

Barwon Water

Barwon Sewer Aqueduct
Structural Options Assessment

September 2017

Executive summary

This structural options assessment report considers provision of safe access under the Barwon Sewer Aqueduct as part of the proposed Aqueduct Park. The Barwon Sewer Aqueduct is a heritage-listed structure constructed between 1913 and 1915 owned by Barwon Water. This structural options assessment report is to assist Barwon Water in the selection of a feasible option for the provision of safe access along the Barwon River Parklands precinct, so that members of the public can pass through the park preferably on land and water.

The aqueduct structure is in very poor condition and, in its current condition, poses a risk to the public. Public access under the structure is currently not permitted on land or river. The primary risks to the public are considered to be from spalling 'chunks' of concrete, falling sections of structure (i.e. sections of ovoid sewer), or collapse of the large sections of the structure as a whole.

The structural options considered in this report address the risks noted above. They do not address the question of how to preserve and/or strengthen the structure due to the age, poor condition and significant costs associated with preserving and/or strengthening the structure. The options considered for the structure in order to provide safe passage along the river address the key requirements as follows:

- provide safe access to the public through protection from spalling concrete and partial and/ or segmental collapse, or through demolition, and
- can be constructed or demolished in a safe manner

Whilst some consideration has been given in the assessment to other driving factors in the feasibility of each option such as heritage value, impact on waterway, operation and maintenance cost, planning and approvals processes, the focus has been on the above requirements that relate directly to the structure.

The structural options considered technically viable are:

- Safe access under one land span using concrete culverts – on ground or depressed into the ground
- Safe access under one or both river spans using steel truss protective structures
- Safe access under one river span using catenary protective structure
- Partial demolition of the structure over the river and adjacent land span
- Complete demolition of the structure over the river and adjacent land span
- Complete demolition of the entire structure

All options presented achieve the key requirements of partial or more extensive safe access, but many have constructability issues associated with working over or around water and in the vicinity of highly dilapidated structure that is susceptible to collapse. The feasibility of some options is also limited by cost of the structural works and safety measures required for workers facilitating the construction or demolition works.

This report provides a series of technically feasible structural options with associated cost estimates. An options assessment is provided to compare options on the basis of public access, residual safety risks, flood and water way impact, structural heritage impact, capital cost, and operation and maintenance cost. Holistic consideration of the development the Aqueduct Park precinct is required in conjunction with a technically feasible structural option for safe passage.

As such no recommended outcome is made, other than to provide considered information on technically feasible structural options, costs and other factors to assist Barwon Water and relevant stakeholders in the selection of a preferred outcome that is commensurate to funding available for the project.

Table of contents

1. Introduction 1
   - 1.1 Purpose of this Report 1
   - 1.2 Scope and Limitations 1
2. Project Appraisal 3
   - 2.1 History of the Aqueduct 3
   - 2.2 Current Condition of the Aqueduct 6
   - 2.3 Previous Reports Review 10
   - 2.4 Existing Drawings 12
   - 2.5 Requirements for Proposed Structures 12
3. Structural Concepts 14
   - 3.1 Vertical Propping of Spans 14
   - 3.2 Other Propping Concepts 15
   - 3.3 Protection Structures 15
   - 3.4 Demolition 17
   - 3.5 Aqueduct Remediation 19
4. Structural Option Assessment Criteria 20
   - 4.1 Access for Public 20
   - 4.2 Residual Safety Risk 20
   - 4.3 Flood and Waterway Impact 20
   - 4.4 Structural Heritage Impact 21
   - 4.5 Cost 21
   - 4.6 Operational and Maintenance Requirements 21
   - 4.7 Other Considerations 22
5. Structural Options, Costings and Approvals 23
   - 5.1 Structural Options 23
   - 5.2 Cost Estimates 30
6. Planning and Approvals 31
   - 6.1 Land tenure 31
   - 6.2 Planning Controls 31
   - 6.3 Permit Requirements 33
   - 6.4 Planning and Approvals Conclusion 34
7. Options Assessment 35

Table index

Table 1: Option Costs Summary 30

Table 2: Planning Permit Controls 32

Table 3: Summary of Approval Requirements 33
Table 4: Options Assessment Tabulation 35

Figure index

Figure 1: Options 1a & 1b - Provision of safe access under one land span - Culvert or Depressed Culvert 24
Figure 2: Option 2a - Provision of safe access under one land span (culvert) and one river span (protective structure) 25
Figure 3: Option 2b - Provision of safe access under one land span (culvert) and both river spans (protective structure) 26
Figure 4: Option 2c - Provision of safe access under one land span and one river span (catenary structure) 27
Figure 5: Option 3a - Demolish both river spans and adjacent land spans - leaving towers 28
Figure 6: Option 3b - Demolish both river spans and adjacent land spans - including towers 29

Appendices

Appendix A – Structural Options Sketches
Appendix B – Cost Estimates
Appendix C – Original Layout Drawings and Structural Drawings, Stone and Siddeley

1. Introduction

1.1 Purpose of this Report

This report has been prepared for Barwon Water, and provides structural options for the Barwon Sewer Aqueduct, a heritage listed structure owned by Barwon Water. The aqueduct structure is in very poor condition and, in its current condition, poses a risk to the public who are currently not permitted to pass under it, either on land or on the river. It is proposed that a linear park, the Aqueduct Park, be established and the structural options described in this report are intended to assist in the development of this park so that members of the public can pass through the park and under the aqueduct structure in safety, on land and water.

The structural options provided in this report address the risks of concrete spalls falling on the public and fundamental failures of the aqueduct structure. They do not address the question of how to preserve and/or strengthen the structure, which has been addressed by other studies. The purpose of this report is to consider various structural options that provide safe access along the proposed linear Aqueduct Park, with further detailed assessment and relevant approval applications to be made, following selection of a preferred option.

1.2 Scope and Limitations

The following report has been prepared based on the following basis.

The options considered for the structure in order to provide safe passage along the river address the key requirements as follows:

- provide safe passage to the public through protection from spalling concrete and partial and/ or segmental collapse, or through demolition, and
- can be constructed or demolished in a safe manner

Whilst some consideration is given in the structural assessment to external driving factors in the decision process, the focus has been on the above key requirements. While the structural options assessment does consider the heritage value of the aqueduct structure in accordance with the Burra Charter, it is noted that further heritage, environmental, social and other studies and considerations may be required in order to short-list or select a preferred option. The report does include preliminary assessment and listing of likely environmental, heritage, planning, building works and other approvals that may be required.

The structural options assessment includes public safety as a priority. With this in mind, in order to restrict public access under or immediately surrounding the aqueduct, it is understood that Barwon Water are proposing to construct a public protection fence surrounding the structure to be retained, outside of any potential designated crossing points.

All options presented achieve the key requirements of partial or more extensive safe passage. However it is noted that some options have more complex constructability issues that would require further careful planning and assessment of safe work methodologies predominantly associated with working over or around water and in the vicinity of highly dilapidated structure,

This report has been prepared by GHD for Barwon Water and may only be used and relied on by Barwon Water for the purpose agreed between GHD and the Barwon Water as set out in Section 1.1 of this report.

GHD disclaims responsibility to any person other than Barwon Water arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible. The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report, including Section 1.3. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by Barwon Water and others who provided information to GHD (including Government authorities)], which GHD has not independently verified or checked beyond the agreed scope of work.

GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

GHD has prepared the preliminary cost estimates set out in Appendix B of this report.

2. Project Appraisal

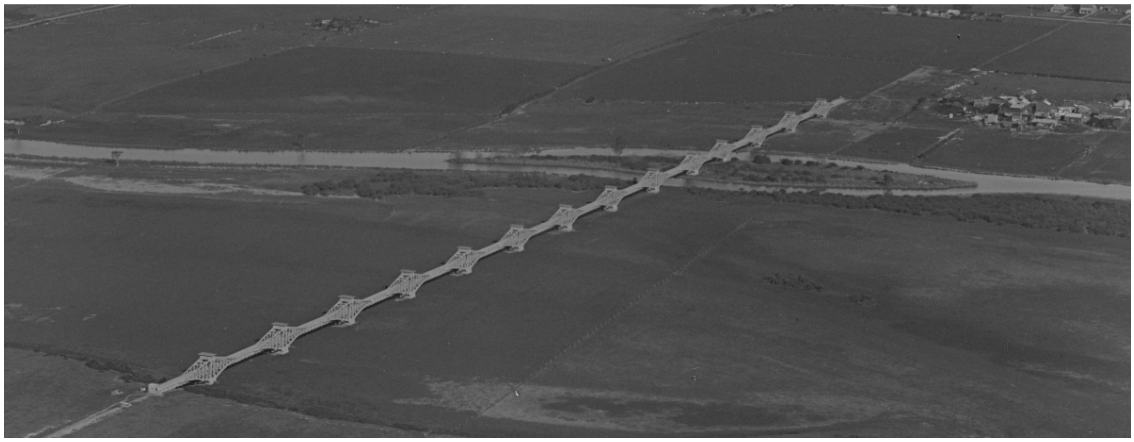
2.1 History of the Aqueduct

The Barwon Ovoid Sewer Aqueduct was constructed between 1913 and 1915 as part of the first Geelong sewerage scheme. Located south of Breakwater, the structure carried sewage from Geelong to the outfall and the treatment plant at Black Rock until it was decommissioned in 1992. It is a remarkable structure, one of the first reinforced concrete bridges in Australia, and the only surviving example of the considered construction technique in Australia. It is 756 m long and has 14 piers supporting pairs of triangular trusses on either side, between the ends of which the walkway structure supports the sewer. The sewer is an ovoid shaped pipe, also constructed of reinforced concrete, supported by beams running between the trusses on either side of the sewer, or hanging under the walkway. The structure was added to the Victorian Heritage Register in October 1991.

The Barwon River Parklands strategy identifies the river and adjoining floodplain surrounding the Aqueduct as a strategic link in the network of public open space between Geelong and Barwon Heads. The proposed Aqueduct Park extends both sides of the structure on and north of the river.

The aqueduct structure has deteriorated to the point where many pieces of concrete have fallen from the structure and overall collapse of the structure cannot be ruled out. To protect the public, Barwon Water have fenced off the area of the aqueduct and closed the river, creating a barricade across the Barwon River flats that prevents access past the structure on both land and water. The aqueduct has had structural and durability problems from early in its life, starting with the walkway, where it acts as a beam to support the sewer between the ends of the trusses. The major problem has been the porosity of the concrete, which has caused carbonation of the concrete, reducing its ability to protect the reinforcement, which has corroded, expanded and caused the concrete to spall. During the operational life of the structure, Barwon Water undertook a series of minor and major repairs. These increased in extent, complexity and cost as the structure aged. Unfortunately, the corrosion of the reinforcement was not able to be halted without substantial funding and preventative works. Despite the extensive repair efforts, continued maintenance and repair of the structure became unviable. The structure was subsequently decommissioned in 1992.

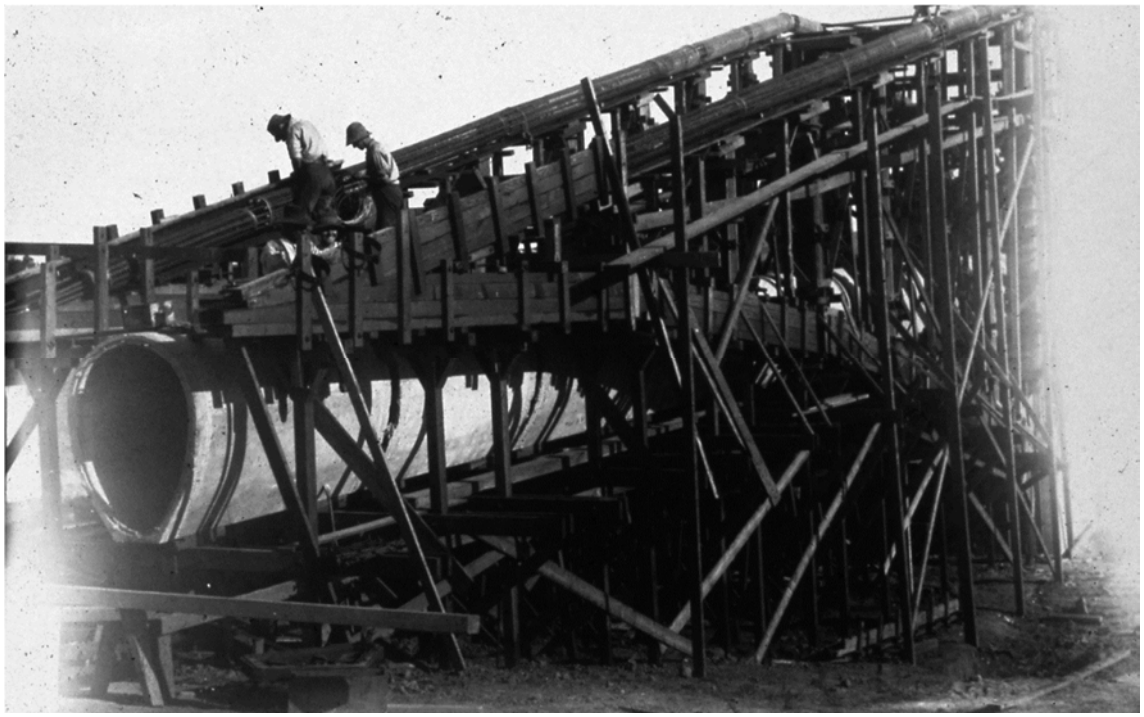
Barwon Water has now engaged GHD to investigate structural options which might allow the public to cross through the alignment of the decommissioned Barwon Ovoid Sewer Aqueduct, preferably on both land and water. The objective is to provide safe access to cross through the alignment of the aqueduct and connect the Barwon River Parklands upstream and downstream of the Aqueduct.



Historical Aerial Image of Barwon Sewer Aqueduct



Photographic Elevation of Barwon Sewer Aqueduct. 1916.

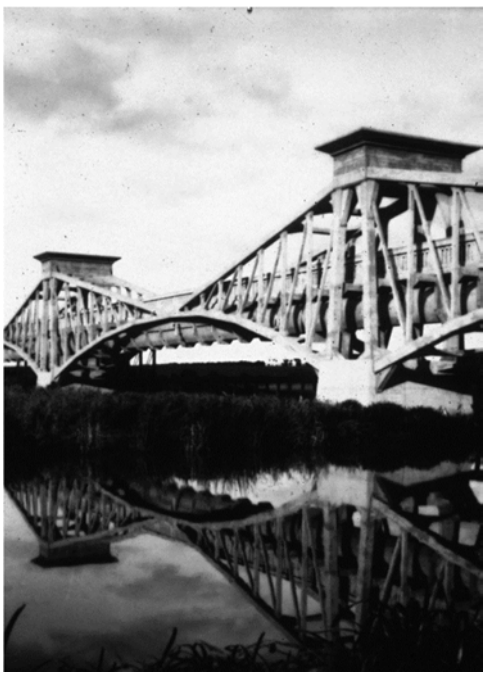


Photograph of Ovoid Sewer and Truss Formwork during Construction. Circa 1915.

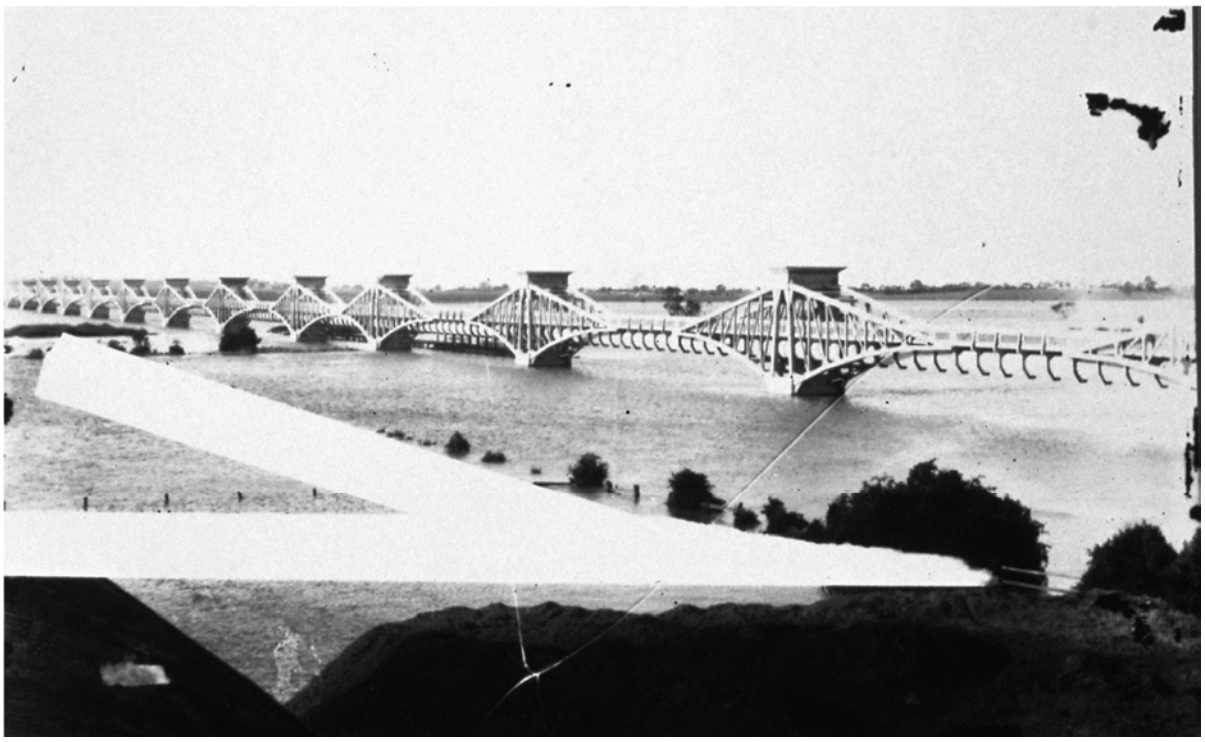


Photograph of Barwon Sewer Aqueduct Concrete Balanced Cantilever Truss. Circa 1915.





Photographs of Construction of Barwon Sewer Aqueduct. Circa 1915.



Historical Photographs of Constructed Barwon Sewer Aqueduct.

2.2 Current Condition of the Aqueduct

2.2.1 General

As noted above, the poor condition of the structure is primarily due to the porosity of the original concrete. This has caused carbonation of the concrete, corrosion of the reinforcement and spalling of the cover concrete. Because the structure is essentially a truss, the failure of any member may cause the structure to collapse and many members have serious deficiencies. It should be noted that the structural issues relate to strength, the loadings are predominantly dead load, which is not varying, and there has been no sewage loading since 1992.

2.2.2 Compression members

The compression members consist of the bottom chords, the vertical web members of the truss and the vertical legs of the towers. Many of these members have deteriorated to the point where the cover concrete has become fully detached, and in many locations has fallen off. The helical reinforcement has corroded and, in some locations, is completely missing. The longitudinal reinforcement is corroding and in some locations, unrestrained reinforcing bars have buckled away from the remaining core concrete.

Some members have been reduced to the point where the load is being carried by the core concrete on its own. This means that the effective area of the member has been reduced by 50% or more and the reinforcement is no longer effective. The capacity of the member will have been reduced by perhaps 60% or more, but the rate of loss of strength is likely to have slowed.



Photograph showing Spalled Concrete and Corroded Reinforcement to Truss Bottom Chord (Compression Member) and Truss Top Chord (Tension Member)

2.2.3 Tension members

The tension members consist of the top chords and the inclined web members of the truss. These members appear to have been given priority in the maintenance undertaken by Barwon Water prior to 1992, but now several of these members have also lost their cover concrete with the reinforcement exposed and corroding. The residual strength of these members consists of the tensile capacity of the reinforcement, which is slowly corroding and any tensile capacity of the concrete (which is expected to be low and is not normally considered in structural design).

In addition, there are the issues of reinforcement anchorage and splicing. It may be that the tension reinforcement in the inclined web members is continuous for the full length of the members and is satisfactorily anchored at each end by hooks in the node concrete. There are, however, locations in the top chords where the tension reinforcement is exposed for the full length of its splice and the splice capacity is severely compromised.

There is no guarantee that some tension members will not fail suddenly, with potentially catastrophic results.



Photograph showing Spalled Concrete and Corroded Reinforcement to Vertical Member (Compression Strut) and Concrete Spalling to lower portion of Inclined Member (Tension Strut)

2.2.4 Walkway and tower tops

Large areas of the soffits of the walkway and tower tops have spalled. There are other extensive areas where the soffit concrete is loose and could fall at any moment. The vertical faces of the tower tops and the architectural feature have also spalled, with other spalled pieces of concrete on the verge of falling.

The walkway acts as a beam with the handrail acting as the top flange and the balustrade acting as the web to carry the shear. The handrail has spalled significantly, in a similar manner to the truss compression members and the balustrade is also spalling in locations. There is a danger of falling concrete and the strength of the walkway cannot be confirmed, despite the fact that there is no longer any sewage in the ovoid sewer pipe which has reduced the loadings considerably.



Photograph showing Spalled Concrete and Exposed Reinforcement Tower Top Soffit

2.2.5 Sewer support members

The ovoid sewer is supported at 2.44 m (8 foot) centres, either by transverse members between the two sides of the truss, or by brackets supported from the walkway structure. Some of these supports have spalled with the reinforcing fully exposed and corroding. It appears that the reinforcing is continuous around the sewer, and is only corroding slowly, but its anchorage (for example into the slab of the walkway) cannot be guaranteed, and a sudden failure, allowing a length of the sewer pipe to fall, cannot be ruled out.

Prior to 1992 Barwon Water installed external steel straps to provide additional support for some sewer pipes from the walkway. These have corroded and some have now completely failed, but there is no longer any sewage in the ovoid sewer pipe, so the danger of failure has reduced in these locations.



Photograph showing Spalled Concrete, Exposed and Corroded Reinforcement and Bolts to the Ovoid Sewer connection to Walkway Slab over

2.2.6 Tower foundations

The towers are founded on concrete piles of variable length which were anecdotally driven to rock. By looking along the walkway it can be seen that the alignment of the aqueduct has been compromised. This may mean that some of the towers have rotated and that some of the piles have settled, or it may be that the trusses have deformed. It may also indicate that that some of the towers are being partially supported against rotation by adjacent towers, with some the expansion joints between adjacent towers having closed, and others having opened.

This is not an indication of incipient failure, but it underlines the need to make provisions for stabilisation of the remaining structure, should partial demolition be considered.

2.3 Previous Reports Review

The Barwon Sewer Aqueduct has previously been assessed as having an unacceptable level of risk associated with collapse of the structure or spalling concrete. Notable reports providing background understanding of the structure include:

- The Structural Integrity Assessment of the Barwon River Ovoid Sewer Aqueduct by Taywood – Maunsell Consulting Engineers (April 1991)
- The Barwon Sewer Aqueduct Panel of Independent Inquiry (May 1996)
- The Barwon Water Submission to Independent Panel of Inquiry (February 1996)
- The Heritage Victoria Barwon Ovoid Sewer Aqueduct Rehabilitation Trials report by Australian Corrosion Consultants (June 2009)
- The Barwon Sewerage Aqueduct Feasibility Study into the Potential for Use in the Barwon River Parklands Land Use Connections by GHD (August 2009), and
- The Engineering Study: Options for partial demolition and conservation of the structure by MacLeod Consulting (April 2016).

There are also numerous other reports and studies that provide further information on this structure of significance.

The purpose of this report is to provide structural options which allow the public to pass under the aqueduct safely, not to address the current condition of the structure or future options to repair, remediate, replace or otherwise, the structure.

It is nevertheless appropriate to make some comments, in particular on the most recent report (by MacLeod Consulting – April 2016) in order to clarify the risks, which have been addressed, in the structural options presented in this report.

2.3.1 Heritage Victoria – Barwon Ovoid Sewer Aqueduct Rehabilitation Trials

In October 2002 Heritage Victoria conducted trials of a repair method known as re-carbonisation, which achieved variable results. In February 2009 Heritage Victoria conducted a trial of an alternative repair method known as re-alkalisation, and also trialled cathodic protection. The report titled “Heritage Victoria, Barwon Ovoid Sewer Aqueduct Breakwater, Victoria, Rehabilitation Trials” was produced by Australian Corrosion Consultants and dated June 2009.

While budget estimates in this report are significantly outdated in the context of current 2017 construction prices and further degradation of the structure since the trials, it is worth noting that the budgets developed for either patch repairs (17% of concrete surface only) or realkalization (excluding ovoid sewer pipe) or cathodic protection (excluding ovoid sewer pipe) were all upwards of $13.3m (unadjusted 2009 estimate) plus ongoing annual maintenance costs.

2.3.2 GHD 2009 Report – Feasibility Study into the Potential for Use in the Barwon River Parklands Land Use Connections

GHD’s 2009 report concluded as follows:

- The Barwon Ovoid Sewer Aqueduct had deteriorated substantially since the 1994-1996 assessment and due to the complex nature of the structure and its deterioration, structural adequacy could not be established by conventional analysis;
- The ability to safely repair the structure in its current condition was uncertain and complete recasting of the structural elements was likely to be more economical and effective than cathodic protection or re-alkalisation;

- The 1994 Maunsell and 2009 ACC cost estimates for remedial works were considered to understate the probable repair costs; and
- Construction of new river crossings and demolition of the entire aqueduct structure achieved the highest triple bottom line score and would be much cheaper than full or partial concrete remediation.

2.3.3 MacLeod Consulting Report – April 2016

The MacLeod report of April 2016 provided options for partial demolition and conservation of the structure of the sewer aqueduct. It was prepared as a guide for the long term management of the aqueduct as a "ruin", not allowing any access to the structure, and not restoring it. This report concludes that the capacity and longevity of the structure can be improved by installing props under the ends of the trusses, although it does not quantify the increased capacity or future life.

Concrete Remediation

The report concludes that improving the condition of the structure's concrete and reinforcement could be undertaken, but would be expensive. GHD considers that remediation may be highly impractical, because of the difficulties with each option as stated below:

- Patch repair would require the removal of concrete from behind the reinforcement. Removing concrete from members which are already much reduced in size could prove impossible, because it would be necessary to demonstrate the ability of the reduced members to carry their loads, including at the joints. Safety considerations during undertaking patch repairs would impose significant safe work measures and associated costs, in addition to the actual patch repair costs.
- Re-alkalisation would require the removal of all delaminated and spalled concrete and require the reinforcement to be made electrically continuous. Temporary support would have to be installed and it would be extremely difficult, if not impossible, to demonstrate that safe access and work procedures could be provided for all necessary work. The tests by Australian Corrosion Consultants in 2009 found that re-alkalisation was ineffective in some areas.
- Cathodic protection of the structure would also require the removal of all delaminated and spalled concrete and that the reinforcement to be made electrically continuous. The need to provide temporary support and ensuring safe access and work procedures at all times would also make this option highly difficult, if not impossible.

Partial Demolition over the River

Demolishing the spans between the ends of the southern Pier 8 cantilever and the northern Pier 13 cantilever without damaging the piers themselves would be difficult. The spans would require extensive temporary support to allow them to be cut and removed piece by piece, along with expensive temporary works to provide safe access for workers and equipment to each cut location. The procedure would need to ensure that no worker is at risk from falling elements of spalled concrete and there is no risk from the failure of any structural elements or more global failure as structural elements are removed. Costs are considered to be significantly higher than stated due to the fact that much of the work would have to be undertaken above the river.

Other Comments

Section B3: MacLeod states that it is primarily the compression members that are at risk, because of the corrosion of the winding reinforcement. As noted in Section 2.2 above, GHD considers that there are several other key risks, including: failure of the reinforcement of the

tension members, due to corrosion anchorage failure or splicing failure; and failure of the supports to the ovoid sewer pipe itself.

Section C2: Deterioration of the Structure and Elements. The report expects any failure to be ductile, but GHD does not believe this can be assumed. Some compression members have lost their cover concrete and ligatures, and the longitudinal bars have buckled, leaving the load to be carried by the core concrete, which is liable to fail as a concrete cylinder i.e. in a brittle fashion. Some tension members have lost their cover concrete and the reinforcement is corroding. If the reinforcement corrodes locally it may fail with limited ductility and failure might be an anchorage or splice failure, in which case there would be very little ductility.

Section C3: Investigations by Australian Corrosion Consultants (ACC). ACC's report suggests that reinforcement exposed to air will only corrode with a 10% loss of area in 100 years. This may explain the slow apparent rate of structural deterioration over the last 25 years, but all possible modes of failure need to be considered (as listed in Section 2.2 above).

2.4 Existing Drawings

The Barwon Sewer Aqueduct original layout drawing and structural drawings by Stone and Siddeley are included in Appendix C of this report.

2.5 Requirements for Proposed Structures

2.5.1 Protection of the public

The protection structures proposed by this report aim to ensure that the public can pass the alignment of the structure in safety. Some of the particular risks that the structures need to address are:

- **The danger of spalling concrete falling on the public.**
  As noted above, there are numerous locations where spalling is occurring, including the truss members, the tower, the walkway and the sewer supports. Spalls, up to the size of several bricks, can be seen lying on the ground under the aqueduct and many loose sections of concrete can be seen on the structure, waiting to fall. In addition, there are many pieces of spalled concrete now balanced on top of members and far from secure. Any protection structure needs to be able to prevent the fall of such spalls impacting the public. It is considered a satisfactory outcome if the protective structure itself is damaged by the design impact and needs repair, provided the public remains safe and the protective structure can viably be repaired in a safe and cost effective manner.
- **The danger of the structure collapsing onto the public**.
  As noted above, many major members have seriously deteriorated, their strength cannot be confirmed, and the possibility of a sudden, brittle failure cannot be ruled out. At Pier 14 a structure has been provided which supports the truss at each bottom node to prevent structural collapse. This form of support could be placed at other piers, or alternatively, the end of each truss could be supported, to reduce the load in the truss members and significantly reduce the risk of a major collapse, but without eliminating it. If the public is to pass under the structure, the truss should be supported at each bottom node. Providing a support at each end of each truss (even beyond public access zones) would provide reasonable certainty that the structure would remain intact for a period, and would potentially limit the propagation of failure into adjacent spans should partial collapse occur. This would be also subject to providing support to the ovoid sewer pipe along its length and supporting the walkway sections over, particularly between trusses.
- **The danger that a significant component of the structure could fall onto the public.**
  Because the residual strength of the structure and its components is unknown, there are

many such possibilities, but the most significant appears to be the possibility that a section of the sewer pipe might fall, due to the failure of one of its supports.

2.5.2 Structures associated with partial demolition

Partial demolition would be complex in both determining a safe demolition method, but also in determining structural requirements for permanent propping and/or counterbalancing adjacent spans to be retained. This is discussed in more detail in Section 3.

2.5.3 Safety during construction

All the structures proposed in this report need to be installed so that the workers installing them can undertake the work safely. The structural options need to be developed with this in mind, so that satisfactory work methods are able to be developed at a later stage. The structural options need to ensure that:

- At no stage are workers located where concrete spalls could fall on them. To meet this requirement, the options have been developed so that:
  - Piling is installed at least 1 m away from the plan location of the structure,
  - Driven piling is avoided on land because of the vibrations involved,
  - Any new structure under the aqueduct can be installed from a position at least 1 m away from the plan location of the structure, and
  - Any work that has to be undertaken under the structure is done using remotely controlled equipment.
- No workers are to be on the structure at any time.

3. Structural Concepts

3.1 Vertical Propping of Spans

The objective of propping the spans would be to reduce the likelihood of collapse of the structure. As a minimum it should extend the life of the structure and mitigate against progressive collapse.

The concept would be to prop the ends of each truss, i.e. provide two pairs of props in each span and jack some load into each prop. This would reduce the likelihood of collapse, but not eliminate it, and because of the different stiffness and characteristics of the props and trusses, the loads in the props and trusses would vary with time and temperature. Nevertheless, the loads in the truss members would be reduced and collapse would therefore potentially be delayed until the deterioration of the structure was much more advanced. The risk of failure of a section of the structure, in particular the ovoid sewer pipe, would not be reduced.

Note that vertical propping of a span does not, by itself, enable the public to pass under that span of the aqueduct, either on land or along the river. It aids in reducing the risk of the structure collapsing catastrophically, but does not address the dangers from spalling concrete, or from a falling section or component of the structure.

