North Queensland Bulk Ports

Bowen Wharf Refurbishment Study

Design Report

SCMC-23029-RPT-001 | Rev 2 | 16 November 2023

SHORELINE

CIVIL AND MARINE CONSULTING

Bowen Wharf Refurbishment Study | Design Report

Prepared For (Client)	Prepared By
North Queensland Bulk Ports	Shoreline Civil & Marine Consulting Pty Ltd ABN: 68 633 921 472

Client Representative(s)
Hossein Sadai, Anoop Pillai, Bart Wassink

Project Title	Bowen Wharf Refurbishment Study
Project No.	23029
Document Title	Design Report
Document No.	SCMC-23029-RPT-001

Prepared By	Reviewed By	Approved By
Michael Kelleher	Peter Kastrup	Peter Kastrup
Signatures on file	Signatures on file	Signatures on file

Revision	Date	Purpose	Description	Amended By
Rev A	13 Sept 2023	For Review	Draft Issue	-
Rev 0	6 Oct 2023	Issue for Use	NQBP comments incorporated	M. Kelleher
Rev 1	27 Oct 2023	Issue for Use	Additional NQBP comments incorporated	M. Kelleher
Rev 2	16 Nov 2023	Issue for Use	RLB cost estimate incorporated	M. Kelleher

Statement of Limitations

The purpose of this report and the associated services performed by Shoreline Civil and Marine Consulting (SCMC) is to document the concept design of refurbishment works at Bowen Wharf in accordance with the scope of services set out in the contract between SCMC and North Queensland Bulk Ports ('the Client'). That scope of services was defined by the requests of the Client, by the time and budgetary constraints imposed by the Client, and by the availability of access to the site / structures.

In preparing this report, SCMC has relied upon and presumed accurate certain information (or absence thereof) relative to Bowen Wharf structures provided by the Client and others identified herein. Unless as otherwise stated in this report, SCMC has not attempted to verify the accuracy or completeness of any such information.

SCMC derived the data in this report from existing drawings, previous reports by others, historical photos and visual inspections. The passage of time, manifestation of latent conditions or impacts of future events may require further exploration at the site and subsequent data analysis, and re-evaluation of the findings, observations and conclusions expressed in this report.

This report has been prepared on behalf of and for the exclusive use of the Client and is subject to and issued in connection with the provisions of the agreement between SCMC and the Client. SCMC accepts no liability or responsibility whatsoever for or in respect of any use of or reliance upon this report by any third party.

Contents

Executive Summary **1**

1 Introduction **8**

1.1 Background 8
1.2 Scope 8

2 Previous Studies & Information **10**

2.1 Arup Documents 10
2.2 Jacobs Documents 11
2.3 KBR Documents 11
2.4 Wisely Documents 11
2.5 NQBP Documents 12

3 Bowen Wharf Structure Description **13**

3.1 Repairs Undertaken since the 2018 WSCAM Inspection 14
3.2 Current Loadings 14

4 Condition Inspection Findings **15**

4.1 Wharf Stem Structures 16
4.2 Public Wharf Structure 16

5 Refurbishment Concept **22**

5.1 Overview 22
5.2 Functional Requirements 22
5.3 Maintenance/Repair Strategy 24
5.4 Demolition 24
5.5 Middle Stem and Outer Stem Refurbishment 25
5.6 Public Wharf Refurbishment 30
5.7 Architectural Features 33
5.8 Estimated Future Maintenance 33
5.9 Bill of Quantities 36
5.10 Cost Estimate 36

6 Refurbishment Concept Risk & Opportunities **37**

7 Refurbishment vs New Structure Comparison **39**

7.1 Purpose 39
7.2 Concept Description 39
7.3 Capital Cost / Constructability 41
7.4 Durability / Maintenance 41
7.5 Resilience 42
7.6 Commercial Functionality 45

7.7 Public Amenity 45
7.8 Heritage 46
7.9 Environment / Sustainability 49
7.10 Accessibility 50
8 Summary 51
8.1 Condition Inspection Findings 51
8.2 Refurbishment Concept 51
8.3 Refurbishment vs New Structure Comparison 53
Appendix A Condition Rating Heat Map Markups and Sample Condition Report
Appendix B Concept Sketches

Executive Summary

Background

We understand that the Queensland Government, as part of the 2023-2024 budget, has announced that $50 million has been allocated to "*help pay for the replacement of the Bowen wharf to support continued community access with the plans, designs, and approvals subject to further consultation with stakeholders*". The scope of this project undertaken by Shoreline Civil and Marine Consulting (SCMC) is to provide advice relating to extending the life of the existing publicly accessible Bowen Wharf structure to inform the next stage of design at Bowen Wharf.

Scope

The scope of this project was to review the asset condition of Bowen Wharf and identify suitable refurbishment works to maintain the existing structure as a public asset. The assessment was limited to refurbishment and maintenance of existing structures and excludes demolition/replacement/like-for-like rebuild at the outset or during the design life. Like-for-like replacement of timber elements was however deemed acceptable.

The SCMC scope consisted of:

- Desktop review of existing reports that detail the asset condition and other available documentation relevant to the project.
- Site visit to undertake a high-level targeted assessment of the current condition of concrete elements for comparison with the previous 2018 WSCAM condition assessment and to assess where the condition has notably changed.
- Investigations into feasible refurbishment works and preparation of concept sketches and bill of quantities including likely future maintenance requirements.
- High level holistic comparison of refurbishment of the existing structure compared with adopting a new structure.

Condition Inspection Findings

SCMC undertook a high-level visual targeted condition inspection on the 29th August 2023. The visual inspection scope included the concrete elements on the Bowen Wharf Middle Stem, Outer Stem and Public Wharf, comparing observations to the 2018 WSCAM inspection to assess where the condition has notably changed.

The inspection focussed on elements rated in good condition in 2018 to allow easier identification of where the condition has changed / deteriorated in the intervening five years. Only a proportion of elements were inspected. The objective was to gain a broad understanding of the current condition to allow estimation of the quantity and rate of deterioration since 2018. In summary, while the rate of deterioration growth varied, the site visit provided a broad understanding of the current condition to allow estimation of the growth in deterioration since 2018. The refurbishment concept design is described in detail in Section 5 however at a high level, considering the current condition and rate of deterioration observed the following strategy is recommended for concrete elements including estimated repair quantum as a percentage of the element volume:

- Piles (underwater cracking evident on almost all piles) – encapsulate all piles using pile wrapping system
  - 100% of piles for initial refurbishment
  - re-encapsulate approx. 50% of piles as maintenance
- Headstocks (localized defects) – patch repair all headstocks
  - approx. 30% for initial refurbishment
  - approx. 150% as ongoing maintenance

- Cross beams (widespread major defects) – replace all concrete and deteriorated reinforcement in public wharf cross beams
  - 100% for initial refurbishment
  - approx. 60% as ongoing maintenance
- Edge beams (widespread major defects) – replace more than half of all concrete and deteriorated reinforcement in public wharf edge beams
  - 100% for initial refurbishment
  - approx. 60% as ongoing maintenance
- Deck soffit (widespread major defects) – replace all concrete and deteriorated reinforcement
  - approx. 70% for initial refurbishment (represents full soffit area to 150mm depth)
  - approx. 15% as ongoing maintenance (represents 60% of soffit area to 150mm depth)
- Topping slab (widespread cracking and delamination) – remove and replace with new topping slab
  - 100% for initial refurbishment
  - Crack repairs as ongoing maintenance.

Refurbishment Concept

Through discussions with NQBP, the scope of the refurbishment concept detailed herein has been defined as follows:

- Rehabilitation of the existing Middle Stem and Outer Stem (a proactive rehabilitation strategy with early spending to minimise ongoing maintenance costs, hence different to the KBR concept (BEJ271-03-TD-ST-REP-0001 Concept Assessment Report (Rev 0) dated 20/12/2022), which deferred spending for as long as possible). Findings from the site visit incorporated. Ongoing maintenance allowed for as still required for an older existing structure.

- Rehabilitation of the existing Public Wharf (demolition/rebuild at the outset or during the design life to be avoided). Same rehabilitation strategy as the stems. Findings from the site visit incorporated. Ongoing maintenance allowed for as still required for an older existing structure.

- Scoping of minor demolition along the Middle Stem and Outer Stem. Demolition of the Coal Pier Stem and Tug Wharf is excluded (by others). Note that as demolition of the Coal Pier Stem may occur at a later date, it is assumed that Coal Pier Stem girders are not planned for re-use on the Middle and Outer Stems.

The refurbishment concept has been prepared based on previous available data (inspection, design and construction documentation from KBR, Arup, Jacobs and Wisely – refer Section 2). The assessment relies on previous reports and analysis undertaken by others and structural analysis was excluded from the scope. The findings from a high-level targeted site inspection have been incorporated into the concept design.

The proposed rehabilitation works are presented in the concept sketches in Appendix B with repairs for the stems and public wharf summarised below.

The design life of the refurbishment works is 100 years. The proposed maintenance/repair strategy for the existing structures is as follows:

- undertake refurbishment of existing structures to repair observed defects.

- significant repairs occur at the 25-year, 50-year and 75-year mark to allow ongoing use with minor maintenance activities occurring at shorter intervals.

As the rate of deterioration is unknown, monitoring/regular inspections are essential to capture any early warning signs that the structure needs additional attention.

A technical memo including quantities the repair works and anticipated future maintenance has been prepared to support cost estimation.

A refurbished structure (such as the Refurbishment Concept described in this report) could achieve a basic functionality as recommended by Australian Standards. However, a new structure provides an opportunity for enhanced functionality which refurbishment may not allow. This could include wide open public walking areas or infrastructure to support recreational and commercial boating for example.

Modern design codes and factors could be adopted and met with the refurbished design including Australian Standard factors of safety for pedestrian and vehicle loading (with the possible exception of vehicle guardrails).

Structural resilience against environmental loads (seismic, wind, wave) has not been assessed. If future assessment demonstrates the structural resilience is not in accordance with modern codes, the vulnerability of the refurbished structure and associated risk profile may be deemed unacceptable by the asset owner. This will need to be considered as the design progresses and any deficiencies may lead to creep in cost and extent of strengthening works required. It is considered likely that the public wharf will be able to resist imposed lateral loads as it was originally designed for railway cars and trucks as well as berthing and mooring of ships. However there is a risk that the stem structures cannot withstand the imposed lateral loads from modern design codes and more piling or bracing is required which may also impact on heritage due to changes in structural form. This is considered to be a low risk and it is recommended that this risk is captured through contingency allowance in the cost estimates.

The following are open risks that require consideration/mitigation at detailed design which are associated with refurbishment and are not present through adoption of a new structure:

- Structural resilience against environmental loads (seismic, wind, wave) need to be considered as the design progresses and may require additional strengthening works or acceptance of reduced resilience. Note there is limited information available on existing pile toe levels to inform lateral load capacity checks. Contingency allowance to be included in the cost estimate.

- Traffic barriers to prevent errant vehicles falling off the stems / wharf could be installed which would increase refurbishment costs (quite significantly if code compliant barriers are required).

- There is a risk of overtopping of the structure due to wave action and/or storm surge, particularly with sea level rise. It is not practical to raise the existing structure to mitigate this risk. Over the course of a 50 year or 100 year design life, this means potential closure periods for clean up and minor maintenance which is not required for a new structure.

- Condition of piles below seabed is unknown and cannot be verified easily. This is a low risk but increases over time. Existing piles which are redundant/demolished could be extracted and inspected to provide an indication of typical pile condition below seabed in advance of commencing the refurbishment works, however no other practical mitigations exist. Repair of piles below seabed not feasible and installation of new piles would be required if risk eventuates (i.e. refurbishment option is likely to be non-viable and construction of new stem and public wharf structures may be required).

- Risk of ongoing maintenance costs and repair quantities being underestimated. The Arup testing showed that chloride levels are high in non-defect locations, hence high risk of corrosion, which will likely lead to requirement for concrete repairs in future in areas which are not currently exhibiting signs of deterioration. Note that as long as the piles (existing piles below seabed and new pile wrapping system above seabed) remain capable of supporting the structure, the concrete and timber elements can be repaired / replaced indefinitely (assuming no budgetary constraints). The original form of the structure will remain, but the original fabric (i.e. the concrete elements) is estimated to be repaired ~1.5 times over during the 100 years. The exact quantum of repair over the life of the structure is impossible to predict with accuracy and should be considered an estimate only with suitable risk and contingency allowances.

- The existing structure is less resilient than the new structure, therefore there is greater risk of damage during an extreme event (e.g. cyclone) which could prevent commercial activities for a period of time.

- Some headstocks on the outer stem extend beyond the extent of deck and locals sometimes climb over the handrails and stand on the headstocks where there are no handrails to fish. This is a safety risk.

- Hazardous working conditions below deck of the public wharf. Below deck is tidally constrained with limited headroom and subject to wave action with poor access for extraction if there is an accident. Deteriorated concrete segments may fall onto workers or the access platform during repair works. This is a safety and constructability risk.

A refurbishment concept cost estimate has been derived based on expected refurbishment, replacement and ongoing maintenance activities associated with prolonging the life of the existing structure. This cost estimate has been prepared by specialist cost and quantity consultant Rider Levett Bucknall (RLB). A full breakdown is provided in the cost estimate by RLB.

CAPEX costs are provided in Table 1 below, extracted from the RLB cost estimate.

Table 1: CAPEX costs (extracted from RLB Cost Estimate)

Item	Amount (Excl GST)
Direct Job Cost	$26,047,220
Indirect Job Cost	$5,209,444
Offsite Overhead and Margin	$3,125,667
Total Construction Cost	**$34,382,331**
Design Fees	Excl
Project Specific Contingency for Structural Capacity	$3,438,234
Risk Contingency	$11,346,170
Qleave	$282,722
Escalation	Excl
Authority Fees & Charges	Excl
Infrastructure Upgrades	Excl
NQBP Cost	Excl
GST	Excl
Total Project Cost (Excl GST)	**$49,449,457**

In addition to the costs included above, escalation, design fees, surveys, project management and testing would require budgeting. Based on the RLB cost estimate, inclusion of these items may require a budget above $50M.

OPEX costs for 50yr and 100yr schemes are provided in Table 2 below, extracted from the RLB cost estimate:

Table 2: OPEX costs for 50 and 100 year schemes (extracted from RLB Cost Estimate)

	50 Year Scheme		100 Year Scheme	
Element / Description	Total Cost (Escalated) over 50 years	Average Cost per Year (Escalated)	Total Cost (Escalated) over 100 years	Average Cost per Year (Escalated)
Capital Replacement	$27,809,914	$556,198	$228,771,018	$2,287,710
Planned maintenance	$17,223,322	$344,466	$89,163,781	$891,638
Re-active maintenance	$2,465,035	$49,301	$14,042,834	$140,428
Operational Costs	-	-	-	-
Management Fee	$2,377,000	$47,540	$16,604,000	$166,040
Sundry Items	$200,000	$4,000	$300,000	$3,000
Total (escalated cost)	**$50,075,271**	**$1,001,505**	**$348,881,633**	**$3,488,816**
Net Present Cost (7%)	**$8,292,222**		**$12,929,104**	

It is important to note that OPEX costs for refurbishment include significant capital replacement and reactive maintenance costs specifically associated with maintaining existing structures that are reaching end of life. Some of these costs include significant intervention and capital replacement costs in year 26 for example would not be required if maintaining a new structure.

Refurbishment vs New Structure Comparison

The purpose of this comparison is to provide a broad understanding of the differences between the refurbishment concept and a new structure concept and highlight key advantages, disadvantages, risks and opportunities to inform the next stage of design. It is expected that a multi-criteria analysis will need to be undertaken during the next stage of design to determine the preferred option, noting there are several opportunities described herein which could be explored further.

Based on the assessment undertaken in this report, a high-level summary comparison table for the various assessed comparison categories is provided in Table 3.

Table 3: Comparison Summary

Category	Anticipated Preferred Option	Notes
Capital Cost	**New Structure**	• Refurbishment likely to have higher capital cost. • If the new structure is built on a separate alignment, the existing structure could be left as-is and made safe (i.e. prevent access). This would significantly reduce demolition costs associated with the new structure concept.
Constructability	**New Structure**	• Difficult access and working conditions below the public wharf deck for refurbishment option. • The new structure includes precast construction which maximises off-site fabrication and improves concrete quality.
Durability / Maintenance	**New Structure**	• A new structure is inherently more durable with reduced ongoing maintenance, particularly in the first 50 years. • Maintenance costs for the refurbishment concept are expected to be greater with an increasing rate of deterioration anticipated over its service life, given the structure is already 100 years old.
Resilience	**New Structure**	• The new structure deck levels are raised by 1m which provides resilience against overtopping due to sea level rise (SLR), storm surge and waves. • The HAT design water level table for 2050 (incl +0.4m SLR) is 4.16m CD, only slightly below the existing deck level. Wave splash/spray above existing deck level will become more commonplace with SLR and the existing deck will be, based on current SLR modelling predictions / guidelines, submerged at HAT by the year 2100, with 20 years of design life still remaining. • During extreme wave events the refurbished structure is likely to be submerged/overtopped by ‘green’ water waves and will need to be closed for safety.
Commercial Functionality	**New Structure**	• The existing structure is less resilient, therefore there is greater risk of damage during an extreme event (e.g. cyclone) which could prevent commercial activities for a period of time. • The new structure will likely have greater impact to commercial operations during construction, however this can be mitigated by building the new structure on a new alignment which would actually reduce impact compared to the refurbishment option.

Category	Anticipated Preferred Option	Notes
Public Amenity	**New Structure**	• Increased ongoing maintenance and repairs for the refurbishment option may impact on public amenity (both visually and physically).
Heritage	**Refurbishment**	• Repair and replacement of heritage elements like-for-like where necessary is preferred from a heritage perspective. Noting some impacts will be incurred due to loss of some original fabric where it has failed. • A new structure could incorporate or reuse existing heritage components while achieving new structure benefits. • Existing piles which are 'exceptional' heritage significance will be covered by the pile encapsulation system which will also change the shape of the pile from square to round which may impact on visual amenity. • Demolition of the existing structure may result in total loss of its heritage values and may have irreversible negative impacts (requires specialist heritage advice to confirm). This could be mitigated by building the new structure on a new alignment and retaining the existing original wharf structures where possible.
Environment / Sustainability	**No clear preference**	• The refurbishment option minimises use of construction materials by extending the life of the asset (i.e. avoids new construction) however this option will require an expected high level of ongoing maintenance construction works (and material requirements). • New materials and construction practices used in the new structure provide longer term durability / reduced ongoing maintenance and repair works requirement.
Accessibility	**New Structure**	• New structure includes rest areas and can be designed to incorporate improved accessibility. • Refurbishment option may be difficult to ensure DDA compliance with timber decking (due to drying shrinkage and warping / deterioration of timber over time). • The existing structure has no existing rest areas and no wheelchair passing zones on the middle stem.
Overall Indicative Preferred Option	**New Structure**	• Refurbishment preferred in one category. • New structure preferred in seven categories. • No clear preference in one category.

Based on the assumed category preferences above, it appears at this early stage of the options assessment process, that the refurbishment option may be preferred in one category, the new structure may be preferred in seven categories and there is one category in which there is no clear preference. Hence the new structure concept would appear to be preferred overall.

The assessment undertaken in this report is very high level and based on the available information to date. It is recommended that a holistic view is taken to determine the preferred approach in the next phase of design.

Cost Comparison

Based on the RLB cost estimates, and summarized above a refurbished option has the potential to cost more than $50M.

Regarding OPEX costs, a new structure could be designed with low maintenance requirements as a consideration. This would be through additional concrete cover, corrosion inhibitors in the concrete mix design, installation of cathodic protection, use of stainless steel (where economically viable) and use of robust painting systems and pile wrapping systems (e.g. Denso Seashield). Under such case, the maintenance costs would be expected to be significantly less than those associated with maintaining the existing structures. In particular, a new structure designed for a 100-year design life would not typically include the major capital replacement costs associated with maintaining the existing. If the existing wharf were to be refurbished the future asset owner will be required to fund significant replacement costs in years 26, 51 and 76.

1 Introduction

1.1 Background

Bowen Wharf is a highly valued public asset with historic and cultural significance to the local community as well as being a commercially operational tug operations wharf used to service the Port of Abbot Point. North Queensland Bulk Ports (NQBP) is responsible for the management of Bowen Wharf.

Bowen Wharf currently provides two major functions as follows:

- provides for the mooring of tug vessels along with infrastructure to provision and service the tug fleet; and
- provides public amenities in the way of access for walking, fishing and other general recreational activities.

To maintain an acceptable level of service for both public and commercial use, NQBP completed refurbishment works in 2021 to extend the usable life and allow continued functionality for another 5 years of commercial and public activity.

We understand that Queensland Government, as part of the 2023-2024 budget, has announced that $50 million has been allocated to *"help pay for the replacement of the Bowen wharf to support continued community access with the plans, designs, and approvals subject to further consultation with stakeholders"*. The scope of this project is to provide advice relating to extending the life of the existing publicly accessible Bowen Wharf structure to inform the next stage of design at Bowen Wharf.

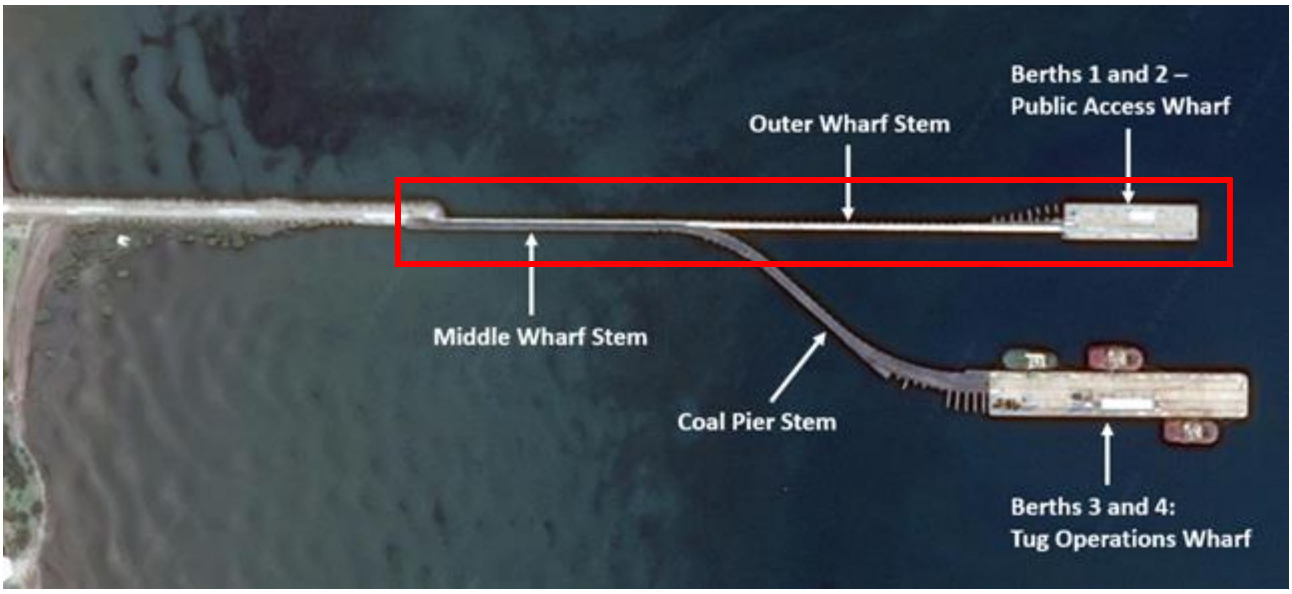


Figure 1: Bowen Wharf Aerial Image

1.2 Scope

The scope of this project was to review the asset condition of Bowen Wharf and identify suitable refurbishment works to maintain the existing structure as a public asset. The assessment was limited to refurbishment and maintenance of existing structures and excludes demolition/replacement/like-for-like rebuild at the outset or during the design life. Like-for-like replacement of timber elements was however deemed acceptable.

The SCMC scope consisted of:

- Desktop review of existing reports that detail the asset condition and other available documentation relevant to the project.
- Site visit to undertake a high-level targeted assessment of the current condition of concrete elements for comparison with the previous 2018 WSCAM condition assessment and to assess where the condition has notably changed.
- Investigations into feasible refurbishment works and preparation of concept sketches and bill of quantities including likely future maintenance requirements.
- High level holistic comparison of refurbishment of the existing structure compared with adopting a new structure.

This report documents the proposed scope of works to achieve the above objectives and the anticipated ongoing maintenance requirements.

2 Previous Studies & Information

The following reports, drawings and other documentation were reviewed as part of this assessment. These documents were prepared by Arup, KBR, Jacobs, Wisely and NQBP for use by NQBP. These documents have been provided to SCMC as reliance documents. A summary of each document is provided below.

2.1 Arup Documents

2.1.1 264408-00-REP-002 Advanced WSCAM Inspection and Load Rating Report (Rev 1B)

This report dated 2nd April 2019 documents the findings of an advanced WSCAM inspection (visual inspection) of the wharf structural components and assessment of the load carrying capacity of the structure to determine if the wharf in its current condition could satisfy operational loading requirements.

2.1.2 264408-00-REP-003 Options Analysis Report (Rev 1)

This report dated 12th April 2019 documents a range of future use scenarios and high-level repair/replacement strategies including a SWOT analysis and high-level costs for each option.

It should be noted that there have been some key changes since this report was prepared, including:

- Girder and concrete testing
- Bowen Wharf Repair Project detailed design including risk-based approach
- Bowen Wharf Repair Project refurbishment works
- Jacobs concept option designs

2.1.3 264408-00-REP-004 Testing Report (Rev 2)

This report dated 15th March 2020 documents the investigation and testing of the condition of selected wharf structural components. The scope of testing included:

- Timber girder probing testing of all girders
- Concrete condition testing at 20 test point locations
- Concrete coring and scanning at headstock 218 next to joint in public wharf
- Diving inspection of 5% of the piles

2.1.4 272940-RPT-001 Design Report (Issue 1)

The purpose of this document (dated 20th October 2021) is to communicate to NQBP the design basis adopted for the detailed design of Bowen Wharf Repair Project, which was constructed in 2021. This report also serves to document the design process, which includes assessment of existing structural element residual strength and the design outcomes for improvement works where recommended.

2.1.5 Bowen Wharf Repair Project – For Construction Drawings (Rev 0)

Issue for construction drawing set (dated 14th December 2020) for the recently completed Bowen Wharf Repair Project. The construction works included refurbishment works to extend usable life and allow continued functionality for another 5 years of commercial and public activity.

2.2 Jacobs Documents

2.2.1 W242800-0000-CM-RPT-0001 Concept Design Report (Rev B)

This report dated 2nd November 2020 describes three concept options that have been developed for the replacement of the existing Bowen Wharf with a new public stem and wharf. For each option a level 4 capital estimate (CAPEX) and a whole of life maintenance cost estimate (OPEX) have been developed. This report includes concept drawings.

2.2.2 IW242800-0000-SM-MEM-0001 Bowen Jetty Deck Replacement Concept (Rev B)

This technical memo dated 21st December 2022 describes a concept design for a new concrete deck on the jetty stems and re-use of the existing piles and headstocks. The refurbishment of the existing piles and headstock is assumed to be undertaken by others. The new stem deck is raised by approximately 1.0m to +5.5 mCD to accommodate sea level rise and has a design life of 50 years. and includes a level 4 capital estimate (CAPEX) and a whole of life maintenance cost estimate (OPEX).

2.3 KBR Documents

2.3.1 BEJ271-03-TD-ST-REP-0001 Concept Assessment Report (Rev 0)

This report dated 16th December 2022 describes refurbishment of the existing middle and outer stem structures to provide a 50 year life extension with a new public wharf, with a focus on repairing observed defects while minimising initial capital cost and deferring expenditure for as long as reasonably possible. The report includes a capital estimate (CAPEX) and a whole of life maintenance cost estimate (OPEX) as well as concept sketches.

2.4 Wisely Documents

2.4.1 As Constructed Drawings

Red line markup drawings (undated) prepared by Wisely documenting the Bowen Wharf Repair Project as built works.

2.4.2 Contract Schedule of Rates - Bowen Wharf Repair Project

Contract schedule of rates for construction dated 10 December 2020 from the recently completed Bowen Wharf Repair Project.

2.5 NQBP Documents

2.5.1 Bowen Wharf Repair Project (BWRP) - Close Out Report (Rev 0)

A project close-out report prepared by NQBP dated 28th October 2021 following completion of the Bowen Wharf Repair Project construction works.

3 Bowen Wharf Structure Description

Bowen Wharf extends approximately 750m from Santa Barbara Park into the waters of Port Denison. Constructed in the late 1860's, and then reconstructed and extended between the 1880's and the 1950's, Bowen Wharf is a historically and culturally significant piece of infrastructure, being one of the oldest examples of port structures in North Queensland. A Bowen Wharf aerial layout showing the various wharf sections is shown in Figure 2.

Figure 2: Bowen Wharf existing layout

A summary of the existing structure is provided below. Additional information including typical sections and member sizes is provided in the Concept Sketches in Appendix A.

Table 4: Existing structure summary

Section	Geometry	Description	Purpose
Causeway (excluded from scope)	Approx. 270 m long	Rubblemound rock structure	Shared port traffic and public pedestrian access
Middle stem	Approx. 165 m long and 5.7 m clear width typically	Suspended timber deck supported by concrete headstock and piles	Shared port traffic and public pedestrian access
Public Wharf	Approx. 78 m long and 20 m wide	Reinforced concrete structure	Public pedestrian access only (no vessel usage)
Outer stem	Approx. 225 m long and 3.2 m clear width typically	Suspended timber deck supported by concrete headstock and piles	Public pedestrian access only
Coal pier stem	Approx. 210 m long, width varies	Suspended timber deck supported by concrete headstock and piles	Port traffic access only
Tug Wharf	Approx. 150 m long and 25 m wide	Reinforced concrete structure	Tug and other vessel mooring to facilitate servicing of the vessels.

3.1 Repairs Undertaken since the 2018 WSCAM Inspection

The Bowen Wharf Repair Project refurbishment works completed in 2021 were designed to extend the usable life and allow continued functionality for another 5 years of commercial and public activity. This project included replacement of the most critically deteriorated timber girders and repairs to timber corbels, decking and other deck furniture. This project excluded repair of the public wharf, tug wharf or any concrete elements on the stem structures.

Major repairs to the public wharf have not been carried out since the 2018 WSCAM Inspection.

3.2 Current Loadings

The current vertical imposed loads on the structure are shown in Table 5.

Table 5: Existing vertical imposed loads

Description	Areas	Requirement
15,000L Fuel Truck (partially full to axle restrictions)	Middle and Coal Pier Stems Tug Wharf	Tri-axle semi-trailer with axle loads of 4 t (front axle), 10.7 t (double axle) and 14.0 t (tri axle). Axle spacings are nominated in the Arup Design Report.
20 t Franna Crane	Middle and Coal Pier Stems Tug Wharf	Franna cane with 10 t axle limit and 4.5 m axle spacing
5 kPa Pedestrian UDL	Middle and Outer Stems Public Wharf	5 kPa area load
16 kN total weight ATV	All Areas	ATV equivalent to RTV-X1120 Series with total weight including payload of 1.6 t and a 40/60 split between front and rear axles.

It should be noted that the current vehicles accessing the structure are tightly controlled by NQBP. The Bowen Wharf Repair Project assessment did not apply load factors (except a dynamic load allowance of 1.1) to live loads given the above, and the 5 kPa live load was considered as a ‘ULS load’. In effect this resulted in the serviceability pedestrian load on the structure being reduced from 5 kPa to 3.33 kPa for the short life extension and this was deemed acceptable by NQBP (i.e. 3.33 kPa SLS live load multiplied by 1.5 load factor = 5 kPa ULS).

4 Condition Inspection Findings

SCMC undertook a high-level targeted visual condition inspection of the wharf on the 29th August 2023. The visual inspection scope included the concrete elements on the Bowen Wharf Middle Stem, Outer Stem and Public Wharf, comparing observations to the 2018 WSCAM inspection to assess where the condition has notably changed.

The inspection focussed on elements rated in good condition in 2018 to allow easier identification of where the condition has changed / deteriorated in the intervening five years. Only a proportion of elements were inspected. The objective was to gain a broad understanding of the current condition to allow estimation of the quantity and rate of deterioration since 2018.

The WSCAM condition ratings range from 1 to 7 with description of each rating for reinforced concrete provided in Figure 3.

Figure 3: WSCAM Condition Rating Description for Reinforced Concrete (Extract from 2022 WSCAM Manual Table 2-3)

CONDITION RATING	DESCRIPTION	EXPECTED REM. LIFE (% of original design life)	RECOMMENDED ACTIONS
1	New with no visible defects/damage.	91–100	No repairs required. Re-inspection at next scheduled inspection may be considered.
2	As new. Hairline cracks (<0.1mm). No exposed reinforcement or surface evidence of corrosion of reinforcement. Minor efflorescence, no observable dampness or leakage.	56–90	No repairs required. Re-inspection at next scheduled inspection may be considered.
3	Fine cracking (0.1mm - <0.3mm), surface staining from weathering, minor voids, rust stains, minor surface erosion or honeycombing.	41–55	Planned and preventative maintenance works may be considered.
4	Medium cracking (0.3mm - 0.5mm) and rust staining present. Minor spalling and exposed reinforcement affecting less than 5 percent of surface area; <20% of surface area undergoing delamination. Moderate surface erosion.	26–40	Further testing; reactive maintenance and some minor upgrades may be considered. Structural assessment is recommended in the case of significant localised deterioration.
5	Large cracks (>0.5mm - 2mm), moderate concrete spalling and exposed reinforcement affecting up to 20% of surface area. Moderate delamination up to 50% surface area. Up to 10% section loss of reinforcement.	16–25	Structural assessment is recommended. Further investigation may be required to inform the structural assessment. Maintenance; upgrade or rehabilitation works may be considered.
6	Major cracks (>2mm), severe concrete spalling and exposed reinforcement affecting up to 50% of surface area. Severe delamination >50% surface area. 10- 20% section loss of reinforcement.	1–15	Structural assessment is recommended. Further investigation may be required to inform the structural assessment. Rehabilitation or renewal works may be considered.
7	Very severe concrete spalling with exposed reinforcement and reinforcement section loss of > 20%. Component has failed.	0	Rehabilitation required immediately or replace component/asset. Structural assessment is recommended where rehabilitation works are to be undertaken. Further investigation may be required to inform the structural assessment.

4.1 Wharf Stem Structures

A summary of the 2023 condition ratings for observed stem elements is provided in Table 6 below. On some elements the deterioration appeared similar to 2018, but on the majority of elements there was a noticeable growth in deterioration. In general, the observed stem headstocks have had moderate growth in extent of deterioration since 2018.

Table 6: 2023 WSCAM Condition Ratings Stem Structures

Element ID	2023 Condition Rating	Element ID	2023 Condition Rating
Middle Stem Headstocks		**Outer Stem Headstocks**	
55	4	82	4
60	4	86	5
61	4	87	5
62	4	95	4
64	4	104	5
65	4	105	5
67	4	108	4
74	4	109	4

4.2 Public Wharf Structure

A summary of the 2023 condition ratings for observed public wharf elements is provided in Table 7 below.

Table 7: 2023 WSCAM Condition Ratings Public Wharf Structure

Element ID	2023 Condition Rating	Element ID	2023 Condition Rating
Headstocks		**Piles (top)**	
HS 201 B-C	4	201 D	2
HS 201 C-D	2	201 F	2
HS 201 E-F	6	201 I	5
HS 201 F-G	6	201 H raker	6
HS 201 G-H	6	203 H raker	6
HS 201 H-I	2	205 H raker	5
HS 202 B-C	2	206 I	5
HS 202 C-D	2	206 F	4
HS 202 E-F	5	206 E	4
HS 202 F-G	5	207 I	5
HS 202 G-H	5	210 I	5
HS 204 G-H	5	214 I	5
HS 204 H-I	5	**Cross Beams**	
HS 205 H-I	4	CB 201-202 0	5
HS 206 F-G	2	CB 201-202 1	6

Element ID	2023 Condition Rating	Element ID	2023 Condition Rating
Headstocks		**Piles (top)**	
HS 206 G-H	4	CB 201-202 2	2
HS 206 H-I	5	CB 201-202 3	6
Deck Soffit		CB 202-203 0	5
201-202 0-1	4	CB 202-203 5	5
201-202 1-2	4		
201-202 2-3	4		
202-203 0-1	5		
202-203 1-2	4		
202-203 2-3	5		

On some elements the deterioration appeared similar to 2018, but on the majority of elements there was a noticeable growth in deterioration. In general, the public wharf has had moderate growth in extent of deterioration since 2018. A WSCAM heat map with on-site markups is provided in Appendix A along with a sample condition inspection report.

On some public wharf headstocks, the condition remained good with little observable defects, however in others there was some cracking observed and some spalling of previous repaired areas. Regardless of the visual observations, it is known based on previous concrete chloride and half-cell testing undertaken in areas without visual deterioration, that the reinforcement corrosion risk is generally high and therefore spalling is likely to accelerate into the future (refer to 264408-00-REP-004 Arup Testing Report). Furthermore, it was noted that several locations of repair grout or shotcrete applied to the headstock had delaminated, behind which was significant spalling (i.e. previously hidden defects).

The top of the piles were generally in fair condition, however localised cracking was noticed and the row I piles along the eastern edge of the wharf were in poor condition where the piles extend up into the edge beam (also in poor condition). The difference in condition rating may be due to the top of the piles being considered part of the edge beam previously (i.e. confluence of elements considered slightly differently). It should also be noted that limited diving inspections were previously undertaken which found significant underwater defects.

The deck soffit is generally in very poor condition, except for a few panels in one corner of the wharf. These were observed to have minor spalling, particularly around penetration edges.

The cross (secondary) beams are generally in very poor condition. Of the cross beams observed, some exhibited no change in condition, however some appeared to have worsened considerably.

In summary, while the rate of deterioration growth varied, the site visit provided a broad understanding of the current condition to allow estimation of the growth in deterioration since 2018. The refurbishment concept design is described in detail in Section 5 however at a high level, considering the current condition and rate of deterioration observed the following strategy is recommended for concrete elements including estimated repair quantum as a percentage of the element volume:

- Piles (underwater cracking evident on almost all piles) – encapsulate all piles using pile wrapping system
    - 100% of piles for initial refurbishment
    - re-encapsulate approx. 50% of piles as maintenance
- Headstocks (localized defects) – patch repair all headstocks
    - approx. 30% for initial refurbishment
    - approx. 150% as ongoing maintenance
- Cross beams (widespread major defects) – replace all concrete and deteriorated reinforcement in public wharf cross beams
    - 100% for initial refurbishment
    - approx. 60% as ongoing maintenance

- Edge beams (widespread major defects) – replace more than half of all concrete and deteriorated reinforcement in public wharf edge beams
    - 100% for initial refurbishment
    - approx. 60% as ongoing maintenance
- Deck soffit (widespread major defects) – replace all concrete and deteriorated reinforcement
    - approx. 70% for initial refurbishment (represents full soffit area to 150mm depth)
    - approx. 15% as ongoing maintenance (represents 60% of soffit area to 150mm depth)
- Topping slab (widespread cracking and delamination) – remove and replace with new topping slab
    - 100% for initial refurbishment
    - Crack repairs as ongoing maintenance

Photos illustrating the typical condition for each element type are provided below.

Figure 4: Middle and Outer Stem Headstocks

Figure 5: Public Wharf Headstocks

Figure 6: Public Wharf Piles (top)

Figure 7: Public Wharf Cross Beams

Figure 8: Public Wharf Deck Soffit

Figure 9: Public Wharf Edge Beam

5 Refurbishment Concept

5.1 Overview

Through discussions with NQBP, the scope of the refurbishment concept detailed herein has been defined as follows:

- Rehabilitation of the existing Middle Stem and Outer Stem (a proactive rehabilitation strategy with early spending to minimise ongoing maintenance costs, hence different to the KBR concept (BEJ271-03-TD-ST-REP-0001 Concept Assessment Report (Rev 0)), which deferred spending for as long as possible). Findings from the site visit incorporated. Ongoing maintenance allowed for as still required for an older existing structure.
- Rehabilitation of the existing Public Wharf (demolition/rebuild at the outset or during the design life to be avoided). Same rehabilitation strategy as the stems. Findings from the site visit incorporated. Ongoing maintenance allowed for as still required for an older existing structure.
- Scoping of minor demolition along the Middle Stem and Outer Stem. Demolition of the Coal Pier Stem and Tug Wharf is excluded (by others). Note that as demolition of the Coal Pier Stem may occur at a later date, it is assumed that Coal Pier Stem girders are not planned for re-use on the Middle and Outer Stems.

The refurbishment concept has been prepared based on previous available data (inspection, design and construction documentation from KBR, Arup, Jacobs and Wisely - refer Section 2). The assessment relies on previous reports and analysis undertaken by others and structural analysis was excluded from the scope. The findings from a high-level targeted site inspection have been incorporated into the concept design.

5.2 Functional Requirements

5.2.1 Design Life

The design life of the refurbishment works is 100 years. Ongoing minor and major maintenance will be required. The maintenance strategy is described in Section 5.3.

5.2.2 Design Loads

The proposed vertical imposed loads on the structure are shown in Table 8.

Table 8: Proposed vertical imposed loads

Description	Areas	Requirement
Fire Truck [1]	Middle Stem	6.6 t front axle, 8.8 t rear axle with 4.6 m axle spacing
5 kPa Pedestrian UDL [2]	Middle and Outer Stem Public Wharf	5 kPa area load
16 kN total weight ATV	All Areas	ATV equivalent to RTV-X1120 Series with total weight including payload of 1.6 t and a 40/60 split between front and rear axles

Note 1 – Fire Truck axle loads and spacing as per Bowen Wharf Repair Project provided by NQBP as an 'additional vehicle'.

