Bowen Wharf Concrete Testing

Report Summary

In May 2024, North Queensland Bulk Ports engaged the global consultancy firm Arup to coordinate concrete testing for the existing concrete piles and headstocks at Bowen Wharf. The purpose of the inspection was to increase the sample size of testing data and to provide a comparison to the results of similar tests conducted in 2019.

Australian Concrete X-Ray (ACX) was commissioned to undertake the site work, manage the laboratory testing, and provide a factual inspection report, which can be found in Attachment A.

Seventeen test locations were successfully assessed, and fourteen additional chloride tests were completed. Please refer to Attachment A for a detailed report, including the pile gridlines for each location.

The concrete inspections and tests conducted by Arup in 2019 and more recently by ACX confirm that the reinforcement in the piles and headstocks is corroding. This finding is also supported by the observed concrete delamination and spalling on site.

The results from the 2024 testing, including chloride testing, half-cell testing, and resistivity testing, are consistent with the findings from the 2019 inspection.

Given the severity and widespread nature of the corrosion confirmed by the concrete testing, the age of the structure (over 100 years old), and the 100-year design life requirement for the future use of the jetty, repairing the existing piles and headstocks to support a new deck was found not a practical solution for the Bowen Wharf project.

The data collected from the concrete testing, which have been reviewed against industry standards referenced in this document, suggest that the best outcome for the Bowen Wharf Project is to replace the piles and headstocks.

This replacement will eliminate any safety risks associated with the long-term performance of the existing piles and ensure a safe and durable structure.

Technical Note

Project title	Bowen Wharf Project
Job number	299445
File reference	299445-ARUP-ZZ-XX-RP-CM-000003
cc	Nawar Spear
Date	26 July 2024
Subject	Summary of Concrete Testing at Bowen Wharf – Final Issue

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1. Introduction

This document summarises the findings of the concrete testing undertaken for the existing concrete piles and headstocks at Bowen Wharf and provides a comparison to the results from the same tests Arup undertook in 2019 at different locations. The purpose of the inspection work was to increase the sample size of testing data for the concrete piles and headstocks, to achieve a higher level of confidence of the test samples being representative of the entire structure.

The procurement of the concrete testing contractor was coordinated by Arup, with Australian Concrete X-Ray (ACX) commissioned to undertake the site works and manage the laboratory testing. A factual inspection report has been provided by ACX and is included in Attachment A. NQBP provided a workboat and skipper for the inspection works. Arup was not present on site for the testing.

1.1 Reference Information

Background information relevant to this testing is included in the documents listed below:

- Arup: Bowen Wharf Future Options Assessment – Testing Report (REV 2), 15 March 2020 (264408-00-REP-004)
- Shoreline Civil and Marine Consulting: Bowen Wharf Refurbishment Study – Design Report, 16 November 2023 (SCMC-23029-RPT-001)

2. Scope of Work

The scope for the concrete testing works included the following items:

- Undertake the following tasks and testing at a minimum of 23 nominated test locations (as per the inspection plan included in Attachment B):
  - Surface preparation of the test point, involving removal of marine growth and cleaning of the location to be suitable for the testing.

- Half-cell potential testing to determine the probability of corrosion within the reinforcement by chloride exposure.
- Resistivity testing to determine the corrosion in the reinforcement by impedance measurement technique.
- Chloride content testing by coring in up to 3 increments to determine the progression of chloride ingress through the concrete according to the AS1478.1 / AS1379 requirements.
  - The reinforcement was identified using a covermeter / ground penetrating rader (GPR) prior to testing to determine the required depth for the tests.
  - At a minimum, the chloride testing was taken up to the depth of the reinforcement within the concrete section. The planned increments are as per the following indicative testing regime, which included 3 samples per test location of length proportionate to the concrete cover:
    - 0-15mm / 0-35mm
    - 16-30mm / 36-55mm
    - 31-45mm / 56-80mm

    The above measurements are net of 10mm at either end of the core.
  - Re-instatement of core-holes using a suitable high-strength, non-shrink grout.
- Undertake concrete coring at two locations within the un-used sections of Piers 119, 120 or 121 (exact locations determined on site to enable suitable coring). The core was required to intercept the reinforcement in the pile. Re-instatement of the core-hole to be undertaken as per the chloride testing reinstatement.
- Coordinate the lab testing of the samples taken from site.

The nominated test locations were randomly selected prior to the inspection across the publicly accessible areas of Bowen Wharf, ensuring that no previously inspected piles were re-inspected. These nominated piles are outlined in Table 1 (refer to Attachment A for pile gridlines for each location).

Table 1: Nominated locations for concrete testing

Location	Pile ID*	Headstock ID*
Middle Wharf Stem	61B, 71A, 72B	61A, 64B, 72A
Outer Wharf Stem	81A, 86B, 96B, 111B, 115A, 118A	78A, 84A, 94A, 97A, 112A, 117D
Public Wharf	202B, 203E, 206C, 210C, 213C, 219E	201F, 202C, 203H, 209A, 212H, 217B

Refer to Attachment A plans for exact location

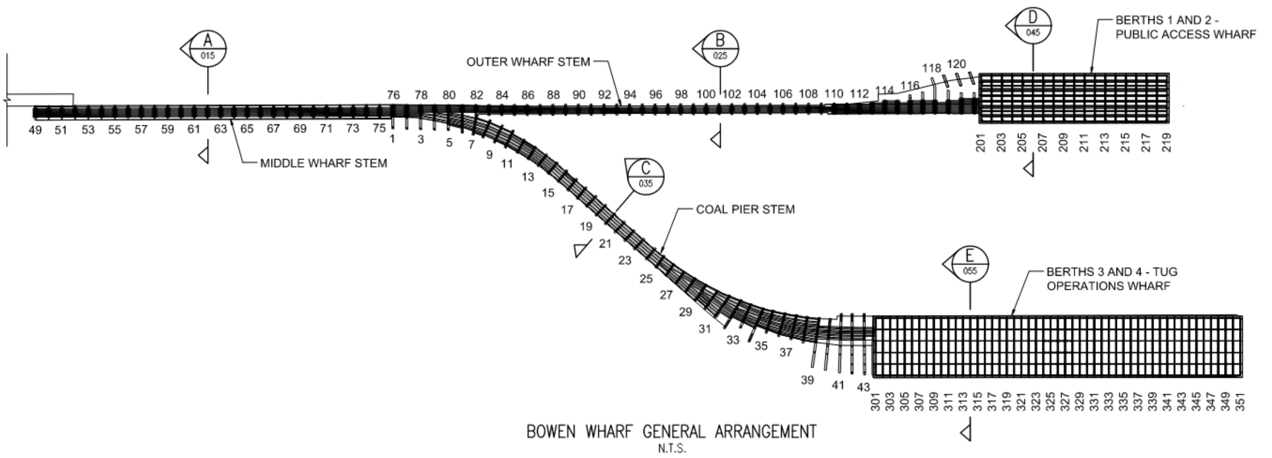


Figure 1: Bowen Wharf general arrangement

3. Inspection and Testing Methodology

The inspection was carried out from the 13th to the 17th of May 2024 by 2 ACX technicians, using a workboat provided by NQBP (with coxswain) and via access from the deck in areas where it was deemed safe.

3.1.1 Limitations to Testing

During the nominated inspection timeframe, difficult weather conditions including high swell and high wind conditions limited the window for which the workboat could be used safely for the test sampling. This issue, combined with the assessment from ACX and the NQBP coxswain that the nominated test locations underneath the Public Wharf were deemed not safe to inspect based on large sections of delamination presenting a significant risk of falling concrete, prevented the team to fully complete the scope of work. It was noted that whilst on site, evidence of falling concrete was observed.

Where possible, alternative locations were tested to offset these difficulties however it resulted in the full selection of test locations not being completed. Overall, a total of 17 test locations were tested, with 14 additional chloride tests being carried out successfully.

For the chloride cores, a number of samples broke down during the extraction process, resulting in some of the tested locations only having some of the increments able to be tested. In lieu of this, ‘blocks’ of delaminated concrete sections at the test locations were taken and samples were prepared in the laboratory for testing.

3.2 Half-Cell Potential Testing

The half-cell potential test is a method used to assess the likelihood of corrosion in reinforced concrete structures.

The half-cell potential measurement principle is to measure the potential difference of dissolved ferrous ions (from the breakdown of the passive film of the reinforcement steel) and the hydroxide formed from the release of these ions combined with water and oxygen. The passive film of the reinforcement is decomposed due to the reaction of the concrete with atmospheric carbon dioxide or by the presence of substances aggressive to steel (in particular chlorides or salt water).

The test specification used for the half-cell testing assessment is against the ASTM C876 Standard Test Method for Half-Cell Potentials of Uncoated Reinforcing Steel in Concrete. The equipment used for this testing was the Proceq Canin+ Corrosion Analysing Instrument. An example of the results from the testing equipment is shown in Figure 2

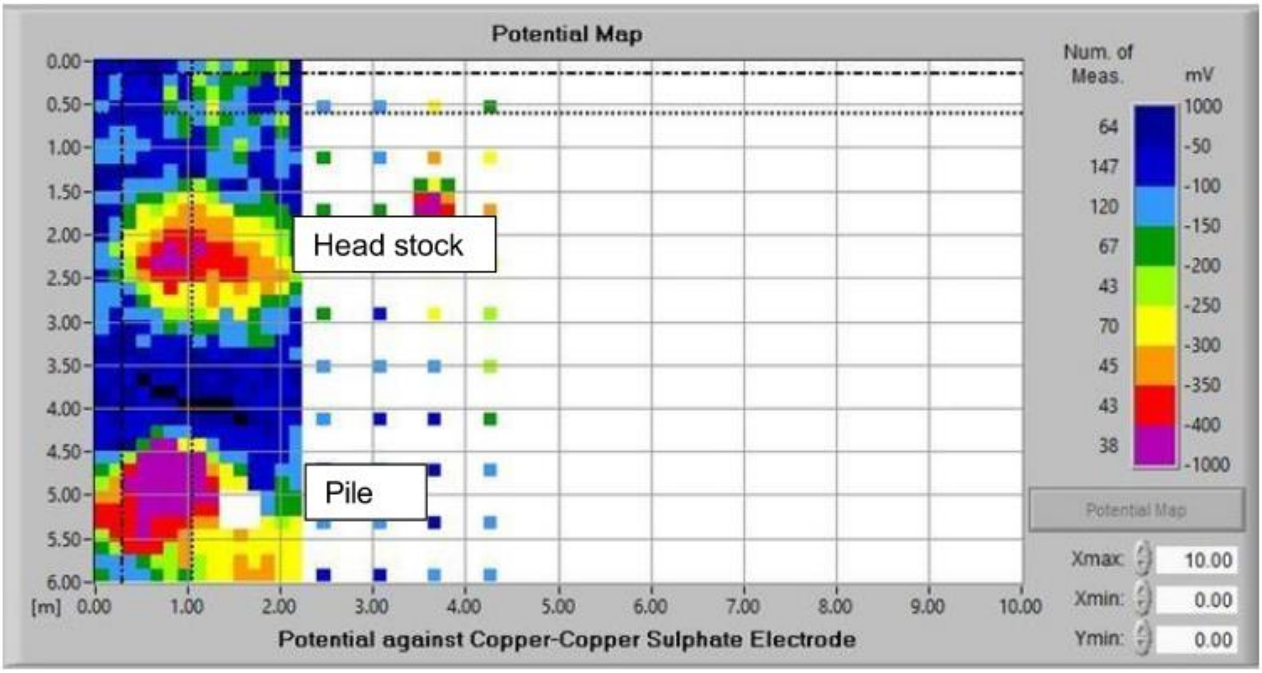


Figure 2: Half-cell potential readings example (test location 8)

Table 2 outlines the corrosion risk for the half-cell testing method based on the potential difference readings.

Table 2: ASTM C876 Cu/CuSO4 Half-Cell Criteria

Half-Cell Potential against $Cu/CuSO_4$	Corrosion Risk
> -200mV	Low (<10% risk of corrosion)
-200 mV to -350mV	Possible corrosion risk
< -350mV	High (>90% risk of corrosion)

3.3 Resistivity Testing

In combination with the half-cell potential testing, resistivity testing was also undertaken for each of the tested locations. As per Standards Australia HB 84: 2018 Guide to Concrete Repair and Protection, resistivity measurements indicate the case with which an electrical charge is transported in concrete and is hence a measure of ionic transport (current) through the concrete. The transport of charge, in principle, largely determines the rate of corrosion of steel reinforcement and thus indicates corrosion probability. Resistivity is usually carried out to complement other tests as part of an overall corrosion survey plan.

Resistivity measurements were taken using the Resipod Proceq-A1, four probe resistivity meter.

The test specification used for the resistivity testing assessment is against the AASHTO TP 95-11 Surface Resistivity Test Method and uses the following reference values in Table 3 to determine the risk of corrosion according to the Resistivity.

Table 3: Reference values for Resistivity Testing

Reference Value at 25ºC	Corrosion Risk
≥ 100 kΩcm	Negligible risk of corrosion
50 ≤ α ≤ 100 kΩcm	Low risk of corrosion
10 ≤ α ≤ 50 kΩcm	Moderate risk of corrosion
≤ 10 kΩcm	High risk of corrosion

3.4 Chloride Testing

Chloride testing of concrete provides a greater understanding of the ingress of chloride ions in the concrete which initiate steel corrosion. Whilst the half-cell potential testing provides indication of the presence of chloride ions by measuring the potential difference, the chloride testing analyses the actual percentage of chloride in the concrete section.

Coring and capture of concrete samples in each of the test locations was undertaken to be analysed for the percentage of chloride ingress into the concrete at progressive increments into the concrete section. The samples were collected by ACX and sent to a laboratory for analysis and testing.

The Standards Australia HB 84: 2018 Table 2.2 specifies the probability of corrosion from chloride ions in Portland cement concrete by total weight by weight of cement. These criteria are summarised in Table 4. It should also be noted that steel reinforcement corrosion can occur when the chloride ion content is more than 0.4% W/W cement and can be sustained when greater than 0.1% W/W.

Table 4: Corrosion risk due to chloride ion content according to SA HB84: 2018)

Total Chloride Ion Content by Weight of Cement (%)	Corrosion Risk
≤ 0.4%	Low
0.4 – 1.0%	Dangerous
> 1.0%	Very Dangerous

It is noted that in the 2020 Arup Testing Report (264408-00-REP-004), the values in Table 4 were denoted as “Low”, “Moderate” and “High” corrosion risk, but refer to the same risk level by % chloride ingress into concrete. For this report, the classifications and descriptions provided in SA HB84:2018 have been used.

4. Basis for Level and Extent of Testing

The proposed test locations were selected across the Middle Stem, Outer Stem and Public Wharf sections, as the areas of the jetty/wharf that are currently publicly accessible. The exact location of specified piles and headstocks for concrete testing were selected at random (to avoid selection bias), with the following permutations:

- No piles or headstock locations previously tested in 2019 have been selected to be re-tested.

- Raker piles on the Public Wharf area were not included in the selected of test locations.
- Piles on Pier 49-52 were not included due to being mostly concealed by causeway rock.

For the avoidance of confusion to the previous pile identification system, a new set of Pile ID's have been marked up on the drawings in Attachment B (and link to Table 1).

Following a review of the 2019 inspection results a total of 11 test locations were identified to have already been inspected across the publicly accessible areas of the structure. The SIGTTO/OCIMF Jetty Maintenance and Inspection Guide (2008), which provides guidance for inspections of structures such as Bowen Wharf, does not specify a minimum or maximum number of piles to be nominated for physical testing, but rather that it should be quantified and assessed on a case-by-case basis. Noting this, Arup have nominated that number of tests should be within the 5-10% range of the overall number of piles to be able to provide a reasonable amount of data to extrapolate out for the entire wharf. To achieve a 10% coverage of piles/headstocks, 23 additional tests were required to be undertaken which was nominated by Arup for ACX to complete on site.

As noted in Section 3.1.1, due to the difficulty of accessing the underside of the structure via boat during the nominated inspection days, only 14 chloride test locations were carried out which is approximately 7.5% of the total piles/headstocks and still falls within the 5-10% target range to be used to extrapolate out for the full structure.

5. Testing Results and Findings

5.1 General Visual Observations – Public Wharf

The following key items were generally observed by ACX throughout the testing programme, particularly for the Public Wharf area, where a number of the test locations were unable to be undertaken for safety reasons. Refer to Attachment A for further images of each of the test locations and general images of the Public Wharf area.

- Widespread, full thickness delamination and exposed reinforcement.
- Unable to perform half-cell potential tests.
- Visual loss of reinforcing thickness, large unstable segments of concrete that appear to be separating from the superstructure.
- Visually observed debris falling whilst on site.
- Job Safety Assessment by ACX and NQBP coxswain deemed that working underneath the deck would present an unacceptable risk, with no tangible way to reduce the risk.

Figure 3 shows some examples of the general condition of the Public Wharf area.

Figure 3: Images of Public Wharf area

5.2 Half-Cell Potential Testing

The review of the half-cell potential tests found that the results indicated High probability of corrosion with readings lower than the -350mV threshold (as per Table 2). In many cases, the readings were significantly lower than the threshold which increases the likelihood that active corrosion is taking place in the reinforcing bars. This result aligns with the visual observation and explains the concrete spalling and exposed reinforcement.

These results are in line with the previous half-cell results from the 2019 testing, where it was also found that almost all tested locations were within the high range for corrosion probability. With the additional sample size of tests in different locations, it is reasonable to conclude that most if not all areas of the publicly accessible area of the wharf have a high risk of active ongoing corrosion.

Refer to Table 5 below for a summary of the results for each test location.

Table 5: Summary of half-cell potential testing results

Location	Element	Test Point (as per ACX Report)	Half-cell reading (mV)	Classification
Middle Wharf Stem				
54A	Pile & Headstock	12	-765	High Risk
57A	Pile & Headstock	11	-814	High Risk
62A	Pile & Headstock	14	-714	High Risk
Outer Wharf Stem				
76A	Pile & Headstock	8	-779	High Risk
80A	Headstock	7	-697	High Risk
84A	Headstock	1	N/A*	N/A*
84B	Headstock	17	-684	High Risk
86B	Headstock	2	N/A*	N/A*
91B	Pile & Headstock	9	-841	High Risk
94B	Headstock	4	-795	High Risk
97A	Headstock	3	-635	High Risk

Location	Element	Test Point (as per ACX Report)	Half-cell reading (mV)	Classification
98A	Headstock	10	-697	High Risk
112A	Pile & Headstock	16	-658	High Risk
114A	Headstock	13	-554	High Risk
115A	Pile & Headstock	18	-613	High Risk
117A	Headstock	5	-593	High Risk
Public Wharf				
201F	Pile & Headstock	6	-785	High Risk
212B	Pile & Headstock	15	-687	High Risk

5.3 Resistivity Testing

From assessment of the resistivity results for the tested areas, it was found that most of the results indicated moderate resistance levels according to the criteria in Table 3. It should be noted however that most of the results were on the lower end of the moderate range, suggesting they are not far from falling into the high-risk range.

These results are generally in line with the 2019 testing results that typically showed low-moderate resistivity levels. As a result of the increased sample size of test results and the trends remaining the same, it can be concluded that these resistivity levels are similar across the entire structure.

Whilst the resistivity tests provide an indication of the corrosion rate and overall risk of corrosion, it is not typically the primary method used to assess the overall corrosion risk to the concrete reinforcement. The results should be assessed in combination with half-cell testing, chloride testing and visual observations.

Refer to Table 6 for the summary of the resistivity testing results.

Table 6: Summary of resistivity testing results

Location	Area Examined	Test Point (as per ACX Report)	Resistivity Reading (kΩ)	Classification
Middle Wharf Stem				
54A	Headstock	12	21.8	Moderate
57A	Pile and Headstock	11	20.5	Moderate
62A	Pile	14	15.9	Moderate
Outer Wharf Stem				
76A	Headstock	8	12.8	Moderate
80A	Headstock	7	12.9	Moderate
84A	Headstock	1	14	Moderate
84B	Headstock	17	37.2	Moderate
86B	Headstock	2	25.9	Moderate
91B	Pile and Headstock	9	15.3	Moderate
94B	Headstock	4	35.2	Moderate
97A	Pile	3	11	High
98A	Pile and Headstock	10	19.8	Moderate
112A	Pile and Headstock	16	18.4	Moderate
114A	Headstock	13	43.2	Moderate
115A	Pile	18	26.5	Moderate
117A	Headstock	5	19.5	Moderate
Public Wharf				
201F	Pile	6	15.4	Moderate
212B	Pile	15	27.3	Moderate

5.4 Chloride Testing

The chloride test results from the laboratory analysis show that most of the core samples indicated dangerous or very dangerous chloride content levels (by % weight) according to the criteria outlined in Table 4. These results provide a clear understanding of the significance of corrosion risk to the reinforcement bars by measuring the actual chloride content in the concrete. They are consistent with the half-cell testing and resistivity measurements.

