tire fenders to keep the boat hulls from rubbing on the cribwork face.

   La réparation/l'entretien du mur de couronnement comprend l'enlèvement et la réparation des parties fissurées ou brisées du muret de béton et du dessus du mur de couronnement, l'enlèvement et le remplacement des parties brisées du tablier de béton immédiatement derrière le mur de couronnement, la réparation des parties détériorées à la jonction de la dalle-support et des pieds et l'installation de nouvelles défenses de pneus de caoutchouc de plus grandes dimensions pour empêcher la coque des navires de frotter la face du caisson.

4) The estimated cost of repairs outlined above plus the installation of new steel ladders that will extend at least 0.6 m below chart datum elevation is $ 200,000.

   L'estimation des coûts de réparation décrits ci-dessus plus l'installation de nouvelles échelles de béton descendant au moins à 0,6 m sous le zéro des cartes totalise 200,000$.

5) There is some concern with the sheared bolts that were found along the top section of the cribwork just below the underside of the cope wall base. Although it can be rationalized that the horizontal loading in this area of the cribwork is relatively low, there is no sure way of determining whether or not the face timbers will separate from the cribwork structure. A program of regular annual inspection of Wharf 402 (above water and submerged sections) should be implemented to ensure that the cribwork structure remains functional at the location of the sheared bolts.

   Certaines préoccupations es présentent au sujet des boulons cisaillés retrouvés le long de la partie supérieure du caisson juste sous le côté inférieur de la base du mur de couronnement. Bien qu'on puisse avancer que la charge horizontale dans cette partie du caisson est relativement basse, il n'y a pas de manière certaine de déterminer si oui ou non les pièces de bois de la face vont se séparer de l'ossature du caisson. Un programme d'inspection régulière annuelle du quai 402 (parties émergées et submergées) devrait être mis en place pour s'assurer que l'ouvrage demeure fonctionnel là où les boulons sont cisaillés.

6) Future reconstruction of Wharf 402 will also involve the installation of a new anchored wall placed approximately 1.5 m in front of the existing structure face.

   La reconstruction du quai 402 impliquera également l'installation d'un nouveau mur ancré placé à environ 1,5 mètre devant le mur actuel.

7) Option 3 – New Berlin Wall is the least expensive solution if geotechnical investigations confirm that competent bedrock is close to the existing harbour bottom.

The estimated reconstruction cost of for Option 3 is approximately $ 500,000 less than Options 1 or 2.

L'Option 3 – Nouveau mur berlinois, représente la solution la moins chère si les reconnaissances géotechniques confirment la présence d'une assise rocheuse assez solide près du fond marin actuel. Les coûts estimés de reconstruction de l'Option 3 sont d'environ 500,00$ de moins que les Options 1 et 2.

11.3 Additional Investigations *(reconnaissances supplémentaires)*

1) Detailed geotechnical investigations along the walls of Wharves 401, 402, 403 and 404 should be undertaken before proceeding with contract documents for reconstruction.

   Des reconnaissances géotechniques supplémentaires détaillées le long des murs des quais 401, 402, 403 et 404 devraient être prises avant d'aller de l'avant avec la documentation de contrat en vue d'une reconstruction.

Appendix A – Cost Estimate Details

TABLE A1

SHIPPAGAN HARBOUR
CLASS "C" COST ESTIMATE

WHARF 401
OPTION 1 HZ WALL SYSTEM

	Item	Unit	Estimated Quantity	Estimated Unit Cost		Amount
1	Site Organization	Global	n/a	n/a	$	294,135
2	Pavement Demolition and Disposal	m^3	514.0	$ 100.00	$	51,400
3	Excavation and Disposal	m^3	10,305.0	$ 10.00	$	103,050
4	Supply Steel HZ King Piles	m	2,898.0	$ 579.14	$	1,678,348
5	Install Steel HZ King Ppiles	m	2,898.0	$ 150.00	$	434,700
6	Supply Intermediate Steel Sheet Piles	m^2	3,663.2	$ 349.69	$	1,280,984
7	Install Intermediate Steel Sheet Piles	m^2	3,663.2	$ 75.00	$	274,740
8	Supply and Install Steel HZ Pile Protection Points	unit	164	$ 500.00	$	82,000
9	Supply and Place Reinforced Concrete Cope Wall	m^3	296	$ 800.00	$	236,800
10	Supply and Install Type 1 Tie-Rod Anchors	unit	90.0	$ 2,290.00	$	206,100
11	Supply and Install Type 2 Tie-Rod Anchors	unit	37.0	$ 2,580.00	$	95,460
12	Supply and Install Pre-cast Concrete Anchor Blocks	unit	90.0	$ 3,000.00	$	270,000
13	Supply and Place Quarry Run Rock Fill	tonnes	17866	$ 15.00	$	267,990
14	Supply and Place Granular Sub Base	tonnes	2600	$ 17.50	$	45,500
15	Supply and Place Granular Base	tonnes	3900	$ 17.50	$	68,250
16	Supply and Place Cast-in-place Deck Slab	m^3	889	$ 400.00	$	355,600
17	Supply and Install Steel HSS Curb	m	307.5	$ 105.00	$	32,288
18	Supply and Install Steel Guide Rail and Posts	m	120	$ 75.00	$	9,000
19	Supply and Install New Steel Ladders	unit	16	$ 3,000.00	$	48,000
20	Supply and Install Bollards	unit	16	$ 2,500.00	$	40,000
21	Supply and Install Rubber Tire Fenders	unit	205	$ 500.00	$	102,500
22	Electrical Services and Lighting	Global	-	-	$	100,000
23	Water Supply Services	Global	-	-	$	100,000
				Construction Cost	$	6,176,845
				Contingencies 15%	$	926,527
				Engineering and Site Supervision 16%	$	988,295
				Estimated Total Project Cost	$	8,091,667

TABLE A2

SHIPPAGAN HARBOUR
CLASS "C" COST ESTIMATE

WHARF 401
OPTION 2 STEEL PIPE PILE/SHEET PILE COMBINATION WALL

	Item	Unit	Estimated Quantity	Estimated Unit Cost		Amount
1	Site Organization	Global	n/a	n/a	$	299,506
2	Pavement Demolition and Disposal	m^3	514.0	$ 100.00	$	51,400
3	Excavation and Disposal	m^3	10,305.0	$ 10.00	$	103,050
4	Supply Steel Pipe King Piles	m	2,279.0	$ 787.40	$	1,794,485
5	Install Steel Pipe King Ppiles	m	2,279.0	$ 300.00	$	683,700
6	Supply Intermediate Steel Sheet Piles	m^2	2,828.6	$ 349.69	$	989,133
7	Install Intermediate Steel Sheet Piles	m^2	2,828.6	$ 75.00	$	212,145
8	Supply and Install Steel Pipe Pile Protection Points	unit	129	$ 500.00	$	64,500
9	Supply and Place Concrete Fill For Pipe Piles	m^3	440	$ 500.00	$	220,000
10	Supply and Place Reinforced Concrete Cope Wall	m^3	296	$ 800.00	$	236,800
11	Supply and Install Type 1 Tie-Rod Anchors	unit	67.0	$ 2,640.00	$	176,880
12	Supply and Install Type 2 Tie-Rod Anchors	unit	30.0	$ 2,930.00	$	87,900
13	Supply and Install Pre-cast Concrete Anchor Blocks	unit	67.0	$ 3,000.00	$	201,000
14	Supply and Place Quarry Run Rock Fill	tonnes	17866	$ 15.00	$	267,990
15	Supply and Place Granular Sub Base	tonnes	2600	$ 17.50	$	45,500
16	Supply and Place Granular Base	tonnes	3900	$ 17.50	$	68,250
17	Supply and Place Cast-in-place Deck Slab	m^3	889	$ 400.00	$	355,600
18	Supply and Install Steel HSS Curb	m	307.5	$ 105.00	$	32,288
19	Supply and Install Steel Guide Rail and Posts	m	120	$ 75.00	$	9,000
20	Supply and Install New Steel Ladders	unit	16	$ 3,000.00	$	48,000
21	Supply and Install Bollards	unit	16	$ 2,500.00	$	40,000
22	Supply and Install Rubber Tire Fenders	unit	205	$ 500.00	$	102,500
23	Electrical Services and Lighting	Global	-	-	$	100,000
24	Water Supply Services	Global	-	-	$	100,000
				Construction Cost	$	6,289,626
				Contingencies 15%	$	943,444
				Engineering and Site Supervision 16%	$	1,006,340
				Estimated Total Project Cost	$	8,239,410

TABLE A3

SHIPPAGAN HARBOUR
CLASS "C" COST ESTIMATE

WHARF 401
OPTION 3 BERLIN WALL AND HZ WALL SYSTEM

	Item	Unit	Estimated Quantity	Estimated Unit Cost		Amount
1	Site Organization	Global	n/a	n/a	$	284,732
2	Pavement Demolition and Disposal	m^3	514.0	$ 100.00	$	51,400
3	Excavation and Disposal	m^3	10,305.0	$ 10.00	$	103,050
4	Supply Steel King Piles (Berlin Wall)	m	513.5	$ 318.00	$	163,293
5	Drill Sockets and Install King Piles (Berlin Wall)	unit	33.0	$ 3,680.00	$	121,440
6	Place Tremie Concrete In King Pile Sockets	m^3	78.3	$ 500.00	$	39,150
7	Supply Pre-Cast Concrete Slabs	m^2	800.0	$ 280.00	$	224,000
8	Install Pre-Cast Concrete Slabs	m^2	800.0	$ 65.00	$	52,000
9	Tremie Concrete Seal At Base of Pre-Cast Slabs	m^3	82.5	$ 350.00	$	28,875
10	Supply and Place Scour Protection For Berlin Wall	tonnes	592.0	$ 40.00	$	23,680
11	Supply Steel HZ King Piles	m	2,206.0	$ 579.14	$	1,277,583
12	Install Steel HZ King Ppiles	m	2,206.0	$ 150.00	$	330,900
13	Supply Intermediate Steel Sheet Piles	m^2	3,014.0	$ 349.69	$	1,053,966
14	Install Intermediate Steel Sheet Piles	m^2	3,014.0	$ 75.00	$	226,050
15	Supply and Install Steel HZ Pile Protection Points	unit	121	$ 500.00	$	60,500
16	Supply and Place Reinforced Concrete Cope Wall	m^3	296	$ 800.00	$	236,800
17	Supply and Install Type 1 Tie-Rod Anchors	unit	78.0	$ 2,290.00	$	178,620
18	Supply and Install Type 2 Tie-Rod Anchors	unit	37.0	$ 2,580.00	$	95,460
19	Pre-cast Concrete Anchor Blocks Type 1	unit	45.0	$ 3,000.00	$	135,000
20	Pre-cast Concrete Anchor Blocks Type 2	unit	33.0	$ 3,750.00	$	123,750
21	Supply and Place Quarry Run Rock Fill	tonnes	17866	$ 15.00	$	267,990
22	Supply and Place Granular Sub Base	tonnes	2600	$ 17.50	$	45,500
23	Supply and Place Granular Base	tonnes	3900	$ 17.50	$	68,250
24	Supply and Place Cast-in-place Deck Slab	m^3	889	$ 400.00	$	355,600
25	Supply and Install Steel HSS Curb	m	307.5	$ 105.00	$	32,288
26	Supply and Install Steel Guide Rail and Posts	m	120	$ 75.00	$	9,000
27	Supply and Install New Steel Ladders	unit	16	$ 3,000.00	$	48,000
28	Supply and Install Bollards	unit	16	$ 2,500.00	$	40,000
29	Supply and Install Rubber Tire Fenders	unit	205	$ 500.00	$	102,500
30	Electrical Services and Lighting	Global	-	-	$	100,000
31	Water Supply Services	Global	-	-	$	100,000
				Construction Cost	$	5,979,376
				Contingencies 15%	$	896,906
				Engineering and Site Supervision 16%	$	956,700
				Estimated Total Project Cost	$	7,832,983

TABLE A4

SHIPPAGAN HARBOUR
CLASS "C" COST ESTIMATE

WHARF 402
OPTION 1 HZ WALL SYSTEM

	Item	Unit	Estimated Quantity	Estimated Unit Cost		Amount
1	Site Organization	Global	n/a	n/a	$	142,573
2	Pavement Demolition and Disposal	m^3	485.0	$ 100.00	$	48,500
3	Excavation and Disposal	m^3	8,893.0	$ 10.00	$	88,930
4	Supply Steel HZ King Piles	m	1,185.0	$ 579.14	$	686,281
5	Install Steel HZ King Ppiles	m	1,185.0	$ 150.00	$	177,750
6	Supply Intermediate Steel Sheet Piles	m^2	1,092.0	$ 349.69	$	381,861
7	Install Intermediate Steel Sheet Piles	m^2	1,092.0	$ 75.00	$	81,900
8	Supply and Install Steel HZ Pile Protection Points	unit	79	$ 500.00	$	39,500
9	Supply and Place Reinforced Concrete Cope Wall	m^3	141	$ 800.00	$	112,800
10	Supply and Install Type 1 Tie-Rod Anchors	unit	79.0	$ 2,290.00	$	180,910
11	Supply and Install Pre-cast Concrete Anchor Blocks	unit	79.0	$ 3,000.00	$	237,000
12	Supply and Place Quarry Run Rock Fill	tonnes	13107	$ 15.00	$	196,605
13	Supply and Place Granular Sub Base	tonnes	1892	$ 17.50	$	33,110
14	Supply and Place Granular Base	tonnes	2838	$ 17.50	$	49,665
15	Supply and Place Cast-in-place Deck Slab	m^3	646.8	$ 400.00	$	258,720
16	Supply and Install Steel HSS Curb	m	147	$ 105.00	$	15,435
17	Supply and Install New Steel Ladders	unit	7	$ 3,000.00	$	21,000
18	Supply and Install Bollards	unit	7	$ 2,500.00	$	17,500
19	Supply and Install Rubber Tire Fenders	unit	98	$ 500.00	$	49,000
20	Electrical Services and Lighting	Global	-	-	$	75,000
21	Water Supply Services	Global	-	-	$	100,000
				Construction Cost	$	2,994,041
				Contingencies 15%	$	449,106
				Engineering and Site Supervision 16%	$	479,047
				Estimated Total Project Cost	$	3,922,193

TABLE A5

SHIPPAGAN HARBOUR
CLASS "C" COST ESTIMATE

WHARF 402
OPTION 2 STEEL PIPE PILE/SHEET PILE COMBINATION WALL

	Item	Unit	Estimated Quantity	Estimated Unit Cost		Amount
1	Site Organization	Global	n/a	n/a	$	143,626
2	Pavement Demolition and Disposal	m^3	485.0	$ 100.00	$	48,500
3	Excavation and Disposal	m^3	8,893.0	$ 10.00	$	88,930
4	Supply Steel Pipe King Piles	m	900.0	$ 787.40	$	708,660
5	Install Steel Pipe King Ppiles	m	900.0	$ 300.00	$	270,000
6	Supply Intermediate Steel Sheet Piles	m^2	826.0	$ 349.69	$	288,844
7	Install Intermediate Steel Sheet Piles	m^2	826.0	$ 75.00	$	61,950
8	Supply and Install Steel Pipe Pile Protection Points	unit	60	$ 600.00	$	36,000
9	Supply and Place Concrete Fill For Pipe Piles	m^3	205	$ 500.00	$	102,400
10	Supply and Place Reinforced Concrete Cope Wall	m^3	141	$ 800.00	$	112,800
11	Supply and Install Type 1 Tie-Rod Anchors	unit	60.0	$ 2,640.00	$	158,400
12	Supply and Install Pre-cast Concrete Anchor Blocks	unit	60.0	$ 3,000.00	$	180,000
13	Supply and Place Quarry Run Rock Fill	tonnes	13107	$ 15.00	$	196,605
14	Supply and Place Granular Sub Base	tonnes	1892	$ 17.50	$	33,110
15	Supply and Place Granular Base	tonnes	2838	$ 17.50	$	49,665
16	Supply and Place Cast-in-place Deck Slab	m^3	646.8	$ 400.00	$	258,720
17	Supply and Install Steel HSS Curb	m	147	$ 105.00	$	15,435
18	Supply and Install New Steel Ladders	unit	7	$ 3,000.00	$	21,000
19	Supply and Install Bollards	unit	7	$ 2,500.00	$	17,500
20	Supply and Install Rubber Tire Fenders	unit	98	$ 500.00	$	49,000
21	Electrical Services and Lighting	Global	-	-	$	75,000
22	Water Supply Services	Global	-	-	$	100,000
				Construction Cost	$	3,016,145
				Contingencies 15%	$	452,422
				Engineering and Site Supervision 16%	$	482,583
				Estimated Total Project Cost	$	3,951,150