Note 2 – An ambulance may be required to access the new Public Wharf via the Outer Stem. It is expected that an ambulance would be similar order of magnitude to 5 kPa loading. Note ambulance access on Outer Stem and Public Wharf is currently not allowed.

Unlike the risk-based approach undertaken for Bowen Wharf Repair Project's short life extension, it is expected that load factors in accordance with relevant Standards would need to be applied as part of the design.

It should be noted that lateral loads on the existing structure (e.g. wave, wind, current, seismic) have not been included in the scope of previous assessments. These will need to be considered as the design progresses and any deficiencies may lead to creep in cost and extent of strengthening works required. There is also a risk that the stem structures cannot withstand the imposed lateral loads from modern design codes and more piling or bracing is required which may also impact on heritage due to changes in structural form. This is considered to be a low risk and it is recommended that this risk is captured through contingency allowance in the cost estimates.

This study does not include structural analysis, and instead relies on vertical load capacity assessments undertaken and detailed in previous reports.

5.2.3 Water Levels

The Bowen tidal planes are shown below.

Table 9: Tidal plane heights at Bowen (MSQ, 2021)

Tidal Plane	Chart Datum	Tidal Plane
Highest Astronomical Tide (HAT)	+3.73	+1.95
Mean High Water Springs (MHWS)	+2.83	+1.05
Mean High Water Neap (MHWN)	+2.21	+0.43
Australian Height Datum (AHD)	+1.78	0.0
Mean Sea Level (MSL)	+1.76	-0.02
Mean Low Water Neap (MLWN)	+1.31	-0.47
Mean Low Water Springs (MLWS)	+0.67	-1.11
Lowest Astronomical Tide (LAT)	0.0	-1.78

Sea level rise, based on current industry modelling predictions / guidelines, is expected to be approximately 0.6 m to the year 2070 and 1.0 m by the year 2120.

5.2.4 Design Water Levels

The Jacobs report describes the design water levels for the Bowen coast, extracted for present and future years from BMT (2018) and shown in Table 10. These design water levels consider sea level rise and combine non-cyclonic and cyclone surge effects as well as wave setup.

Table 10: Design water levels (incl SLR) (BMT 2018, Table 2-10, 2-11, 2-12)

ARI	Design Water Level 2020	Design Water Level 2050	Design Water Level 2070	Design Water Level 2100
	m CD (m AHD)	m CD (m AHD)	m CD (m AHD)	m CD (m AHD)
HAT	3.76 (1.98)	4.16 (2.38)	4.32 (2.54)	4.56 (2.78)
100-year ARI	4.26 (2.48)	4.69 (2.91)	4.88 (3.10)	5.17 (3.39)
200-year ARI	4.43 (2.65)	4.96 (3.18)	5.16 (3.38)	5.46 (3.68)
500-year ARI	5.12 (3.34)	5.86 (4.08)	6.10 (4.32)	6.45 (4.67)

5.2.5 Wave Conditions

The Jacobs report describes the wave conditions at Bowen. An operational wave height (1-year Average Recurrence Interval (ARI)) of H_{m0} = 0.7 m, T_p = 3.9 s was adopted based on a wave penetration study for a proposed breakwater at Bowen Boat Harbour Marina undertaken by BMT (2017).

The Jacobs report also provides extreme wave conditions extracted from BMT (2018) and shown in Table 11. The wave conditions are based on extreme synthetic tropical cyclone wave modelling under both present day and 2100 climates. The values for 2070 are linearly interpolated from 2050 and 2100 values.

Table 11: Extreme wave conditions at Bowen (BMT 2018, Table 2-7, 2-8, 2-9)

ARI	Extreme Wave Conditions 2020		Extreme Wave Conditions 2050		Extreme Wave Conditions 2070		Extreme Wave Conditions 2100	
	Hs (m)	Tp (s)	Hs (m)	Tp (s)	Hs (m)	Tp (s)	Hs (m)	Tp (s)
100	1.51	4.15	1.86	4.55	1.86	4.54	1.86	4.52
200	1.88	4.59	2.14	4.99	2.18	5.00	2.25	5.01
500	2.44	6.47	2.75	6.62	2.83	6.67	2.94	6.74

5.2.6 Structure Design Levels

The finished surface level of the Middle Stem, Outer Stem and Public Wharf is currently +4.5 m CD. Raising the deck level of the structures is not considered practical for the rehabilitation option. Therefore, it is assumed that the existing deck levels will remain unchanged.

Note that this is 1 m lower than the wharf level proposed by Jacobs (+5.5 m CD) and may result in reduced durability of the wharf structure compared to a higher structure.

It should also be noted that the structure is likely to be overtopped during extreme wave action, particularly as sea levels rise. In addition, the structure, causeway and landside areas are likely to be overtopped / flooded during storm surge events.

5.3 Maintenance/Repair Strategy

The proposed maintenance/repair strategy for the existing structures is as follows:

- undertake refurbishment of existing structures to repair observed defects.
- significant repairs occur at the 25-year, 50-year and 75-year mark to allow ongoing use with minor maintenance activities.

As mentioned previously it is not possible to accurately predict the rate of timber deterioration, therefore we can only nominate repairs based on available information and make a nominal allowance for future deterioration. As the rate of deterioration is unknown, monitoring/regular inspections are essential to capture any early warning signs that the structure needs additional attention.

The recent site inspection observed that some growth in size of observed concrete defects has occurred, however due to the high-level nature of the site inspection and varying stages of deterioration, it is not possible to accurately determine the rate of deterioration. Therefore, as noted above, regular monitoring and inspections are essential to capture any early warning signs that the structure needs additional attention.

Further detail on expected maintenance and repair activities is provided in Section 5.8.

5.4 Demolition

The demolition works include the following:

- Demolition of the Outer Stem independent disused piles and headstocks 119, 120 and 121.
- Demolition of the cantilever portion of Middle Stem deck (southern side).
- Demolition of all existing handrails and replacement with new handrails.
- All demolished piles to be fully extracted.

- Demolition of the Coal Pier Stem and Tug Wharf is excluded (by others).

The demolition works are shown on the concept sketches provided in Appendix B.

5.5 Middle Stem and Outer Stem Refurbishment

5.5.1 Stem Pile Encapsulation

A selection of piles (representing approx. 5% of total piles) were visually inspected by divers as described in the Arup Testing Report. For the Middle and Outer Stems, a total of nine piles were tested. The results showed that approximately 66% of piles exhibited large vertical cracks (1 to 3 mm or greater) on several faces. The remaining 33% piles did not exhibit visible cracking. However in order to provide a 100-year design life as well as for consistency (both visually and for future structural assessment and maintenance), all piles are proposed to be rehabilitated initially.

PileMedic or similar pile wrapping system is proposed to be used for pile rehabilitation. The PileMedic system consists of fibreglass laminate jackets coated with an epoxy paste wrapped two or more times around the pile to create a multi-ply impervious shell. The pile wrap is installed from seabed up to the soffit of headstock. The space between the jacket and pile is filled with epoxy resin.

The pile wrapping laminate jackets are typically prepared in sections above water and lowered into place with each section overlapping the section above. Once the jacket is in contact with the seabed, the base is sealed before filling the space between the jacket and pile with epoxy resin. FRP reinforcing bars can be added if additional strength is required. The aim of the pile wrapping system is to provide equal or greater strength to the original pile.

5.5.2 Stem Concrete Headstock Repairs

The WSCAM inspection previously undertaken by Arup in 2018 details the surface area of the headstocks affected by cracking and spalling. The headstock repair proposed includes repair of the areas identified in the WSCAM report, plus an allowance for growth since the WSCAM was undertaken based on the recent high-level inspection and an allowance for growth due to chasing out any significantly deteriorated reinforcement.

The crack and spall pattern typically includes a horizontal crack close to the base of the headstock between piles and spalling at the top corners as shown in Figure 10 and Figure 11 respectively.

Figure 10: Headstock typical crack close to soffit

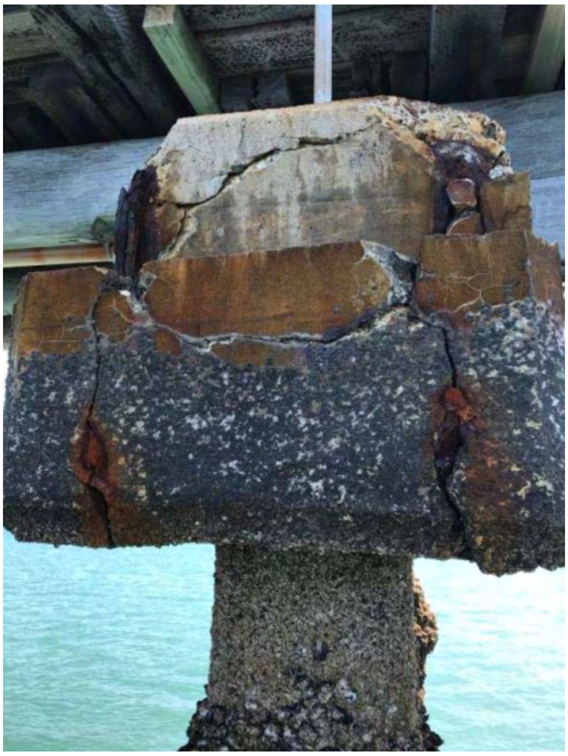


Figure 11: Headstock typical spall at each end

The proposed headstock repair includes breaking out the deteriorated concrete and chasing out any deteriorated reinforcement. The edge of the repair will need to be sawcut to provide a suitable edge to tie into existing concrete (i.e. prevention of feather edging). Any reinforcement with excessive deterioration would need to be removed and replaced with new reinforcement by drilling and epoxy gluing the new bars into sound concrete, effectively lapping onto suitable existing reinforcement. Marine grade self-compacting concrete will then be placed in the repair area. The concrete mix may require high early strength or accelerators to prevent freshly placed concrete from washing away before it sets. The repair area will need to be formed up with ports for inserting the self-compacting concrete such that it flows into all areas.

The headstock repairs will require a temporary platform for access, similar to the examples shown below but with a lower platform height to allow access to the base of headstock. Access to the headstock repairs will be tidally constrained. The formwork will need to be temporarily supported.

Environmental controls may be required prior to jackhammering and concreting including encapsulation, protective barriers, floating booms, etc. Spillage of break out and repair materials into the sea should be prevented.

Figure 12: Example headstock access (note platform would need to be lowered to access base of headstock)

5.5.3 Cathodic Protection for the Reinforced Concrete Elements

There is currently no cathodic protection on the stem structures. As the concrete repairs on the stem structures are for isolated areas, an impressed current cathodic protection system (ICCP) is not suitable. However sacrificial anodes may be installed within the repaired areas and this is recommended as part of the 100 year design life strategy. These anodes replace the existing corroding reinforcement “anodes”. It is noted that corrosion will continue to occur in areas that have not been repaired, hence why allowance for future concrete repairs is made. The anodes may need to be replaced eventually.

5.5.4 Timber Girder Replacement

Extensive girder drill testing was undertaken by Arup previously to estimate the heart void size in each girder (based on three drill locations per girder).

The recent Bowen Wharf Repair Project replaced a number of girders to provide a modest life extension based on a risk-based approach with tight vehicle controls and extensive maintenance and inspection requirements. For this project, a more proactive approach is proposed, with all girders and corbels to be initially replaced (except for those recently replaced under the Bowen Wharf Repair Project). It is expected that these girders will then be replaced at the 50-year mark to allow for the 100-year design life, with a small number of replacements during interim periods.

The Bowen Wharf Repair Project introduced edge girders in certain locations to allow the deck to span over a deteriorated girder and avoid removing the deck. These edge girders will no longer be required and will be removed to improve the structural uniformity of the stems. The new edge girders and corbels will be re-used elsewhere.

Similar to the Bowen Wharf Repair Project, the deck will need to be removed to provide access for girder replacement. It is assumed that the girders will be installed using similar construction methodology, as shown below.

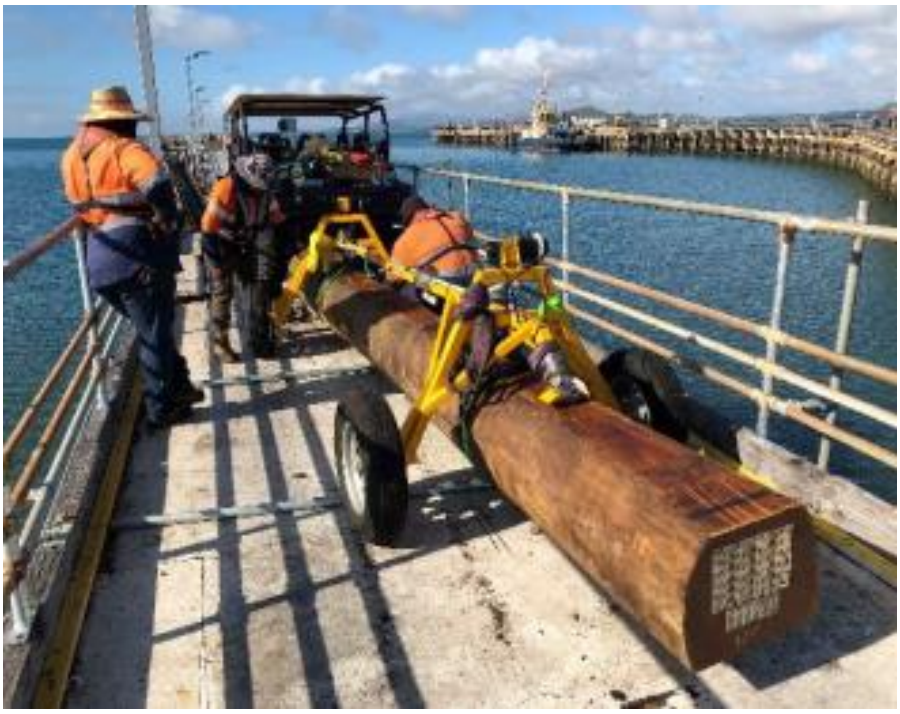


Figure 13: Girder replacement with a jinker trailer assembly

Figure 14: Girder replacement with a Telehandler (middle stem)

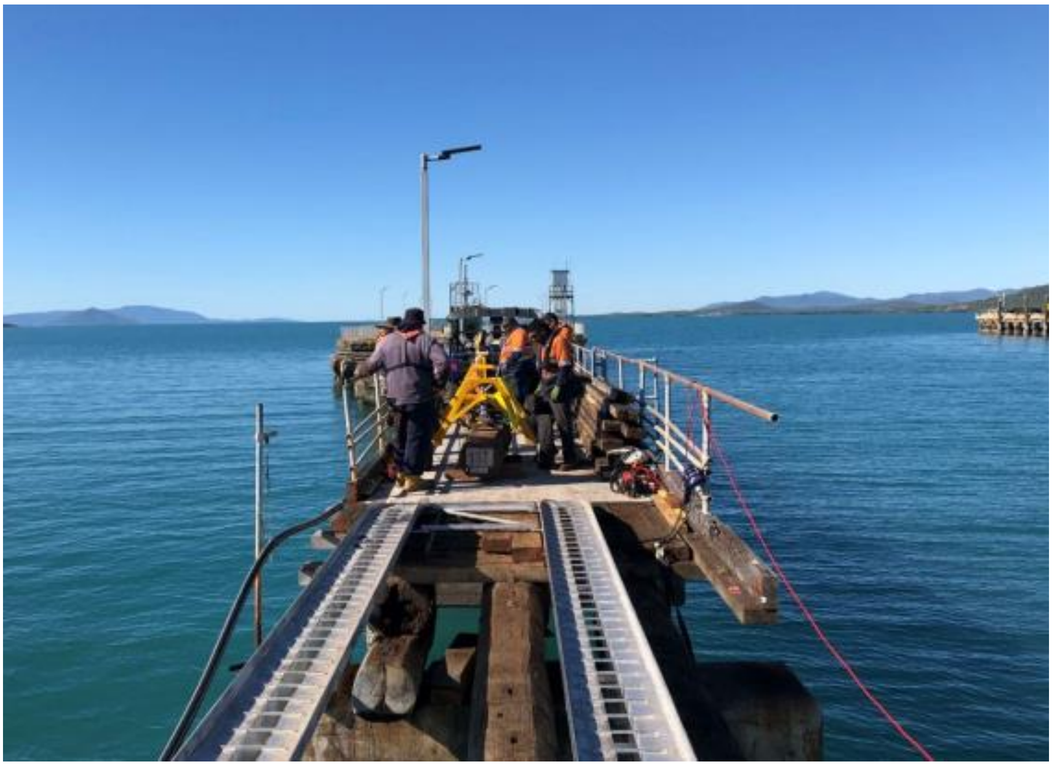


Figure 15: Jinker trailer assembly and access ramps (outer stem)

A small number of replacement girder hold down bolts has been allowed for in the cost estimate.

5.5.5 Timber Corbel Replacement

Many of the existing corbels feature vertical or multi-directional splitting. While it is possible to maintain these to provide a short life extension, it is recommended to replace all corbels initially (except for those recently replaced under the Bowen Wharf Repair Project) and again at the 50-year mark, with minor corbel repairs in the interim periods. Corbel replacement follows a similar construction methodology as girders except that two deck spans need to be removed for access.

5.5.6 Timber Corbel Repair

As all corbels will initially be replaced, corbel repairs will only be required during the maintenance period. Corbel repair type 1 consists of installing a horizontal bolt through the corbel to resist vertical end splitting. Corbel repair type 2 consists of 6 mm diameter stainless steel wire wrapped around the corbel four times per hole using three separate holes and tensioning up the cable before locking it off.

The corbel repairs can be undertaken from below using a temporary platform hanging from headstock, similar to the headstock repairs.

Figure 16: Type 2 Corbel Repair "Wire Wrap" Testing during Bowen Wharf Repair Project

5.5.7 Timber Cross Beams Repair / Replacement / Installation

The cross beams are generally in good condition. A small number were previously replaced as part of the Bowen Wharf Repair Project. Additional replacement of cross beams is not anticipated to be required initially.

5.5.8 Timber Deck

The marine ply is proposed to be removed to expose the underlying timber decking and also as the marine ply tends to trap moisture underneath and accelerate deterioration. The worst areas of the deck have been repaired as part of the Bowen Wharf Repair Project however in order to bring the stems up to a good standard at the outset of the 100-year design life it is proposed to replace half the deck timbers. An allowance of 50% of the deck planking is nominated for replacement including any damage when removing the deck for access to girders.

5.5.9 Fixings

All new fixings are proposed to be stainless steel with replacement at the 50-year mark or earlier. This applies to all new fixings including deck replacement, re-fixing decking which is removed for access, deck furniture, corbel bolts and girder bolts. Where an existing element is not removed, then existing fixings are assumed to be left as-is.

5.5.10 Deck Furniture

A nominal allowance for replacement of kerbs and wheel guides has been included.

All existing handrails are to be removed and replaced with new handrails. The handrails are to be grade 316 stainless steel and compliant with AS1428 in vertical infill style (e.g. Moddex CB30 or similar).

5.6 Public Wharf Refurbishment

5.6.1 Public Wharf Concrete Pile Encapsulation

A selection of piles (representing approx. 5% of total piles) were visually inspected by divers as described in the Arup Testing Report. For the Public Wharf, a total of ten piles were tested. The results showed that 90% of piles exhibited defects ranging from hairline cracks to large vertical cracks (1 to 3 mm or greater) on several faces. In order to provide a 100-year design life as well as for consistency (both visually and for future structural assessment and maintenance), all piles are to be encapsulated.

PileMedic or similar pile wrapping system is proposed to be used for pile rehabilitation, as described in Section 5.5.1.

The top of piles where they extend into the headstock is also proposed to be repaired using the concrete repair method described in Section 5.6.7.

5.6.2 Public Wharf Headstock Repairs

The WSCAM inspection previously undertaken by Arup in 2018 details the surface area of the headstocks affected by cracking and spalling. The headstock repair proposed includes repair of the areas identified in the WSCAM report, plus an allowance for growth since the WSCAM was undertaken based on the recent high-level inspection and an allowance for growth due to chasing out any significantly deteriorated reinforcement.

The headstocks are generally in fair condition, with localised spalling and cracking. The construction joint at location D-E requires repair at each bent. As the headstock is only 380 mm wide, the repairs are proposed to be for the full width of the headstock.

The headstocks are proposed to be repaired using the concrete repair method described in Section 5.6.7 with cathodic protection installed as described in Section 5.6.8.

5.6.3 Public Wharf Cross Beam Repairs

The concrete cross beams are generally in very poor condition and it is proposed to repair all cross beams including reinstatement of the reinforcement. The full width and length of the cross beam typically requires repair and it is expected that the repair would typically extend beyond the level of the slab soffit also.

The cross beams are proposed to be repaired using the concrete repair method described in Section 5.6.7 with cathodic protection installed as described in Section 5.6.8.

5.6.4 Public Wharf Edge Beam Repairs

The concrete edge beams on the seaward and eastern side are in very poor condition whereas the edge beams on the landward and western side are in moderate condition. It is proposed to fully repair the cross beams on the seaward and eastern side with an allowance for approximately half the cross beams on the landward and western side to be repaired.

The edge beams are proposed to be repaired using the concrete repair method described in Section 5.6.7 with cathodic protection installed as described in Section 5.6.8.

5.6.5 Public Wharf Deck Soffit Repairs

The concrete deck soffit is generally in very poor condition. It is proposed to repair all deck soffit panels including reinstatement of the soffit reinforcement.

The deck soffit panels are proposed to be repaired using the concrete repair method described in Section 5.6.7 with cathodic protection installed as described in Section 5.6.8.

5.6.6 Public Wharf Topping Slab Replacement

The base slab is 220 mm thick with two topping slabs of 160 mm and 60 mm above the base slab. As the base slab soffit is to be repaired, it is prudent to also repair the concrete above to prevent moisture ingress from above (e.g. rainfall) becoming trapped within the structure and causing corrosion. As the existing topping slabs are in partially poor to partially fair condition, it is proposed to remove both topping slabs and reinstate them with a single topping slab to the same level. The new topping slab should be constructed to be integral with the base slab.

The heritage railway tracks embedded within the deck will need to be protected during the removal of the topping slab. The rails could be removed, cleaned and polished prior to reinstatement in the new topping slab.

Removal of the topping slab may alter the load distribution pattern and temporary support may be required, depending on whether the topping slab is replaced prior to or after the below deck works. The below deck works including access arrangements and formwork may also need to be supported from above using hangar bars through cored holes in the existing deck, therefore the construction sequencing will need careful planning.

During the topping slab replacement all benches, navigation lead lights, fish cleaning tables, storm tide monitoring station, etc will need to be removed and reinstated following the works. Likewise, any services will need to be temporarily supported or removed and replaced where impacted by the repair works.

5.6.7 Concrete Repair Methodology

The concrete repair includes breaking out the deteriorated concrete and chasing out any deteriorated reinforcement. The edge of repair will need to be sawcut to provide a suitable edge to tie into existing concrete (i.e., prevention of feather edging). Any reinforcement with excessive deterioration would need to be removed and replaced with new reinforcement by drilling and epoxy gluing the new bars into sound concrete, effectively lapping onto suitable existing reinforcement. Marine grade self-compacting concrete will then be placed in the repair area. The concrete mix may require high early strength or accelerators to prevent freshly placed concrete from washing away before it sets. The repair area will need to be formed up with ports for inserting the self-compacting concrete such that it flows into all areas.

The below deck repairs will require a temporary platform for access, similar to the examples shown in Figure 17. Access to the below deck repairs will be tidally constrained. The formwork will need to be temporarily supported.

Environmental controls may be required prior to jackhammering and concreting including encapsulation, protective barriers, floating booms, etc. Spillage of break out and repair materials into the sea should be prevented.

Figure 17: Example headstock and pile below deck repairs with fixed platform system. Note extent of works to be similar to that pictured with full removal and reconstruction of some elements

5.6.8 Cathodic Protection

There is currently no cathodic protection on the public wharf structure. Given the 100-year design life it is recommended to install cathodic protection. Where isolated repairs are undertaken (i.e. pile tops, headstocks, western and landward edge beams) sacrificial anodes are to be installed within the repaired areas. These anodes replace the existing corroding reinforcement “anodes”. It is noted that corrosion will continue to occur in areas that have not been repaired. The sacrificial anodes may require replacement during the design life.

For areas where extensive repairs are undertaken (i.e. cross beams, deck soffit, seaward and eastern edge beams, and topping slab), an ICCP system installation is recommended using titanium mesh anodes installed into the concrete cover. The mesh becomes the anode due to application of an external electrical current.

5.7 Architectural Features

While the scope of this report focusses on the base structure, the revitalisation of Bowen Wharf will likely include additional features such as recreational amenity (boating, fishing, water play), architectural balustrades, architectural lighting, shade, shelter and seating elements, heritage features, interpretative signage and public art. These elements have not been included however they will all add to the construction and ongoing maintenance cost.

5.8 Estimated Future Maintenance

The inspections and maintenance expected during the 100-year design life for the existing stem structures is provided in Table 12.

Table 12: OPEX inspections and maintenance – stem structures

	Year	Middle Stem	Outer Stem	Quantity Explanation
Termite box maintenance	Every 3 months	Incl	Incl	Maintenance of termite boxes and spot checks for evidence of termite infestation. Undertaken by pest control contractor using boat.
Annual Inspection	Annually	Incl	Incl	Visual inspection above and below deck by asset owner. Include nominal allowance for minor repairs / touch ups e.g. tighten bolts, replace isolated wheel guides, deck plank, damaged handrail etc.
Ad-hoc inspection following extreme event	Every 3 years	Incl	Incl	Assume one extreme event every 3 years. Visual inspection above and below deck by asset owner.
Inspection by Structural Engineer	Every 5 years (except at 25, 50, 75 years)	Incl	Incl	Visual inspection by structural engineer above and below deck.
Inspection by Structural Engineer	25, 50, 75	Incl	Incl	Detailed visual inspection and intrusive testing of concrete headstocks and timber girders. Drill testing all girders (3 drill holes per girder) and Design & Documentation of Repairs - cost approx. $500k @ todays prices.
Pile wrap	50, 75	14	29	Replace pile wrap as needed. Assume 25% of piles.
Select headstock repair volume (m3)	Every 5 years (except at 25, 50, 75 years)	0.77 m^3 on 3No. headstocks	0.79 m^3 on 9No. headstocks	As per headstock repair above. Assumes 10% of middle stem headstocks require repairs of 50% of initial repair quantity, per headstock. Assumes 20% of outer stem headstocks require 100% of initial repair quantity, per headstock as outer stem initial repair volumes are less and headstocks are typically larger.
Each headstock average repair volume (m3)	25, 50, 75	1.53	0.79	As per headstock repair above. Assumes 100% of above repair quantity, per headstock.

	Year	Middle Stem	Outer Stem	Quantity Explanation
Spans Removed	25, 75	10	15	Total number of spans to be removed for girder or corbel replacement. Spans to be removed for access to girder/corbel replacements and then reinstalled. This includes any decking, crossbeams, wheel guides, kerbs, etc within the deck areas. Allow nominal 10% of deck elements to be damaged/replaced during removal. This is additional to 10% deck replacement noted below.
Spans Removed	50	All	All	Total number of spans to be removed for girder or corbel replacement. Spans to be removed for access to girder/corbel replacements and then reinstalled. This includes any decking, crossbeams, wheel guides, kerbs, etc within the deck areas. Allow nominal 10% of deck elements to be damaged/replaced during removal. This is additional to 10% deck replacement noted below.
Girders Replaced	25, 75	13	18	Nominal 10% of girders to be replaced at 25 and 75 years. Girder hold down bolts to also be replaced (2 per girder)
Girders Replaced	50	135	178	All girders to be replaced at 50 years.
Girder hold down bolts replaced	50	264	310	Each girder to be replaced shall include all required fixings. Assume M24 bolt 900 mm long. Grade A4-70 stainless. One each end of girder.
Corbels Replaced	50	135	155	All corbels to be replaced at 50 years.
Timber cross beams	50	270	578	All cross beams to be replaced at 50 years. Assume 10 timber cross beams per span on middle stem. Assume 17 timber cross beams per span on outer stem, with no cross beams beyond bent 110 (34 spans).
Corbel Repair (Type 1)	20, 25, 30, 35, 40, 45, 70, 75, 80, 85, 90, 95	7	8	Number of corbels with vertical splits to be repaired (assumed 5%). Grade A4-70 stainless.
Corbels Repair (Type 2)	20, 25, 30, 35, 40, 45, 70, 75, 80, 85, 90, 95	7	8	Number of corbels with multidirectional splits to be repaired (assumed 5%). Grade A4-70 stainless.
Decking Replaced (m2)	Every 5 years	160	188	Deteriorated decking to be replaced. Nominal allowance based on 20% of total.
Wheel Guides Replaced (m2)	Every 5 years	175	-	Area of wheel guides that is deteriorated and needs to be replaced. Nominal allowance based on 100% of total.
New Handrail (m)	25, 50, 75	300	488	Quantity includes stems only. Handrails to be grade 316 stainless steel and compliant

	Year	Middle Stem	Outer Stem	Quantity Explanation
				with AS1428 in vertical infill style (e.g. Moddex CB30 or similar).
New lightpoles	25	Estimator to quantify	Estimator to quantify	All lightpoles replaced like-for-like
Kerb Replacement (m)	Every 5 years	60	98	Deteriorated kerb to be replaced. Nominal allowance based on 20% of total.

The inspections and maintenance for the existing public wharf structures is provided in Table 13.

Table 13: OPEX inspections and maintenance – public wharf

	Year	Public Wharf	Quantity Explanation
Annual Inspection	Annually	Incl	Visual inspection above and below deck by asset owner. Include nominal allowance for minor repairs / touch ups e.g. damaged handrail, lighting, minor concrete repairs etc.
Ad-hoc inspection following extreme event	Every 3 years	Incl	Assume one extreme event every 3 years. Visual inspection above and below deck by asset owner.
Inspection by Structural Engineer	Every 5 years (except at 25, 50, 75 years)	Incl	Visual inspection by structural engineer above and below deck. Design & Documentation of Repairs - cost approx. $50k @ todays prices.
Inspection by Structural Engineer	25, 50, 75	Incl	Detailed visual inspection and intrusive testing of concrete elements. Design & Documentation of Repairs - cost approx. $100k @ todays prices.
Inspection by Cathodic Protection / Electrical Engineer	Every 5 years	Incl	Visual inspection and testing of the ICCP system. Design and documentation of repairs (replace worn cabling, replace transformer rectifier unit every 15 years, etc)
Pile wrap	50, 75	43	Replace pile wrap as needed. Assume 25% of piles.
Select headstock repair volume (m3)	Every 5 years (except at 25, 50, 75 years)	0.47 m^3 on 27 No. headstocks	As per headstock repair above. Assumes 20% of headstocks require 100% of initial repair quantity, per headstock.
Each headstock average repair volume (m3)	25, 50, 75	0.47	As per headstock repair above. Assumes 100% of above repair quantity, per headstock.
Cross beam average repair volume (m3)	25, 50, 75	40.5m3 across 36 No. cross beams	As per cross beam repair above. Assumes 20% of cross beams require major repairs at 25-year intervals.
Deck soffit panel average repair volume (m3)	25, 50, 75	32.6m3 across 32 No. deck soffits	As per deck soffit repair above. Assumes 20% of deck soffits require major repairs at 25-year intervals.
Select edge beams	25, 50, 75	6.5m3	Assumes 20% of initial edge beam repair at 25-year intervals.

	Year	Public Wharf	Quantity Explanation
Deck topping slab crack repair	25, 50, 75	467m	Crack repairs on deck top surface. Assume crack length of 1m per m2 of deck on 50% of deck area.
New Handrail (m)	25, 50, 75	200	Handrails to be grade 316 stainless steel and compliant with AS1428 in vertical infill style (e.g. Moddex CB30 or similar).
New lightpoles	25	Estimator to quantify	All lightpoles replaced like-for-like

5.9 Bill of Quantities

A technical memo including quantities the repair works and anticipated future maintenance has been prepared to support cost estimation.

5.10 Cost Estimate

A refurbishment concept cost estimate has been prepared by specialist cost and quantity consultant Rider Levett Bucknall (RLB). The cost estimate has been derived based on expected refurbishment, replacement and ongoing maintenance activities associated with prolonging the life of the existing structure. The cost estimate includes CAPEX and OPEX costs, with major OPEX capital replacement tranches undertaken in years 26, 51 and 76 due to ongoing deterioration of the refurbished structures. Refer to the cost estimate for details.

6 Refurbishment Concept Risk & Opportunities

Table 14 below presents key risks and opportunities identified and recommended mitigations for consideration.

Table 14: Key risks & opportunities

Item	Risk / Opportunity Description	Risk / Opportunity	Recommended Mitigation	Post-Mitigation Residual Risk
01	Risk of vehicles overloading the wharf and potential for failure. This could include unauthorised vehicle, overloaded vehicle, vehicle not following designated path on the wharf, vehicle driving too fast on wharf, etc	High Risk	Asset owner to impose strict vehicle controls considering allowable loads. This is an existing risk that is unchanged by the proposed program of works.	Medium Risk
02	No code compliant vehicle barriers are currently provided or proposed for the concept design. There is a risk that errant vehicles may fall off wharf.	High Risk	This is an existing risk that is unchanged by the proposed program of works. Asset owner to manage through vehicle controls such as low speed environment, drivers who are familiar with the structure, wheel guides, kerbs etc. Alternatively, barriers could be installed which would increase refurbishment costs (quite significantly if code compliant barriers are required).	Medium Risk (Low Risk if barriers are installed)
03	Lateral load capacity of structure is unknown.	Medium Risk	Future design stages to consider lateral loads on structure (wind, wave, current, vessel impact, seismic, etc). Contingency allowance to be included in cost estimate.	Low Risk
04	There is a risk of overtopping of the structure due to wave action and/or storm surge, particularly with sea level rise.	Medium Risk	It is not practical to raise the existing stem or public wharf structures. Note landside areas are similar level to the existing structure.	Medium Risk
05	Condition of piles below the seabed is unknown and cannot easily be verified. Corrosion of reinforcement requires oxygen and therefore progresses at a slower rate below the seabed. This risk increases over time.	Low Risk	Repair of piles below seabed not feasible and installation of new piles would be required if risk eventuates (i.e.	Low Risk

Item	Risk / Opportunity Description	Risk / Opportunity	Recommended Mitigation	Post-Mitigation Residual Risk
			refurbishment option is likely to be non-viable and construction of new stem and public wharf structures may be required). Review and test pile condition of any redundant/demolished piles in advance of commencing refurbishment works.	
06	Risk of ongoing maintenance costs and repair quantities being underestimated. The Arup testing showed that chloride levels are high in non-defect locations, hence high risk of corrosion, which will likely lead to requirement for concrete repairs in the future in areas which are not currently exhibiting signs of deterioration.	High Risk	SCMC has included an assumed allowance for defect growth in this study. The asset owner will need to place significant effort on monitoring deterioration, planning and budgeting for ongoing future maintenance and repair.	High Risk
07	Hazardous working conditions below deck of the public wharf. Poor access if there is an accident. Tidally constrained with limited headroom and subject to wave action. Deteriorated concrete segments may fall onto workers or the access platform during repair works.	High Risk	Full removal of the public wharf deck to provide access from above. This reduces the extent of existing fabric which can be retained.	Low Risk
08	There is a risk that the refurbishment works may not be able to maintain as much of the existing fabric as anticipated. For example, when chasing out deteriorated concrete, the extent to be removed may require full replacement of the element. In which case the original intent of retaining original fabric is lost locally.	Medium Risk	There are no mitigations for this risk other than the contractor exercising due skill and care. Where encountered, deteriorated concrete and reinforcement will need to be replaced.	Medium Risk
09	Newly installed girders on the coal pier stem could be re-used on the middle and outer stems if the coal pier stem is demolished.	Opportunity		

7 Refurbishment vs New Structure Comparison

7.1 Purpose

The purpose of this comparison is to provide a broad understanding of the differences between the refurbishment concept and a new structure concept and highlight key advantages, disadvantages, risks and opportunities to inform the next stage of design. It is expected that a multi-criteria analysis will need to be undertaken during the next stage of design to determine the preferred option, noting there are several opportunities described herein which could be explored further.

This comparison has been undertaken at a high level with commentary on the following areas:

- Capital Cost / Constructability
- Durability / Maintenance
- Resilience
- Commercial Functionality
- Public Amenity
- Heritage
- Environment / Sustainability
- Accessibility

7.2 Concept Description

A refurbished structure (such as the Refurbishment Concept described in this report) could achieve a basic functionality as recommended by Australian Standards. However, a new structure provides an opportunity for enhanced functionality which refurbishment may not allow. This could include wide open public walking areas or infrastructure to support recreational and commercial boating for example.

Modern design codes and factors could be adopted and met with the refurbished design including Australian Standard factors of safety for pedestrian and vehicle loading (with the possible exception of vehicle guardrails).

Structural resilience against environmental loads (seismic, wind, wave) has not been assessed. If future assessment demonstrates the structural resilience is not in accordance with modern codes, the vulnerability of the refurbished structure and associated risk profile may be deemed unacceptable by the asset owner. This will need to be considered as the design progresses and any deficiencies may lead to creep in cost and extent of strengthening works required. It is considered likely that the public wharf will be able to resist imposed lateral loads as it was originally designed for railway cars and trucks as well as berthing and mooring of ships. However there is a risk that the stem structures cannot withstand the imposed lateral loads from modern design codes and more piling or bracing is required which may also impact on heritage due to changes in structural form. This is considered to be a low risk and it is recommended that this risk is captured through contingency allowance in the cost estimates.

Capital and maintenance costs, as well as resilience, durability and heritage will be significantly different between the refurbishment and new structure concepts and this is described in more detail below.

7.2.1 Refurbishment Concept Description

The refurbishment concept is as described in Section 5 of this report and shown in the concept sketches in Appendix B. In summary the refurbishment concept repairs the existing middle stem, outer stem and public wharf with the aim of extending the service life for a further 100 years. This option includes regular replacement of timber elements and extensive repair of concrete elements both initially and as part of ongoing maintenance.

It is noted that concrete elements in the marine environment typically have a design life of 50 years. Therefore, extending the life of a structure that is already 100 years old by a further 100 years is considered to be extremely challenging, even with the installation of cathodic protection (where possible) to minimise corrosion in repaired areas. **As long as the piles (existing piles below seabed and new pile wrapping system above seabed) remain capable of supporting the structure, the concrete and timber elements can be repaired / replaced indefinitely (assuming no budgetary constraints). The original form of the structure will remain, but the original fabric (i.e. the concrete elements) is estimated to be repaired ~1.5 times over during the 100 years. The exact quantum of repair over the life of the structure is impossible to predict with accuracy and should be considered an estimate only with suitable risk and contingency allowances.**

7.2.2 New Structure Concept Description

The new structure is as per the Jacobs design documented in 'W242800-0000-CM-RPT-0001 Concept Design Report Rev B' for Concept Option 3 which features a similar size wharf to the existing public wharf.

The new structure concept replaces the existing middle and outer stems and public wharf on the same alignment but with an intermediate widened section. current stem alignment. The new structure concept includes some architectural / heritage features.

The structure includes driven steel piles with precast headstocks and simply supported steel girders. Precast deck planks will sit on top of the steel girders with a grouted shear stud connection. The new structure concept features a deck level of +5.5 mCD which is 1 m higher than existing.

The design life is 50 years which is less than the refurbishment concept however the design could achieve the 100 years design life through major refurbishment beyond 50 years and / or through appropriate design measures prior to construction such as denso pile wrapping, concrete sealants, cathodic protection and use of FRP. Design loads are similar to the refurbishment concept. A typical cross section for the new structure is shown in Figure 18.

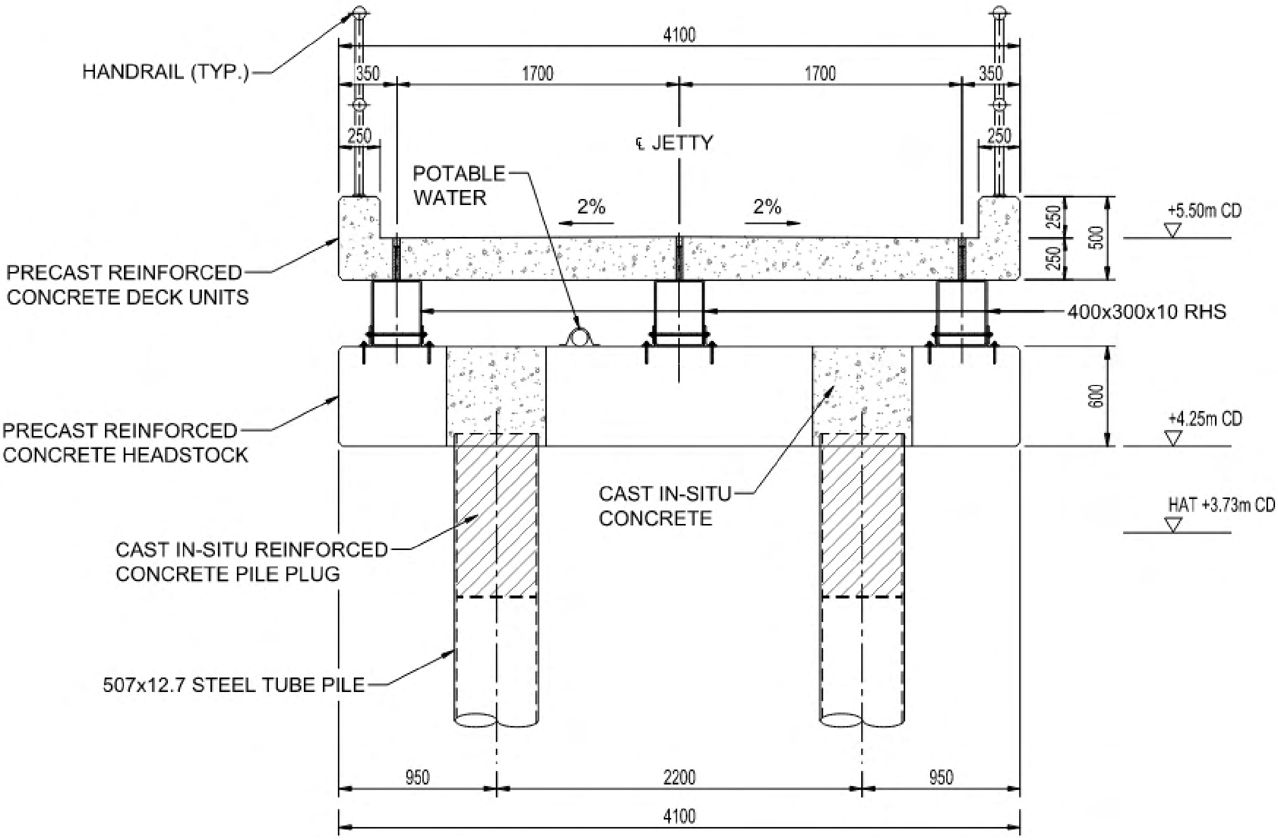


Figure 18: New structure typical jetty cross section (new wharf similar)

7.3 Capital Cost / Constructability

Initial capital costs are available to allow comparison. The constructability of each option has also been considered.