3.1.1 Propping land spans

Two pairs of props would be provided to each land span, under the ends of each truss on each side of the sewer. The props would be supported on bored piles, installed a least 1 m outside the plan position of the trusses. The props would be placed under the aqueduct and installed using two cranes, one on each side of the aqueduct which would rotate the props to the vertical position and place them on the piles. Packers and flat jacks would be placed on the top of each prop, a nominated load jacked into it and the flat jack grouted.

3.1.2 Propping spans over the river

The same concept of propping the end of each truss would also be adopted for the spans over water but achieving the same support would be much more difficult. One significant cost would be the need for temporary bridges to provide access for construction equipment onto the island (both upstream and downstream of the aqueduct), or the provision of a construction barge

One approach would be to use the same arrangement as for the work over land, but with driven piles placed in the river. This would be costly because of the need for water-borne plant, or alternatively for large cranes with sufficient reach. It would also create issues in regards to restrictions to river flow and flow forces on the piles, noting that further environmental issues also require consideration. It is considered that the inclusion of any new support structure within the river would be deemed unacceptable by the CCMA due to potential impacts on the floodway management of the river.

Another approach would be to place piles on either side of the river and install steel trusses across the river (one on either side of the aqueduct) with two cross frames to support the tips of the trusses. Installation of the piles would be straightforward but installation of the trusses and cross frames would be more difficult. This approach is similar to the provision of a full protection structure under the river and is developed in further detail in later sections.

3.2 Other Propping Concepts

It would be possible to prop each bottom node of each of the trusses. This would substantially further reduce the loads in the truss members potentially further extending the life of the structure, although it will have no impact on the rate of decay of the current members.

It would also be possible to provide temporary support at each location where the sewer pipe is currently supported from the walkway. This would reduce, if not eliminate, the risk of a section of sewer pipe falling, but would be expensive because of the number of supports required. One approach would be to provide eight piles in each span, supporting beams on either side of the aqueduct with cross beams from the main beams, to support the sewer pipe at every 2.44 m. Each cross beam would be equipped with packers and a flat jack to support the sewer pipe. Installation would be expensive over land.

Both these approaches could be installed over the river, but would require piles in the river or piles on the shore with major trusses (as outlined in Section 3.1.2 above). This form of propping would be much more expensive for the river spans.

3.3 Protection Structures

To provide safe access under a span, the risks to the public as outlined in Section 2.5.1 need to be addressed. These are:

- Protection against falling concrete spalls,
- Prevention of the collapse of the structure, and
- Prevention (or protection from) a falling component of the structure.

3.3.1 Access under land spans

Culvert on Ground

To provide safe access under a land span an option is:

- The structure be propped at each side of the proposed public access, with props at the ends of the two adjacent trusses, as described in Section 3.1.1 above. This will prevent the possibility of either of the adjacent balanced cantilever structures falling into the area of the proposed public access. It will not prevent the possibility of partial collapses, but these would be outside the area of the proposed public access; and
- A large concrete culvert be installed beneath the section of the sewer which is supported by the walkway, between the ends of the trusses. The culvert section would be sufficiently large for pedestrians and cyclists and sufficiently strong to protect users from falling concrete spalls. It could be specially detailed to protect users should a section of the sewer fall. The culvert could be installed by jacking it into place, from outside the footprint of the aqueduct, which would provide safety benefits during construction.

Culvert Depressed below Ground

An alternative method of providing safe access under a land span would be to depress a culvert into the ground, in conjunction with props at the ends of the two adjacent trusses. This approach would be less visually intrusive than having the culvert on ground. The depressed culvert could be installed by jacking it into place, from outside the footprint of the aqueduct, which would provide safety benefits during construction. There would, however, be some substantial disadvantages, such as:

- A culvert below ground level would be prone to flooding during periods of high river levels, or other wet weather, or ground water, and a permanent pumping arrangement would be required.
- The length of the culvert would need to be greater to cater for the lowered height, natural light would not penetrate the length and safety lighting would be required.
- There is currently no power supply along the length of the structure.

Installation of a culvert below ground would likely require substantial excavation and may trigger the need for a Cultural Heritage Management Plan.

3.3.2 Access under the river spans

Piled Steel Truss Structure

To provide safe access along the river and under the aqueduct one option is to:

- Install four large piles at the edges of the river, adjacent to the first node of the truss, some 2.5 m from the face of the aqueduct towers.
- Span steel beams between pairs of piles (one on each side of the river).
- Fabricate a pair of triangular steel trusses joined by beams underneath, to create a structure with an overall "U" cross section to permit it to wrap around the existing aqueduct structure and support it.
- The steel truss structure would be sized so that it did not extend above the level of the handrail of the existing aqueduct, to limit its visual impact.
- Place this steel structure on barges and floated it into position under the river span and the steel beams at each river bank. Jack the structure up to the steel beams using heavy lifting jacks and fix the structure to the steel beams.
- The steel truss structure would then span the river (with one triangular truss on either side of the aqueduct). The cross beams would be located at the bottom nodes of the aqueduct trusses and the ends of each section of sewer pipe. Flat jacks would be supported on the cross beams, pushed into position, and inflated to touch the existing structure, so that it can not collapse, while not affecting its existing load conditions.
- This would prevent the overall collapse of the river span of the aqueduct structure or the failure of large sections of the sewer. It would also prevent large sections of concrete from falling into the river.
- To provide protection against falling concrete spalls, a secondary structural steel grid and relatively fine safety mesh would be supported from the cross beams of the steel truss structure. The steel members of this grid could be designed to deform under larger impacts, while smaller spalls could be contained by a suitable safety mesh.

This form of structure could be provided across either, or both, branches of the river subject to funding.

Catenary Structure

It has been suggested that the river spans of the aqueduct could be supported by a catenary structure. The concept would be to construct steel towers adjacent to the existing towers, which would support cables spanning the river. The towers would be founded on piles and cables would be located on either side of the aqueduct, supporting transverse "hanger" cables passing under the sewer and/or truss to support the dead load of the aqueduct.

The existing towers could not be used to support the catenary cables because of their condition. There is no certainty that the extensive work required to modify them so that cables could be fitted to them would not cause them to fail and their appearance would be changed irrevocably.

This would be a complex structure to design and build, partly because of the different behaviour of the flexible catenary structure and the stiff aqueduct. As each hanger cable was tightened, the shape of the catenary would alter and the load in each of the other hangers would alter, meaning that final load in each of the hangers would need to be checked and adjusted, and access to the hangers for personnel and equipment would require extensive temporary access. Once the hangars are installed and adjusted, it is considered unlikely that further adjustment would be required unless substantial movement or failure of the structure occured. The anchorages for the catenary cables would need to be piled structures with large inclined ground anchors, to react against the horizontal forces in the catenary cables. In addition the truss on the opposite side of each tower would need support.

3.4 Demolition

3.4.1 Full demolition

Full demolition of the structure is relatively straightforward, subject to environmental and cultural heritage requirements associated with these works. Demolition could potentially be completed using controlled explosives and appropriate measures to limit the damage and clear away the debris while minimising impact on the existing land and waterway.

The requirements for protecting the river would need consideration, but it is suggested that the best approach would be to place a suitable “net” across the river to catch and contain the debris and allow it to be completely removed. The demolition staging would require particular consideration to ensure a safe means of demolition while minimising impacts on the existing flora and fauna, water quality and cultural heritage.

3.4.2 Partial demolition – including demolition of tower/s

Partial demolition would require careful consideration of how to ensure that the remaining structure is not damaged during the works and is supported post works. Partial demolition should involve the demolition of the section of aqueduct supported by a tower, plus the adjacent sections where the ovoid sewer pipe is supported from the walkway.

If such a section of the aqueduct were to be removed, including the tower, one approach would be to:

- Support the ends of the trusses from the affected towers,
- Support the sections of ovoid sewer pipe and walkway between the ends of the trusses on either side of the tower to be removed.
- Cut the sewer and walkway at the ends of each truss, using a diamond wire saw operated from equipment supported away from the aqueduct.
- Remove the cut section of sewer and walkway. This could be done either by using a crane to remove the whole section, or by designing the temporary support system so that it could be jacked down to ground by operators located remotely.
- Demolish some of the towers and their trusses. This could be done relatively simply, by ensuring that the towers fall away from the line of the aqueduct, well away from the remainder of the aqueduct.

3.4.3 Partial demolition – retaining towers

If a section of the aqueduct were to be removed, but without removing the towers, it would be a more complex task. One approach would be to:

- Support the ends of the trusses from the affected towers,
- Support the sections of sewer and walkway between the ends of the trusses.
- Cut the sewer and walkway at the ends of each truss, as described above.
- Remove the cut section of sewer and walkway as described above.
- Support the trusses which are to be removed at additional bottom node points, including the node next to the tower. The number of additional supports will depend on the size of the sections that are to be cut and removed.
- Cut the trusses and the associated walkway and sewer pipe into sections and remove. As each section is cut from the structure, both the cut section and the remainder of the structure, including the sections still to be removed, need to be supported so that uncontrolled collapse is avoided. This will require detailed planning and extensive propping.

If one span is to be demolished while the adjacent spans are retained, unbalanced loadings could be applied to the towers. If a truss is removed to one side of a tower, then it needs to also be removed to the other side due to unbalanced loads (see Section 3.4.4). To avoid the unbalanced loadings on the remaining towers due to the discontinuity of the walkway and sewer pipe, permanent propping will be required at the ends of the trusses to the retained spans.

If partial demolition is to be undertaken over the river, the tasks listed above will all become much more difficult and expensive, and in addition temporary access to the island will be required, both upstream and downstream of the aqueduct.

3.4.4 Extent of demolition

If the aqueduct is to be partially demolished, the extent of demolition can be varied as required. Nevertheless it would be unwise to demolish the trusses on only one side of a retained tower because of the discontinuity created and out-of-balance loads experienced by the towers. There is also the risk of loss of reinforcement anchorages in cut truss members. Whilst propping could be adopted, the effects of propping the retained portion of truss could be significant with tension members being put in compression and vice-versa, potentially resulting in overstressing of members. At each tower it would be prudent to either remove both trusses or neither. The section of sewer between the ends of the trusses should be removed and the ends of the trusses on the opposite side of the towers should be propped, so that overturning moments do not occur in the towers.

Retaining Towers

If the spans across the river are to be demolished, the trusses on either side of Towers 9, 10, 11 and 12 (the towers on the river banks) should be removed and props provided under the trusses on the southern side of Tower 13 and the northern side of Tower 8. Access along the river banks would become available, with a gap of approximately 30 m between the tower and the end of the adjacent truss, which is sufficient for public access, while keeping the public at least 5 m from the remaining structure. A similar arrangement could be provided if only one branch of the river is to be made safe for public access.

Removing Towers

A similar arrangement would apply if the towers are removed. If the structure is to be demolished across both sides of the river, the same extent of public access would be available, and props would be required under the trusses on the southern side of Tower 13 and the northern side of Tower 8.

3.5 Aqueduct Remediation

As noted above in respect of the MacLeod Report of April 2016, GHD is of the opinion that the condition of the structure has deteriorated so far that remediation is now impractical and would be highly difficult and expensive. The difficulties with each option can be summarised as follows:

- Patch repair would require the removal of concrete from behind the reinforcement. Removing concrete from members which are already much reduced in size could only be undertaken after it had been proven that the further reduced the members would still be adequate to safely carry the loads in the structure. This might prove impossible, particularly since the strength of the details would also need to be proven. Temporary support would have to be installed and it would be extremely difficult, if not impossible, to demonstrate that safe access and protection could be provided for the necessary work at all times. A further issue is the distribution of load between the existing material and any repair material. It is quite possible that the repair material would create increased loads in the structure without carrying any of those loads.
- Re-alkalisation would require the removal of all delaminated and spalled concrete and require the reinforcement to be made electrically continuous. Temporary support would have to be installed and it would be extremely difficult, if not impossible, to demonstrate that safe access and protection could be provided for the necessary work at all times. The tests by Australian Corrosion Consultants in 2009 found that re-alkalisation was ineffective in some areas.
- Cathodic protection of the structure would also require the removal of all delaminated and spalled concrete and that the reinforcement to be made electrically continuous. The need to provide temporary support and safe access and protection at all times during the work would also make this option difficult, if not impossible.

It should also be noted that without full repair of all members, the risks to the public from spalling sections of concrete, falling components or complete collapse cannot be ruled out. The ongoing operational and maintenance costs associated with such works would also require careful consideration.

4. Structural Option Assessment Criteria

The assessment criteria below will be used to develop a "traffic light" identification system for assessing the different structural options against each other. The general assessment of each option, based on these criteria, can be found in Section 6.

4.1 Access for Public

The most important objective is to stop the aqueduct creating a barrier across the valley, and to permit the public to travel along the Barwon River Parklands either by land or water, or by both. It would be advantageous if access could be provided under one or more sections of the aqueduct on land or along both branches of the river.

Red – Restricted access provided (land only)

Orange – Restricted access provided (land and one river branch)

Green – Clear access provided (both land and water)

4.2 Residual Safety Risk

The structural options that are presented have been developed on the basis that they would meet the required safety criteria for the designated extent of safe passage across the aqueduct alignment. Opening the Barwon River Parklands will increase the exposure of the remaining aqueduct structure to the public, meaning that there is an increased likelihood of people accessing any remaining parts of the aqueduct, despite the fact that it will be fenced off. Preventing access along the river has also proven difficult, so there is a safety benefit in removing restrictions to river access.

Red – High residual risk to users from dilapidated structure.

Orange – Medium residual risk to users from dilapidated structure.

Green – Low residual risk to users from dilapidated structure

4.3 Flood and Waterway Impact

4.3.1 CCMA – Works on floodplain

CCMA has floodplain management responsibilities for this region. One of the key functions is the control of developments that have occurred or may be proposed for land below the flood level. Potential environmental impacts could relate to flora and fauna, water quality, afflux causing flooding, amongst other considerations.

City of Greater Geelong's planning scheme requires a planning permit for buildings and works in the floodplain, with the flood overlay applying over the entire aqueduct site. A building permit may be required for any building works on the site but, potentially, not for demolition works. The CCMA is primarily concerned with any works within the flood plain which may pose safety risks or consequentially impact the water flow during flood.

4.3.2 CCMA – Works on waterway

CCMA authorises works on designated waterways via an authority permit in accordance with the CMA's "Waterways Protection" by-law. The types of works that require approval include:

- Waterway crossings – including repairs to existing crossings
- Other structures in waterway

The by-law states that a person must not, unless in accordance with a permit issued under this by-law, construct, alter, remove, obstruct or interfere with any structures or works in, under, on or over a designated waterway or any designated land. Potential impacts could relate to flora and fauna, water quality, afflux causing flooding, amongst other considerations.

Red – Works expected to significantly impact flood and waterway management

Orange – Works expected to moderately impact flood and waterway management

Green – Works not expected to impact flood and waterway management

4.4 Structural Heritage Impact

The Barwon River Ovoid Sewer Aqueduct was added to the Victorian Heritage Register, gazetted on 23 October 1991, affording it protection under the Historic Buildings Act 1981, which was subsequently replaced by the Heritage Act 1995. The aqueduct is currently registered by Heritage Victoria (VHR H0895) and covered by a Heritage Overlay (H056) in the Greater Geelong Planning Scheme.

The objective for structural heritage is to retain as much of the structure as possible. In addition, there is an objective of retaining the structure for as long as possible, meaning that propping provides a potential benefit in terms of structural heritage.

The below criteria is provided for structural heritage impact only, noting that any other cultural and indigenous cultural heritage values should be assessed separately.

Red – Potential significant impact on structural heritage value

Orange – Potential moderate impact on structural heritage value

Green – Potential low impact on structural heritage value

4.5 Cost

The cost for the various options proposed vary considerably. It is understood from Barwon Water that the funding available is likely to be in the order of $2m to $4m. It is also noted that prior reports considering remediation options in 2009 included budget estimates that were upwards of $13m.

The following criteria is provided to assess costs.

Red – Significant up-front costs (>$5m)

Orange – Moderate up-front costs (>$2m and <$5m)

Green – Potential low up-front costs (<$2m)

4.6 Operational and Maintenance Requirements

All the proposed new structures will need to be maintained, in particular the steel structures. They will be galvanised, which should provide a long, maintenance free life but some maintenance will be required and providing safe access for this work will be problematic. Each of the structural options presented are assumed to have a design life of at least 20 years, this means that minimum maintenance is expected within the first 20 year period. It should be noted however that for any bridge type structures, i.e. the river crossing protection structures, it is normal for maintenance programs to include monitoring of the structure and level 2 assessments every 5 years.

No maintenance is proposed to be undertaken on the existing aqueduct structure, apart from maintaining the fencing around it. It is noted however, that some clean-up of spalled concrete and fallen sections is likely to be required into the future, particularly if considering an extended period of up to 50 years.

Red – Expected high operational and maintenance demands (greater than $50k pa)

Orange – Expected moderate operational and maintenance demands ($20km to $50k pa)

Green – Expected minimal operational and maintenance demands (less than $50k pa)

4.7 Other Considerations

There are numerous other considerations such as social impact and constructability. Constructability is reflected generally in the “Cost” to construct. As such a separate criteria specifically for constructability has not been included.

In respect to social impact, as the sewer has been out of service since 1992 and the Barwon Sewer Aqueduct has not been accessible to the public for a significant period of time, it has been considered that the structural options will not have any significant social impact, that has not already been captured under the existing criteria.

5. Structural Options, Costings and Approvals

Structural options considered are outlined in Section 5.1, cost estimates are outlined in Section 5.2 and detailed in Appendix B. It is noted that all structural options considered would be subject to liaison with authorities and stakeholders and outcomes of statutory approvals. An outline of planning and approval requirements is provided in Section 6. The structural options set out below are preliminary, and upon selection of a short-list or preferred option, further broader discussion, investigations and approval applications are necessary.

5.1 Structural Options

The structural options set out below are combinations of the structural concepts described above in Section 3. They are described in this section, the criteria against which they should be assessed are set out in Section 4 and the assessment is provided in Section 7.

5.1.1 Option 1a – Provision of safe access under one land span (Culvert above ground)

This option provides safe access for pedestrians and cyclists under one of the land spans, but no access is to be provided under the river spans. River users would be required to traverse the line of the aqueduct by passing through the culvert, rather than passing underneath the aqueduct at the river.

The proposed location of the culvert is as indicated in Figure 1

The structural works required are as described in Section 3.3.1.

The proposed structure is as described in Appendix A.

A variation of this option would be to also prop the remaining spans, to reduce the loads in the structure and increase the life of the existing structure.

5.1.2 Option 1b – Provision of safe access under one land span (Depressed culvert)

This option provides safe access for pedestrians and cyclists under one of the land spans, but no access under the river spans. River users would be required to traverse the line of the aqueduct by passing through the culvert, rather than passing underneath the aqueduct at the river.

The proposed location of the culvert is as indicated in Figure 1

The structural works required are as described in Section 3.3.1.

The proposed structure is as described in Appendix A.

A variation of this option would be to prop the remaining spans, to reduce the loads in the structure and increase the life of the existing structure.

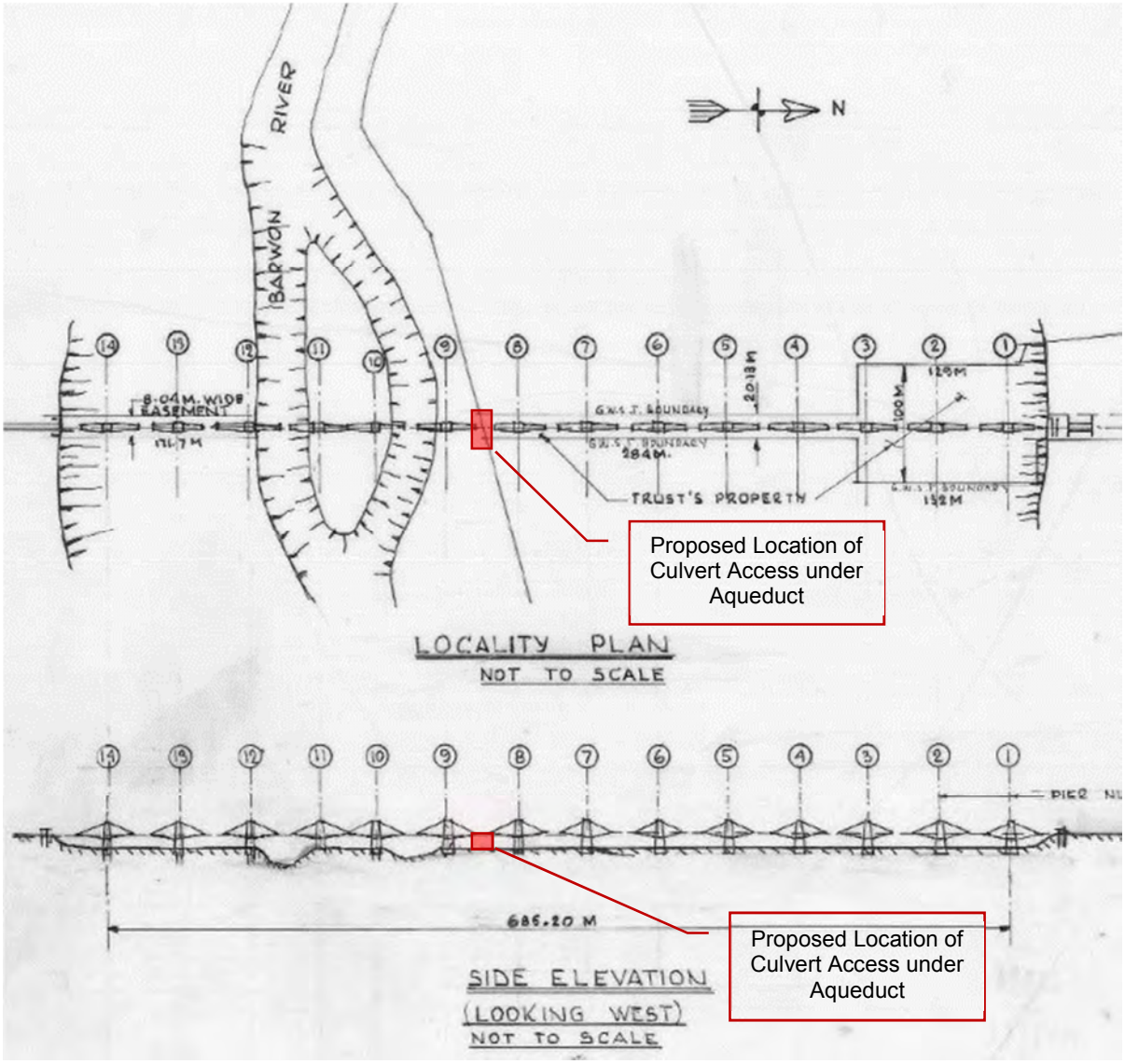


Figure 1: Options 1a & 1b - Provision of safe access under one land span - Culvert or Depressed Culvert

5.1.3 Option 2a – Provision of safe access under one land span and one river span

This option provides safe access for pedestrians and cyclists under one of the land spans, and enables river users to use one branch of the river, through the provision of two different protective structures. On land, the proposed protective structure is a culvert (as per Option 1a) and under the river a piled steel truss structure is to be provided

The proposed location of the protective structures is as indicated in Figure 2.

The structural works required are as described in Sections 3.3.1 and 3.3.2.

The proposed structures are as described in Appendix A.

A variation of this option would be to prop the remaining spans, to reduce the loads in the structure and increase the life of the existing structure.

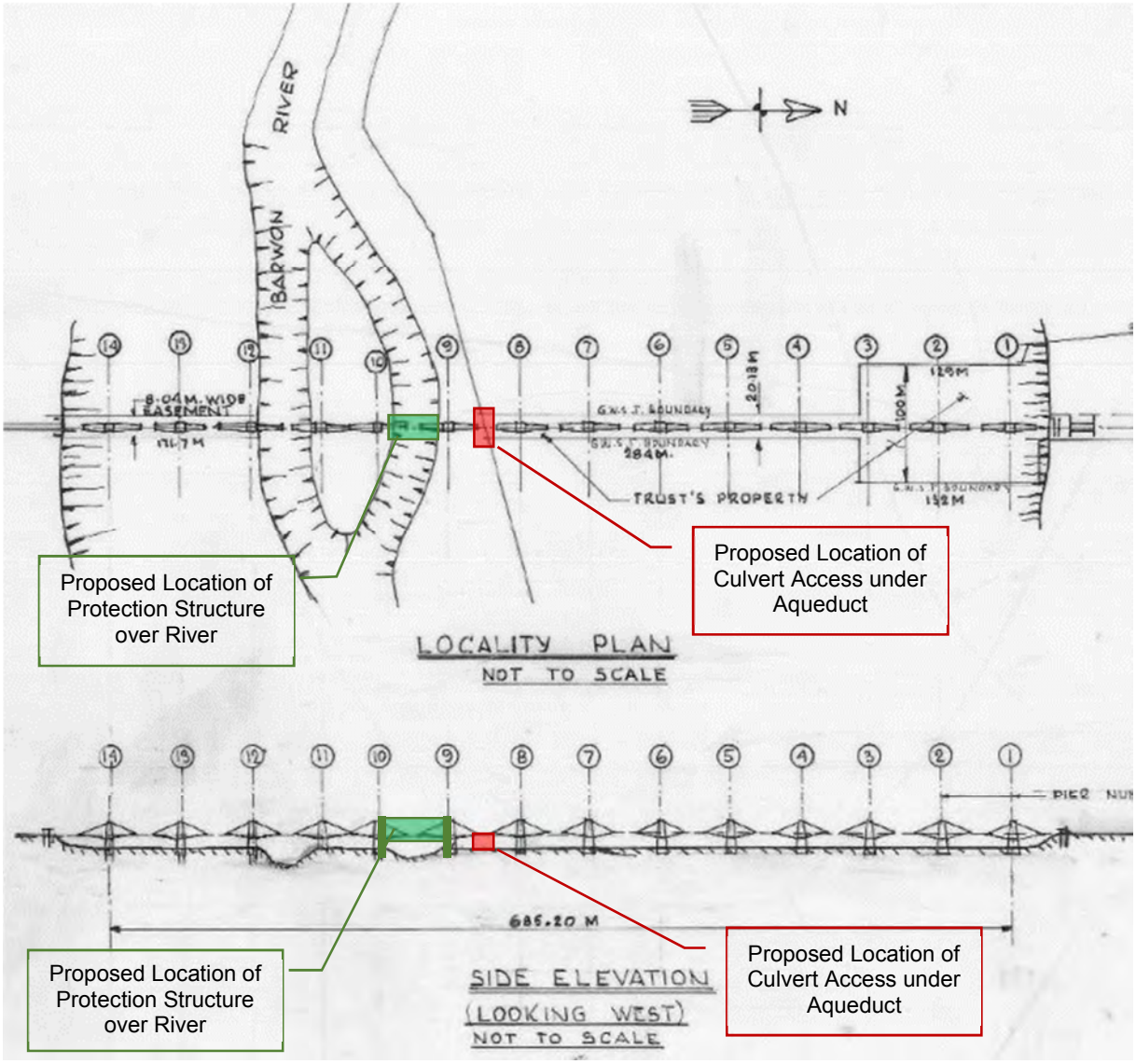


Figure 2: Option 2a - Provision of safe access under one land span (culvert) and one river span (protective structure)

5.1.4 Option 2b – Provision of safe access under one land span and both river spans

This option provides safe access for pedestrians and cyclists under one of the land spans, and enables river users to use both branches of the river, through the provision of two different protective structures. On land, the proposed protective structure is a culvert (as per Option 1a) and under the river spans a piled steel truss structure is to be provided.

The proposed location of the protective structures is as indicated in Figure 3.

The structural works required are as described in Sections 3.3.1 and 3.3.2.

The proposed structures are as described in Appendix A.

A variation of this option would be to prop the remaining spans, to reduce the loads in the structure and increase the life of the existing structure.

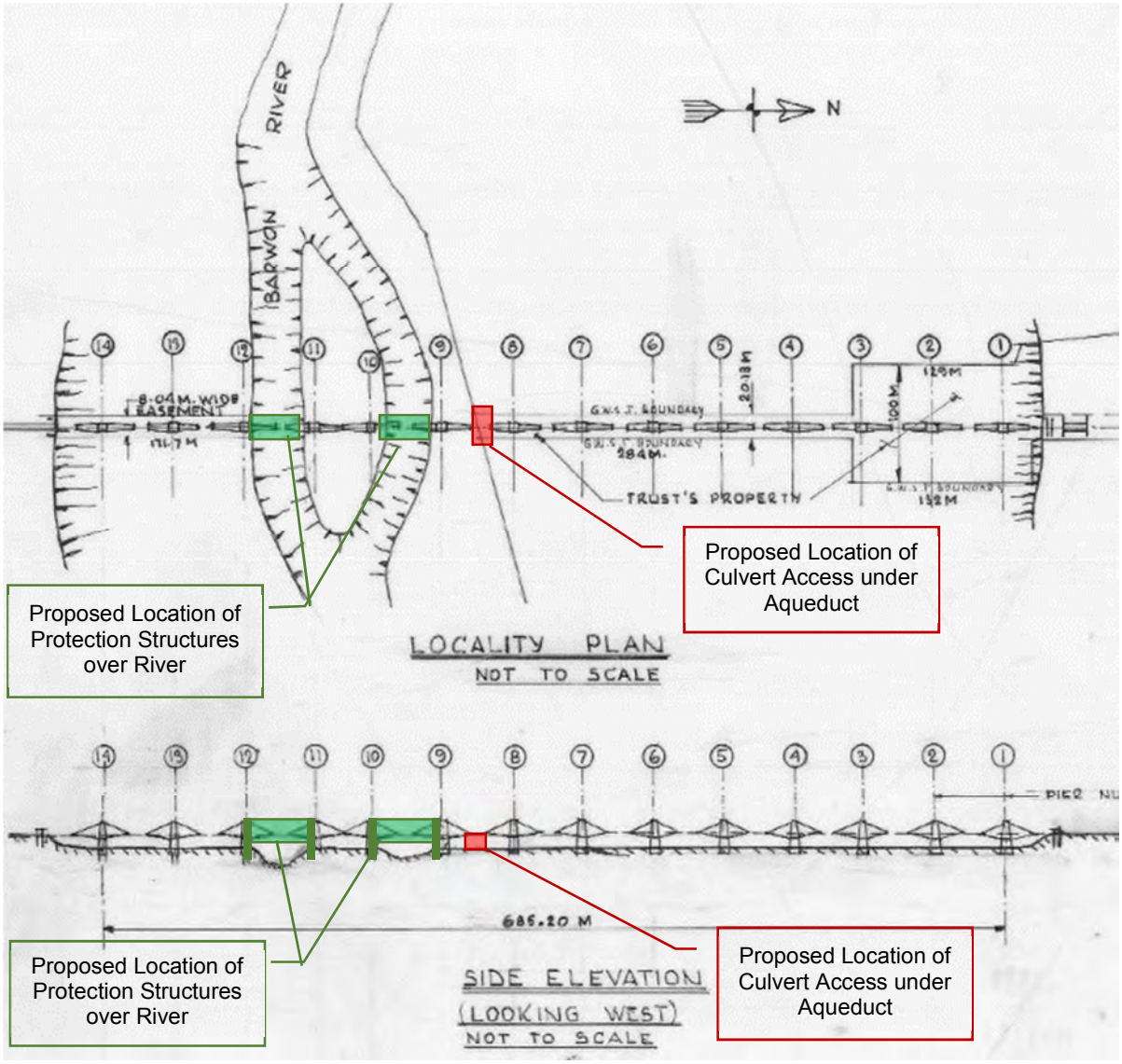


Figure 3: Option 2b - Provision of safe access under one land span (culvert) and both river spans (protective structure)

5.1.5 Option 2c – Provision of safe access under one land span and one river span (Catenary Structure)

This option provides safe access for pedestrians and cyclists under one of the land spans, and enables river users to use one branch of the river, through the provision of two different protective structures. On land, the proposed protective structure is a culvert (as per Option 1a) and under the river spans a catenary structure is to be provided to support the existing aqueduct over.

The proposed location of the protective structures is as indicated in Figure 4.

The structural works required are as described in Sections 3.3.1 and 3.3.2.