These results are in line with the 2019 testing results that typically showed dangerous and very dangerous chloride levels as per the SA HB84:2018 criteria. As a result of the increased sample size of test results and the trends remaining the same, it can be concluded that these results are consistent across the entire structure.

The results of the chloride testing classify the chloride content as dangerous and very dangerous; this corresponds to a high risk of corrosion in the reinforcement. The classification does not relate to the safety of the structure, rather it is an indicator of the corrosion in the reinforcement.

Refer to Table 7 for the summary of the chloride testing results.

Table 7: Summary of chloride testing results

Location	Test Point (as per ACX Report)	Chloride Content (%)	Classification
Middle Wharf Stem			
54A	12	1.60%	Very Dangerous
57A	11	1.00%	Very Dangerous
62A	14	1.60%	Very Dangerous
Outer Wharf Stem			
76A	8	0.33%	Low
80A	7	0.63%	Dangerous
84A	1	N/A	N/A
84B	17	2.10%	Very Dangerous
86B	2	N/A	N/A
91B	9	1.80%	Very Dangerous
94B	4	1.10%	Very Dangerous
97A	3	0.50%	Dangerous
98A	10	1.50%	Very Dangerous
112A	16	1.50%	Very Dangerous
114A	13	2.20%	Very Dangerous
115A	18	N/A	N/A
117A	5	0.56%	Dangerous
Public Wharf			
201F	6	0.61%	Dangerous
212B	15	N/A	N/A

6. Conclusion

The concrete inspection and testing undertaken by Arup in 2019 and recently by ACX confirm that the reinforcement in the piles and headstocks is corroding. This result is also supported by the evident concrete delamination and spalling that was observed on site. It was found through all of the chloride testing, half-cell testing and the resistivity testing that the results found in the 2024 testing are in-line with the results from the 2019 inspection.

Note that the results of the chloride testing classify the chloride content as dangerous and very dangerous; this corresponds to a high risk of corrosion in the reinforcement. The classification does not relate to the safety of the structure, rather it is an indicator of the corrosion in the reinforcement

The same conclusions as the Arup 2020 report, below reported, apply to the continued use of the wharf.

Concrete elements: As the risk of corrosion in the concrete elements is high, it is recommended that these elements are rehabilitated if NQBP intend to continue the use of the asset for longer than 10 years. For up to 10 years continued asset use we recommend a regular monitoring strategy, such that any observed deterioration is repaired as required.

In summary,

Considering the severity and widespread corrosion that the concrete testing has confirmed, the age of the structure (over 100-year-old), and the 100-year design life requirement for future use of the jetty, repairing the existing piles and headstocks to support a new deck is not a practical solution for the project. The data collected with the concrete testing, which have been reviewed against industry standards mentioned in this document, and our understanding of the deterioration mechanism of reinforced concrete structures, suggest that the best outcome for the project is to replace the piles and headstocks. The piles and headstocks replacement will eliminate any safety risks associated with the long-term performance of the existing piles and provide a safe and durable structure.

Attachment A – Australian Concrete X-Ray Concrete Testing Report

REPORT NO:	ACX240067-01 Arup Bowen Wharf - HCP
REPORT DATE:	14th June, 2024
CLIENT:	ARUP on behalf of Asset owner
ORDER NUMBER:	Sub-Consultant Agreement
PLACE OF TEST:	Bowen Wharf outer Wharf Stem
CORROSION POTENTIAL SURVEY EXAMINATION OF:	Piles and Headstocks corrosion assessment
EXAMINATION CRITERIA:	1. Visual inspection of reinforcement for corrosion 2. Half-cell potential testing 3. Resistivity 4. Chloride Ingress.

DISCLAIMER:

Provided that the corrosion conditions are equal (chloride content or carbonation of the concrete at the steel surface) the main influences upon the half-cell potentials are:

Moisture
Moisture has a large effect on the measured potential leading to more negative values.

Temperature
In order to measure the potential there must be a contact between the probe and the electrolytes in the pore system of the concrete. Therefore a measurement below the freezing point is not recommended and can lead to incorrect readings.

Concrete cover thickness
The potential that can be measured at the surface becomes more positive with increasing concrete cover. Variations in the concrete cover can cause deviations in the measurements. Very low concrete cover can lead to more negative potentials which would seem to indicate high levels of corrosion.

Oxygen content at the reinforcement
With decreasing oxygen concentration and increasing pH-value at a steel surface its potential becomes more negative. In certain cases of concrete components with a high degree of water saturation, low porosity and/or very high concrete cover and thus low oxygen supply, the potential at the steel surface may be very negative even though no active corrosion is taking place. Without checking the actual corrosion state this may lead to misinterpretation of the potential data.

The latest equipment is used to carefully carry out examinations however due to limitations of the technology the value of scanning is as a risk reduction method and the use of GPR cannot guarantee that all objects will be detected or all reflections interpreted correctly.

For greater risk reduction we recommend gamma radiography examination, which requires clearance of 25m minimum, horizontally and the floors above and below, followed by high pressure water blasting or careful chiselling.

ACX does not accept liability under any circumstances for non-detection of objects and if this is required you must consult your insurance suppler.

Technical Data:

Technician/s:	
Surface Appearance:	Smooth Concrete
Preparation:	GPR mapping of reinforcement and saturating concrete surfaces

Australian Concrete X-Ray

REPORT NO: ACX ACX240067-01 Arup Bowen Wharf – HCP **Test Date/s**: 13th through to 17th May 2024

Test Units	**Ground Penetrating Radar [GPR]**	**Corrosion Analysing Instrument**
Brand / Model	GSSI: Structure Scan Mini XT®	PROCEQ ***CANIN+*** (SN 19.1457)
Test Method	Line Scans	Copper/Copper Sulphate wheel electrode (single electrode)
Other Details	Antenna: 2700 MHz [S/N: 1153] Orientation: Polarised	Earth to reinforcement. Continuity checked using a resistance meter.

Reinforcement Earth or other earth position:	**Pile and headstock Reinforcment.**
Surface Temperature:	27°C - Ambient Temperature
Electrode:	Probe
Electrolyte:	Copper Sulphate
Surface Condition:	Exposed aggregate
Equipment: Serial No:	Proceq Canin Corrosion Analysing Instrument 19.1457
Test Specification:	ASTM C876 Standard Test Method for Half-Cell Potentials of Uncoated Reinforcing Steel in Concrete

Procedure: In accordance with the manufacturers' instructions.

Accuracy of position: For all targets identified by marking or drawings a safety margin for penetrations of at least ±25mm each side is required. If greater accuracy was requested this can be reduced to ±10mm each side and will be noted on the following pages for the respective locations

Test Limitations: Potential surveys give an indication of the potential for corrosion at the time of measurement. Note the vertical axis can not be adjusted and the blanked out areas in the figures were not tested.
ASTM C876-91 states the following,
Potentials more positive than -200mV indicate there is a greater than 90% probability that no reinforcing steel corrosion is occurring in that area at the time of measurement.
Potentials between -200 and -350 mV indicate corrosion activity of reinforcing steel is uncertain in that area at the time of measurement.
Potentials less positive than -350mV indicate there is a greater than 90% probability that reinforcing steel corrosion is occurring in that area at the time of measurement.
Steel distribution indicated below calculated by selecting assumed representative radar files from each section and using the average spacing.
Non-destructive testing as performed in the following pages does not assess any potential chloride ion attack on the steel. See sperate report.

Corrosion of pre-stressed steel reinforcement is not possible to detect if it is located within a protective tube.
The potential field measurement alone offers no quantitative conclusions about the rate of corrosion. Empirical studies have shown that there is a direct relationship between the corrosion rate and the electrical resistivity. However corrosion rate readings are of limited value as the rebar corrosion rate varies considerably with time. It is more reliable to work with corrosion readings taken over a period of time.

Verification of results: See the following pages.

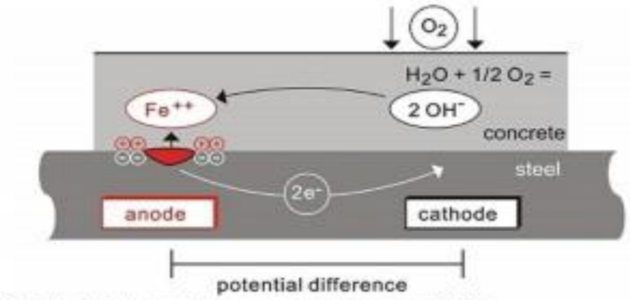
Permanent Test Record: Photographs appear on the following page/s.

2.1 The Half-Cell Potential Measurement Principle

Under normal conditions reinforcement steel is protected from corrosion by a thin, passive film of hydrated iron oxide.

This passive film is decomposed due to the reaction of the concrete with atmospheric carbon dioxide (CO_2, carbonation), or by the penetration of substances aggressive to steel, in particular chlorides from de-icing salt or salt water.

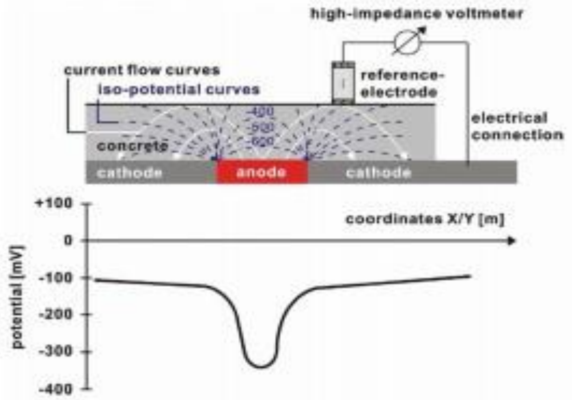
At the anode ferrous ions (Fe++) are dissolved and electrons are set free. These electrons drift through the steel to the cathode, where they form hydroxide (OH-) with the generally available water and oxygen. This principle creates a potential difference that can be measured by the half-cell method.



Principle of steel corrosion in concrete with oxygen availability

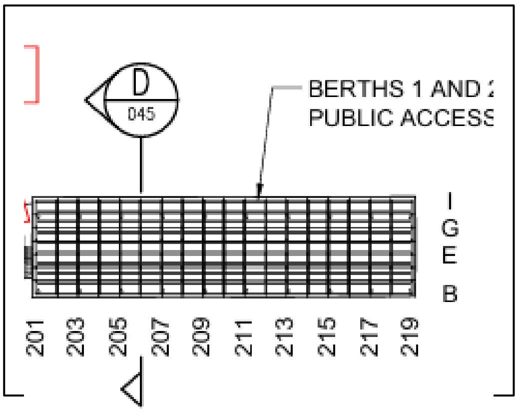
The basic idea of the potential field measurement is to measure the potentials at the concrete surface, in order to get a characteristic picture of the state of corrosion of the steel surface within the concrete. For this purpose a reference electrode is connected via a high-impedance voltmeter (in the case of the system Canin+ R = 10 MΩ) to the steel reinforcement and is moved in a grid over the concrete surface.

The reference electrode of the Canin+ system is a $Cu/CuSO_4$ half-cell. It consists of a copper rod immersed in a saturated copper sulphate solution, which maintains a constant, known potential.



Proposed-Testing Locations.

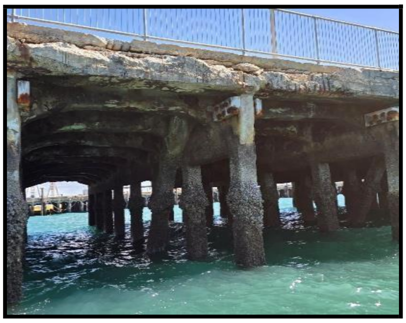
LOCATION	PILE ID	HS / PILE?
Middle Wharf Stem	61A	HS
Middle Wharf Stem	61B	P
Middle Wharf Stem	64B	HS
Middle Wharf Stem	71A	P
Middle Wharf Stem	72A	HS
Middle Wharf Stem	72B	P
Outer Wharf Stem	78A	HS
Outer Wharf Stem	81A	P
Outer Wharf Stem	84A	HS
Outer Wharf Stem	86B	P
Outer Wharf Stem	94A	HS
Outer Wharf Stem	96B	P
Outer Wharf Stem	97A	HS
Outer Wharf Stem	111B	P
Outer Wharf Stem	112A	HS
Outer Wharf Stem	115A	P
Outer Wharf Stem	117D	HS
Outer Wharf Stem	118A	P
Public Wharf	201F	HS
Public Wharf	202B	P
Public Wharf	202C	HS
Public Wharf	203E	P
Public Wharf	203H	HS
Public Wharf	206C	P
Public Wharf	209A	HS
Public Wharf	210C	P
Public Wharf	212H	HS
Public Wharf	213C	P
Public Wharf	217B	HS
Public Wharf	219E	P



Any nominated test locations under the public wharf where, deemed not safe for testing due to large sections of delamination which could fall with little or no contact, visual observations were made of sizable pieces of concrete debris falling randomly and without notice.

Test restrictions due to high swell and high wind for 3.5 days prevented some of the nominated test areas being tested, however new test sites were within proximity where possible, the decision was made to progress with alternative locations rather than forgo testing altogether.

Visual inspection of the underside of public wharf.









Observations of public Wharf visual Inspection

- Widespread full thickness delamination, exposed reinforcing.
- Not able to perform HCP test.
- Visual loss of reinforcing thickness, large unstable segments of concrete appear to be separating from super structure.
- Visually observed debris.
- Deemed unsafe to access after Job safety assessment was carried out.

- The risk ranking was assessed to be **S = Significant** to **H = High** with no tangible way to reduce to risk.

Likelihood	Consequence					Risk Ranking
	Very Low	**Minor**	**Moderate**	**Major**	**Catastrophic**	
Almost Certain	L	**S**	**S**	**H**	**H**	
Likely to occur	L	M	**S**	**H**	**H**	**H = High**
Moderate	L	M	**S**	**S**	**H**	**S = Significant**
Unlikely	L	L	M	**S**	**H**	**M = Moderate**
Rare	L	L	M	**S**	**H**	**L = Low**

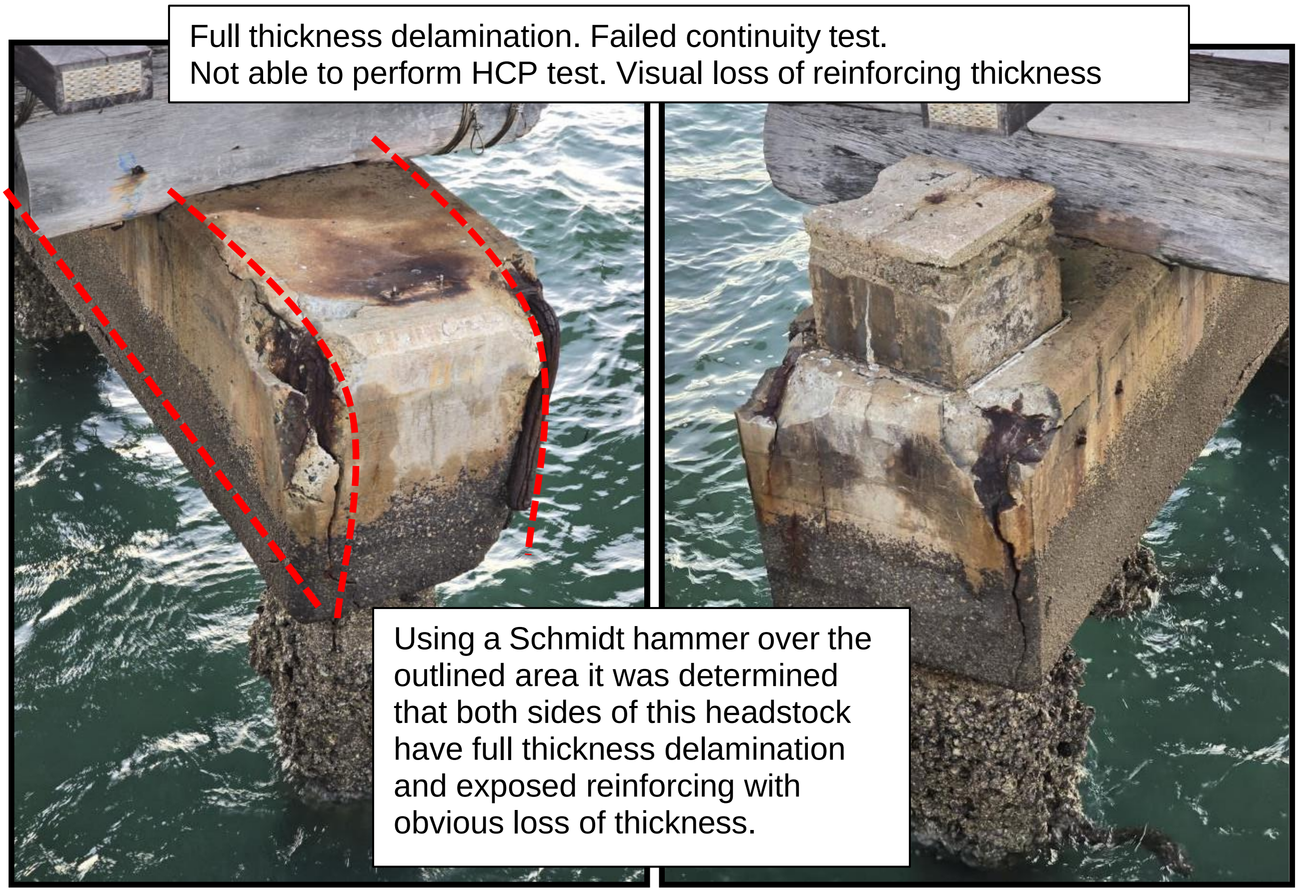
Visual Inspection and assessment for testing.

LOCATION 1 - 84 A&B HS. Outer wharf stem.

Visual Inspection

The location was scanned with ground penetrating radar in polarised orientation from both sides of the headstock and there was 1 layer of reinforcing detected on each side at approximately 70mm (average) depth.

Reinforcement locations were marked, and a hole drilled until steel was first encountered. corrosion is visual evident, Loss of reinforcing thickness was evident.



Calibration

Function Check of electrodes:	Result .01 mV Tolerances 0±5mV Reference with rod electrode 0±5mV Reference with wheel electrode 0 + 20mV
Steel reinforcement connectivity	No

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LOCATION 2 - 86 B Outer wharf stem.

Visual Inspection

The location was scanned with ground penetrating radar in polarised orientation from both sides of the headstock and there was 1 layer of reinforcing detected on each side at approximately 70mm (average) depth.

Reinforcement locations were marked, and a hole drilled until steel was first encountered.

corrosion is visual evident, Loss of reinforcing thickness was evident.

Full thickness delamination. Failed continuity test.
Not able to perform HCP test. Visual loss of reinforcing thickness

Function Check of electrodes:	Result .01 mV Tolerances 0±5mV Reference with rod electrode 0±5mV Reference with wheel electrode 0 + 20mV
Steel reinforcement connectivity	No

LOCATION 3 - 97 A HS Outer wharf stem.

Visual Inspection

The location was scanned with ground penetrating radar in polarised orientation from both sides of the headstock and there was 1 layer of reinforcing detected on each side at approximately 80mm (average) depth.

Reinforcement locations were marked, and a hole drilled until steel was first encountered.

corrosion is visually evident, Loss of reinforcing thickness was evident.