Table 15: Capital Cost Comparison

	Refurbishment	New Structure
Advantages	• Limited demolition costs • Stem structures can be constructed predominantly from above without marine plant • Public access could be maintained for large portions of the construction works	• Likely to have lower capital cost (including demolition) (based on available cost estimates) • Precast construction maximises off-site fabrication and improves concrete quality.
Disadvantages	• Difficult access and working conditions below the public wharf deck. • Likely to have higher capital cost (based on available cost estimates)	• Significant demolition costs • Likely requirement for significant floating plant for demolition, installation of piles and other structural elements. • Piles and precast concrete don't support local fabrication and workforce.
Opportunities	• Ongoing repair work could provide opportunities for local tradesmen. • Demolition and replacement of the public wharf deck (i.e. cross beams, edge beams and deck slab) may provide improved access for repair and construction while retaining existing piles and headstocks.	• If the new structure is built on a separate alignment, the existing structure could be left as-is and made safe (i.e. prevent access). This would also reduce demolition costs.
Risks	• Extent of repairs may grow more than anticipated	• Nil

Based on the above it is anticipated that the new structure option will be preferred for both capital cost and constructability.

7.4 Durability / Maintenance

The design life for the new structure concept is 50 years which is less than the refurbishment concept. Additional measures may be required to provide a 100-year design life, e.g. corrosion protection for steel and concrete, pile denso wrapping as well as increased maintenance.

Table 16: Durability / Maintenance Comparison

	Refurbishment	New Structure
Advantages	• Maintenance of the timber stems is relatively low cost and can be undertaken from above, without significant disruption to pedestrian access.	• A new structure is inherently more durable, at least for the first 50 years. • Reduced ongoing maintenance, particularly in the first 50 years. • As the structure is higher up it is less prone to being submerged and splashed and as such the environmental conditions are better than a structure lower down.
Disadvantages	• Maintenance costs are expected to be greater, given the structure is already 100 years old.	• The proposed steel beams supporting the precast may require frequent repainting in the medium to long term. It is recommended

	Refurbishment	New Structure
	• The maintenance costs for concrete elements, which are already 100 years old, are difficult to predict. It is likely that some repaired areas will need to be re-repaired over the 100-year design life. • As the structure is more prone to being submerged and splashed, the timber and concrete also experience worse environmental conditions which may reduce durability. • Tidal windows for repairs to below deck elements will reduce over time with sea level rise, making repairs more difficult. • Timber elements can be subject to hidden deterioration i.e. termite activity, internal fungal rot, etc.	that the durability / maintenance requirement for these elements be further considered during the next phase of design.
Opportunities	• Nil	• Using a thicker precast concrete deck in lieu of steel beams plus precast will likely reduce maintenance effort (frequent repainting).
Risks	• Condition of piles below seabed is unknown and cannot be verified easily. This is a low risk but increases over time. Existing piles which are demolished could be extracted and inspected to provide an indication of typical pile condition below seabed however no other practical mitigations exist.	• New structure concept needs to be updated for 100-year design life. • If material selection, specification and construction is not adequately tailored to the site, the 100-year design life and to achieve a very high quality, then there is a risk of increasing maintenance requirements in the medium to long term.

Based on the above it is anticipated that the new structure option will be preferred.

7.5 Resilience

Resilience describes the ability of a structure to continue functioning as normal following an event such as sea level rise (SLR), cyclones, storm surge, wave action, accidental impact (e.g. vessel impact) or overloading. The tidal levels for the stems and public wharf are shown in Figure 19 and Figure 20 below. For comparison the tidal levels relative to the new structure are shown in Figure 18 above.

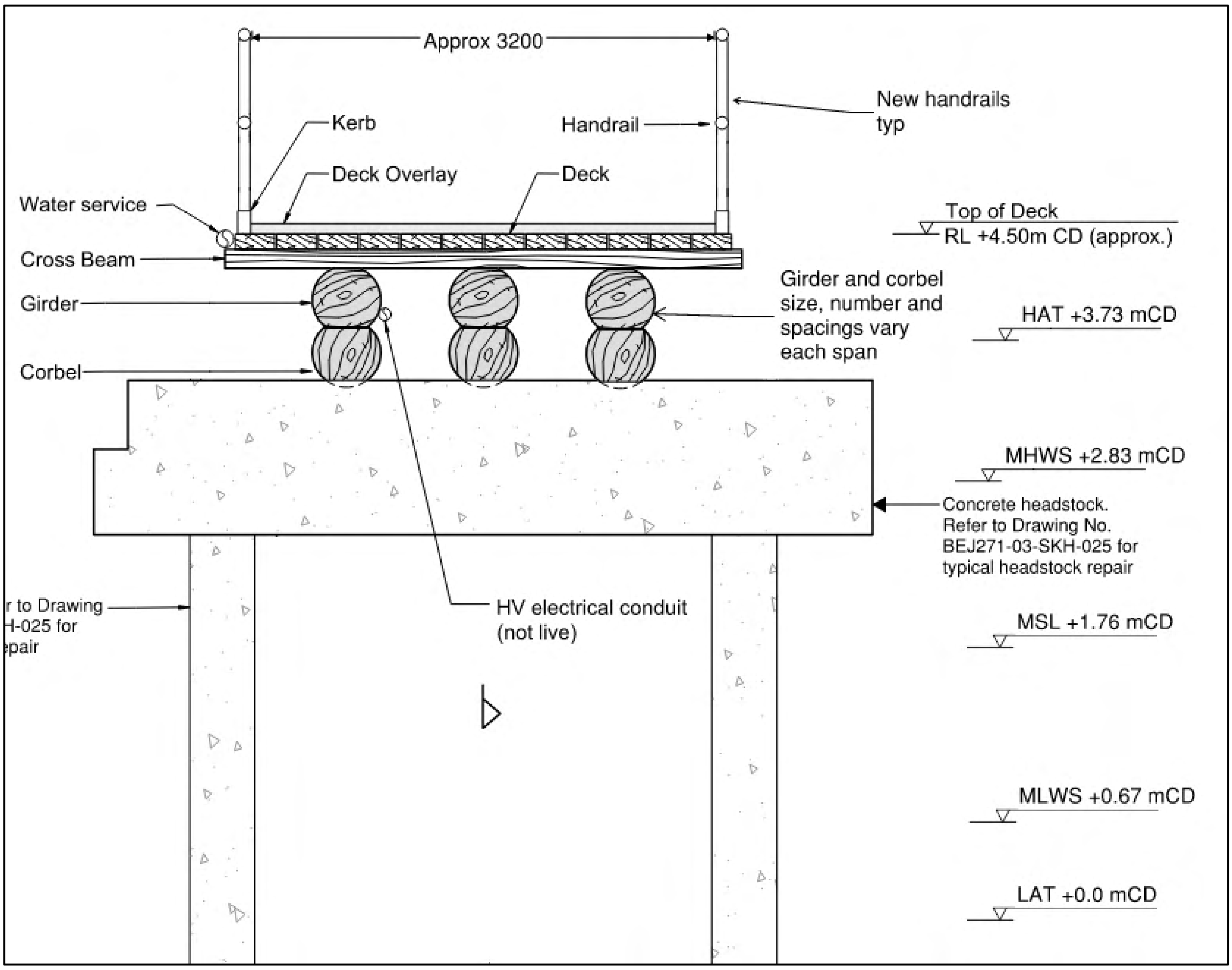


Figure 19: Stem structure with tidal levels (approx.)

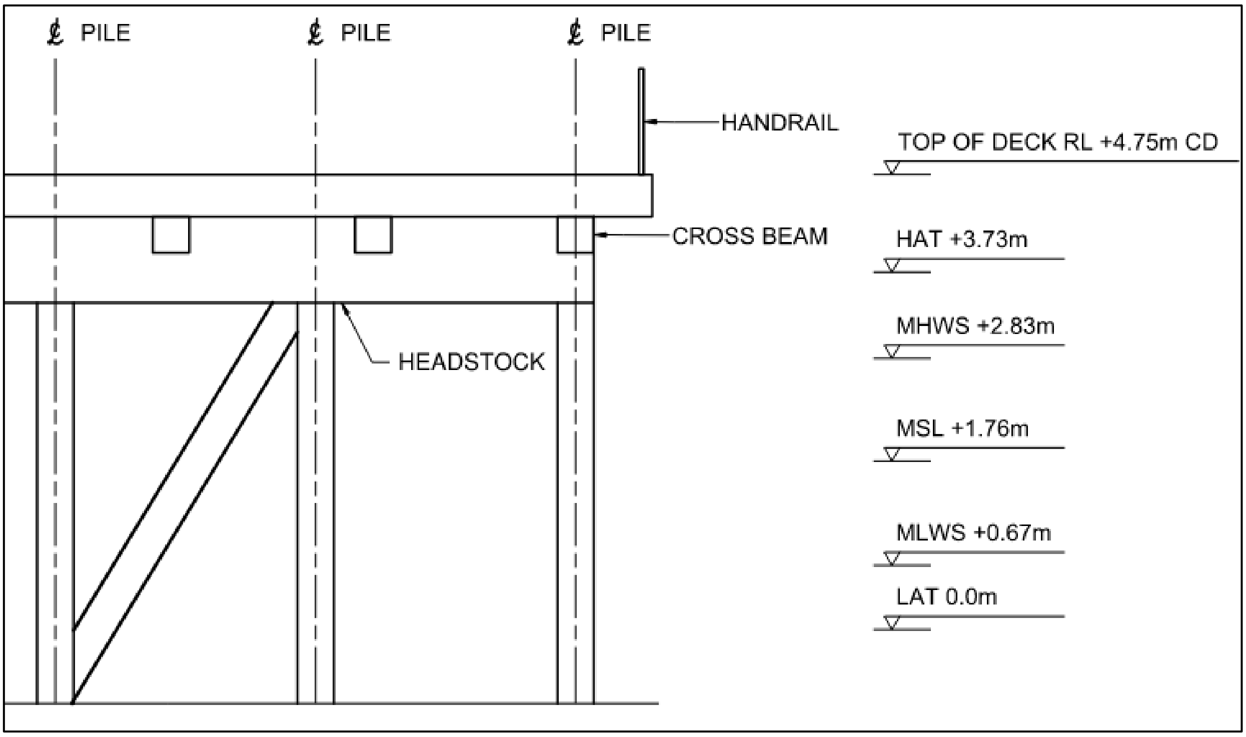


Figure 20: Public wharf structure with tidal levels (approx.)

Table 17: Resilience Comparison

	Refurbishment	New Structure
Advantages	• The existing timber girders and deck have proven to be relatively resilient against overloading. There is some ability to redistribute vertical loads within the structure if one element is deteriorated.	• Raising deck levels by 1m provides resilience against overtopping due to sea level rise, storm surge and waves. • The new structure can be designed to be resilient to overloading and vessel impact.
Disadvantages	• The existing deck level of approximately +4.5m CD is 1m lower than the proposed new structure deck level. • The HAT design water level table for 2050 (incl +0.4m SLR) is 4.16m CD, only slightly below deck level. Wave splash/spray above deck level will become more commonplace with SLR and the deck will be submerged at HAT by the year 2100, with 20 years of design life still remaining. • Higher water levels due to sea level rise will lead to increased corrosion and maintenance costs. • Waves of 0.2 to 0.3 m can be expected to occur during strong SE winds. The 1-year ARI wave height is 0.7 m. The 100-year ARI wave height is almost 2 m and the 500-year ARI wave height is almost 3 m. During extreme wave events the structure is likely to be submerged under 'green' water and will need to be closed for safety.	• The new structure will be subject to wave impact during extreme events and will need to be designed accordingly.
Opportunities	• Raising the existing deck level while retaining as much of the existing structure (e.g. by installing a tiered headstock) can technically be done but has many associated disadvantages (such as impact to heritage value and visual amenity, more structure to maintain, increased surface area for wave impact loads, higher load center for pile design actions) and is therefore not recommended.	• Removal of the steel beams will raise the concrete headstocks even higher out of the water.
Risks	• Both the foreshore area and the wharf are at similar level with potential for flooding during extreme events. • Limited information available on existing pile toe levels to inform lateral load capacity checks. • Resilience of the structure to extreme wave loads will need to be calculated so the risk is better understood. • Resilience of the structure to vessel impact will need to be calculated so the risk is better understood.	• While the new structure may be resilient to storm surge and sea level rise, the existing foreshore remains at a lower level with potential for flooding during extreme events.

Based on the above it is anticipated that the new structure option will be preferred.

7.6 Commercial Functionality

Bowen Wharf is the home port for tug vessels which operate at the Abbot Point coal export terminal. At present there are no alternative facilities available to service these tug vessels. The vessels berth at the Tug Wharf and service vehicles including small cranes, rubbish trucks and fuel trucks access the Tug Wharf via the middle stem and coal pier stem. Therefore vehicular access along the middle stem and coal pier stem will need be maintained while this commercial activity is ongoing.

Table 18: Commercial Activities Comparison

	Refurbishment	New Structure
Advantages	• Proposed vertical design loads are less than current service loads particularly along the middle stem, however the proposed refurbishment will exceed the design load and can accommodate existing commercial vehicle loading. • Existing structure is retained, therefore no change to existing commercial operations. • Minimal impact during construction (as demonstrated by Bowen Wharf Repair Project).	• Proposed vertical design loads are less than current service loads particularly along the middle stem, however the new structure can be designed to accommodate commercial vehicle loading.
Disadvantages	• Nil	• Potential impact to existing operations during construction.
Opportunities	• When commercial activities cease, timber elements in good condition could be re-used on the middle and outer stems.	• New structure could be built on a new alignment with no impact to existing middle stem or coal pier stem. This would result in additional maintenance (more marine structure to maintain).
Risks	• Existing structure is less resilient, therefore there is greater risk of damage during an extreme event (e.g. cyclone) which could prevent commercial activities for a period of time.	• Building a new structure which also needs to accommodate commercial vehicles (fuel trucks, cranes, etc) for a period of time may compromise public amenity, or result in more structure than actually required with an associated maintenance burden.

Based on the above it is anticipated that the new structure option will be preferred.

7.7 Public Amenity

In addition to the commercial activities mentioned in the previous section, Bowen Wharf also provides recreational value to the community. The middle stem, outer stem and public wharf structures are used by the public for recreational activities such as:

- Fishing
- Spotting marine life / over water experience
- Swimming (illegally)
- Strolling with family, dog walking, taking photos

- Sitting to watch the sun rise / set
- Exercise, running, cycling
- Eating
- Boating & powerboat race spectating

Other nearby community facilities along Santa Barbara Parade include playground, skate park, swimming and leisure centre, public toilets, Bowen Water Park, BBQ's, shelters and picnic facilities, the Catalina Commemorative area and War Memorial and the Port Denison Sailing Club. It is important that the design of the wharf revitalisation continues to provide users with recreational amenity while also integrating with the design character, quality and materiality of recently upgraded foreshore works in order to contribute to the appeal of the Bowen foreshore precinct as a whole.

Table 19: Public Amenity Comparison

	Refurbishment	New Structure
Advantages	• Refurbishment of timber decking on the stems and removal of marine ply overlays will provide a more rustic and charming experience for the public.	• New structure features local widening for shaded rest areas. • Less maintenance over the design life therefore reduced impact on public amenity due to repair works (both visually and physically).
Disadvantages	• Existing structure does not include rest areas, shade structures, etc. • Ongoing maintenance and repairs may impact on public amenity (both visually and physically). • Pile encapsulation requires cleaning off all marine growth on the structure which may reduce fishing amenity temporarily.	• Demolition of existing structures including marine growth on the structure may reduce fishing amenity temporarily. • Demolition of existing structures will reduce public amenity during construction.
Opportunities	• Addition of vessel berthing facilities to support eco-tourism. • Addition of architectural features to improve public amenity such as local widenings for shaded rest areas, viewing platforms, etc.	• Addition of vessel berthing facilities to support eco-tourism. • New structure could be built on a new alignment allowing public access to the existing structure while the new structure is being constructed.
Risks	• Some headstocks on the outer stem extend beyond the extent of deck and locals sometimes climb over the handrails and stand on the headstocks where there are no handrails to fish. This is a safety risk.	• Nil

Based on the above it is anticipated that the new structure option will be preferred, although the refurbishment option could include additional architectural features to improve public amenity.

7.8 Heritage

Bowen Wharf has evolved significantly over the past 150 years. There is opportunity for the design of the replacement wharf to reflect or be influenced by its historical form, detailing, materiality and stories. The following brief historical timeline is derived from the Bowen Wharf Conservation Management Plan, dated 30 May 2018 by Niche Environment and Heritage.

Table 20: Bowen Wharf Historical Timeline

Period	Description
1865-67s	Timber jetty built (855m long and 4.2m wide with a 11.7 x 7.8m wharf head), weatherboard shed at end, bathing house midpoint, tracks to transfer cargo (meat, sugar, coal), cranes or derricks.
Late 1800s	Borer infestations, reconstructions and enlargements for repairs and to accommodate larger ships.
1911 – 1915	Head extended by 69m and railway approach constructed alongside stem.
1922 – 1926	Coal pier constructed – joining the jetty at midpoint creating the distinctive ‘Y’ junction that exists today. Concrete and timber decking, electric crane. This section reflects some of the earliest use of reinforced concrete in a marine infrastructure in QLD.
1957	Stone causeway of inner sections was constructed. Old jetty was widened.
1958	Major cyclone struck Bowen, destroying the jetty from the stone approach seawards for 325m. Approximately 60% of concrete roadway and the old jetty head were damaged. Rather than reconstruct the demolished jetty stem, decking was laid between the rails on the concrete railway approach. This created a new roadway, shared with the railway line
1960s	Lost the sugarcane trade to Proserpine, meat works turned to road transport, Bowen Jetty now solely used for coal market.
1970s	Travelling crane removed to make way for more modern bulk coal loading
1980s	Industrial use declines except for use as berths for tugs. Abbot Point Coal Terminal, to the north of Bowen opened for the export of coal from the northern Bowen Basin.
1988	The original jetty head was demolished leaving only the concrete section dating from 1911.

Most timber components of the jetty have been replaced during major overhauls and routine maintenance conducted throughout the life of the jetty, particularly between the 1930s and 1950s. The earliest known extant fabric is the reinforced concrete jetty head (1911 - 1926) and the concrete piles and headstocks of the railway approach (1915). However, the size, overall form and location of the jetty reflect the original role and aspirations of a town which, in 1861, looked set to become North Queensland's foremost port.

The required heritage management approach for each grading/category of heritage significance is provided in Table 21, including elements which fall into that grading category. This table is extracted from the 264408-00-REP-003 Options Analysis Report (Rev 1) by Arup.

Table 21: Heritage Grading (extracted from 264408-00-REP-003 Options Analysis Report (Rev 1) by Arup)

Grading	Justification	Management
Exceptional (Piles, bracing, headstocks, corbels, girders, deck and rails)	• Elements that demonstrate critical periods in the evolution of the site and are reasonably intact or are rare evidence of their period; • Characteristic elements that are good or rare examples of importance in understanding the evolution of bridges in the region; • Elements that are distinctive in Queensland for their historical; aesthetic, creative or technical value.	• Retain, conserve and maintain in accordance with the Burra Charter. • Intervention should be minimised, and adaptions should be reversible and temporary in nature. • Adaptation should only occur if essential for the ongoing protection or preservation of the building, feature and/or overall complex. • Any proposed change must be preceded by careful

Grading	Justification	Management
		consideration, assessment and recording.
Considerable (Rail stop blocks and mooring bollards)	• Elements that are important for demonstrating critical periods in the evolution of the site but are less intact; • Characteristic elements that are good examples of importance in understanding the evolution of bridges in the region but are less intact; • Elements that are distinctive for their historical, aesthetic, creative or technical value; • Elements that are likely to be crucial for the attachment of the local community to the site.	• Maintain, conserve, restore, reconstruct and adapt or otherwise act in accordance with the Burra Charter. • Intervention should be minimised. • Removal in part or full may be acceptable if no alternative option is available, however there would need to be a compelling reason for removal of heritage features (no prudent or feasible alternative).available, however there would need to be a compelling reason for removal of heritage features (no prudent or feasible alternative).
Some (Timber handrail and fender piles)	• Elements relating to less important periods of evolution of the site that are distinctive and reasonably intact; • Characteristic elements that are less intact and where better examples of their type exist elsewhere; • Elements that are likely to be valued by the community but are incidental to the evolution of the site.	• Maintain, conserve, restore, reconstruct and adapt or otherwise act in accordance with the Burra Charter wherever possible. • Could be intervened with in a sensitive and controlled manner. • Alterations and adaptation generally acceptable but should be sympathetic to the surrounding heritage features and values.
No significance (Steel handrail, navigation aids, and tug mooring equipment)	• Does not have heritage value.	• Need not be conserved. • Intervention or new work is appropriate, providing that no nearby areas of higher cultural significance are compromised. • Retain, adapt, remove or modify as required.
Intrusive (Non-original elements)	• Intrusive to the overall heritage values of the place.	• Should be removed. • Original form reconstructed, or new compatible adaptation made.

Table 22 compares the heritage impacts of the refurbishment concept with the new structure concept. It is recommended that a detailed assessment by a specialist heritage consultant be undertaken in the next stage of design.

Table 22: Heritage Comparison

	Refurbishment	New Structure
Advantages	• Repair and replacement of heritage elements like-for-like where necessary is preferred from a heritage perspective.	• Nil
Disadvantages	• Some impacts will be incurred due to loss of some original fabric where it has failed, but this option allows the structure to be retained with original fabric where possible. • Existing piles which are 'exceptional' heritage significance will be covered by the pile wrapping system. The pile wrapping system will also change the shape of the pile from square to round which may impact on visual amenity.	• Demolition of the existing structure will result in total loss of its heritage values and will have irreversible negative impacts.
Opportunities	•	• Heritage elements, historical photos, etc can be built into the new structure to tell the history of the structure. • There may be an opportunity to retain the existing heritage significance by constructing the new structure on a new alignment and allowing the existing structures to deteriorate. Access to the existing structures would need to be prevented. Public safety would need to be considered.
Risks	• Nil	• Nil

Based on the above it is anticipated that the refurbishment option will be preferred.

7.9 Environment / Sustainability

This section describes the impact on the environment and sustainability of each of the concept options.

Table 23: Environment / Sustainability Comparison

	Refurbishment	New Structure
Advantages	• Minimise use of construction materials by extending life of asset (i.e. avoids new construction). • Timber is a sustainable resource.	• Potential to re-use / recycle demolished heavy timbers on other projects. • New materials and constrction practices provide longer term durability / reduced ongoing maintenance and repair works requirement.
Disadvantages	• Controls required to prevent spillage to the marine environment during concrete repairs. • Existing marine life / vegetation on piles will need to be removed for pile encapsulation.	• Replacement will disturb the status quo for current marine life / vegetation. • Carbon footprint associated with the new suspended structures is produced. • Existing marine life / vegetation impacted by pile demolition.

	Refurbishment	New Structure
	• Chemicals used in timber preservation are toxic.	
Opportunities	• Nil	• Nil
Risks	• Nil	• Nil

Based on the above it is difficult to assume a preferred option, hence scored as even at the time of writing

7.10 Accessibility

This section compares the accessibility (DDA compliance) of each of the concept options.

Table 24: Accessibility Comparison

	Refurbishment	New Structure
Advantages	• Nil	• New structure includes rest areas and is wide enough for wheelchairs to pass. • Concrete deck is DDA compliant.
Disadvantages	• Difficult to ensure DDA compliance with timber decking (due to drying shrinkage and warping / deterioration of timber over time). • No existing rest areas. • Middle stem pedestrian area is 1.2m wide. No passing zones currently available for wheelchairs.	• Nil
Opportunities	• Install local widenings for wheelchair passing zones and rest areas.	• Nil
Risks	• Nil	• Nil

Based on the above it is anticipated that the new structure will be preferred.

8 Summary

8.1 Condition Inspection Findings

SCMC undertook a high-level visual targeted condition inspection on the 29th August 2023. The visual inspection scope included the concrete elements on Middle Stem, Outer Stem and Public Wharf, comparing observations to the 2018 WSCAM inspection to assess where the condition has changed.

The inspection focussed on elements rated in good condition in 2018 to allow easier identification of where the condition has changed in the intervening five years. Only a proportion of elements were inspected. The objective was to gain a broad understanding of the current condition to allow estimation of growth in deterioration since 2018. In summary, while the rate of deterioration growth varied, the site visit provided a broad understanding of the current condition to allow estimation of growth in deterioration since 2018. The refurbishment concept design is described in detail in Section 5 however at a high level, considering the current condition and rate of deterioration observed the following strategy is recommended for concrete elements including estimated repair quantum as a percentage of the element volume:

- Piles (underwater cracking evident on almost all piles) – encapsulate all piles using pile wrapping system
    - 100% of piles for initial refurbishment
    - re-encapsulate approx. 50% of piles as maintenance
- Headstocks (localized defects) – patch repair all headstocks
    - approx. 30% for initial refurbishment
    - approx. 150% as ongoing maintenance
- Cross beams (widespread major defects) – replace all concrete and deteriorated reinforcement in public wharf cross beams
    - 100% for initial refurbishment
    - approx. 60% as ongoing maintenance
- Edge beams (widespread major defects) – replace more than half of all concrete and deteriorated reinforcement in public wharf edge beams
    - 100% for initial refurbishment
    - approx. 60% as ongoing maintenance
- Deck soffit (widespread major defects) – replace all concrete and deteriorated reinforcement
    - approx. 70% for initial refurbishment (represents full soffit area to 150mm depth)
    - approx. 15% as ongoing maintenance (represents 60% of soffit area to 150mm depth)
- Topping slab (widespread cracking and delamination) – remove and replace with new topping slab
    - 100% for initial refurbishment
    - Crack repairs as ongoing maintenance.

8.2 Refurbishment Concept

Through discussions with NQBP, the scope of this refurbishment concept has been defined as follows:

- Rehabilitation of the existing Middle Stem and Outer Stem (a proactive rehabilitation strategy with early spending to minimise ongoing maintenance costs, hence different to the KBR concept, which deferred spending for as long as possible). Findings from the site visit incorporated. Ongoing maintenance allowed for as still required for an older existing structure.

- Rehabilitation of the existing Public Wharf (demolition/rebuild at the outset or during the design life to be avoided). Same rehabilitation strategy as the stems. Findings from the site visit incorporated. Ongoing maintenance allowed for as still required for an older existing structure.

- Scoping of minor demolition along the Middle Stem and Outer Stem. Demolition of the Coal Pier Stem and Tug Wharf is excluded (by others). Note that as demolition of the Coal Pier Stem may occur at a later date, it is assumed that Coal Pier Stem girders are not re-used on the Middle and Outer Stems.

The refurbishment concept has been prepared based on previous available data (inspection, design and construction documentation from KBR, Arup, Jacobs and Wisely). The assessment relies on previous reports and analysis undertaken by others and structural analysis is excluded from scope. The findings from a high-level targeted site inspection are incorporated into the concept design.

The proposed rehabilitation works are presented in the concept sketches in Appendix B with repairs for the stems and public wharf summarised below.

The design life of the refurbishment works is 100 years. The proposed maintenance/repair strategy for the existing structures is as follows:

- undertake refurbishment of existing structures to repair observed defects.
- significant repairs occur at the 25-year, 50-year and 75-year mark to allow ongoing use with minor maintenance activities occurring at shorter intervals.

As the rate of deterioration is unknown, monitoring/regular inspections are essential to capture any early warning signs that the structure needs attention.

A technical memo including quantities the repair works and anticipated future maintenance has been prepared to support cost estimation.

A refurbishment concept cost estimate has been prepared by specialist cost and quantity consultant Rider Levett Bucknall (RLB). The cost estimate has been derived based on expected refurbishment, replacement and ongoing maintenance activities associated with prolonging the life of the existing structure. The cost estimate includes CAPEX and OPEX costs, with major OPEX repair tranches undertaken in years 26, 51 and 76 due to ongoing deterioration of the refurbished structures. Refer to the cost estimate for details.

A refurbished structure (such as the Refurbishment Concept described in this report) could achieve a basic functionality as recommended by Australian Standards. However, a new structure provides an opportunity for enhanced functionality which refurbishment may not allow. This could include wide open public walking areas or infrastructure to support recreational and commercial boating for example.

Modern design codes and factors could be adopted and met with the refurbished design including Australian Standard factors of safety for pedestrian and vehicle loading (with the possible exception of vehicle guardrails).

Structural resilience against environmental loads (seismic, wind, wave) has not been assessed. If future assessment demonstrates the structural resilience is not in accordance with modern codes, the vulnerability of the refurbished structure and associated risk profile may be deemed unacceptable by the asset owner. This will need to be considered as the design progresses and any deficiencies may lead to creep in cost and extent of strengthening works required. It is considered likely that the public wharf will be able to resist imposed lateral loads as it was originally designed for railway cars and trucks as well as berthing and mooring of ships. However there is a risk that the stem structures cannot withstand the imposed lateral loads from modern design codes and more piling or bracing is required which may also impact on heritage due to changes in structural form. This is considered to be a low risk and it is recommended that this risk is captured through contingency allowance in the cost estimates.

The following are open risks that require consideration/mitigation at detailed design which are associated with refurbishment and are not present through adoption of a new structure:

- Structural resilience against environmental loads (seismic, wind, wave) need to be considered as the design progresses and may require additional strengthening works or acceptance of reduced resilience. Note there is limited information available on existing pile toe levels to inform lateral load capacity checks. Contingency allowance to be included in the cost estimate.
- Traffic barriers to prevent errant vehicles falling off the stems / wharf could be installed which would increase refurbishment costs (quite significantly if code compliant barriers are required).

- There is a risk of overtopping of the structure due to wave action and/or storm surge, particularly with sea level rise. It is not practical to raise the existing structure to mitigate this risk. Over the course of a 50 year or 100 year design life, this means potential closure periods for clean up and minor maintenance which is not required for a new structure.
- Condition of piles below seabed is unknown and cannot be verified easily. This is a low risk but increases over time. Existing piles which are redundant/demolished could be extracted and inspected to provide an indication of typical pile condition below seabed in advance of commencing the refurbishment works, however no other practical mitigations exist. Repair of piles below seabed not feasible and installation of new piles would be required if risk eventuates (i.e. refurbishment option is likely to be non-viable and construction of new stem and public wharf structures may be required).
- Risk of ongoing maintenance costs and repair quantities being underestimated. The Arup testing showed that chloride levels are high in non-defect locations, hence high risk of corrosion, which will likely lead to requirement for concrete repairs in future in areas which are not currently exhibiting signs of deterioration. Note that as long as the piles (existing piles below seabed and new pile wrapping system above seabed) remain capable of supporting the structure, the concrete and timber elements can be repaired / replaced indefinitely (assuming no budgetary constraints). The original form of the structure will remain, but the original fabric (i.e. the concrete elements) is estimated to be repaired ~1.5 times over during the 100 years. The exact quantum of repair over the life of the structure is impossible to predict with accuracy and should be considered an estimate only with suitable risk and contingency allowances.
- The existing structure is less resilient than the new structure, therefore there is greater risk of damage during an extreme event (e.g. cyclone) which could prevent commercial activities for a period of time.
- Some headstocks on the outer stem extend beyond the extent of deck and locals sometimes climb over the handrails and stand on the headstocks where there are no handrails to fish. This is a safety risk.
- Hazardous working conditions below deck of the public wharf. Below deck is tidally constrained with limited headroom and subject to wave action with poor access for extraction if there is an accident. Deteriorated concrete segments may fall onto workers or the access platform during repair works. This is a safety and constructability risk.

8.3 Refurbishment vs New Structure Comparison

The purpose of this comparison is to provide a broad understanding of the differences between the refurbishment concept and a new structure concept and highlight key advantages, disadvantages, risks and opportunities to inform the next stage of design. It is expected that a multi-criteria analysis will be undertaken during the next stage of design to determine the preferred option, noting there are several opportunities described herein which could be explored further.

Based on the assessment undertaken in this report a high-level summary comparison table for the various assessed comparison categories is provided in Table 25.

Table 25: Comparison Summary

Category	Anticipated Preferred Option	Notes
Capital Cost	**New Structure**	• Refurbishment likely to have higher capital cost. • If the new structure is built on a separate alignment, the existing structure could be left as-is and made safe (i.e. prevent access). This would significantly reduce demolition costs associated with the new structure concept.
Constructability	**New Structure**	• Difficult access and working conditions below the public wharf deck for refurbishment option. • The new structure includes precast construction which maximises off-site fabrication and improves concrete quality.

Category	Anticipated Preferred Option	Notes
Durability / Maintenance	**New Structure**	• A new structure is inherently more durable with reduced ongoing maintenance, particularly in the first 50 years. • Maintenance costs for the refurbishment concept are expected to be greater with an increasing rate of deterioration anticipated over its service life, given the structure is already 100 years old.
Resilience	**New Structure**	• The new structure deck levels are raised by 1m which provides resilience against overtopping due to sea level rise (SLR), storm surge and waves. • The HAT design water level table for 2050 (incl +0.4m SLR) is 4.16m CD, only slightly below the existing deck level. Wave splash/spray above existing deck level will become more commonplace with SLR and the existing deck will be, based on current SLR modelling predictions / guidelines, submerged at HAT by the year 2100, with 20 years of design life still remaining. • During extreme wave events the refurbished structure is likely to be submerged/overtopped by ‘green’ water waves and will need to be closed for safety.
Commercial Functionality	**New Structure**	• The existing structure is less resilient, therefore there is greater risk of damage during an extreme event (e.g. cyclone) which could prevent commercial activities for a period of time. • The new structure will likely have greater impact to commercial operations during construction, however this can be mitigated by building the new structure on a new alignment which would actually reduce impact compared to the refurbishment option.
Public Amenity	**New Structure**	• Increased ongoing maintenance and repairs for the refurbishment option may impact on public amenity (both visually and physically).
Heritage	**Refurbishment**	• Repair and replacement of heritage elements like-for-like where necessary is preferred from a heritage perspective. Noting some impacts will be incurred due to loss of some original fabric where it has failed. • A new structure could incorporate or reuse existing heritage components while achieving new structure benefits. • Existing piles which are ‘exceptional’ heritage significance will be covered by the pile wrapping system which will also change the shape of the pile from square to round which may impact on visual amenity. • Demolition of the existing structure may result in total loss of its heritage values and may have irreversible negative impacts (requires specialist heritage advice to confirm). This could be mitigated by building the new structure on a new alignment and retaining the existing original wharf structures where possible.
Environment / Sustainability	**No clear preference**	• The refurbishment option minimises use of construction materials by extending the life of the asset (i.e. avoids new construction) however this option will require an expected high level of ongoing maintenance construction works (and material requirements).

Category	Anticipated Preferred Option	Notes
		• New materials and construction practices used in the new structure provide longer term durability / reduced ongoing maintenance and repair works requirement.
Accessibility	**New Structure**	• New structure includes rest areas and can be designed to incorporate improved accessibility. • Refurbishment option may be difficult to ensure DDA compliance with timber decking (due to drying shrinkage and warping / deterioration of timber over time). • The existing structure has no existing rest areas and no wheelchair passing zones on the middle stem.
Overall Indicative Preferred Option	**New Structure**	• Refurbishment preferred in one category. • New structure preferred in seven categories. • No clear preference in one category.

Based on the assumed category preferences above, it appears at this early stage of the options assessment process, that the refurbishment option may be preferred in one category, the new structure may be preferred in seven categories and there is one category in which there is no clear preference. Hence the new structure concept would appear to be preferred overall.

The assessment undertaken in this report is very high level and based on the available information to date. It is recommended that a holistic view is taken to determine the preferred approach in the next phase of design.

Cost Comparison

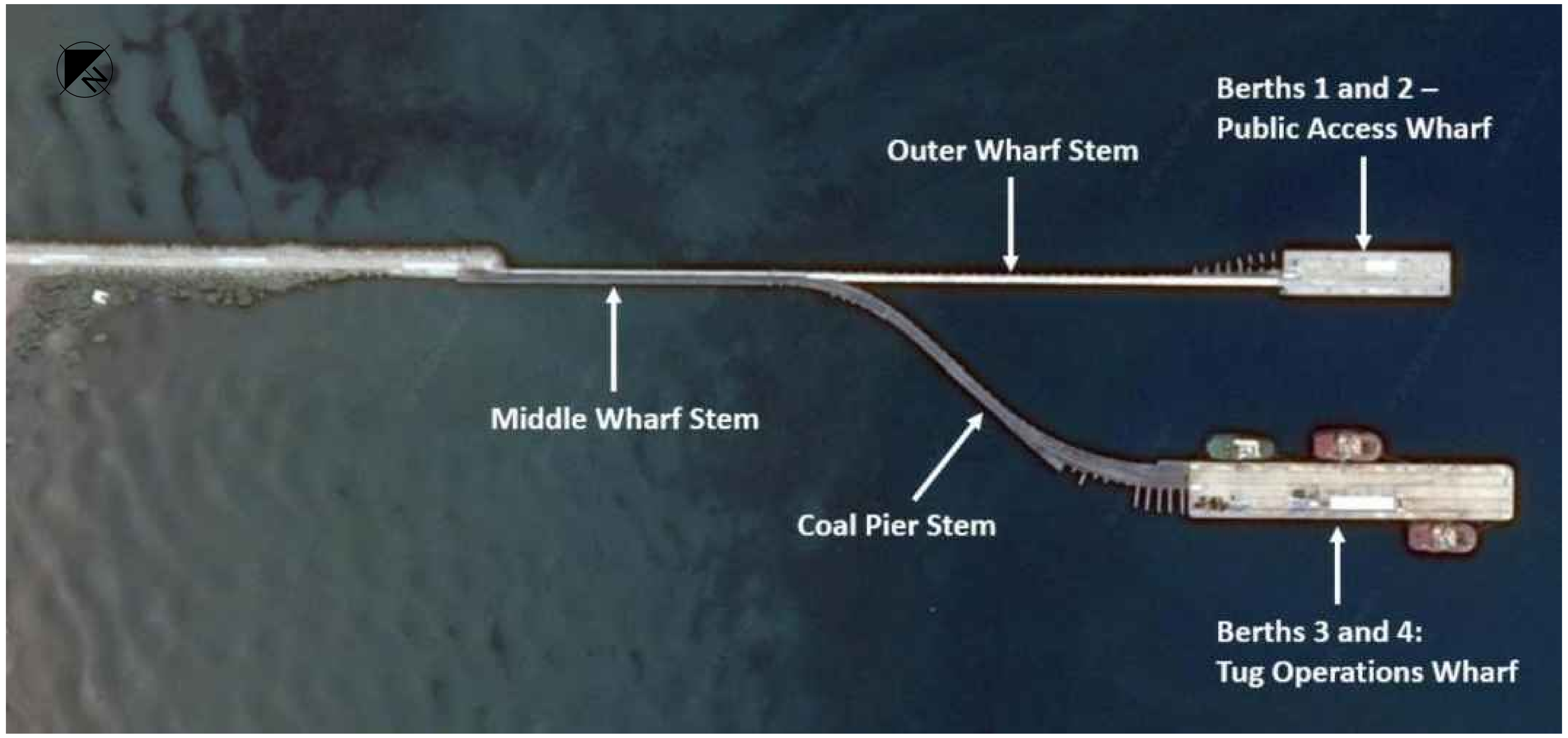
Based on the RLB cost estimates, a refurbished option has the potential to cost more than $50M.

Regarding OPEX costs, a new structure could be designed with low maintenance requirements as a consideration. This would be through additional concrete cover, corrosion inhibitors in the concrete mix design, installation of cathodic protection, use of stainless steel (where economically viable) and use of robust painting systems and pile wrapping systems (e.g. Denso Seashield). Under such case, the maintenance costs would be expected to be significantly less than those associated with maintaining the existing structures. In particular, a new structure designed for a 100-year design life would not typically include the major capital replacement costs associated with maintaining the existing. If the existing wharf were to be refurbished the future asset owner will be required to fund significant replacement costs in years 26, 51 and 76.

Appendix A Condition Rating Heat Map Markups and Sample Condition Report

BOWEN WHARF
FUTURE OPTIONS ASSESSMENT

WITH SITE OBSERVATIONS FROM SHORELINE TARGETED INSPECTION ON 29 AUGUST 2023



LOCALITY PLAN
N.T.S.