The proposed structures are as described in Appendix A.

A variation of this option would be to prop the remaining spans, to reduce the loads in the structure and increase the life of the existing structure.

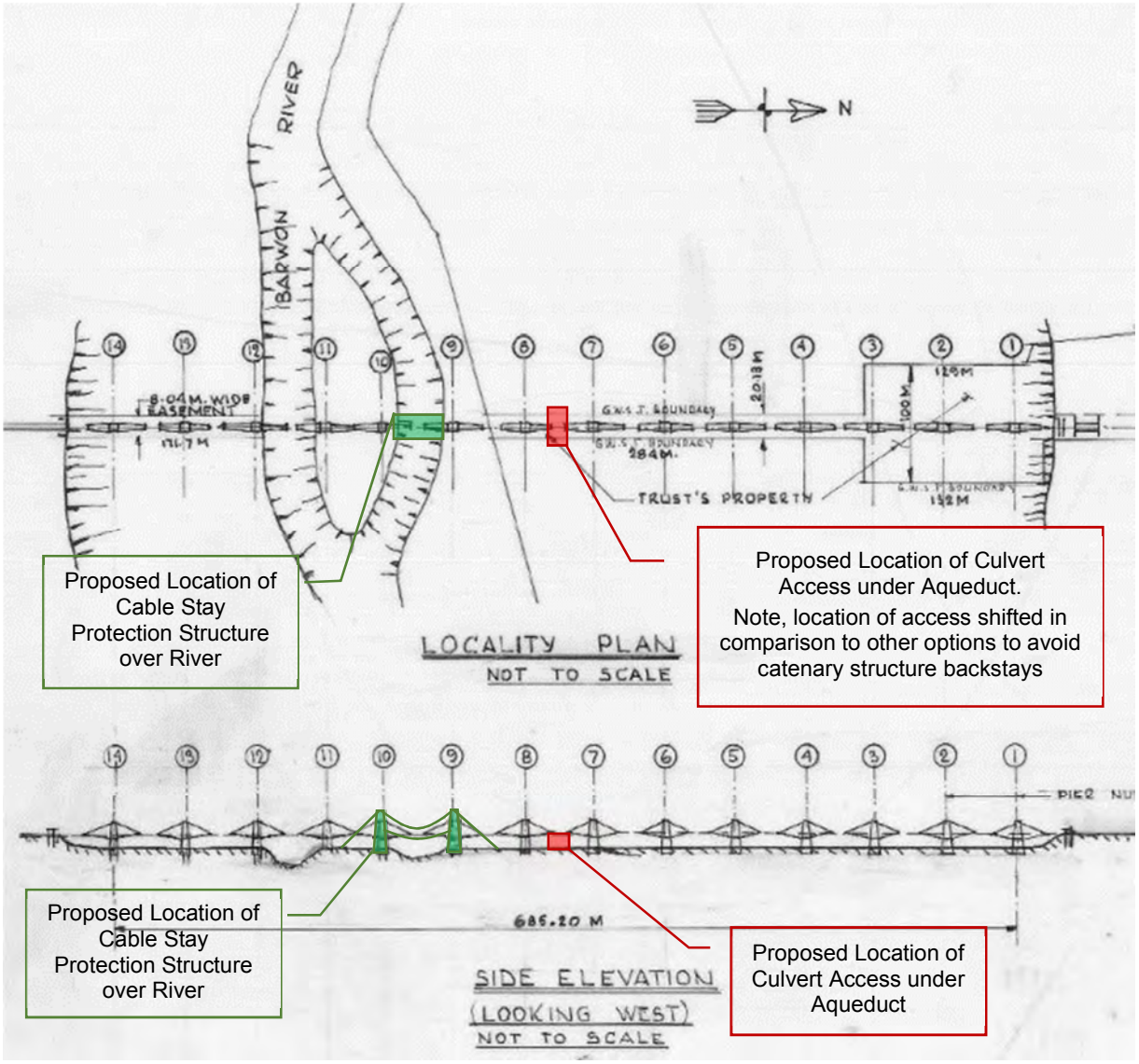


Figure 4: Option 2c - Provision of safe access under one land span and one river span (catenary structure)

5.1.6 Option 3a – Demolish both river spans and adjacent land spans – leaving towers

This option provides safe access for pedestrians and cyclists on land in a zone adjacent to the river edge, and enables river users to use both branches of the river.

The proposed extent of the demolition works is as indicated in Figure 5.

The structural works required are as described in Sections 3.4.3, noting the issues with demolition in the river spans.

The proposed demolition construction sequence is described in Appendix A.

A variation of this option would be to prop the remaining land spans, to reduce the loads in the structure and increase the life of the existing structure.

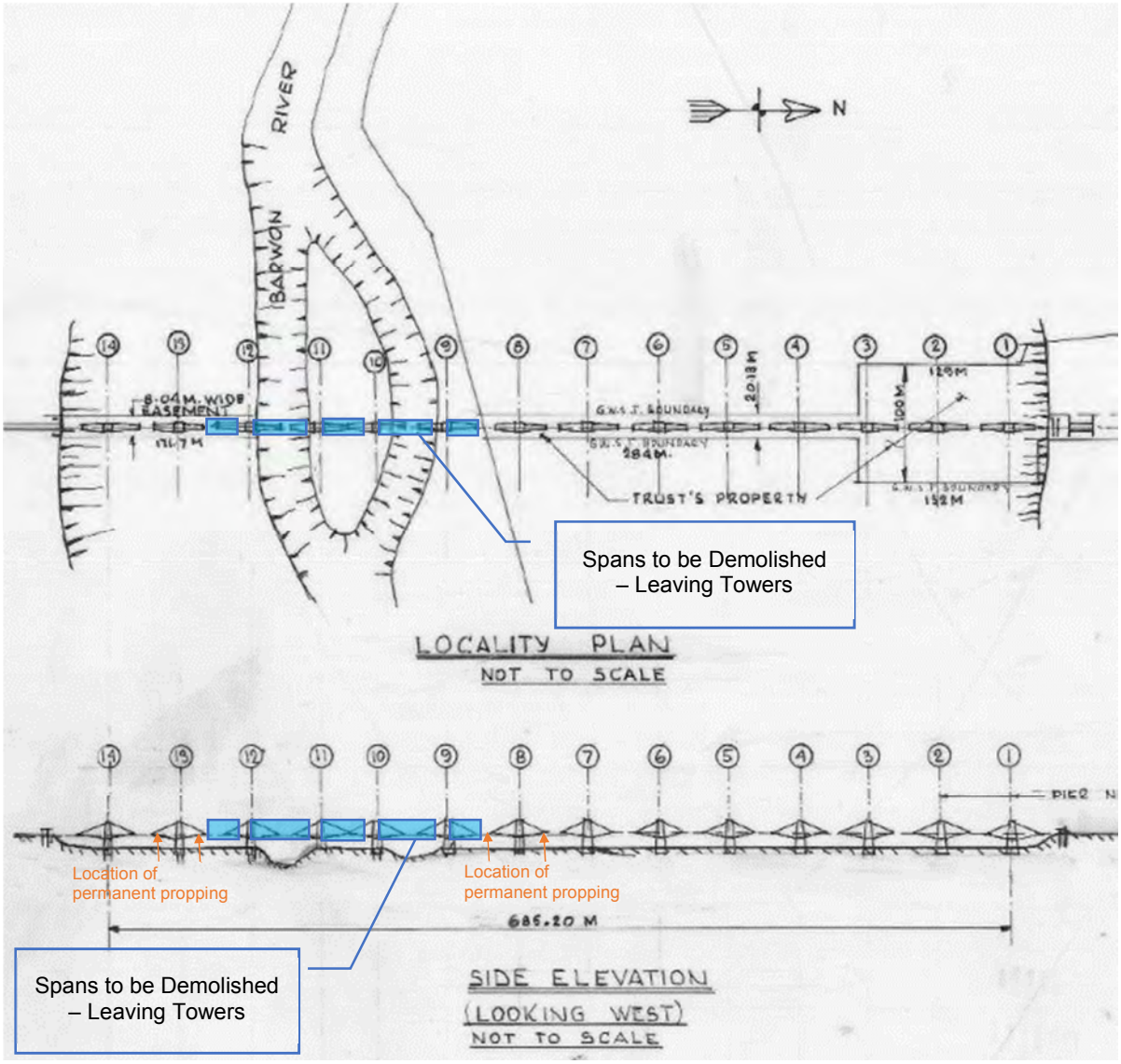


Figure 5: Option 3a - Demolish both river spans and adjacent land spans - leaving towers

5.1.7 Option 3b – Demolish both river spans and adjacent land spans – including towers

This option provides safe access for pedestrians and cyclists on land in a zone adjacent to the river edge, and enables river users to use both branches of the river.

The proposed extent of the demolition works is as indicated in Figure 6.

The structural works required are as described in Sections 3.4.2, noting the issues with demolition in the river spans.

A variation of this option would be to prop the remaining land spans, to reduce the loads in the structure and increase the life of the existing structure.

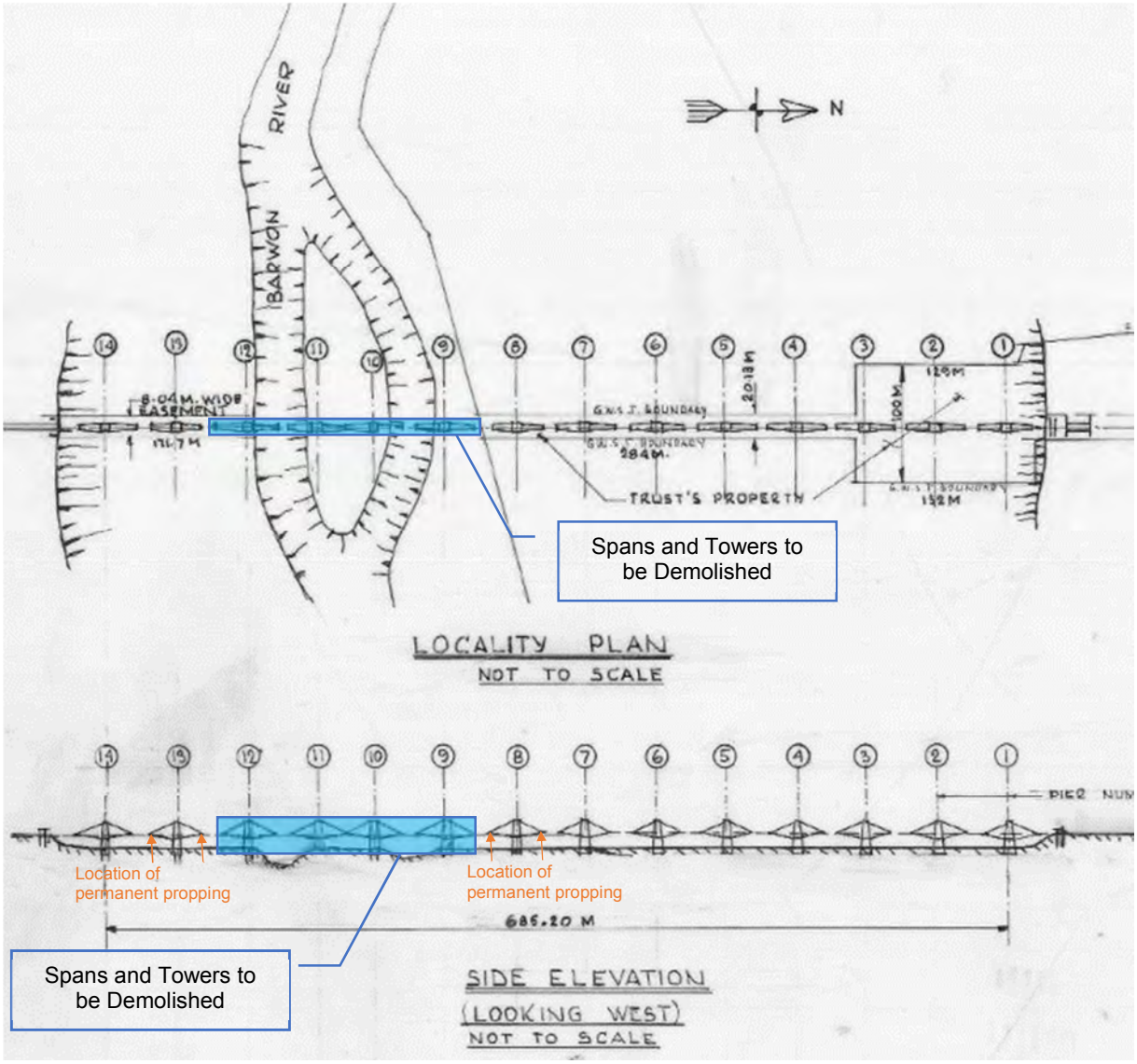


Figure 6: Option 3b - Demolish both river spans and adjacent land spans - including towers

5.1.8 Option 4 – Demolish all spans of Aqueduct Structure

This option provides safe access for pedestrians and cyclists as well as full access for river users to both branches of the river.

The structural work required is as described in Section 3.4.1.

5.1.9 Other Options

There is a significant amount of other options that pertain to extending the life of the structure. Patch repairs, re-alkalisation and cathodic protection are not suggested given the expense, state of the existing structure and significant difficulty in successfully undertaken any of the these remediation works on a significant scale. One option considered to be of potential merit, subject to available funding, is propping structural elements to be retained with a view to extend the potential life prior to structural failure. There are a range of propping scenarios and extent of propping that could be undertaken. Propping would be in addition to minimum requirements as outlined in Option 1 to Option 3 above.

Cost estimates for various extents of additional propping works are included in Section 5.2 below.

5.2 Cost Estimates

Cost estimates for Option 1 to 4 are provided in Table 1 below.

Table 1: Option Costs Summary

Structural Option	CAPEX ($)
Option 1a: Provision of Safe Access under One Land Span (Culvert)	**427,766**
Option 1b: Provision of Safe Access under One Land Span (Depressed Culvert)	**618,879**
Option 2a: Provision of Safe Access under One Land Span (Culvert) and One River Span (Protective Structure)	**2,865,866**
Option 2b: Provision of Safe Access under One Land Span (Culvert) and Two River Spans (Protective Structure)	**4,840,757**
Option 2c: Provision of Safe Access under One Land Span (Culvert) and One River Span (Catenary Structure)	**8,328,354**
Option 3a: Demolish Both River Spans and adjacent Land Spans – Leaving Towers	**3,301,422**
Option 3b: Demolish Both River Spans and adjacent Land Spans – Including Towers	**2,931,813**
Option 4: Demolish Entire Structure – Including Towers	**4,358,857**
Propping: Propping to underside of cantilever trusses – per prop, 2 no. required per span (as a means of extending the life of the existing structure)	**67,600**

Refer to Appendix B for cost estimate breakdowns.

GHD has prepared the preliminary cost estimates set out in this report ("Cost Estimated") using information reasonably available to the GHD employee(s) who prepared this report; and based on assumptions and judgments made by GHD.

The Cost Estimates have been prepared to provide Barwon Water with initial estimates for the possible cost of the works, and should not be used for any other purpose at this stage, noting that upon selection of a preferred option further assessment and development of cost estimates is required.

The Cost Estimate is a preliminary estimate only. Actual prices, costs and other variables may be different to those used to prepare the Cost Estimate and may change. Unless as otherwise specified in this report, no detailed quotation has been obtained for actions identified in this report.

GHD does not represent, warrant or guarantee that the works can or will be undertaken at a cost which is the same or less than the Cost Estimate.

Where estimates of potential costs are provided with an indicated level of confidence, notwithstanding the conservatism of the level of confidence selected as the planning level, there remains a chance that the cost will be greater than the planning estimate, and any funding would not be adequate. The confidence level considered to be most appropriate for planning purposes will vary depending on the conservatism of the user and the nature of the project. The user should therefore select appropriate confidence levels to suit their particular risk profile.

6. Planning and Approvals

This planning assessment refers to the Barwon Sewer Aqueduct structure in its entirety as the full extent of proposed works required and a preferred option is unknown at this time. In addition, the assessment also considers the construction of walking and cycle pathways and associated works (trails, interpretive signage and viewing platforms) along the northern edge of the Barwon River as advised in discussions with Steve Reddington of Barwon Water.

The planning and approval requirements will require review upon selection of a preferred option. Further detailed investigations, studies and supporting documentation would be required for lodgement of any approval applications.

6.1 Land tenure

The following assessment applies to land described at:

- Lot 1, TP844852, 42 Leather Street, Breakwater, VIC
- Crown Allotment 5, Section 12A, Parish of Corio
- Crown Allotment 6, Section 12A, Parish of Corio
- Crown Allotment 2042, Parish of Corio
- Lot 1, PS308402, 91-97 Tannery Road, Marshall, VIC

6.2 Planning Controls

The assessment includes permit and approval requirements from the City of Greater Geelong, Heritage Victoria and Aboriginal Victoria. A summary of likely approvals required are outlined below.

6.2.1 City of Greater Geelong

A planning permit would be required from the City of Greater Geelong (CoGG) for the works relating to the aqueduct structure and the walking/ cycling pathway. The nature of the works are to be confirmed, however the relevant land use definition include:

- Minor utility installation (for any works relating to the aqueduct)
- Informal outdoor recreation (for the walking/ cycling pathways and associated works).

Consultation with the CoGG is recommended to discuss the project, confirm the land use definitions, and also the extent of permit triggers that would not be assessed under any permit obtained through Heritage Victoria.

The Barwon Sewer Aqueduct is referred to as the area north and south of the Barwon River, including the river itself and Goat Island.

Table 2 identifies the zone and overlay, and particular provisions relative to the project area.

Table 2: Planning Permit Controls

Location	Applicable Control	Permit Required Yes/ No/ Potentially
Land north of Barwon River (including Barwon River and Goat island)	Clause 36.03 – Public Conservation and Resource Zone (PCRZ)	No – *as Barwon Water are the public land manager*
Land south of Barwon River (excluding the river and Goat island)	Clause 35.07 – Farming Zone (FZ)	No – use and buildings and works are exempt. The extent of earthworks will not trigger a permit as confirmed by Barwon Water
	Clause 37.07 – Urban Growth Zone, Schedule 1 (UGZ1)	No – as no works are proposed in this area
	Clause 42.01 – Environmental Significant Overlay, Schedule 2 (ESO2)	Yes – *for native vegetation removal and buildings and works*
	Clause 45.06 – Development Contribution Plan Overlay, Schedule 1 (DCPO1)	No – as no works are proposed in this area
	Clause 52.16 – Native Vegetation Precinct Plan	No – as no works are proposed in this area
Affects the whole site	Clause 43.01 – Heritage Overlay, Schedule 56 (HO56)	No – *exempt as a Heritage Victoria Registration applies*
	Clause 44.03 – Flood Overlay (FO)	Yes – *for works, including bicycle pathways and trails*
	Clause 52.17 – Native Vegetation	Yes – *for native vegetation removal*

6.2.2 Heritage Victoria

The entire Barwon Sewer Aqueduct is on the Victorian Heritage Register (VHR), *VHR Number 'H0895 – Ovoid Sewer Aqueduct over Barwon River'*.

As specified on the VHR H0895 citation, the extent of the heritage registration is as follows:

- The whole of the structure known as the ovoid sewer aqueduct
- Land 10 metres either side of the structure
- Land 10 metres to the northern end of the structure (Barwon Water freehold land north of the river).

A permit from Heritage Victoria is required for works within the abovementioned areas. Consultation with Heritage Victoria is necessary to confirm permit application requirements and any exemptions that may relate to the nature of works proposed.

6.2.3 Aboriginal cultural heritage

The site is located within an identified area of Aboriginal Cultural Heritage Sensitivity.

It is recommended that a Cultural Heritage Assessment be undertaken to assess the known and predicted cultural heritage values in the area. An outcome of this assessment may be the requirement to undertake a mandatory Cultural Heritage Management Plan (CHMP).

6.3 Permit Requirements

A summary of potential approval requirements for project works is provided in Table 3 below. In the absence of consultation with HV and CoGG, the extent of the permit requirements may change.

Table 3: Summary of Approval Requirements

Control	Permit Trigger	Comments/ Application Requirements	Authority
Planning permit requirements			
ESO2	Buildings and works Remove, destroy or lop any vegetation	A permit is required for buildings and works. This permit trigger only applies to options involving project works on the south side of the river. A permit is required to remove, destroy or lop native vegetation, including dead vegetation (some exotic vegetation removal is not exempt if it is protected under legislation specified in the schedule to the overlay).	Council
FO	Buildings and works	A permit is required for buildings and works, including bicycle pathways and trails. An application must be accompanied by a flood risk report satisfying the application requirements outlined in the overlay.	Council
Clause 52.17	Native vegetation removal	A permit is required to remove, destroy or lop any native vegetation, including dead vegetation (unless exempt).	Council
Additional permit requirements			
VHR H0895	Works within the citation area defined by VHR H0895	A permit is required from Heritage Victoria for works within the area defined as H0895 Consultation with Heritage Victoria is required to confirm permit requirements	Heritage Victoria
Aboriginal Cultural Heritage	Works are located on land identified as an area of Aboriginal cultural heritage sensitivity	A Cultural Heritage Assessment (or similar) is required A CHMP is likely to be required	Aboriginal Victoria and the Wadawurrung

6.3.1 Other approval requirements

Other permits and approvals may be required for the project including, but not limited to:

- Works on waterways permit/ authorisation – Corangamite Catchment Management Authority (CCMA)
- Local laws approvals – City of Greater Geelong

Furthermore, obtaining Crown Land title details to determine licencing information is required.

6.4 Planning and Approvals Conclusion

Based on the above we consider a planning permit is required (buildings and works and native vegetation removal), with the specific planning permit triggers to be confirmed once a preferred option and scope of works is determined. A permit from Heritage Victoria is also required, as are other potential approvals.

7. Options Assessment

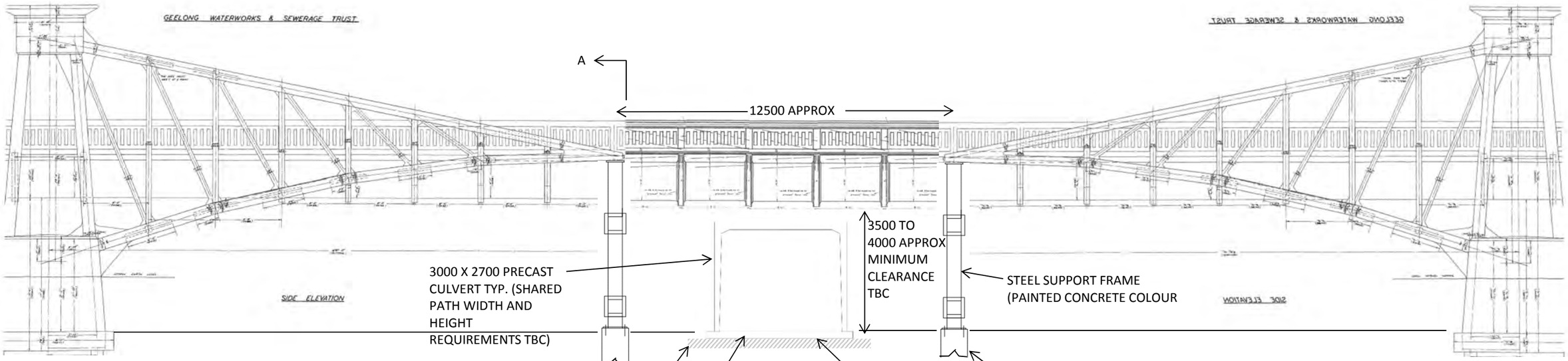
A tabulated matrix of the options addressing each of the assessment criteria from Section 4 is provided in Table 4. The “traffic light” assessment format is provided as a high level comparison tool of the options and their individual performances under the assessment criteria.

Table 4: Options Assessment Tabulation

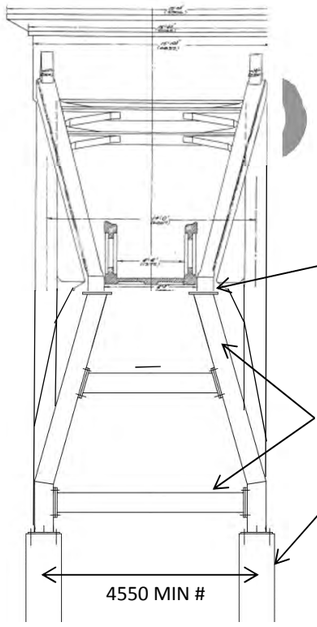
Option	Public Access	Residual Risk	Floodplain and Waterway Impact	Structural Heritage Impact	Capital Cost	Maintenance & Operations
Option 1a: Provision of Safe Access under One Land Span (Culvert)						
Option 1b: Provision of Safe Access under One Land Span (Depressed Culvert)						
Option 2a: Provision of Safe Access under One Land Span (Culvert) and One River Span (Protective Structure)						
Option 2b: Provision of Safe Access under One Land Span (Culvert) and Two River Spans (Protective Structure)						
Option 2c: Provision of Safe Access under One Land Span (Culvert) and One River Span (Cable Stay Protective Structure)						
Option 3a: Demolish Both River Spans and adjacent Land Spans – Leaving Towers						
Option 3b: Demolish Both River Spans and adjacent Land Spans – Including Towers						
Option 4: Demolish Entire Structure – Including Towers						

Appendices

Appendix A – Structural Options Sketches & Visualisations

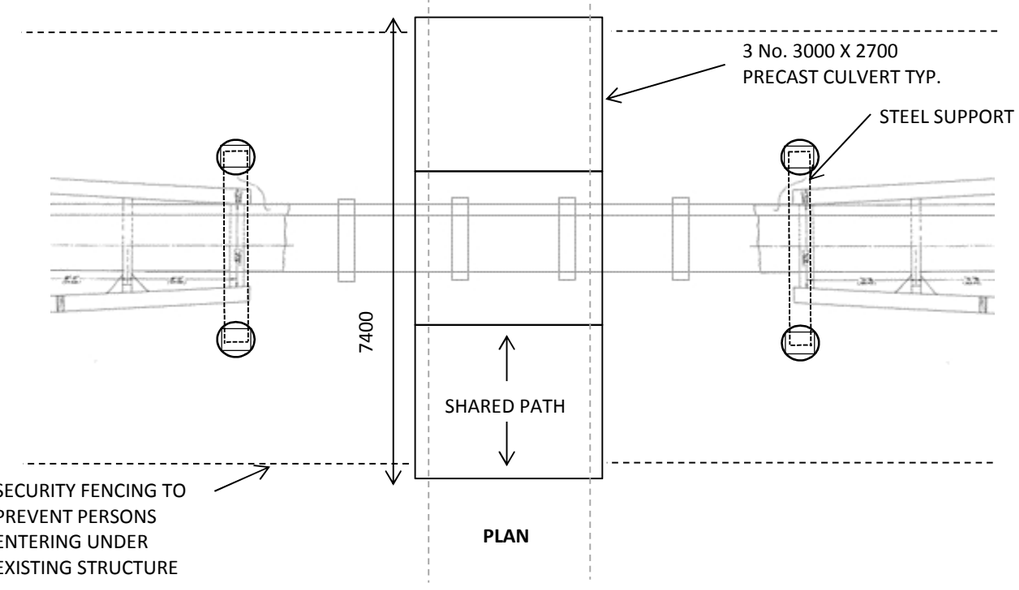


ELEVATION



SECTION A-A

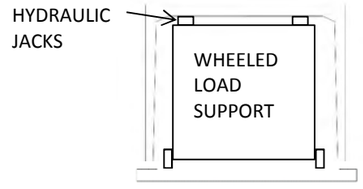
PILE SPACING TBC TO ENABLE SAFE INSTALLATION OF PILES AND SUPPORT FRAME ADJACENT TO EXISTING STRUCTURE.