TABLE A6

SHIPPAGAN HARBOUR
CLASS "C" COST ESTIMATE

WHARF 402
OPTION 3 BERLIN WALL

	Item	Unit	Estimated Quantity	Estimated Unit Cost		Amount
1	Site Organization	Global	n/a	n/a	$	125,584
2	Pavement Demolition and Disposal	m^3	485.0	$ 100.00	$	48,500
3	Excavation and Disposal	m^3	8,893.0	$ 10.00	$	88,930
4	Supply Steel King Piles (Berlin Wall)	m	861.4	$ 318.00	$	273,925
5	Drill Sockets and Install King Piles (Berlin Wall)	unit	59.0	$ 3,680.00	$	217,120
6	Place Tremie Concrete In King Pile Sockets	m^3	145.3	$ 500.00	$	72,650
7	Supply Pre-Cast Concrete Slabs	m^2	1,286.3	$ 280.00	$	360,164
8	Install Pre-Cast Concrete Slabs	m^2	1,286.3	$ 65.00	$	83,610
9	Supply and Place Scour Protection For Berlin Wall	tonnes	714.0	$ 40.00	$	28,560
10	Tremie Concrete Seal At Base of Pre-Cast Slabs	m^3	151.5	$ 350.00	$	53,025
11	Supply and Place Reinforced Concrete Cope Wall	m^3	141	$ 800.00	$	112,800
12	Supply and Install Type 1 Tie-Rod Anchors	unit	59.0	$ 2,290.00	$	135,110
13	Supply and Install Pre-cast Concrete Anchor Blocks	unit	59.0	$ 3,750.00	$	221,250
14	Supply and Place Quarry Run Rock Fill	tonnes	13107	$ 15.00	$	196,605
15	Supply and Place Granular Sub Base	tonnes	1892	$ 17.50	$	33,110
16	Supply and Place Granular Base	tonnes	2838	$ 17.50	$	49,665
17	Supply and Place Cast-in-place Deck Slab	m^3	646.8	$ 400.00	$	258,720
18	Supply and Install Steel HSS Curb	m	147	$ 105.00	$	15,435
19	Supply and Install New Steel Ladders	unit	7	$ 3,000.00	$	21,000
20	Supply and Install Bollards	unit	7	$ 2,500.00	$	17,500
21	Supply and Install Rubber Tire Fenders	unit	98	$ 500.00	$	49,000
22	Electrical Services and Lighting	Global	-	-	$	75,000
23	Water Supply Services	Global	-	-	$	100,000
				Construction Cost	$	2,637,263
				Contingencies 15%	$	395,589
				Engineering and Site Supervision 16%	$	421,962
				Estimated Total Project Cost	$	3,454,814

TABLE A7

SHIPPAGAN HARBOUR
CLASS "C" COST ESTIMATE

WHARF 402
OPTION 4 REPAIR

	Item	Unit	Estimated Quantity	Estimated Unit Cost		Amount
1	Site Organization	Global	n/a	n/a	$	7,250
2	Pavement and Curb Demolition	Global	-	-	$	50,000
3	Chip and Patch Concrete at Cold Joint	Global	-	-	$	25,000
4	Supply and Install New Ladders	unit	7.0	$ 3,000.00	$	21,000
5	Supply and Install New Fenders	unit	98.0	$ 500.00	$	49,000
				Construction Cost	$	152,250
				Contingencies 15%	$	22,838
				Engineering and Site Supervision 16%	$	24,360
				Estimated Total Project Cost	$	199,448

TABLE A8

SHIPPAGAN HARBOUR
CLASS "C" COST ESTIMATE

WHARF 403
OPTION 1 HZ WALL SYSTEM

	Item	Unit	Estimated Quantity	Estimated Unit Cost	Amount
1	Site Organization	Global	n/a	n/a	$ 94,921
2	Pavement Demolition and Disposal	m^3	289.0	$ 100.00	$ 28,900
3	Excavation and Disposal	m^3	3,332.0	$ 10.00	$ 33,320
4	Supply Steel HZ King Piles	m	720.0	$ 579.14	$ 416,981
5	Install Steel HZ King Ppiles	m	720.0	$ 150.00	$ 108,000
6	Supply Intermediate Steel Sheet Piles	m^2	723.8	$ 349.69	$ 253,106
7	Install Intermediate Steel Sheet Piles	m^2	723.8	$ 75.00	$ 54,285
8	Supply and Install Steel HZ Pile Protection Points	unit	48	$ 500.00	$ 24,000
9	Supply and Place Reinforced Concrete Cope Wall	m^3	84	$ 800.00	$ 67,280
10	Supply and Install Type 1 Tie-Rod Anchors	unit	31.0	$ 2,290.00	$ 70,990
11	Supply and Install Type 2 Tie-Rod Anchors	unit	17.0	$ 2,000.00	$ 34,000
12	Supply and Install Pre-cast Concrete Anchor Blocks	unit	31.0	$ 3,000.00	$ 93,000
13	Supply and Install Steel Pipe Anchor Piles	m	255.0	$ 787.40	$ 200,787
14	Supply and Place Concrete Fill For Pipe Piles	m^3	255.0	$ 500.00	$ 127,500
15	Supply and Place Quarry Run Rock Fill	tonnes	5199	$ 15.00	$ 77,985
16	Supply and Place Granular Sub Base	tonnes	820	$ 17.50	$ 14,350
17	Supply and Place Granular Base	tonnes	1230	$ 17.50	$ 21,525
18	Supply and Place Cast-in-place Deck Slab	m^3	280.5	$ 400.00	$ 112,200
19	Supply and Install Steel HSS Curb	m	87.65	$ 105.00	$ 9,203
20	Supply and Install New Steel Ladders	unit	4	$ 3,000.00	$ 12,000
21	Supply and Install Bollards	unit	4	$ 2,500.00	$ 10,000
22	Supply and Install Rubber Tire Fenders	unit	58	$ 500.00	$ 29,000
23	Electrical Services and Lighting	Global	-	-	$ 50,000
24	Water Supply Services	Global	-	-	$ 50,000
				Construction Cost	$ 1,993,332
				Contingencies 15%	$ 299,000
				Engineering and Site Supervision 16%	$ 318,933
				Estimated Total Project Cost	$ 2,611,265

TABLE A9

SHIPPAGAN HARBOUR
CLASS "C" COST ESTIMATE

WHARF 403
OPTION 2 STEEL PIPE PILE/SHEET PILE COMBINATION WALL

	Item	Unit	Estimated Quantity	Estimated Unit Cost		Amount
1	Site Organization	Global	n/a	n/a	$	92,699
2	Pavement Demolition and Disposal	m^3	289.0	$ 100.00	$	28,900
3	Excavation and Disposal	m^3	3,332.0	$ 10.00	$	33,320
4	Supply Steel Pipe King Piles	m	608.0	$ 787.40	$	478,739
5	Install Steel Pipe King Ppiles	m	608.0	$ 300.00	$	182,400
6	Supply Intermediate Steel Sheet Piles	m^2	569.8	$ 349.69	$	199,253
7	Install Intermediate Steel Sheet Piles	m^2	569.8	$ 75.00	$	42,735
8	Supply and Install Steel Pipe Pile Protection Points	unit	38	$ 600.00	$	22,800
9	Supply and Place Concrete Fill For Pipe Piles	m^3	174	$ 500.00	$	87,200
10	Supply and Place Reinforced Concrete Cope Wall	m^3	84	$ 800.00	$	67,280
11	Supply and Install Type 1 Tie-Rod Anchors	unit	25.0	$ 2,640.00	$	66,000
12	Supply and Install Type 2 Tie-Rod Anchors	unit	13.0	$ 2,350.00	$	30,550
13	Supply and Install Pre-cast Concrete Anchor Blocks	unit	25.0	$ 3,000.00	$	75,000
14	Supply and Install Steel Pipe Anchor Piles	m	195.0	$ 787.40	$	153,543
15	Supply and Place Quarry Run Rock Fill	tonnes	5199	$ 15.00	$	77,985
16	Supply and Place Granular Sub Base	tonnes	820	$ 17.50	$	14,350
17	Supply and Place Granular Base	tonnes	1230	$ 17.50	$	21,525
18	Supply and Place Cast-in-place Deck Slab	m^3	280.5	$ 400.00	$	112,200
19	Supply and Install Steel HSS Curb	m	87.65	$ 105.00	$	9,203
20	Supply and Install New Steel Ladders	unit	4	$ 3,000.00	$	12,000
21	Supply and Install Bollards	unit	4	$ 2,500.00	$	10,000
22	Supply and Install Rubber Tire Fenders	unit	58	$ 500.00	$	29,000
23	Electrical Services and Lighting	Global	-	-	$	50,000
24	Water Supply Services	Global	-	-	$	50,000
				Construction Cost	$	1,946,683
				Contingencies 15%	$	292,002
				Engineering and Site Supervision 16%	$	311,469
				Estimated Total Project Cost	$	2,550,155

TABLE A10

SHIPPAGAN HARBOUR
CLASS "C" COST ESTIMATE

WHARF 403
OPTION 3 BERLIN WALL

	Item	Unit	Estimated Quantity	Estimated Unit Cost		Amount
1	Site Organization	Global	n/a	n/a	$	78,262
2	Pavement Demolition and Disposal	m^3	289.0	$ 100.00	$	28,900
3	Excavation and Disposal	m^3	3,332.0	$ 10.00	$	33,320
4	Supply Steel King Piles (Berlin Wall)	m	544.6	$ 318.00	$	173,183
5	Drill Sockets and Install King Piles (Berlin Wall)	unit	35.0	$ 3,680.00	$	128,800
6	Place Tremie Concrete In King Pile Sockets	m^3	86.1	$ 500.00	$	43,050
7	Supply Pre-Cast Concrete Slabs	m^2	873.0	$ 280.00	$	244,440
8	Install Pre-Cast Concrete Slabs	m^2	873.0	$ 65.00	$	56,745
9	Supply and Place Scour Protection For Berlin Wall	tonnes	649.0	$ 40.00	$	25,960
10	Tremie Concrete Seal At Base of Pre-Cast Slabs	m^3	90.4	$ 350.00	$	31,640
11	Supply and Place Reinforced Concrete Cope Wall	m^3	84	$ 800.00	$	67,280
12	Supply and Install Type 1 Tie-Rod Anchors	unit	23.0	$ 2,290.00	$	52,670
13	Supply and Install Type 2 Tie-Rod Anchors	unit	12.0	$ 2,000.00	$	24,000
14	Supply and Install Pre-cast Concrete Anchor Blocks	unit	23.0	$ 3,750.00	$	86,250
15	Supply and Install Steel Pipe Anchor Piles	m	180.0	$ 787.40	$	141,732
16	Supply and Place Concrete Fill For Pipe Piles	m^3	82.0	$ 500.00	$	41,000
17	Supply and Place Quarry Run Rock Fill	tonnes	5199	$ 15.00	$	77,985
18	Supply and Place Granular Sub Base	tonnes	820	$ 17.50	$	14,350
19	Supply and Place Granular Base	tonnes	1230	$ 17.50	$	21,525
20	Supply and Place Cast-in-place Deck Slab	m^3	280.5	$ 400.00	$	112,200
21	Supply and Install Steel HSS Curb	m	87.65	$ 105.00	$	9,203
22	Supply and Install New Steel Ladders	unit	4	$ 3,000.00	$	12,000
23	Supply and Install Bollards	unit	4	$ 2,500.00	$	10,000
24	Supply and Install Rubber Tire Fenders	unit	58	$ 500.00	$	29,000
25	Electrical Services and Lighting	Global	-	-	$	50,000
26	Water Supply Services	Global	-	-	$	50,000
				Construction Cost	$	1,643,495
				Contingencies 15%	$	246,524
				Engineering and Site Supervision 16%	$	262,959
				Estimated Total Project Cost	$	2,152,978

TABLE A11

SHIPPAGAN HARBOUR
CLASS "C" COST ESTIMATE

WHARF 404
OPTION 1 HZ WALL SYSTEM

	Item	Unit	Estimated Quantity	Estimated Unit Cost		Amount
1	Site Organization	Global	n/a	n/a	$	30,916
2	Excavation and Disposal	m^3	390.0	$ 10.00	$	3,900
3	Supply Steel HZ King Piles	m	330.0	$ 579.14	$	191,116
4	Install Steel HZ King Ppiles	m	330.0	$ 150.00	$	49,500
5	Supply Intermediate Steel Sheet Piles	m^2	338.8	$ 349.69	$	118,475
6	Install Intermediate Steel Sheet Piles	m^2	338.8	$ 75.00	$	25,410
7	Supply and Install Steel HZ Pile Protection Points	unit	22	$ 500.00	$	11,000
8	Supply and Place Reinforced Concrete Cope Wall	m^3	40	$ 800.00	$	32,240
9	Supply and Install Tie-Rod Anchors	unit	22.0	$ 2,290.00	$	50,380
10	Supply and Place Concrete Waler Beam	m^3	20.0	$ 800.00	$	16,000
11	Supply and Place Quarry Run Rock Fill	tonnes	1026	$ 15.00	$	15,390
12	Supply and Place Granular Sub Base	tonnes	153.6	$ 17.50	$	2,688
13	Supply and Place Granular Base	tonnes	230.3	$ 17.50	$	4,030
14	Supply and Place Cast-in-place Deck Slab	m^3	52.5	$ 400.00	$	21,000
15	Install Steel HSS Curb	m	87.65	$ 25.00	$	2,191
16	Supply and Install New Steel Ladders	unit	2	$ 3,000.00	$	6,000
17	Supply and Install Bollards	unit	2	$ 2,500.00	$	5,000
18	Supply and Install Rubber Tire Fenders	unit	28	$ 500.00	$	14,000
19	Electrical Services and Lighting	Global	-	-	$	25,000
20	Water Supply Services	Global	-	-	$	25,000
				Construction Cost	$	649,237
				Contingencies 15%	$	97,386
				Engineering and Site Supervision 16%	$	103,878
				Estimated Total Project Cost	$	850,500