[illegible]

[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]

NOT FOR CONSTRUCTION

NOTE: WSCAM RATINGS ARE BASED ON WSCAM VISUAL INSPECTION (OCT. 2018) AND HAVE NOT BEEN UPDATED FOR TIMBER TESTING RESULTS

WSCAM Condition Rating

1 2 3 4 5 6 7

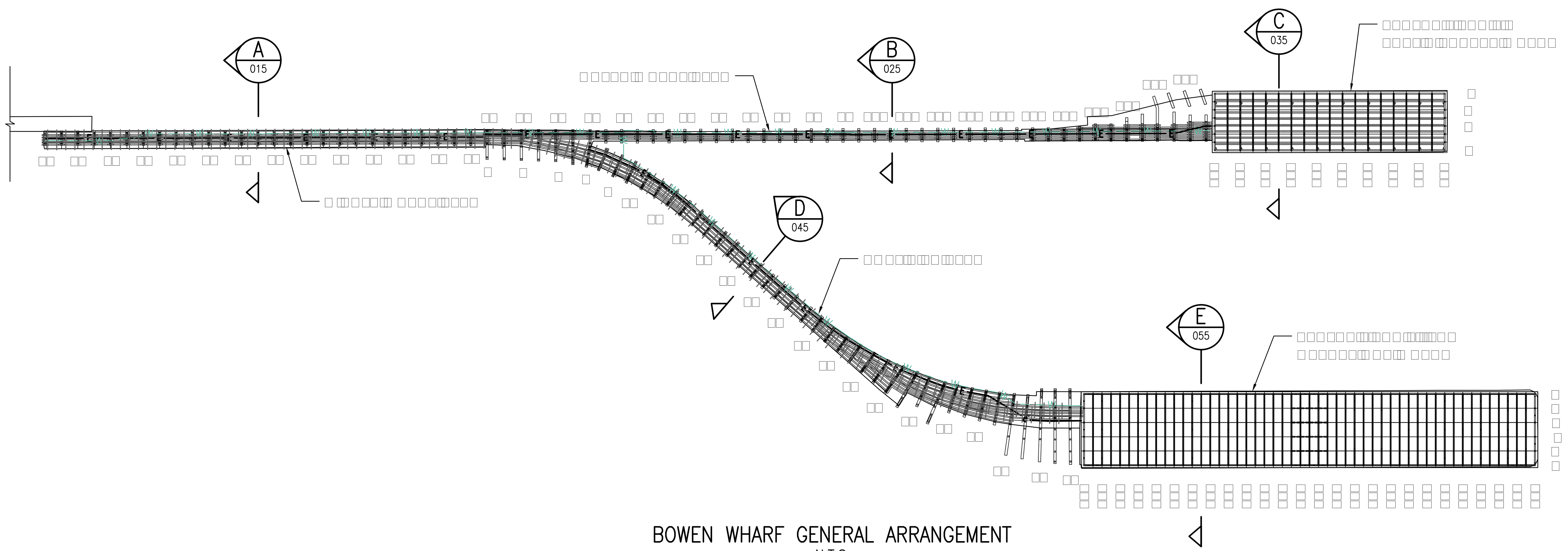
ARUP

CONSULT AUSTRALIA

NORTH QUEENSLAND BULK PORTS CORPORATION

264408-00 Draft

264408-CS-001 B



BOWEN WHARF GENERAL ARRANGEMENT
N.T.S.

SECTION	GEOMETRY	DESCRIPTION	PURPOSE
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

NOT FOR CONSTRUCTION

NOTE: WSCAM RATINGS ARE BASED ON WSCAM VISUAL INSPECTION (OCT. 2018) AND HAVE NOT BEEN UPDATED FOR TIMBER TESTING RESULTS

WSCAM Condition Rating

1 2 3 4 5 6 7

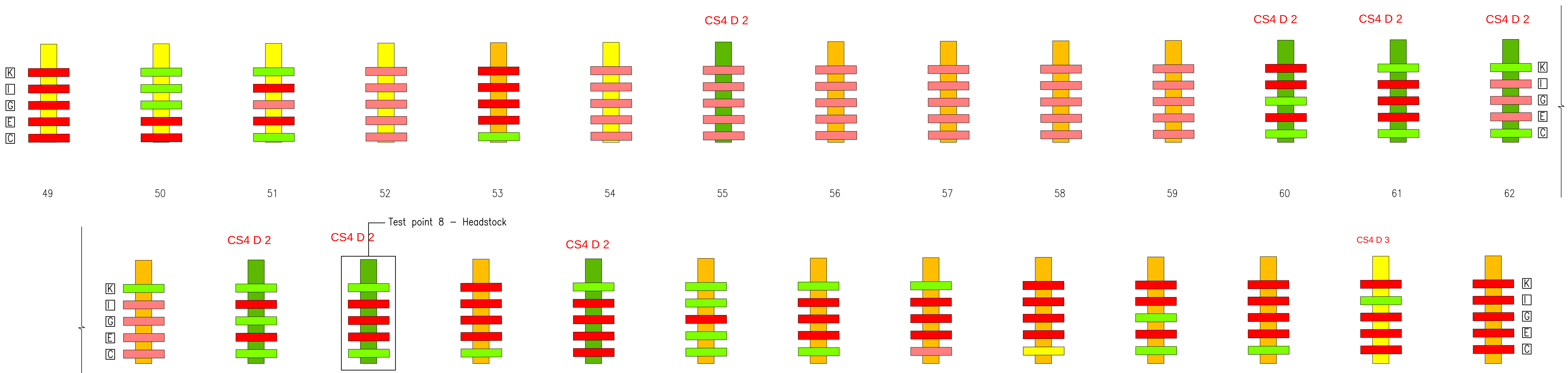
ARUP

CONSULT AUSTRALIA

264408-00

264408-CS-005

B



LEGEND FOR THE SITE OBSERVATIONS FROM 29 AUGUST 2023
CS# - Condition State Number
D# - Delamination with area in m²
S# - Spalling with area in m²
C# - Crack with length in m

MIDDLE WHARF – CROSS HEADS & CORBELS

N.T.S.

NOT FOR CONSTRUCTION

NOTE: WSCAM RATINGS ARE BASED ON WSCAM VISUAL INSPECTION (OCT. 2018) AND HAVE NOT BEEN UPDATED FOR TIMBER TESTING RESULTS

WSCAM Condition Rating

1 2 3 4 5 6 7

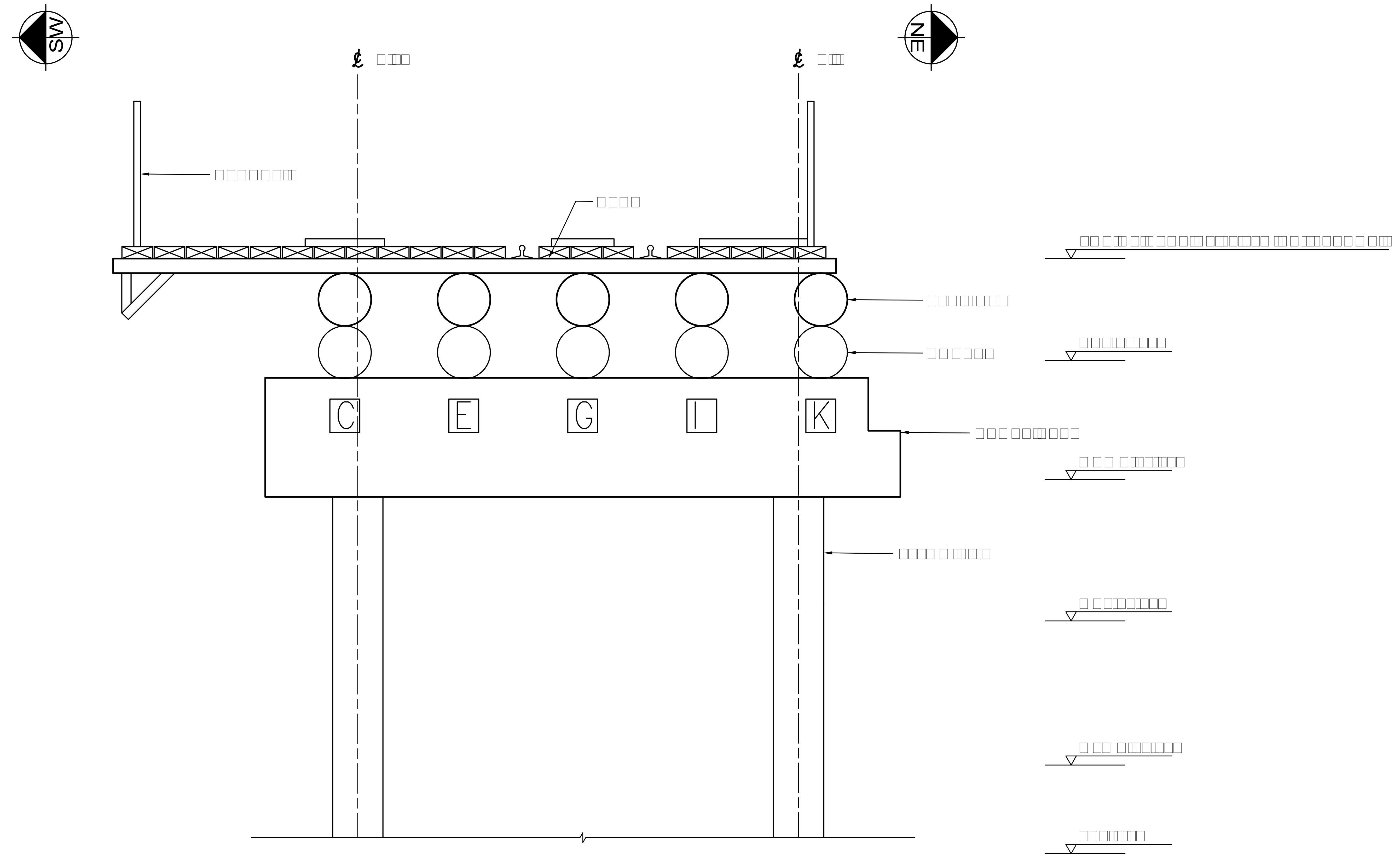
ARUP

CONSULT AUSTRALIA

NORTH QUEENSLAND BULK PORTS CORPORATION

264408-00 Draft

264408-CS-010 D



MIDDLE WHARF STEM TYPICAL CROSS SECTION

N.T.S.

A
005

MIDDLE WHARF STEM GEOMETRY		
ELEMENT	**MATERIAL**	**TYPICAL APPROXIMATE GEOMETRY**
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	Ø400MM, 2M LENGTH
[illegible]	[illegible]	Ø400MM, 4NO. ASSUMED [illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

NOT FOR CONSTRUCTION

NOTE: WSCAM RATINGS ARE BASED ON WSCAM VISUAL INSPECTION (OCT. 2018) AND HAVE NOT BEEN UPDATED FOR TIMBER TESTING RESULTS

WSCAM Condition Rating

1 2 3 4 5 6 7

ARUP

CONSULT AUSTRALIA

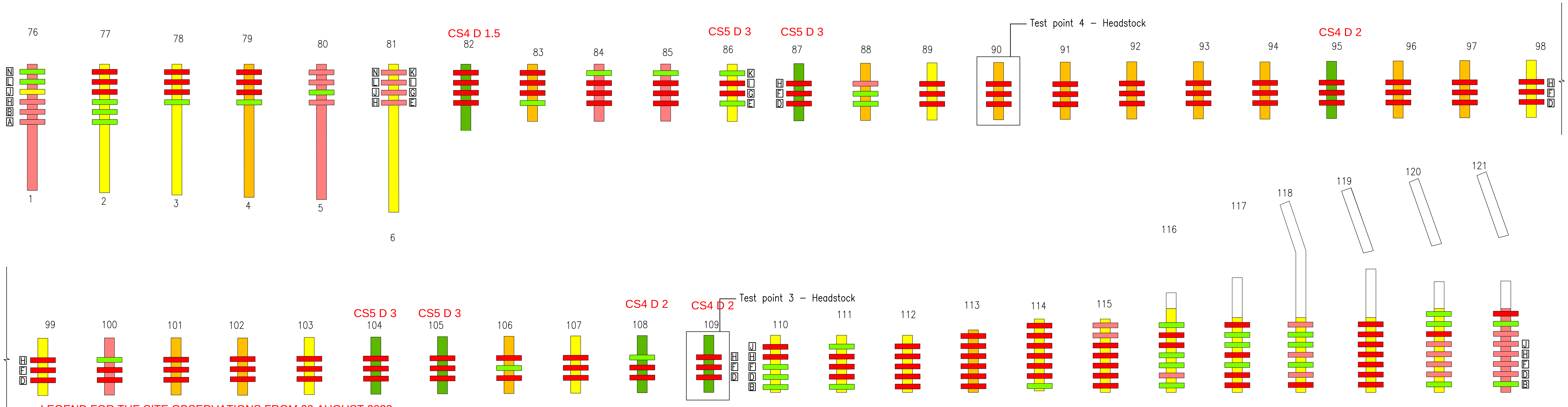
NORTH QUEENSLAND BULK PORTS CORPORATION

264408-00

264408-CS-015

A

...\260000\264408-00 – Bowen Wharf\Work\Internal\Drawings\Civil Str\Sheets\264408-CS-015



LEGEND FOR THE SITE OBSERVATIONS FROM 29 AUGUST 2023

CS# - Condition State Number

D# - Delamination with area in m^2

S# - Spalling with area in m^2

C# - Crack with length in m

OUTER WHARF – CROSS HEADS & CORBELS

N.T.S.

NOT FOR CONSTRUCTION

NOTE: WSCAM RATINGS ARE BASED ON WSCAM VISUAL INSPECTION (OCT. 2018) AND HAVE NOT BEEN UPDATED FOR TIMBER TESTING RESULTS

WSCAM Condition Rating

1	2	3	4	5	6	7

ARUP

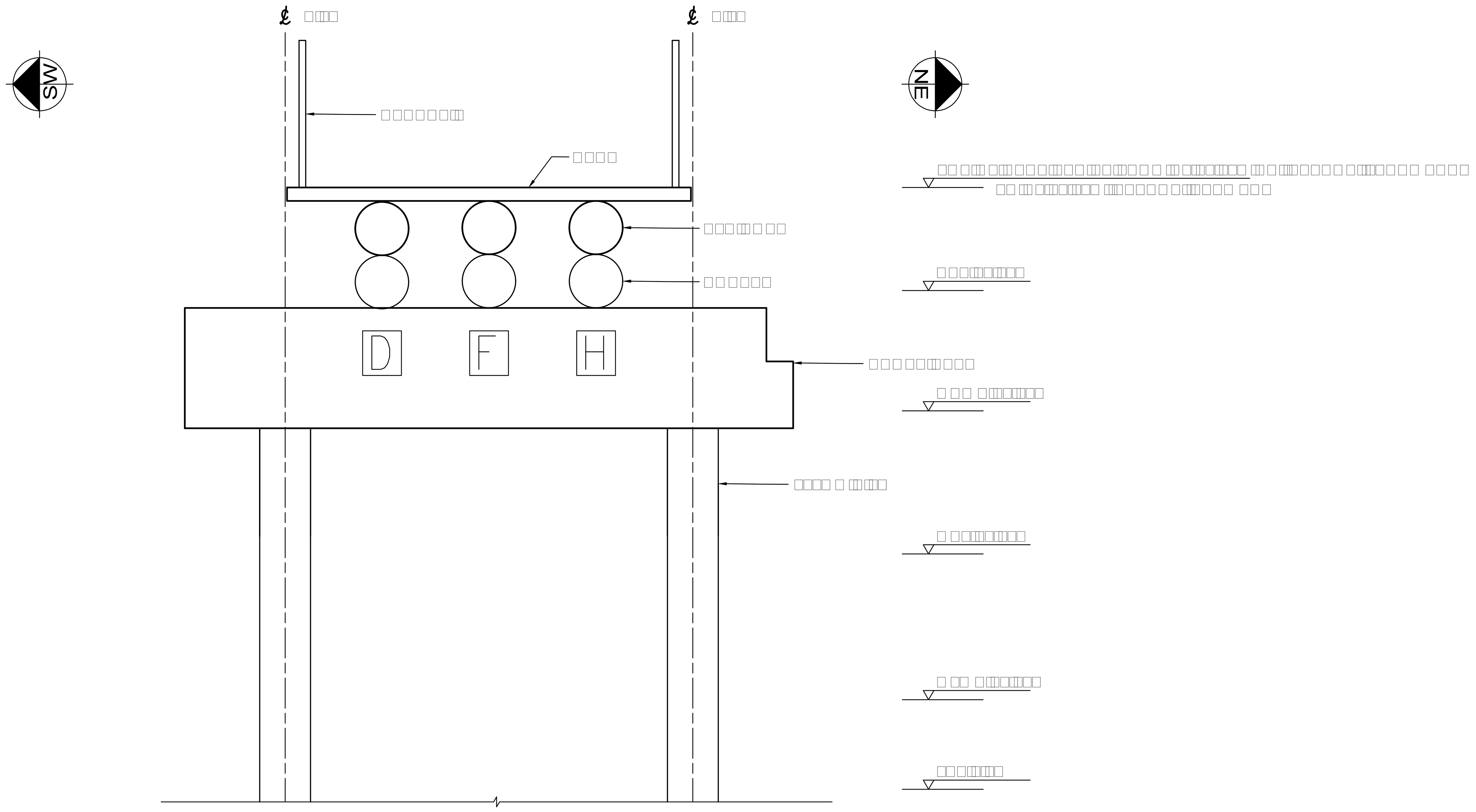
CONSULT AUSTRALIA

NORTH QUEENSLAND BULK PORTS CORPORATION

264408-00 Draft

264408-CS-020 D

User : Tim Murfet Plot Date : 11/11/2019 2:51:36 PM



OUTER WHARF STEM TYPICAL CROSS SECTION (B / 005)

N.T.S.

OUTER WHARF STEM GEOMETRY		
ELEMENT	**MATERIAL**	**TYPICAL APPROXIMATE GEOMETRY**
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	Ø400MM, 2M LENGTH
[illegible]	[illegible]	Ø400MM, 3NO. ASSUMED [illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

NOT FOR CONSTRUCTION

NOTE: WSCAM RATINGS ARE BASED ON WSCAM VISUAL INSPECTION (OCT. 2018) AND HAVE NOT BEEN UPDATED FOR TIMBER TESTING RESULTS

WSCAM Condition Rating

1 2 3 4 5 6 7

ARUP

CONSULT AUSTRALIA

NORTH QUEENSLAND BULK PORTS CORPORATION

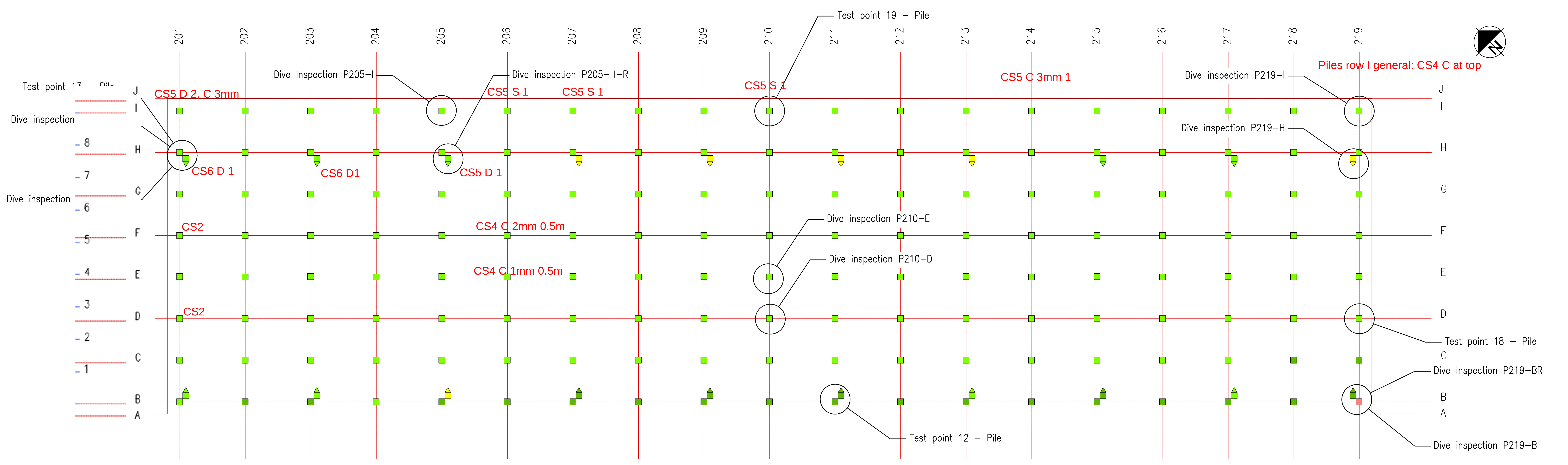
264408-00

264408-CS-025

A

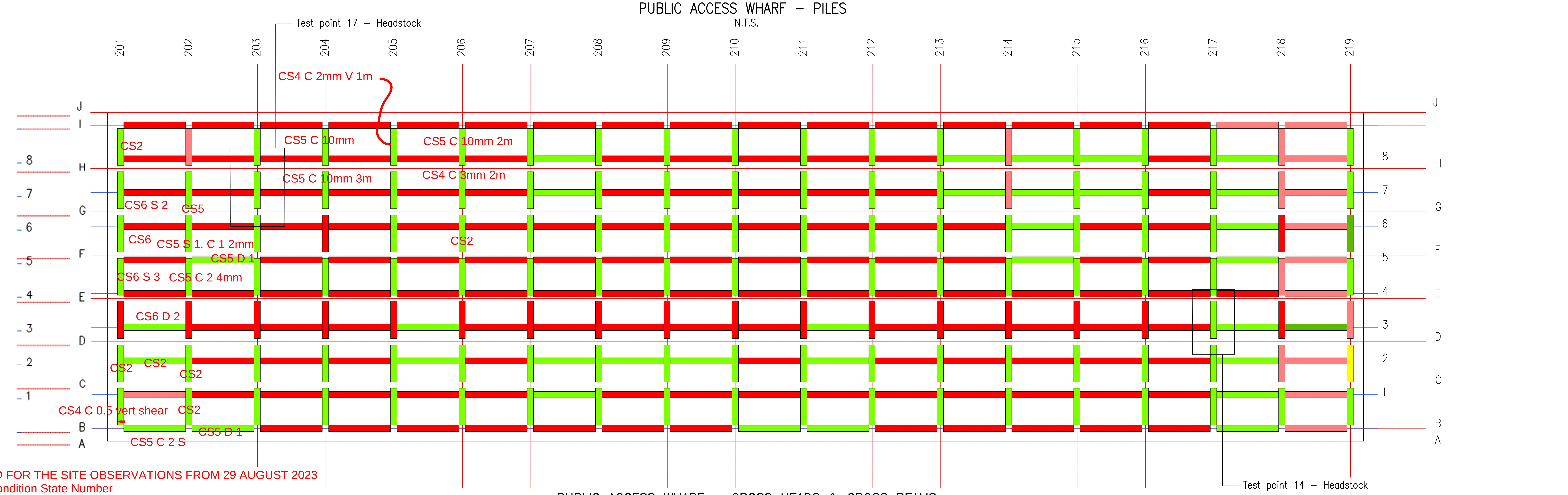
User : Tim Murfet Plot Date : 11/11/2019 2:51:51 PM

\260000\264408-00 - Bowen Wharf\Work\Internal\Drawings\Civil Str\Sheets\264408-CS-025



PUBLIC ACCESS WHARF – PILES

N.T.S.



LEGEND FOR THE SITE OBSERVATIONS FROM 29 AUGUST 2023

CS# - Condition State Number

D# - Delamination with area in m²

S# - Spalling with area in m²

C# - Crack with length in m

PUBLIC ACCESS WHARF – CROSS HEADS & CROSS BEAMS

N.T.S.

NOT FOR CONSTRUCTION

NOTE: WSCAM RATINGS ARE BASED ON WSCAM VISUAL INSPECTION (OCT. 2018) AND HAVE NOT BEEN UPDATED FOR TIMBER TESTING RESULTS

WSCAM Condition Rating

1	2	3	4	5	6	7

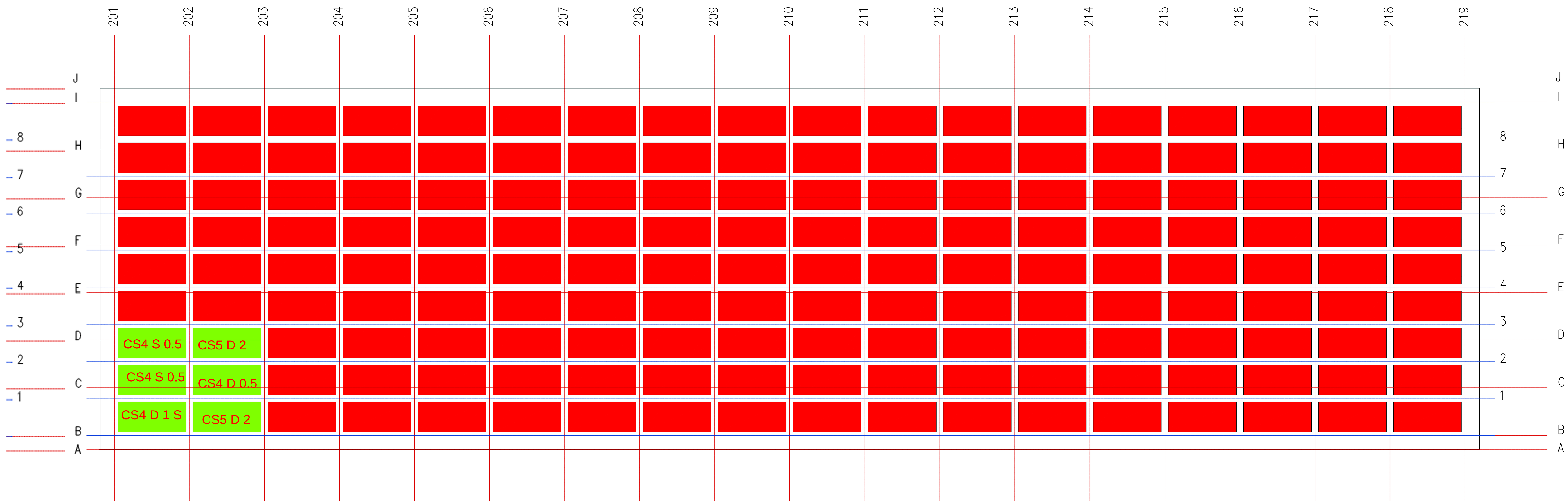
ARUP

CONSULT AUSTRALIA

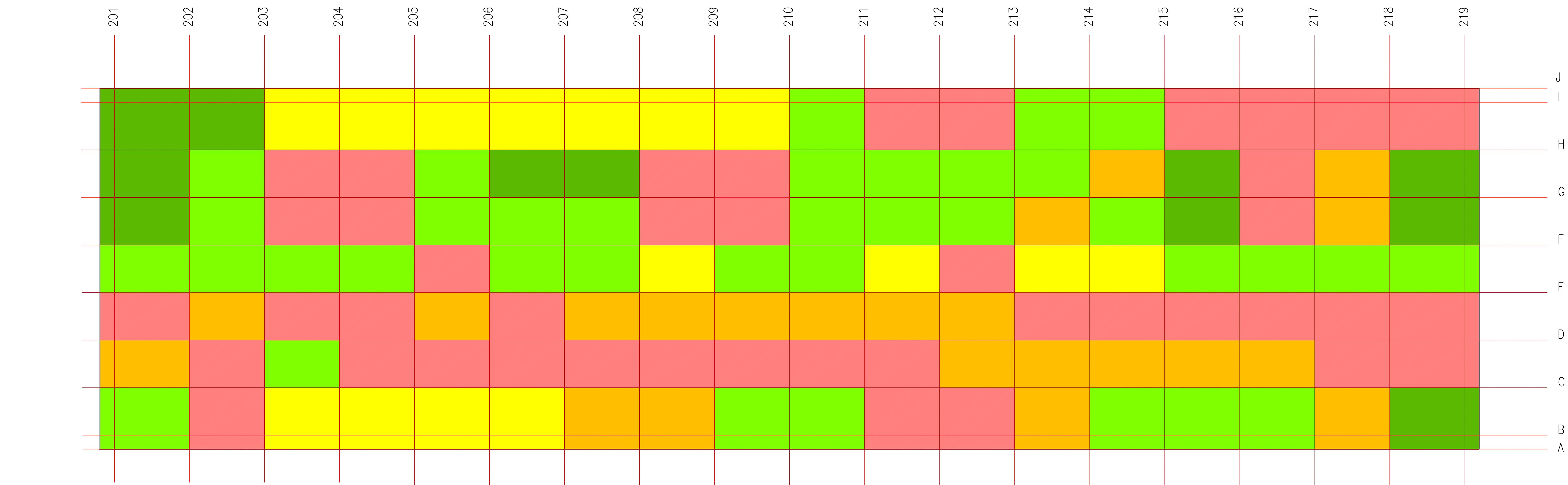
NORTH QUEENSLAND BULK PORTS CORPORATION

264408-00 | Draft

264408-CS-030 | D



PUBLIC ACCESS WHARF – DECK SOFFIT
N.T.S.



LEGEND FOR THE SITE OBSERVATIONS FROM 29 AUGUST 2023
CS# - Condition State Number
D# - Delamination with area in m²
S# - Spalling with area in m²
C# - Crack with length in m

PUBLIC ACCESS WHARF – DECK TOP
N.T.S.

NOT FOR CONSTRUCTION

NOTE: WSCAM RATINGS ARE BASED ON WSCAM VISUAL INSPECTION (OCT. 2018) AND HAVE NOT BEEN UPDATED FOR TIMBER TESTING RESULTS

WSCAM Condition Rating

1	2	3	4	5	6	7

ARUP

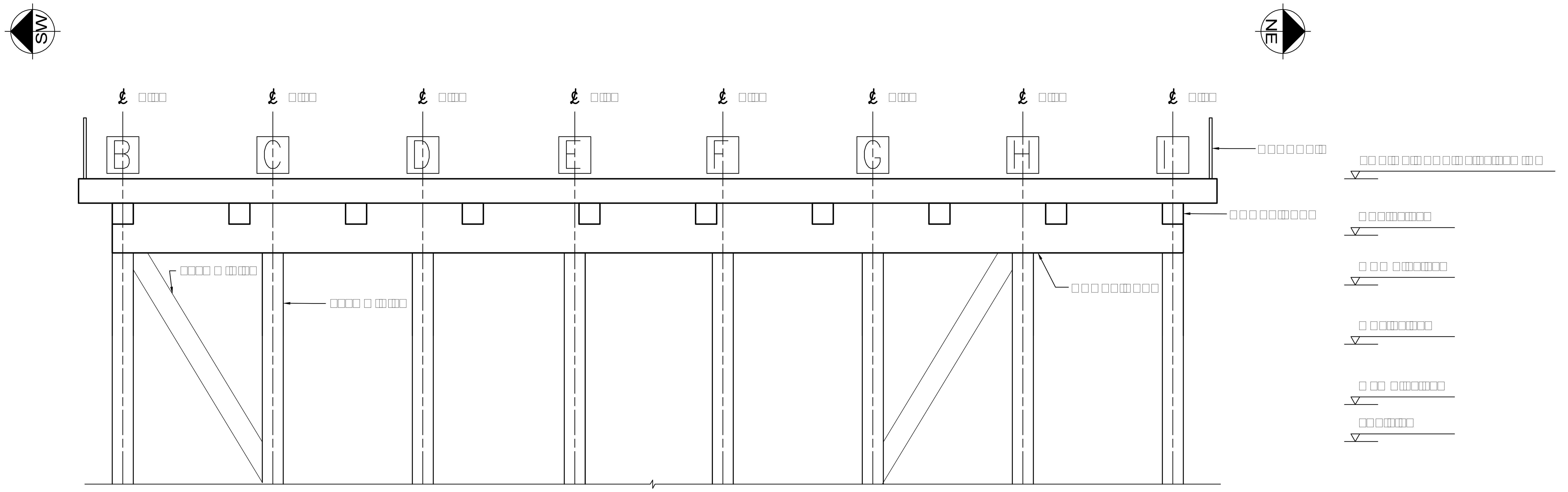
CONSULT AUSTRALIA

NORTH QUEENSLAND BULK PORTS CORPORATION

264408-00 Draft

264408-CS-031 B

User : Tim Murfet Plot Date : 11/1/2019 2:52:19 PM



PUBLIC WHARF TYPICAL CROSS SECTION C
N.T.S. 005

PUBLIC WHARF GEOMETRY		
ELEMENT	**MATERIAL**	**TYPICAL APPROXIMATE GEOMETRY**
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

NOT FOR CONSTRUCTION

NOTE: WSCAM RATINGS ARE BASED ON WSCAM VISUAL INSPECTION (OCT. 2018) AND HAVE NOT BEEN UPDATED FOR TIMBER TESTING RESULTS

WSCAM Condition Rating

1 2 3 4 5 6 7

ARUP

CONSULT AUSTRALIA

NORTH QUEENSLAND BULK PORTS CORPORATION

264408-00

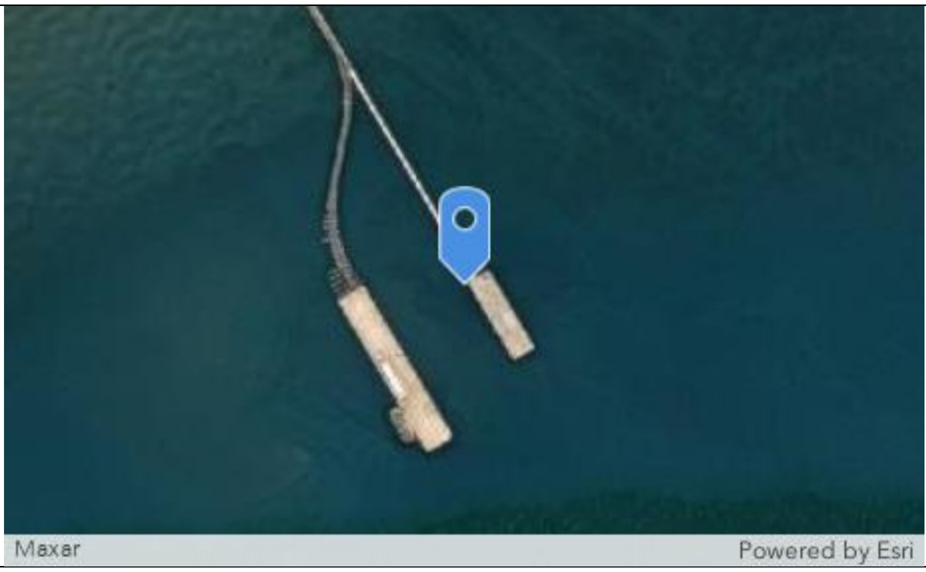
264408-CS-035

A

\260000\264408-00 - Bowen Wharf\Work\Internal\Drawings\Civil Str\Sheets\264408-CS-035

© Arup

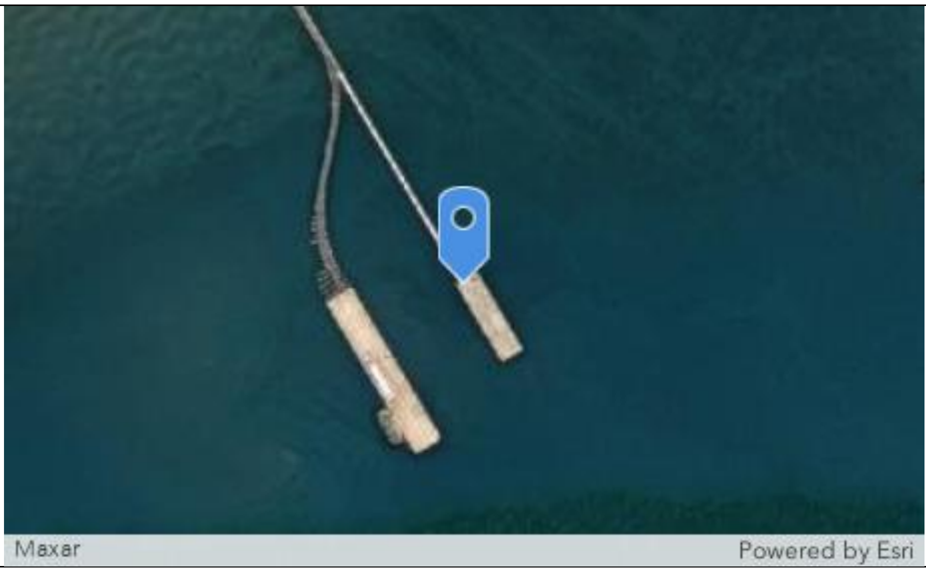
Factual Inspection Record

Structure	Bowen Wharf Refurbishment Study
Time of Inspection	August 29, 2023 6:26 AM
Observation Plan Location	
Observation Location	Below Deck
Structure Name	Public Access Wharf

Observation Details	
Observation I.D	**1**
Condition Rating (1-7)	Condition Rating 4
Component	Deck Soffit (DS) 201-202 B - 1
Material	Concrete (C)
Defect Type	Delamination (D)
Defect Quantity	1
Defect Quantity Unit	m2
Description	

Site Photographs

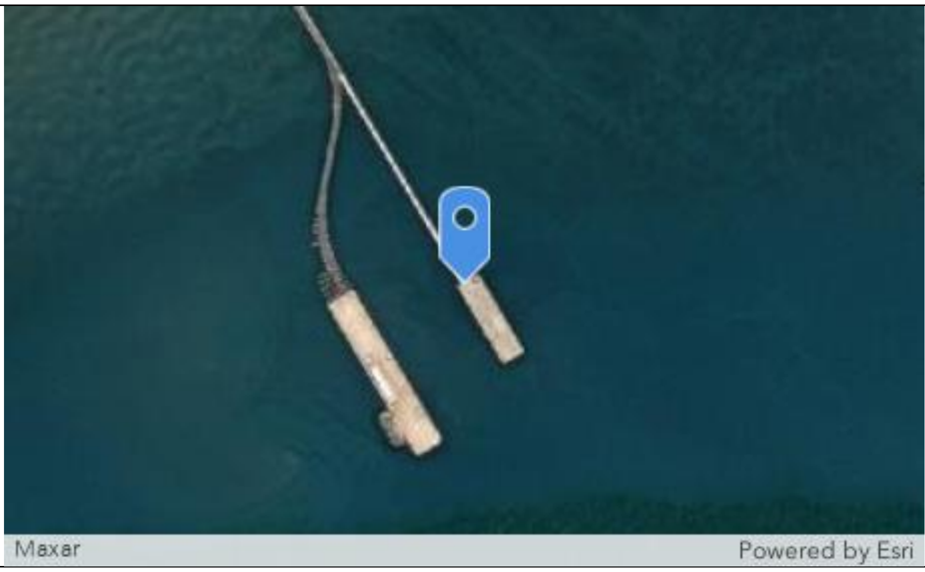
Factual Inspection Record

Structure	Bowen Wharf Refurbishment Study
Time of Inspection	August 29, 2023 6:37 AM
Observation Plan Location	
Observation Location	Below Deck
Structure Name	Public Access Wharf

Observation Details	
Observation I.D	**2**
Condition Rating (1-7)	Condition Rating 4
Component	Deck Soffit (DS) 201-202 1-2
Material	Concrete (C)
Defect Type	Spalling
Defect Quantity	0.5
Defect Quantity Unit	m2
Description	Condition State 4

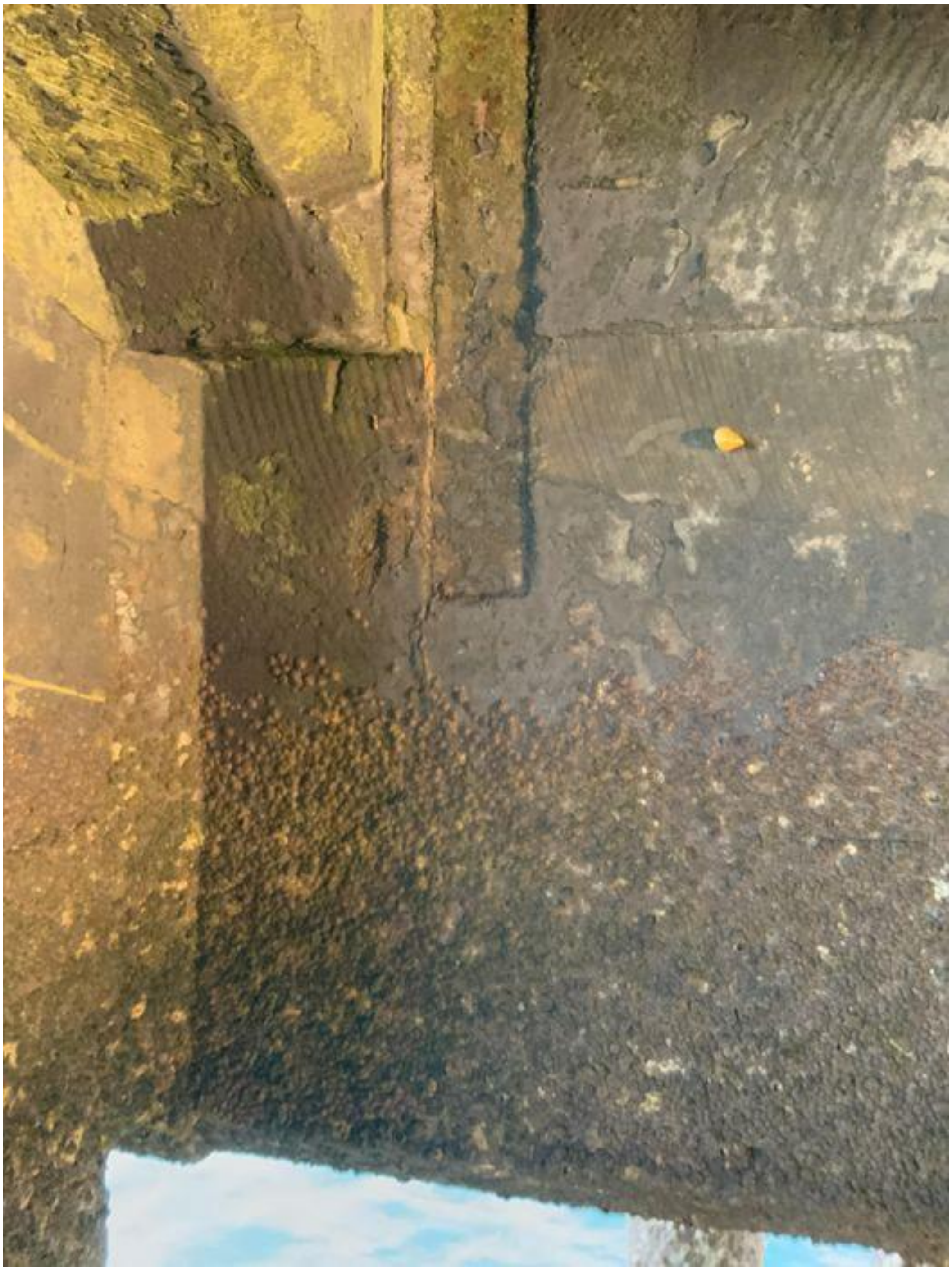
Site Photographs

Factual Inspection Record

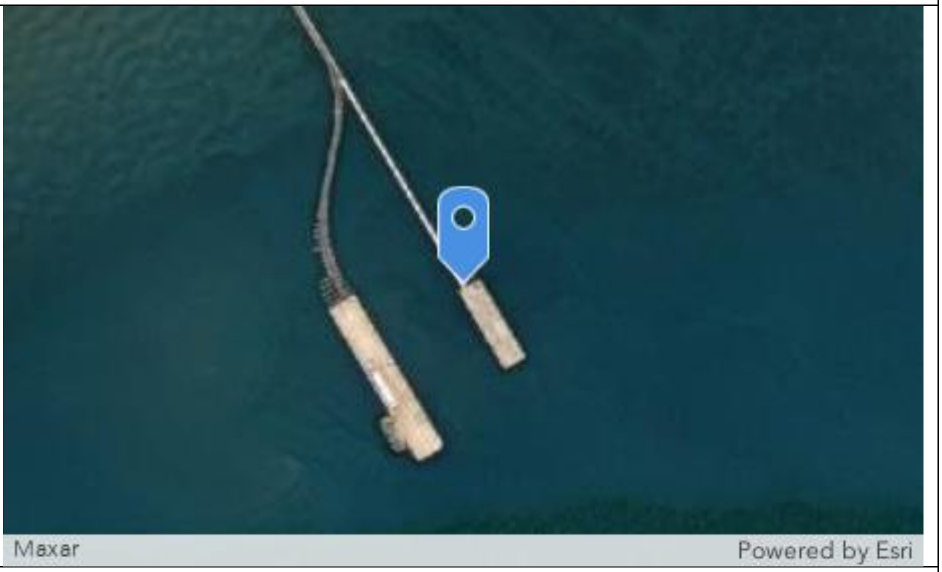
Structure	**Bowen Wharf Refurbishment Study**
Time of Inspection	August 29, 2023 6:42 AM
Observation Plan Location	
Observation Location	Below Deck
Structure Name	Public Access Wharf

Observation Details	
Observation I.D	**3**
Condition Rating (1-7)	Condition Rating 4
Component	Cross Head / Headstock (CH) 201 B-C
Material	Concrete (C)
Defect Type	Cracking (C)
Defect Quantity	1
Defect Quantity Unit	m
Description	Vertical shear crack 0.5 mm wide.