Core sample taken for Chloride ingress test. (separate report)

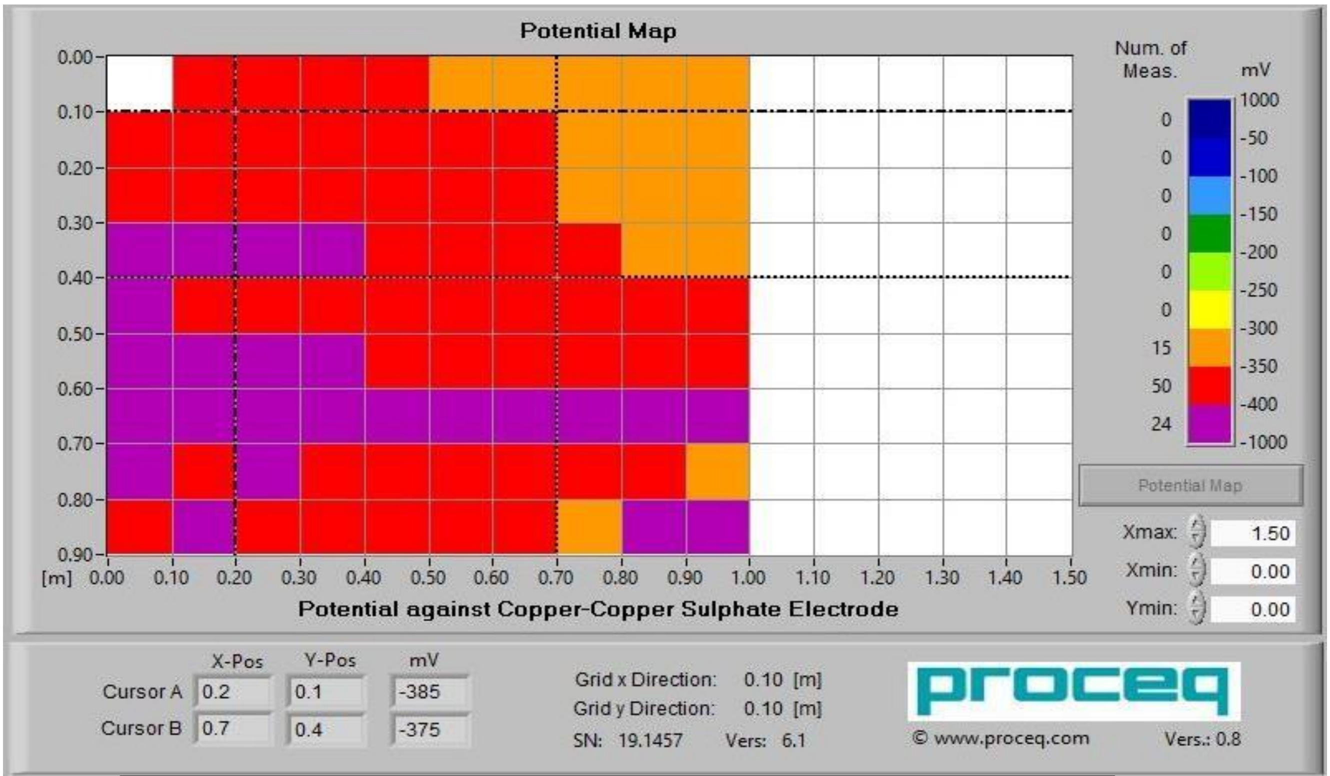
Function Check of electrodes:	Result .01 mV Tolerances 0±5mV Reference with rod electrode 0±5mV Reference with wheel electrode 0 + 20mV
Steel reinforcement connectivity	Yes

Half-cell Potential Testing

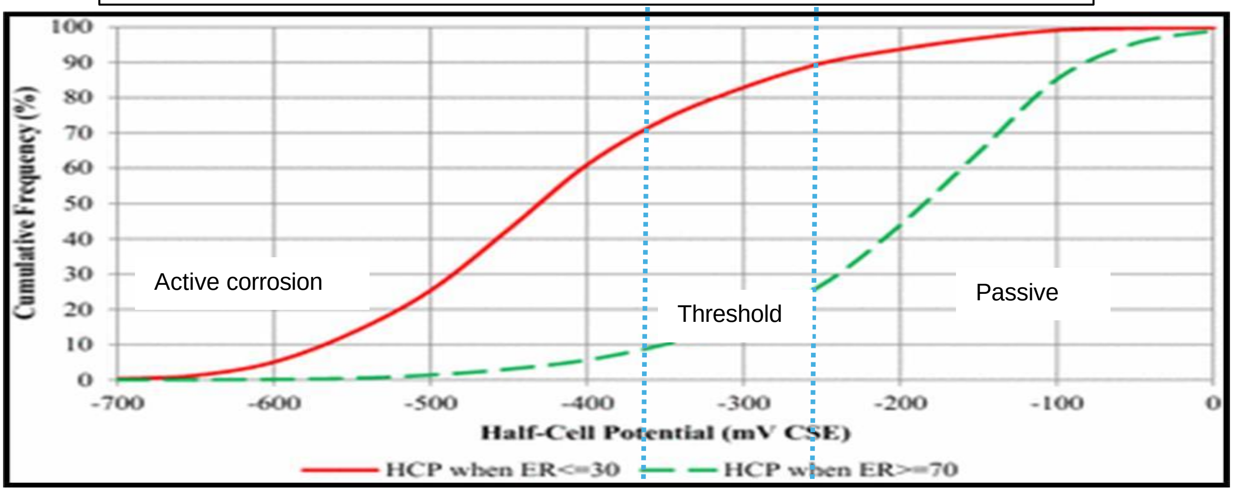
The attached figures show the potential survey results. This is a plan view that shows X vs. Y distances in meters, the column shows the measures in mV (megavolt) with different colors according to its magnitude; the minimum value obtain was [-635 mV] and maximum [-315mV].

Refer to frequency % chart next page Potentials more positive than -200mV indicate there is a greater than 90% probability that no reinforcing steel corrosion is occurring in that area.

Note: Active corrosion



Frequency Chart



LOCATION 4 - 94 B HS Outer wharf stem.

Visual Inspection

The location was scanned with ground penetrating radar in polarised orientation from both sides of the headstock and there was 1 layer of reinforcing detected on each side at approximately 80mm (average) depth.

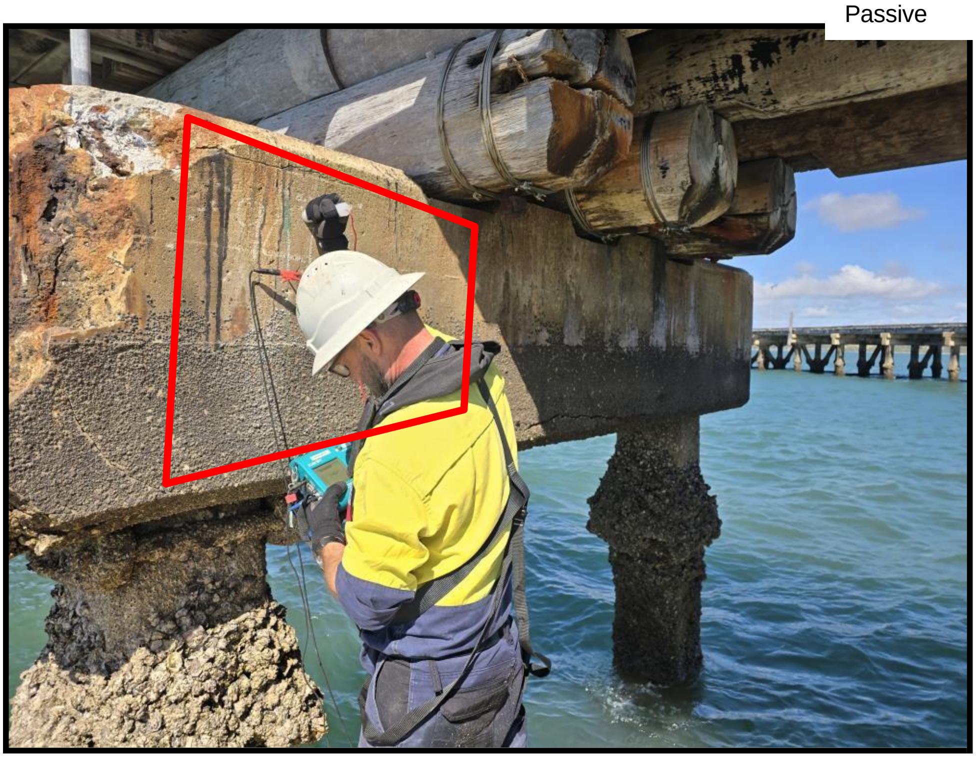
Reinforcement locations were marked, and a hole drilled until steel was first encountered.

corrosion is visually evident, Loss of reinforcing thickness was evident.

Core sample taken for Chloride ingress test. (separate report).

Active Corrosion

Passive



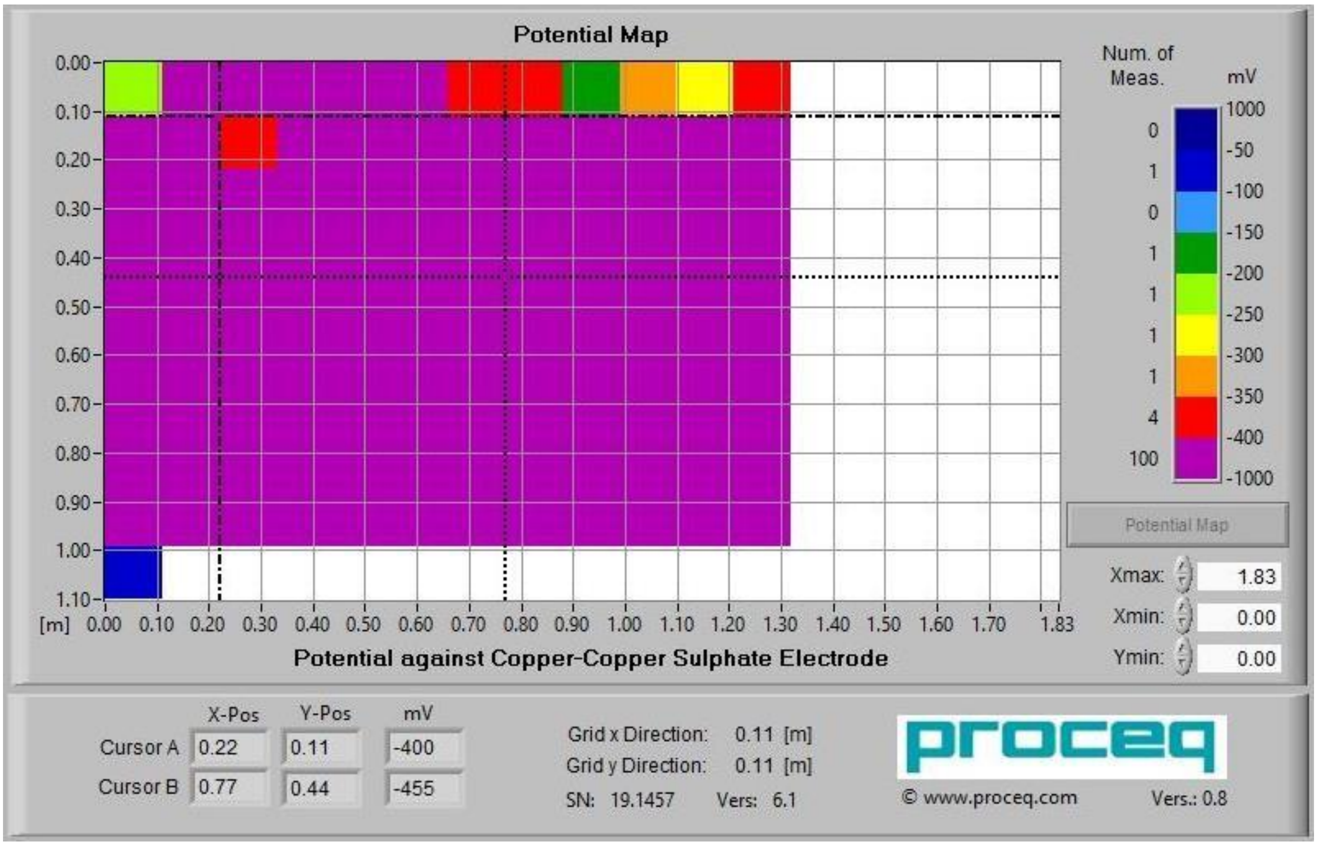
Function Check of electrodes:	Result .04 mV Tolerances 0±5mV Reference with rod electrode 0±5mV Reference with wheel electrode 0 + 20mV
Steel reinforcement connectivity	Yes

Half-cell Potential Testing

The attached figures show the potential survey results. This is a plan view that shows X vs. Y distances in meters, the column shows the measures in mV (megavolt) with different colours according to its magnitude; the minimum value obtain was [-795 mV] and maximum [-295 mV].

Refer to frequency % page 8 Potentials more positive than -200mV indicate there is a greater than 90% probability that no reinforcing steel corrosion is occurring in that area.

Note: Active corrosion.



LOCATION 5 - 117 A HS Outer wharf stem.

Visual Inspection

The location was scanned with ground penetrating radar in polarised orientation from the top of the headstock and there was 1 layer of reinforcing detected at approximately 90mm (average) depth.

Reinforcement locations were marked, and a hole drilled until steel was first encountered.

corrosion is visually evident, Loss of reinforcing thickness was evident.

Block sample taken for Chloride ingress test. (separate report).

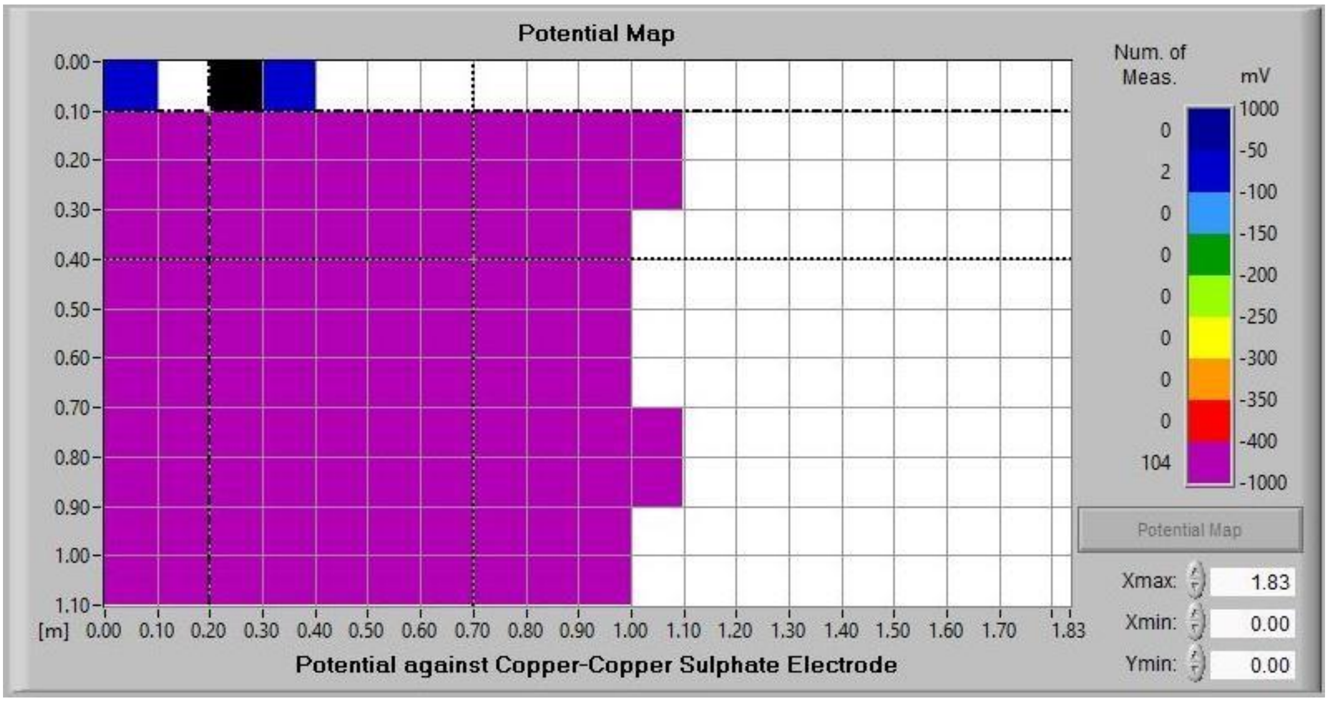
Function Check of electrodes:	Result .02 mV Tolerances 0±5mV Reference with rod electrode 0±5mV Reference with wheel electrode 0 + 20mV
Steel reinforcement connectivity	Yes

Half-cell Potential Testing

The attached figures show the potential survey results. This is a plan view that shows X vs. Y distances in meters, the column shows the measures in mV (megavolt) with different colours according to its magnitude; the minimum value obtain was [-593 mV] and maximum [-495 mV].

Refer to frequency % page 8 Potentials more positive than -200mV indicate there is a greater than 90% probability that no reinforcing steel corrosion is occurring in that area.

Note: Active corrosion.



LOCATION 6 – 201F Hs and Pile Public Wharf.

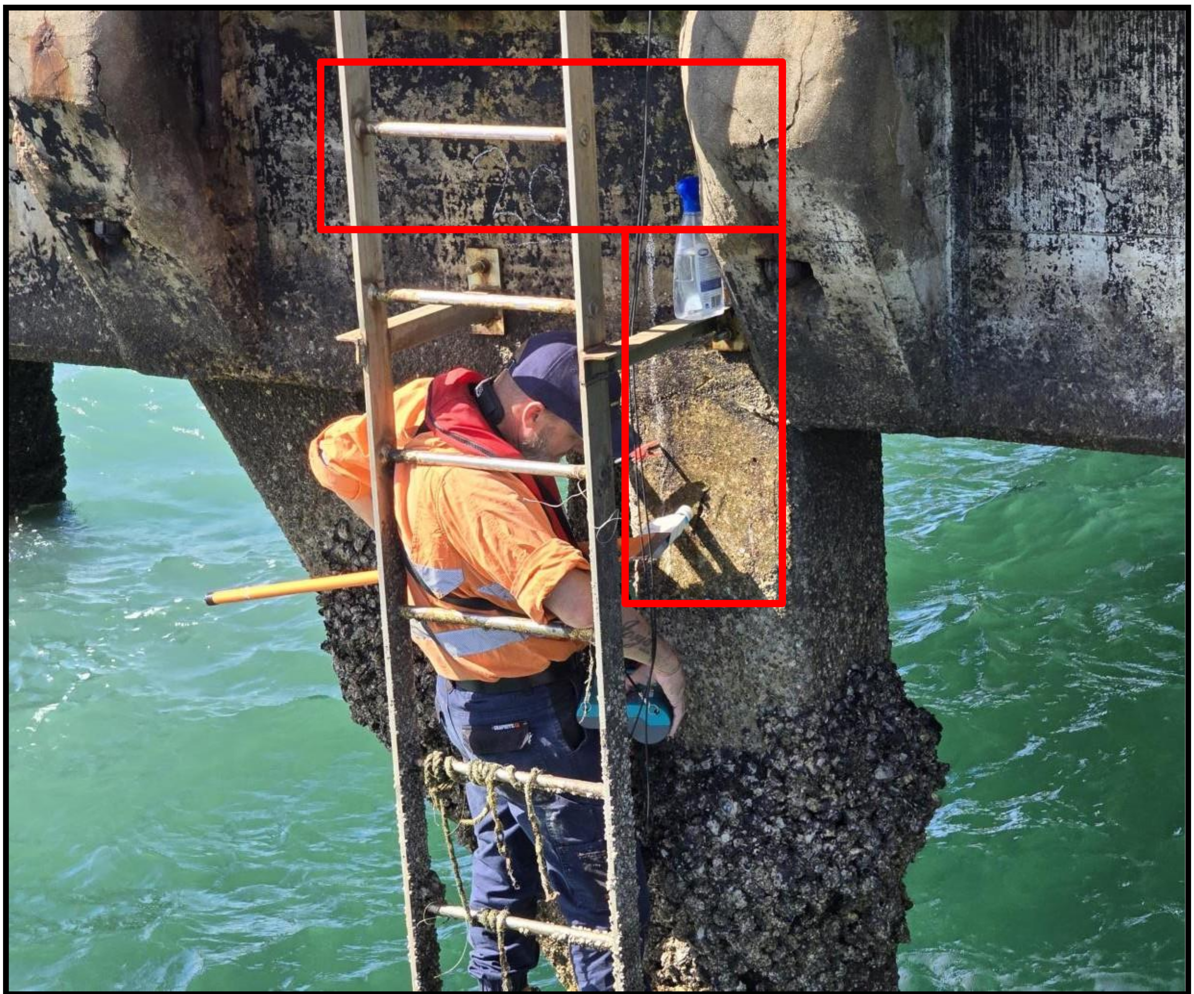
Visual Inspection Head stock and Pile

The location was scanned with ground penetrating radar in polarised orientation from the top of the headstock and there was 1 layer of reinforcing detected at approximately 90mm (average) depth.

Reinforcement locations were marked, and a hole drilled until steel was first encountered.

corrosion is visually evident, Loss of reinforcing thickness was evident.

Block sample taken for Chloride ingress test. (separate report).