TABLE A12

SHIPPAGAN HARBOUR
CLASS "C" COST ESTIMATE

WHARF 404
OPTION 2 STEEL PIPE PILE/SHEET PILE COMBINATION WALL

	Item	Unit	Estimated Quantity	Estimated Unit Cost		Amount
1	Site Organization	Global	n/a	n/a	$	32,549
2	Excavation and Disposal	m^3	390.0	$ 10.00	$	3,900
3	Supply Steel Pipe King Piles	m	272.0	$ 787.40	$	214,173
4	Install Steel Pipe King Ppiles	m	272.0	$ 300.00	$	81,600
5	Supply Intermediate Steel Sheet Piles	m^2	246.4	$ 349.69	$	86,164
6	Install Intermediate Steel Sheet Piles	m^2	246.4	$ 75.00	$	18,480
7	Supply and Install Steel Pipe Pile Protection Points	unit	17	$ 600.00	$	10,200
8	Supply and Place Concrete Fill For Pipe Piles	m^3	58	$ 500.00	$	29,000
9	Supply and Place Reinforced Concrete Cope Wall	m^3	40	$ 800.00	$	32,240
10	Supply and Install Tie-Rod Anchors	unit	17.0	$ 2,290.00	$	38,930
11	Supply and Place Concrete Waler Beam	m^3	20.0	$ 800.00	$	16,000
12	Supply and Place Quarry Run Rock Fill	tonnes	1026	$ 15.00	$	15,390
13	Supply and Place Granular Sub Base	tonnes	153.6	$ 17.50	$	2,688
14	Supply and Place Granular Base	tonnes	230.3	$ 17.50	$	4,030
15	Supply and Place Cast-in-place Deck Slab	m^3	52.5	$ 400.00	$	21,000
16	Install Steel HSS Curb	m	87.65	$ 25.00	$	2,191
17	Supply and Install New Steel Ladders	unit	2	$ 3,000.00	$	6,000
18	Supply and Install Bollards	unit	2	$ 2,500.00	$	5,000
19	Supply and Install Rubber Tire Fenders	unit	28	$ 500.00	$	14,000
20	Electrical Services and Lighting	Global	-	-	$	25,000
21	Water Supply Services	Global	-	-	$	25,000
				Construction Cost	$	683,535
				Contingencies 15%	$	102,530
				Engineering and Site Supervision 16%	$	109,366
				Estimated Total Project Cost	$	895,431

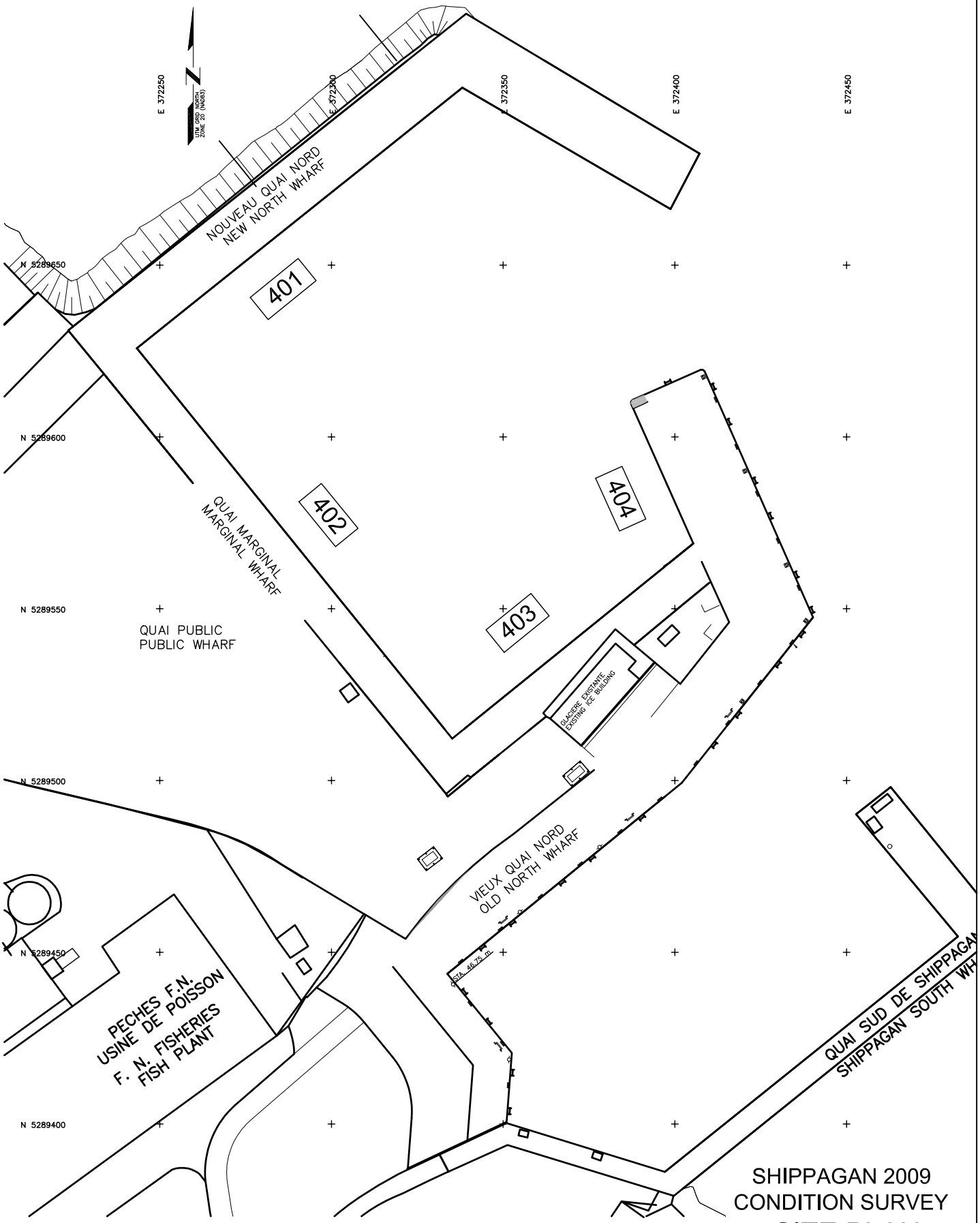
TABLE A13

SHIPPAGAN HARBOUR
CLASS "C" COST ESTIMATE

WHARF 404
OPTION 3 BERLIN WALL

	Item	Unit	Estimated Quantity	Estimated Unit Cost		Amount
1	Site Organization	Global	n/a	n/a	$	27,654
2	Excavation and Disposal	m^3	390.0	$ 10.00	$	3,900
3	Supply Steel King Piles (Berlin Wall)	m	249.0	$ 318.00	$	79,182
4	Drill Sockets and Install King Piles (Berlin Wall)	unit	16.0	$ 3,680.00	$	58,880
5	Place Tremie Concrete In King Pile Sockets	m^3	39.4	$ 500.00	$	19,700
6	Supply Pre-Cast Concrete Slabs	m^2	420.0	$ 280.00	$	117,600
7	Install Pre-Cast Concrete Slabs	m^2	420.0	$ 65.00	$	27,300
8	Supply and Place Scour Protection For Berlin Wall	tonnes	311.0	$ 40.00	$	12,440
9	Tremie Concrete Seal At Base of Pre-Cast Slabs	m^3	43.3	$ 350.00	$	15,155
10	Supply and Place Reinforced Concrete Cope Wall	m^3	40	$ 800.00	$	32,240
11	Supply and Install Tie-Rod Anchors	unit	22.0	$ 2,290.00	$	50,380
12	Supply and Place Concrete Waler Beam	m^3	20.0	$ 800.00	$	16,000
13	Supply and Place Quarry Run Rock Fill	tonnes	1026	$ 15.00	$	15,390
14	Supply and Place Granular Sub Base	tonnes	153.6	$ 17.50	$	2,688
15	Supply and Place Granular Base	tonnes	230.3	$ 17.50	$	4,030
16	Supply and Place Cast-in-place Deck Slab	m^3	52.5	$ 400.00	$	21,000
17	Install Steel HSS Curb	m	87.65	$ 25.00	$	2,191
18	Supply and Install New Steel Ladders	unit	2	$ 3,000.00	$	6,000
19	Supply and Install Bollards	unit	2	$ 2,500.00	$	5,000
20	Supply and Install Rubber Tire Fenders	unit	28	$ 500.00	$	14,000
21	Electrical Services and Lighting	Global	-	-	$	25,000
22	Water Supply Services	Global	-	-	$	25,000
				Construction Cost	$	580,730
				Contingencies 15%	$	87,110
				Engineering and Site Supervision 16%	$	92,917
				Estimated Total Project Cost	$	760,757

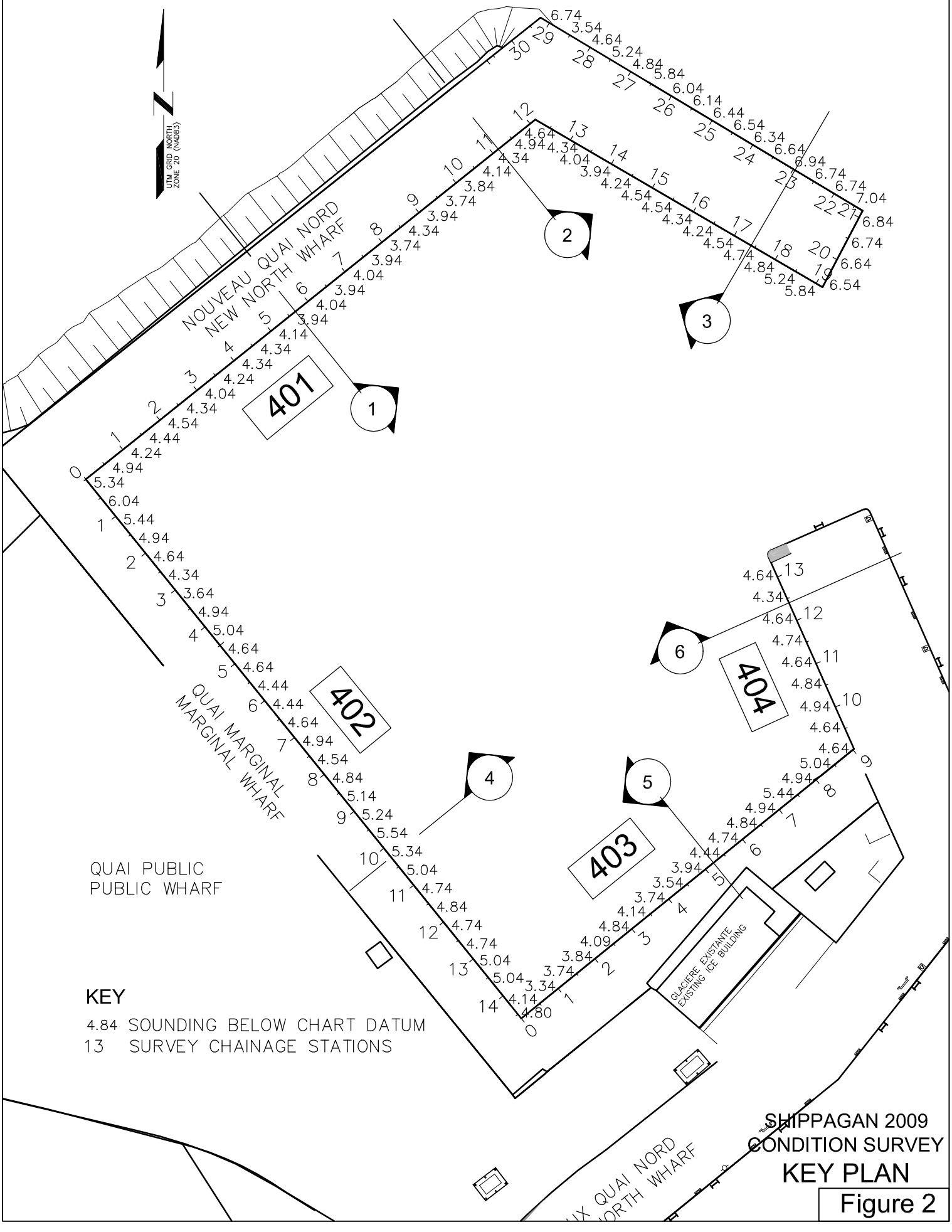
Figures

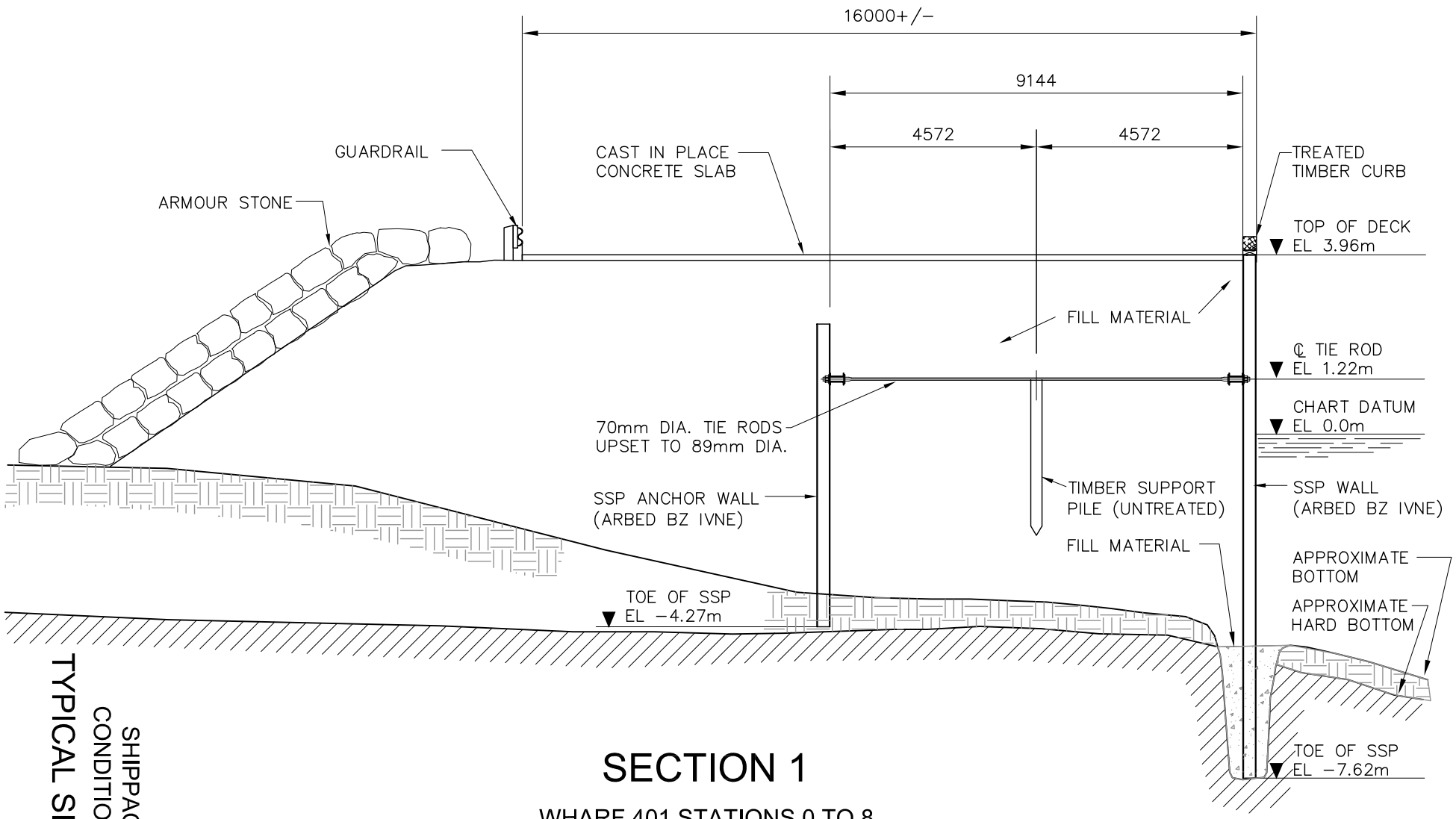


SHIPPAGAN 2009
CONDITION SURVEY

SITE PLAN

Figure 1


UTM GRID NORTH
ZONE 20 (NAD83)
NOUVEAU QUAI NORD
NEW NORTH WHARF
401
402
403
404
QUAI MARGINAL
MARGINAL WHARF
QUAI PUBLIC
PUBLIC WHARF
GLACIERE EXISTANTE
EXISTING ICE BUILDING
1
2
3
4
5
6
KEY
4.84 SOUNDING BELOW CHART DATUM
13 SURVEY CHAINAGE STATIONS
SHIPPAGAN 2009
CONDITION SURVEY
KEY PLAN
Figure 2