PLAN

CONSTRUCTION SEQUENCE

1. PILE AND CONSTRUCT STEEL SUPPORT FRAME
2. PREPARE GROUND, PLACE CRUSHED ROCK BASE USING REMOTELY CONTROLLED EQUIPMENT
3. CRANE PRECAST SLAB SEGMENTS INTO POSITION
4. WHEEL IN PRECAST CULVERT MIDDLE SEGMENT
5. LIFT IN OUTER CULVERT SEGMENTS



PRECAST CULVERT MIDDLE SEGMENT INSTALLATION

NOTES:
ESTIMATED STEEL SUPPORT FRAME QUANTITY 7 TONS TOTAL

No.	Revisions	Approved	Date
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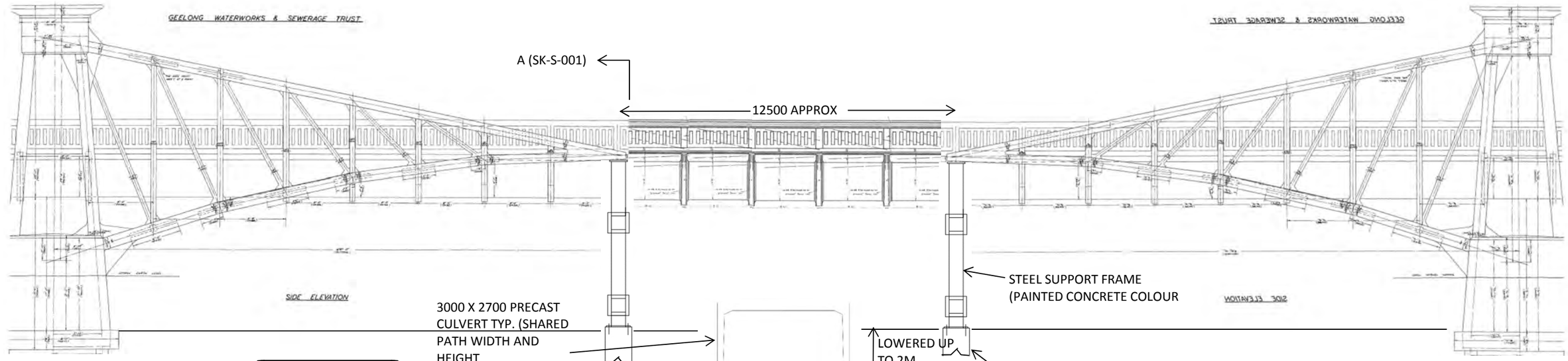
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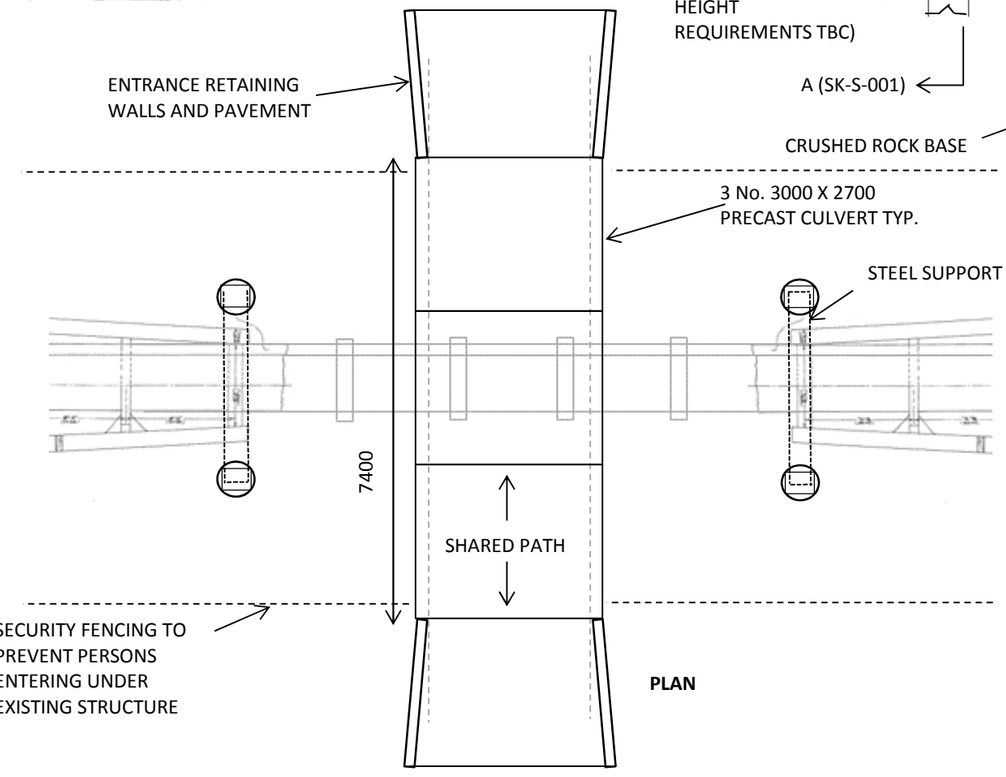
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Drawn	MB	16/03/2017	
Designed	MB	16/03/2017	
Draft Check		/ /	
Design Check	PSS	31/03/2017	
Approved		/ /	

Client	Barwon Water						
Project	Barwon Sewer Aqueduct - Structural Assessment						
Title	Option 1a - Provision of Safe Access under one Land Span - Culvert						
DO NOT SCALE	A3	Drawing No.	SK-S-001	Scale	NTS	Rev.	A



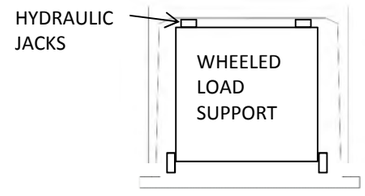


PLAN

200 THK CAST-INSITU CONCRETE SLAB, CAST BELOW INSTALLED CULVERT SECTIONS

CONSTRUCTION SEQUENCE

1. PILE AND CONSTRUCT STEEL SUPPORT FRAME
2. EXCAVATE DEPRESSION, PREPARE GROUND, PLACE CRUSHED ROCK BASE USING REMOTELY CONTROLLED EQUIPMENT
3. WHEEL IN PRECAST CULVERT SEGMENTS
5. CAST BASE SLAB UNDER CULVERTS AND FOR RAMPS
6. CAST RETAINING WALLS BEYOND CULVERTS



PRECAST CULVERT SEGMENT INSTALLATION

NOTES:
ESTIMATED STEEL SUPPORT FRAME QUANTITY 7 TONS TOTAL

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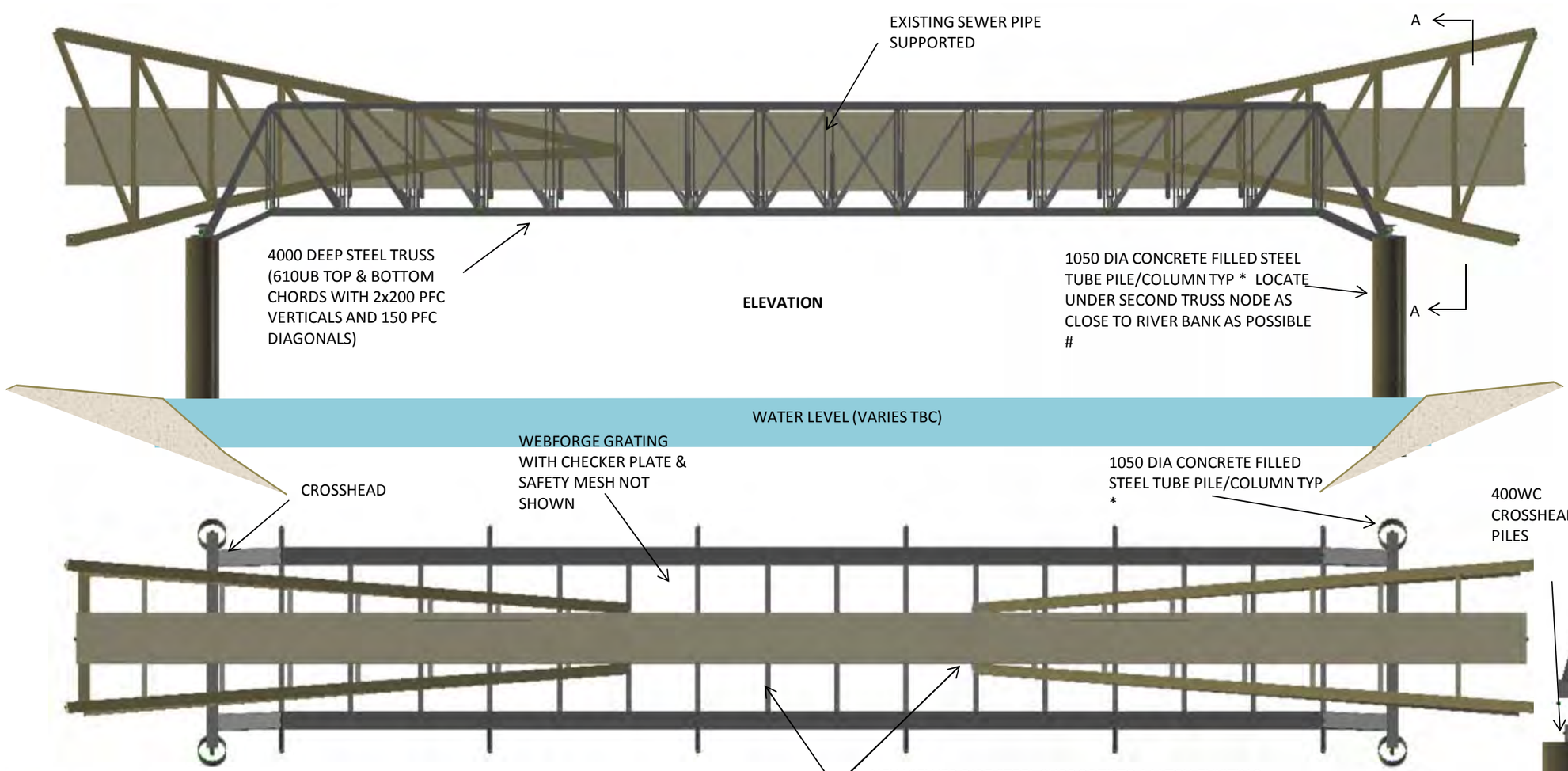
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Designed	HB	28/04/2017	
Draft Check		/ /	
Design Check	DW	28/04/2017	
Approved		/ /	

Client	Barwon Water						
Project	Barwon Sewer Aqueduct - Structural Assessment						
Title	Option 1b - Provision of Safe Access under one Land Span - Depressed Culvert						
DO NOT SCALE	A3	Drawing No.	SK-S-002	Scale	NTS	Rev.	A



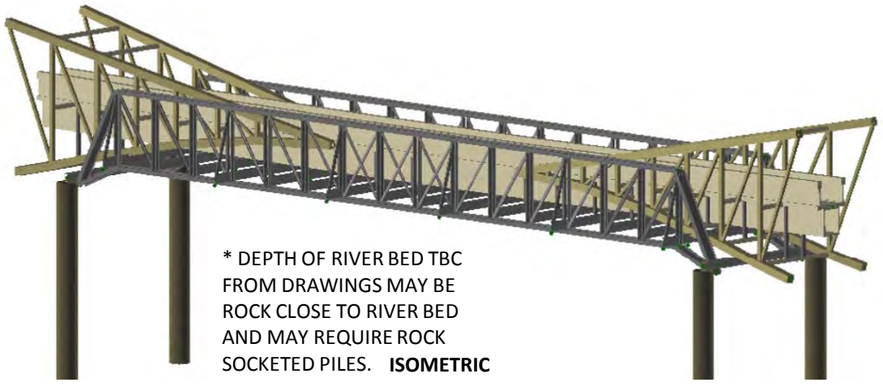
ELEVATION

CONSTRUCTION SEQUENCE

1. PROVIDE CONSTRUCTION ACCESS TO ISLAND
2. DRIVE PILES USING CRANES
3. ASSEMBLE TRUSS ON BARGES
4. FLOAT TRUSS INTO POSITION
5. JACK TRUSS UP PILES
6. JACK SEWER AND CONCRETE TRUSS OFF STEEL TRUSS
7. REMOVE TEMPORARY ACCESS

PLAN

NEW SEWER PIPE STEEL SUPPORTS TO MATCH EXISTING HANGER MEMBERS. TO BE SUPPORTED WITH GROUTED FLAT JACKS BETWEEN EXISTIING CONCRETE AND NEW STEEL SUPPORT TYP.



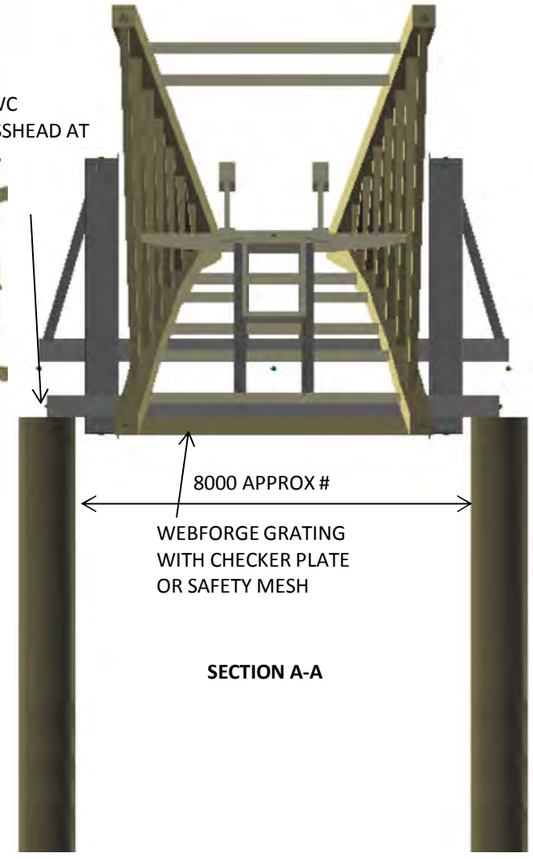
* DEPTH OF RIVER BED TBC FROM DRAWINGS MAY BE ROCK CLOSE TO RIVER BED AND MAY REQUIRE ROCK SOCKETED PILES. **ISOMETRIC**



PILE SPACING TBC TO ENABLE SAFE INSTALLATION OF PILES AND SUPPORT FRAME ADJACENT TO EXISTING STRUCTURE.

NOTES:

ESTIMATED TRUSS STEEL QUANTITY 120 TONNES (PAINTED CONCRETE COLOUR TO MATCH EXISTING)



SECTION A-A

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A	Reduced Height & Amended Framing	PSS	13/9/17

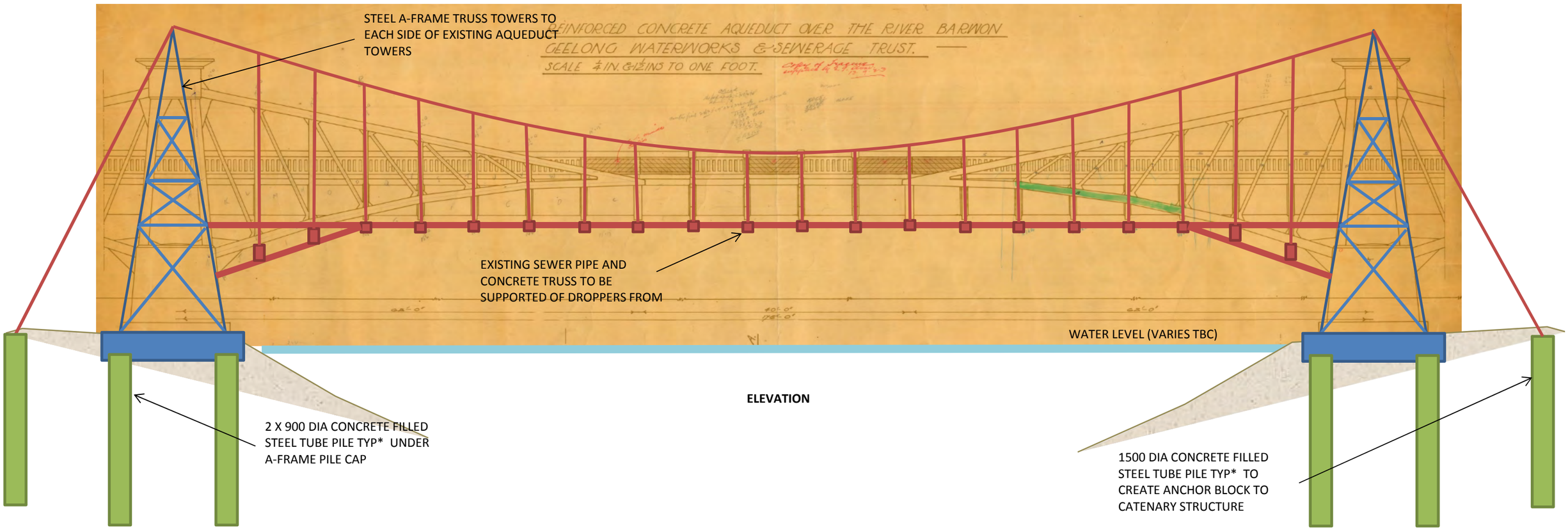
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Designed	PB	7/08/2017	Project: Barwon Sewer Aqueduct - Structural Assessment
Draft Check		/ /	Title: Options 2a & 2b - Single Span Steel Truss Protective Structure
Design Check	PSS	8/08/2017	
Approved		/ /	

DO NOT SCALE | A3 | Drawing No. SK-S-003 | Scale NTS | Rev. B



ELEVATION

NOTE:
STRUCTURE DOCUMENTED IS INDICATIVE ONLY OF A POTENTIAL STRUCTURAL ARRANGEMENT, NO DESIGN HAS BEEN COMPLETED.
COSTS HAVE BEEN DETERMINED BASED ON TYPICAL RATES FOR A CATENARY TYPE PEDESTRIAN BRIDGE STRUCTURE.

* DEPTH OF RIVER BED TBC FROM DRAWINGS MAY BE ROCK CLOSE TO RIVER BED AND MAY REQUIRE ROCK SOCKETED PILES.

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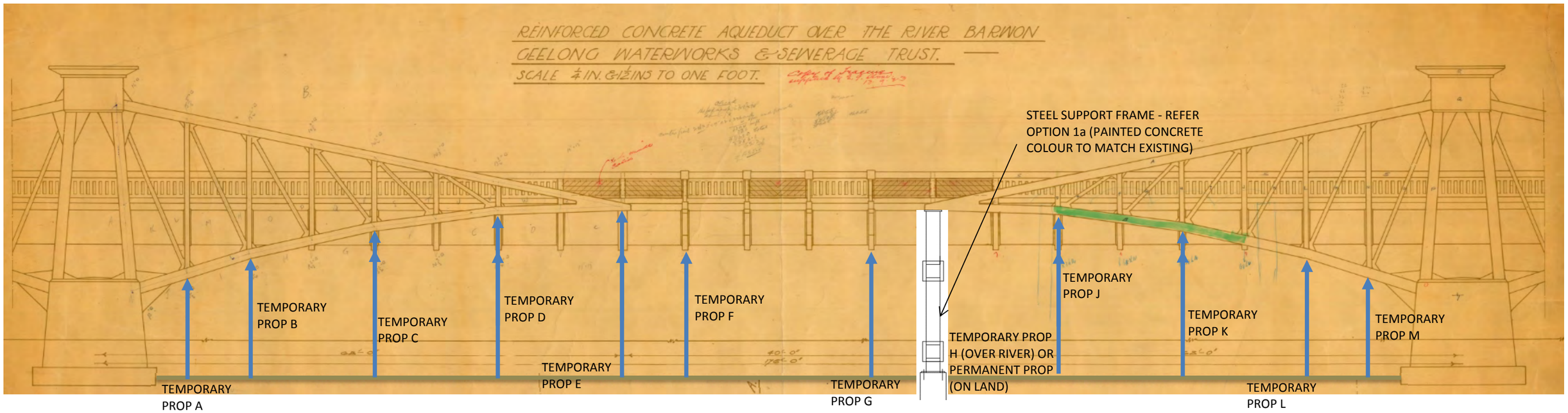
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Drawn	HB	28/04/2017	**Client** Barwon Water
Designed		/ /	**Project** Barwon Sewer Aqueduct - Structural Assessment
Draft Check		/ /	**Title** Option 2c - Single Span Catenary Protective Structure
Design Check	DW	28/04/2017	
Approved		/ /	

DO NOT SCALE	A3	Drawing No.	SK-S-004	Scale	NTS	Rev.	A



ELEVATION

NOTES:
ESTIMATED STEEL SUPPORT FRAME QUANTITY 3.5 TON FOR EACH PERMANANT PROP

CONSTRUCTION SEQUENCE

1. INSTALL PROPS AT EACH LOCATION NOMINATED ABOVE
2. SUPPORT THE AQUEDUCT FROM EACH PROP, USING FLAT JACKS
3. SUPPORT THE ENDS OF THE TRUSSES ON THE OTHER SIDES OF THE TOWERS SHOWN (i.e. AT TEMP PROP E LOCATION)
4. CRANE TO TAKE THE LOAD OF THE STRUCTURE BETWEEN THE PROPS
5. WIRE CUT SEWER ADJACENT TO PROPS E AND H, USING EQUIPMENT SUPPORTED WELL AWAY FROM STRUCTURE
6. REMOVE SECTION OF SEWER BETWEEN PROPS E AND H
7. CRANE TO TAKE TH LOAD OF THE STRUCTURE FROM PROP D TO PROP E
8. ENSURE THAT ALL PARTS OF THE STRUCTURE (TRUSS, SEWER, WALKWAY) ARE PROPERLY SUPPORTED BY THE CRANE
9. WIRE CUT SEWER STRUCTURE ADJACENT TO PROP D, USING EQUIPEMENT SUPPORTED WELL AWAY FROM STRUCTURE
10. REPEAT STEPS 6,7,8 AND 9 AS RELATED TO PROPS C, B, A AND THE TOWER.
11. REPEAT FOR PROPS H TO M

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Design Check	DW	28/04/2017	
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DO NOT SCALE

Client	Barwon Water
Project	Barwon Sewer Aqueduct - Structural Assessment
Title	Option 3a - Demolition of River Spans and Adjacent Land Spans, leaving Towers. Options 3b and 4 similar

A3	Drawing No.	SK-S-005	Scale	NTS	Rev.	A

BEFORE



AFTER



ARTISTIC IMPRESSION
Barwon Sewer Aqueduct

SK001
OPTION 2A

GHDWOODHEAD

BEFORE



AFTER



ARTISTIC IMPRESSION
Barwon Sewer Aqueduct

SK002
OPTION 2A

GHDWOODHEAD

Appendix B – Cost Estimates

CLIENTS | PEOPLE | PERFORMANCE

Client:	**Barwon Water**	**Job no.:**	**31-34965**
Project:	**Barwon Sewer Aqueduct**	**By:**	**Alan Rae**
Subject:	**Summary of Cost Estimates**	**Date:**	**14-09-17**

Option		**Cost**
OPTION 1a - Provision of Safe Access under One Land Span (Culvert)	$	427,766
OPTION 1b - Provision of Safe Access under One Land Span (Depressed Culvert)	$	618,879
OPTION 2a - Provision of Safe Access under One Land Span (Culvert) and One River Span (Protective Structure)	$	2,862,866
OPTION 2b - Provision of Safe Access under One Land Span (Culvert) and Both River Spans (Protective Structure)	$	4,840,757
OPTION 2c - Provision of Safe Access under One Land Span (Culvert) and One River Spans (Catenary Structure)	$	8,328,354
OPTION 3a - Demolish Both River Spans and Adjacent Land Spans - Leaving Towers	$	3,921,399
OPTION 3b - Demolish Both River Spans and Adjacent Land Spans - Including Towers	$	4,141,298
OPTION 4 - Demolish Entire Structure - Including Towers	$	7,874,692

Client:	Barwon Water	Job no.:	31-34965
Project:	Barwon Sewer Aqueduct	By:	Alan Rae
Subject:	Development of Cost Estimates	Date:	14-09-17

OPTION 1a - Provision of Safe Access under One Land Span (Culvert)

Direct Costs					
Environmental management	1	Item	10,000	10,000	
Provide temporary access and remove	1	Item	2,500	2,500	
					12,500
Steel support frames - 2 No					
Establish/demob - piling plant	1	Item	6,000	6,000	
750mm bored pile x 8m depth - 4 No	32	m	500	16,000	
Consider 1 No frame					
Supply steel support frame 400mm SHS	7	T	8,000	56,000	
Provide temporary safe working canopy	1	Item	2,000	2,000	
Install frames - incl. flat jacks	16	Hrs	600	9,600	
Supply & install second frame	1	No	67,600	67,600	
					157,200
Precast Culverts 3000 x 2700 - 3 No					
Provide steel canopy for access x 4m	1	Item	10,000	10,000	
Concrete slab x 250mm incl. bedding	22	m^2	350	7,700	
Supply 3000 x 2700 RCBC	3	No	12,000	36,000	
Install	3	No	3,500	10,500	
					64,200
Total Direct Cost for Option 1a					**233,900**

Indirect Costs		
Contractor's Supervision & Site Overheads	21%	49,119
Contractor's HO Overhead & Profit	8%	22,642
Engineering	6%	14,034
Contract supervision/administration	4%	9,356
Contingency	30%	98,715
Total Indirect Cost for Option 1a		**193,866**

Total Budget Estimate for Option 1a	**427,766**

Client:	Barwon Water	Job no.:	31-34965
Project:	Barwon Sewer Aqueduct	By:	Alan Rae
Subject:	Development of Cost Estimates	Date:	14-09-17

OPTION 1b - Provision of Safe Access under One Land Span (Depressed Culvert)

Direct Costs					
Environmental management	1	Item	10,000	10,000	
Provide temporary access and remove	1	Item	2,500	2,500	
					12,500
Steel Support Frames 2 No	1	Item	157,200	157,200	
Precast Culverts 3000 x 2700 - 3 No	1	Item	64,200	64,200	
Allow excavation say to 2m depth	140	m^3	25	3,500	
Extra ramp concrete	96	m^2	350	33,600	
Extra concrete to retaining walls	64	m^2	350	22,400	
Provision for lighting	1	Item	25,000	25,000	
Provision for pumping	1	Item	20,000	20,000	
					325,900
Total Direct Cost for Option 1b					**338,400**

Indirect Costs		
Contractor's Supervision & Site Overheads	21%	71,064
Contractor's HO Overhead & Profit	8%	32,757
Engineering	6%	20,304
Contract supervision/administration	4%	13,536
Contingency	30%	142,818
Total Indirect Cost for Option 1b		**280,479**

Total Budget Estimate for Option 1b	**618,879**

Client:	**Barwon Water**	**Job no.:**	**31-34965**
Project:	**Barwon Sewer Aqueduct**	**By:**	**Alan Rae**
Subject:	**Development of Cost Estimates**	**Date:**	**14-09-17**

OPTION 2a - Provision of Safe Access under One Land Span (Culvert) and One River Span (Protective Structure)

Direct Cost of land span	1	Item	233,900	233,900	233,900
Direct Cost of River Span					
Environmental management	1	Item	100,000	100,000	
Temporary access incl removal 700m x 5m	3500	m^2	20	70,000	
Mobilise/demob floating plant to support 100T	1	Item	50,000	50,000	
Hire of floating plant	10	Weeks	10,000	100,000	
Supply 1050mm piles 12mm pl x 20m - 4 No	30	T	2,000	60,000	
Install piles	4	No	8,000	32,000	
Provide hardstand for assembly & removal	500	m^2	30	15,000	
Supply supporting steelwork	120	T	6,000	720,000	
Assemble on barge - crane	4	Weeks	8,000	32,000	
- 6No crew x 200 hrs	1200	Hrs	85	102,000	
Final installation - hire jacking system	1	Item	15,000	15,000	
- Crane hire	40	Hrs	250	10,000	
Final installation and connection 6 x 50hrs	300	Hrs	85	25,500	
					1,331,500
Total Direct Cost - Option 2a					**1,565,400**

Indirect Costs		
Contractor's Supervision & Site Overheads	21%	328,734
Contractor's HO Overhead & Profit	8%	151,531
Engineering	6%	93,924
Contract supervision/administration	4%	62,616
Contingency	30%	660,661
Total Indirect Cost for Option 2a		**1,297,466**

Total Budget Estimate for Option 2a	**2,862,866**

Client:	Barwon Water	Job no.:	31-34965
Project:	Barwon Sewer Aqueduct	By:	Alan Rae
Subject:	Development of Cost Estimates	Date:	14-09-17

OPTION 2b - Provision of Safe Access under One Land Span (Culvert) and Both River Spans (Protective Structure)

Direct Cost of land span	1	Item	233,900	233,900	233,900
				-	
Direct Cost of River Spans				-	
Environmental management	1	Item	100,000	100,000	
Temporary access incl removal 700m x 5m	3500	m^2	20	70,000	
Mobilise/demob floating plant to support 180T	1	Item	50,000	50,000	
Hire of floating plant	20	Weeks	10,000	200,000	
Supply 1200mm piles 12mm pl x 20m - 8 No	60	T	2,000	120,000	
Install piles	8	No	8,000	64,000	
Provide hardstand for assembly & removal	500	m^2	30	15,000	
Supply supporting steelwork	240	T	6,000	1,440,000	
Assemble on barge - crane	8	Weeks	8,000	64,000	
- 6No crew x 400 hrs	2400	Hrs	85	204,000	
Final installation - hire jacking system	1	Item	15,000	15,000	
- Crane hire	80	Hrs	250	20,000	
Final installation and connection 6 x 100hrs	600	Hrs	85	51,000	
					2,413,000
Total Direct Cost - Option 2b					**2,646,900**

Indirect Costs		
Contractor's Supervision & Site Overheads	21%	555,849
Contractor's HO Overhead & Profit	8%	256,220
Engineering	6%	158,814
Contract supervision/administration	4%	105,876
Contingency	30%	1,117,098
Total Indirect Cost for Option 2a		**2,193,857**

Total Budget Estimate for Option 2a	**4,840,757**

Client:	**Barwon Water**	**Job no.:**	**31-34965**
Project:	**Barwon Sewer Aqueduct**	**By:**	**Alan Rae**
Subject:	**Development of Cost Estimates**	**Date:**	**14-09-17**

OPTION 2c - Provision of Safe Access under One Land Span (Culvert) and One River Spans (Catenary Structure)

Direct Cost of land span	1	Item	233,900	233,900	233,900
Direct Cost of River Spans					
Environmental management	1	Item	100,000	100,000	
Temporary access incl removal 700m x 5m	3500	m^2	20	70,000	
Mobilise/demob floating plant to support 180T	1	Item	50,000	50,000	
Hire of floating plant	10	Weeks	10,000	100,000	
Cable stayed river structure 50m x 8m	400	m^2	10000	4,000,000	
					4,320,000
Total Direct Cost - Option 2c					**4,553,900**

Indirect Costs		
Contractor's Supervision & Site Overheads	21%	956,319
Contractor's HO Overhead & Profit	8%	440,818
Engineering	6%	273,234
Contract supervision/administration	4%	182,156
Contingency	30%	1,921,928
Total Indirect Cost for Option 2c		**3,774,454**

Total Budget Estimate for Option 2c	**8,328,354**

GHD CLIENTS|PEOPLE|PERFORMANCE

Client:	**Barwon Water**	**Job no.:**	**31-34965**
Project:	**Barwon Sewer Aqueduct**	**By:**	**Alan Rae**
Subject:	**Development of Cost Estimates**	**Date:**	**14-09-17**

OPTION 3a - Demolish Both River Spans and Adjacent Land Spans - Leaving Towers

Direct Costs					
Environmental management	1	Item	100,000	100,000	
Construct access track 500m x 8m incl removal	4000	m^2	25	100,000	
					200,000
Permanent Steel Support Frames 2 No	1	Item	157,200	157,200	
					157,200
Demolish River Spans					
Environmental management	1	Item	100,000	100,000	
Establishment/demob of floating plant	1	No	80,000	80,000	
					180,000
Demolish 1No River Span x 50m	1	No			
Hire of floating plant	12	Weeks	10,000	120,000	
Hire of crane	12	Weeks	4,000	48,000	
Supply & Install fabric mat to recover concrete	800	m^2	25	20,000	
Remove pipes - allow 1/day ea x 21 No - 5 crew	840	Hrs	85	71,400	
misc plant	21	Days	300	6,300	
Provide temp support to cantilevering structure	2	No	20,000	40,000	
Remove balastrade - saw cut - 2m lengths	50	No	1,000	50,000	
- lift and remove	50	No	1,000	50,000	
- cart to recyler	8	Loads	500	4,000	
Remove trusses - provide temporary support	10	No	10,000	100,000	
- saw cuts at supports	10	No	1,000	10,000	
- lift and remove trusses	10	No	2,000	20,000	
- cart to recycler	100	Loads	500	50,000	
					589,700
Demolish 2nd River Span					589,700
Demolish Partial Land Spans - say 2 No x 25m each					
Supply & Install fabric mat to recover concrete	800	m^2	25	20,000	
Provide supporting props to support trusses	4	No	10000	40,000	
Rock breaker/concrete saw	80	Hrs	600	48,000	
Crew 6 No x 80hrs	480	Hrs	85	40,800	
Removal of concrete	100	Loads	500	50,000	
					198,800
Goat Island - demolish span (2No. Partial Spans)	1	No	198,800	198800	
Extra barge hire removal debris	3	Weeks	10000	30000	
					228,800
Total Direct Cost - Option 3a					**2,144,200**

Indirect Costs		
Contractor's Supervision & Site Overheads	21%	450,282
Contractor's HO Overhead & Profit	8%	207,559
Engineering	6%	128,652
Contract supervision/administration	4%	85,768
Contingency	30%	904,938
Total Indirect Cost for Option 3a		**1,777,199**

Total Budget Estimate for Option 3a	**3,921,399**

OPTION 3b - Demolish Both River Spans and Adjacent Land Spans - Including Towers

Direct Costs

River, Land & Island Spans - as per 3a	1	Item	2,144,200	2,144,200	
					2,144,200
Allow to demolish 4 No Towers				-	
Excavator/Breaker 3 days each	96	Hrs	600	57,600	
Crew 4 No	384	Hrs	85	32,640	
Removal of debris	60	Loads	500	30,000	
					120,240
Total Direct Cost - Option 3b					**2,264,440**

Indirect Costs

Contractor's Supervision & Site Overheads	21%	475,532
Contractor's HO Overhead & Profit	8%	219,198
Engineering	6%	135,866
Contract supervision/administration	4%	90,578
Contingency	30%	955,684
Total Indirect Cost for Option 3b		**1,876,858**

Total Budget Estimate for Option 3b	**4,141,298**

Client:	**Barwon Water**	**Job no.:**	**31-34965**
Project:	**Barwon Sewer Aqueduct**	**By:**	**Alan Rae**
Subject:	**Development of Cost Estimates**	**Date:**	**14-09-17**

OPTION 4 - Demolish Entire Structure - Including Towers

Direct Cost					
Environmental management	1	Item	150,000	150,000	
Construct access track 700m x 8m incl removal	5600	m^2	25	140,000	
					290,000
Demolish 11 No Land span -	11	No	198,800	2,186,800	
Demolish river spans	2	No	589,700	1,179,400	
Goat Island 1 No. Land spans	1	No	228,800	228,800	
Demolish towers	14	No	30,060	420,840	
					4,015,840
Total Direct Cost - Option 4					**4,305,840**

Indirect Costs		
Contractor's Supervision & Site Overheads	21%	904,226
Contractor's HO Overhead & Profit	8%	416,805
Engineering	6%	258,350
Contract supervision/administration	4%	172,234
Contingency	30%	1,817,237
Total Indirect Cost for Option 4		**3,568,852**

Total Budget Estimate for Option 4	**7,874,692**

Appendix C – Original Layout Drawings and Structural Drawings, Stone and Siddeley

NFORCED CONCRETE AQUEDUCT OVER THE RIVER BARWON.