Function Check of electrodes:	Result .09 mV Tolerances 0±5mV Reference with rod electrode 0±5mV Reference with wheel electrode 0 + 20mV
Steel reinforcement connectivity	Yes

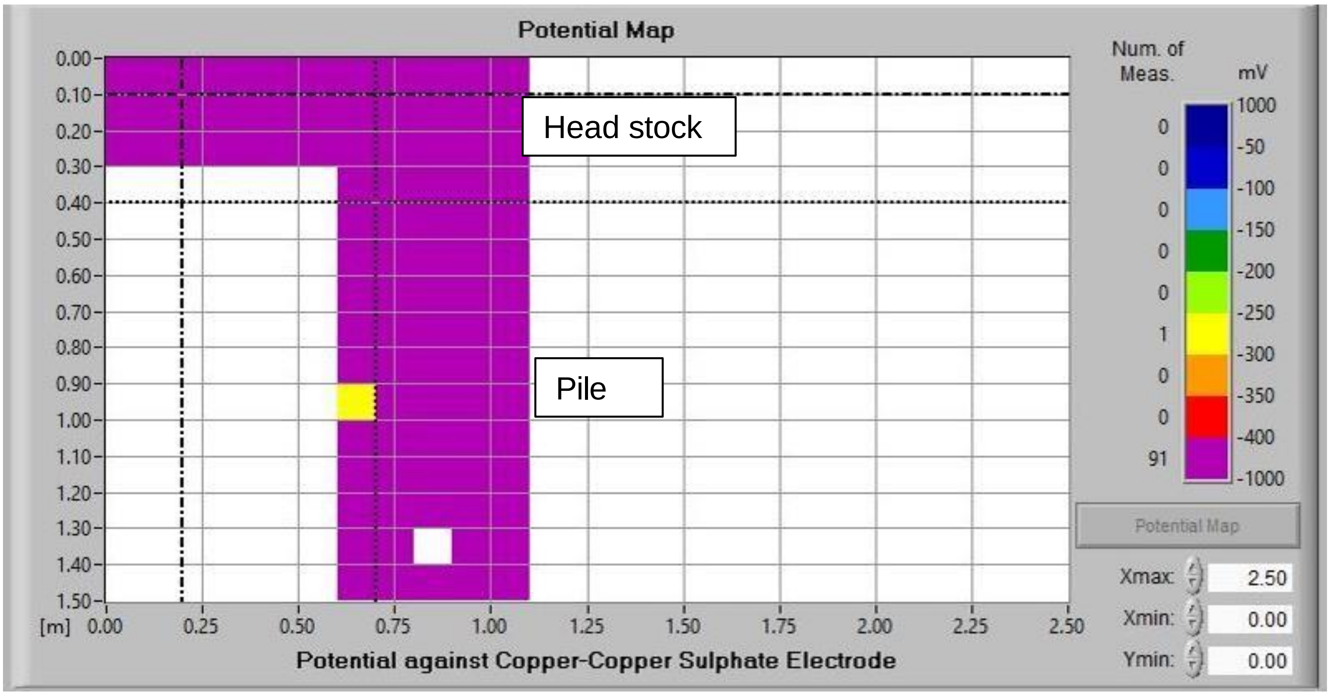
Half-cell Potential Testing

The attached figures show the potential survey results. This is a plan view that shows X vs. Y distances in meters, the column shows the measures in mV (megavolt) with different colours according to its magnitude; the minimum value obtain was [-785 mV] and maximum [-675 mV].

Refer to frequency % page 8 Potentials more positive than -200mV indicate there is a greater than 90% probability that no reinforcing steel corrosion is occurring in that area.

Note: Active corrosion.

Extending the through the transition between Edge beam and Pile.



LOCATION 7 – 5-80a HS Public Wharf.

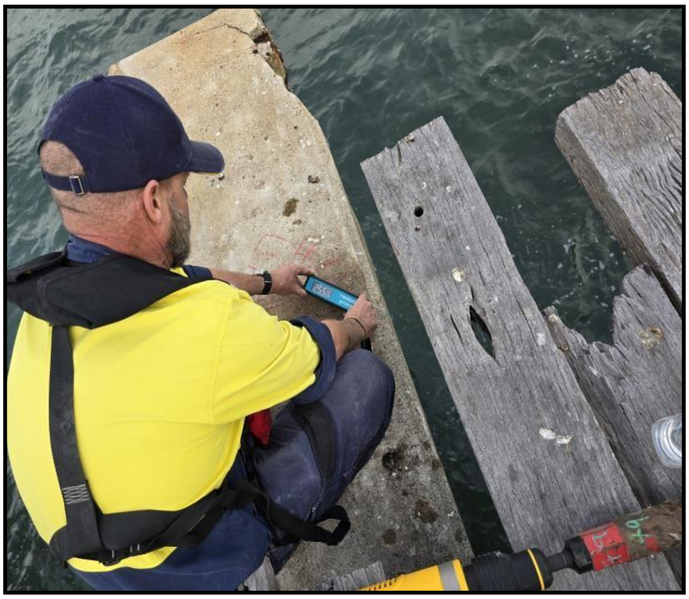
Visual Inspection

The location was scanned with ground penetrating radar in polarised orientation from the top of the headstock and there was 1 layer of reinforcing detected at approximately 70mm (average) depth.

Reinforcement locations were marked, and a hole drilled until steel was first encountered.

corrosion is visually evident, Loss of reinforcing thickness was evident.

Block sample taken for Chloride ingress test. (separate report).



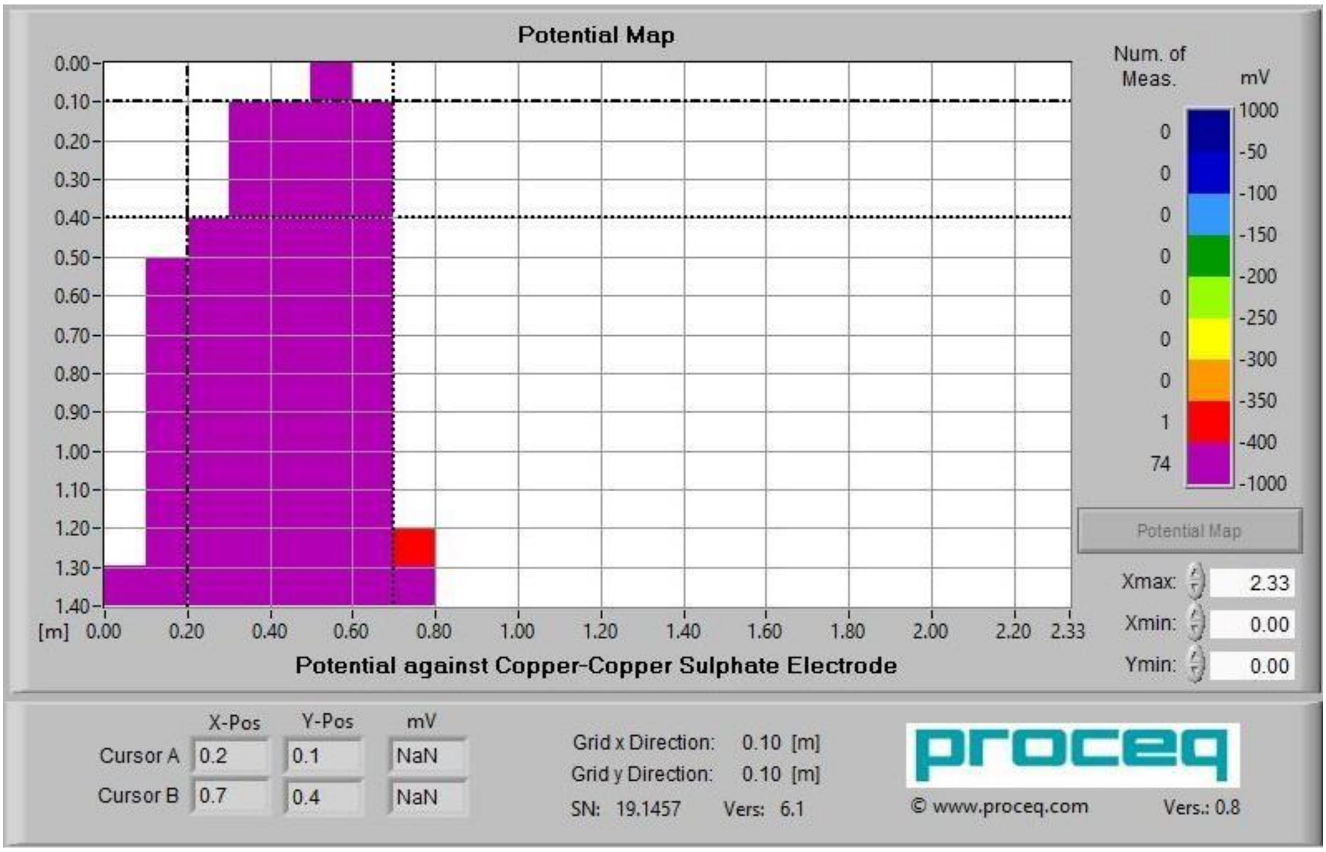
Function Check of electrodes:	Result .09 mV Tolerances 0±5mV Reference with rod electrode 0±5mV Reference with wheel electrode 0 + 20mV
Steel reinforcement connectivity	Yes

Half-cell Potential Testing

The attached figures show the potential survey results. This is a plan view that shows X vs. Y distances in meters, the column shows the measures in mV (megavolt) with different colours according to its magnitude; the minimum value obtain was [-697 mV] and maximum [-643 mV].

Refer to frequency % page 8 Potentials more positive than -200mV indicate there is a greater than 90% probability that no reinforcing steel corrosion is occurring in that area.

Note: Active corrosion.



LOCATION 8 – 1a HS/ Pile coal Pier stem/Public wharf.

Visual Inspection

The location was scanned with ground penetrating radar in polarised orientation from the top of the headstock and there was 1 layer of reinforcing detected at approximately 70mm (average) depth.

Reinforcement locations were marked, and a hole drilled until steel was first encountered.

corrosion is visually evident, Loss of reinforcing thickness was evident.

Block sample taken for Chloride ingress test. (separate report).

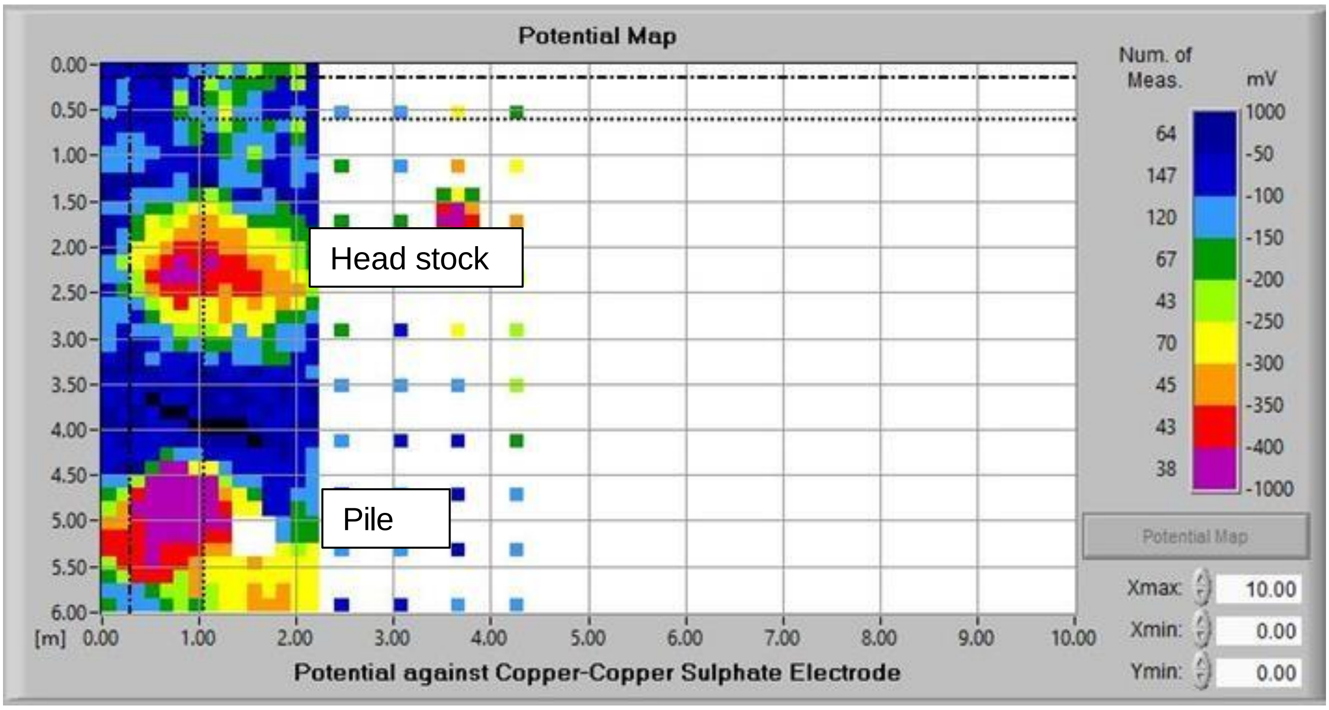
Function Check of electrodes:	Result .03 mV Tolerances 0±5mV Reference with rod electrode 0±5mV Reference with wheel electrode 0 + 20mV
Steel reinforcement connectivity	Yes

Half-cell Potential Testing

The attached figures show the potential survey results. This is a plan view that shows X vs. Y distances in meters, the column shows the measures in mV (megavolt) with different colours according to its magnitude; the minimum value obtain was [-779 mV] and maximum [641mV].

Refer to frequency % page 8 Potentials more positive than -200mV indicate there is a greater than 90% probability that no reinforcing steel corrosion is occurring in that area.

Note: Active corrosion.
Extending through the transition between Headstock and Pile.



LOCATION 9 – 91b Hs and pile Public wharf.

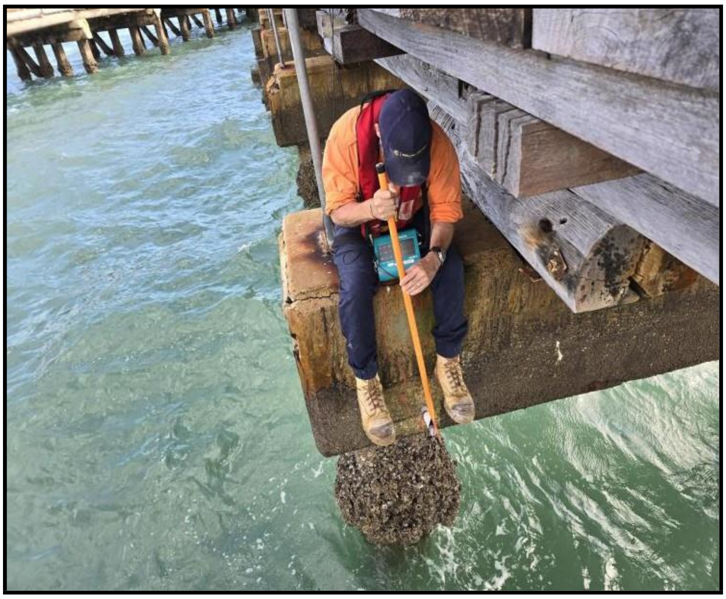
<u>Visual Inspection Head stock and Pile</u>

The location was scanned with ground penetrating radar in polarised orientation from the top of the headstock and there was 1 layer of reinforcing detected at approximately 70mm (average) depth.

Reinforcement locations were marked, and a hole drilled until steel was first encountered.

corrosion is visually evident, Loss of reinforcing thickness was evident.

Block sample taken for Chloride ingress test. (separate report).



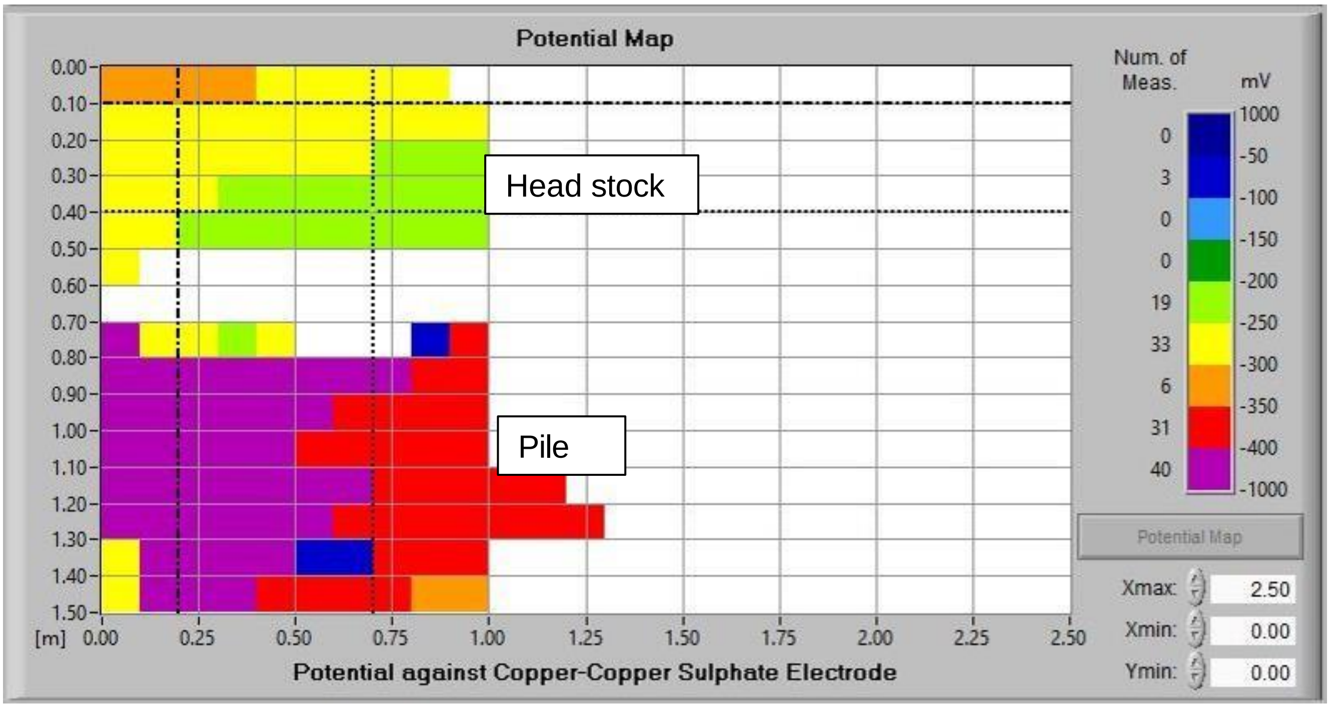
Function Check of electrodes:	Result 1.2 mV Tolerances 0±5mV Reference with rod electrode 0±5mV Reference with wheel electrode 0 + 20mV
Steel reinforcement connectivity	Yes

Half-cell Potential Testing

The attached figures show the potential survey results. This is a plan view that shows X vs. Y distances in meters, the column shows the measures in mV (megavolt) with different colours according to its magnitude; the minimum value obtain was [-841 mV] and maximum [53mV].

Refer to frequency % page 8 Potentials more positive than -200mV indicate there is a greater than 90% probability that no reinforcing steel corrosion is occurring in that area.

Note: Active corrosion.
Extending through the transition between Headstock and Pile.



LOCATION 10 – 98a HS Public wharf.

Visual Inspection

The location was scanned with ground penetrating radar in polarised orientation from the top of the headstock and there was 1 layer of reinforcing detected at approximately 55mm (average) depth.

Reinforcement locations were marked, and a hole drilled until steel was first encountered.

corrosion is visually evident, Loss of reinforcing thickness was evident.

Block sample taken for Chloride ingress test. (separate report).

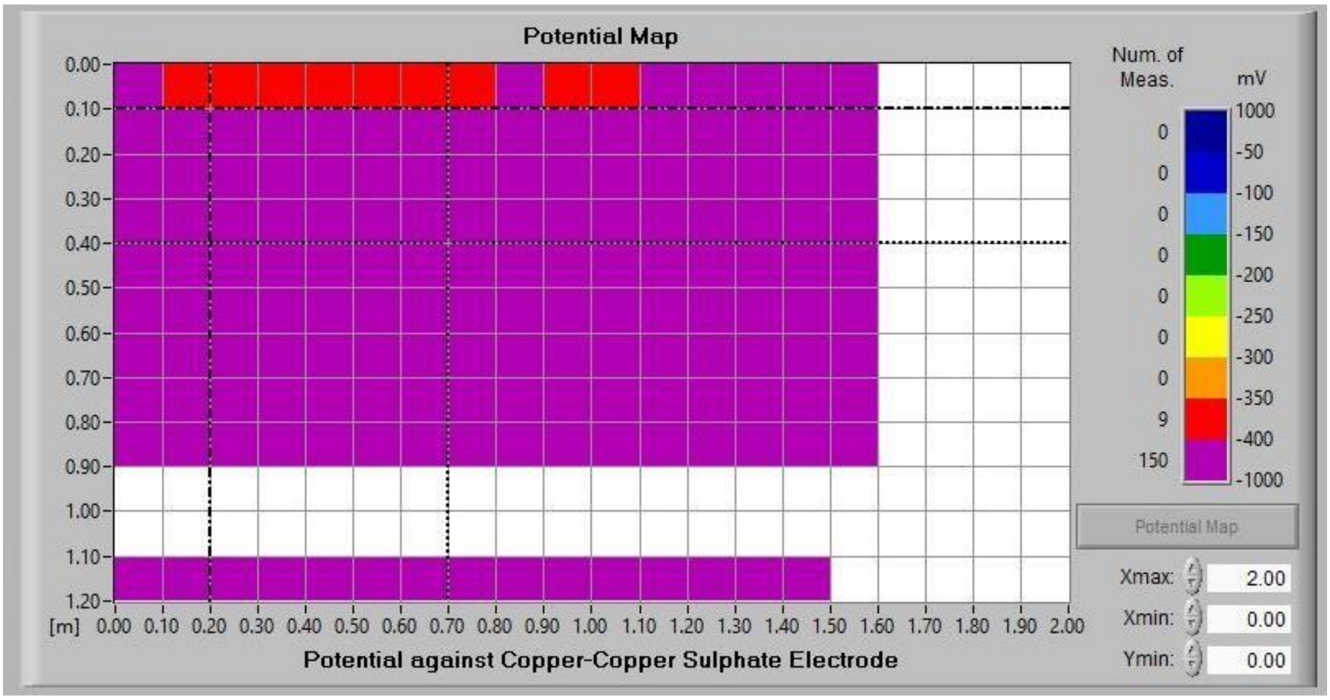
Function Check of electrodes:	Result 0.8 mV Tolerances 0±5mV Reference with rod electrode 0±5mV Reference with wheel electrode 0 + 20mV
Steel reinforcement connectivity	Yes

Half-cell Potential Testing

The attached figures show the potential survey results. This is a plan view that shows X vs. Y distances in meters, the column shows the measures in mV (megavolt) with different colours according to its magnitude; the minimum value obtain was [-697 mV] and maximum [-385mV].