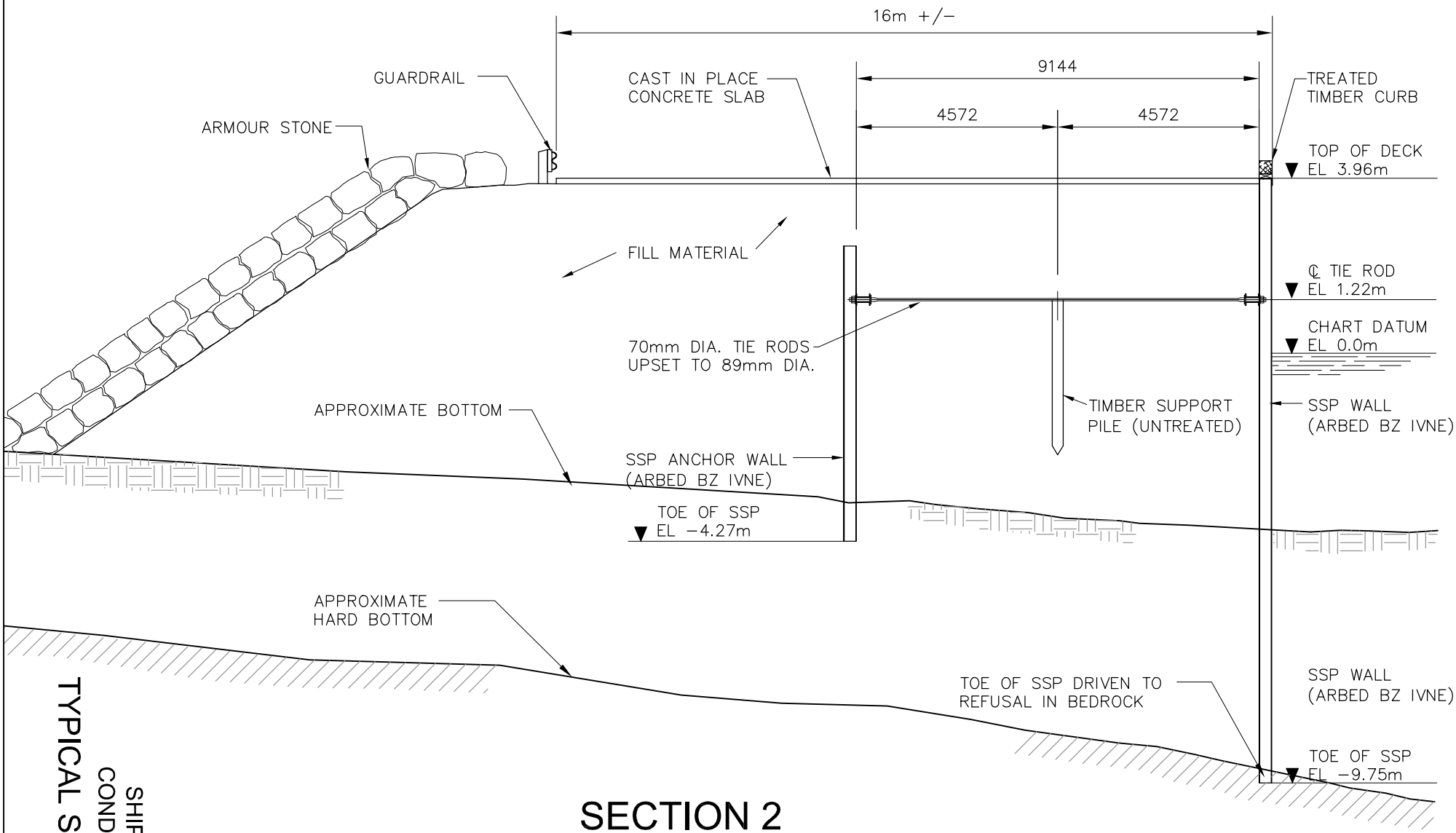
SECTION 1

WHARF 401 STATIONS 0 TO 8

SHIPPAGAN 2009
CONDITION SURVEY

TYPICAL SECTION 0-8

Figure 3



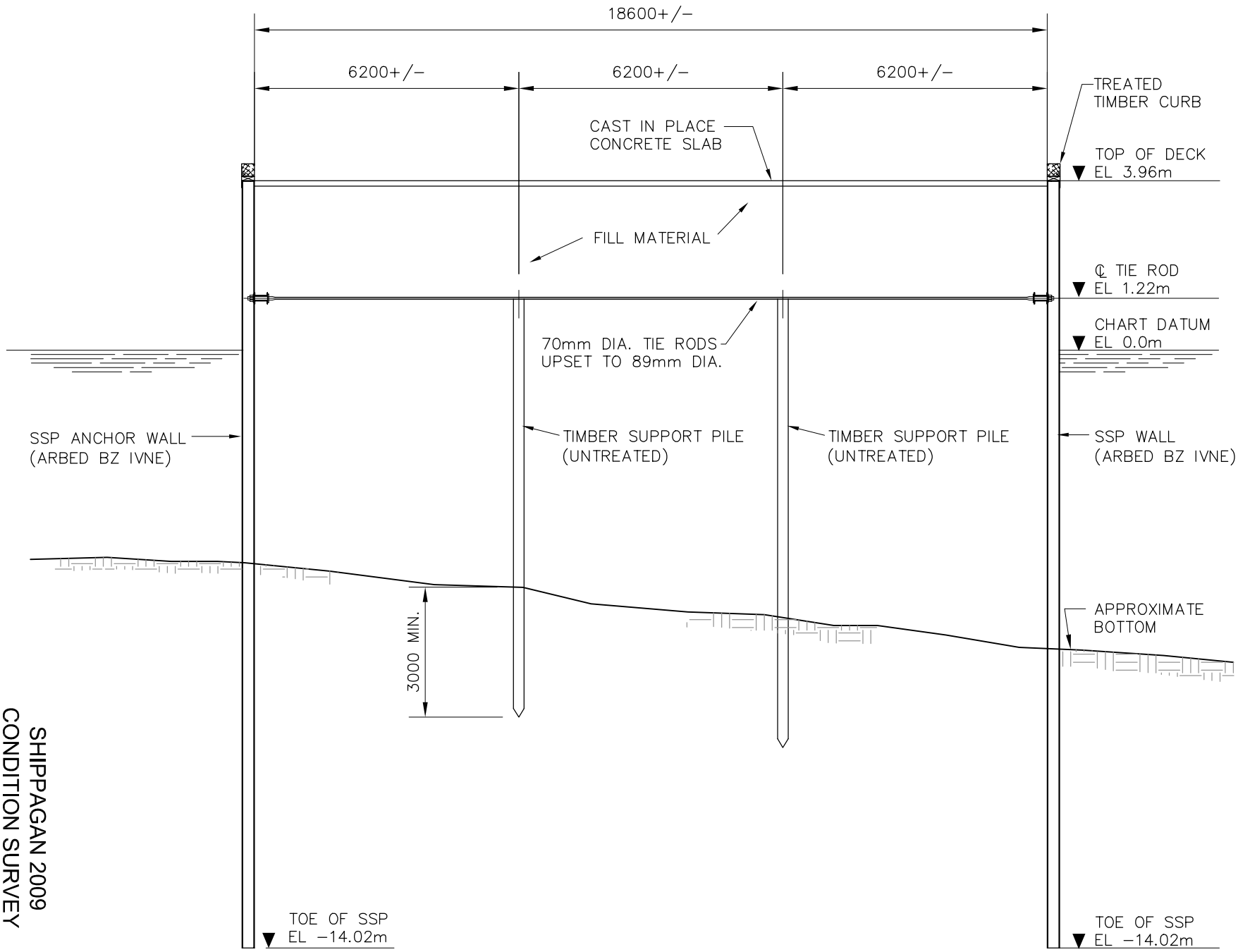
SECTION 2

WHARF 401 STATIONS 8 TO 12.2

SHIPPAGAN 2009
CONDITION SURVEY

TYPICAL SECTION 8-12.2

Figure 4



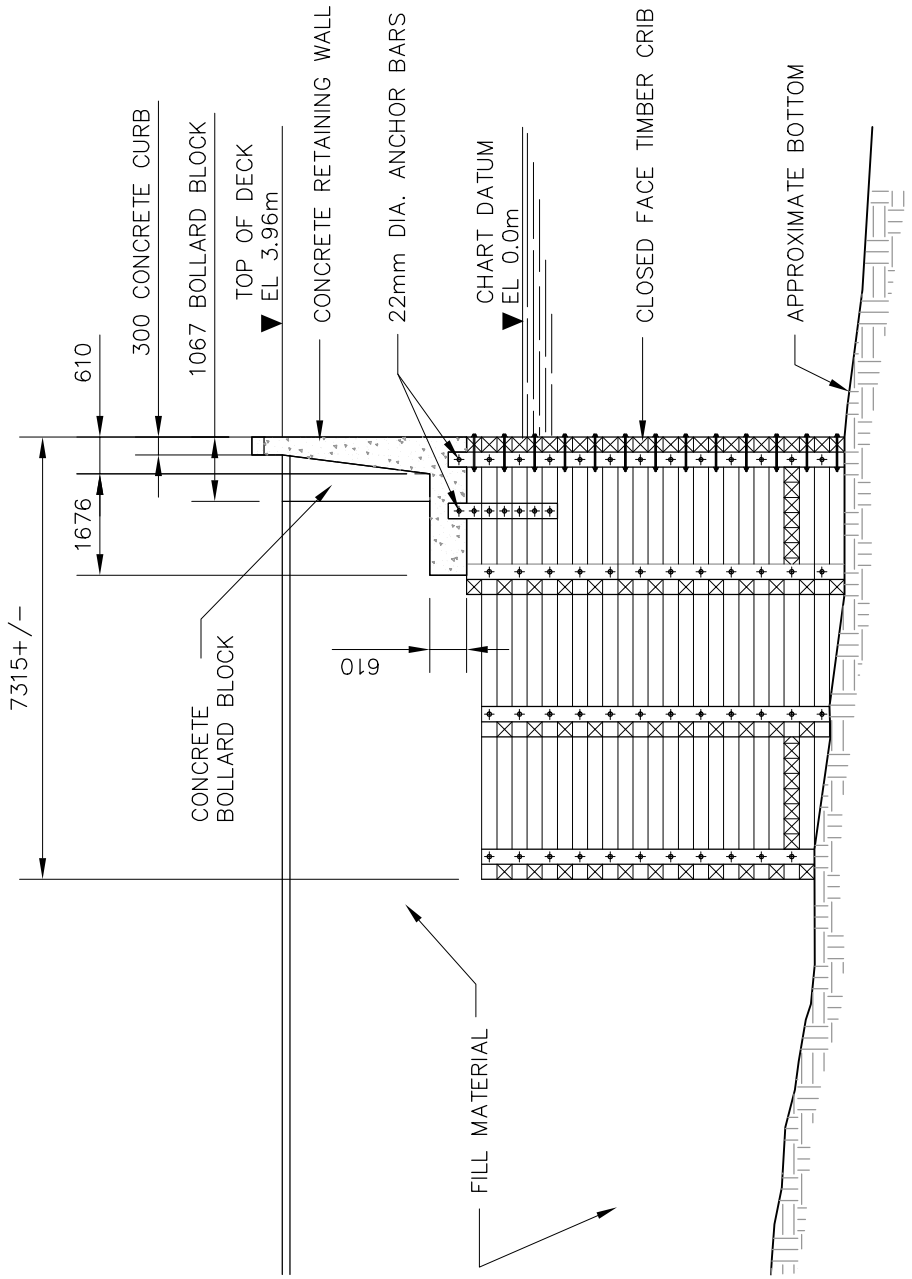
SECTION 3

WHARF 401 STATIONS 12.2 TO 29.2

SHIPPAGAN 2009
CONDITION SURVEY

TYPICAL SECTION 12.2-29.2

Figure 5



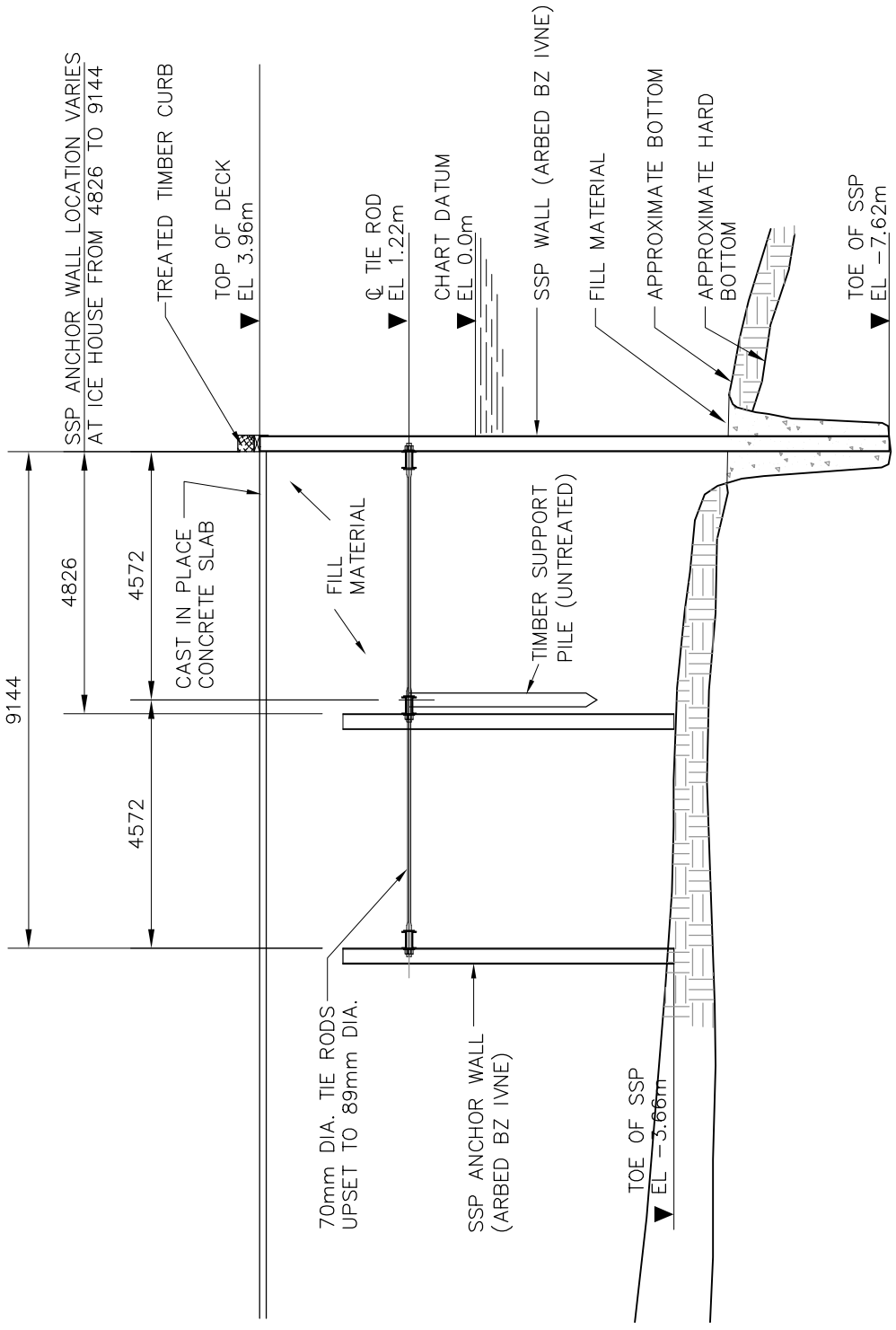
SECTION 4

WHARF 402 STATIONS 0 TO 14.7

SHIPPAGAN 2009
CONDITION SURVEY

TYPICAL SECTION 0-14.7

Figure 6



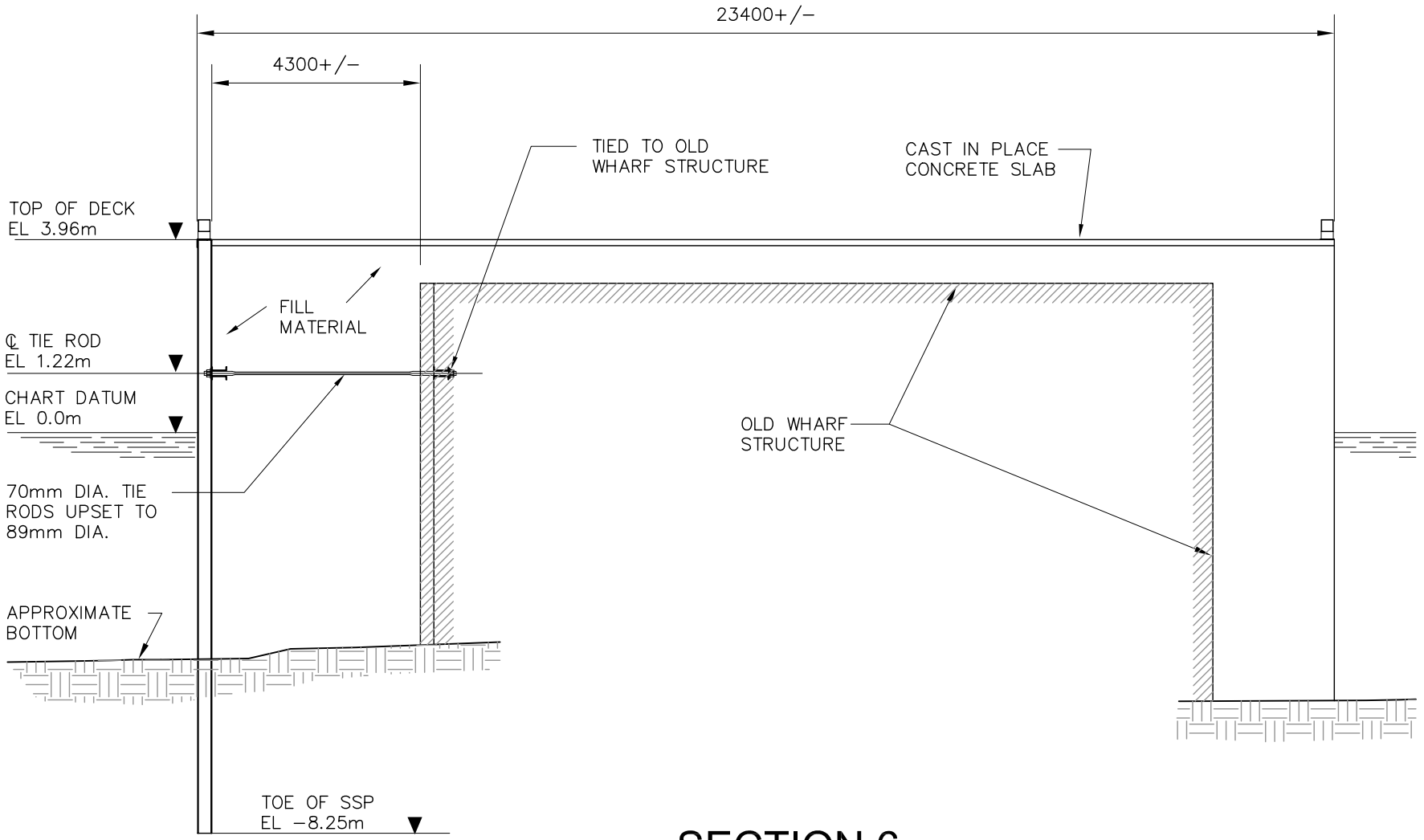