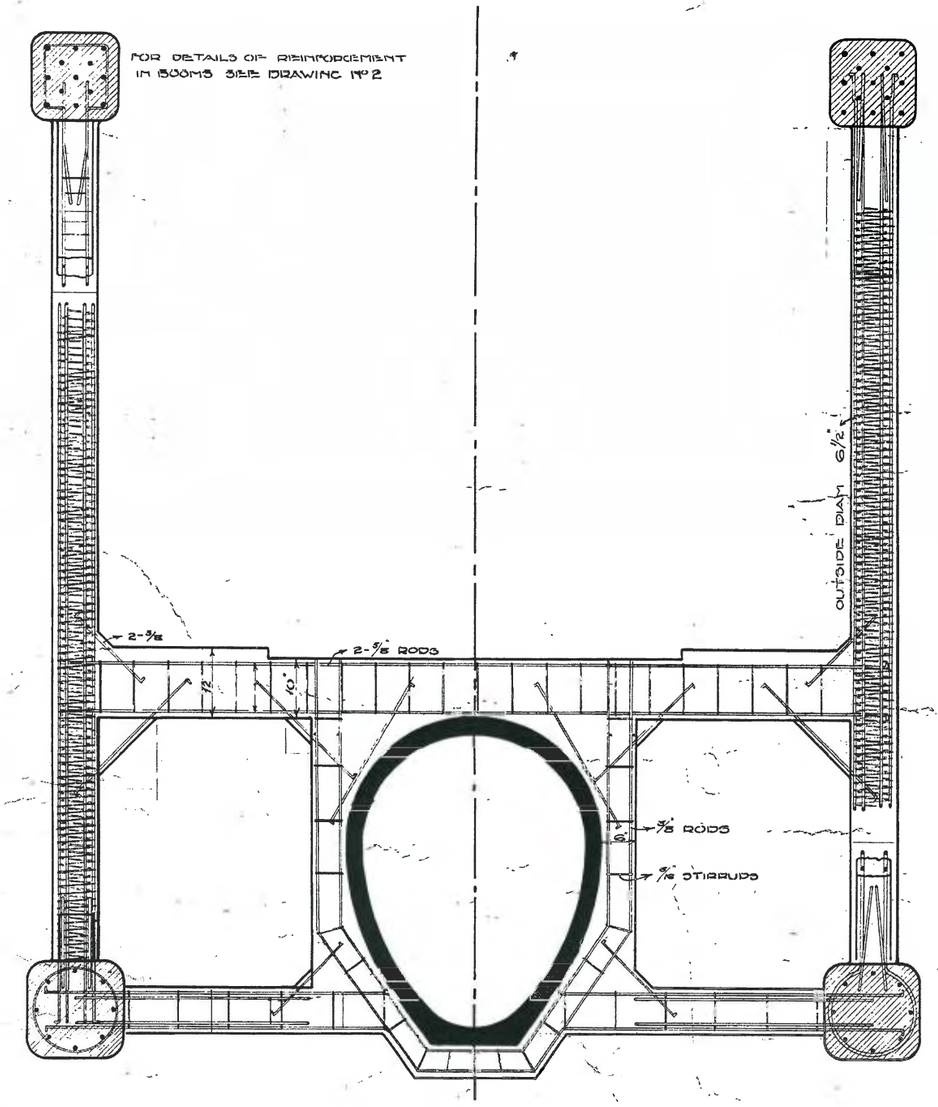
LONG WATERWORKS AND SEWERAGE TRUST CONTRACT Nº 4

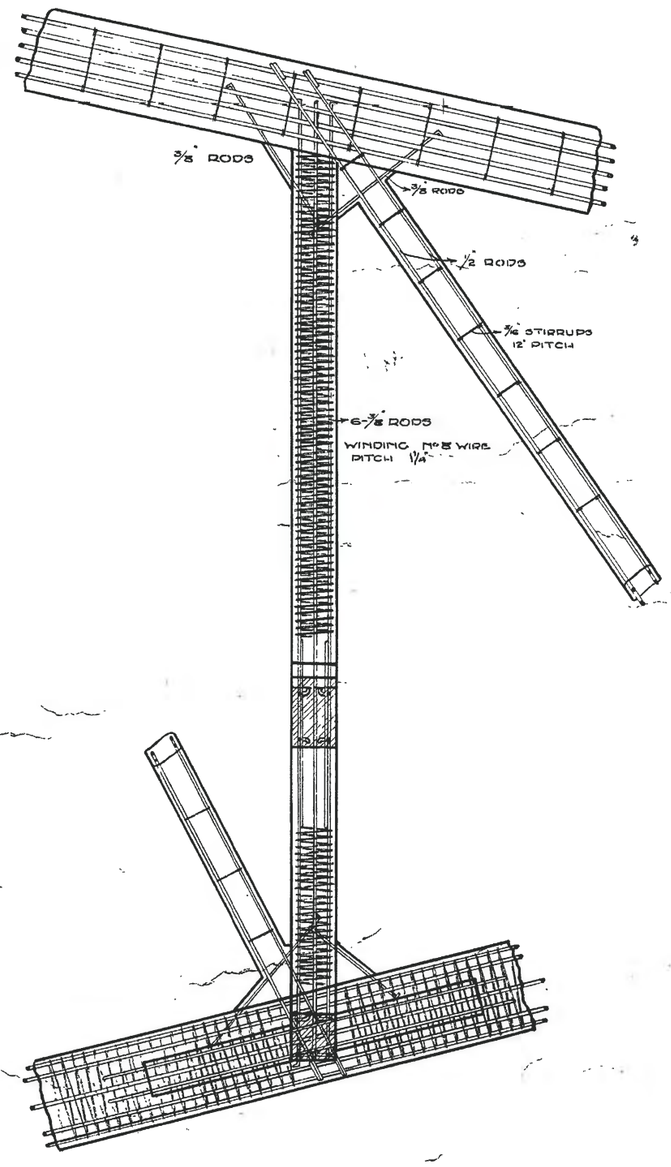
TAILS OF REINFORCEMENTS IN MEMBERS AT JOINT Nº 3

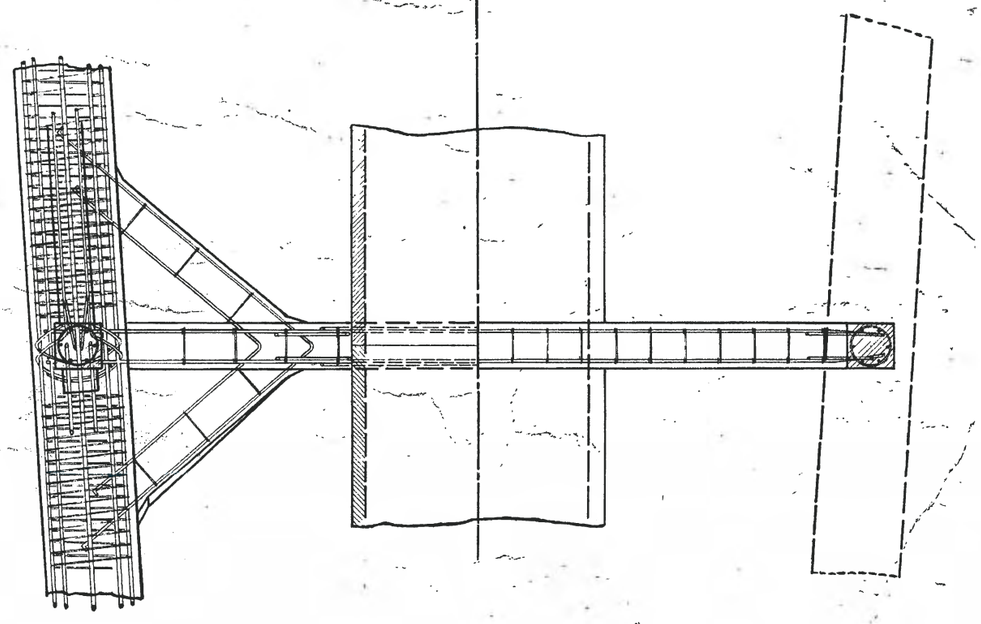
ALE ONE INCH TO ONE FOOT

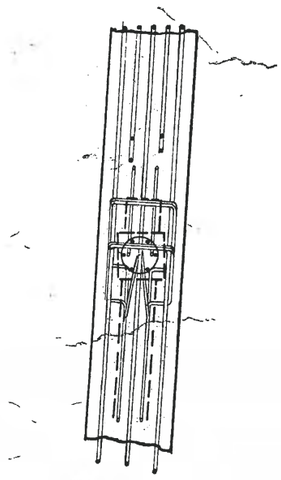
DESIGNED BY STONE & SIDDELEY

REINFORCED CONCRETE SPECIALISTS









EINFORCED CONCRETE AQUEDUCT OVER THE RIVER BARWON

ELONG WATERWORKS AND SEWERAGE TRUST CONTRACT No 4

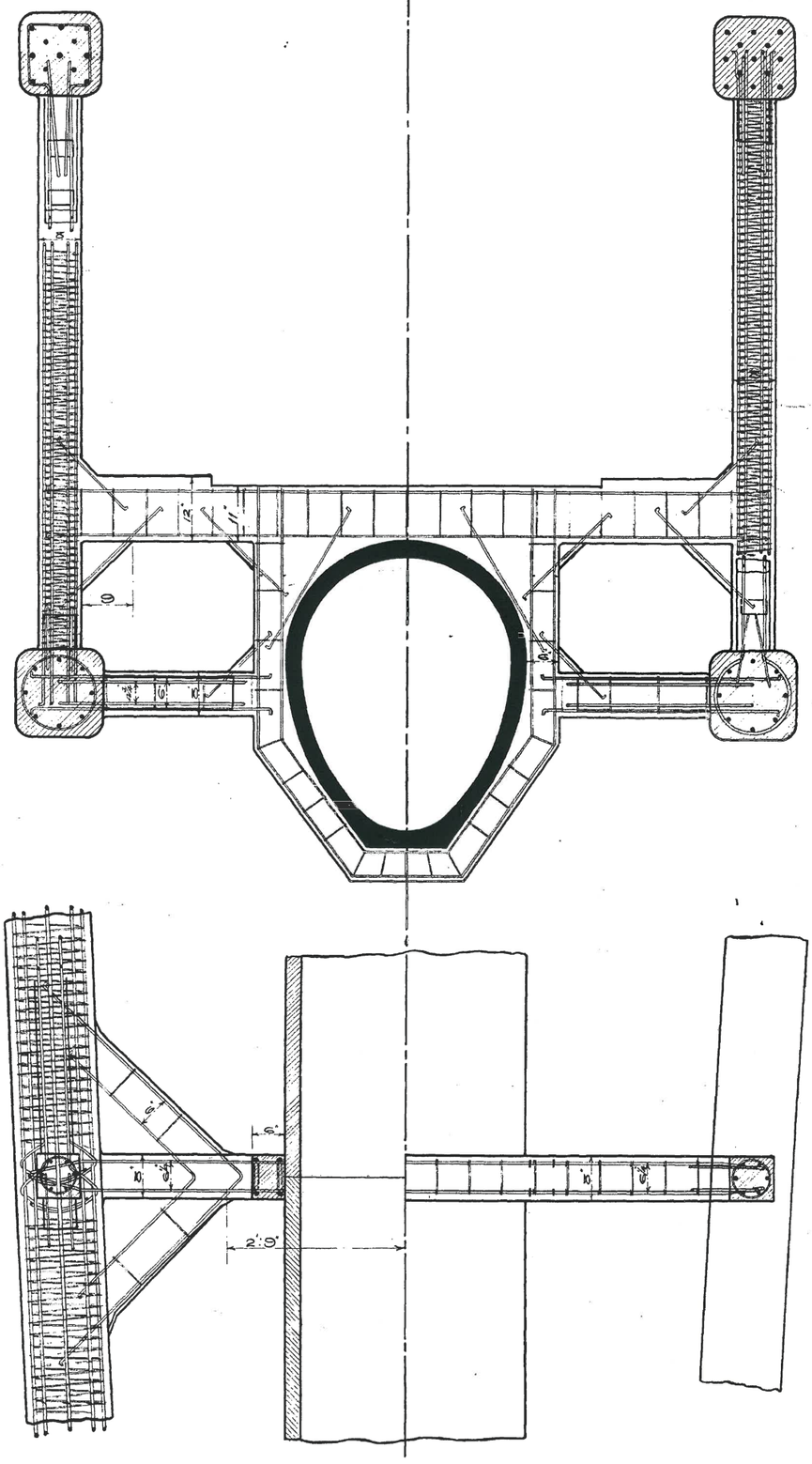
ETAILS OF REINFORCEMENTS IN MEMBERS AT JOINT No4

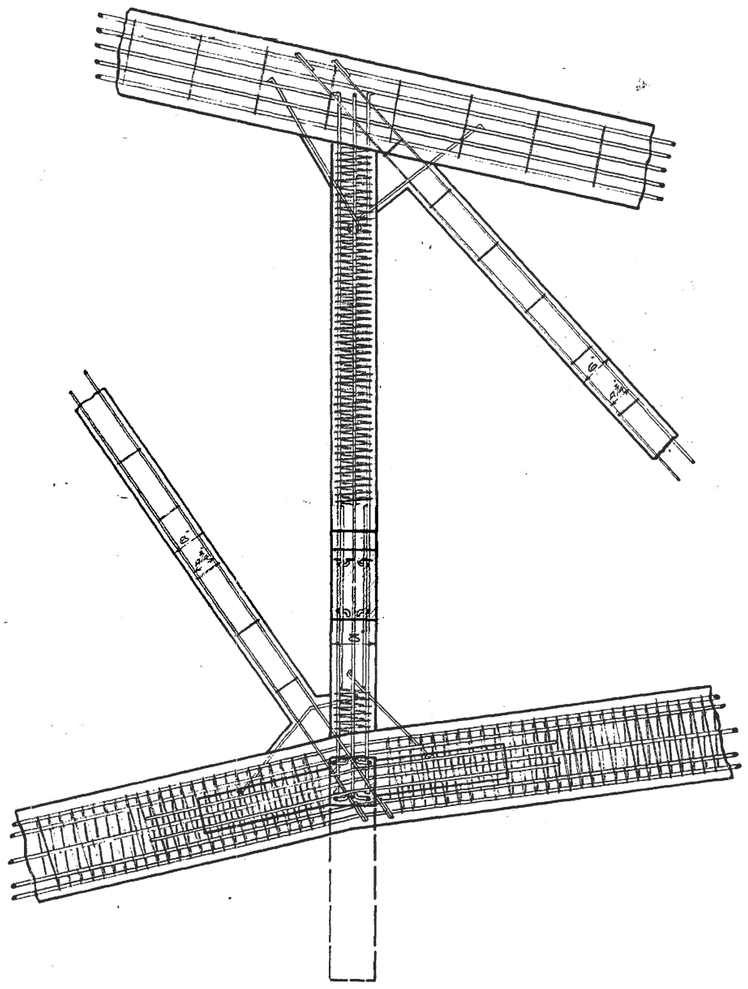
CALE ONE INCH TO ONE FOOT

DESIGNED BY STONE & SIDDELEY

REINFORCED CONCRETE SPECIALISTS

Edward P. Stone





NFORCED CONCRETE AQUEDUCT OVER THE RIVER BARWON

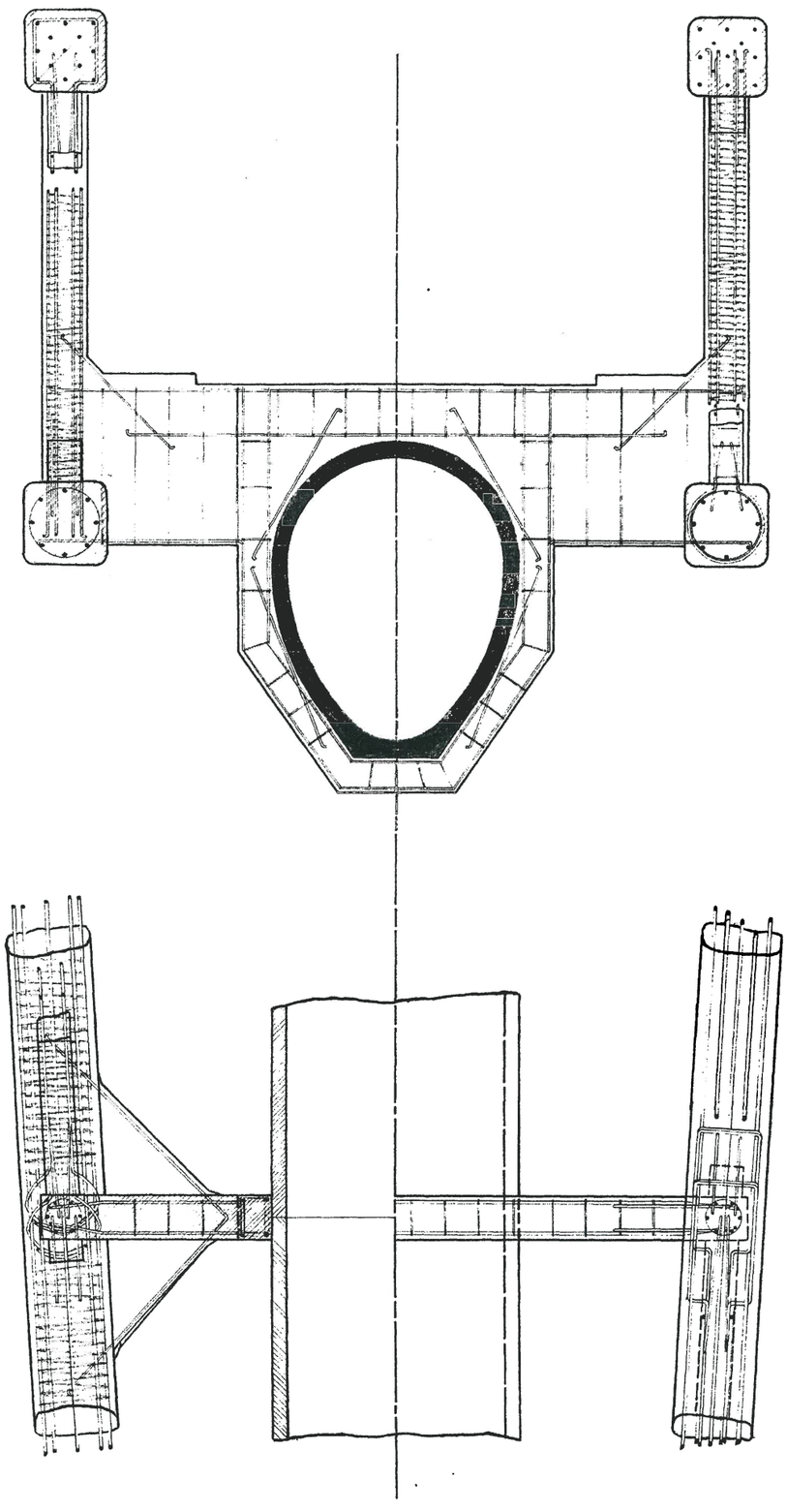
LONG WATERWORKS AND SEWERAGE TRUST CONTRACT Nº 4

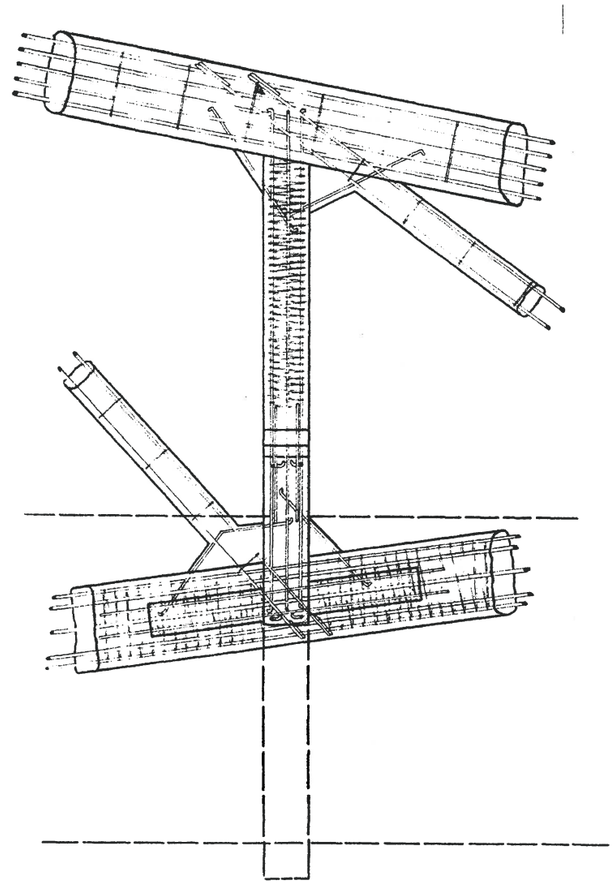
TAILS OF REINFORCEMENTS IN MEMBERS AT JOINT Nº 5

ALE ONE INCH TO ONE FOOT

DESIGNED BY STONE & SIDDELEY

REINFORCED CONCRETE SPECIALISTS



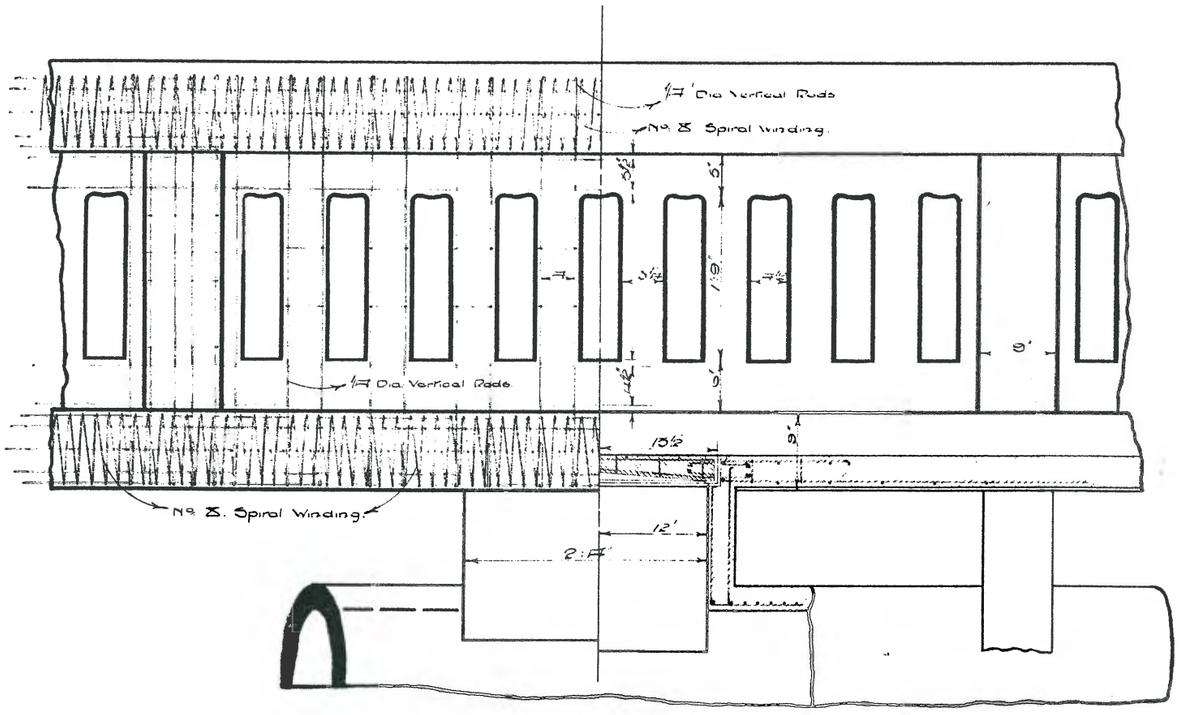


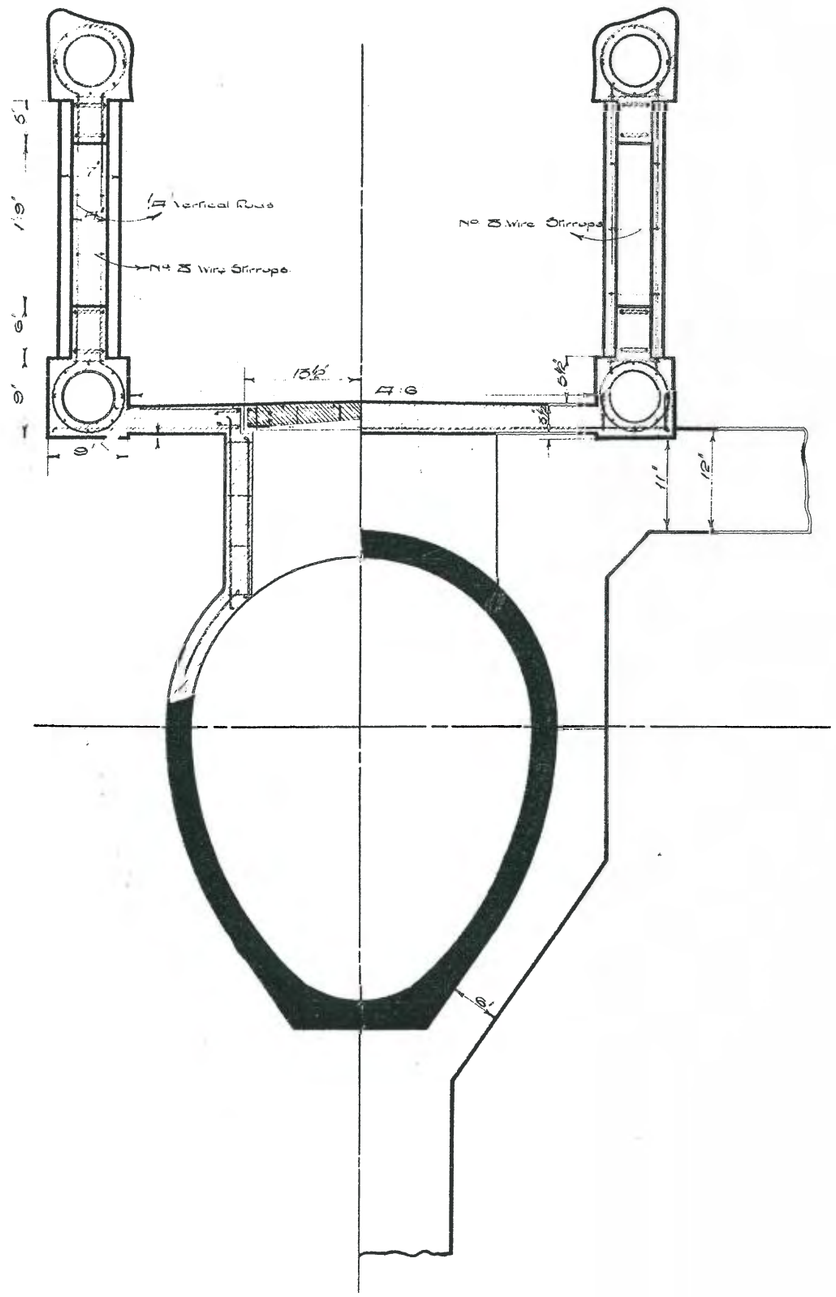
GEELONG WATERWORKS AND SEWERAGE TRUST. CONTRACT No 4.

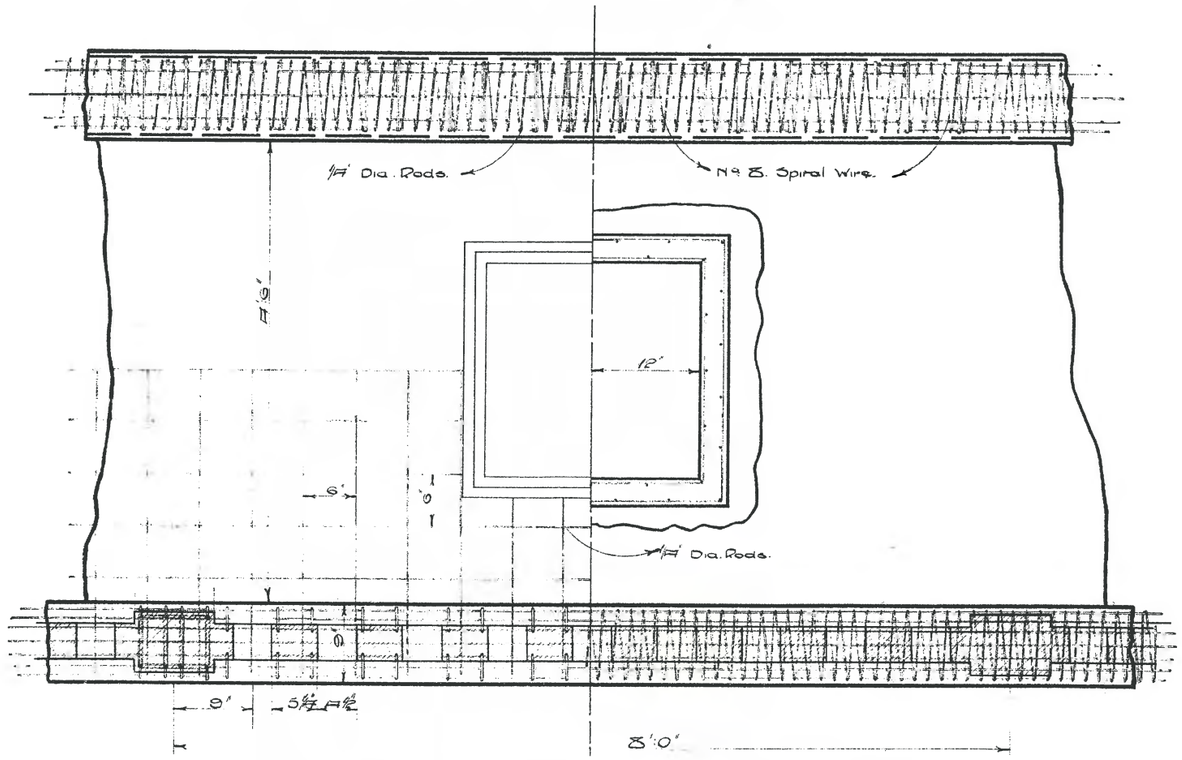
DESIGN FOR INSPECTION MANHOLES.

SCALE :- 1½ INS TO ONE FOOT.

DESIGNED BY.
STONE AND SIDDELEY.
REINFORCED CONCRETE SPECIALISTS.