Site Photographs



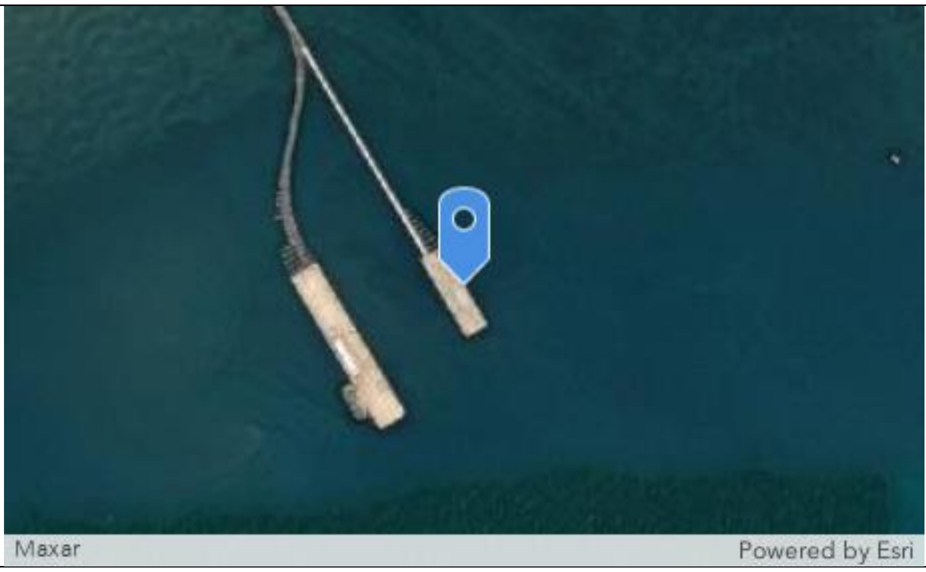
Factual Inspection Record

Structure	**Bowen Wharf Refurbishment Study**
Time of Inspection	August 29, 2023 6:49 AM
Observation Plan Location	
Observation Location	Below Deck
Structure Name	Public Access Wharf

Observation Details	
Observation I.D	**4**
Condition Rating (1-7)	Condition Rating 5
Component	Beam / Girder (Longitudinal) 201-202A
Material	Concrete (C)
Defect Type	Cracking (C)
Defect Quantity	2
Defect Quantity Unit	m
Description	Shear cracking both ends of secondary longitudinal beam. Local spalling to cracks

Site Photographs

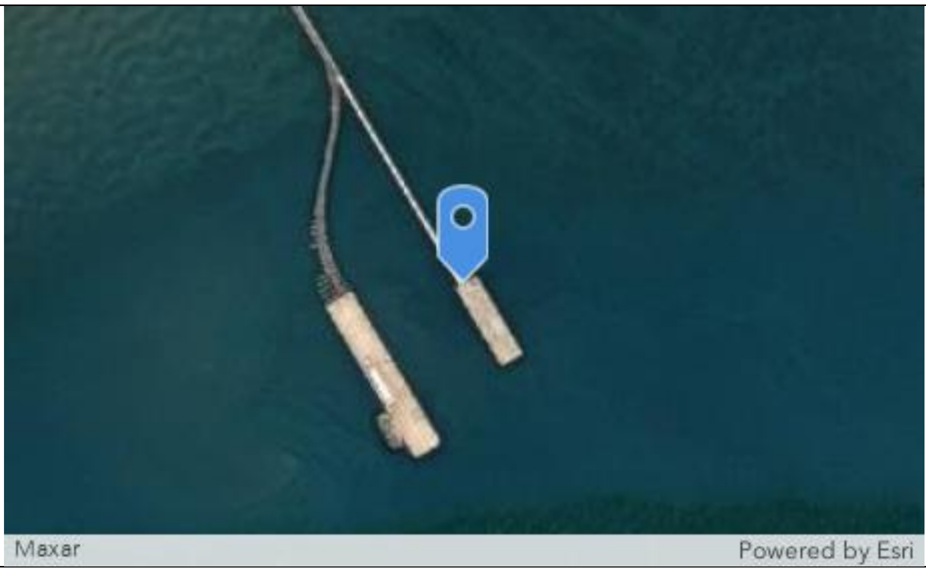
Factual Inspection Record

Structure	**Bowen Wharf Refurbishment Study**
Time of Inspection	August 29, 2023 6:54 AM
Observation Plan Location	
Observation Location	Below Deck
Structure Name	Public Access Wharf

Observation Details	
Observation I.D	**5**
Condition Rating (1-7)	Condition Rating 6
Component	Transverse Beam (TB) Sec beam 201-202 D
Material	Concrete (C)
Defect Type	Delamination (D)
Defect Quantity	2
Defect Quantity Unit	m2
Description	

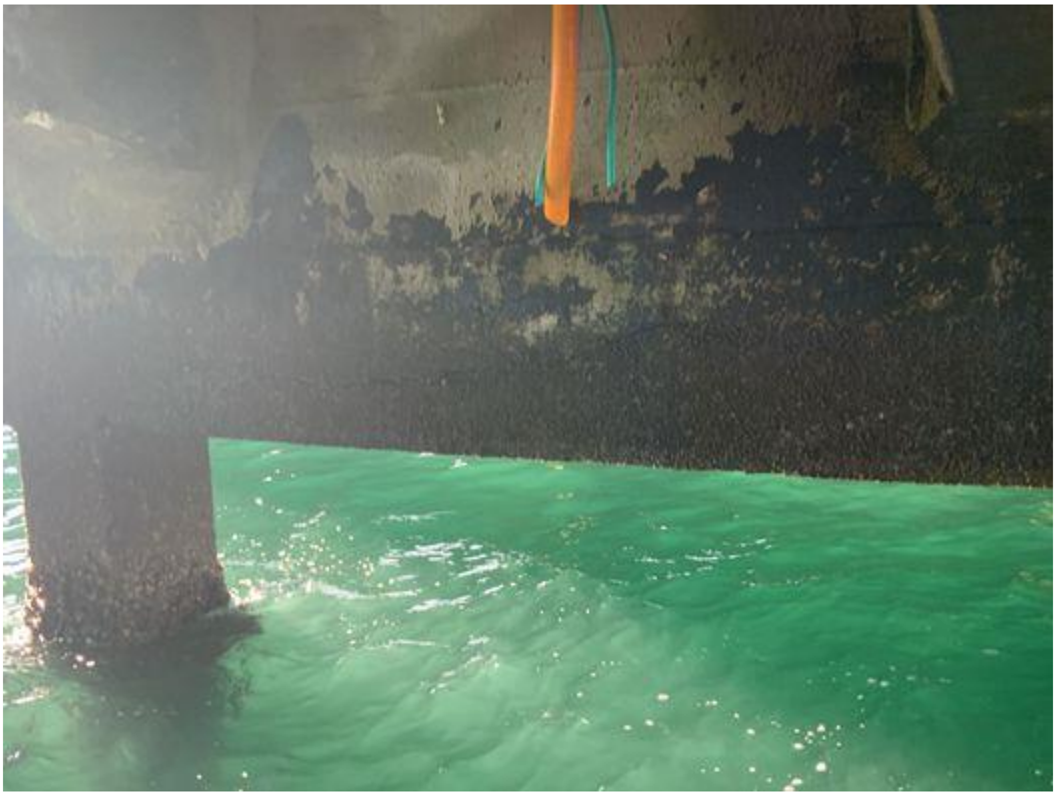
Site Photographs

Factual Inspection Record

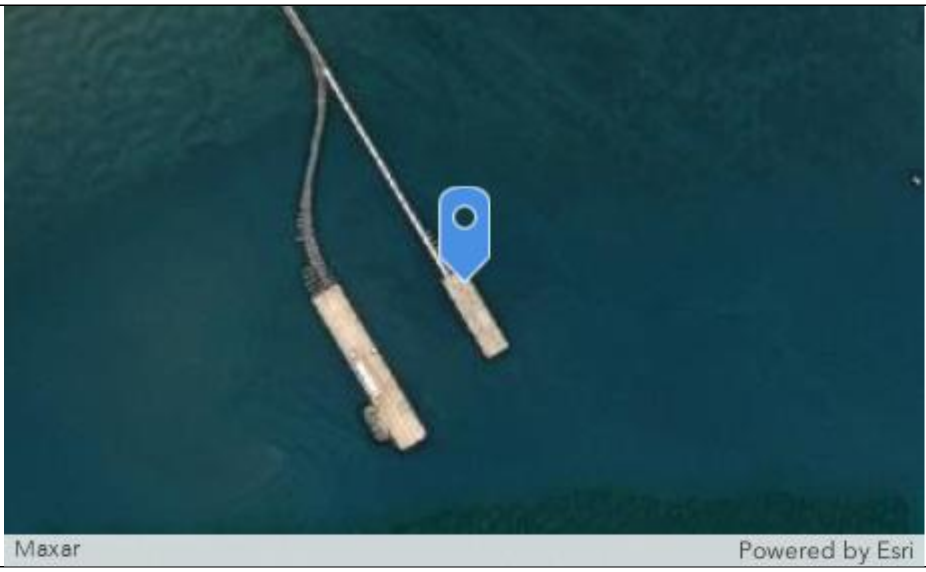
Structure	**Bowen Wharf Refurbishment Study**
Time of Inspection	August 29, 2023 6:58 AM
Observation Plan Location	
Observation Location	Below Deck
Structure Name	Public Access Wharf

Observation Details	
Observation I.D	**6**
Condition Rating (1-7)	Condition Rating 5
Component	Cross Head / Headstock (CH) 202 E-F
Material	Concrete (C)
Defect Type	Cracking (C)
Defect Quantity	2
Defect Quantity Unit	m2
Description	

Site Photographs



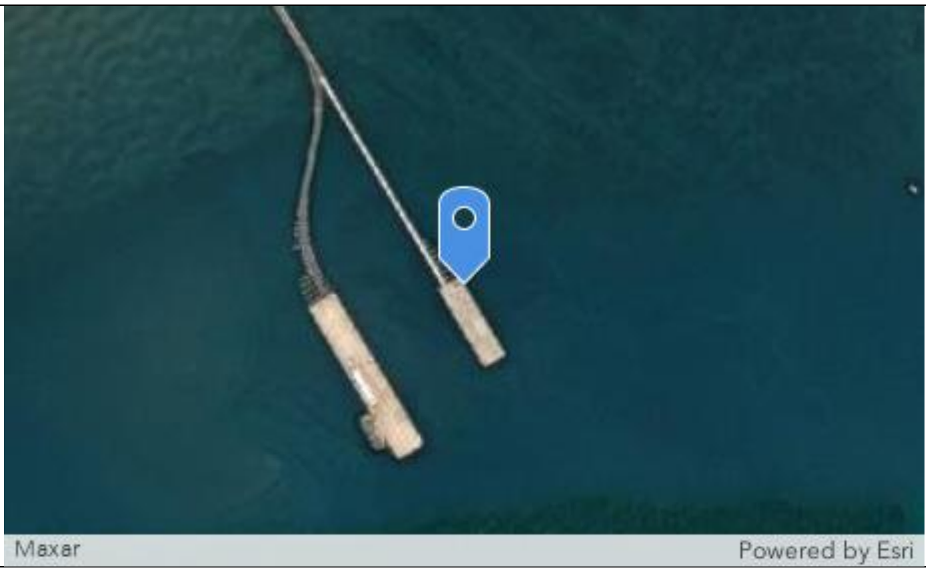
Factual Inspection Record

Structure	**Bowen Wharf Refurbishment Study**
Time of Inspection	August 29, 2023 7:04 AM
Observation Plan Location	
Observation Location	Below Deck
Structure Name	Public Access Wharf

Observation Details	
Observation I.D	**7**
Condition Rating (1-7)	Condition Rating 4
Component	Deck Soffit (DS) 201-202 2-3
Material	Concrete (C)
Defect Type	Spalling
Defect Quantity	0.5
Defect Quantity Unit	m2
Description	

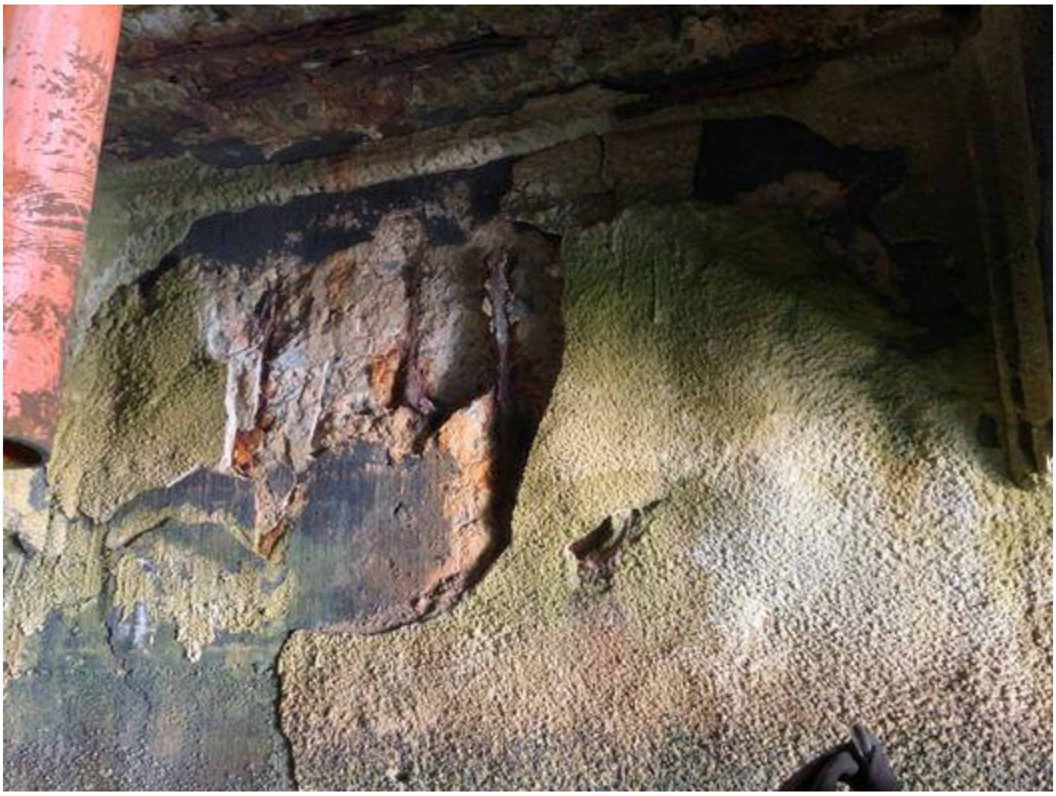
Site Photographs

Factual Inspection Record

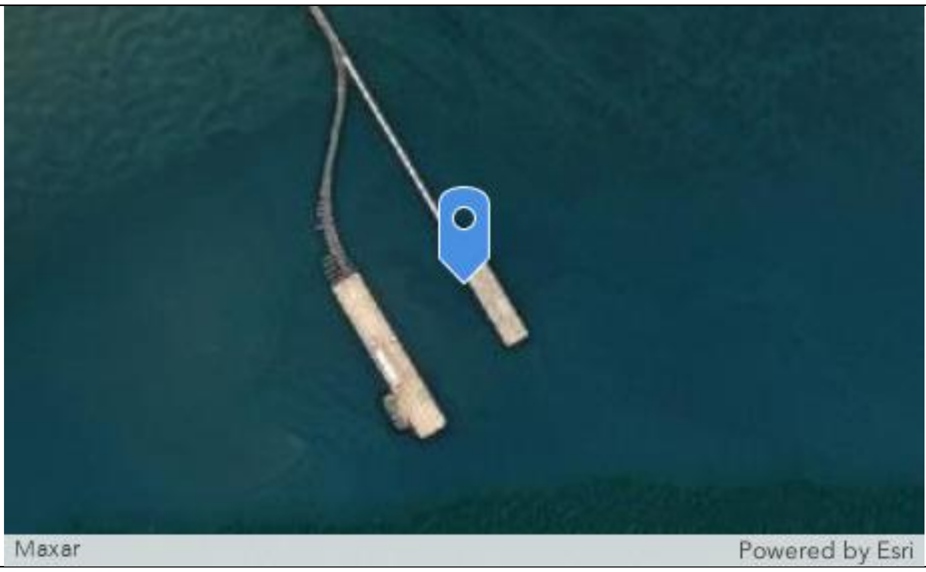
Structure	Bowen Wharf Refurbishment Study
Time of Inspection	August 29, 2023 7:09 AM
Observation Plan Location	
Observation Location	Below Deck
Structure Name	Public Access Wharf

Observation Details	
Observation I.D	**8**
Condition Rating (1-7)	Condition Rating 6
Component	Cross Head / Headstock (CH) 201 E-F
Material	Concrete (C)
Defect Type	Spalling
Defect Quantity	3
Defect Quantity Unit	m2
Description	Shotcrete repair delamination

Site Photographs



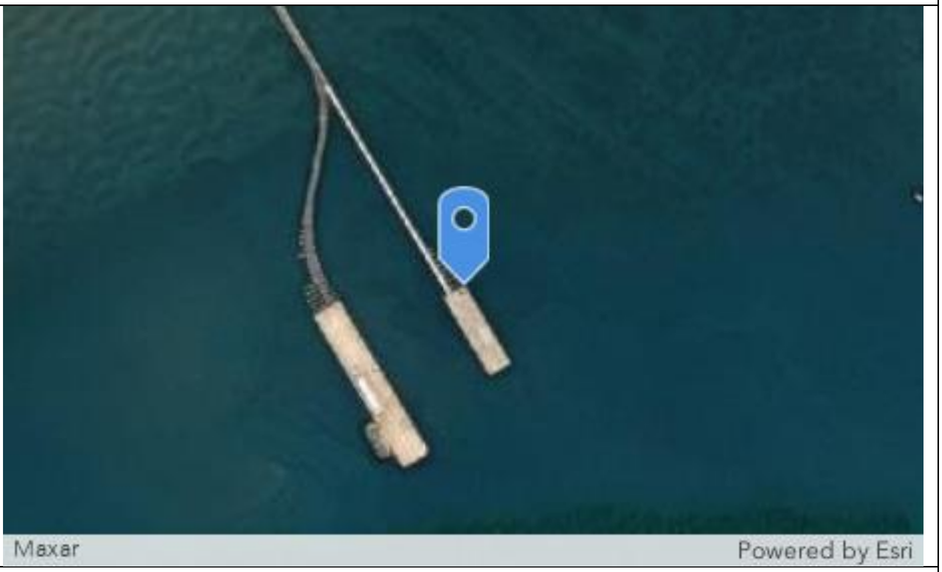
Factual Inspection Record

Structure	**Bowen Wharf Refurbishment Study**
Time of Inspection	August 29, 2023 7:14 AM
Observation Plan Location	
Observation Location	Below Deck
Structure Name	Public Access Wharf

Observation Details	
Observation I.D	**9**
Condition Rating (1-7)	Condition Rating 6
Component	Cross Head / Headstock (CH) 201 G-F
Material	Concrete (C)
Defect Type	Delamination (D)
Defect Quantity	2
Defect Quantity Unit	m2
Description	

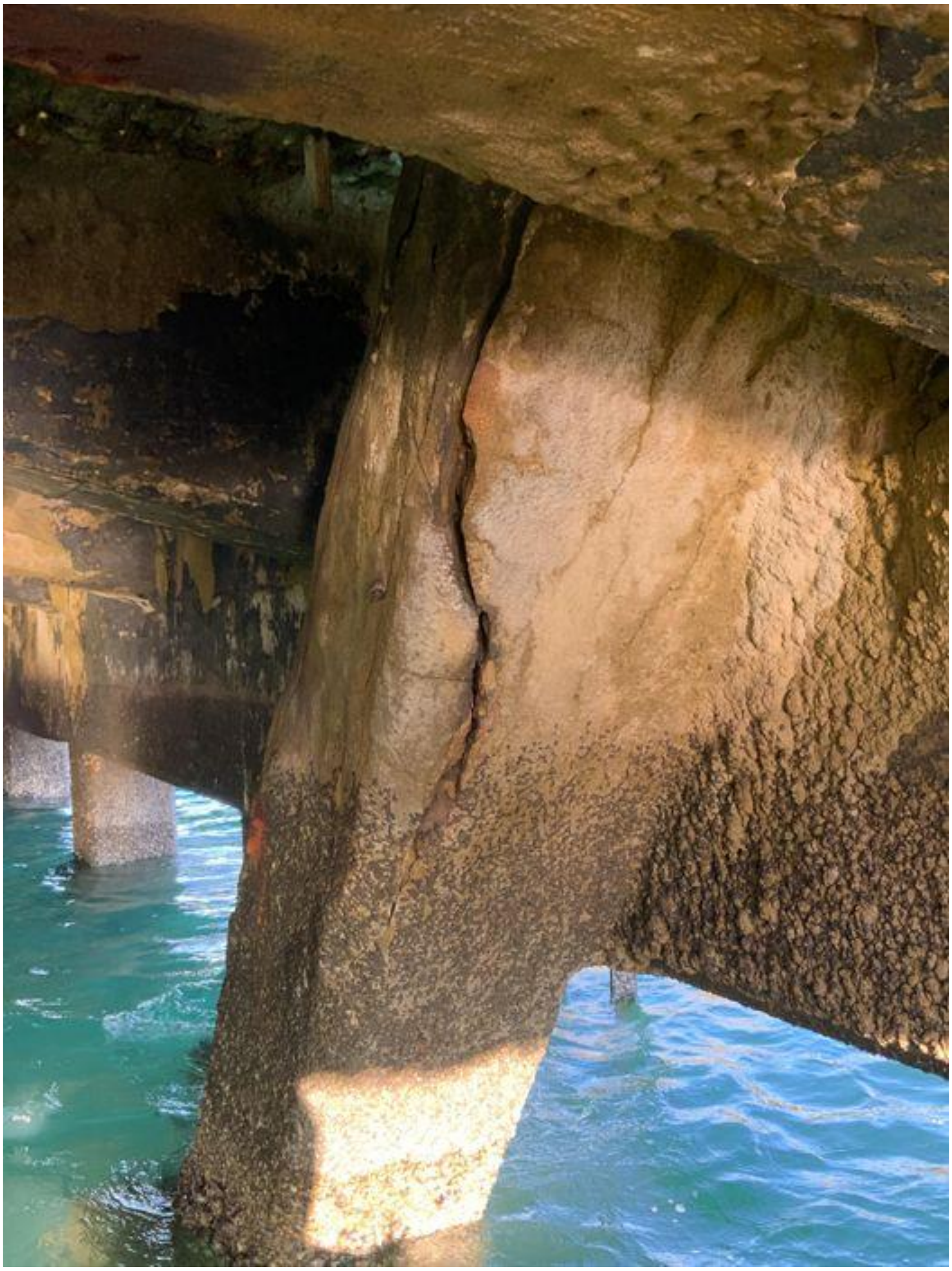
Site Photographs

Factual Inspection Record

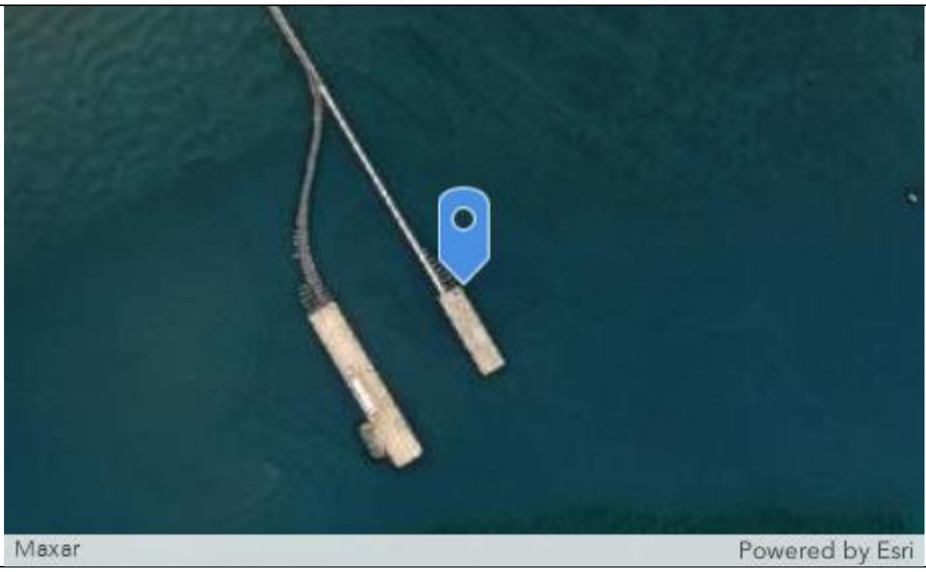
Structure	**Bowen Wharf Refurbishment Study**
Time of Inspection	August 29, 2023 7:28 AM
Observation Plan Location	
Observation Location	Below Deck
Structure Name	Public Access Wharf

Observation Details	
Observation I.D	**10**
Condition Rating (1-7)	Condition Rating 6
Component	Pile (P) 201H Raker
Material	Concrete (C)
Defect Type	Delamination (D)
Defect Quantity	2
Defect Quantity Unit	m2
Description	Large spall at top of pile. Appears to be a previous repair which is spalling / delaminating.

Site Photographs



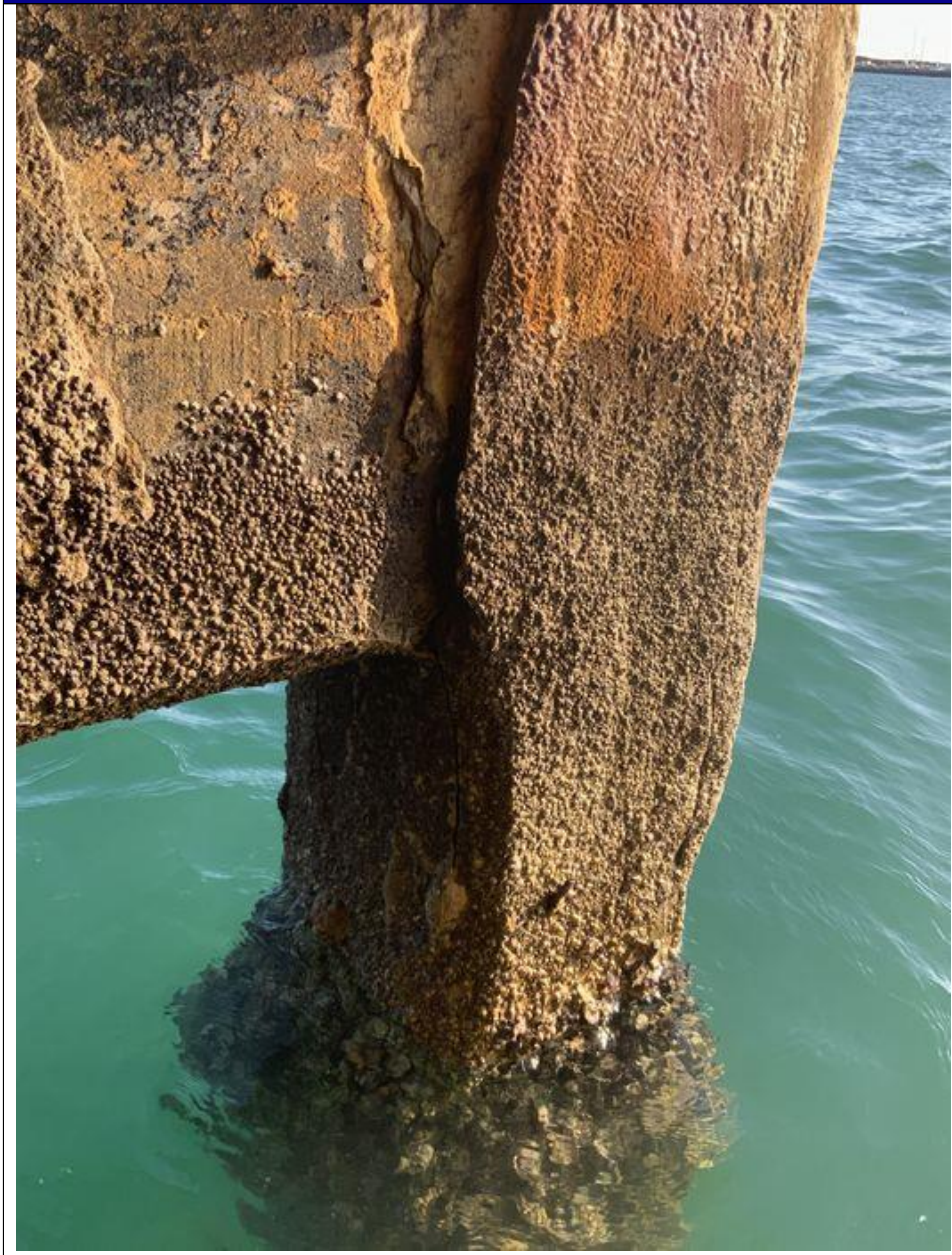
Factual Inspection Record

Structure	**Bowen Wharf Refurbishment Study**
Time of Inspection	August 29, 2023 7:33 AM
Observation Plan Location	
Observation Location	Below Deck
Structure Name	Public Access Wharf

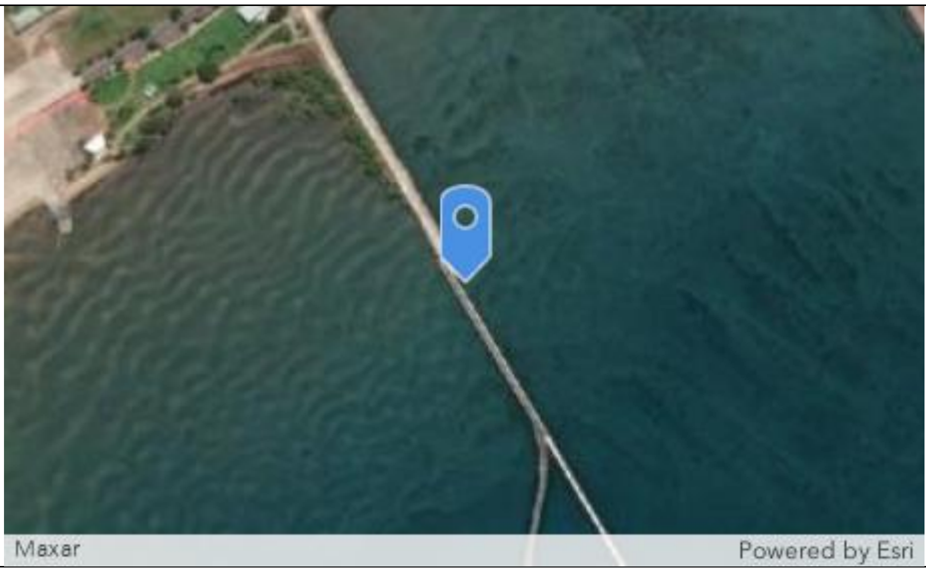
Observation Details	
Observation I.D	**11**
Condition Rating (1-7)	Condition Rating 5
Component	Pile (P) 201 I
Material	Concrete (C)
Defect Type	Delamination (D)
Defect Quantity	1
Defect Quantity Unit	m2
Description	Delamination and large cracking at top of pile. Appears to be a previous repair.

Site Photographs

Site Photographs



Factual Inspection Record

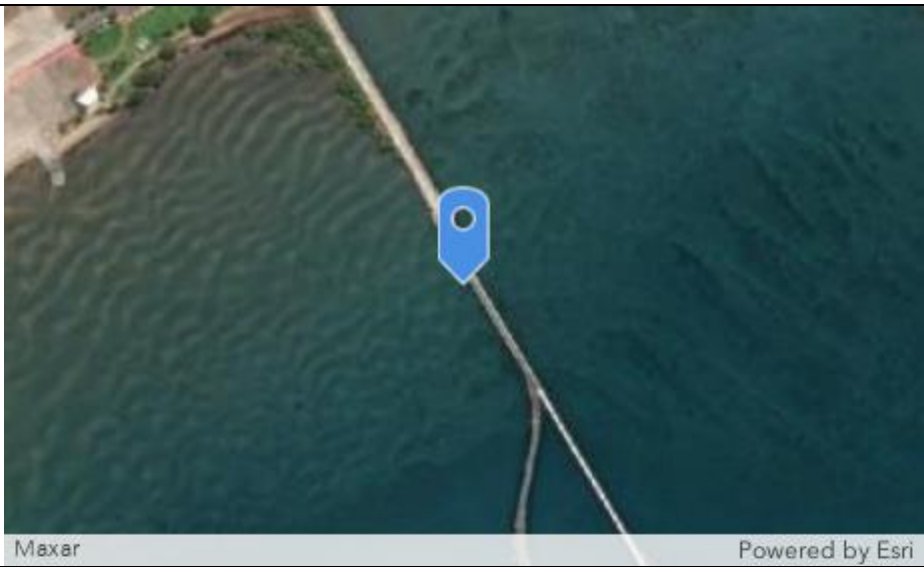
Structure	**Bowen Wharf Refurbishment Study**
Time of Inspection	August 29, 2023 7:56 AM
Observation Plan Location	
Observation Location	Below Deck
Structure Name	Middle Wharf Stem

Observation Details	
Observation I.D	**12**
Condition Rating (1-7)	Condition Rating 4
Component	Cross Head / Headstock (CH) 55
Material	Concrete (C)
Defect Type	Delamination (D)
Defect Quantity	2
Defect Quantity Unit	m2
Description	

Site Photographs

Site Photographs

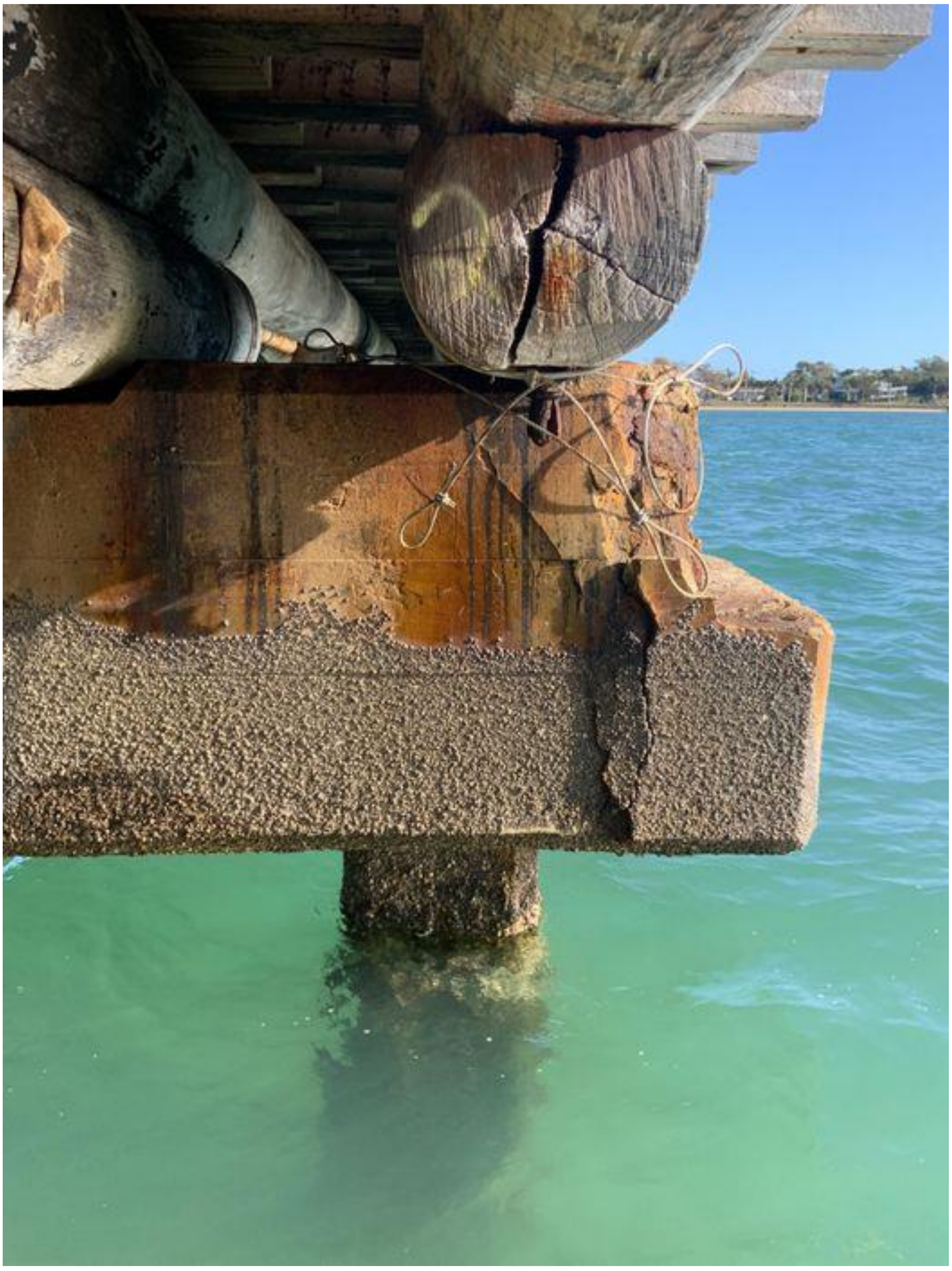
Factual Inspection Record

Structure	Bowen Wharf Refurbishment Study
Time of Inspection	August 29, 2023 8:07 AM
Observation Plan Location	
Observation Location	Below Deck
Structure Name	Middle Wharf Stem

Observation Details

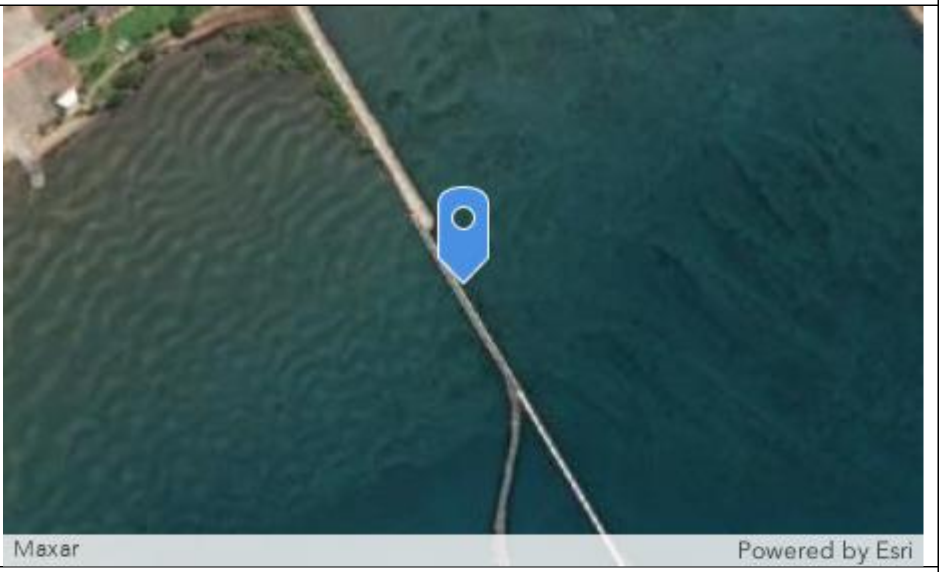
Observation I.D	13
Condition Rating (1-7)	Condition Rating 4
Component	Cross Head / Headstock (CH) 60
Material	Concrete (C)
Defect Type	Delamination (D)
Defect Quantity	2
Defect Quantity Unit	m2
Description	