SECTION 5

WHARF 403

SHIPPAGAN 2009
CONDITION SURVEY

TYPICAL SECTION WHARF 403

Figure 7



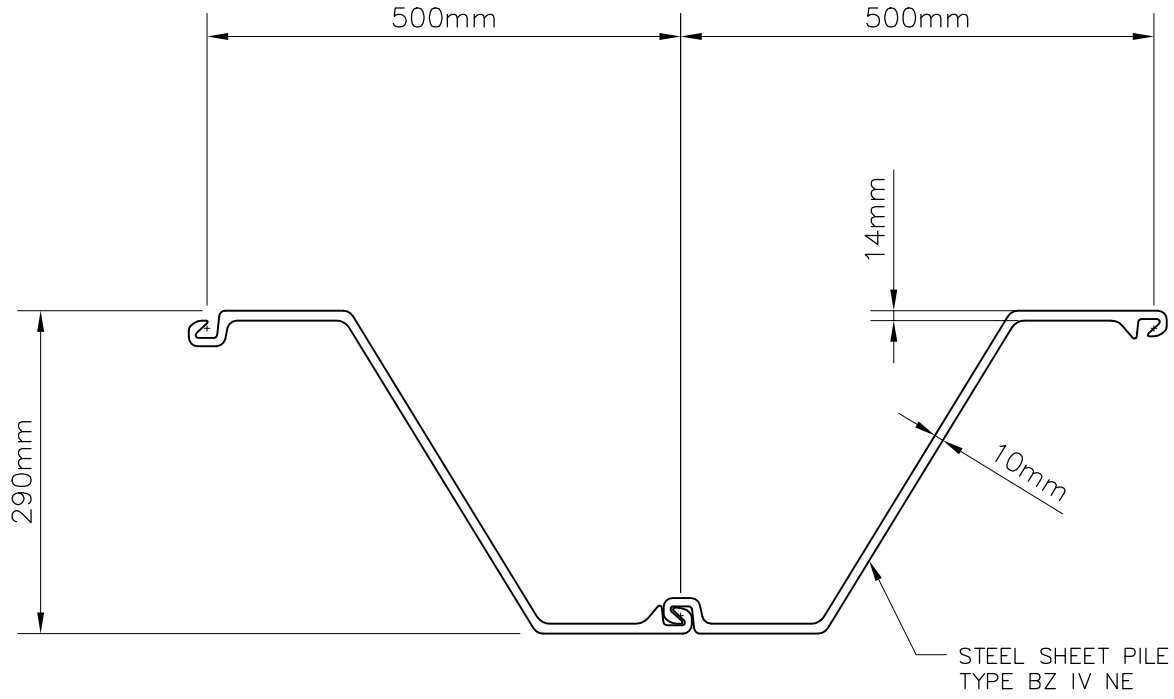
SECTION 6

WHARF 404

TYPICAL SECTION WHARF 404

SHIPPAGAN 2009
CONDITION SURVEY

Figure 8



STEEL SHEET PILING DIMENSIONS
ARBED BZ IV NE

SHIPPAGAN 2009
CONDITION SURVEY

SSP DIMENSIONS

Figure 9

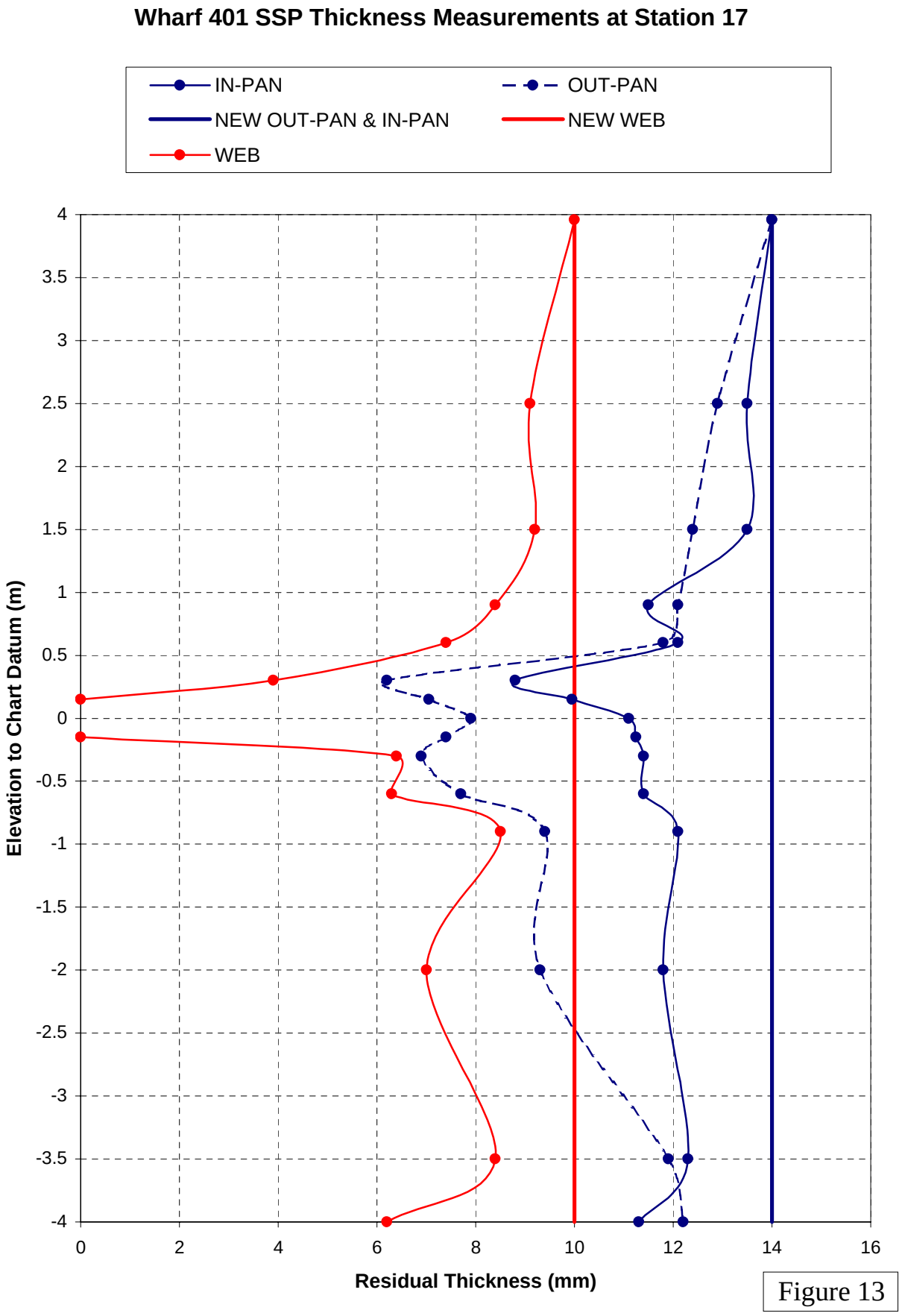

Wharf 401 SSP Thickness Measurements at Station 17
IN-PAN
OUT-PAN
NEW OUT-PAN & IN-PAN
NEW WEB
WEB
Elevation to Chart Datum (m)
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
0
2
4
6
8
10
12
14
16
Residual Thickness (mm)