:INFORCED CONCRETE AQUEDUCT OVER THE RIVER BARWON

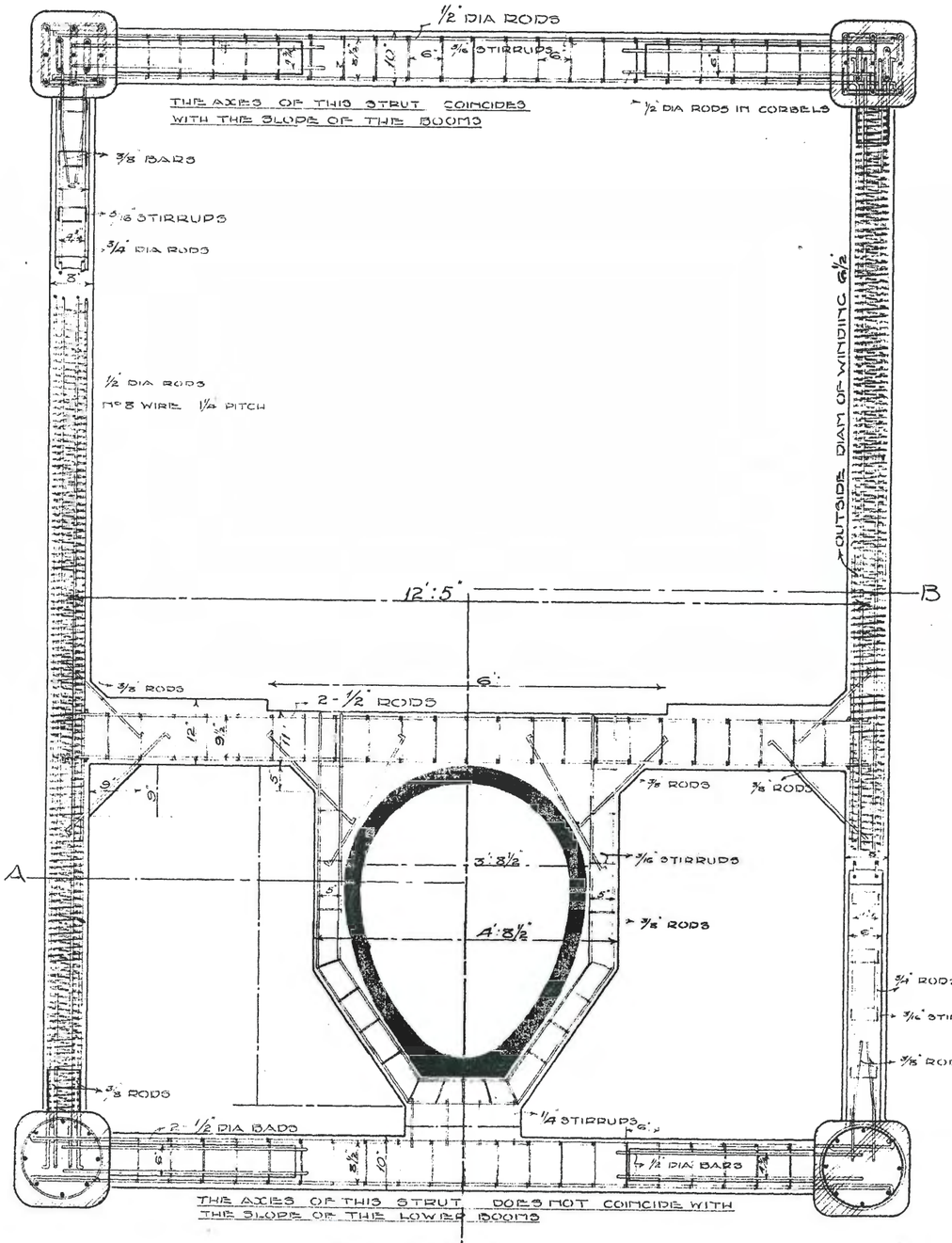
ELONG WATERWORKS AND SEWERAGE TRUST CONTRACT Nº 4

:TAILS OF REINFORCEMENTS IN MEMBERS AT JOINT Nº 2 SEE GENERAL DESIGN

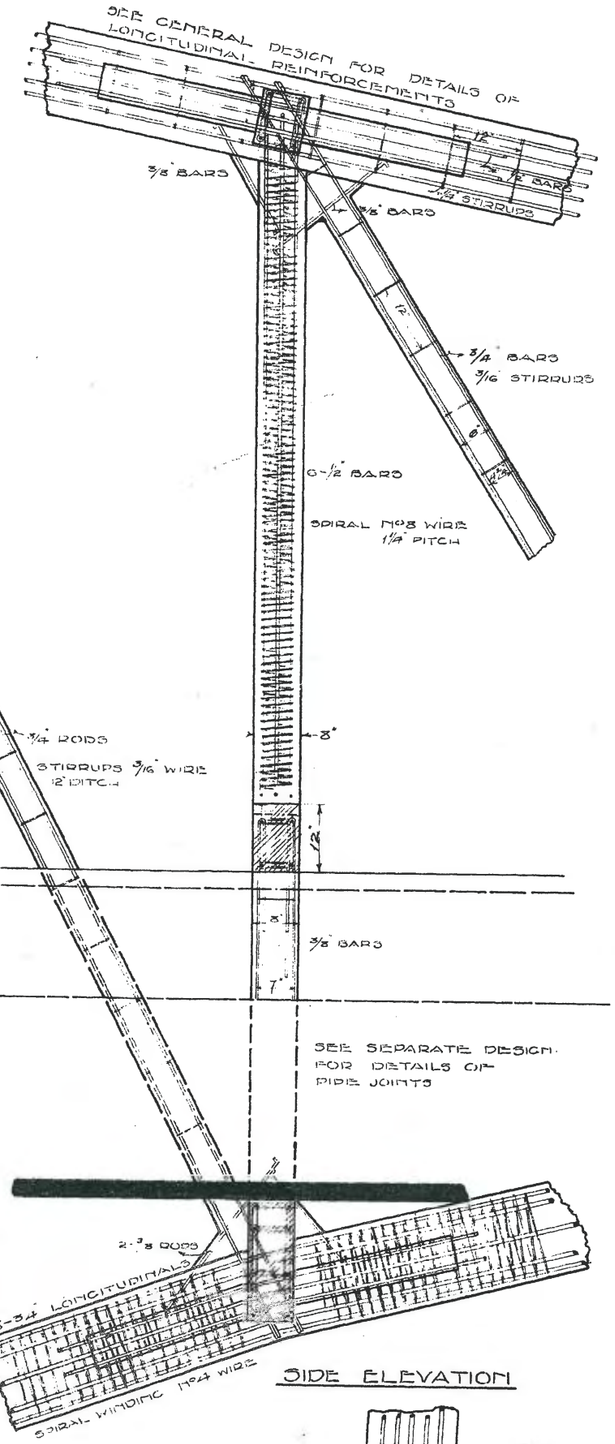
:ALE ONE INCH TO ONE FOOT

DESIGNED BY STONE & SIDDELEY

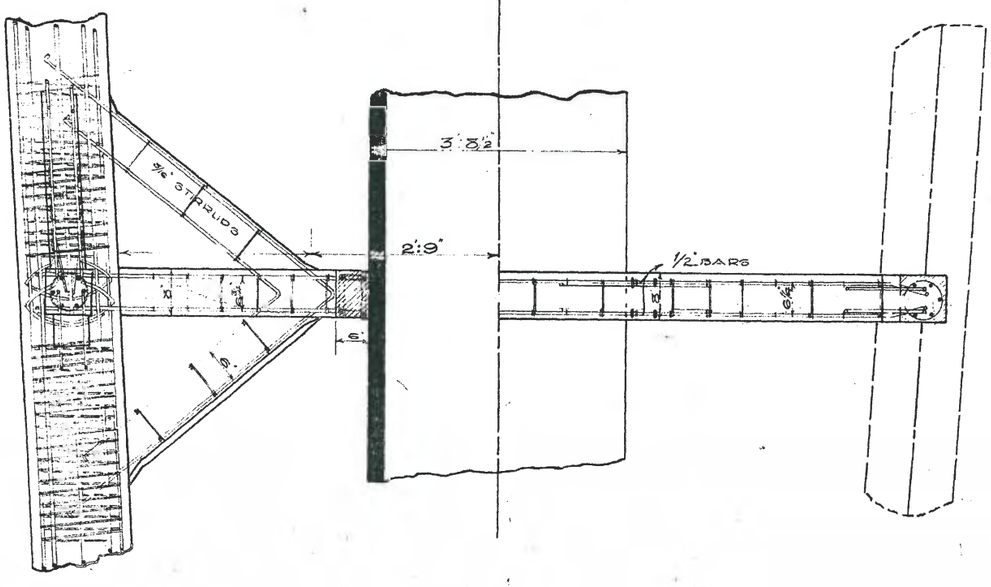
REINFORCED CONCRETE SPECIALISTS



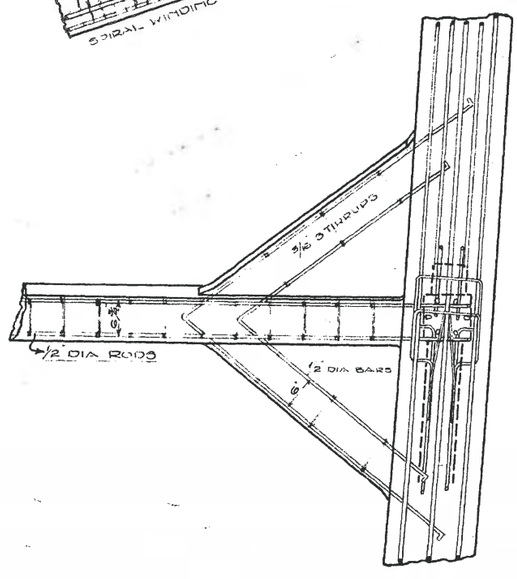
END ELEVATION



SIDE ELEVATION

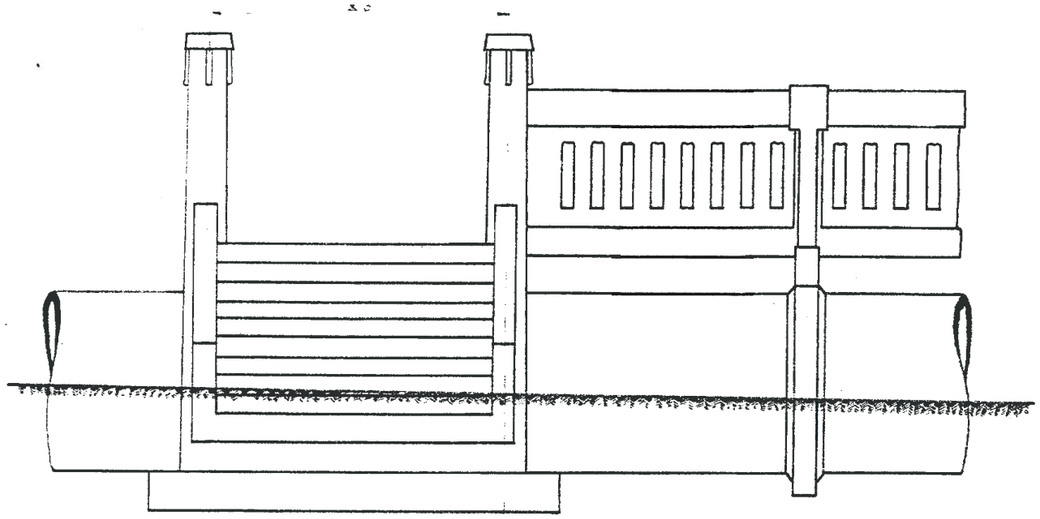


PLAN ON LINE A-B

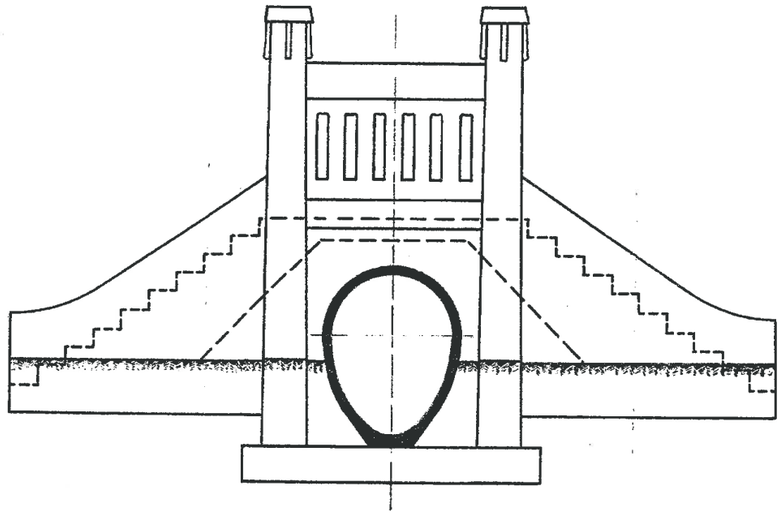


PLAN SHEWING REINFORCEMENT IN MEMBERS JOINING UPPER BOOM

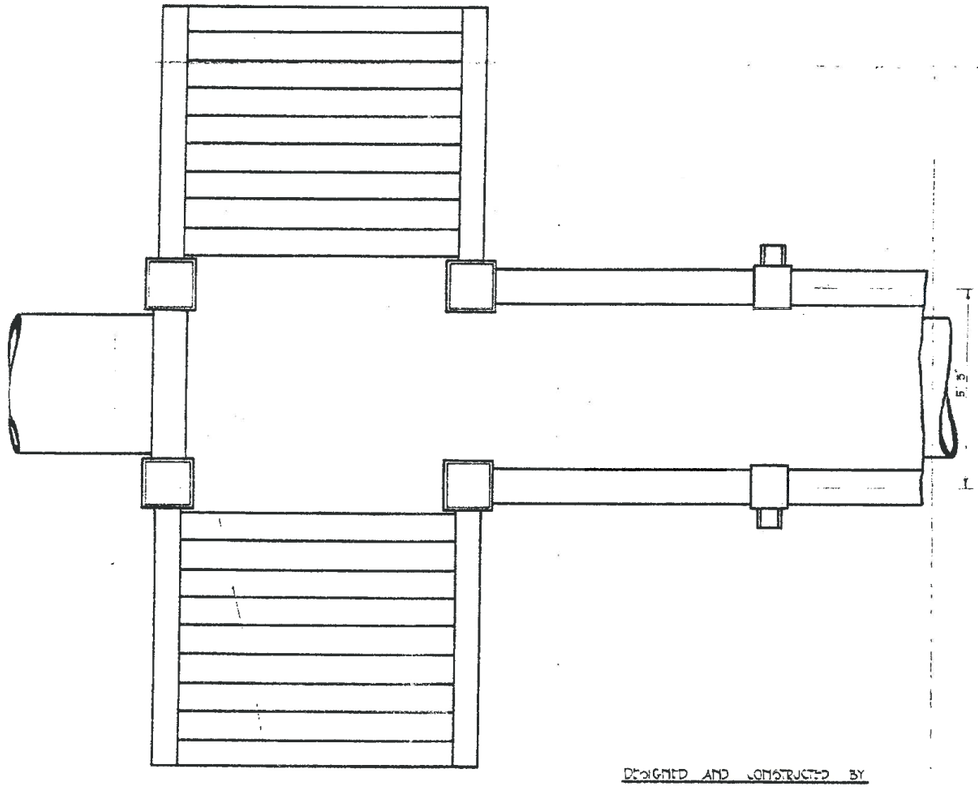
DRAWING Nº 47



SIDE ELEVATION.



END ELEVATION.



PLAN

REINFORCED CONCRETE AQUEDUCT OVER THE RIVER BARWON.

GEELONG WATERWORKS AND SEWERAGE TRUST CONTRACT No. 4.

DESIGN FOR ENTRANCE TO AQUEDUCT.

SCALE — 2 FEET TO ONE INCH.

DESIGNED AND CONSTRUCTED BY

STONE AND SIDDELEY.

REINFORCED CONCRETE SPECIALISTS,

ADELAIDE, SYDNEY AND MELBOURNE.

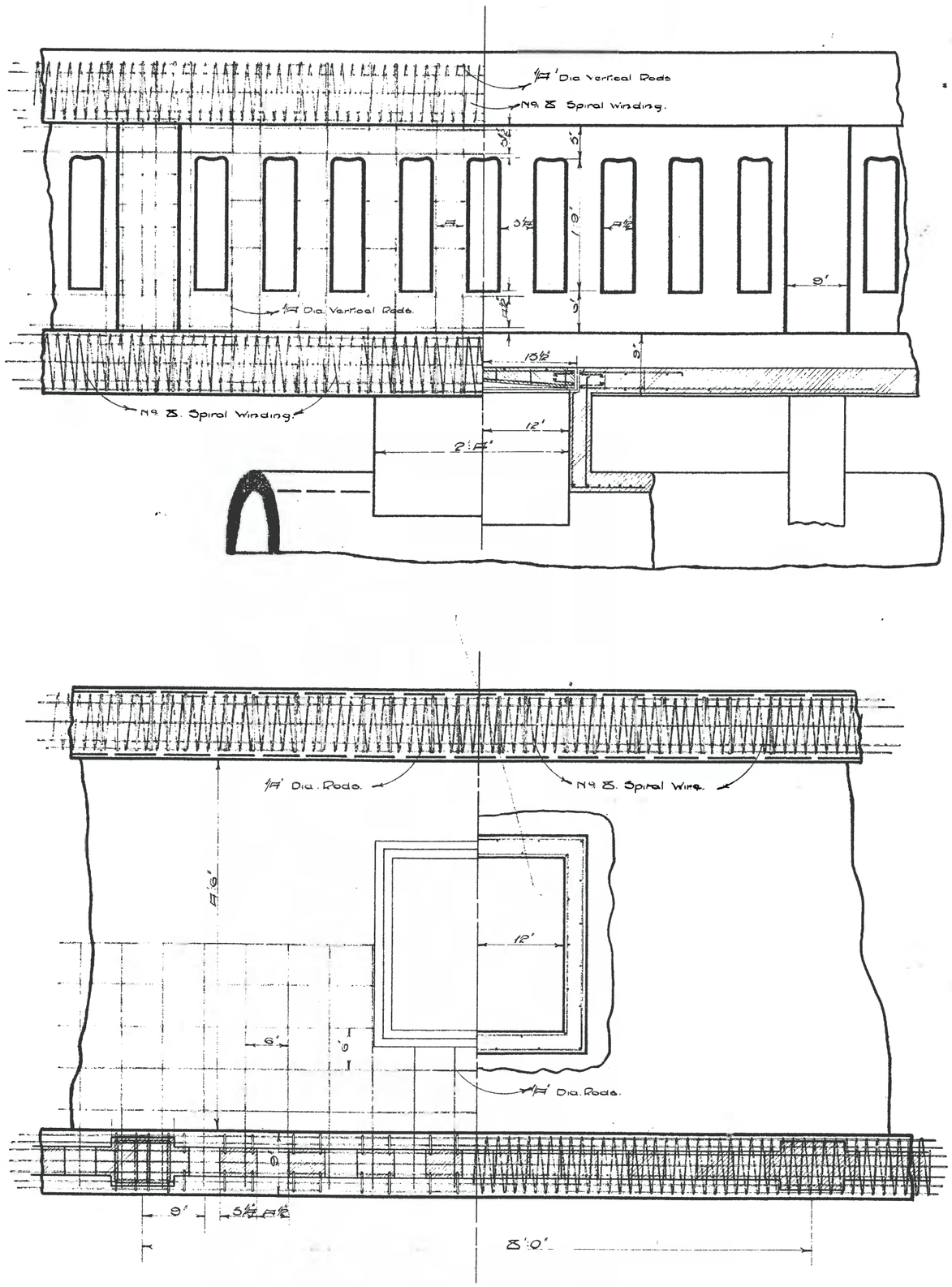
STONE & SIDDELEY
CONSULTING AND CONSTRUCTIONAL ENGINEERS
REINFORCED CONCRETE SPECIALISTS
HINDMARSH SQ. ADELAIDE

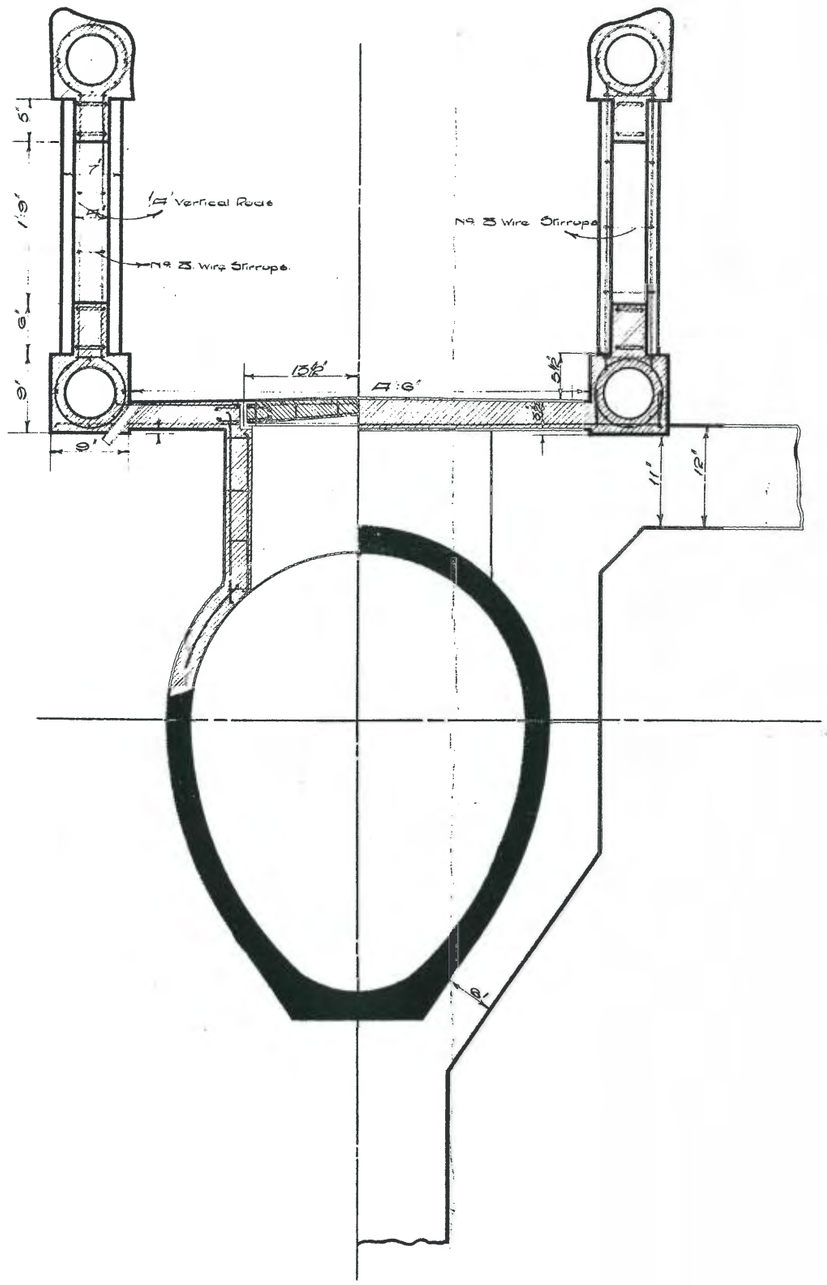
GEELONG WATERWORKS AND SEWERAGE TRUST. CONTRACT Nº 4.

DESIGN FOR INSPECTION MANHOLES.

SCALE :- 1½ INS TO ONE FOOT.

DESIGNED BY.
STONE AND SIDDELEY.
REINFORCED CONCRETE SPECIALISTS.





REINFORCED CONCRETE AQUEDUCT OVER THE RIVER BARWON

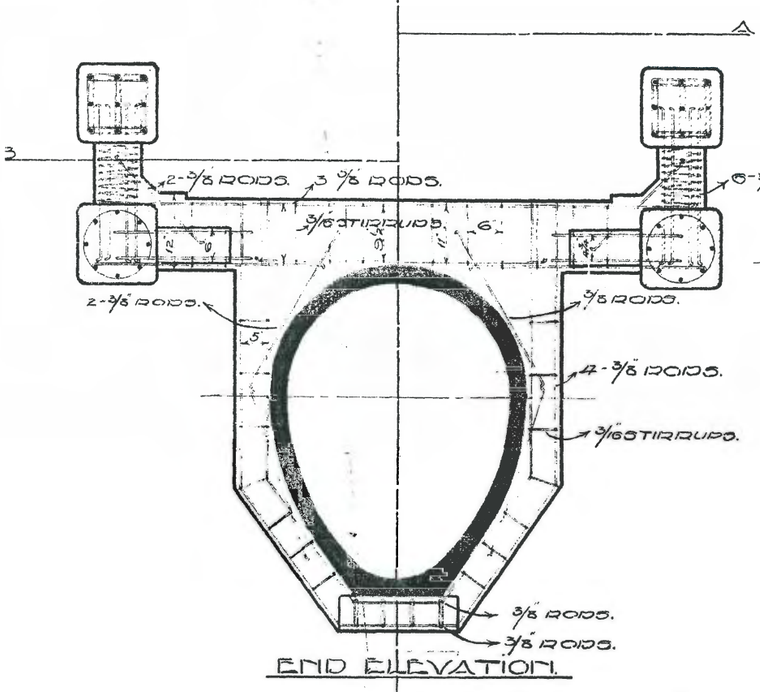
GEELONG WATERWORKS AND SEWERAGE TRUST CONTRACT Nº 4

DETAILS OF REINFORCEMENTS IN MEMBERS AT JOINT Nº 7.

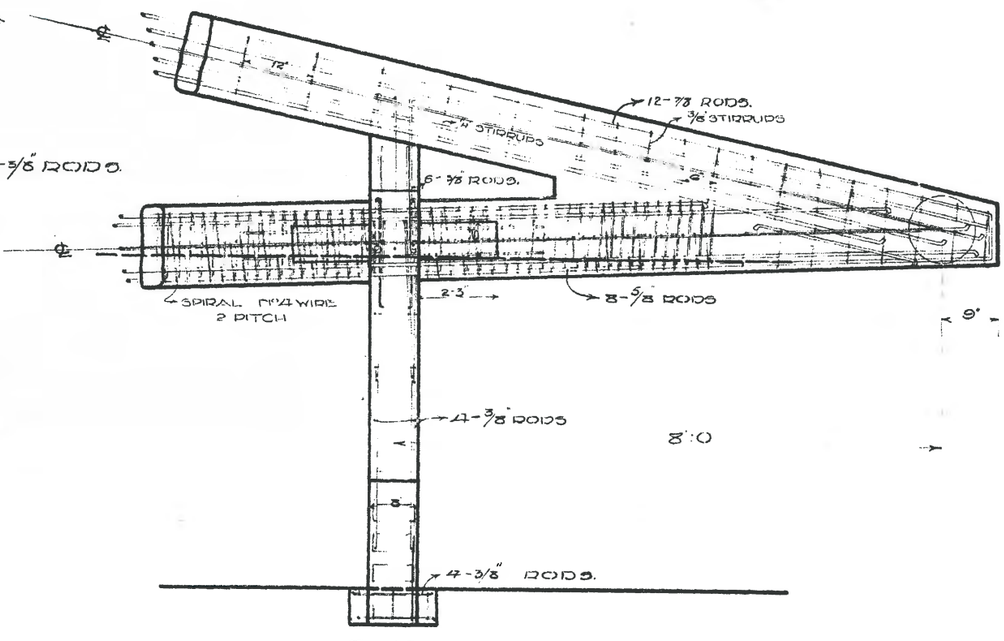
SCALE ONE INCH TO ONE FOOT.

DESIGNED BY STONE & SIDDELEY.

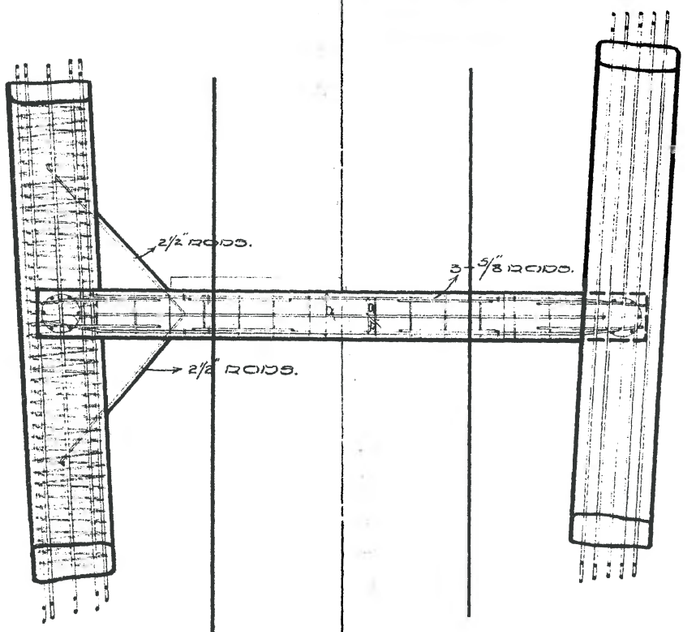
REINFORCED CONCRETE SPECIALISTS.



END ELEVATION.



SIDE ELEVATION.



PLAN ON LINE A-B.

CEILOMO

SIDE ELEVATION

END ELEVATION

NOTE — COLUMN REINFORCEMENTS TO BE STRONGLY STIRRUPED FOR THE FIRST 2'10" FROM

THIS SPACE TO BE FILLED WITH POOR CONCRETE

THIS SPACE TO BE FILLED WITH POOR CONCRETE

THIS FACE IS PARALLEL TO THE ℄ OF COLUMNS

℄ OF COLUMNS

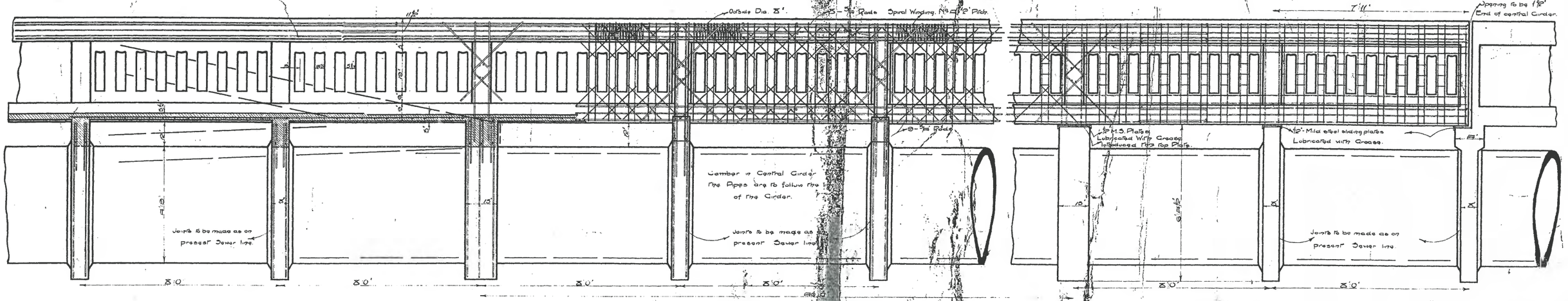
REINFORCED CONCRETE AQUEDUCT OVER THE RIVER BARWON.

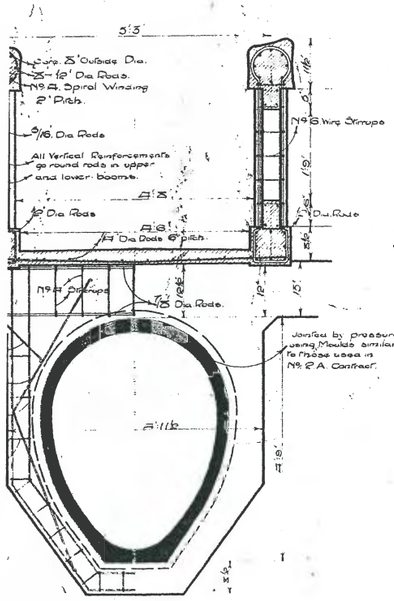
GEELONG WATERWORKS AND SEWERAGE TRUST. CONTRACT. No. 4

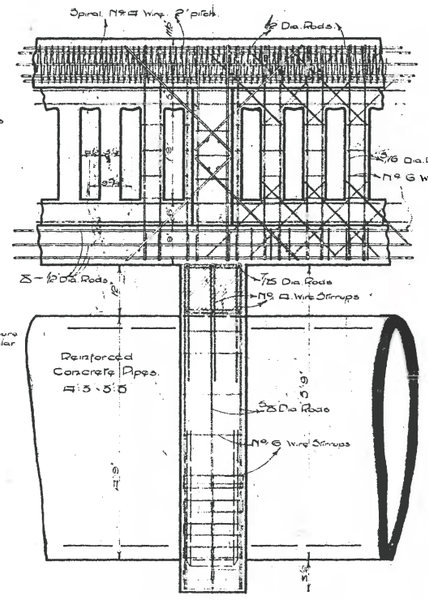
DESIGN AND DETAILS FOR CENTRAL GIRDER.

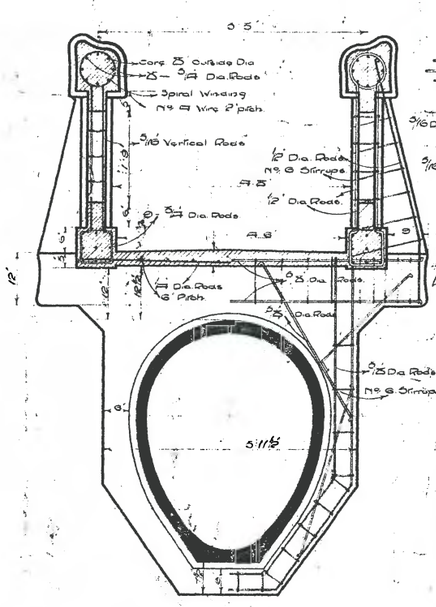
SCALE :- GENERAL DESIGN. 3/16 INCH. DETAILS. ONE INCH TO ONE FOOT.

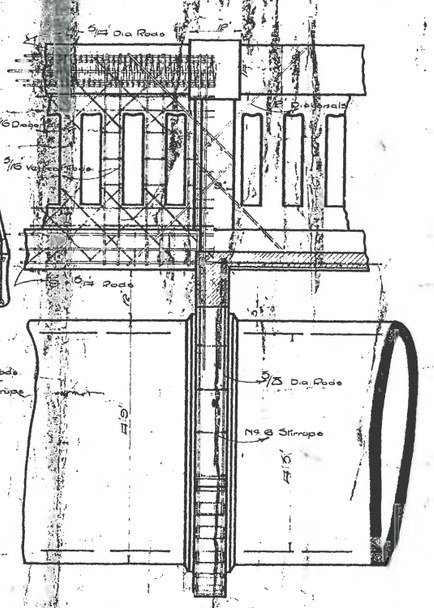
DESIGNED BY
STONE AND SIDDELEY
REINFORCED CONCRETE SPECIALIST.