Site Photographs



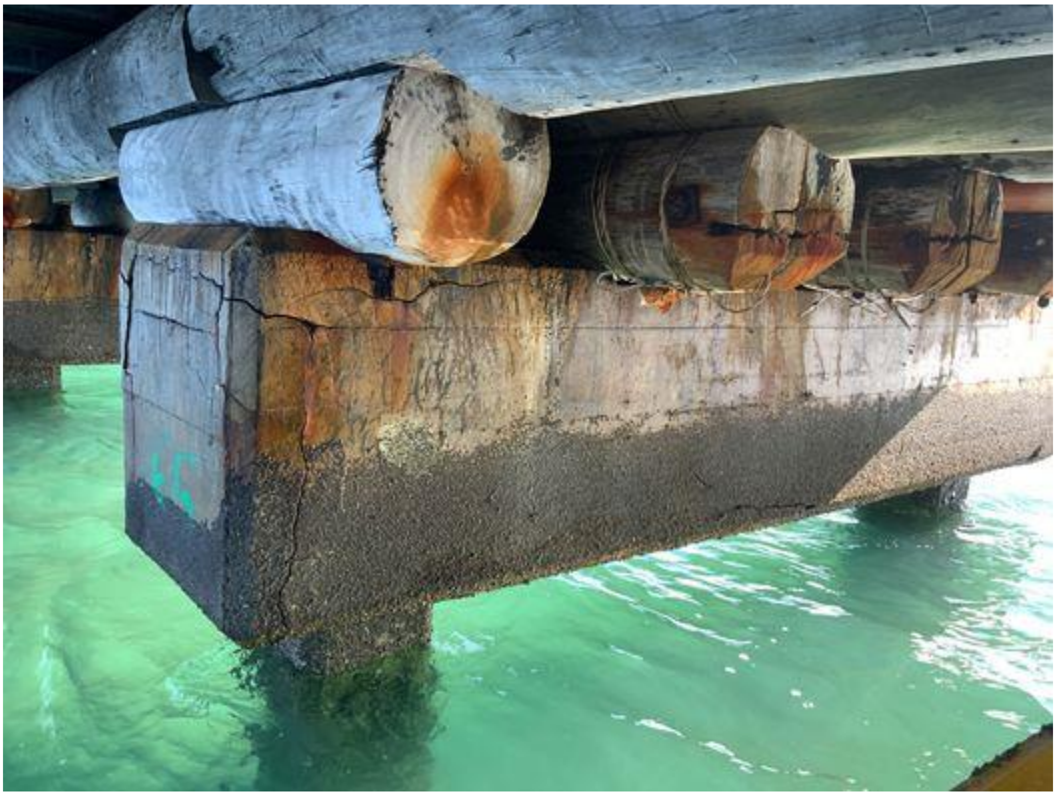
Site Photographs

Factual Inspection Record

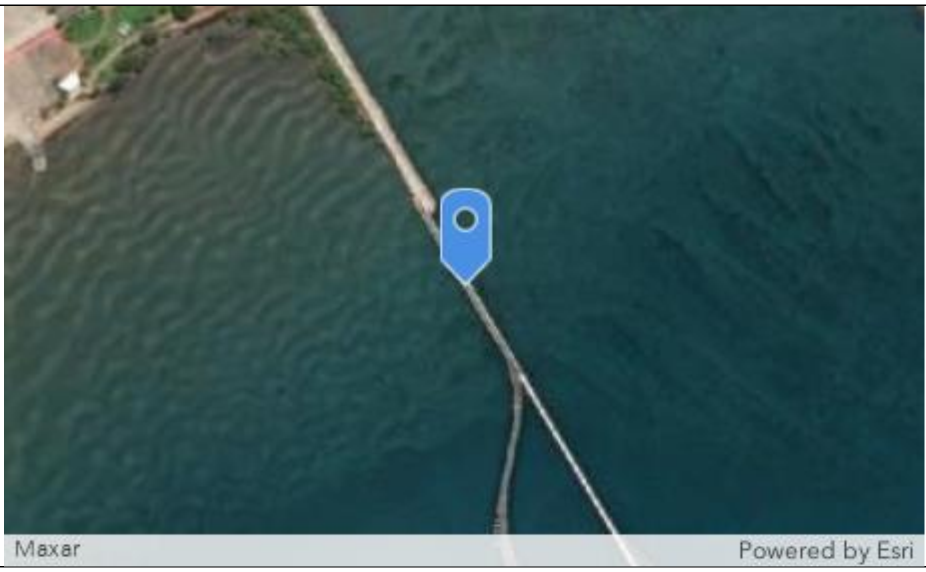
Structure	**Bowen Wharf Refurbishment Study**
Time of Inspection	August 29, 2023 8:13 AM
Observation Plan Location	
Observation Location	Below Deck
Structure Name	Middle Wharf Stem

Observation Details	
Observation I.D	**14**
Condition Rating (1-7)	Condition Rating 4
Component	Cross Head / Headstock (CH) 65
Material	Concrete (C)
Defect Type	Delamination (D)
Defect Quantity	2
Defect Quantity Unit	m2
Description	

Site Photographs



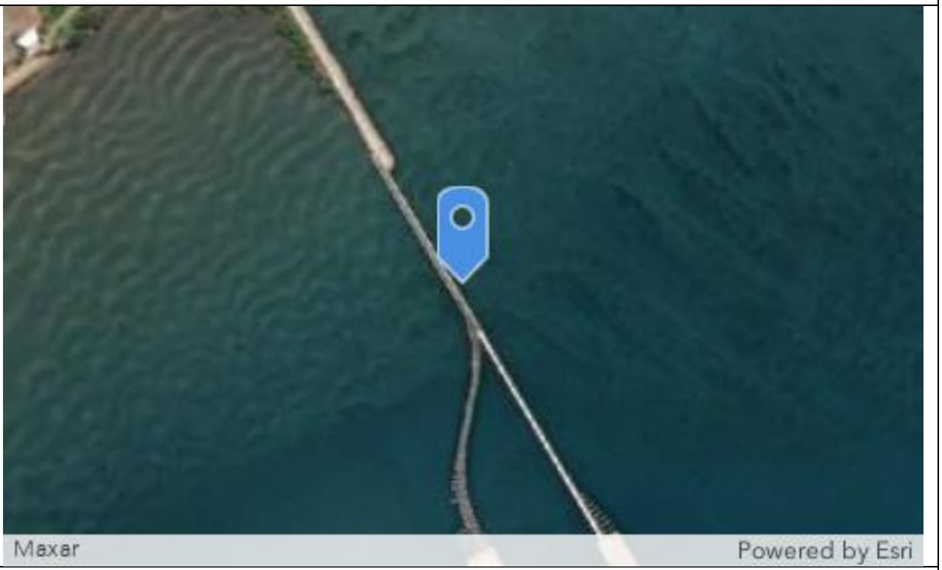
Factual Inspection Record

Structure	Bowen Wharf Refurbishment Study
Time of Inspection	August 29, 2023 8:16 AM
Observation Plan Location	
Observation Location	Below Deck
Structure Name	Middle Wharf Stem

Observation Details	
Observation I.D	**15**
Condition Rating (1-7)	Condition Rating 4
Component	Cross Head / Headstock (CH) 57
Material	Concrete (C)
Defect Type	Delamination (D)
Defect Quantity	2
Defect Quantity Unit	m2
Description	

Site Photographs

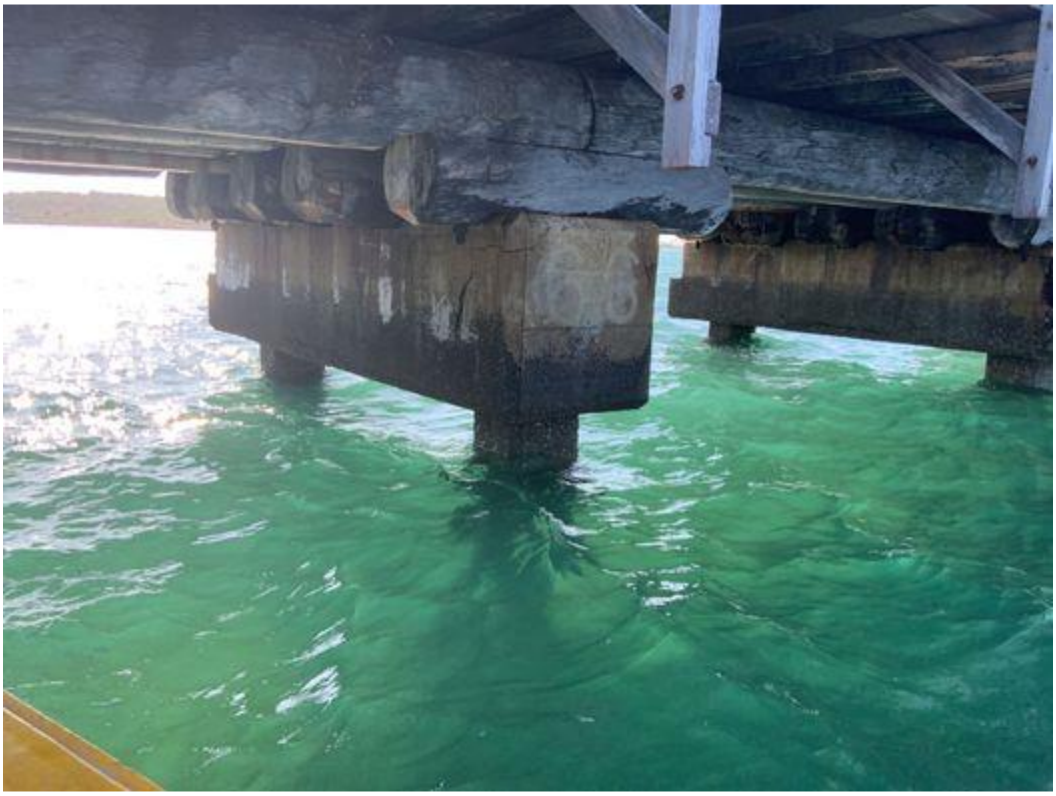
Factual Inspection Record

Structure	**Bowen Wharf Refurbishment Study**
Time of Inspection	August 29, 2023 8:28 AM
Observation Plan Location	
Observation Location	Below Deck
Structure Name	Middle Wharf Stem

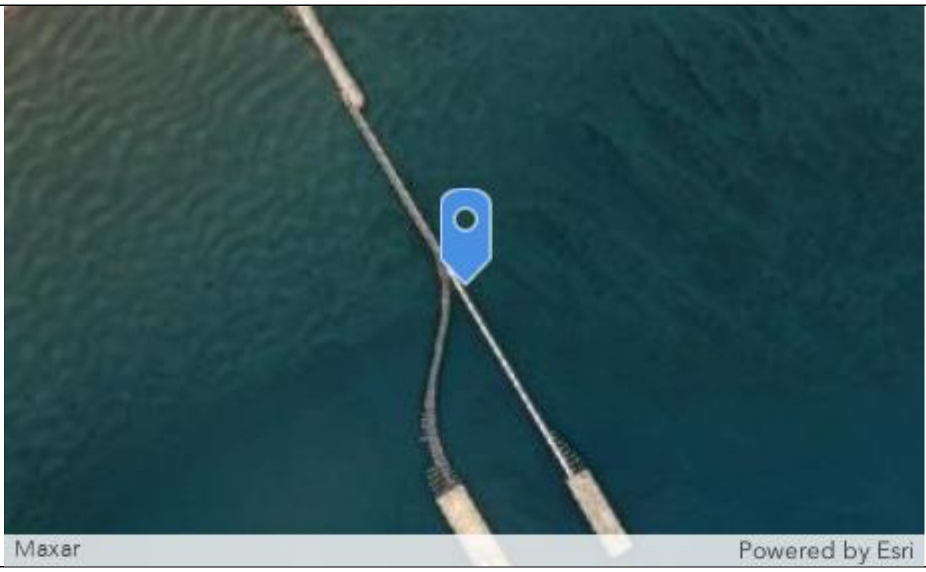
Observation Details	
Observation I.D	**16**
Condition Rating (1-7)	Condition Rating 4
Component	Cross Head / Headstock (CH) 74
Material	Concrete (C)
Defect Type	Delamination (D)
Defect Quantity	2
Defect Quantity Unit	m2
Description	

Site Photographs

Site Photographs



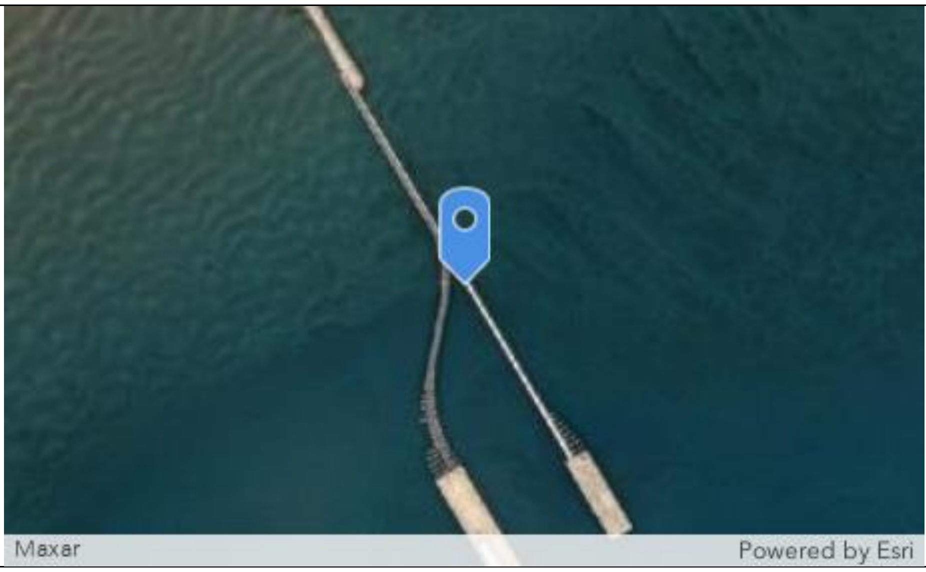
Factual Inspection Record

Structure	**Bowen Wharf Refurbishment Study**
Time of Inspection	August 29, 2023 8:42 AM
Observation Plan Location	
Observation Location	Below Deck
Structure Name	Outer Wharf Stem

Observation Details	
Observation I.D	**17**
Condition Rating (1-7)	Condition Rating 4
Component	Cross Head / Headstock (CH) 82
Material	Concrete (C)
Defect Type	Delamination (D)
Defect Quantity	1.5
Defect Quantity Unit	m2
Description	

Site Photographs

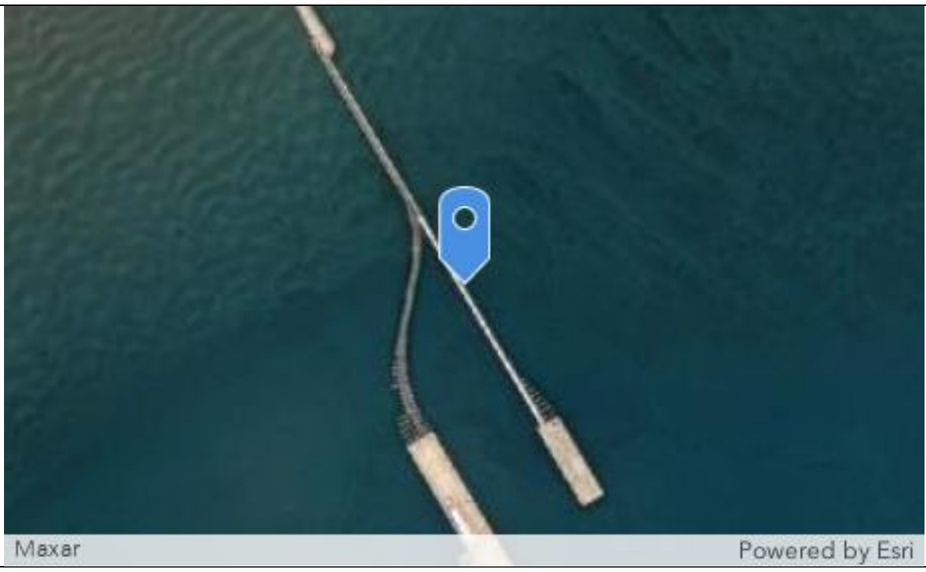
Factual Inspection Record

Structure	**Bowen Wharf Refurbishment Study**
Time of Inspection	August 29, 2023 8:48 AM
Observation Plan Location	
Observation Location	Below Deck
Structure Name	Outer Wharf Stem

Observation Details	
Observation I.D	**18**
Condition Rating (1-7)	Condition Rating 5
Component	Cross Head / Headstock (CH) 87
Material	Concrete (C)
Defect Type	Delamination (D)
Defect Quantity	3
Defect Quantity Unit	m2
Description	

Site Photographs

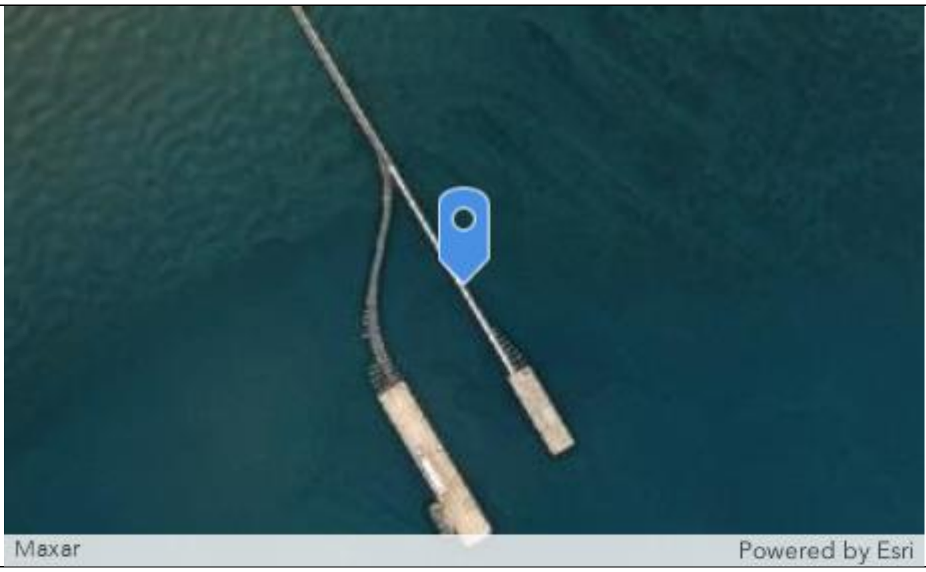
Factual Inspection Record

Structure	Bowen Wharf Refurbishment Study
Time of Inspection	August 29, 2023 8:54 AM
Observation Plan Location	
Observation Location	Below Deck
Structure Name	Outer Wharf Stem

Observation Details	
Observation I.D	**19**
Condition Rating (1-7)	Condition Rating 4
Component	Cross Head / Headstock (CH) 95
Material	Concrete (C)
Defect Type	Delamination (D)
Defect Quantity	2
Defect Quantity Unit	m2
Description	

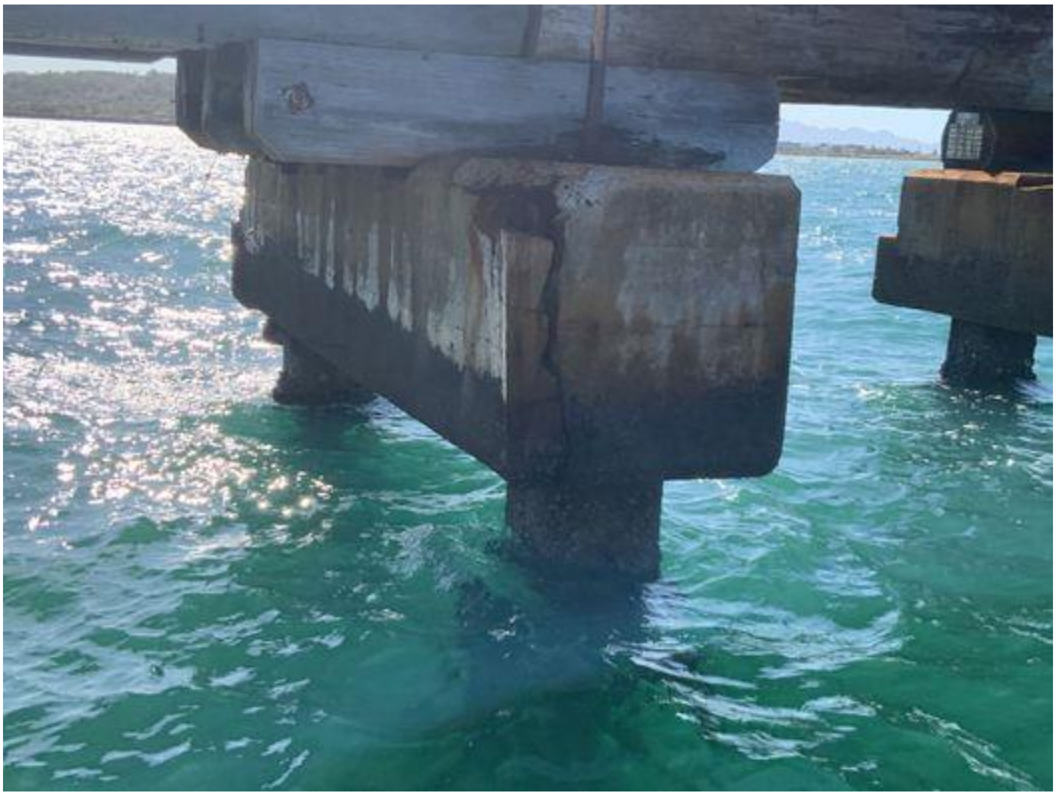
Site Photographs

Factual Inspection Record

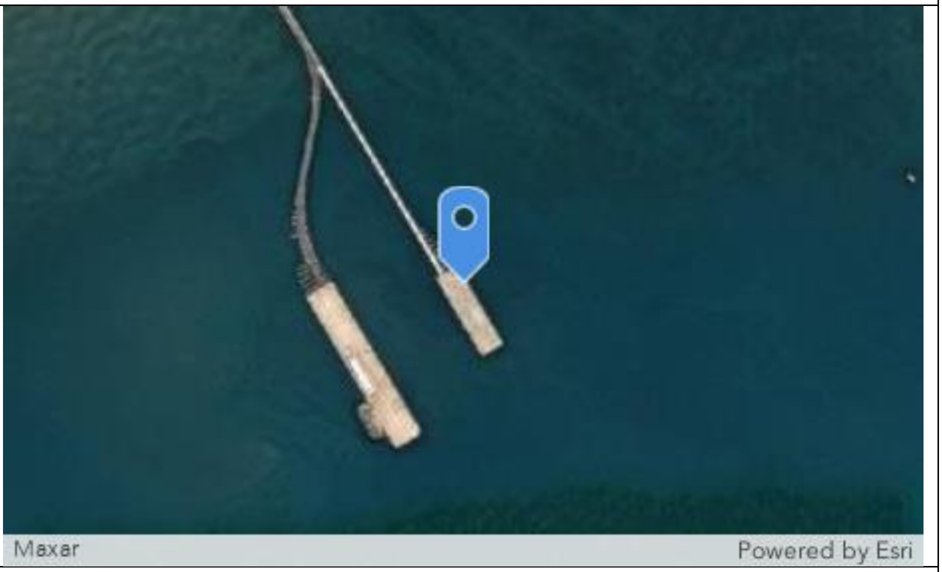
Structure	**Bowen Wharf Refurbishment Study**
Time of Inspection	August 29, 2023 8:57 AM
Observation Plan Location	
Observation Location	Below Deck
Structure Name	Outer Wharf Stem

Observation Details	
Observation I.D	**20**
Condition Rating (1-7)	Condition Rating 5
Component	Cross Head / Headstock (CH) 104
Material	Concrete (C)
Defect Type	Delamination (D)
Defect Quantity	3
Defect Quantity Unit	m2
Description	

Site Photographs



Factual Inspection Record

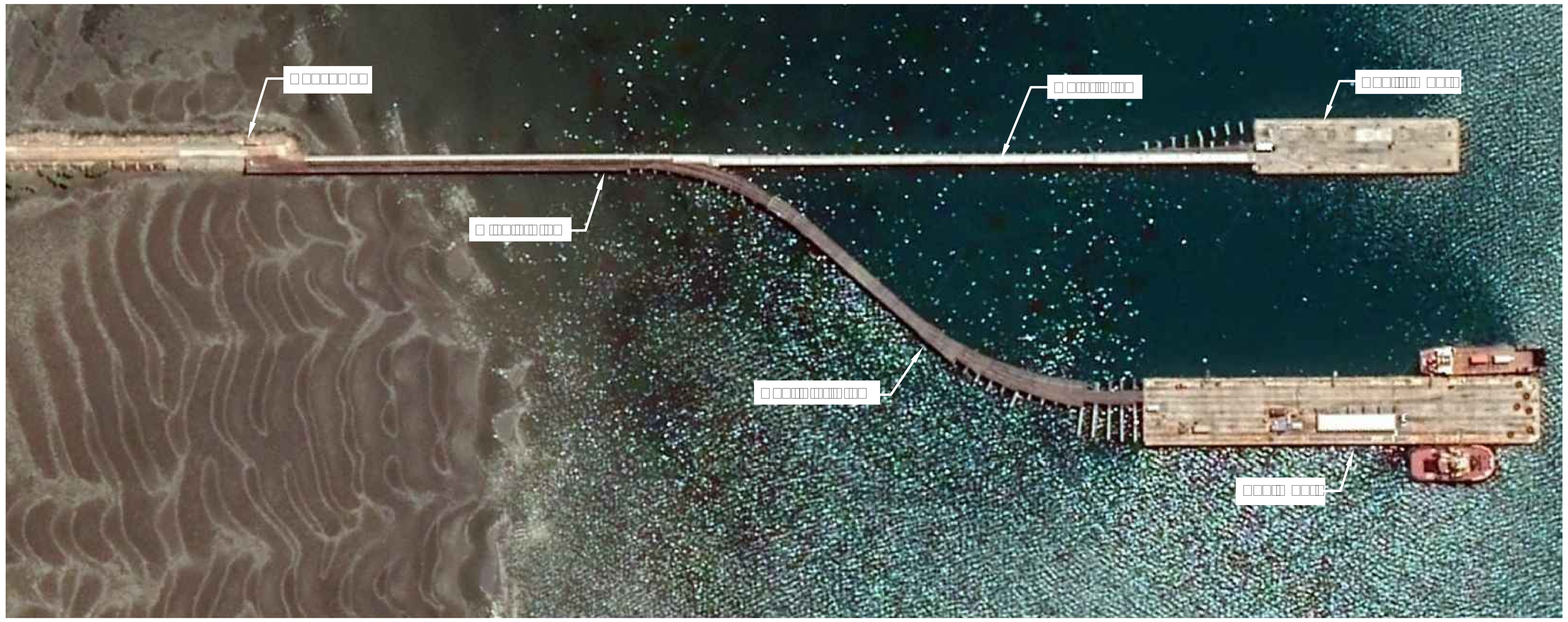
Structure	**Bowen Wharf Refurbishment Study**
Time of Inspection	August 29, 2023 9:14 AM
Observation Plan Location	
Observation Location	Below Deck
Structure Name	Public Access Wharf

Observation Details	
Observation I.D	**21**
Condition Rating (1-7)	Condition Rating 5
Component	Cross Head / Headstock (CH) 204 F — I
Material	Concrete (C)
Defect Type	Cracking (C)
Defect Quantity	3
Defect Quantity Unit	m
Description	

Site Photographs

Appendix B Concept Sketches

BOWEN WHARF REFURBISHMENT STUDY

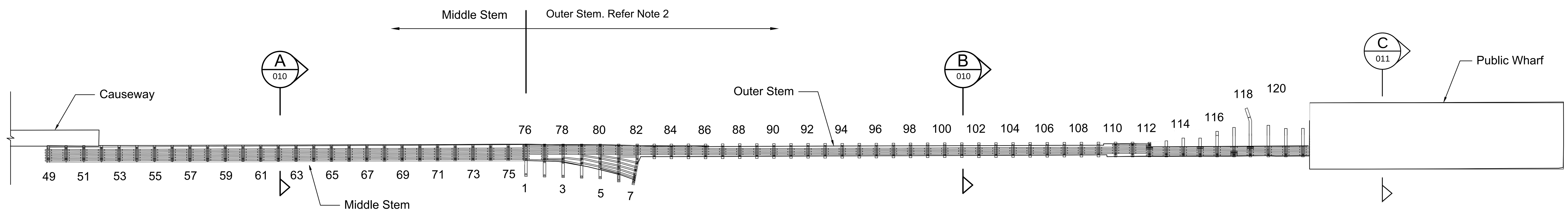


Drawing Index

SCMC-23029-SKE-001 - Locality Plan and Drawing Index
SCMC-23029-SKE-005 - General Arrangement
SCMC-23029-SKE-010 - Typical Sections Sheet 1
SCMC-23029-SKE-011 - Typical Sections Sheet 2
SCMC-23029-SKE-015 - Demolition Plan
SCMC-23029-SKE-016 - Demolition Sections Sheet 1
SCMC-23029-SKE-025 - Stem Pile and Headstock Repair
SCMC-23029-SKE-030 - Stem Girder Replacement Sheet 1
SCMC-23029-SKE-031 - Stem Girder Replacement Sheet 2
SCMC-23029-SKE-035 - Stem Corbel Replacement Sheet 1
SCMC-23029-SKE-036 - Stem Corbel Replacement Sheet 2
SCMC-23029-SKE-040 - Stem Corbel Repair Sheet 1
SCMC-23029-SKE-041 - Stem Corbel Repair Sheet 2
SCMC-23029-SKE-050 - Public Wharf General Arrangement
SCMC-23029-SKE-055 - Public Wharf Repair Sheet 1
SCMC-23029-SKE-056 - Public Wharf Repair Sheet 2
SCMC-23029-SKE-060 - Public Wharf Existing Condition Photos

NOT FOR CONSTRUCTION

SHORELINE CIVIL AND MARINE CONSULTING			SKETCH TITLE: **LOCALITY PLAN AND DRAWING INDEX** PROJECT NAME: BOWEN WHARF REFURBISHMENT STUDY	
DRAWING SCALE: NTS	DATE: 06/10/2023	ORIG. SIZE: A1	SKETCH NO.: SCMC-23029-SKE-001	REVISION: 0
DESIGNER / ENGINEER: M. KELLEHER				



Bowen Wharf General Arrangement
N.T.S.

NOTES
1. Unless noted otherwise, these notes apply to all drawings in this set.

2. The datum for all levels shall be Chart Datum (CD):

Tidal plane	Level (mCD)	Level (mAHD)
HAT - Highest Astronomical Tide	3.73	1.95
MHWS - Mean High Water Springs	2.83	1.05
MHWN - Mean High Water Neap	2.21	0.43
AHD – Australian Height Datum	1.78	0
MSL - Mean Sea Level	1.76	-0.02
MLWN - Mean Low Water Neap	1.31	-0.47
MLWS - Mean Low Water Springs	0.67	-1.11
LAT - Lowest Astronomical Tide	0.00	-1.78

3. Design Loading:
- 152 kN fire truck (middle stem only)
- 5 kPa area load on outer stem and public wharf (note ambulance expected to be similar order of magnitude)
- 16 kN ATV equivalent to RTV-X1120

2. Nominal allowances for replacement/repair of deteriorated corbels, deck planks, kerbs, wheel guides and deck overlay.

3. Seven additional safety ladders required to meet AS4997-2005.

4. Timber requirements as follows:

Timber Girders:	Timber Deck Planks:	Timber Cross Beams:
- Length: 6m - Diameter: 400mm SED (small end diameter) - Strength grade: F22 or above - Treatment requirements: H4 (Tanalised Ecowood with Tanatone) - Min Durability Class 2 - Seasoning requirements: Unseasoned Note: corbels are similar but 2m long	- Length: 7m - Sawn, fully seasoned or partially seasoned timber - Section: 220mm width x 100mm depth - Strength grade: Min. F17 - Treatment requirements: H4 (Tanalised Ecowood with Tanatone) - Min Durability Class 2	- Length: 6m - Sawn, fully seasoned or partially seasoned timber - Section: 230mm width x 120mm depth - Strength grade: Min. F17 - Treatment requirements: H4 (Tanalised Ecowood with Tanatone) - Min Durability Class 2

5. All fasteners to be Stainless Grade A4-70. Expected deck plank to girder/cross beam fixings to be M12 150 long CS coach screws, two per connection. Expected kerb to deck fixings to be M12 280 long CS coach screws, one per connection.

6. Handrails to be painted and compliant with AS1657 (Moddex TR20 or similar). NQBP to consult with Council to confirm child safety of handrail.

7. Lockable traffic bollards to be provided at entrance to Middle Stem and Outer Stem to prevent unauthorised vehicles from accessing the Middle Stem, Outer Stem and Wharf to be provided.

8. A crocodile and stinging jelly fish safety managment plan to be prepared, approved by the Principal, and implemented prior to any diving work and/or work close to the water.

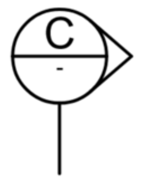
9. Pile lengths, penetration below seabed and founding soil conditions unknown. To be confirmed on site.

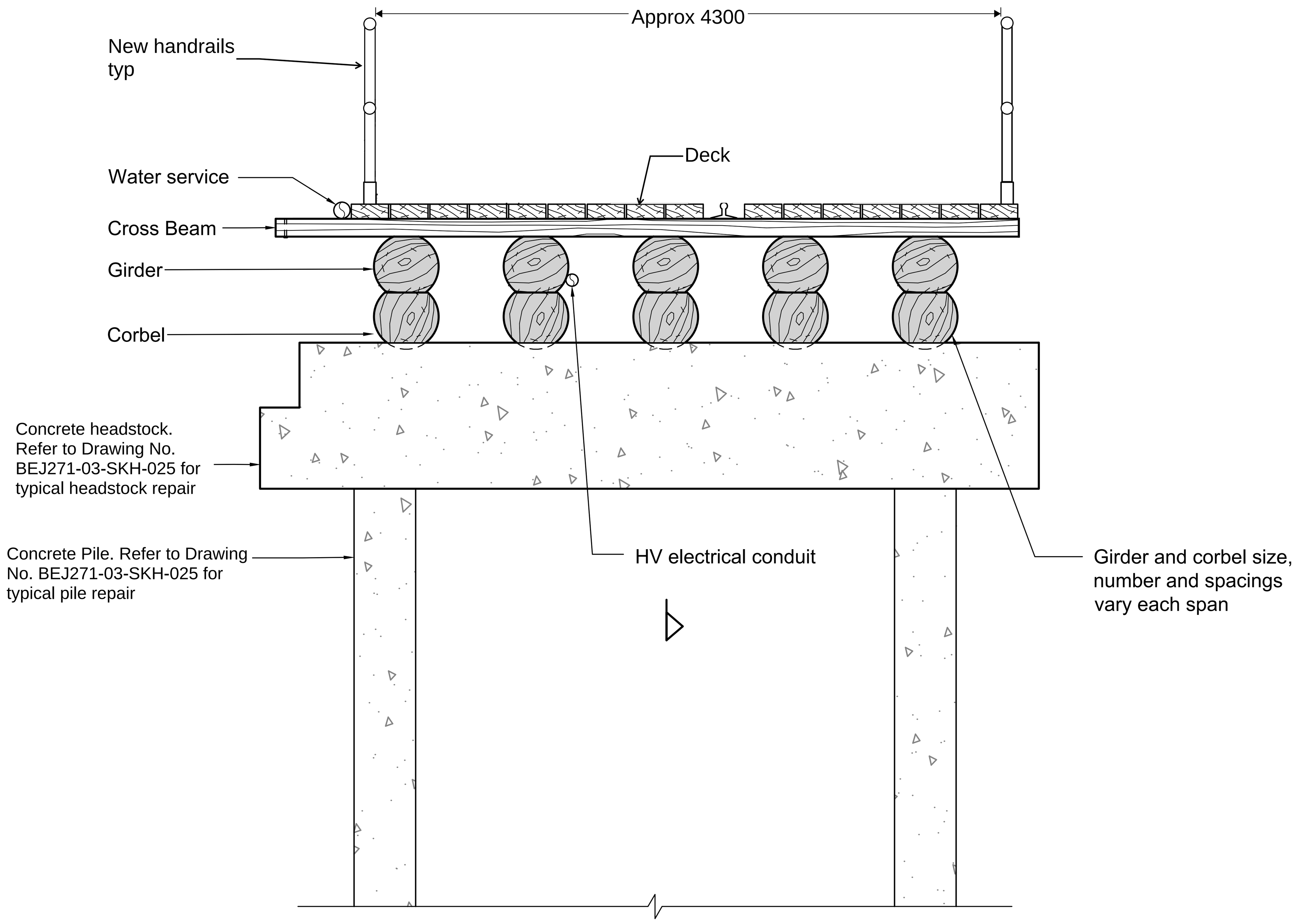
NOT FOR CONSTRUCTION

SHORELINE CIVIL AND MARINE CONSULTING

SKETCH TITLE	GENERAL ARRANGEMENT
PROJECT NAME	BOWEN WHARF REFURBISHMENT STUDY
DRAWING SCALE	NTS
DATE	06/10/2023
ORIG. SIZE	A1
SKETCH NO.	SCMC-23029-SKE-005
REVISION	0
DESIGNER / ENGINEER:	M. KELLEHER

Do not scale





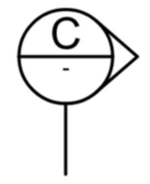
Middle Stem Typical Cross Section A 005
N.T.S.