Figure 13

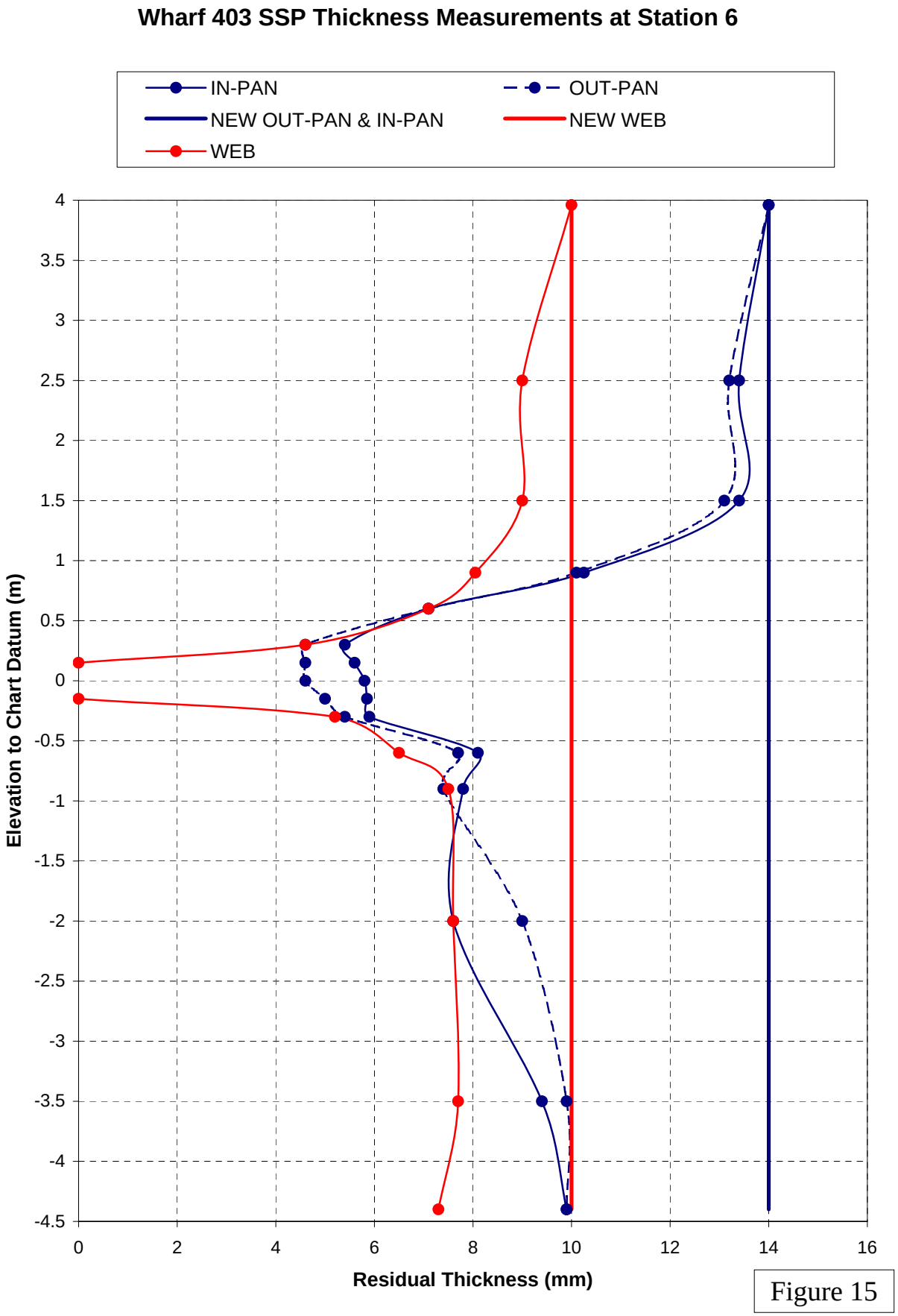
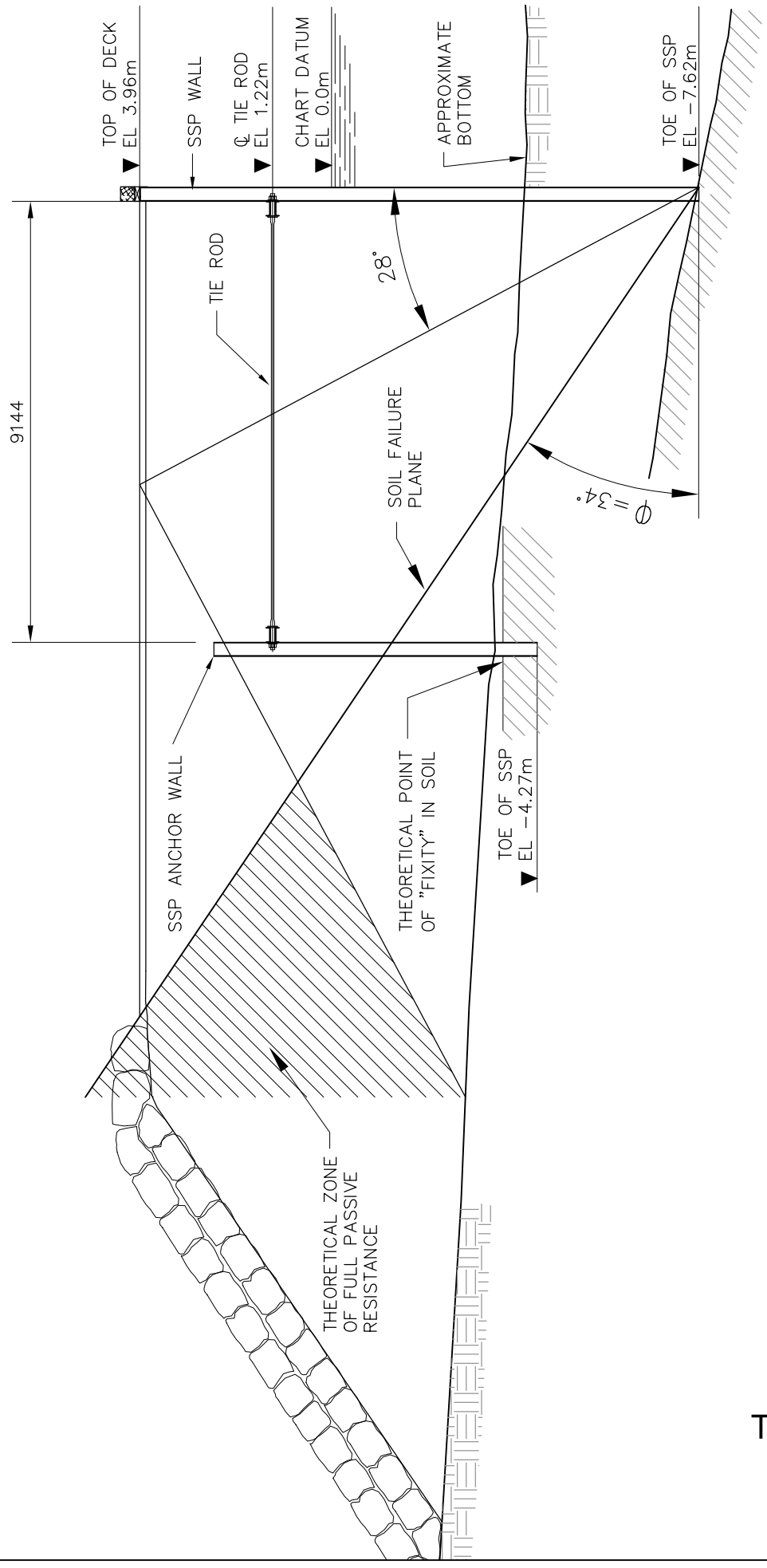

Wharf 403 SSP Thickness Measurements at Station 6
IN-PAN
OUT-PAN
NEW OUT-PAN & IN-PAN
NEW WEB
WEB
Elevation to Chart Datum (m)
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
-4.5
0
2
4
6
8
10
12
14
16
Residual Thickness (mm)

Figure 15

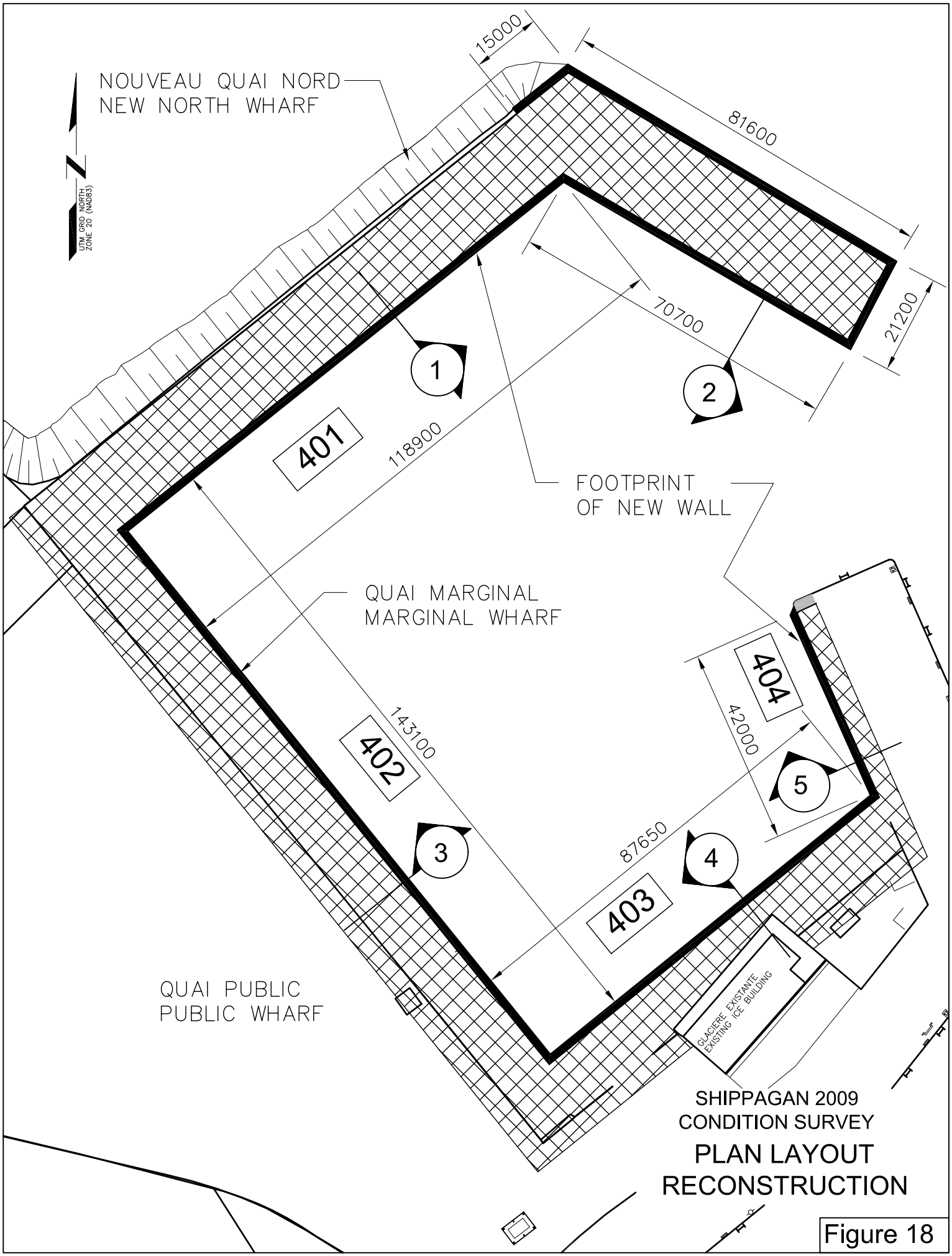


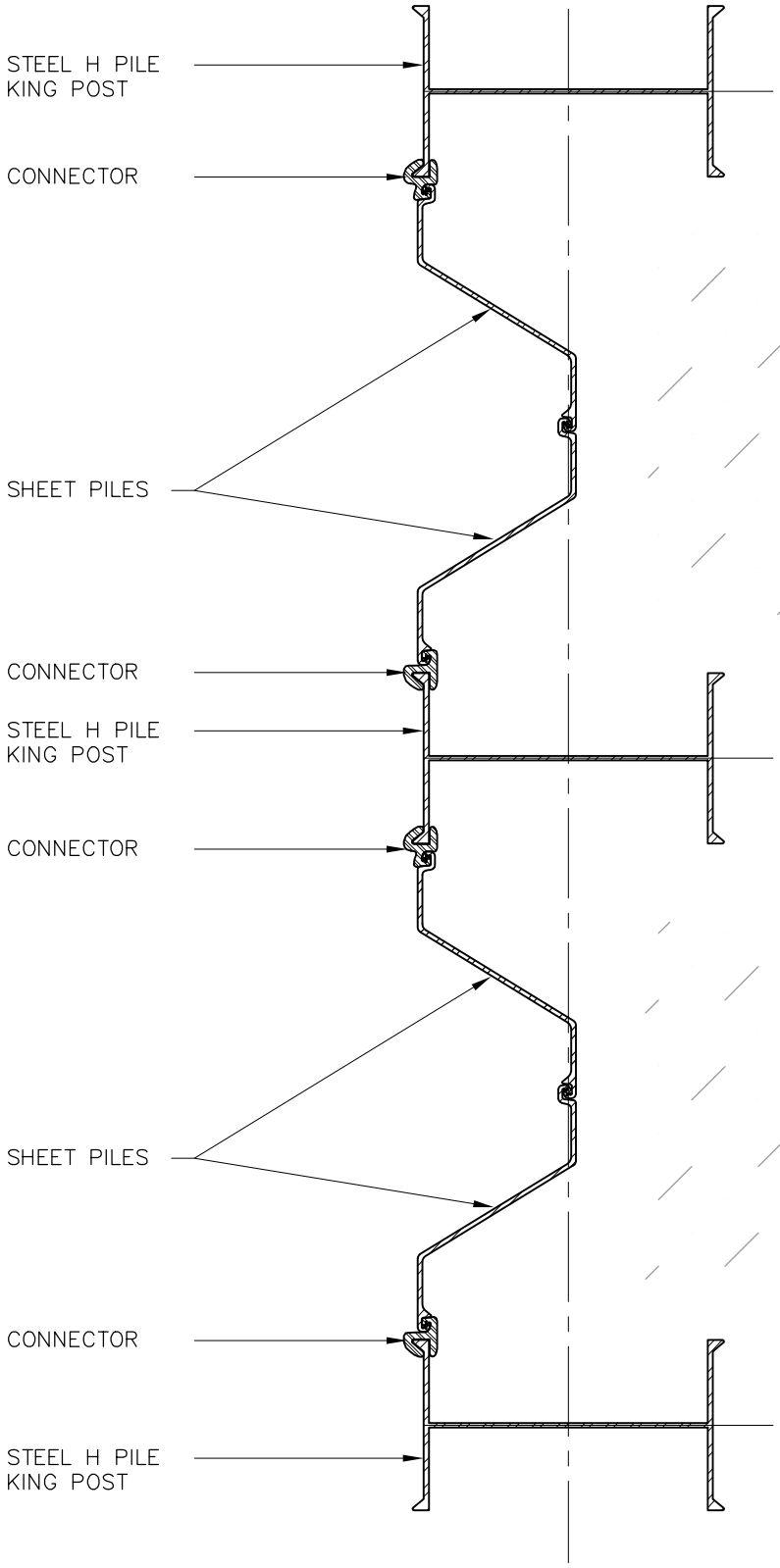
SOIL ANCHOR LOCATION AND THEORETICAL FAILURE PLANE

SHIPPAGAN 2009
CONDITION SURVEY

THEORETICAL SOIL FAILURE PLANE

Figure 17


NOUVEAU QUAI NORD
NEW NORTH WHARF
UTM GRID NORTH
ZONE 20 (NAD83)
15000
81600
21200
70700
118900
1
2
401
FOOTPRINT
OF NEW WALL
QUAI MARGINAL
MARGINAL WHARF
404
42000
143100
402
5
3
87650
4
403
QUAI PUBLIC
PUBLIC WHARF
GLACIERE EXISTANTE
EXISTING ICE BUILDING
SHIPPAGAN 2009
CONDITION SURVEY
PLAN LAYOUT
RECONSTRUCTION
Figure 18