Refer to frequency % page 8 Potentials more positive than -200mV indicate there is a greater than 90% probability that no reinforcing steel corrosion is occurring in that area.

Note: Active corrosion.



LOCATION 11 – 57a P/hs Public wharf.

Visual Inspection head stock

The location was scanned with ground penetrating radar in polarised orientation from the top of the headstock and there was 1 layer of reinforcing detected at approximately 60mm (average) depth.

Reinforcement locations were marked, and a hole drilled until steel was first encountered.

corrosion is visually evident, Loss of reinforcing thickness was evident.

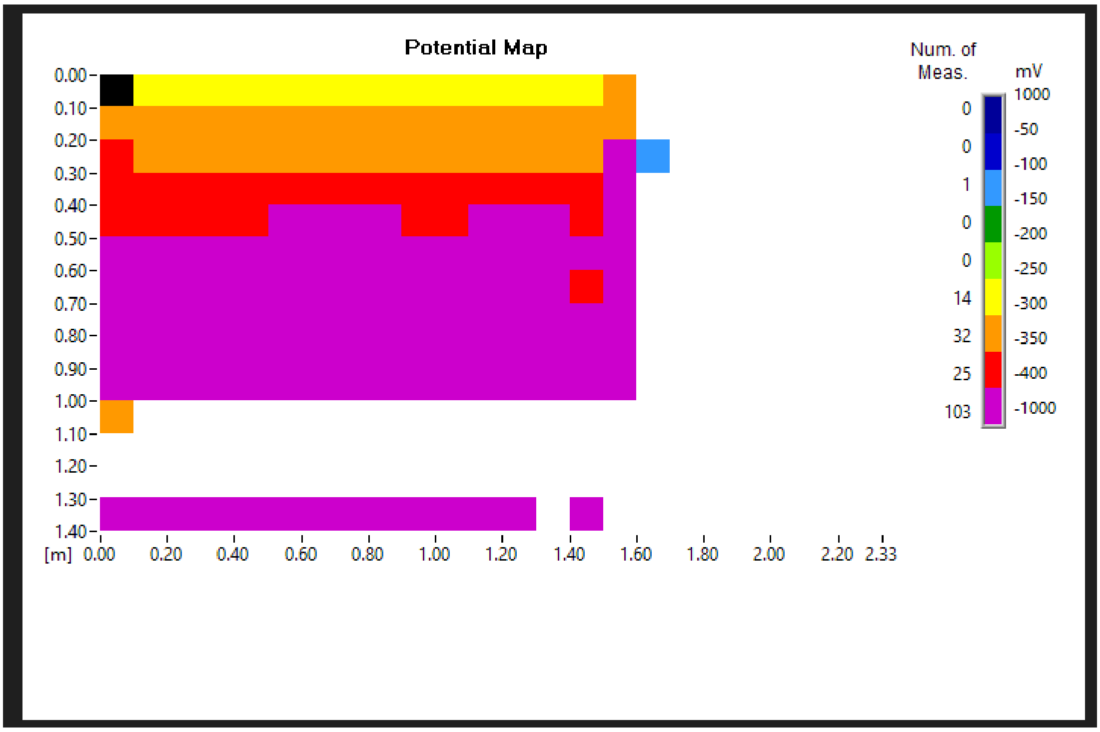
Function Check of electrodes:	Result 0.15 mV Tolerances 0±5mV Reference with rod electrode 0±5mV Reference with wheel electrode 0 + 20mV
Steel reinforcement connectivity	Yes

Half-cell Potential Testing

The attached figures show the potential survey results. This is a plan view that shows X vs. Y distances in meters, the column shows the measures in mV (megavolt) with different colours according to its magnitude; the minimum value obtain was [-814 mV] and maximum [-321mV].

Refer to frequency % page 8 Potentials more positive than -200mV indicate there is a greater than 90% probability that no reinforcing steel corrosion is occurring in that area.

Note: Active corrosion.



LOCATION 12 – 54a P/hs Public wharf.

Visual Inspection head stock and pile

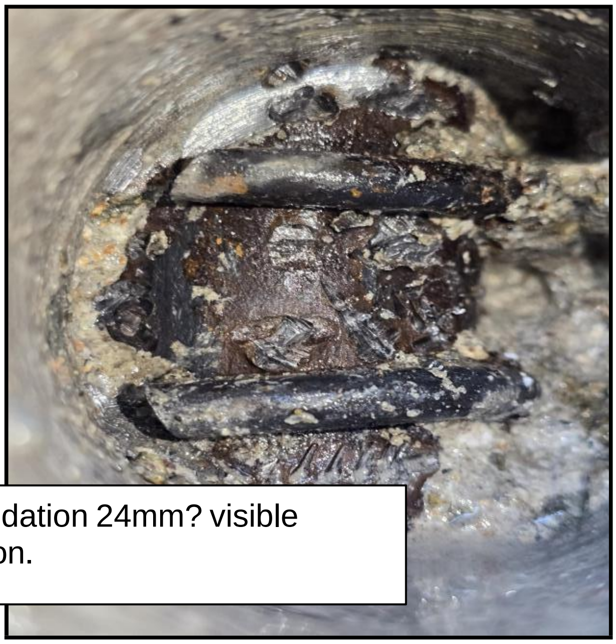
The location was scanned with ground penetrating radar in polarised orientation from the top of the headstock and there was 1 layer of reinforcing detected at approximately 60mm (average) depth.

Reinforcement locations were marked, and a hole drilled until steel was first encountered.

corrosion is visually evident, Loss of reinforcing thickness was evident.

Block sample taken for Chloride ingress test. (separate report).

Validation was performed on the pile(see Photo).



Bar validation 24mm? visible corrosion.

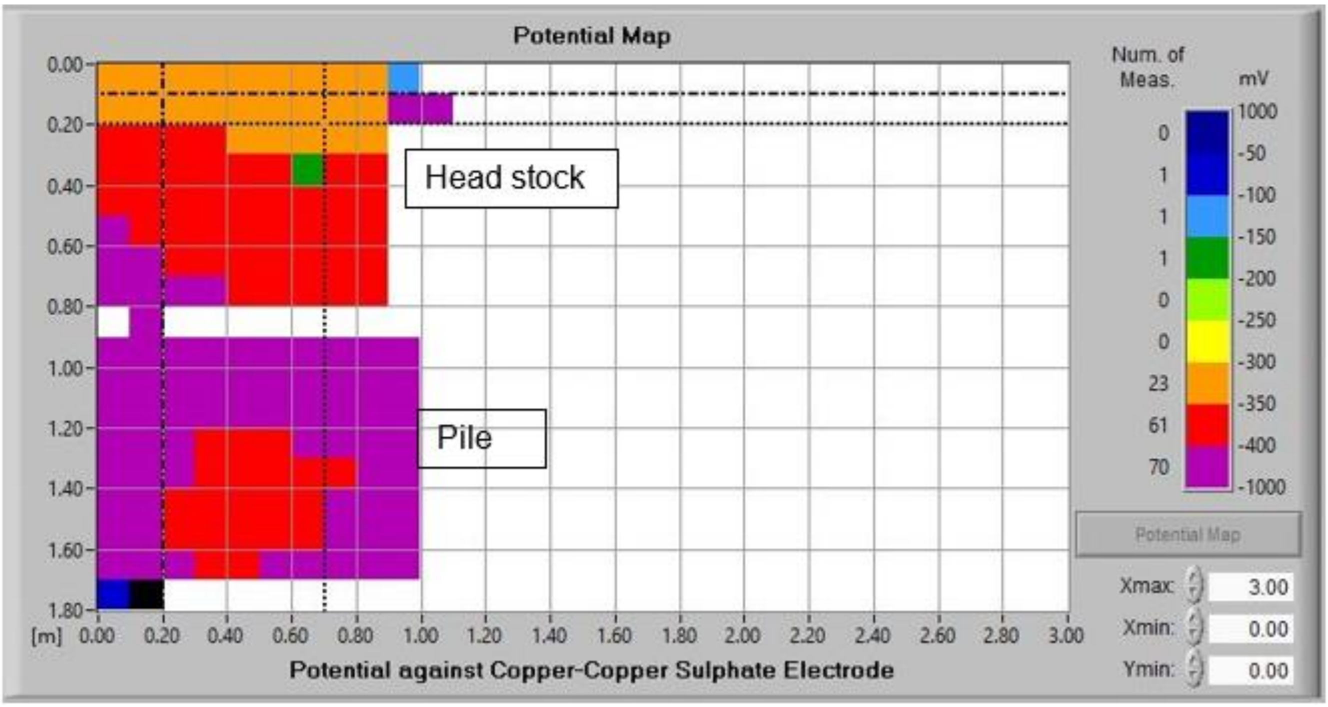
Function Check of electrodes:	Result 0.3 mV Tolerances 0±5mV Reference with rod electrode 0±5mV Reference with wheel electrode 0 + 20mV
Steel reinforcement connectivity	Yes

Half-cell Potential Testing

The attached figures show the potential survey results. This is a plan view that shows X vs. Y distances in meters, the column shows the measures in mV (megavolt) with different colours according to its magnitude; the minimum value obtain was [-765 mV] and maximum [-337mV].

Refer to frequency % page 8 Potentials more positive than -200mV indicate there is a greater than 90% probability that no reinforcing steel corrosion is occurring in that area.

Note: Active corrosion.
Extending through the transition between Headstock and Pile.



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LOCATION 13 – 114a hs Public wharf.

Visual Inspection head stock and pile

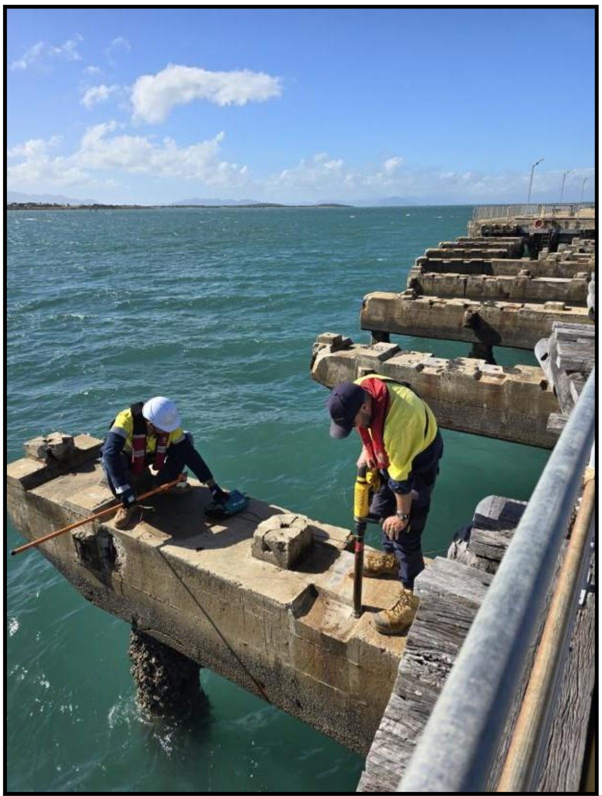
The location was scanned with ground penetrating radar in polarised orientation from the top of the headstock and there was 1 layer of reinforcing detected at approximately 60mm (average) depth.

Reinforcement locations were marked, and a hole drilled until steel was first encountered.

corrosion is visually evident, Loss of reinforcing thickness was evident.

Block sample taken for Chloride ingress test. (separate report).

Validation was performed on the pile(see Photo).



Bar validation
24mm?
visible corrosion.

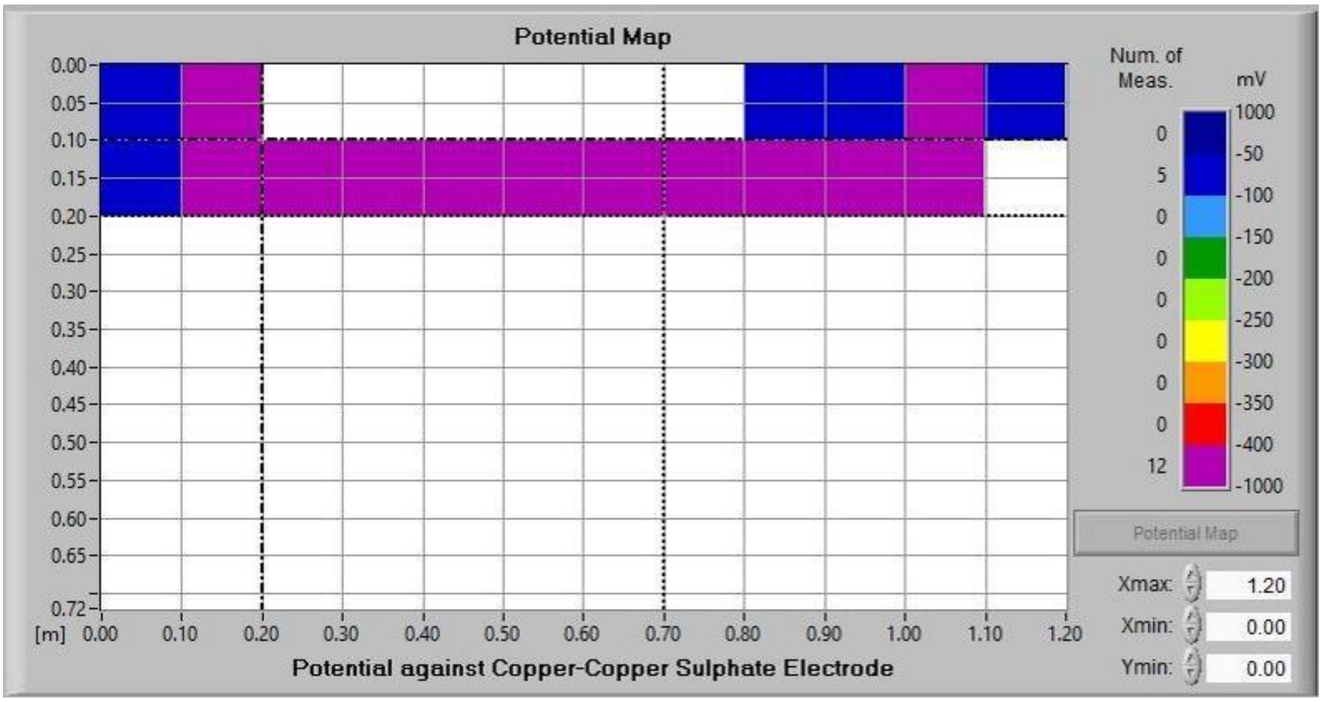
Function Check of electrodes:	Result 0.3 mV Tolerances 0±5mV Reference with rod electrode 0±5mV Reference with wheel electrode 0 + 20mV
Steel reinforcement connectivity	Yes

Half-cell Potential Testing

The attached figures show the potential survey results. This is a plan view that shows X vs. Y distances in meters, the column shows the measures in mV (megavolt) with different colours according to its magnitude; the minimum value obtain was [-554mV] and maximum [-85mV].

Refer to frequency % page 8 Potentials more positive than -200mV indicate there is a greater than 90% probability that no reinforcing steel corrosion is occurring in that area.

Note: Active corrosion.



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LOCATION 14 – 62a hs/P Public wharf.

<u>Visual Inspection head stock and pile</u>

The location was scanned with ground penetrating radar in polarised orientation from the top of the headstock and there was 1 layer of reinforcing detected at approximately 60mm (average) depth.

Reinforcement locations were marked, and a hole drilled until steel was first encountered.

corrosion is visually evident, Loss of reinforcing thickness was evident.

Block sample taken for Chloride ingress test. (separate report).

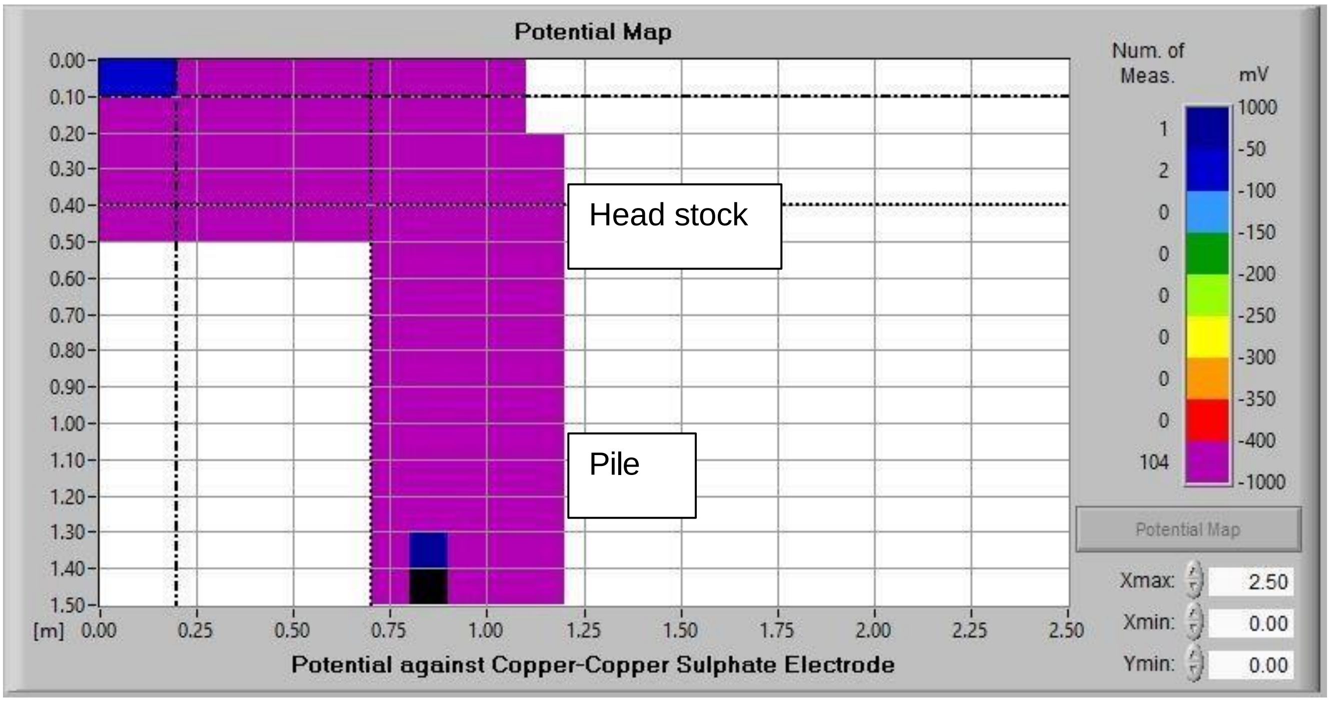
Function Check of electrodes:	Result 0.3 mV Tolerances 0±5mV Reference with rod electrode 0±5mV Reference with wheel electrode 0 + 20mV
Steel reinforcement connectivity	Yes

Half-cell Potential Testing

The attached figures show the potential survey results. This is a plan view that shows X vs. Y distances in meters, the column shows the measures in mV (megavolt) with different colours according to its magnitude; the minimum value obtain was [-714mV] and maximum [-379mV].

Refer to frequency % page 8 Potentials more positive than -200mV indicate there is a greater than 90% probability that no reinforcing steel corrosion is occurring in that area.

Note: Active corrosion.
Extending through the transition between Headstock and Pile.



LOCATION 15– 212b Hs and pile Public wharf.