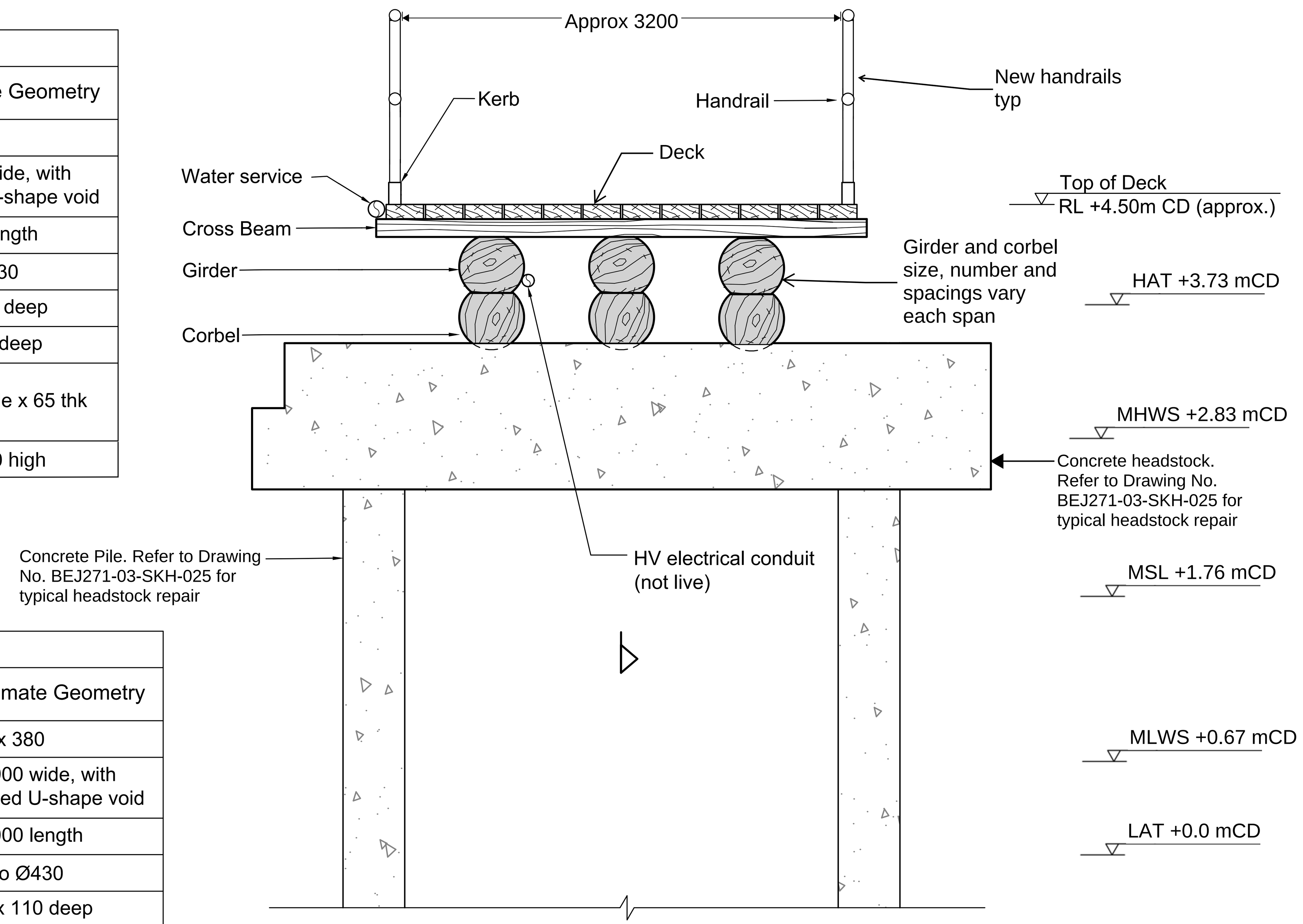
Middle Stem Geometry

Element	Material	Typical Approximate Geometry
Piles	Concrete	380 x 380
Headstock	Concrete	900 deep x 900 wide, with 400 x 400 inverted U-shape void
Corbels	Timber	Ø400, 2000 length
Girders	Timber	Ø380 to Ø430
Cross Beams	Timber	230 wide x 110 deep
Deck	Timber	230 wide x 90 deep
Wheel Guides	Timber. Bridge decking plywood	2440 long x 600 wide x 65 thk
Kerbs	Timber	100 wide x 200 high

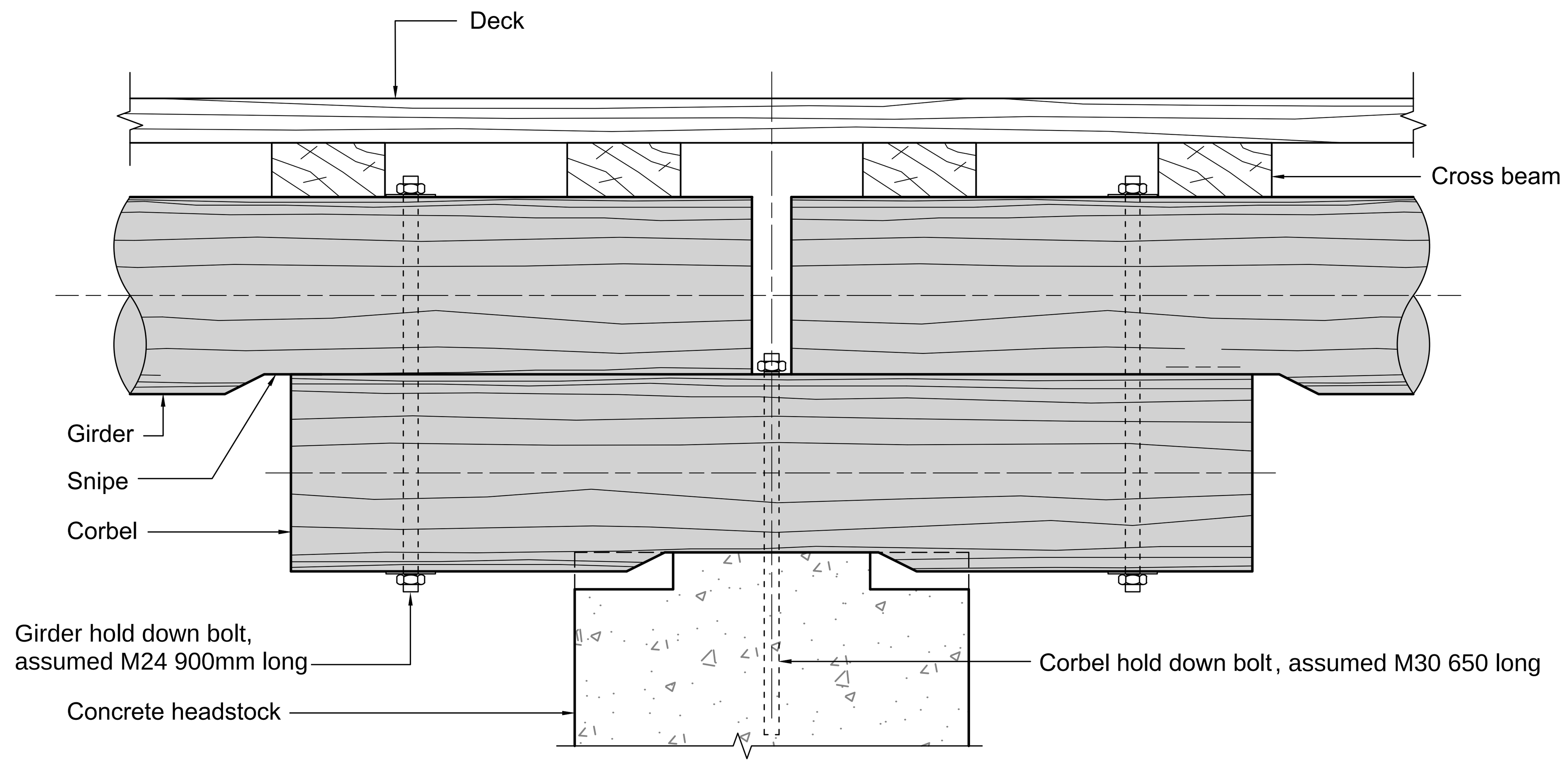
Outer Stem Geometry

Element	Material	Typical Approximate Geometry
Piles	Concrete	380 x 380
Headstock	Concrete	900 deep x 900 wide, with 400 x 400 inverted U-shape void
Corbels	Timber	Ø400, 2000 length
Girders	Timber	Ø380 to Ø430
Cross Beams	Timber	230 wide x 110 deep
Deck	Timber	220 wide x 100 deep
Deck Overlay	Timber (Structural form ply)	Full width, 2400x1200x18 sheets
Kerbs	Timber	100 wide x 200 high





Outer Stem Typical Cross Section B 005
N.T.S.



Section C -
N.T.S.
Typical arrangement at headstock on middle stem and outer stem.

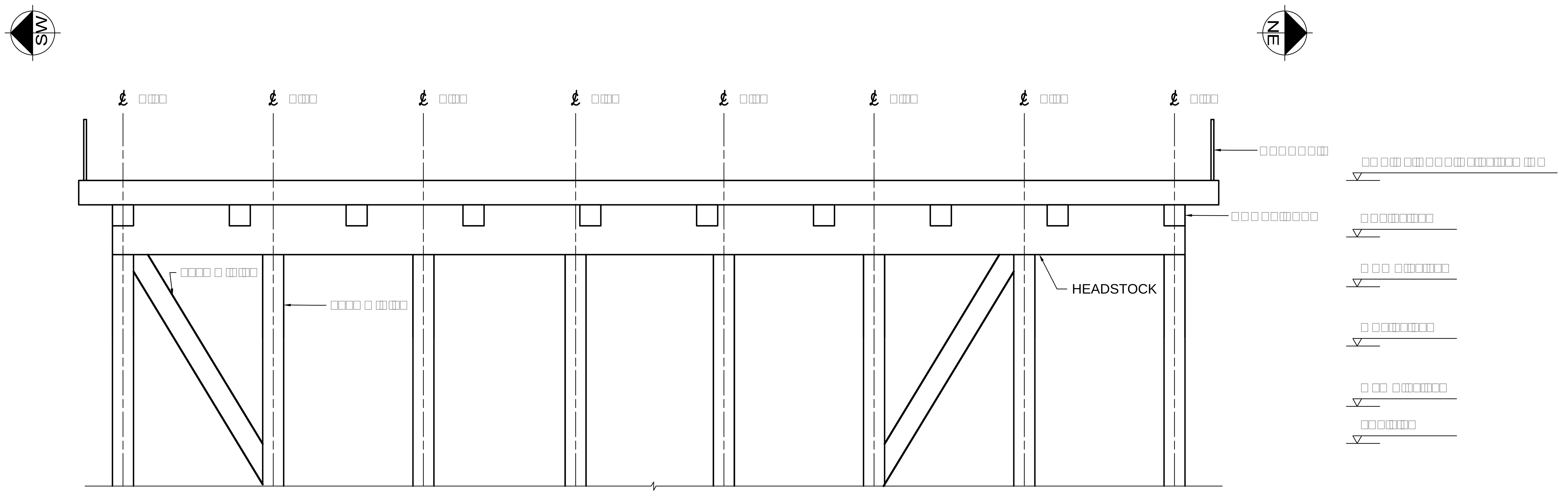
NOTES
1. Levels shown indicatively only.

NOT FOR CONSTRUCTION

SHORELINE CIVIL AND MARINE CONSULTING

SKETCH TITLE	TYPICAL SECTIONS SHEET 1
PROJECT NAME	BOWEN WHARF REFURBISHMENT STUDY
DRAWING SCALE	NTS
DATE	06/10/2023
DESIGNER / ENGINEER	M. KELLEHER
ORIG. SIZE	A1
SKETCH NO.	SCMC-23029-SKE-010
REVISION	0

Do not scale



PUBLIC WHARF TYPICAL CROSS SECTION (C / 005)
N.T.S.

PUBLIC WHARF GEOMETRY

ELEMENT	MATERIAL	TYPICAL APPROXIMATE GEOMETRY
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

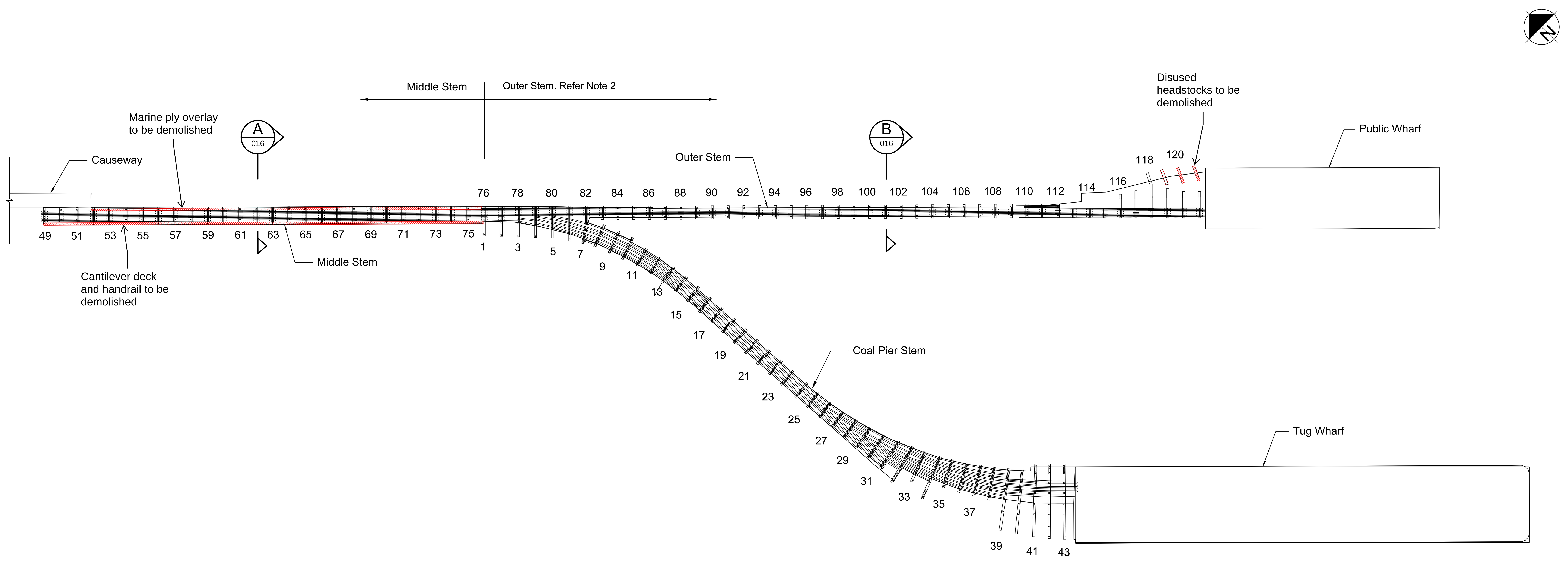
NOT FOR CONSTRUCTION

SHORELINE
CIVIL AND MARINE CONSULTING

SKETCH TITLE
TYPICAL SECTIONS SHEET 2
PROJECT NAME
BOWEN WHARF REFURBISHMENT STUDY

DRAWING SCALE	DATE	ORIG. SIZE	SKETCH NO.	REVISION
NTS	06/10/2023	A1	SCMC-23029-SKE-011	0

DESIGNER / ENGINEER: M. KELLEHER



Bowen Wharf General Arrangement - Demolition
N.T.S.

NOTES
1. All demolished piles to be fully extracted.

LEGEND

Denotes items to be demolished

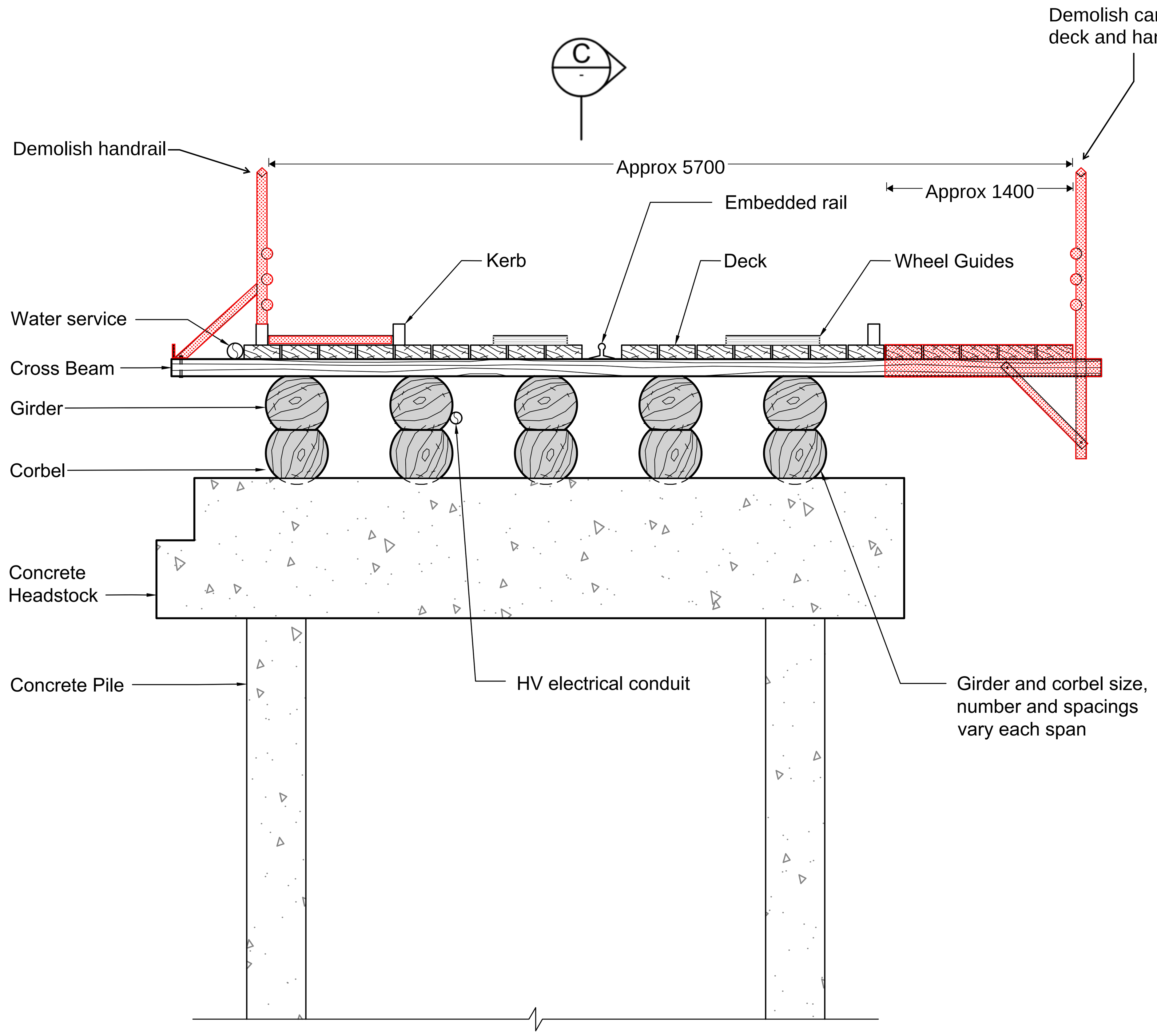
NOT FOR CONSTRUCTION

SHORELINE
CIVIL AND MARINE CONSULTING

SKETCH TITLE	
DEMOLITION PLAN	
PROJECT NAME	BOWEN WHARF REFURBISHMENT STUDY

DRAWING SCALE	DATE	ORIG. SIZE	SKETCH NO.	REVISION
NTS	06/10/2023	A1	SCMC-23029-SKE-015	0
DESIGNER / ENGINEER: M. KELLEHER				

Do not scale



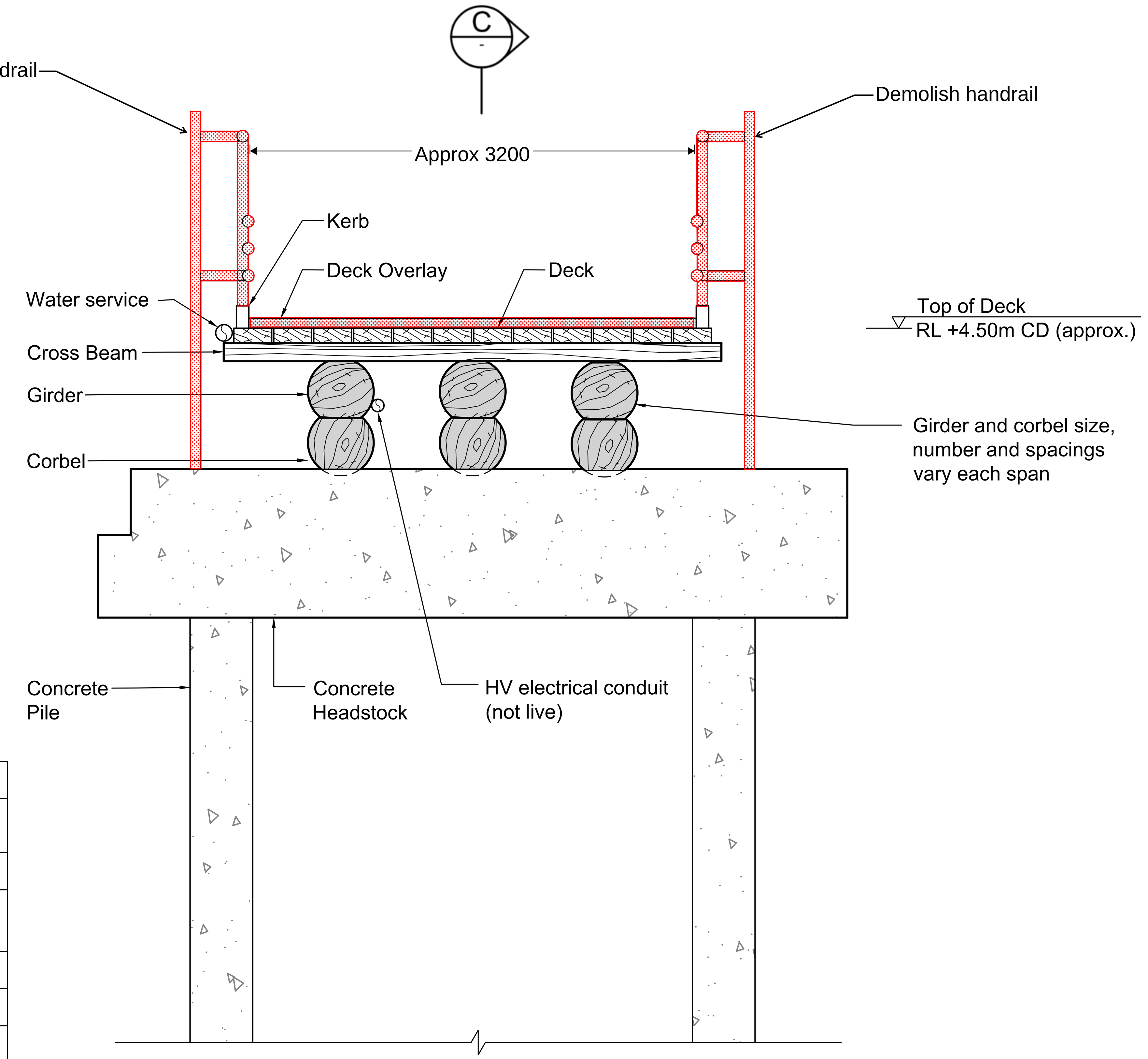
Middle Stem Typical Cross Section (A / 015)
N.T.S.

Middle Stem Geometry

Element	Material	Typical Approximate Geometry
Piles	Concrete	380 x 380
Headstock	Concrete	900 deep x 900 wide, with 400 x 400 inverted U-shape void
Corbels	Timber	Ø400, 2000 length
Girders	Timber	Ø380 to Ø430
Cross Beams	Timber	230 wide x 110 deep
Deck	Timber	230 wide x 90 deep
Wheel Guides	Timber. Bridge decking plywood	2440 long x 600 wide x 65 thk
Kerbs	Timber	100 wide x 200 high

Outer Stem Geometry

Element	Material	Typical Approximate Geometry
Piles	Concrete	380 x 380
Headstock	Concrete	900 deep x 900 wide, with 400 x 400 inverted U-shape void
Corbels	Timber	Ø400, 2000 length
Girders	Timber	Ø380 to Ø430
Cross Beams	Timber	230 wide x 110 deep
Deck	Timber	220 wide x 100 deep
Deck Overlay	Timber (Structural form ply)	Full width, 2400x1200x18 sheets
Kerbs	Timber	100 wide x 200 high



Outer Stem Typical Cross Section (B / 015)
N.T.S.

LEGEND

Denotes items to be demolished

NOT FOR CONSTRUCTION

SHORELINE CIVIL AND MARINE CONSULTING

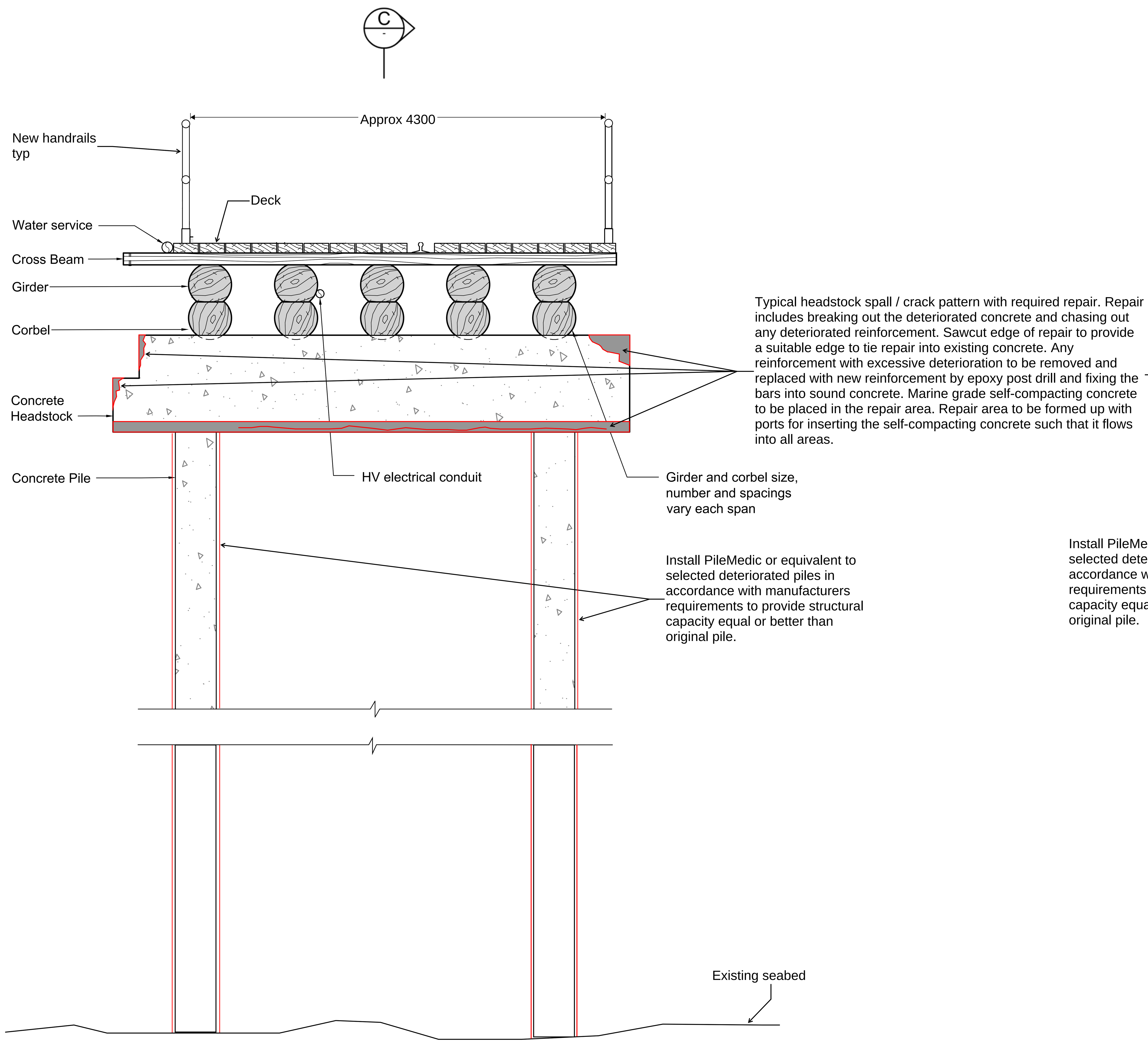
SKETCH TITLE: DEMOLITION SECTIONS SHEET 1

PROJECT NAME: BOWEN WHARF REFURBISHMENT STUDY

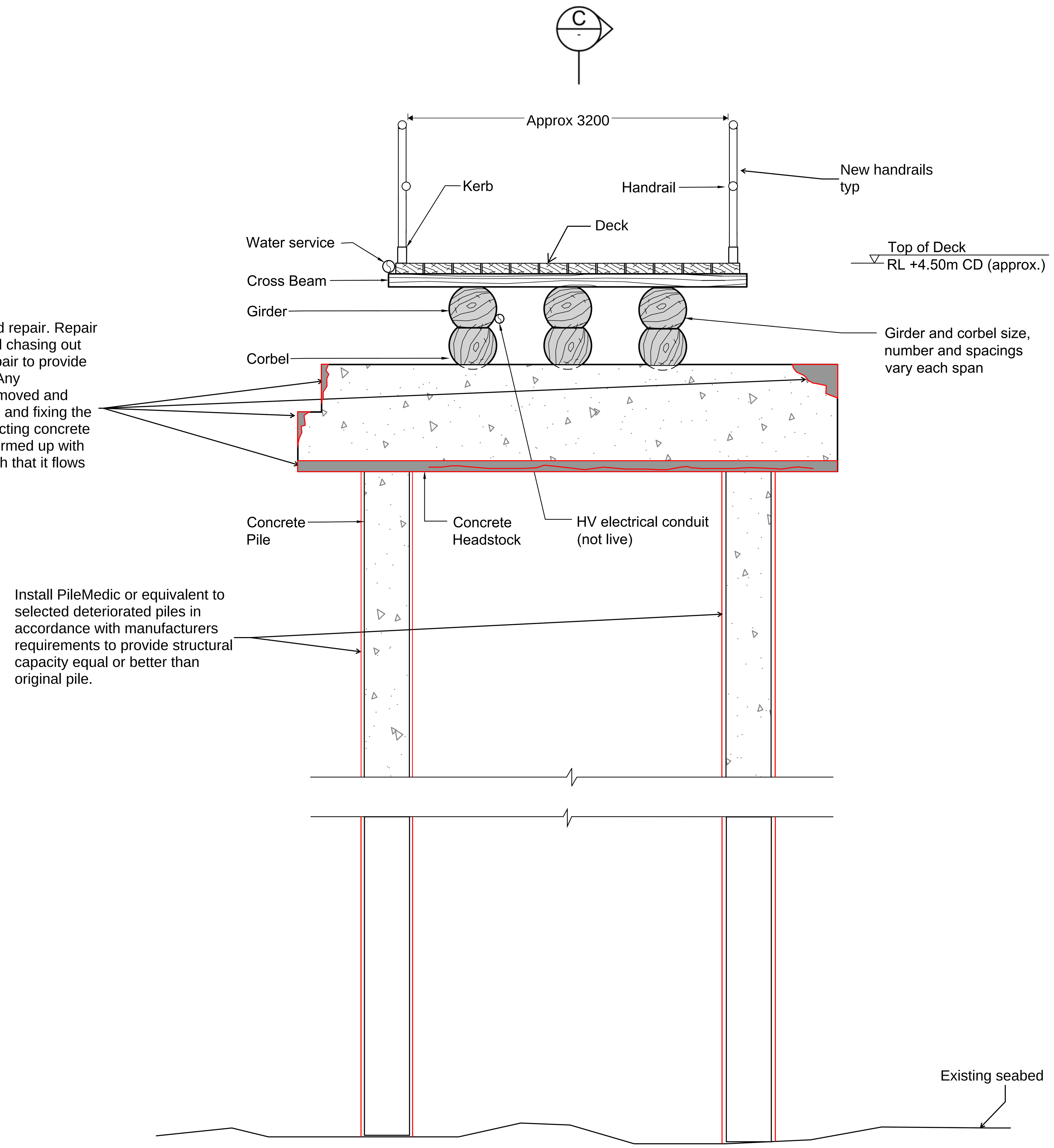
DRAWING SCALE	DATE	ORIG. SIZE	SKETCH NO.	REVISION
NTS	06/10/2023	A1	SCMC-23029-SKE-016	0

DESIGNER / ENGINEER: M. KELLEHER

Do not scale



Middle Stem Typical Cross Section A 005
N.T.S.



Outer Stem Typical Cross Section B 005
N.T.S.

NOT FOR CONSTRUCTION

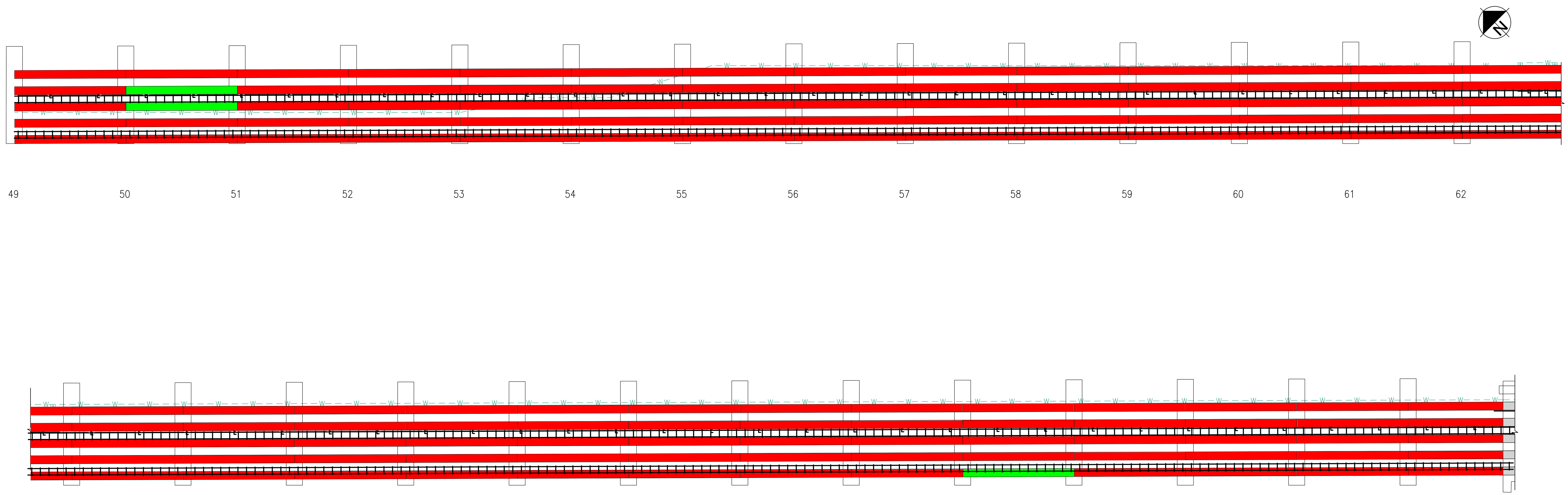
SHORELINE
CIVIL AND MARINE CONSULTING

SKETCH TITLE	**STEM PILE AND HEADSTOCK REPAIR**
PROJECT NAME	BOWEN WHARF REFURBISHMENT STUDY

DRAWING SCALE	DATE	ORIG. SIZE	SKETCH NO.	REVISION
NTS	06/10/2023	A1	SCMC-23029-SKE-025	0

DESIGNER / ENGINEER: M. KELLEHER

Do not scale



Middle Stem - Girders
N.T.S.

LEGEND - MIDDLE STEM

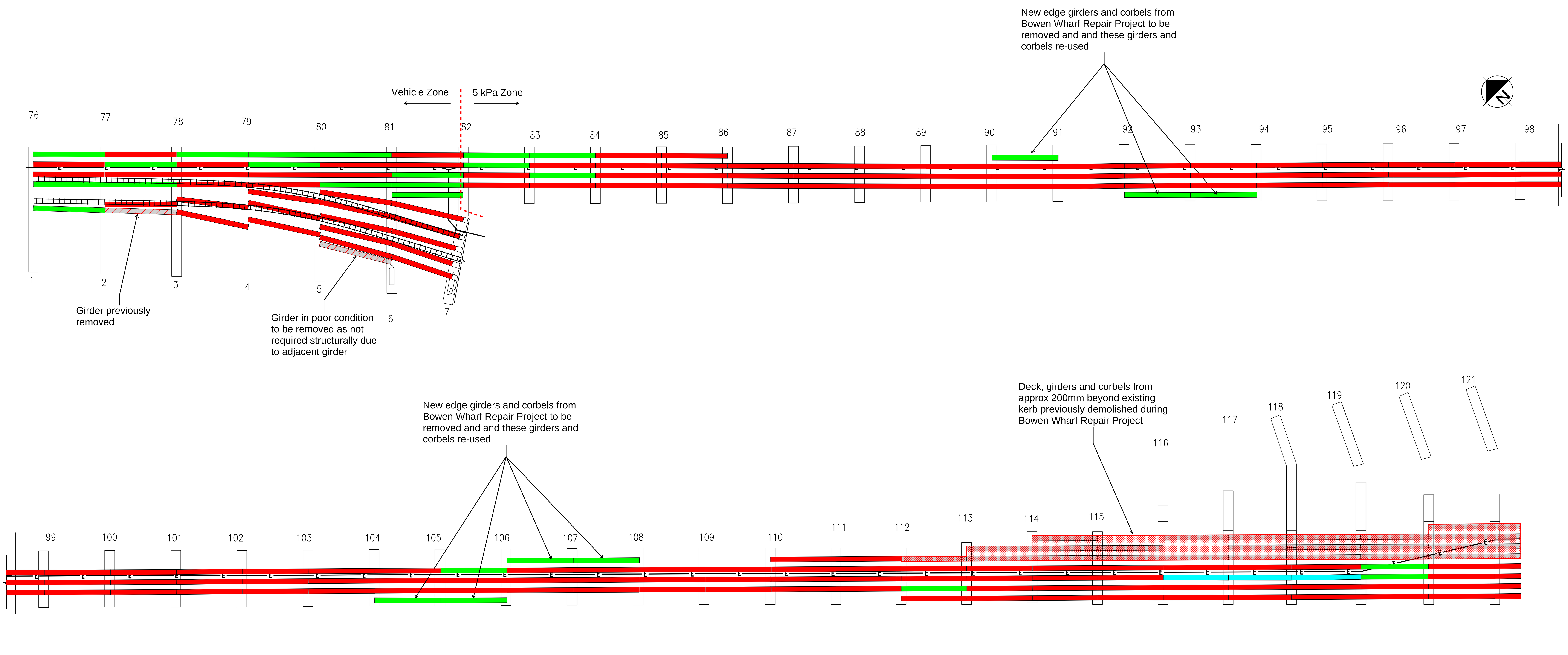
- 132 No. existing girders to be replaced
- 3 No. girder recently replaced under Bowen Wharf Repair Project
- Vehicle path (indicative only)
- HV cable location (indicative only)
- Water pipe location (indicative only)

NOTES
1. All girders to be replaced except for those recently replaced under Bowen Wharf Repair Project

NOT FOR CONSTRUCTION

SHORELINE CIVIL AND MARINE CONSULTING			SKETCH TITLE: STEM GIRDER REPLACEMENT SHEET 1 PROJECT NAME: BOWEN WHARF REFURBISHMENT STUDY	
DRAWING SCALE: NTS	DATE: 06/10/2023	ORIG. SIZE: A1	SKETCH NO.: SCMC-23029-SKE-030	REVISION: 0
DESIGNER / ENGINEER: M. KELLEHER				

Do not scale



Outer Stem - Girders

N.T.S.

LEGEND - OUTER STEM

- 154 No. existing girders to be replaced
- 28 No. girder recently replaced under Bowen Wharf Repair Project
- 3 No. add girder
- Vehicle path (indicative only)
- HV cable location (indicative only)
- Water pipe location (indicative only)

NOTES

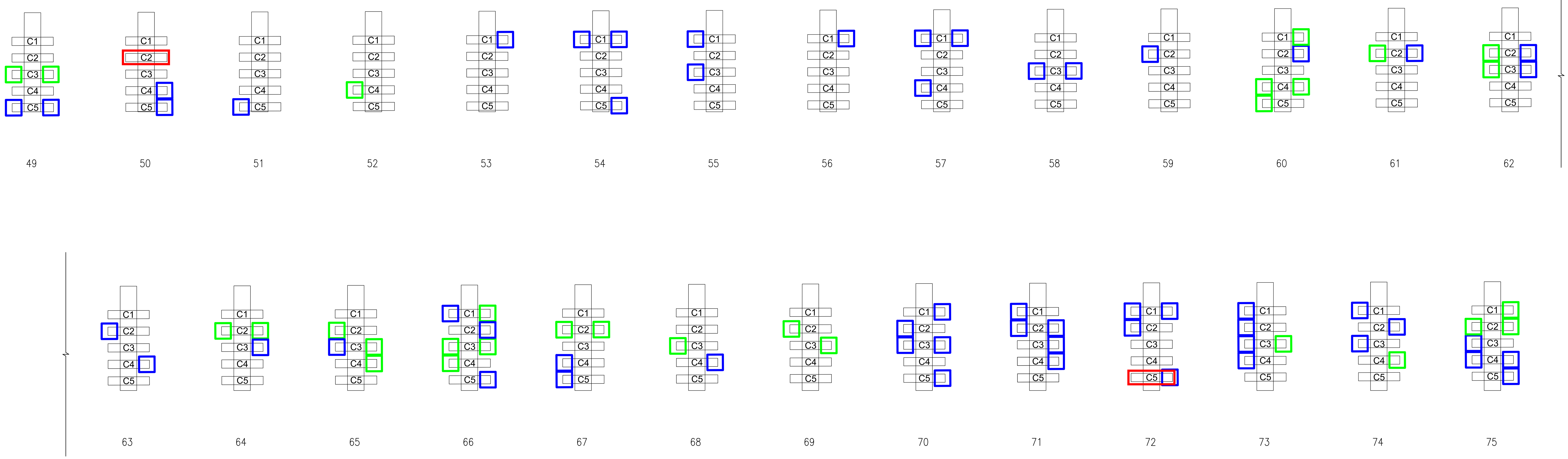
1. All girders to be replaced except for those recently replaced under Bowen Wharf Repair Project

NOT FOR CONSTRUCTION

SHORELINE CIVIL AND MARINE CONSULTING

SKETCH TITLE	**STEM GIRDER REPLACEMENT SHEET 2**
PROJECT NAME	BOWEN WHARF REFURBISHMENT STUDY
DRAWING SCALE	NTS
DATE	06/10/2023
DESIGNER / ENGINEER	M. KELLEHER
ORIG. SIZE	A1
SKETCH NO.	SCMC-23029-SKE-031
REVISION	0

Do not scale



Middle Stem - Corbels
N.T.S.

Legend

- Corbel repair Type 1 recently undertaken for Bowen Wharf Repair Project
- Corbel repair Type 2 recently undertaken for Bowen Wharf Repair Project
- Corbel replacement recently undertaken for Bowen Wharf Repair Project

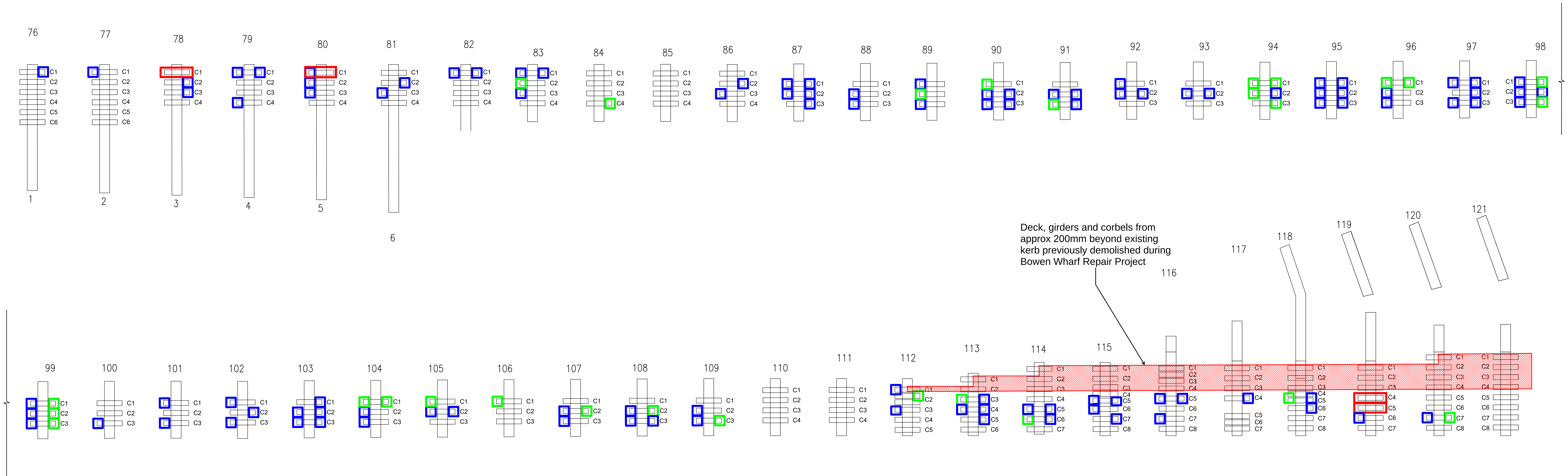
NOTES
1. All corbels to be replaced except for those recently replaced under Bowen Wharf Repair Project

NOT FOR CONSTRUCTION

SHORELINE CIVIL AND MARINE CONSULTING

SKETCH TITLE	STEM CORBEL REPLACEMENT SHEET 1
PROJECT NAME	BOWEN WHARF REFURBISHMENT STUDY
DRAWING SCALE	NTS
DATE	06/10/2023
ORIG. SIZE	A1
SKETCH NO.	SCMC-23029-SKE-035
REVISION	0
DESIGNER / ENGINEER:	M. KELLEHER

Do not scale



Outer Stem & Coal Pier Stem - Corbels
N.T.S.