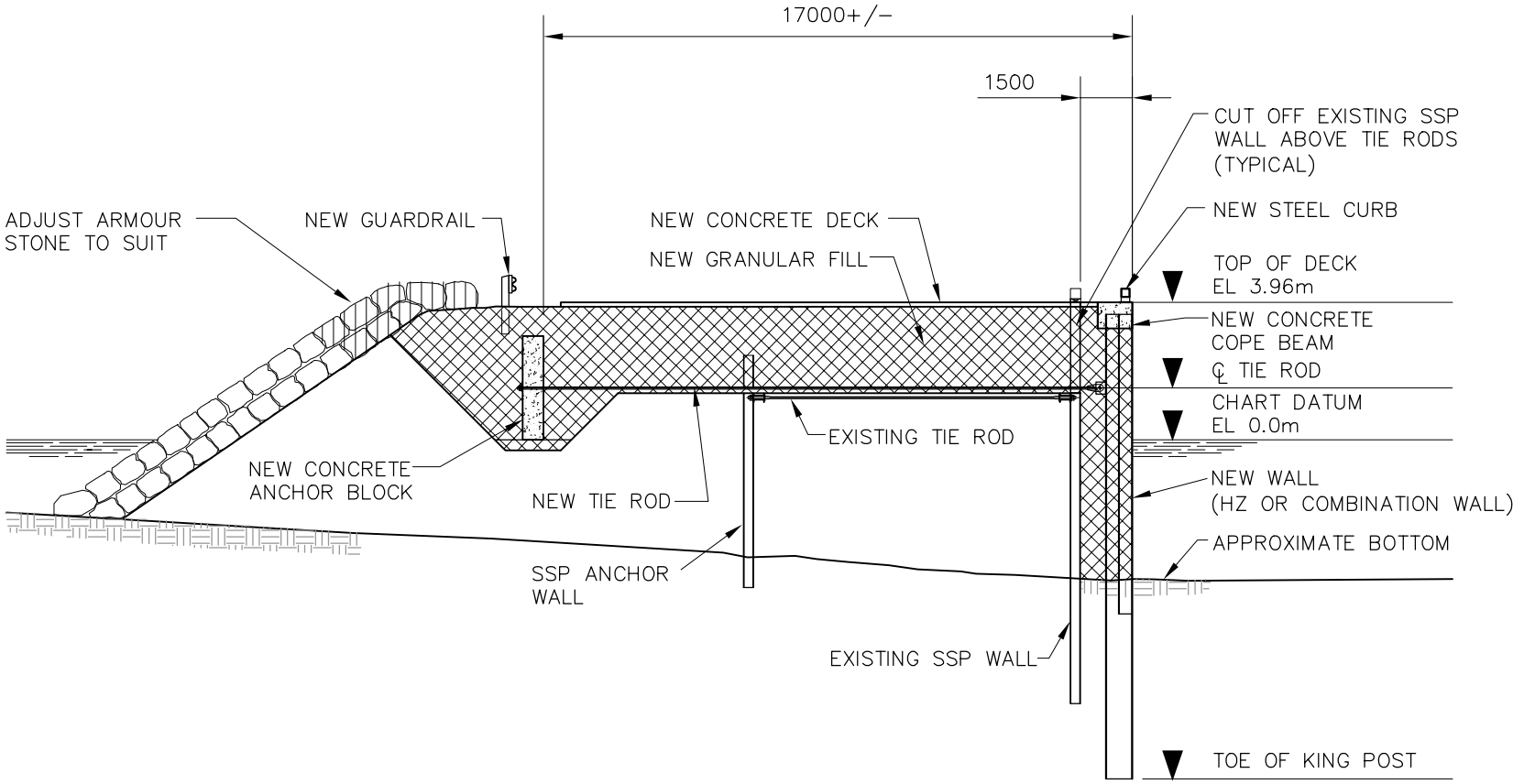


PART PLAN
HZ WALL SYSTEM

SHIPPAGAN 2009
CONDITION SURVEY

HZ WALL SYSTEM

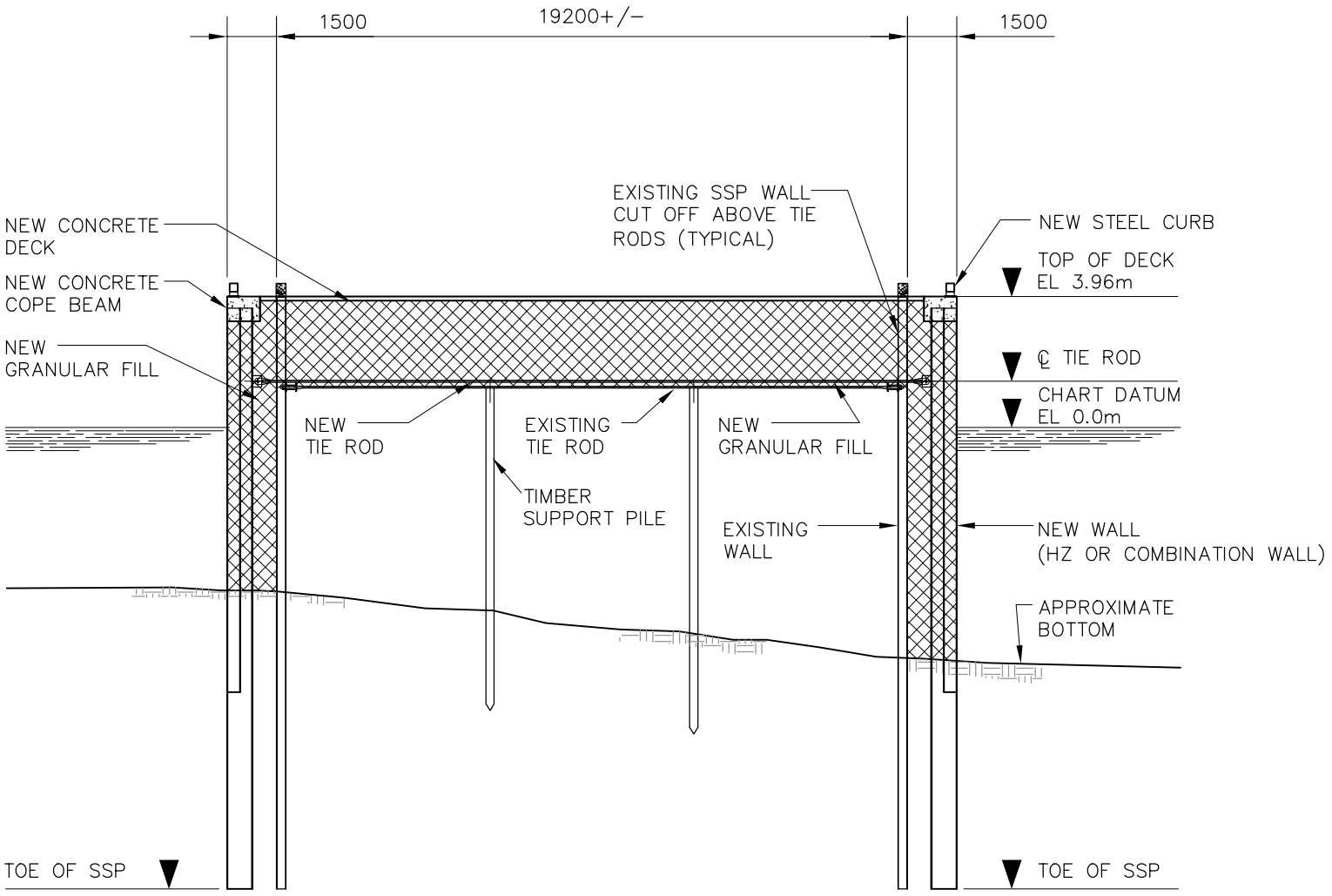
Figure 19



SECTION 1
WHARF 401 RECONSTRUCTION
STATIONS 0 - 12.2

SHIPPAGAN 2009
CONDITION SURVEY
WHARF 401
RECONSTRUCTION

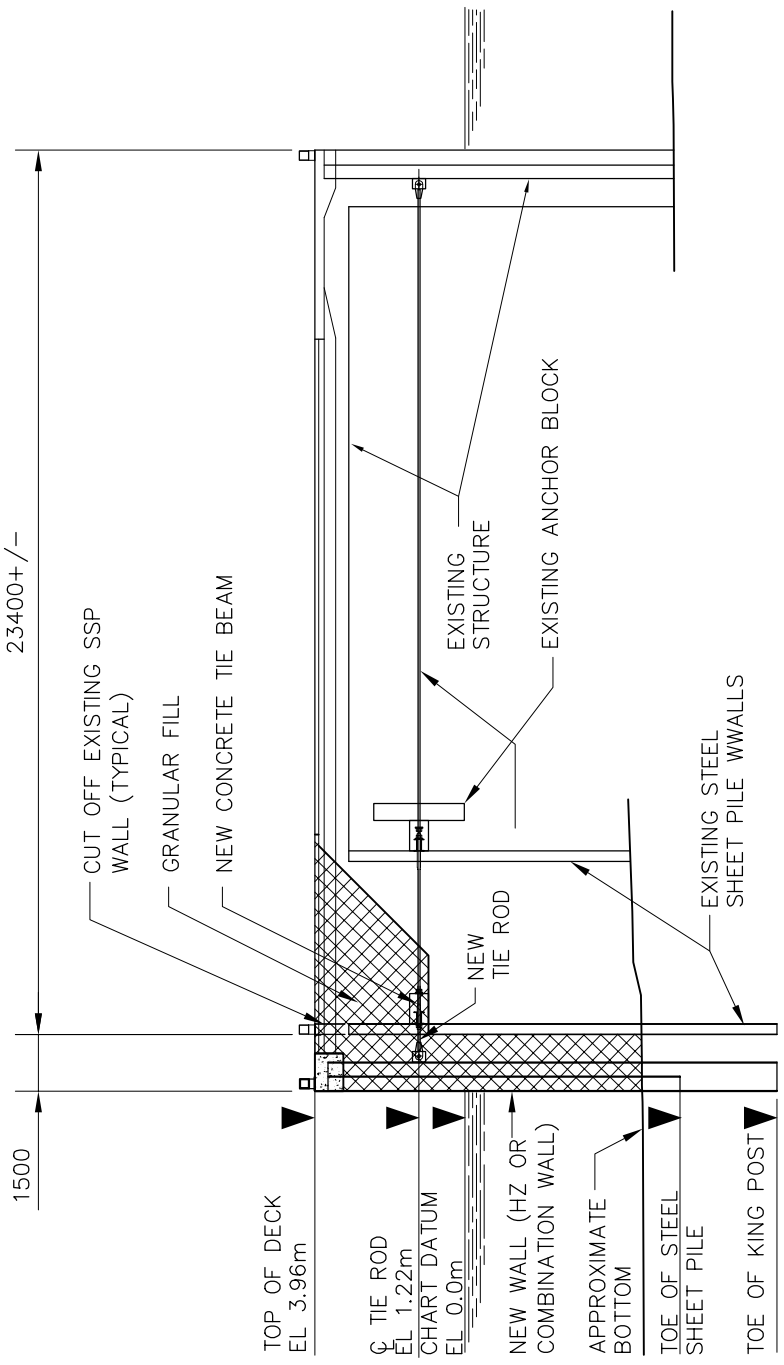
Figure 20



SECTION 2
WHARF 401 RECONSTRUCTION
STATIONS 12.2 - 29.2

SHIPPAGAN 2009
CONDITION SURVEY
WHARF 401
RECONSTRUCTION

Figure 21

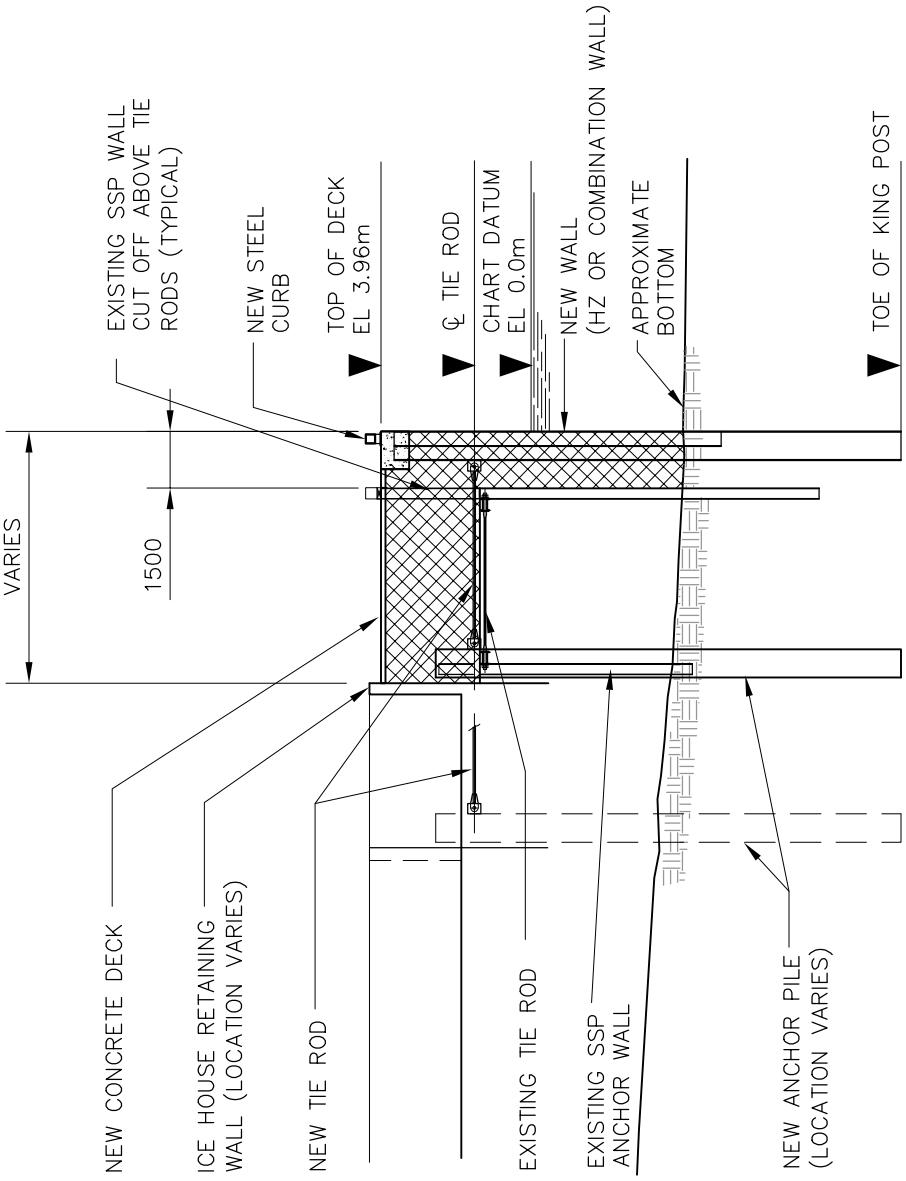


SECTION 5
WHARF 404 RECONSTRUCTION

SHIPPAGAN 2009
CONDITION SURVEY

WHARF 404
RECONSTRUCTION

Figure 22

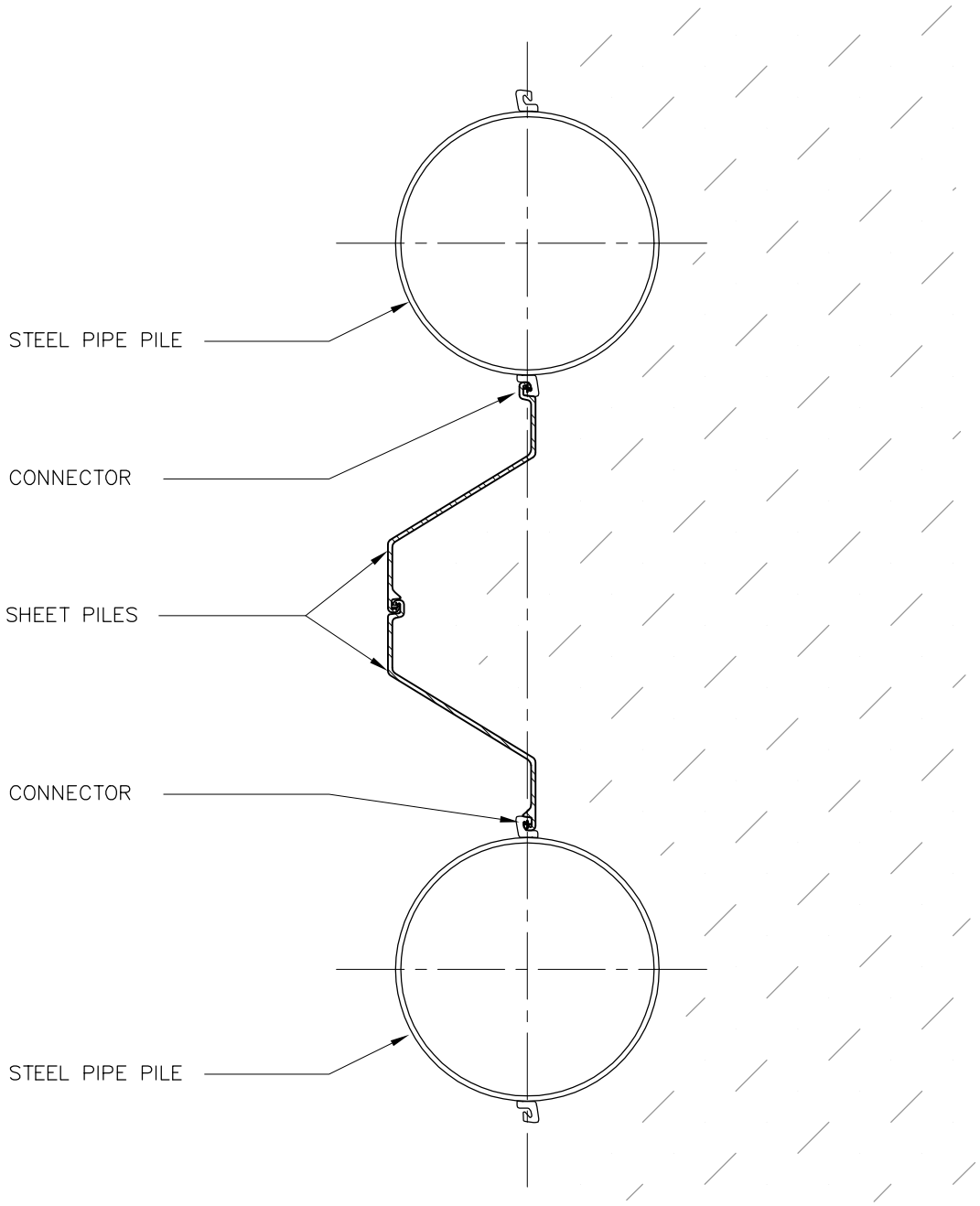


SECTION 4
WHARF 403 RECONSTRUCTION
STATIONS 2.5 - 5.7

SHIPPAGAN 2009
CONDITION SURVEY

WHARF 403