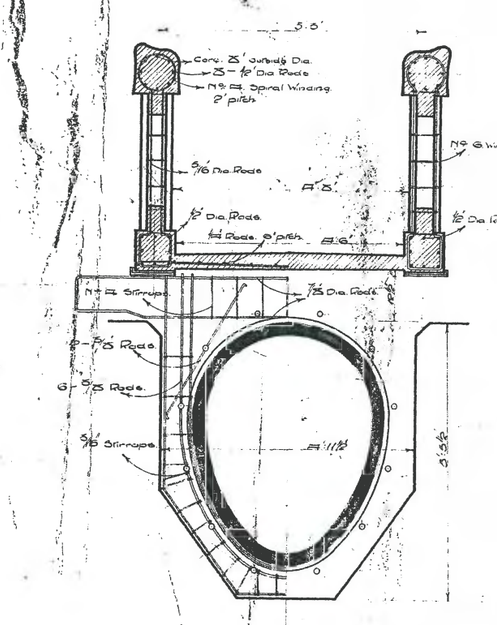


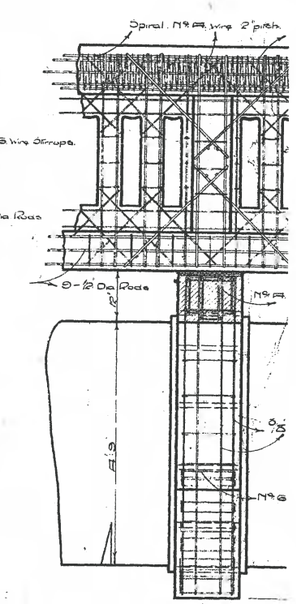


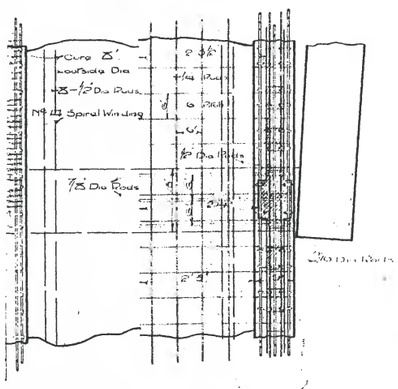


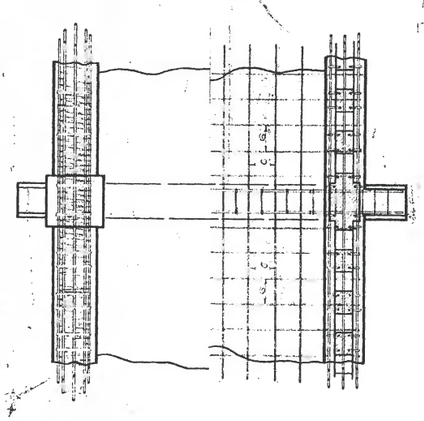


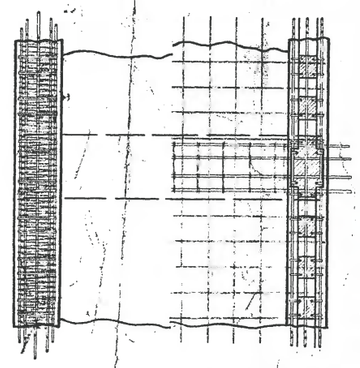


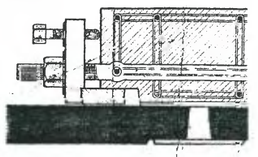




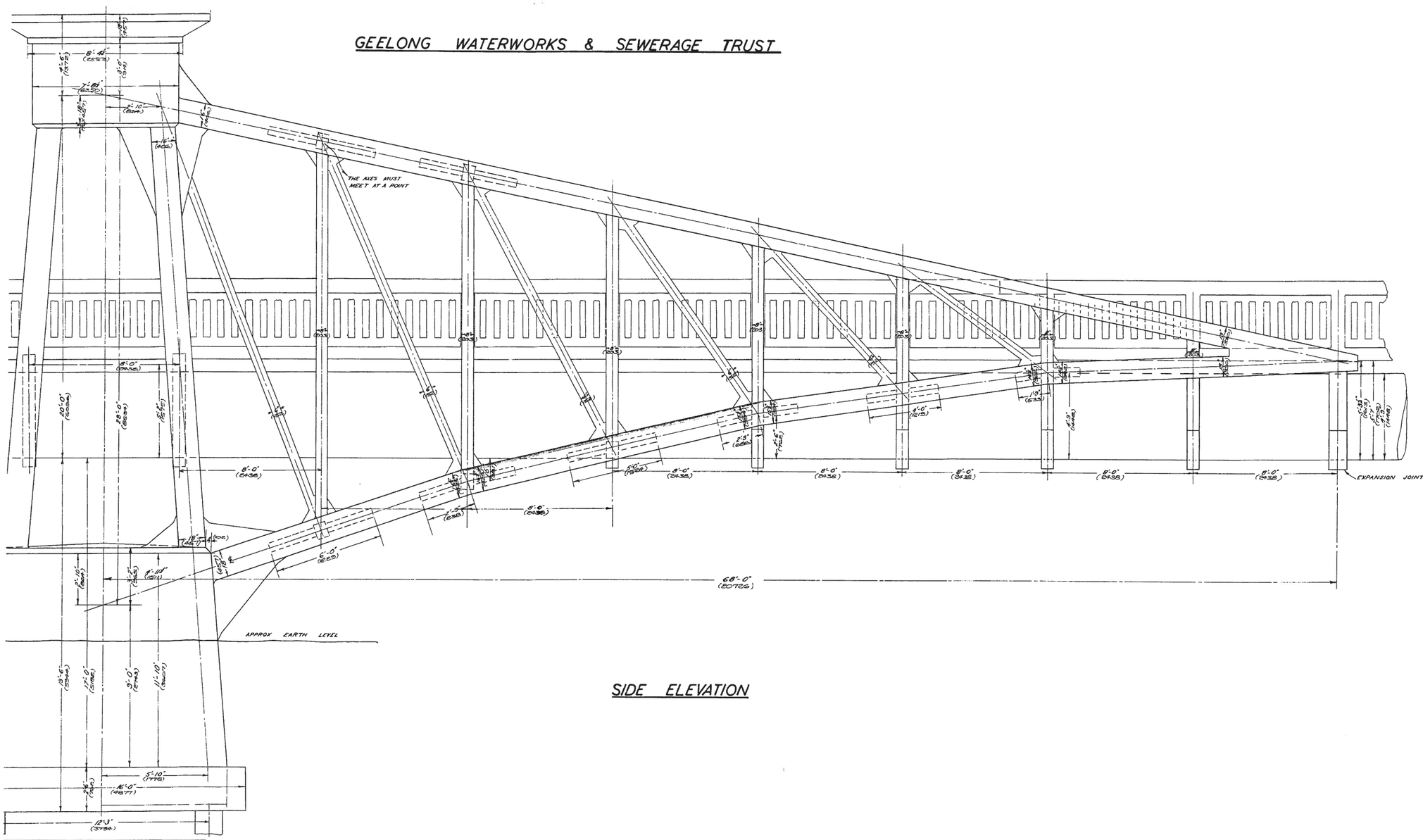




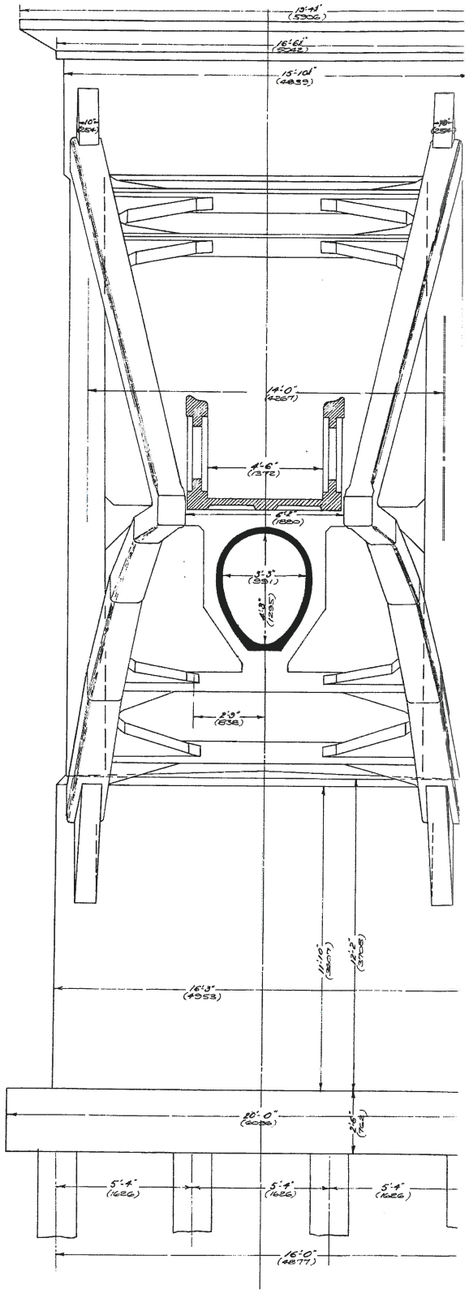




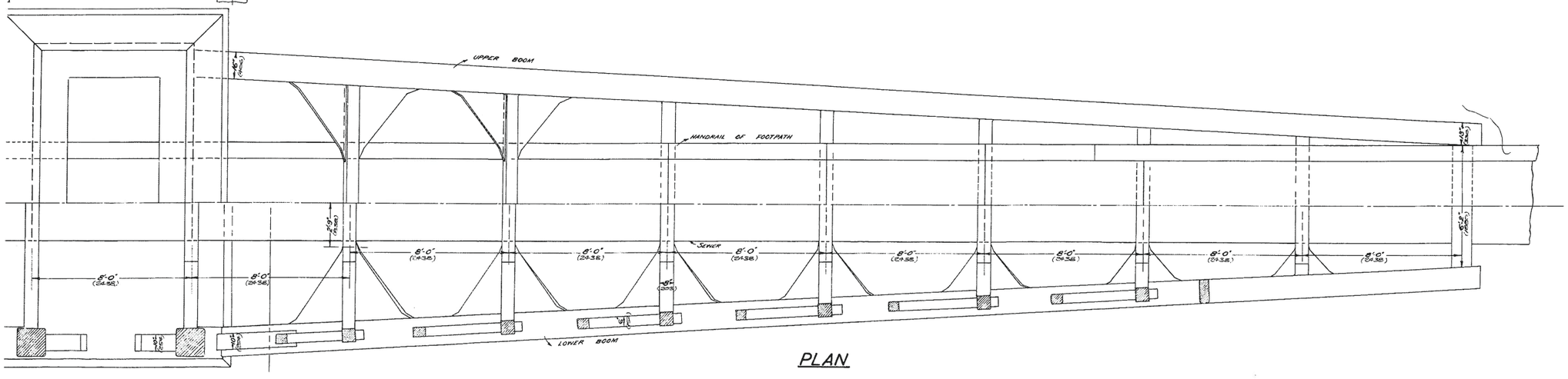
GEELONG WATERWORKS & SEWERAGE TRUST



SIDE ELEVATION



END ELEVATION



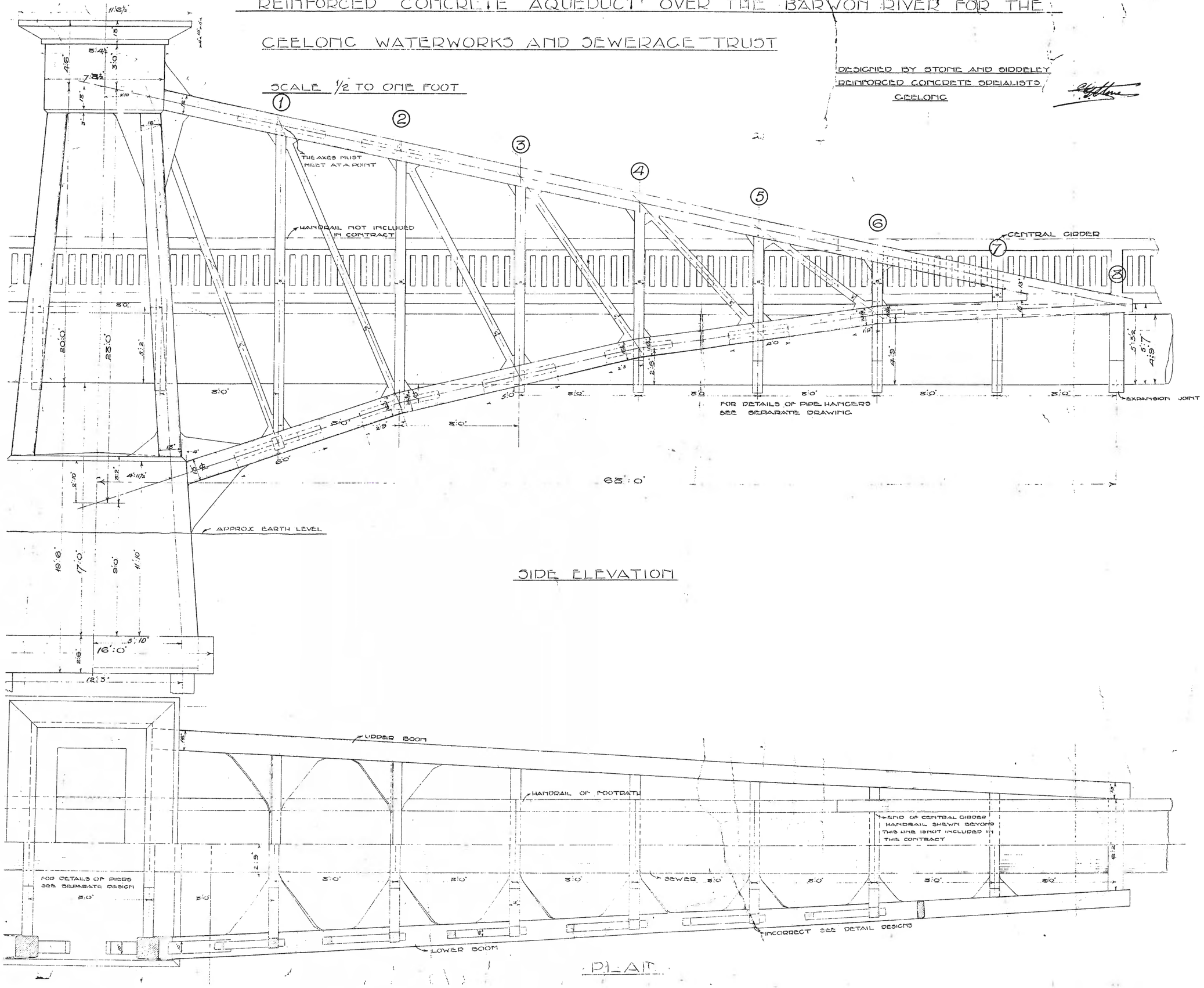
PLAN

TRACED OFF ORIGINAL BLUE PRINT
BY G.P. PLUMMER 23-9-1936

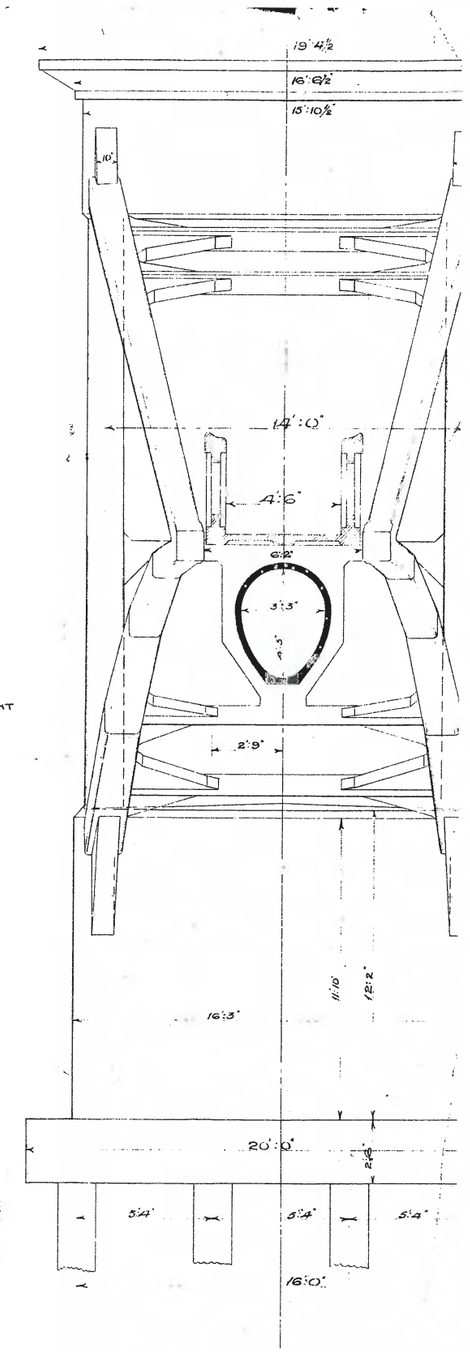
REINFORCED CONCRETE AQUEDUCT OVER THE BARWON RIVER FOR THE GEELONG WATERWORKS AND SEWERAGE TRUST

DESIGNED BY STONE AND SIDDELEY
REINFORCED CONCRETE SPECIALISTS
GEELONG

SCALE ½ TO ONE FOOT



SIDE ELEVATION



END ELEVATION

PLAN

STONE &
REINFORCED CO

INFORCED CONCRETE AQUEDUCT OVER THE RIVER BARWON.

ELONG WATERWORKS AND SEWERAGE TRUST. CONTRACT No 4.

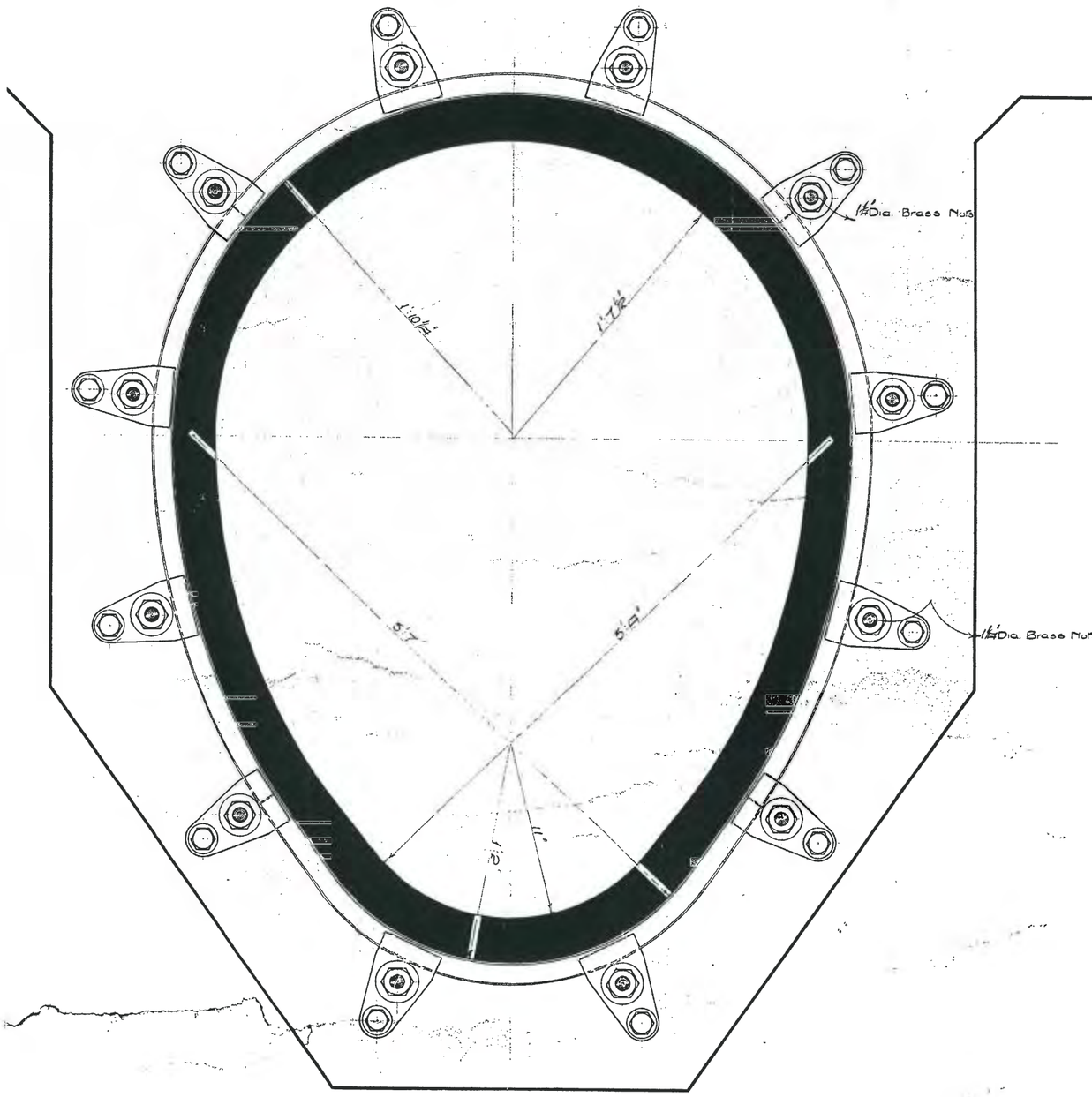
ESIGN OF EXPANSION JOINT.

CALE:— 3 INS. TO ONE FOOT.

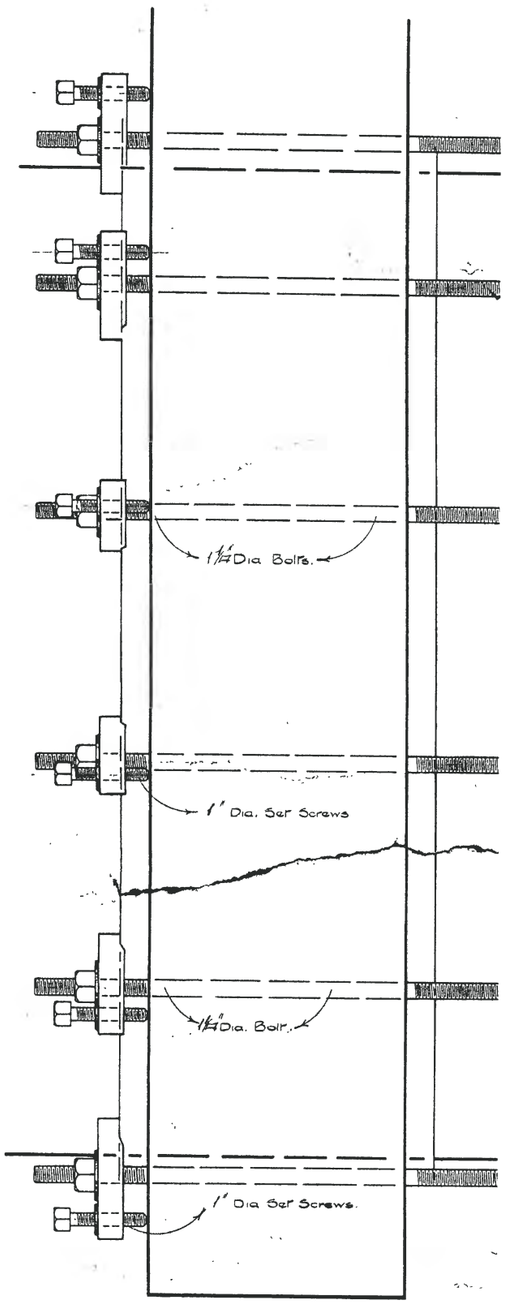
DESIGNED BY

STONE AND SIDDELEY

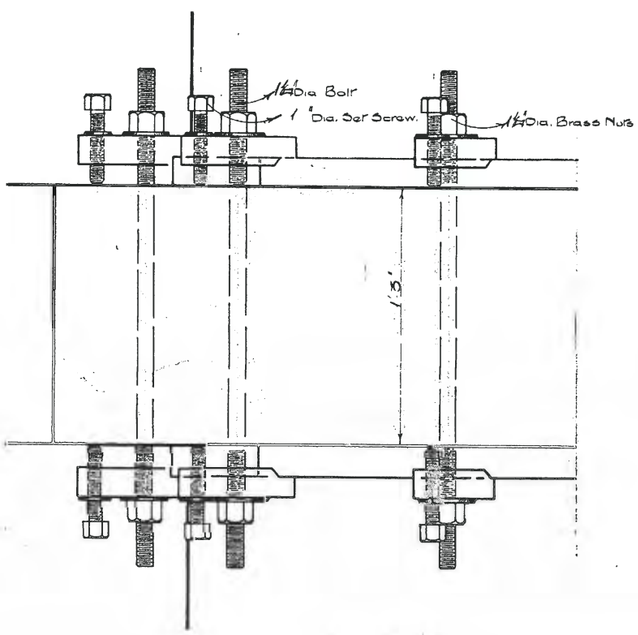
REINFORCED CONCRETE SPECIALISTS.

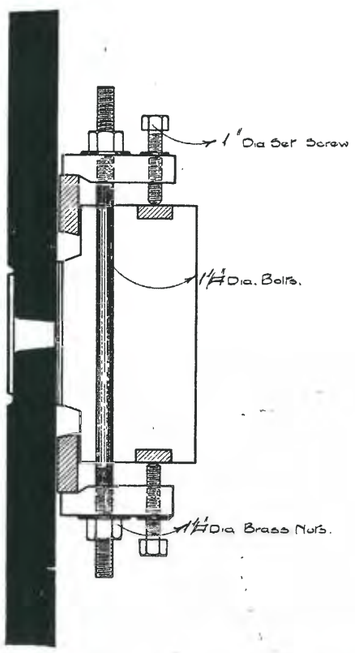


END ELEVATION.



SIDE ELEVATION.





PLAN

FORCED CONCRETE AQUEDUCT OVER THE RIVER BARWON.

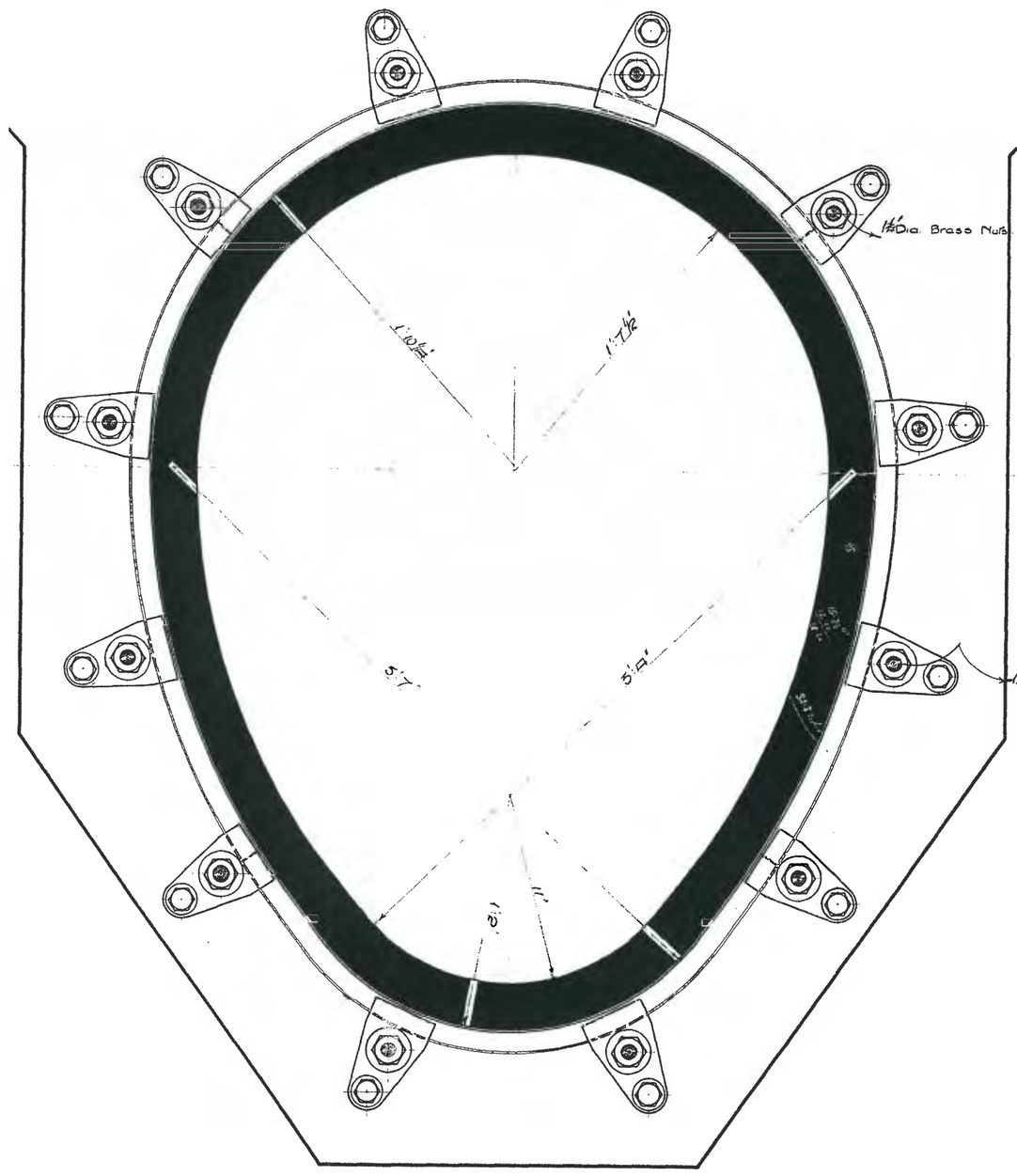
ONG WATERWORKS AND SEWERAGE TRUST. CONTRACT No. 4.

SIGN OF EXPANSION JOINT.

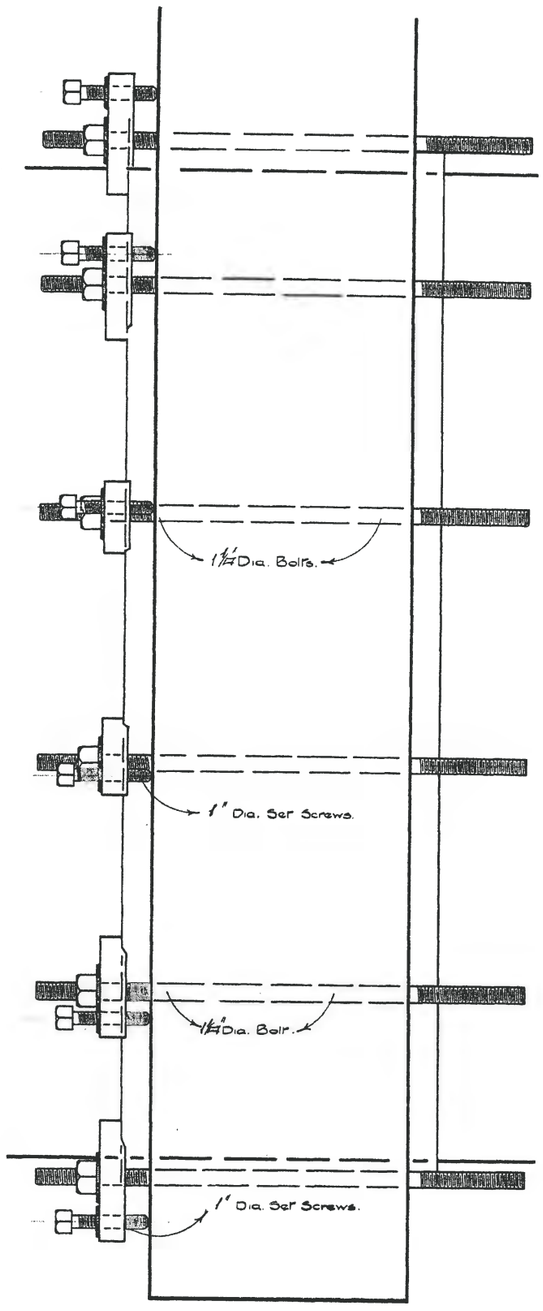
LE:- 3 INS. TO ONE FOOT.