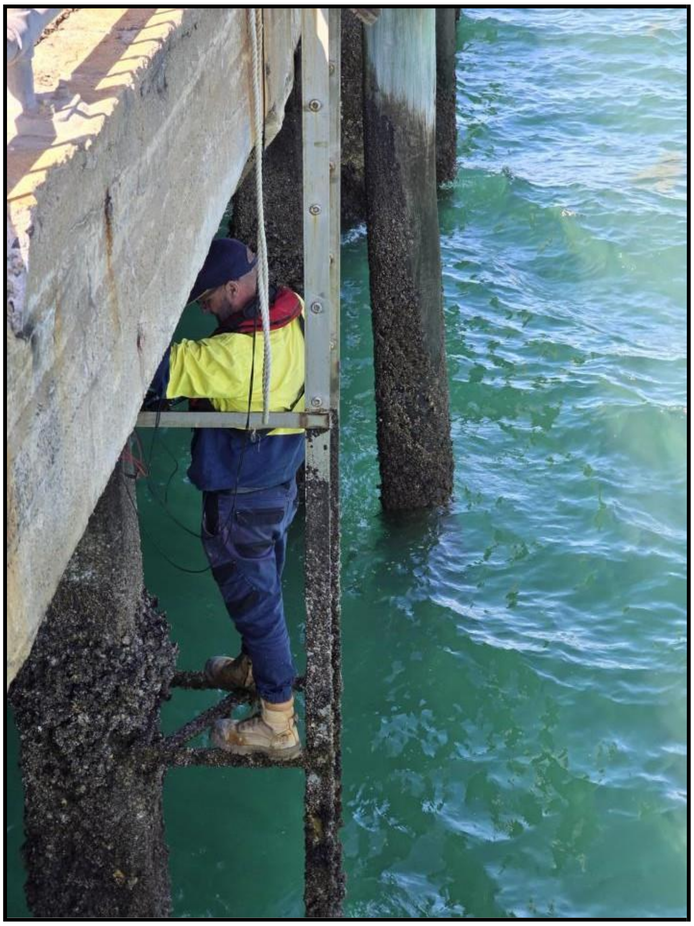
Visual Inspection Head stock and Pile

The location was scanned with ground penetrating radar in polarised orientation from the top of the headstock and there was 1 layer of reinforcing detected at approximately 70mm (average) depth.

Reinforcement locations were marked, and a hole drilled until steel was first encountered.

corrosion is visually evident, Loss of reinforcing thickness was evident.

Block sample taken for Chloride ingress test. (separate report).



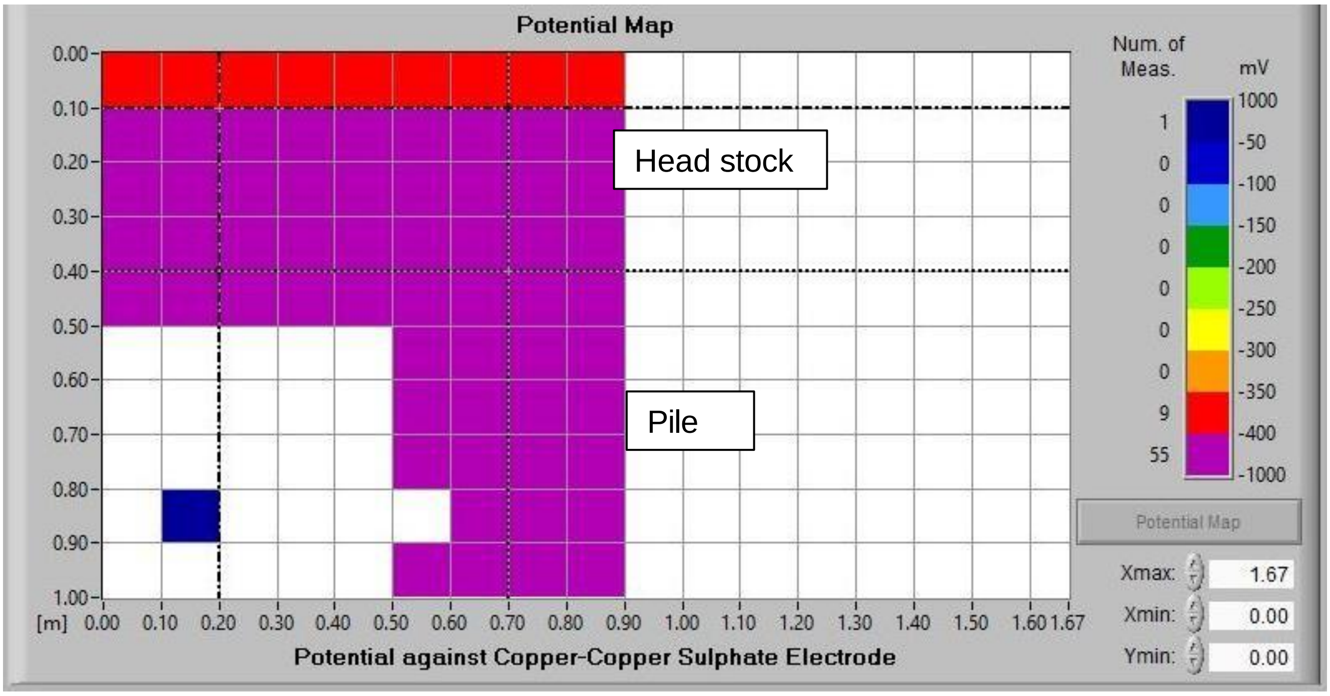
Function Check of electrodes:	Result 0.09 mV Tolerances 0±5mV Reference with rod electrode 0±5mV Reference with wheel electrode 0 + 20mV
Steel reinforcement connectivity	Yes

Half-cell Potential Testing

The attached figures show the potential survey results. This is a plan view that shows X vs. Y distances in meters, the column shows the measures in mV (megavolt) with different colours according to its magnitude; the minimum value obtain was [-687mV] and maximum [-349mV].

Refer to frequency % page 8 Potentials more positive than -200mV indicate there is a greater than 90% probability that no reinforcing steel corrosion is occurring in that area.

Note: Active corrosion.
Extending through the transition between Headstock and Pile.



LOCATION 16 – 112a hs and Pile Public wharf.

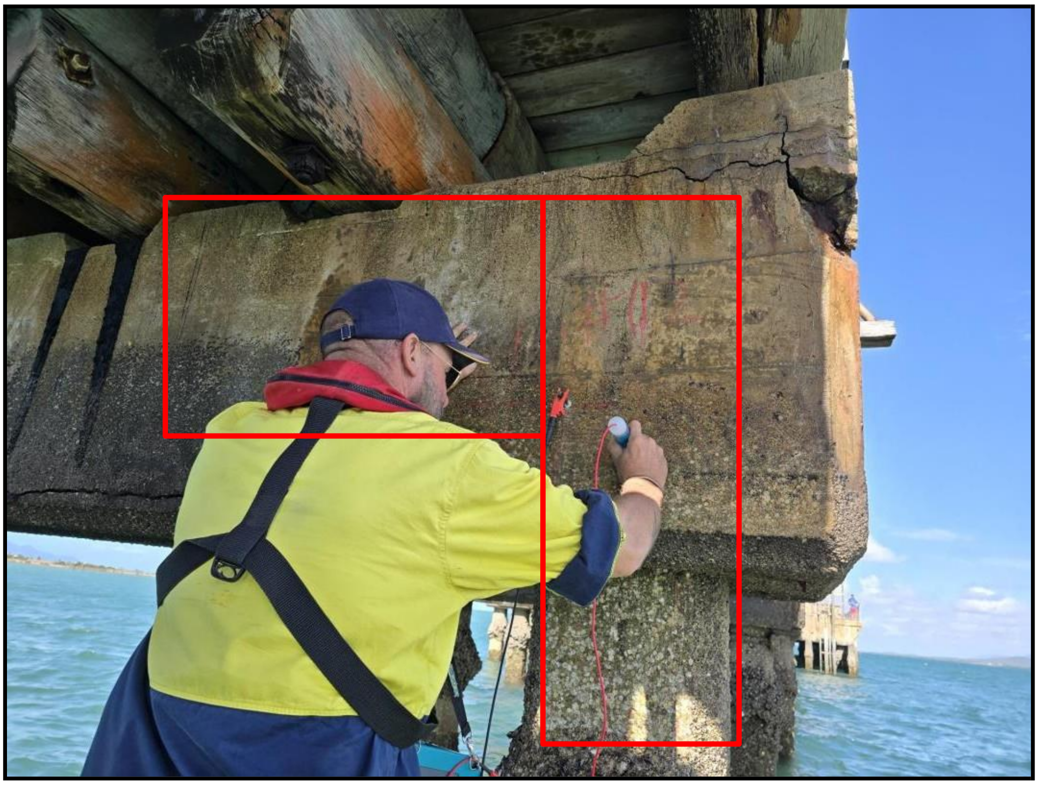
Visual Inspection Head stock and Pile

The location was scanned with ground penetrating radar in polarised orientation from the top of the headstock and there was 1 layer of reinforcing detected at approximately 60mm (average) depth.

Reinforcement locations were marked, and a hole drilled until steel was first encountered.

corrosion is visually evident, Loss of reinforcing thickness was evident.

Block sample taken for Chloride ingress test. (separate report).



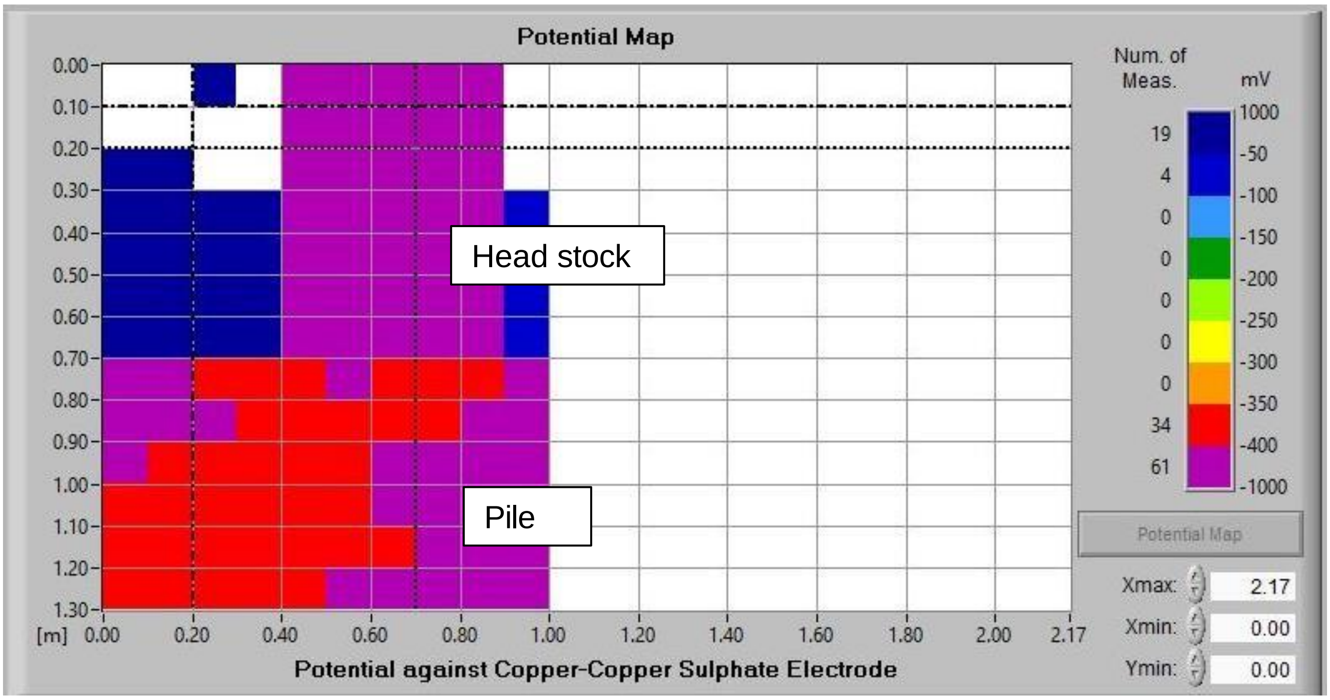
Function Check of electrodes:	Result 0.04mV Tolerances 0±5mV Reference with rod electrode 0±5mV Reference with wheel electrode 0 + 20mV
Steel reinforcement connectivity	Yes

Half-cell Potential Testing

The attached figures show the potential survey results. This is a plan view that shows X vs. Y distances in meters, the column shows the measures in mV (megavolt) with different colours according to its magnitude; the minimum value obtain was [-658mV] and maximum [49mV].

Refer to frequency % page 8 Potentials more positive than -200mV indicate there is a greater than 90% probability that no reinforcing steel corrosion is occurring in that area.

Note: Active corrosion.
Extending through the transition between Headstock and Pile.



LOCATION 17 – 84b hs Public wharf.

<u>Visual Inspection Head stock and Pile</u>

The location was scanned with ground penetrating radar in polarised orientation from the top of the headstock and there was 1 layer of reinforcing detected at approximately 60mm (average) depth.

Reinforcement locations were marked, and a hole drilled until steel was first encountered.

corrosion is visually evident, Loss of reinforcing thickness was evident.

Block sample taken for Chloride ingress test. (separate report).

Bar validation
24mm?
visible corrosion.

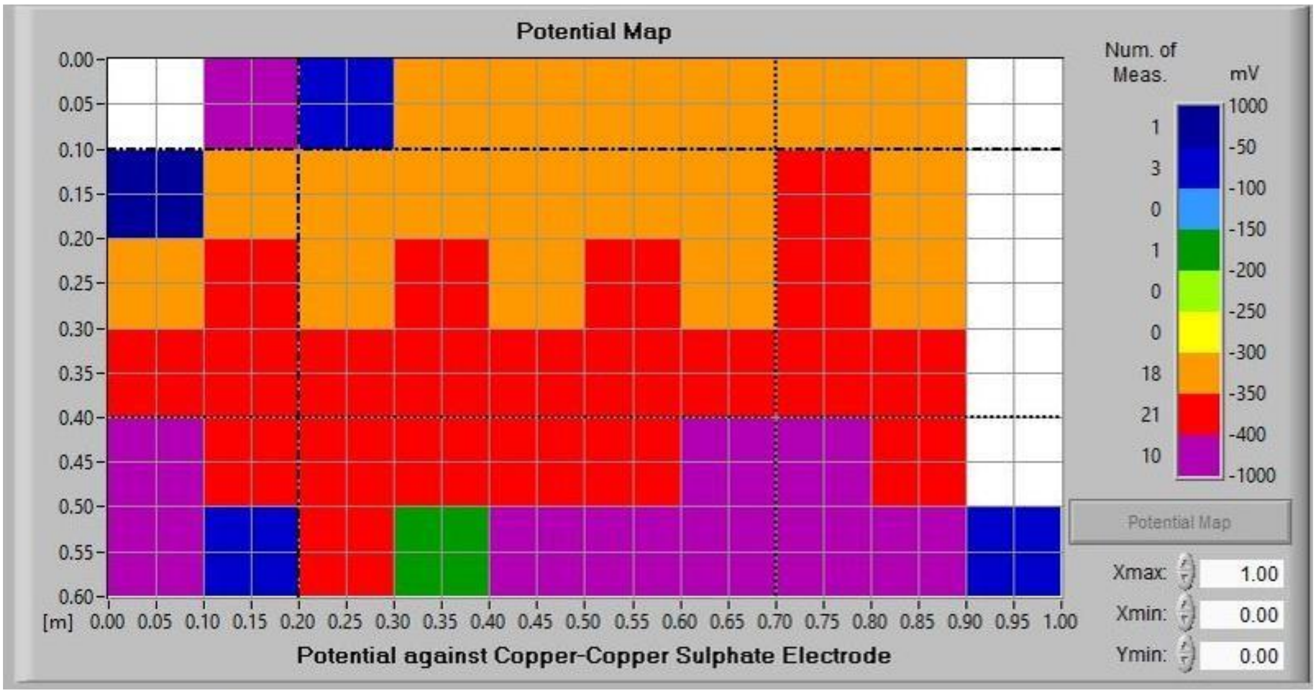
Function Check of electrodes:	Result 1.12mV Tolerances 0±5mV Reference with rod electrode 0±5mV Reference with wheel electrode 0 + 20mV
Steel reinforcement connectivity	Yes

Half-cell Potential Testing

The attached figures show the potential survey results. This is a plan view that shows X vs. Y distances in meters, the column shows the measures in mV (megavolt) with different colours according to its magnitude; the minimum value obtain was [-684mV] and maximum [49mV].

Refer to frequency % page 8 Potentials more positive than -200mV indicate there is a greater than 90% probability that no reinforcing steel corrosion is occurring in that area.

Note: Active corrosion.



LOCATION 18 – 115 a hs and Pile Public wharf.

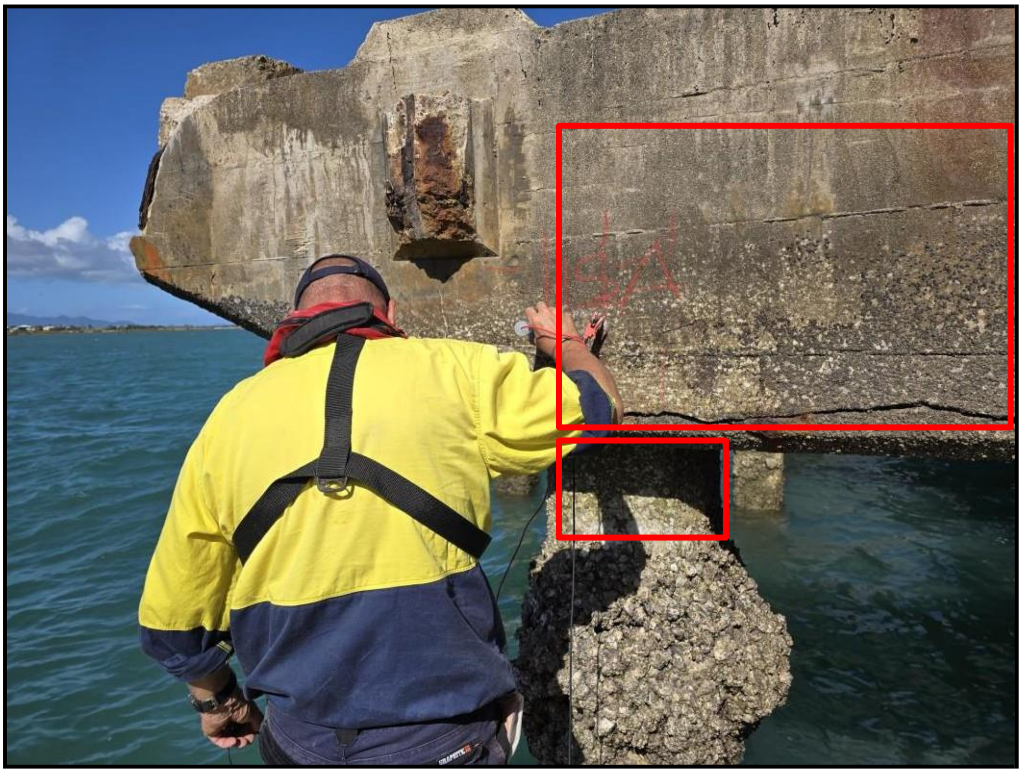
Visual Inspection Head stock and Pile

The location was scanned with ground penetrating radar in polarised orientation from the top of the headstock and there was 1 layer of reinforcing detected at approximately 60mm (average) depth.

Reinforcement locations were marked, and a hole drilled until steel was first encountered.

corrosion is visually evident, Loss of reinforcing thickness was evident.

Block sample taken for Chloride ingress test. (separate report).