Legend

- Corbel repair Type 1 recently undertaken for Bowen Wharf Repair Project
- Corbel repair Type 2 recently undertaken for Bowen Wharf Repair Project
- Corbel replacement recently undertaken for Bowen Wharf Repair Project

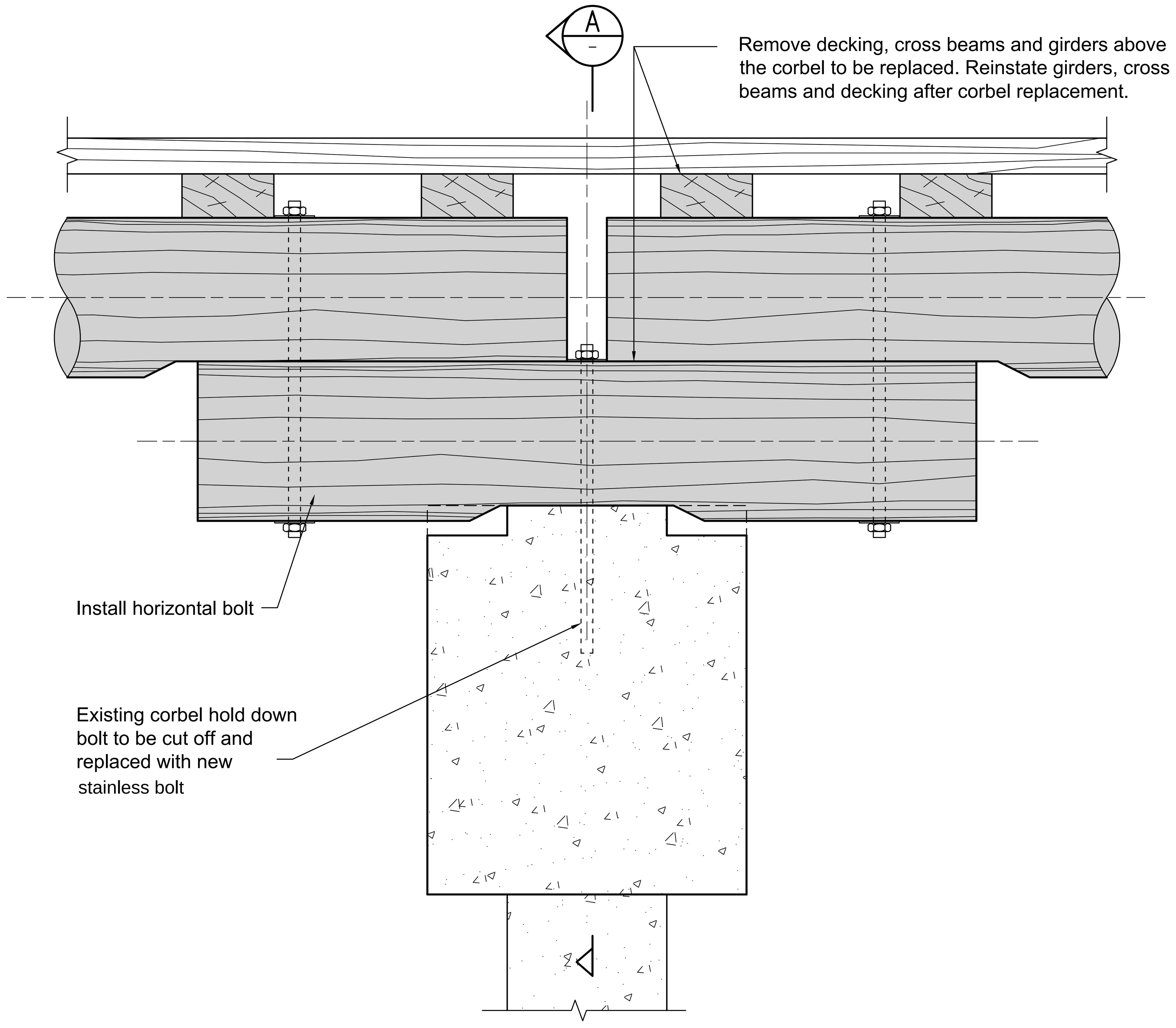
NOTES
1. All corbels to be replaced except for those recently replaced under Bowen Wharf Repair Project

NOT FOR CONSTRUCTION

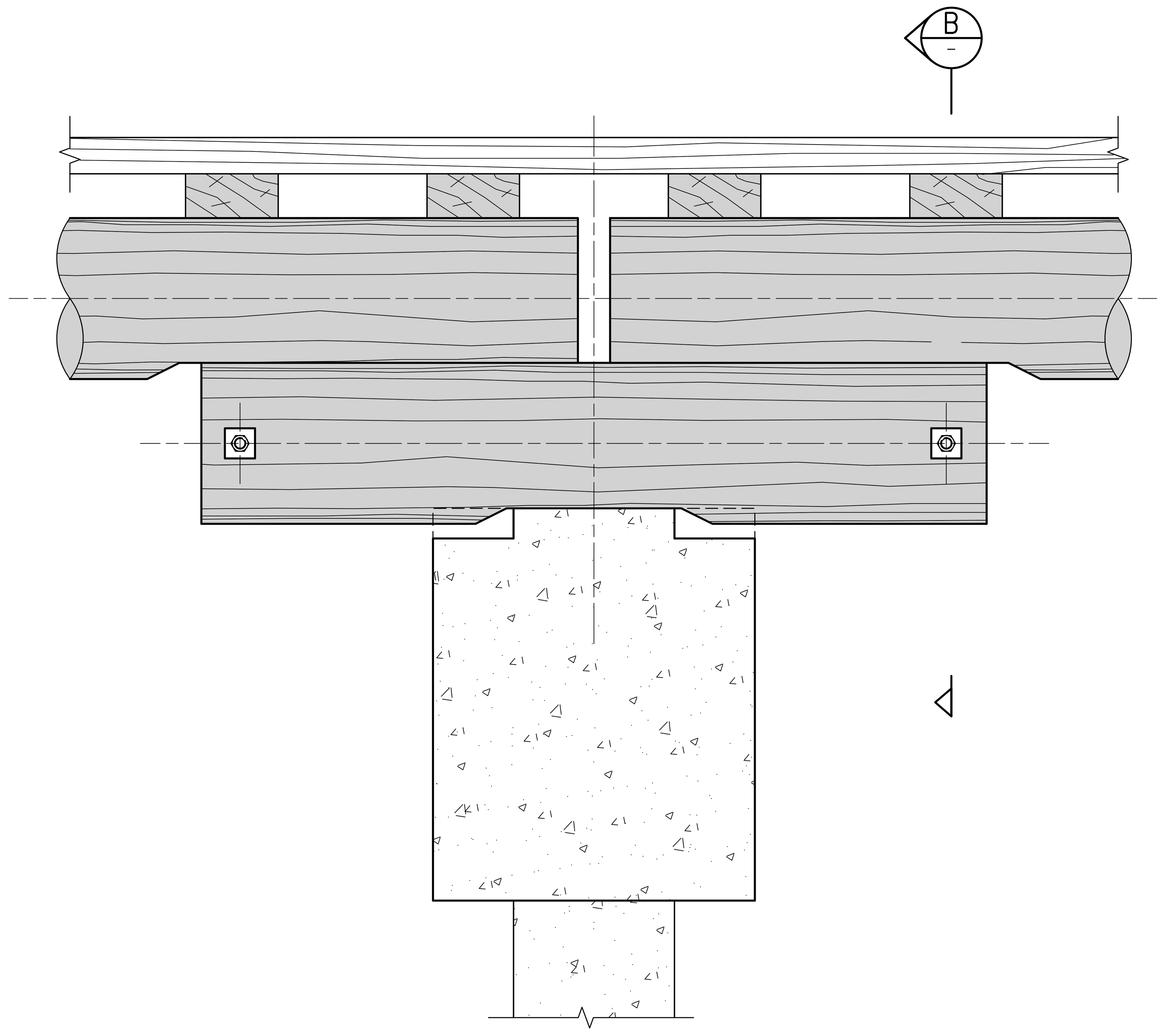
SHORELINE
CIVIL AND MARINE CONSULTING

SKETCH TITLE	STEM CORBEL REPLACEMENT SHEET 2
PROJECT NAME	BOWEN WHARF REFURBISHMENT STUDY
DRAWING SCALE	NTS
DATE	06/10/2023
ORIG. SIZE	A1
SKETCH NO.	SCMC-23029-SKE-036
REVISION	0
DESIGNER / ENGINEER	M. KELLEHER

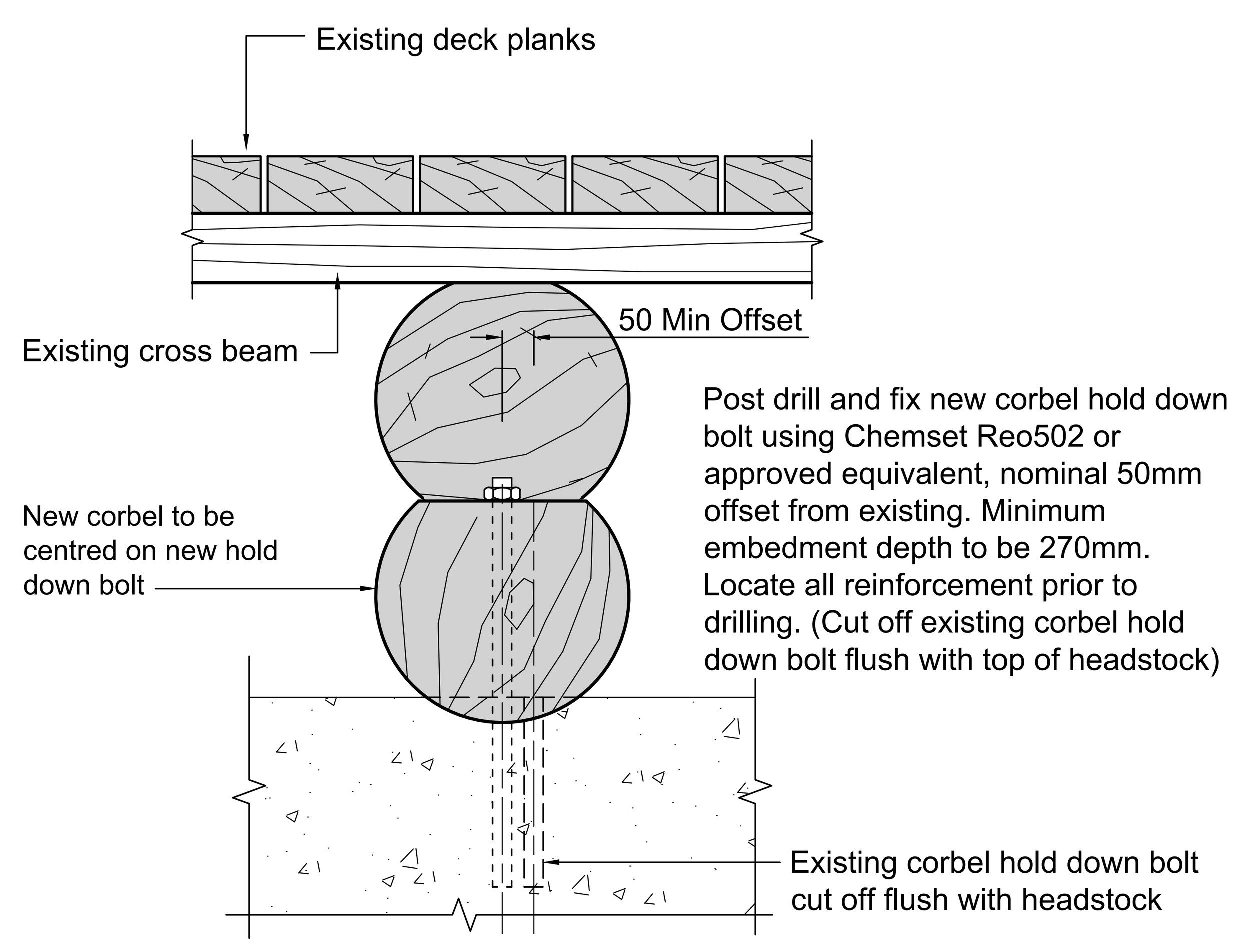
Do not scale



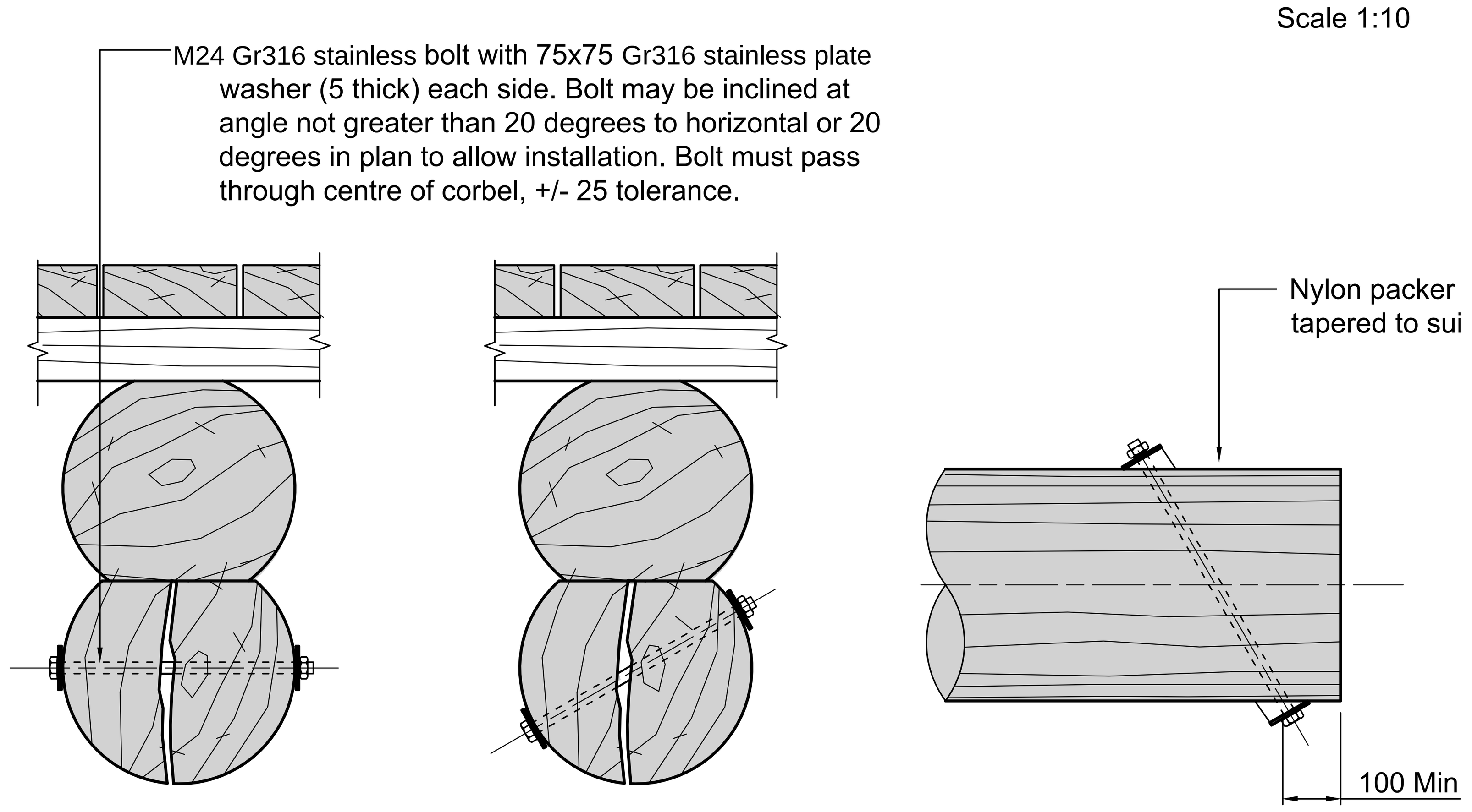
Corbel Replacement
Scale 1:10



Corbel Repair - Type 1
Scale 1:10



Section A
Scale 1:10



Section B
Scale 1:10

Option 1: Bolts unrotated
Refer Note 2

Option 2: Bolts rotated 30° to horizontal

Option 3:Bolts rotated 30° in plan
Note: Corbel shown in plan

NOT FOR CONSTRUCTION

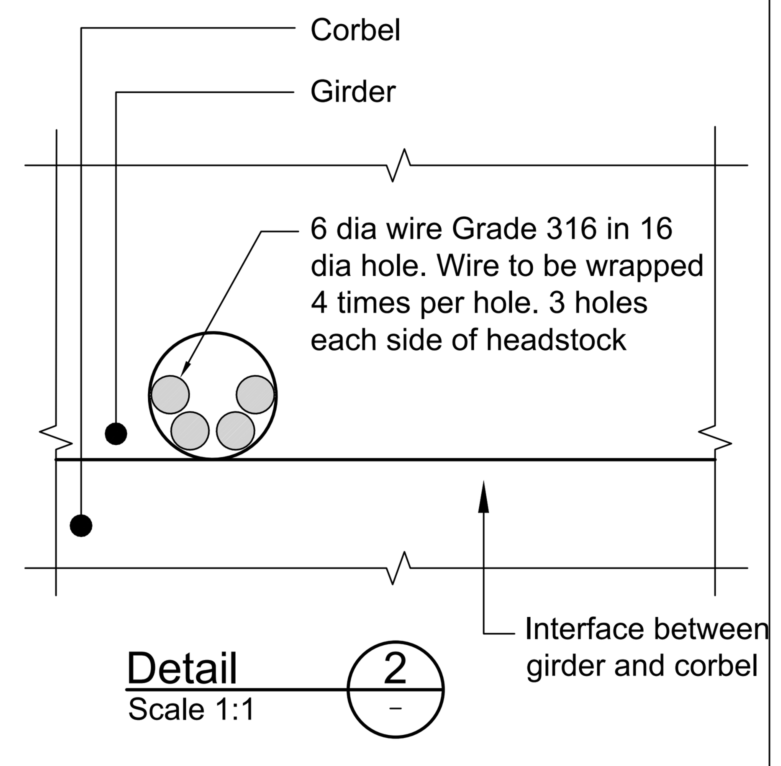
SHORELINE
CIVIL AND MARINE CONSULTING

SKETCH TITLE	STEM CORBEL REPAIR SHEET 1
PROJECT NAME	BOWEN WHARF REFURBISHMENT STUDY

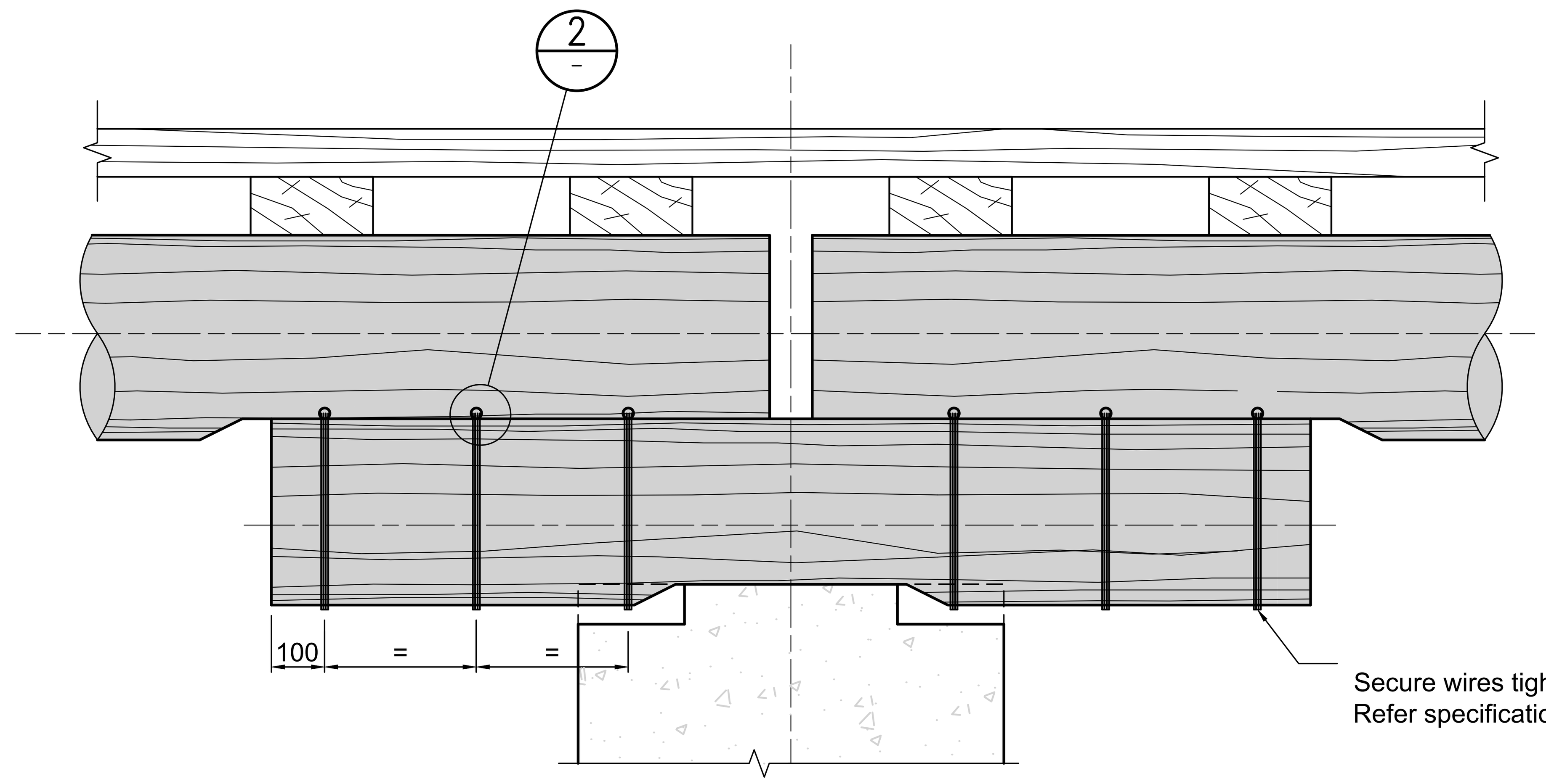
DRAWING SCALE	DATE	ORIG. SIZE	SKETCH NO.	REVISION
NTS	06/10/2023	A1	SCMC-23029-SKE-040	0

DESIGNER / ENGINEER: M. KELLEHER

Do not scale



Detail 2
Scale 1:1



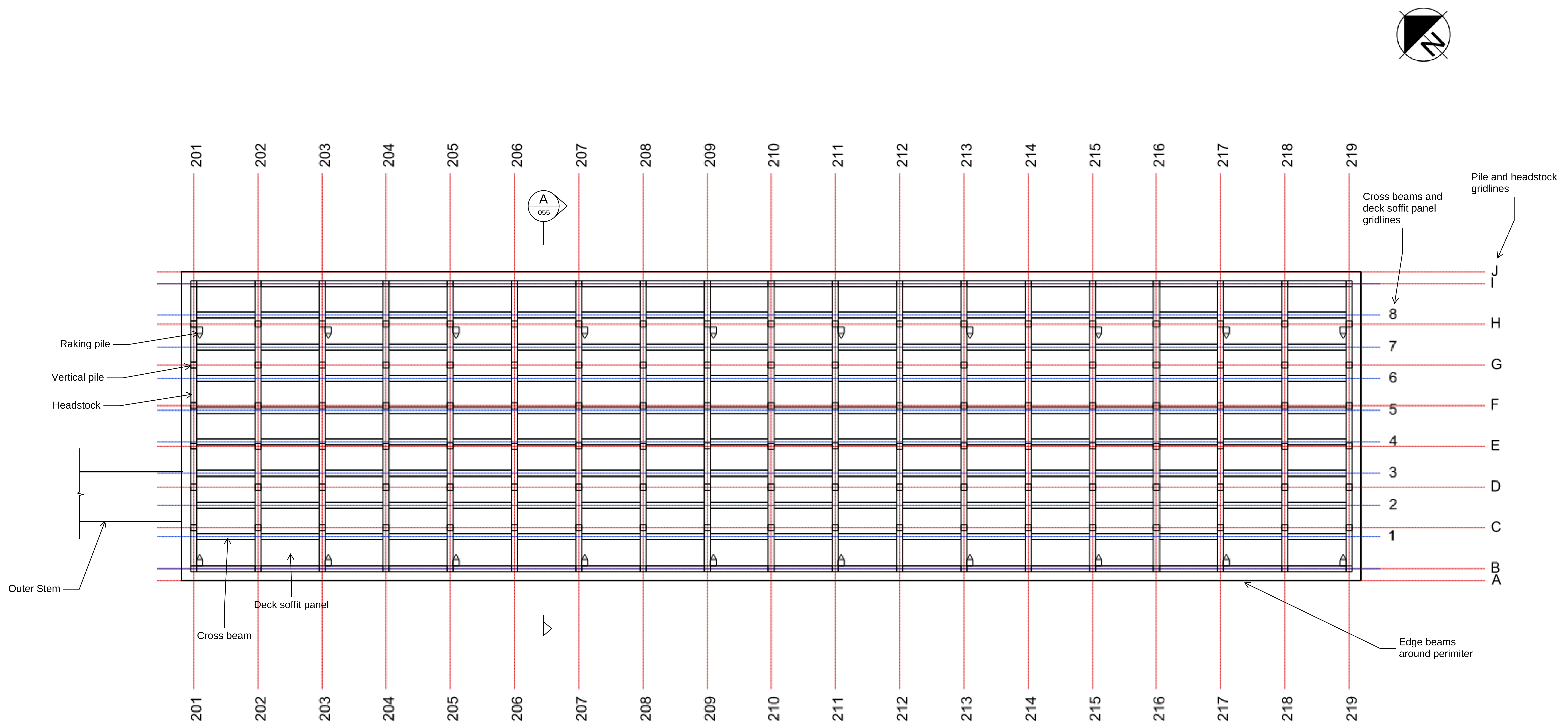
Corbel Repair - Type 2 Wire Wrapping
Scale 1:10

NOT FOR CONSTRUCTION

SHORELINE
CIVIL AND MARINE CONSULTING

SKETCH TITLE	**STEM CORBEL REPAIR SHEET 2**
PROJECT NAME	BOWEN WHARF REFURBISHMENT STUDY
DRAWING SCALE	NTS
DATE	06/10/2023
ORIG. SIZE	A1
SKETCH NO.	SCMC-23029-SKE-041
REVISION	0
DESIGNER / ENGINEER:	M. KELLEHER

Do not scale



Public Wharf - Plan (Below Deck)

N.T.S.

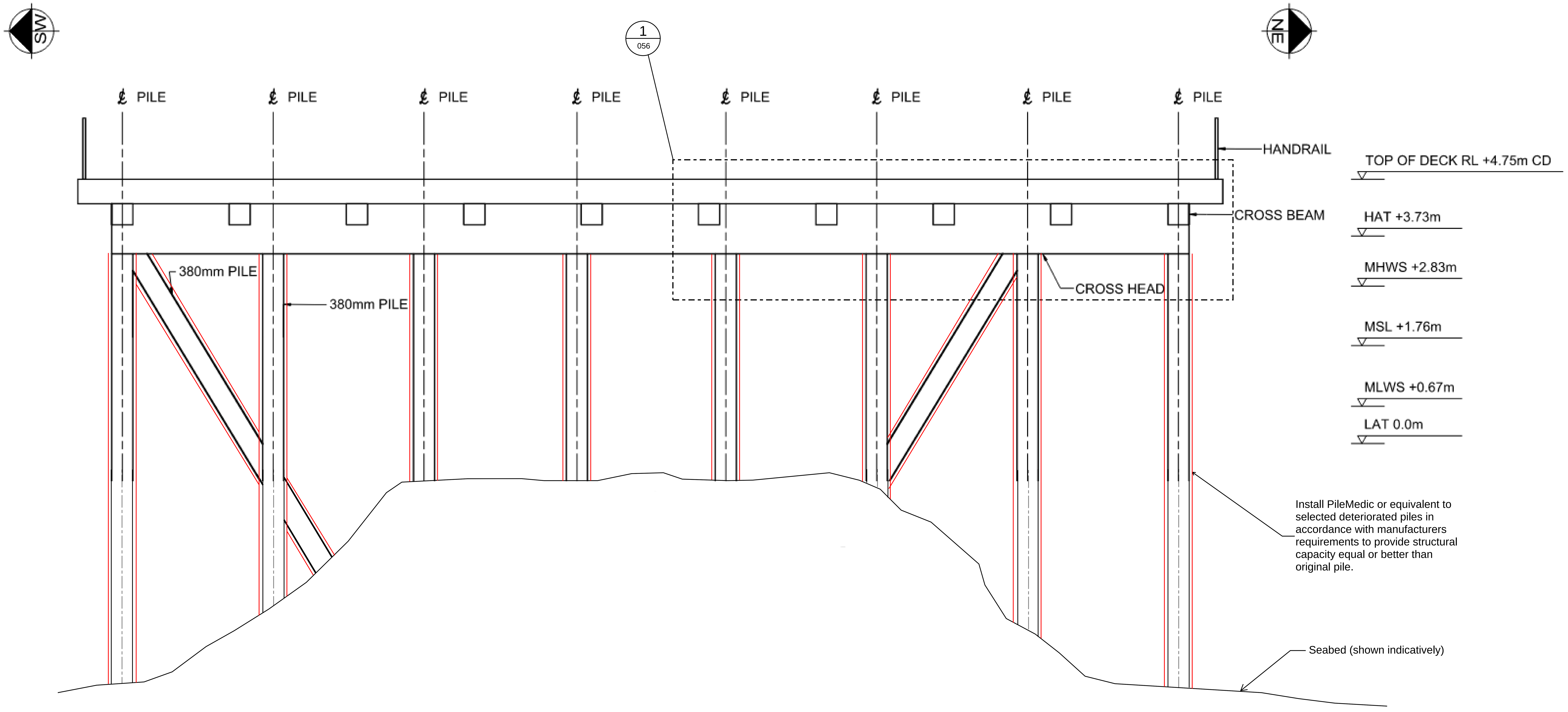
NOT FOR CONSTRUCTION

SHORELINE CIVIL AND MARINE CONSULTING

SKETCH TITLE	PUBLIC WHARF GENERAL ARRANGEMENT
PROJECT NAME	BOWEN WHARF REFURBISHMENT STUDY

DRAWING SCALE	DATE	ORIG. SIZE	SKETCH NO.	REVISION
NTS	06/10/2023	A1	SCMC-23029-SKE-050	0

DESIGNER / ENGINEER: M. KELLEHER

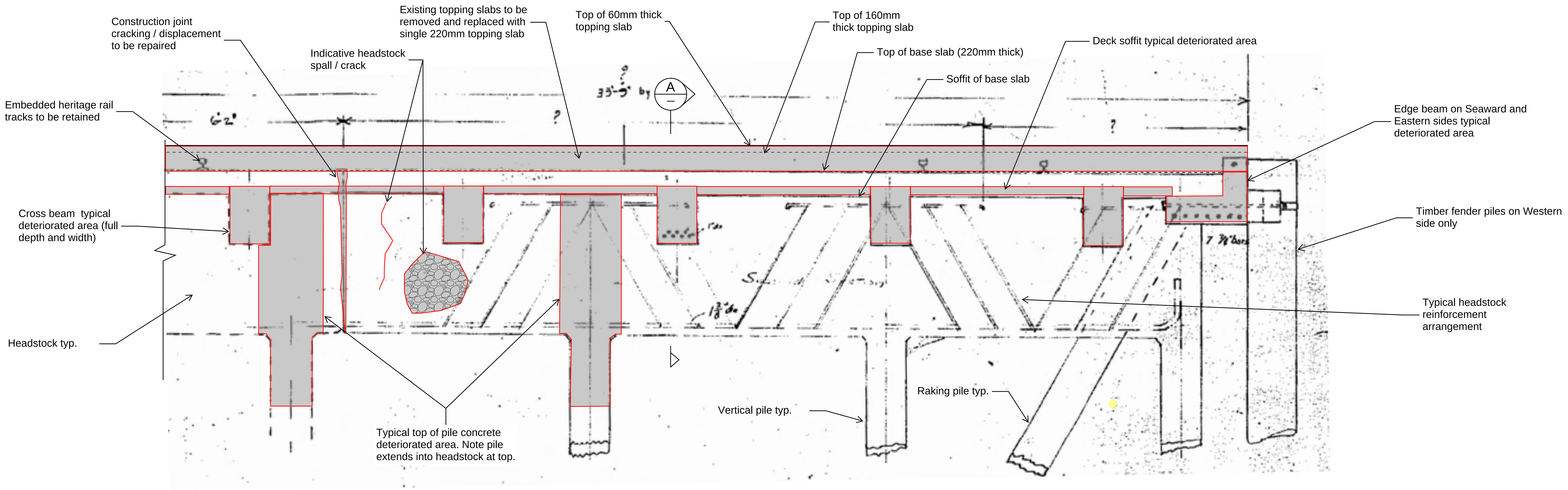


Section A 050
N.T.S.

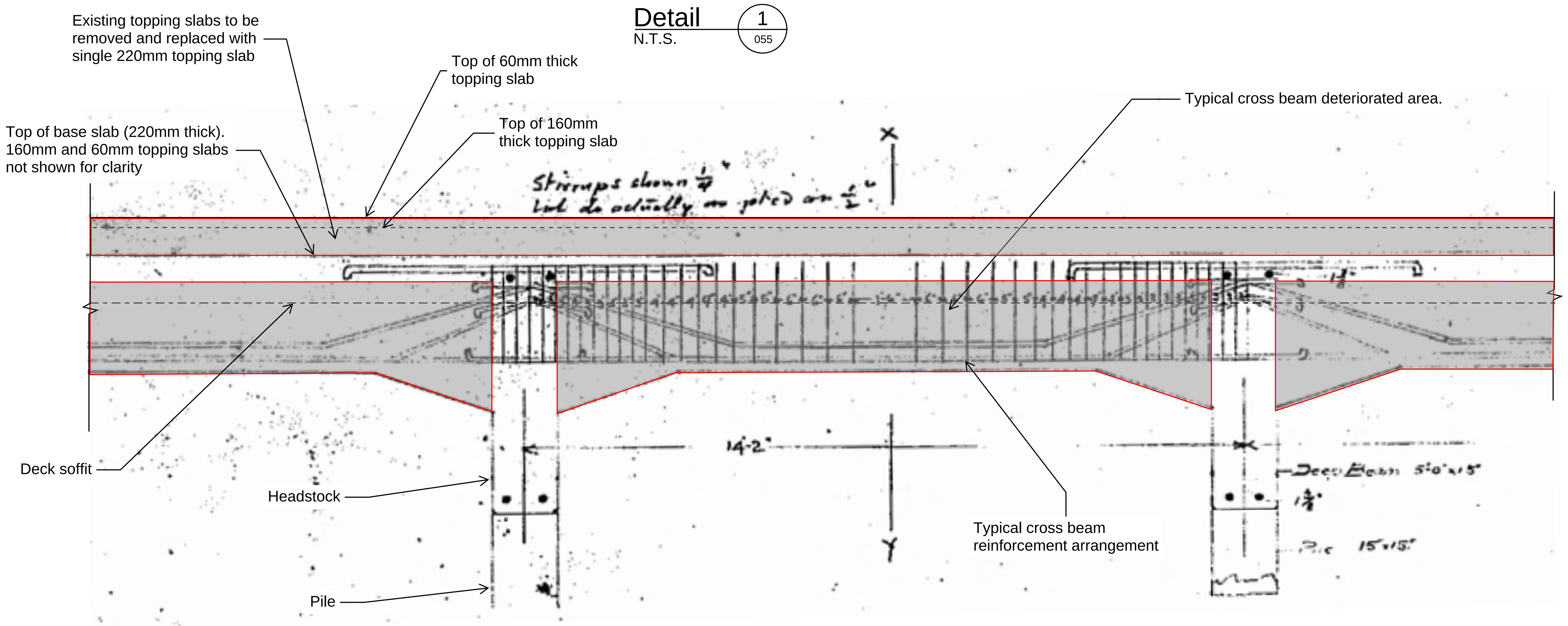
NOT FOR CONSTRUCTION

SHORELINE CIVIL AND MARINE CONSULTING

SKETCH TITLE	**PUBLIC WHARF REPAIR SHEET 1**
PROJECT NAME	BOWEN WHARF REFURBISHMENT STUDY
DRAWING SCALE	NTS
DATE	06/10/2023
ORIG. SIZE	A1
SKETCH NO.	SCMC-23029-SKE-055
REVISION	0
DESIGNER / ENGINEER:	M. KELLEHER



Detail 1
N.T.S. 055



Section A
N.T.S.

NOTES
1. Repair includes breaking out the deteriorated concrete and chasing out any deteriorated reinforcement. Sawcut edge of repair to provide a suitable edge to tie repair into existing concrete. Any reinforcement with excessive deterioration to be removed and replaced with new reinforcement by epoxy post drill and fixing the bars into sound concrete.
2. Marine grade self-compacting concrete to be placed in the repair area. Repair area to be formed up with ports for inserting the self-compacting concrete such that it flows into all areas.

NOT FOR CONSTRUCTION

SHORELINE CIVIL AND MARINE CONSULTING

SKETCH TITLE	PUBLIC WHARF REPAIR SHEET 2
PROJECT NAME	BOWEN WHARF REFURBISHMENT STUDY
DRAWING SCALE	NTS
DATE	06/10/2023
ORIG. SIZE	A1
SKETCH NO.	SCMC-23029-SKE-056
REVISION	0
DESIGNER / ENGINEER:	M. KELLEHER

Photo 1 - Typical Cross Beam and Deck Soffit
N.T.S.

Photo 2 - Edge Beam (Eastern Side)
N.T.S.

Photo 3 - Headstock Construction Joint
N.T.S.

Photo 4 - Typical Deck Slab Top
N.T.S.

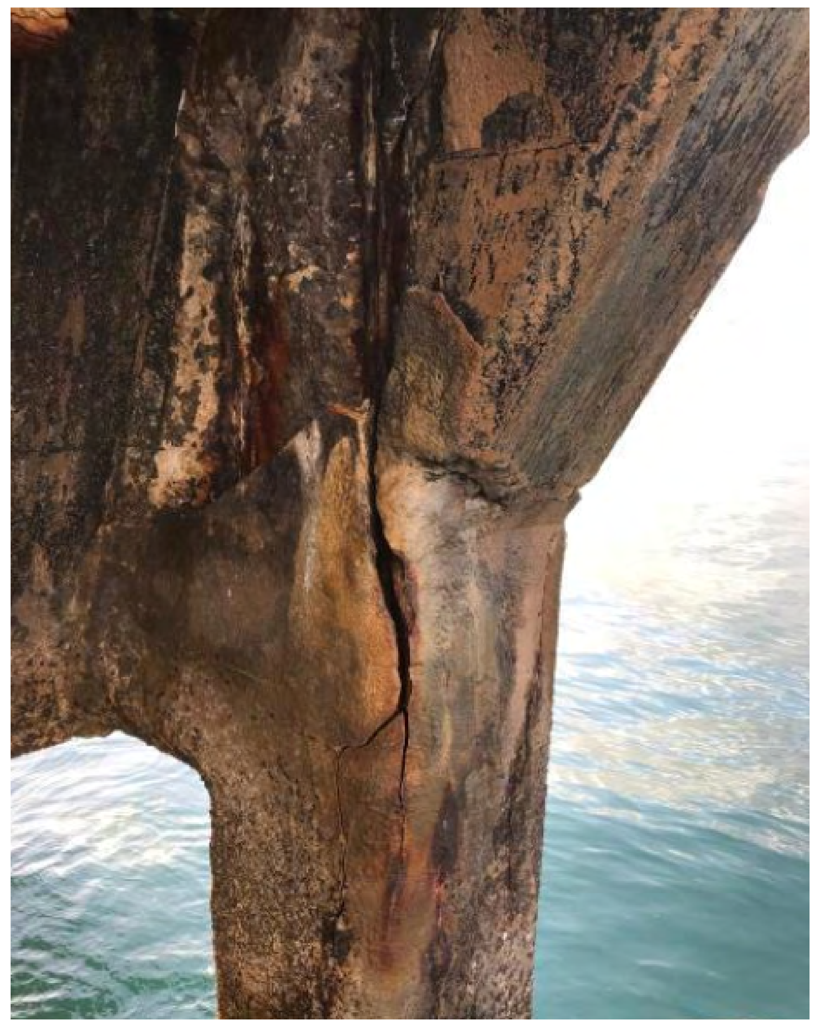


Photo 5 - Pile Spalling at Headstock
N.T.S.

Photo 6 - Pile Spalling at Headstock
N.T.S.

Photo 7 - Headstock Spall
N.T.S.

NOT FOR CONSTRUCTION

SHORELINE
CIVIL AND MARINE CONSULTING

SKETCH TITLE
PUBLIC WHARF EXISTING CONDITION PHOTOS
PROJECT NAME
BOWEN WHARF REFURBISHMENT STUDY

DRAWING SCALE	DATE	ORIG. SIZE	SKETCH NO.	REVISION
NTS	06/10/2023	A1	SCMC-23029-SKE-060	0

DESIGNER / ENGINEER: M. KELLEHER