RECONSTRUCTION

Figure 23

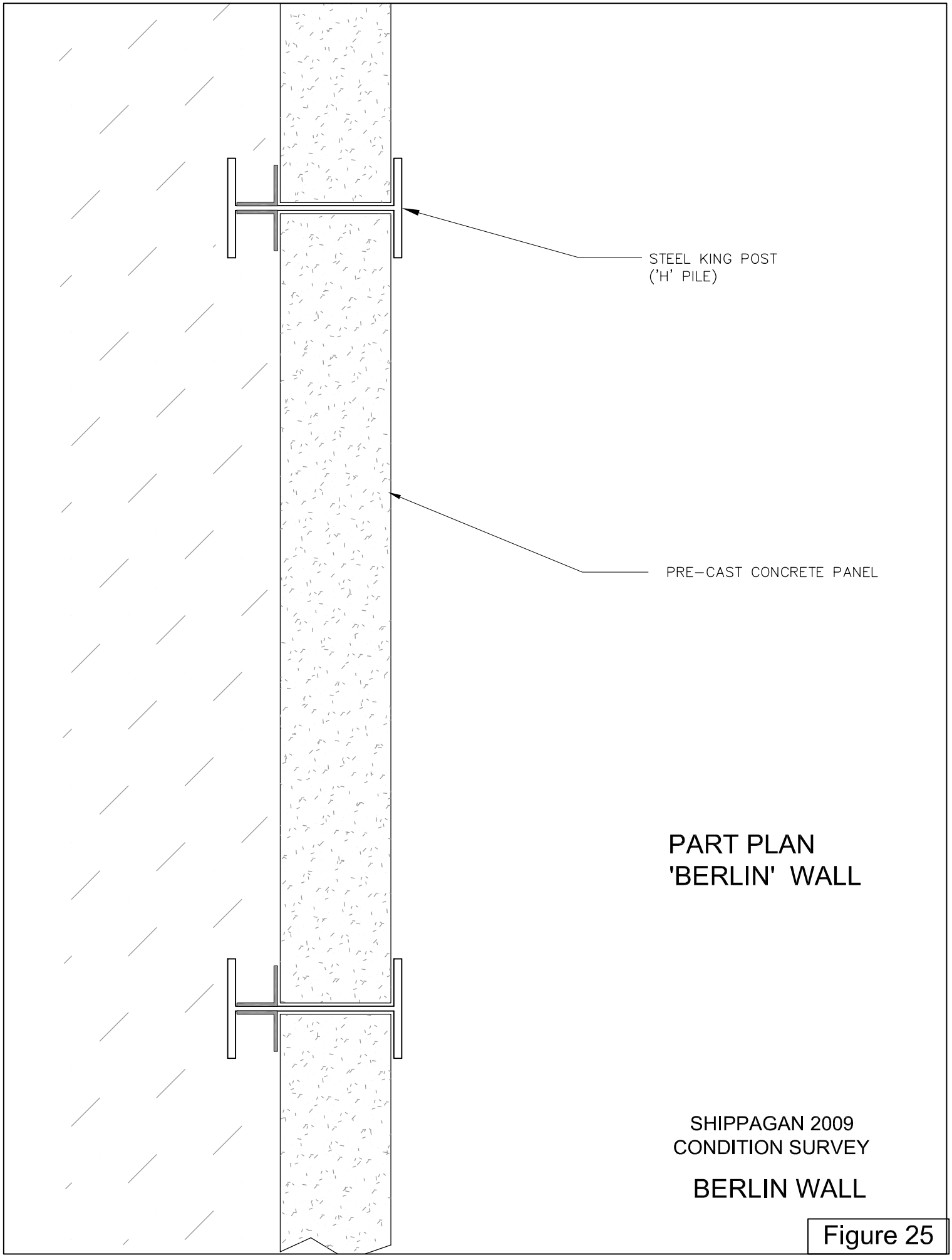


PART PLAN
COMBINATION WALL SYSTEM

SHIPPAGAN 2009
CONDITION SURVEY

STEEL PIPE PILE/SHEET PILE WALL SYSTEM

Figure 24

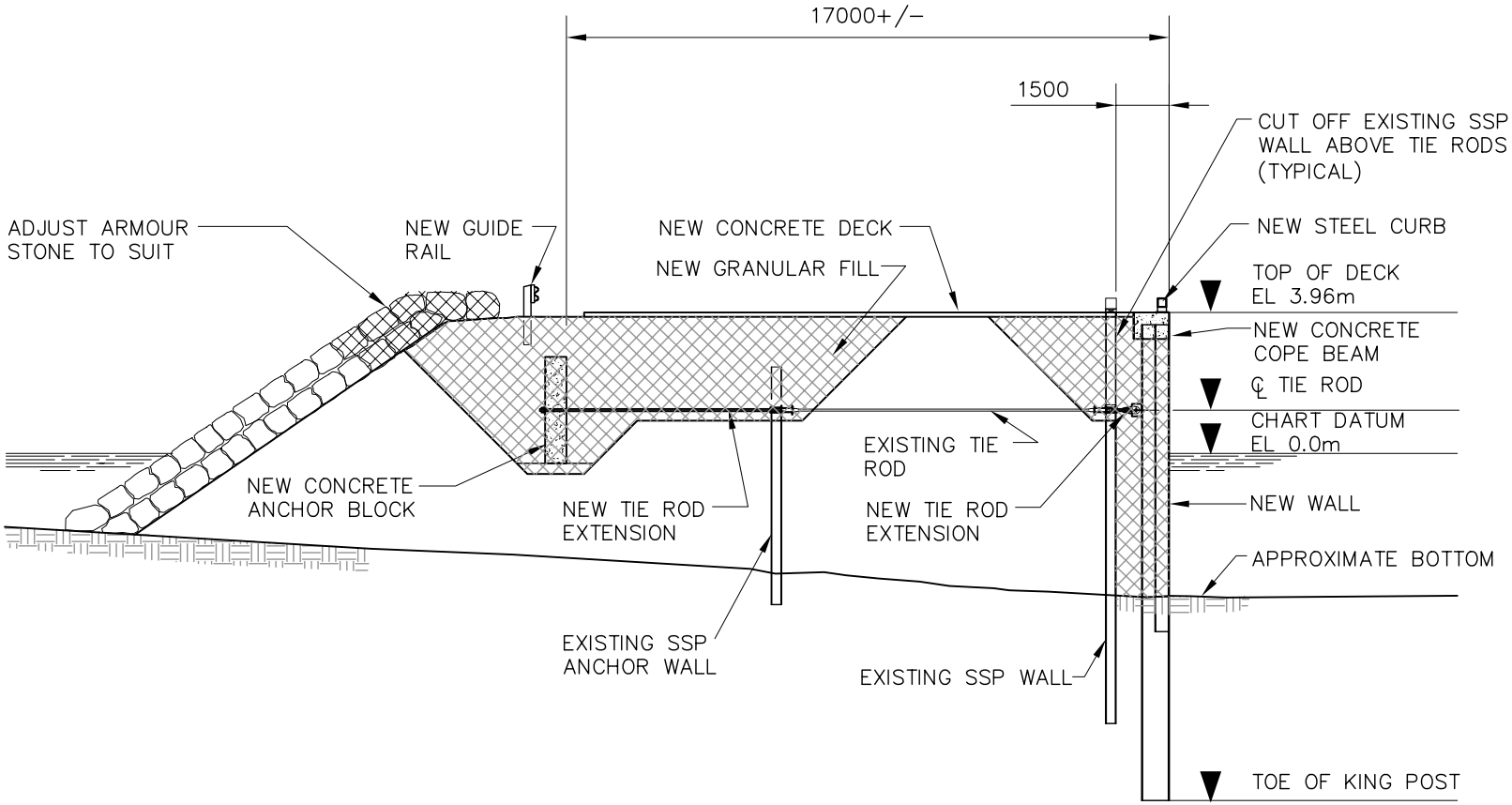


PART PLAN
'BERLIN' WALL

SHIPPAGAN 2009
CONDITION SURVEY

BERLIN WALL

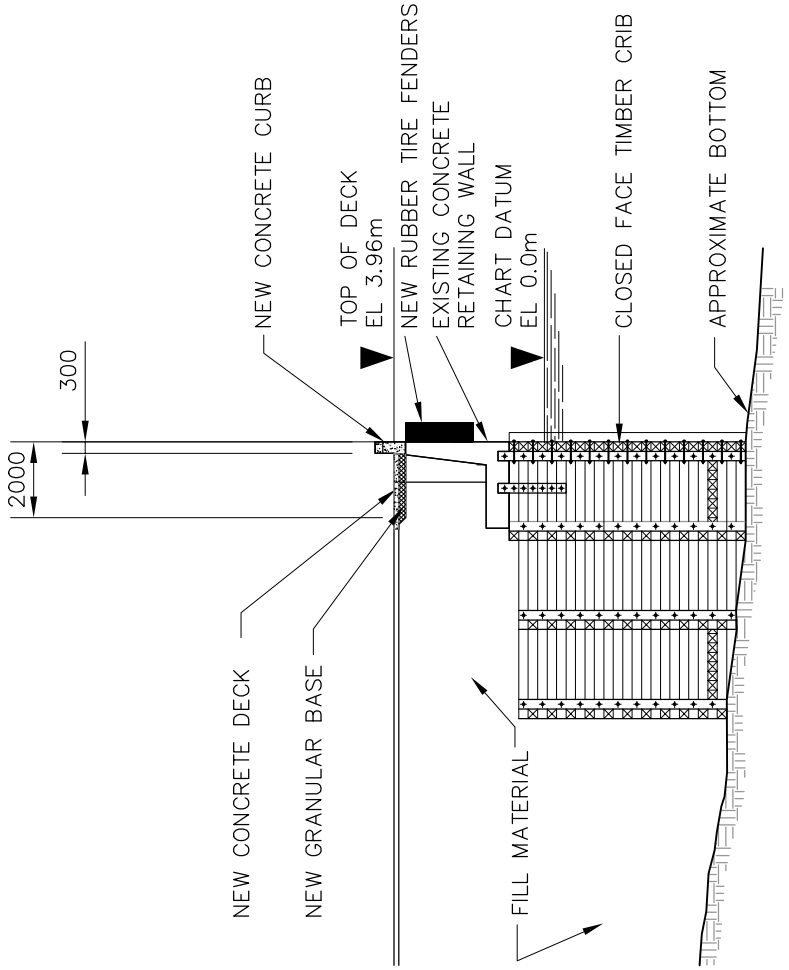
Figure 25



TYPICAL SECTION
WHARF 401 RECONSTRUCTION
(POSSIBLE RE-USE OF EXISTING TIE RODS)

SHIPPAGAN 2009
CONDITION SURVEY
WHARF 401
RECONSTRUCTION

Figure 26

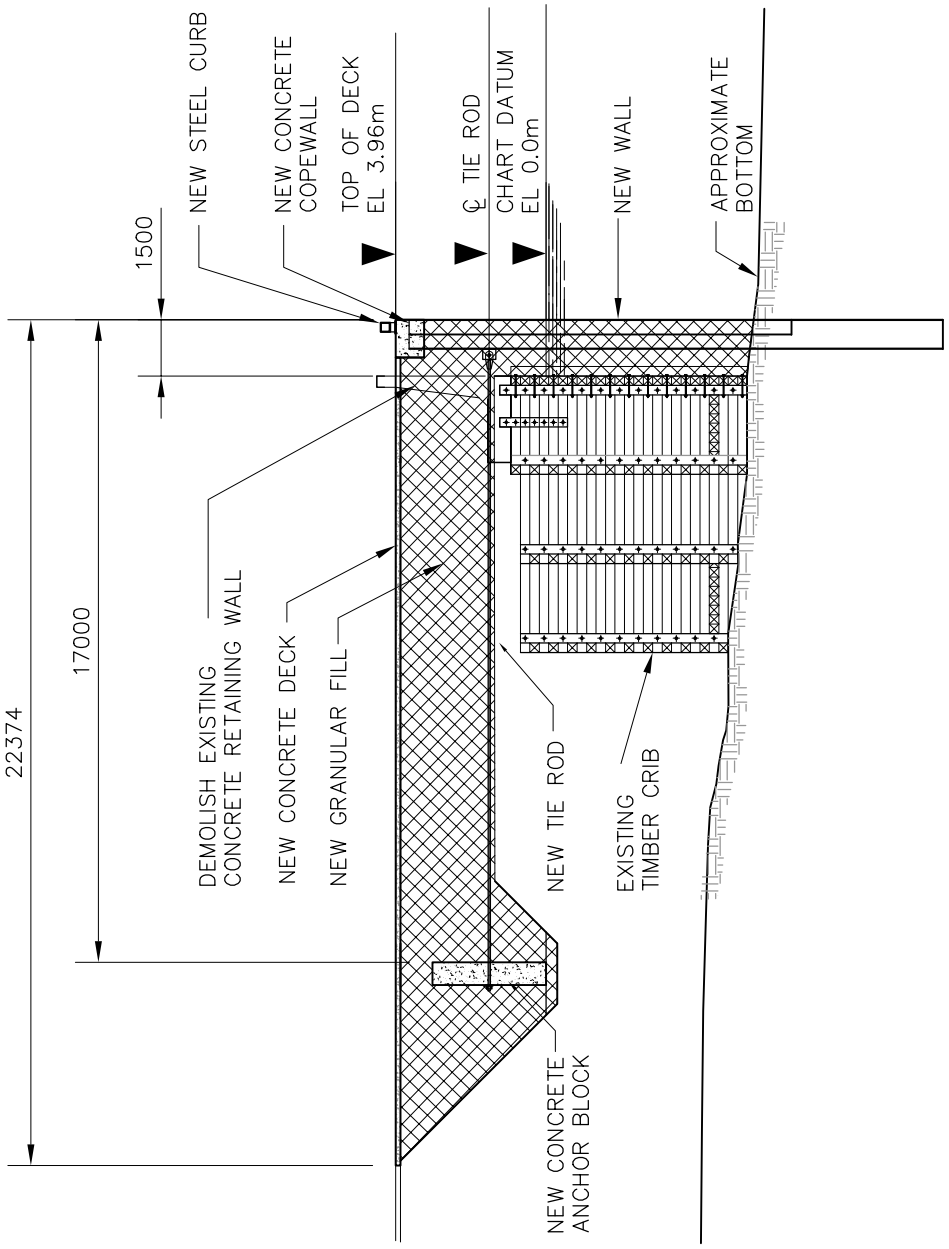


SECTION 3
WHARF 402 REPAIR

SHIPPAGAN 2009
CONDITION SURVEY

WHARF 402
RECONSTRUCTION

Figure 27



SECTION 3
WHARF 402 RECONSTRUCTION

SHIPPAGAN 2009
CONDITION SURVEY

WHARF 402
RECONSTRUCTION

Figure 28