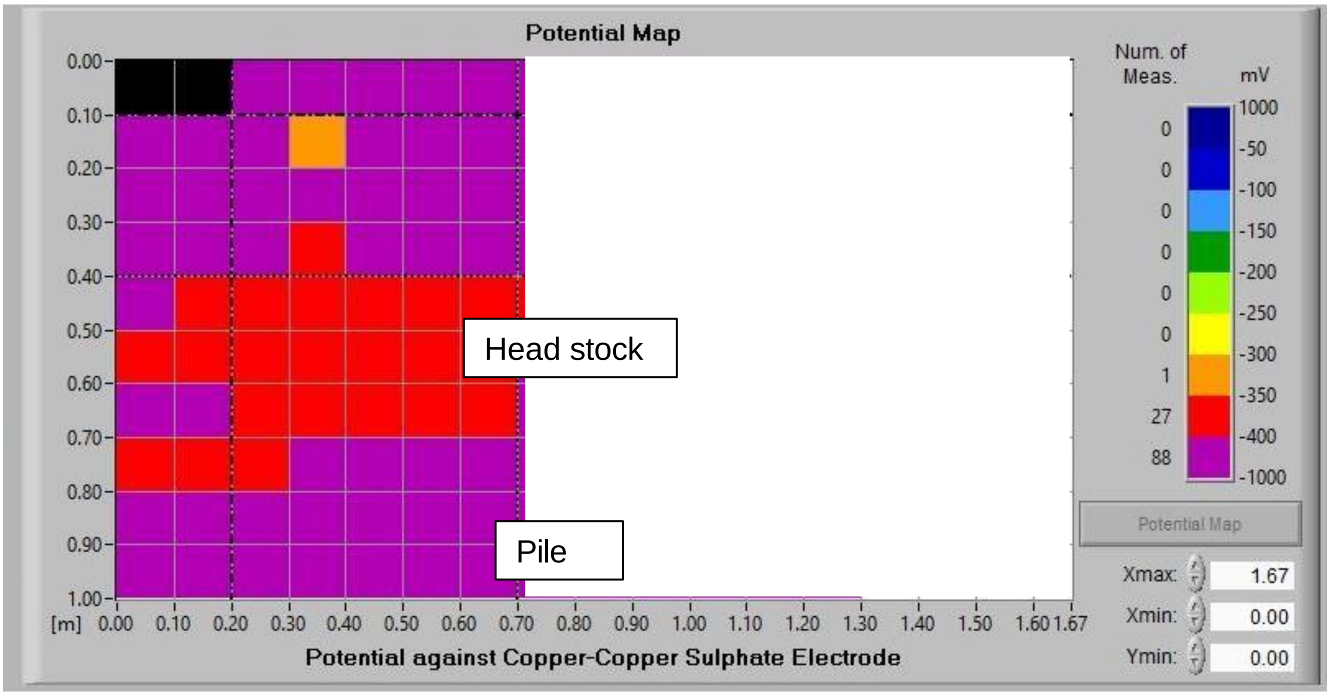
Function Check of electrodes:	Result .22mV Tolerances 0±5mV Reference with rod electrode 0±5mV Reference with wheel electrode 0 + 20mV
Steel reinforcement connectivity	Yes

Half-cell Potential Testing

The attached figures show the potential survey results. This is a plan view that shows X vs. Y distances in meters, the column shows the measures in mV (megavolt) with different colours according to its magnitude; the minimum value obtain was [-613mV] and maximum [49mV].

Refer to frequency % page 8 Potentials more positive than -200mV indicate there is a greater than 90% probability that no reinforcing steel corrosion is occurring in that area.

Note: Active corrosion.
Extending through the transition between Headstock and Pile.



Conclusion; Widespread Active corrosion across all elements tested visual confirmation of active corrosion and visual evidence of delamination. Some elements failed the continuity tests this could indicate major loss of reinforcement thickness.

Resistivity figures next Page.

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Resistivity Results

DISCLAIMER:

Care is taken to avoid testing on areas directly above reinforcement as this affects the resistivity.

Resistivity testing results are only used as an estimation of the likelihood of corrosion and are compared to a large body of empirical resistivity data to gauge severity.

Surface contact is the main source of error when taking resistivity measurements. Each surface must be cleaned and wet enough to allow a current to flow to the concrete surface.

Resistivity can be directly correlated to chloride diffusion rate. The Resipod conforms to the AASHTO TP 95-11 Surface Resistivity Test Method and uses surface resistivity as an indication of the permeability of concrete. With the evaluation of the recorded results, other corrosion inducing factors should also be considered:

The moisture content of the concrete
The environmental circumstances
The conductivity of the saturating solution
The presents of other corrosive materials

Technician/s: Jason Jones
Surface Appearance: Exposed aggregate
Preparation: Scrape and clean
Temperature: 26°C
Relative Humidity:

Test Units	Brand / Model	Test Method	Other Details
Resipod	Proceq – A1[RP02-002-0124]	Surface Probe	38mm Spacing
Ground Penetrating Radar [GPR]	GSSI - SIR: 3000 [S/N:2186]	Line Scans	Antenna: 1600 [S/N:2318] Orientation: Polarised and cross-polarised
Protimeter MMS	General Electric BLD5800 [0509110116]	Hygrometer	Ancillary Components:

Procedure: In accordance with the manufacturers' instructions.

Empirical studies show that a one degree increase in temperature conservatively correlates to a 3% reduction in resistivity. **Reference values**

one degree increase in temperature conservatively correlates to a 3% reduction in resistivity.

	At 20°C	At 25°C
Negligible risk of corrosion	≥ 100 kΩcm	≥ 85.9 kΩcm
Low risk of corrosion	50 ≤ α ≤ 100 kΩcm	42.9 ≤ α ≤ 85.9 kΩcm
Moderate risk of corrosion	10 ≤ α ≤ 50 kΩcm	8.59 ≤ α ≤ 42.9 kΩcm
High risk of corrosion	≤ 10 kΩcm	≤ 8.59 kΩcm

REPORT NO: ACX ACX240067-01 Arup Bowen Wharf – HCP **Test Date/s**: 13th through to 17th May 2024

Area examined	**Identification**	**Resipod Data (kΩcm)**	**Result**
HS	#1	*14*	moderate
HS	#2	*25.9*	moderate
P	#3	*11*	High
HS	#4	*35.2*	moderate
HS	#5	*19.5*	moderate
P	#6	*15.4*	moderate
HS	#7	*12.9*	moderate
HS	#8	*12.8*	moderate
HS/P	#9	*15.3*	moderate
HS/P	#10	*19.8*	moderate
HS/P	#11	*20.5*	moderate
HS	#12	*21.8*	moderate
HS	#13	*43.2*	moderate
P	#14	*15.9*	moderate
P	#15	*27.3*	moderate
HS/P	#16	*18.4*	moderate
HS	#17	*37.2*	moderate
P	#18	*26.5*	moderate

Surface: Exposed Aggregate

Hygrometer surface moisture reading (average of 5 readings):

Weather: 26º C

Reinforcement Spacing: Top: 200mm x 200mm / Irregular

Reinforcement Cover: Top: 80mm ± (10% + 10mm) / Varied.

REPORT NO: ACX ACX240067-01 Arup Bowen Wharf – HCP **Test Date/s**: 13th through to 17th May 2024

CERTIFICATE of TESTING

FINAL

Prior Reports: None

CEMENT AUSTRALIA

Cement Australia Pty Limited
ABN [illegible]
Head Office
18 Station Avenue, Darra QLD [illegible]
PO Box [illegible], Mt Ommaney QLD [illegible]
Tel: [illegible]
www.cementaustralia.com.au

Certificate Number: CERT241694
Issued: 04, June 2024

Client: Inspections X-Ray & Testing Pty Ltd
1/7 Millenium Place
Tingalpa

Date Sampled: 29-May-24
Date Received: 29-May-24

The following test results were obtained by the Darra Laboratory for concrete specimens supplied by the client.

Project: Not Specified
Structure: Aged Marine Environment

Test Results

Specimen Description	*Segment Increment from top* (mm)	*Sample Number*	*Acid Soluble Chloride* (% in concrete)	*Total Sulfate SO_3* (% in concrete)	*Maximum Cement Content* (kg/m³)	*Concrete pH measurement*	*Depth of Carbonation* (mm)
Core #1	Segment 0-10 mm	24051225	0.50	-	-	-	-
	Segment 10-30 mm	24051226	0.11	-	-	-	-
	Segment 30-45 mm	24051227	0.060	-	-	-	-
Core #2	Segment 0-10 mm	24051228	1.1	-	-	-	-
	Segment 10-30 mm	24051229	0.64	-	-	-	-
	Segment 30-50 mm	24051230	0.53	-	-	-	-
	Segment 50-70 mm	24051231	0.29	-	-	-	-
Core #3	Segment 0-10 mm	24051232	0.56	-	-	-	-
	Segment 10-30 mm	24051233	0.48	-	-	-	-
	Segment 30-50 mm	24051234	0.34	-	-	-	-
Core #4	Segment 0-10 mm	24051235	0.61	-	-	-	-
	Segment 10-30 mm	24051236	0.28	-	-	-	-
Core #5	Segment 0-10 mm	24051237	0.63	-	-	-	-
	Segment 10-30 mm	24051238	0.38	-	-	-	-
	Segment 30-50 mm	24051239	0.06	-	-	-	-
Core #6	Segment 0-10 mm	24051240	0.33	-	-	-	-
	Segment 10-30 mm	24051241	0.20	-	-	-	-
	Segment 30-45 mm	24051242	0.068	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-

Approved Signatory

V Connell
Chemical Testing
Construction Materials Testing

Accredited for compliance with ISO/IEC 17025 - Testing. NATA is a signatory to the ILAC Mutual Recognition Arrangement for the mutual recognition of the equivalence of testing, medical testing, calibration, inspection, proficiency testing scheme providers and reference materials producers reports and certificates.

Laboratory accreditation number: [illegible]

NATA
WORLD RECOGNISED ACCREDITATION

Notes:

1. Determination of chloride and sulfate in hardened concrete and concrete aggregates AS 1012.20.1
2. No NATA accreditation for pH of concrete water leachate
3. No NATA accreditation for Carbonation profiling
4. Density to AS1012.12.1
5. Cement content of hardened concrete by classical and XRF using in-house XRF.

Calculated cement content is the maximum content possible following the assumptions that there was no supplementary cementitious material and no calcium bearing aggregate used in the concrete tested. Also an assumed density of 2400 kg/m3 used, unless actual specimen density determined by AS1012.12.1.

Australian Concrete X-Ray

REPORT NO: ACX ACX240067-01 Arup Bowen Wharf – HCP **Test Date/s**: 13th through to 17th May 2024

CERTIFICATE of TESTING

FINAL

Prior Reports: None

CEMENT AUSTRALIA

Cement Australia Pty Limited

Certificate Number: CERT241694

Issued: 04, June 2024

Client: Inspections X-Ray & Testing Pty Ltd
1/7 Millenium Place
Tingalpa

Date Sampled: 29-May-24
Date Received: 29-May-24

The following test results were obtained by the Darra Laboratory for concrete specimens supplied by the client

Project: Not Specified
Structure: Aged Marine Environment

Test Results

Specimen Description	Segment Increment from top (mm)	Sample Number	Acid Soluble Chloride (% in concrete)	Total Sulfate SO_3 (% in concrete)	Maximum Cement Content (kg/m³)	Concrete pH measurement	Depth of Carbonation (mm)
Block 1 core 1	Segment 0-10 mm	24051243	0.98	-	-	-	-
	Segment 10-30 mm	24051244	1.8	-	-	-	-
	Segment 30-50 mm	24051245	1.2	-	-	-	-
	Segment 50-65 mm	24051246	0.89	-	-	-	-
Block 1 core 2	Segment 0-10 mm	24051247	1.0	-	-	-	-
	Segment 10-30 mm	24051248	1.9	-	-	-	-
	Segment 30-50 mm	24051249	1.5	-	-	-	-
	Segment 50-60 mm	24051250	1.5	-	-	-	-
Block 1 core 3	Segment 0-10 mm	24051251	1.0	-	-	-	-
	Segment 10-30 mm	24051252	1.8	-	-	-	-
	Segment 30-50 mm	24051253	1.5	-	-	-	-
	Segment 50-70 mm	24051254	1.3	-	-	-	-
Block 2 core 1	Segment 0-10 mm	24051255	1.5	-	-	-	-
	Segment 10-20 mm	24051256	2.0	-	-	-	-
	Segment 20-30 mm	24051257	1.6	-	-	-	-
	Segment 30-40 mm	24051258	1.5	-	-	-	-
Block 2 core 2	Segment 0-10 mm	24051260	0.90	-	-	-	-
	Segment 10-20 mm	24051261	2.2	-	-	-	-
	Segment 20-30 mm	24051262	2.1	-	-	-	-
	Segment 30-40 mm	24051263	1.6	-	-	-	-
	Segment 40-50 mm	24051264	1.7	-	-	-	-

Approved Signatory

V Connell
Chemical Testing
Construction Materials Testing

Accredited for compliance with ISO/IEC 17025 - Testing. NATA is a signatory to the ILAC Mutual Recognition Arrangement for the mutual recognition of the equivalence of testing, medical testing, calibration, inspection, proficiency testing scheme providers and reference materials producers reports and certificates.

Laboratory accreditation number: 188

NATA
WORLD RECOGNISED ACCREDITATION

Notes:
1. Determination of chloride and sulfate in hardened concrete and concrete aggregates AS 1012.20.1
2. No NATA accreditation for pH of concrete water leachate
3. No NATA accreditation for Carbonation profiling
4. Density to AS1012.12.1
5. Cement content of hardened concrete by classical and XRF using in-house XRF.

Calculated cement content is the maximum content possible following the assumptions that there was no supplementary cementitious material and no calcium bearing aggregate used in the concrete tested. Also an assumed density of 2400 kg/m3 used, unless actual specimen density determined by AS1012.12.1.

Australian Concrete X-Ray

REPORT NO: ACX ACX240067-01 Arup Bowen Wharf – HCP **Test Date/s**: 13th through to 17th May 2024

Core Profiling Project ID 156 29052024
Bowen Wharf chloride ingress Location catalogue.
Sample Listing:

Sample Date	*Product Type*	*Sample Identification*	*Location/Additional Info*	*Segment increment*
29-May	Core Segment	1 location 3		Segment 0-10 mm
29-May	Core Segment	1 location 3		Segment 10-30 mm
29-May	Core Segment	1 location 3		Segment 30-45 mm
29-May	Core Segment	2 Location 4		Segment 0-10 mm
29-May	Core Segment	2 Location 4		Segment 10-30 mm
29-May	Core Segment	2 Location 4		Segment 30-50 mm
29-May	Core Segment	2 Location 4		Segment 50-70 mm
29-May	Core Segment	3 Location 5		Segment 0-10 mm
29-May	Core Segment	3 Location 5		Segment 10-30 mm
29-May	Core Segment	3 Location 5		Segment 30-50 mm
29-May	Core Segment	4 Location 6		Segment 0-10 mm
29-May	Core Segment	4 Location 6		Segment 10-30 mm
29-May	Core Segment	5 Location 7		Segment 0-10 mm
29-May	Core Segment	5 Location 7		Segment 10-30 mm
29-May	Core Segment	5 Location 7		Segment 30-50 mm
29-May	Core Segment	6 Location 8		Segment 0-10 mm
29-May	Core Segment	6 Location 8		Segment 10-30 mm
29-May	Core Segment	6 Location 8		Segment 30-45 mm
29-May	Core Segment	Block 1 core 1 Location 9		Segment 0-10 mm
29-May	Core Segment	Block 1 core 1 Location 9		Segment 10-30 mm
29-May	Core Segment	Block 1 core 1 Location 9		Segment 30-50 mm

29-May	Core Segment	Block 1 core 1 Location 9	Segment 50-65 mm
29-May	Core Segment	Block 1 core 2 location 10	Segment 0-10 mm
29-May	Core Segment	Block 1 core 2 location 10	Segment 10-30 mm
29-May	Core Segment	Block 1 core 2 location 11	Segment 30-50 mm
29-May	Core Segment	Block 1 core 2 location 11	Segment 50-60 mm
29-May	Core Segment	Block 1 core 3 Location 11	Segment 0-10 mm
29-May	Core Segment	Block 1 core 3 Location 12	Segment 10-30 mm
29-May	Core Segment	Block 1 core 3 Location 12	Segment 30-50 mm
29-May	Core Segment	Block 1 core 3 Location 12	Segment 50-70 mm
29-May	Core Segment	Block 2 core 2 Location 13	Segment 0-10 mm
29-May	Core Segment	Block 2 core 2 Location 13	Segment 10-20 mm
29-May	Core Segment	Block 2 core 1 location 14	Segment 20-30 mm
29-May	Core Segment	Block 2 core 1 location 14	Segment 30-40 mm
29-May	Core Segment	Block 2 core 1 location 16	Segment 40-50 mm
29-May	Core Segment	Block 2 core 1 location 16	Segment 0-10 mm
29-May	Core Segment	Block 2 core 1 location 16	Segment 10-20 mm
29-May	Core Segment	Block 2 core 2 Location 17	Segment 20-30 mm
29-May	Core Segment	Block 2 core 2 Location 17	Segment 30-40 mm
29-May	Core Segment	Block 2 core 2 Location 17	Segment 40-50 mm

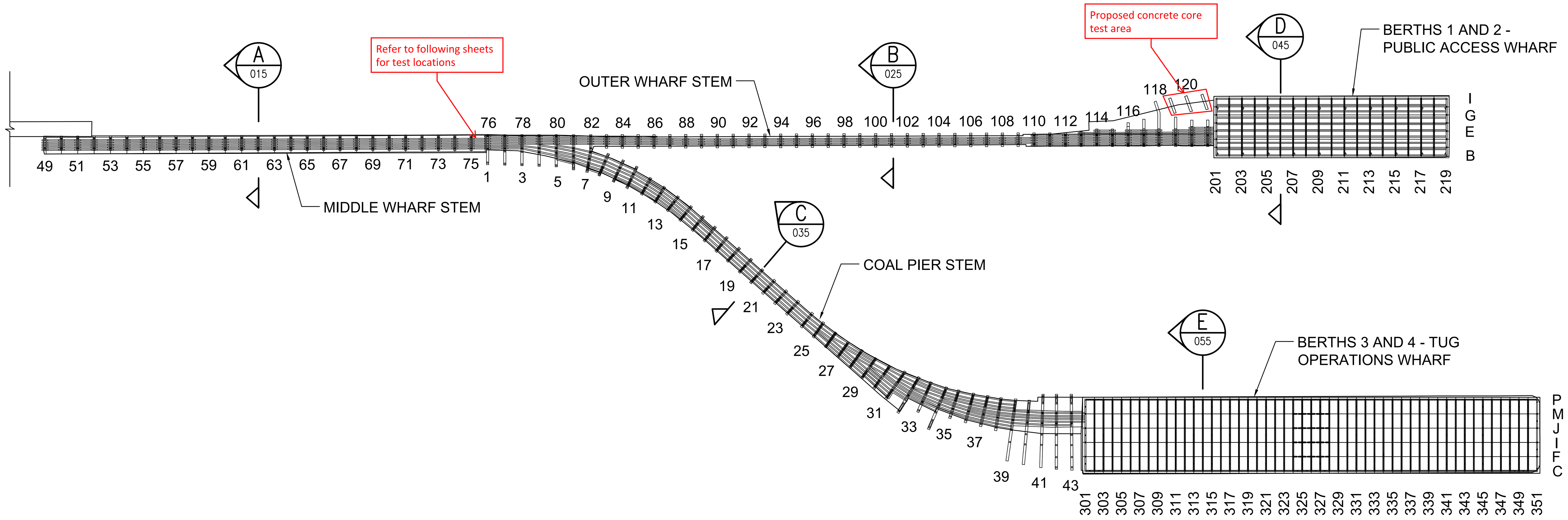
End Report.

Attachment B – Nominated Pile Inspection Plan

LIST OF CONCRETE TEST LOCATIONS

LOCATION	PILE ID	HS / PILE?
Middle Wharf Stem	61A	HS
Middle Wharf Stem	61B	P
Middle Wharf Stem	64B	HS
Middle Wharf Stem	71A	P
Middle Wharf Stem	72A	HS
Middle Wharf Stem	72B	P
Outer Wharf Stem	78A	HS
Outer Wharf Stem	81A	P
Outer Wharf Stem	84A	HS
Outer Wharf Stem	86B	P
Outer Wharf Stem	94A	HS
Outer Wharf Stem	96B	P
Outer Wharf Stem	97A	HS
Outer Wharf Stem	111B	P
Outer Wharf Stem	112A	HS
Outer Wharf Stem	115A	P
Outer Wharf Stem	117D	HS
Outer Wharf Stem	118A	P
Public Wharf	201F	HS
Public Wharf	202B	P
Public Wharf	202C	HS
Public Wharf	203E	P
Public Wharf	203H	HS
Public Wharf	206C	P
Public Wharf	209A	HS
Public Wharf	210C	P
Public Wharf	212H	HS
Public Wharf	213C	P
Public Wharf	217B	HS
Public Wharf	219E	P

1-2 concrete core locations to be taken on detached section of either Pier 119, 120 or 121



BOWEN WHARF GENERAL ARRANGEMENT
N.T.S.

SECTION	GEOMETRY	DESCRIPTION	PURPOSE
CAUSEWAY	~270 M LONG	GRAVITY ROCK STRUCTURE	PROVIDES SHARED PORT TRAFFIC AND PUBLIC PEDESTRIAN ACCESS
MIDDLE WHARF STEM	~165 M LONG	SUSPENDED TIMBER DECK WITH CONCRETE SUBSTRUCTURE	PROVIDES SHARED PORT TRAFFIC AND PUBLIC PEDESTRIAN ACCESS
OUTER WHARF STEM	~225 M LONG	SUSPENDED TIMBER DECK WITH CONCRETE SUBSTRUCTURE	PROVIDES PUBLIC PEDESTRIAN ACCESS ONLY
COAL PIER STEM	~210 M LONG	SUSPENDED TIMBER DECK WITH CONCRETE SUBSTRUCTURE	PROVIDES PORT TRAFFIC ACCESS ONLY
PUBLIC ACCESS WHARF	~78 M LONG AND ~20 M WIDE	CONCRETE STRUCTURE	PROVIDES PUBLIC PEDESTRIAN ACCESS ONLY (NO VESSEL USAGE)
TUG OPERATIONS WHARF	~150 M LONG AND ~25 M WIDE	CONCRETE STRUCTURE	PROVIDES TUG AND OTHER VESSEL MOORING TO FACILITATE SERVICING OF THE VESSELS.

NOT FOR CONSTRUCTION

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Member Firm

Client
NORTH QUEENSLAND BULK PORTS CORPORATION

GENERAL ARRANGEMENT

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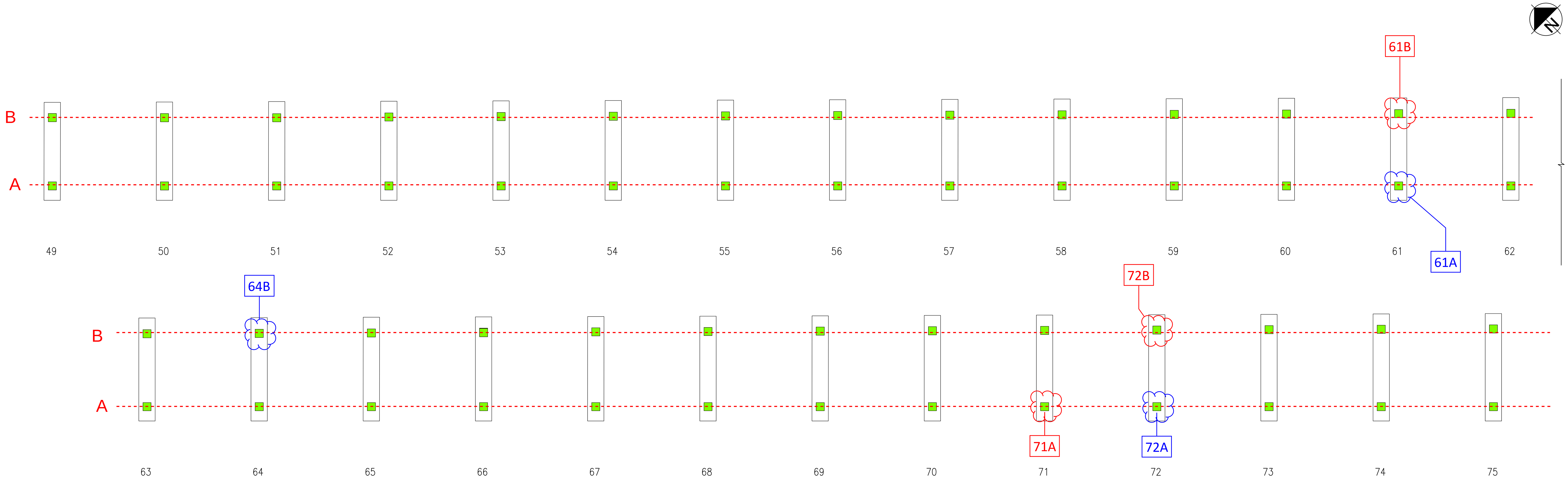

MIDDLE WHARF – PILES
N.T.S.

Locations shown in blue to be tested on headstock

Locations shown in red to be tested on pile

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ABN 18 000 966 165

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BULK PORTS CORPORATION

CONDITION ASSESSMENT
HEAT MAP - MIDDLE WHARF
SHEET 1 OF 2

OUTER WHARF – PILES
N.T.S.

Locations shown in blue to be tested on headstock

Locations shown in red to be tested on pile

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CONDITION ASSESSMENT
HEAT MAP - OUTER WHARF
SHEET 1 OF 2

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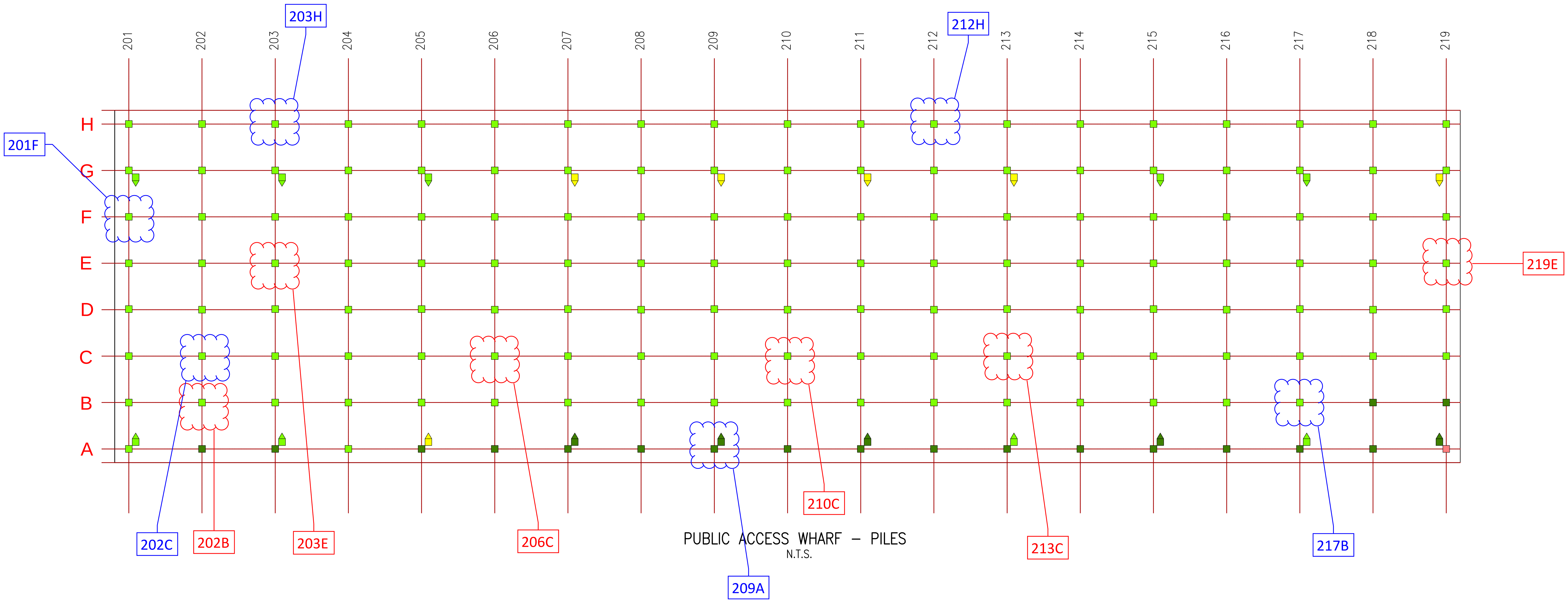

PUBLIC ACCESS WHARF – PILES
N.T.S.

Locations shown in blue to be tested on headstock

Locations shown in red to be tested on pile

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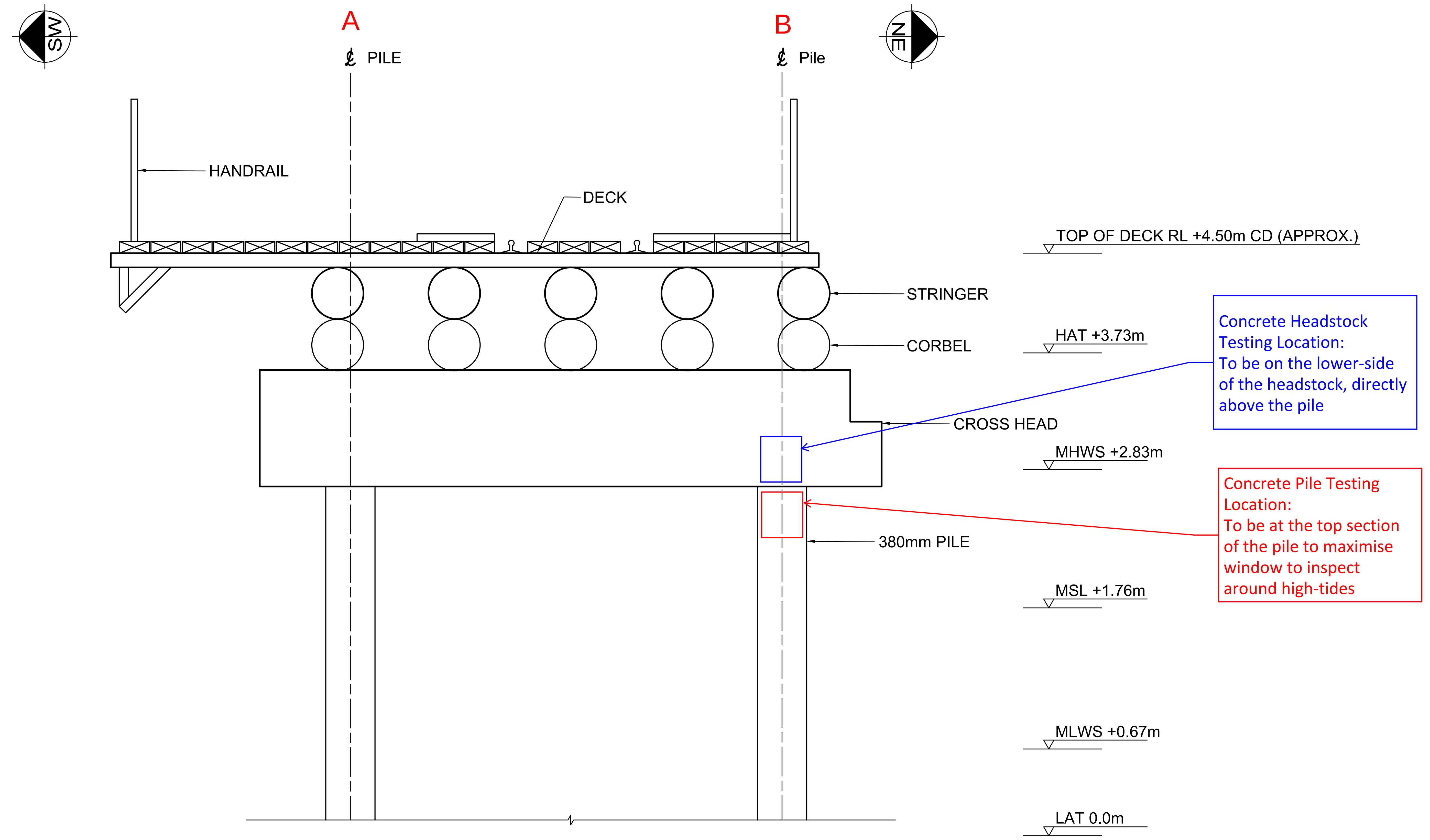
CONDITION ASSESSMENT
HEAT MAP - PUBLIC ACCESS
WHARF - SHEET 1 OF 2



MIDDLE WHARF STEM TYPICAL CROSS SECTION A 005
N.T.S.

MIDDLE WHARF STEM GEOMETRY		
ELEMENT	**MATERIAL**	**TYPICAL APPROXIMATE GEOMETRY**
PILES	CONCRETE	380X380MM
CROSS HEAD / HEADSTOCK	CONCRETE	900MM DEEP X 900MM WIDE, WITH 400X400MM INVERTED U-SHAPE VOID
CORBELS	TIMBER	Ø400MM, 2M LENGTH
STRINGERS / GIRDERS	TIMBER	Ø400MM, 4NO. ASSUMED SUPPORTING ROADWAY, 5.4M SPAN (EXCL CORBELS)
CROSS BEAMS	TIMBER	230MM WIDE X 110MM DEEP
DECK	TIMBER	230MM WIDE X 90MM DEEP
WHEEL GUIDES	TIMBER (MARINE PLY)	2 NO. 600MM WIDE X 60MM THK SPACED AT APPROX. 1050MM

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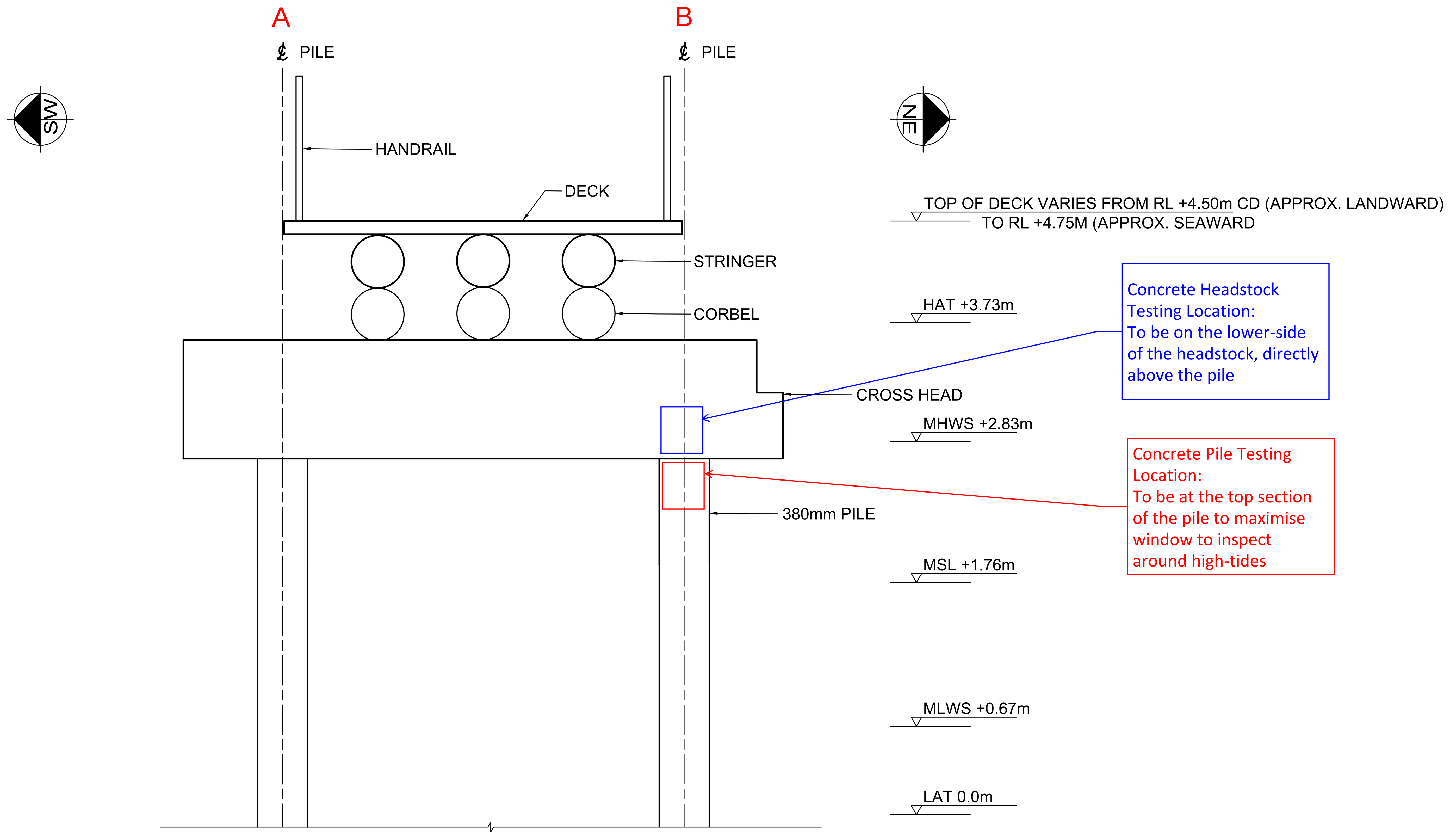
MIDDLE WHARF STEM
TYPICAL CROSS SECTION



OUTER WHARF STEM TYPICAL CROSS SECTION B 005
N.T.S.

OUTER WHARF STEM GEOMETRY		
ELEMENT	**MATERIAL**	**TYPICAL APPROXIMATE GEOMETRY**
PILES	CONCRETE	380X380MM
CROSS HEAD / HEADSTOCK	CONCRETE	900MM DEEP X 900MM WIDE, WITH 400X400MM INVERTED U-SHAPE VOID
CORBELS	TIMBER	Ø400MM, 2M LENGTH
STRINGERS / GIRDERS	TIMBER	Ø400MM, 3NO. ASSUMED SUPPORTING TRAFFICABLE DECK WIDTH, 5.4M SPAN (EXCL. CORBELS)
DECK	TIMBER	220MM X 100MM THK
TOP DECKING	TIMBER (MARINE PLY)	1-2 LAYERS OF SHEETS WITH THICKNESS OF 15-20 MM

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OUTER WHARF STEM
TYPICAL CROSS SECTION

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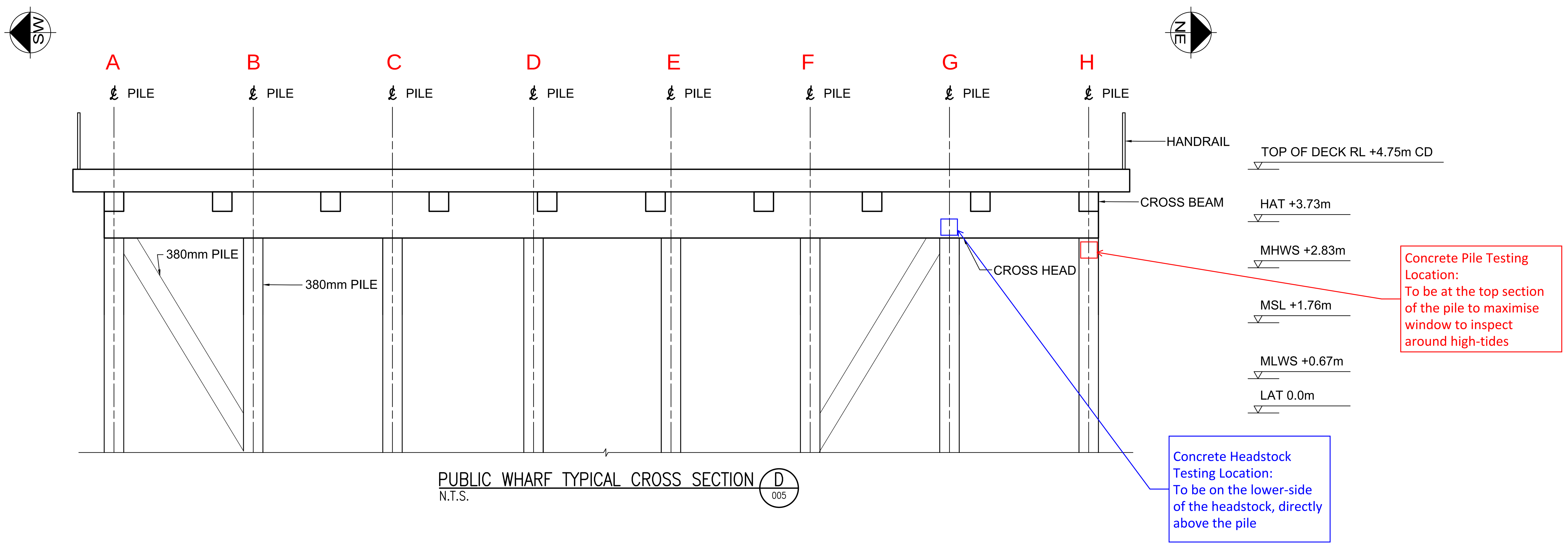
User : Gabriela Barbosa Plot Date : 8/04/2019 12:14:22 PM



PUBLIC WHARF TYPICAL CROSS SECTION
N.T.S.

PUBLIC WHARF GEOMETRY

ELEMENT	MATERIAL	TYPICAL APPROXIMATE GEOMETRY
PILES	CONCRETE	380X380MM. PILES AT 2700MM C/C ALONG HEADSTOCK. 8 PILES PER ROW.
HEADSTOCK / CROSS HEAD	CONCRETE	1750MM DEEP X 380MM WIDE. 4300MM C/C BETWEEN HEADSTOCKS.
CROSS BEAMS	CONCRETE	ASSUME 900MM DEEP X 380MM WIDE AT ENDS OF EACH BEAM, TAPERING TO 500MM DEEP IN MIDDLE. MIDDLE SECTION IS 2300MM LONG, ENDS ARE 1000MM LONG. 10 NO. CROSS BEAMS.
DECK SLAB	CONCRETE	440MM TOTAL DEPTH (IN LAYERS OF 220MM + 160MM + 60MM). 220MM BASE SLAB USED FOR CAPACITY CALCULATIONS.

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PUBLIC WHARF
TYPICAL CROSS SECTION