DESIGNED BY
STONE AND SIDDELEY
REINFORCED CONCRETE SPECIALISTS.

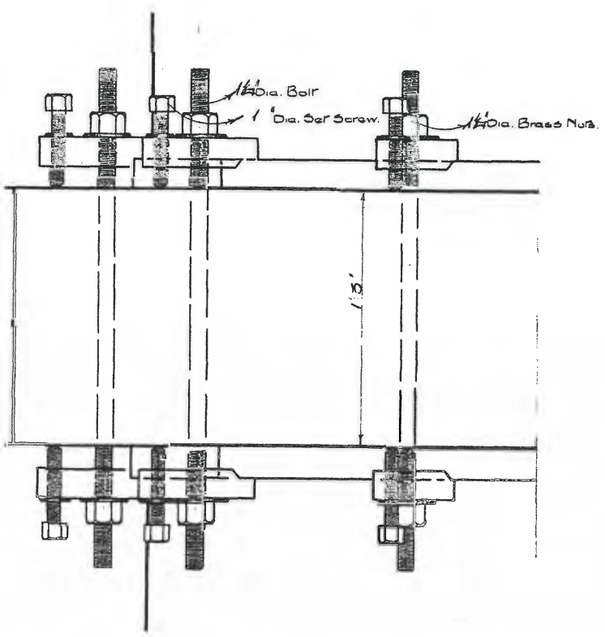
Stone Siddeley.

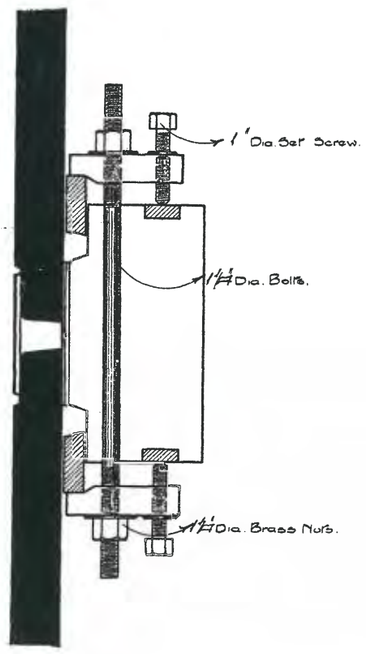


END ELEVATION.



SIDE ELEVATION.





PLAN

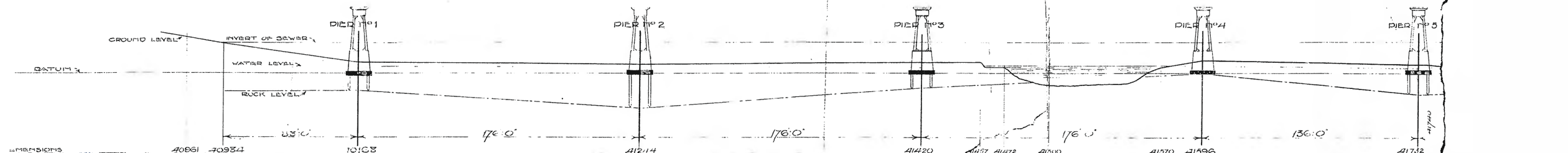
FORCED CONCRETE AQUEDUCT OVER THE RIVER BARWON

C WATERWORKS AND SEWERAGE TRUST

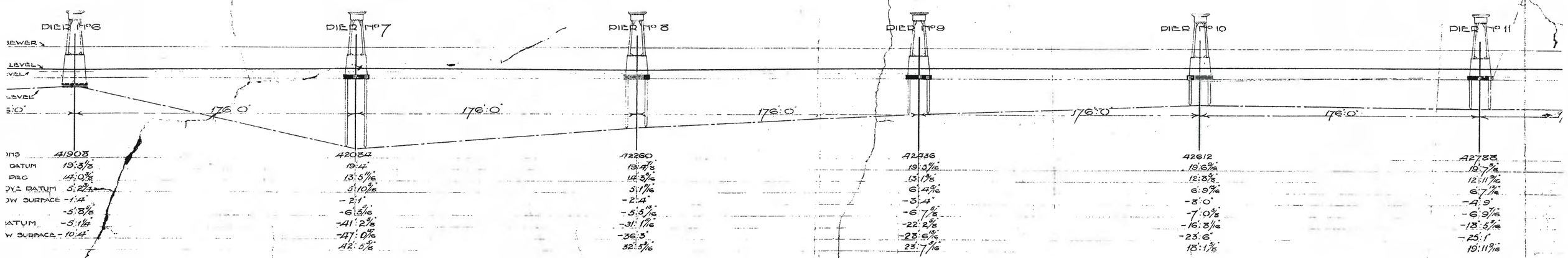
TUDINAL SECTION SHEWING ROCK LEVELS ETC

NTAL AND VERTICAL SCALE 20:0 TO ONE INCH

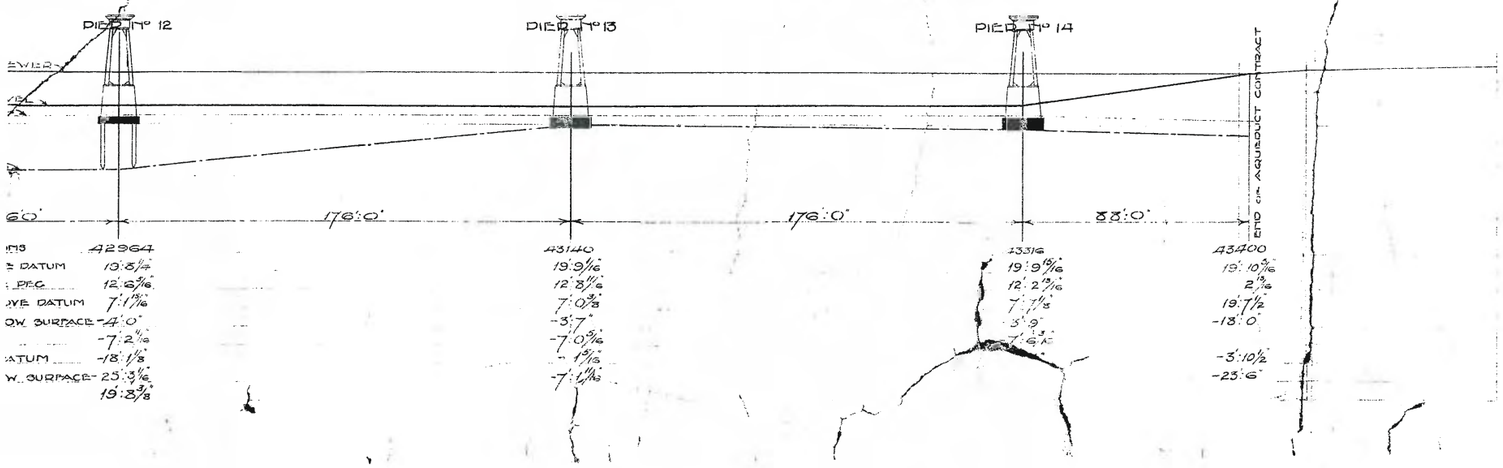
STONE AND SIDDELEY
REINFORCED CONCRETE SPECIALISTS
GEELONG



MENSIONS	A0961	70984	10108	A12114	A11420	A1147	A11472	A1500	A1570	A1596	A1732
BOVE DATUM	18:10⅝	18:10¾	18:11⅛	19:0"	19:0⅛"					19:1⅝	19:2¾
BOVE PEG			12:0⅝	13:6⅜	12:4¼					11:0⅜	13:2¾
ABOVE DATUM	22:8⅝	18:10⅛"	6:10⅛	5:5½	6:7⅛					8:1	5:4¾
BELOW SURFACE		-15:6"	- 2:9"	- 1:9"	- 3:0					3:9"	- 2:0"
RFACE PEG			-7:8⅜	-6:2⅛	-7:4¼					- 8:8⅜	- 5:11⅞
O DATUM		-11:7⅛	-11:7⅛	-22:4⅜	-9:4⅛					- 1"	- 13:3¼
BELOW SURFACE		-30:0"	-18:6⅛	-27:9⅛	-16:0					- 8:2"	- 18:8"
LEG			12:5⅛	23:3⅛	10:3¼						14:4⅞



NS	41908	42084	42260	42436	42612	42788
DATUM	19:3⅛	19:4"	19:4⅞	19:3⅛	19:6⅛	19:7⅛
PEG	14:0⅝	13:5⅛	14:3⅛	13:1⅝	12:3⅝	12:11⅛
VE DATUM	5:2¾	5:10⅜	5:1⅞	6:4⅛	6:9⅛	6:7⅛
OW SURFACE	-1:4"	- 2:1"	- 2:4"	- 3:4"	- 8:0"	- 4:9"
	-5:8⅜	-6:5⅛	- 5:5⅛	-6:7⅞	-7:0⅜	- 6:9⅛
ATUM	-5:1⅛	-41:2⅜	-31:1⅞	-22:2⅜	-16:3⅛	-13:5⅛
W SURFACE	-10:4"	-47:0⅛	-36:3"	-28:6⅛	-23:6"	-25:1"
		A2: 5⅜	32:5⅛	23:7⅛	18:1⅜	19:11⅛

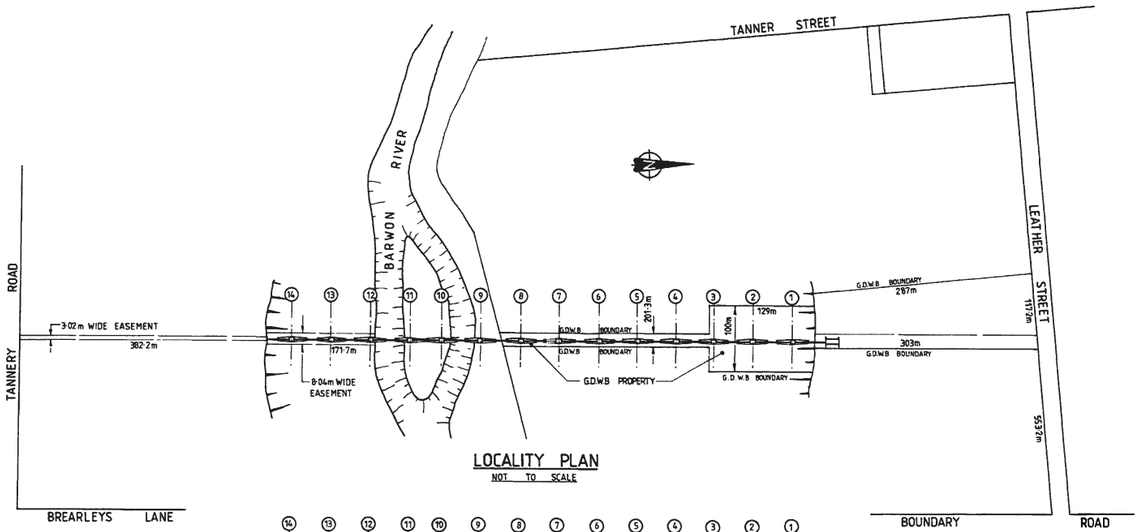


NS	42964	43140	43316	43400
E DATUM	19:5⅛	19:9⅛	19:9⅞	19:10⅝
PEG	12:2⅝	12:8⅛	12:2⅞	2⅛
VE DATUM	7:1⅞	7:0⅜	7:7⅛	19:7½
OW SURFACE	-4:0"	-3:7"	3:9"	-18:0"
	-7:2⅛	-7:0⅜	7:6⅝	
ATUM	-18:1⅛	- 1⅜		-3:10½
W SURFACE	-25:3⅛	-7:1⅛		-25:6"
	19:8⅜			

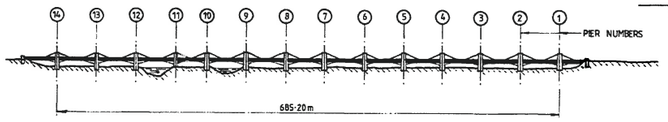
MAXIMUM MANUFACTURED LENGTH OF PILES TO BE 30:0"

FOR POINTS WHERE PIERS REST ON ROCK - SEE SEPARATE DESIGNS - NO RAFT IS REQUIRED

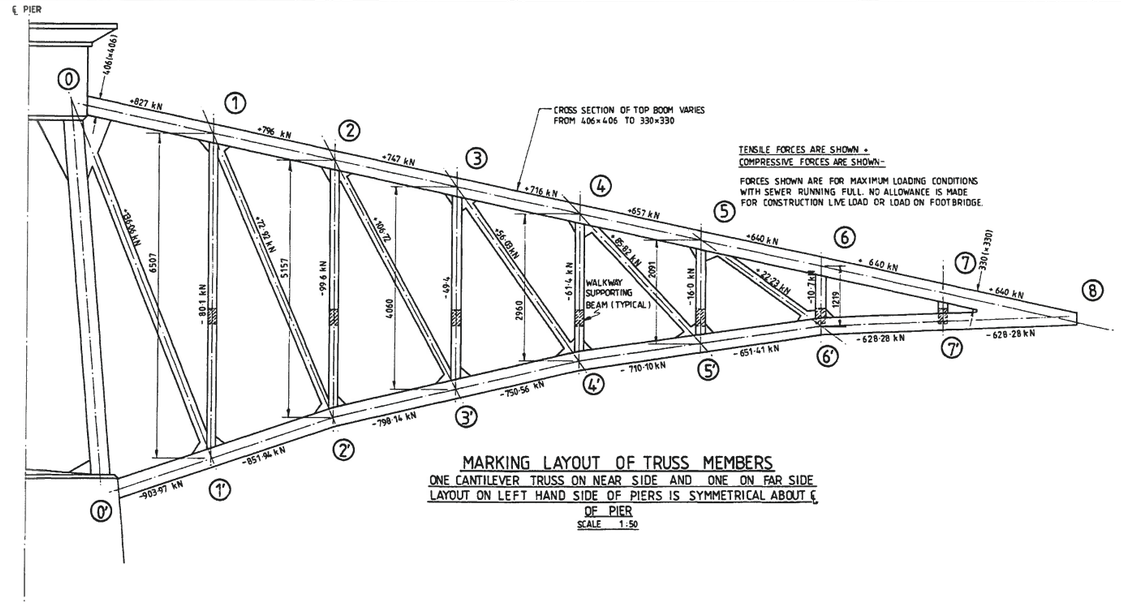
LENGTHS OF PILES GIVEN ARE ONLY APPROXIMATE AND INCLUDE THE DISTANCE EMBEDDED IN RAFT, ALLOWING 2" FOR COVER



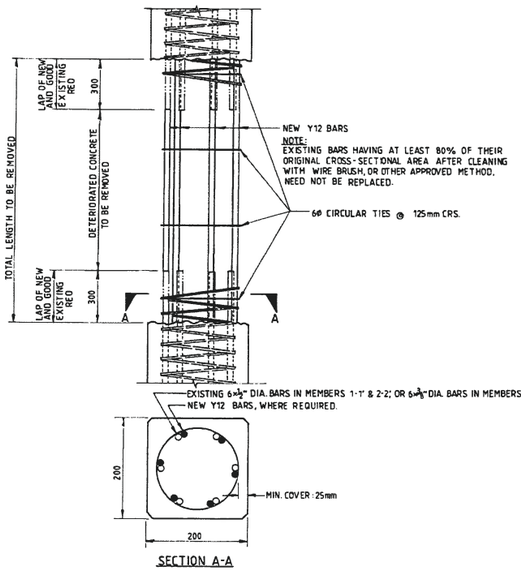
LOCALITY PLAN
NOT TO SCALE



SIDE ELEVATION
(LOOKING WEST)
NOT TO SCALE

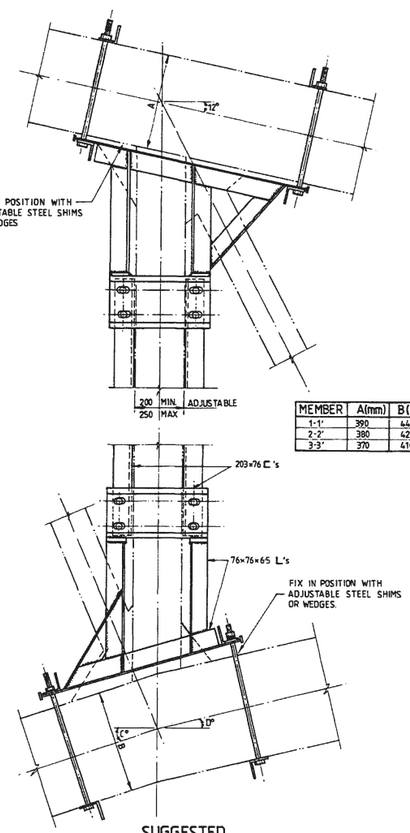


MARKING LAYOUT OF TRUSS MEMBERS
ONE CANTILEVER TRUSS ON NEAR SIDE AND ONE ON FAR SIDE
LAYOUT ON LEFT HAND SIDE OF PIERS IS SYMMETRICAL ABOUT ℄ OF PIER
SCALE 1:50



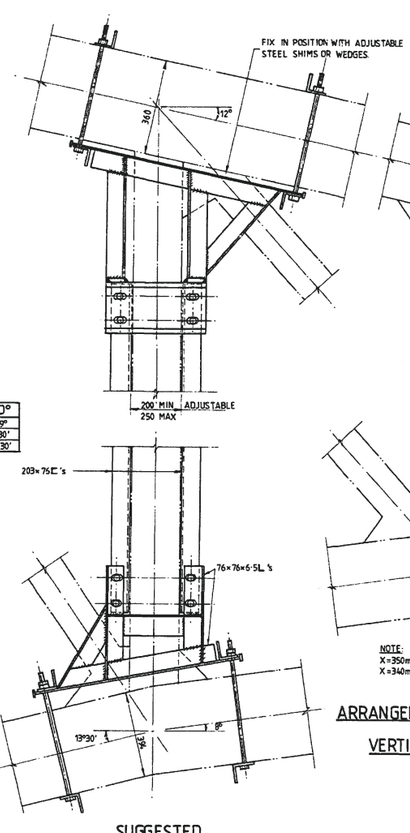
SECTION A-A

METHOD OF REPAIR FOR VERTICAL MEMBERS
SCALE 1:5

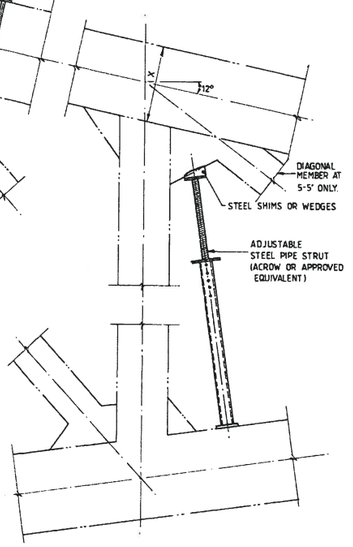


MEMBER	A(mm)	B(mm)	C°	D°
1-1'	390	445	19°	19°
2-2'	380	425	19°	13°30'
3-3'	370	410	13°30'	13°30'

SUGGESTED ARRANGEMENT OF TEMPORARY STEEL STRUTS FOR VERTICAL MEMBERS 1-1', 2-2' AND 3-3'
SCALE 1:10



SUGGESTED ARRANGEMENT OF TEMPORARY STEEL STRUTS FOR VERTICAL MEMBER 4-4'
SCALE 1:10



NOTE:
X=350mm FOR VERTICAL MEMBER 5-5'
X=340mm FOR VERTICAL MEMBER 6-6'

SUGGESTED ARRANGEMENT OF TEMPORARY STEEL STRUT FOR VERTICAL MEMBERS 5-5' AND 6-6'
SCALE 1:10

NOTES

1. ALL VERTICAL MEMBERS WHICH REQUIRE REPAIR WILL BE EXAMINED BY THE SUPERINTENDENT BEFORE AND AFTER REMOVAL OF LOOSE AND DETERIORATED CONCRETE TO ASCERTAIN THE EXTENT OF REPAIR REQUIRED FOR EACH NUMBER.
2. TEMPORARY STRUTS REQUIRED FOR THE VERTICAL WEB MEMBERS MAY BE INSTALLED IN ACCORDANCE WITH THE SUGGESTED ARRANGEMENTS ON THIS DRAWING. HOWEVER THE CONTRACTOR MAY SUBMIT IN HIS TENDER AN ALTERNATIVE METHOD OF TEMPORARY STRUTTING FOR APPROVAL BY THE SUPERINTENDENT. THE TEMPORARY STRUTS SHALL BE ADJUSTED TO TAKE A SMALL INITIAL COMPRESSION BEFORE THE REMOVAL OF CONCRETE FOR REPAIR PURPOSES.
3. LENGTHS AND COMPRESSIVE FORCES IN VERTICAL MEMBERS ARE SHOWN IN THE "MARKING LAYOUT OF TRUSS MEMBERS." THE TENSILE FORCES IN THE TOP BOOM ARE ALSO SHOWN.
4. EXISTING AND NEW REINFORCING BARS SHALL BE CLEANED OF ALL RUST, DIRT, OIL SLAG etc. BY MEANS OF WIRE BRUSHING OR APPROVED METHOD. ACID CLEANING SHALL NOT BE USED.
5. THE VERTICAL MEMBERS SHALL BE RESTORED TO THE REQUIRED SHAPE AFTER THE EXISTING CONCRETE HAS BEEN REMOVED AND REINFORCING REPAIRED. WHERE NEW CONCRETE IS TO BE JOINED TO EXISTING CONCRETE, THE TYPE AND METHOD OF APPLICATION OF BONDING AGENT SHALL BE SUBJECT TO APPROVAL BY THE SUPERINTENDENT.
CONCRETE CHARACTERISTIC STRENGTH: 25MPa AT 28 DAYS.
MAXIMUM SLUMP: 80mm MINIMUM COVER: 25mm MAXIMUM AGGREGATE SIZE: 20mm.
CONCRETE SHALL COMPLY WITH AS 1480-1982, REINFORCING BARS WITH AS 1302-1982, HARD DRAWN STEEL WIRE WITH AS 1303-1984.
WHERE FACES OF TEMPORARY STEEL STRUTS WILL HAVE CONTACT WITH FRESH CONCRETE, THESE FACES FACES SHALL BE COATED WITH OIL.

NOTE: THIS DRAWING SUPERSEDES DRAWING No.16109A.

REFERENCES		REVISIONS				
DRG. No.	TITLE	No.	DATE	DESCRIPTION	BY	APP'D

SURVEY
SURVEY BY .....
DETAIL PLAN No. .....
FIELD BOOK No. .....
LEVEL BOOK No. .....
P.S.M.'s .....
.....
T.B.M.'s .....
.....

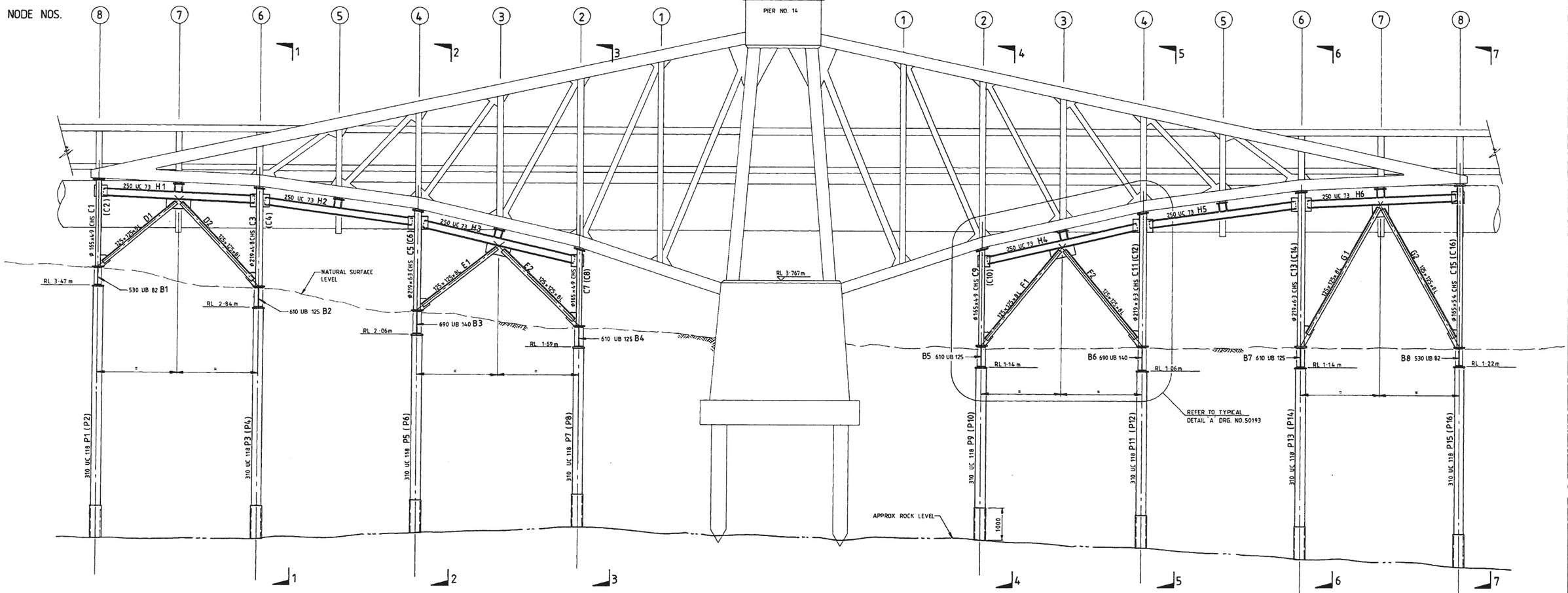
GEELONG AND DISTRICT WATER BOARD
61-67 RYRIE STREET
GEELONG 3220
TEL. (052) 262500
TELEX AA39187
FAX. (052) 218236

OVOID SEWER AQUEDUCT
LOCALITY PLAN AND SUGGESTED ARRANGEMENT OF TEMPORARY STRUTS FOR REPAIR OF VERTICAL MEMBERS

50 182

DESIGNED	DRAWN	CHECKED	SCALES
	P. JOSIPOVIC JUL '87	15/1/88	'AS SHOWN'
ENG. MGR. 15/1/88	EXECUTIVE MGR.	BOARD ENG. 15-1-88	PLAN: SECT: HORIZ: VERT:

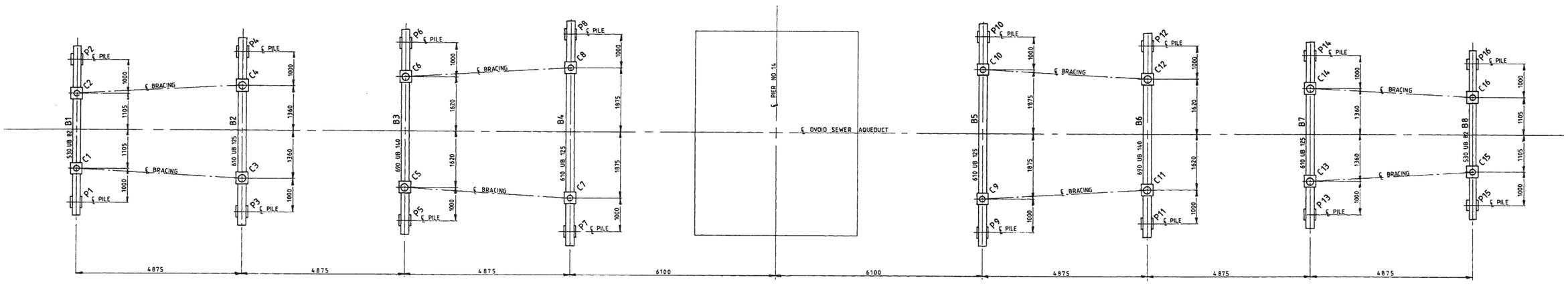
81



EAST ELEVATION PIER NO. 14 SOUTHERN END

SCALE; 1:50

NOTE FOR SECTIONS 1-1 2-2 3-3 4-4
5-5 6-6 & 7-7 REFER TO DRG. NO. 50192



FOOTING PLAN

SCALE; 1:50

NOTES

FOR GENERAL NOTES REFER TO DRG. NO. 50193

REFERENCES

DRG. No.	TITLE
50192	STEELWORK DETAILS SHEET 1 OF 2
50193	STEELWORK DETAILS SHEET 2 OF 2

REVISIONS

No.	DATE	DESCRIPTION	BY	APP'D

SURVEY

SURVEY BY ..... S. SIM
DETAIL PLAN No. .....
FIELD BOOK No. .....
LEVEL BOOK No. .....
P.S.M.'s .....
.....
T.B.M.'s .....
.....

GEELONG AND DISTRICT WATERBOARD
61-67 RYRIE STREET
GEELONG 3220
TEL. (052) 262500
TELEX AA39187
FAX. (052) 218236

OVOID SEWER AQUEDUCT
PIER NO. 14 SUPPORT STRUCTURE
GENERAL ARRANGEMENT

50191

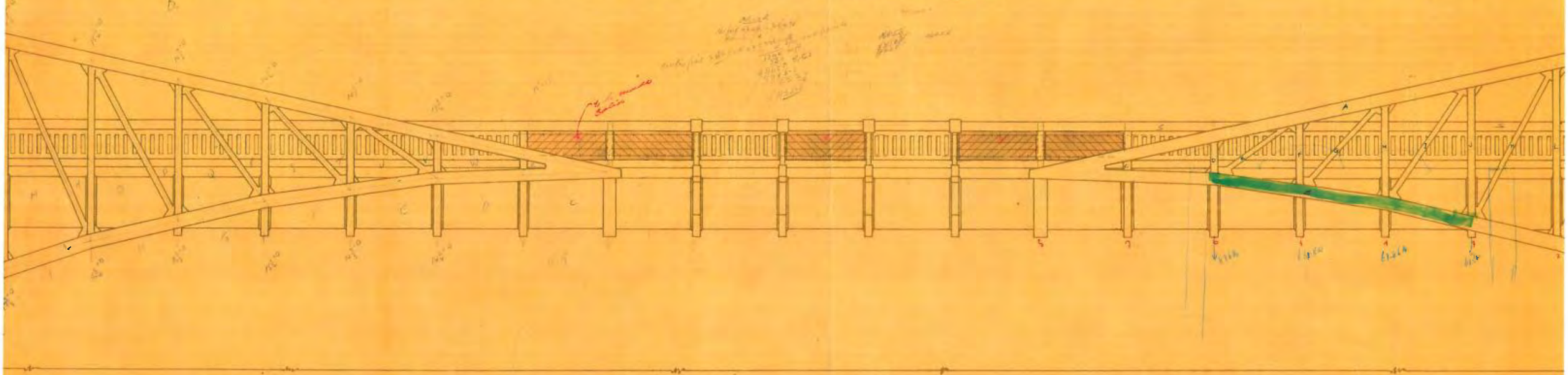
DESIGNED	DRAWN	CHECKED	SCALES
R.LANGEDIJK.	A.HODGSON AUG'89		AS SHOWN
ENG. MGR. 16-10-89 J.R.Jackson	EXECUTIVE MGR. M.B.Hunter 3/1/03		PLAN REGT. HORIZ: VERT:

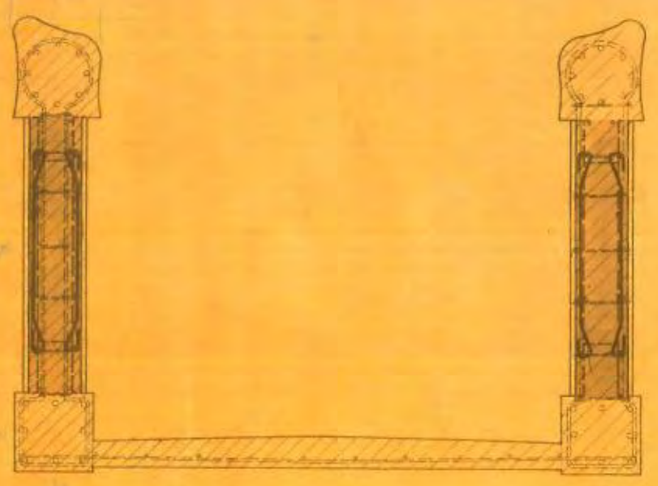
B1

REINFORCED CONCRETE AQUEDUCT OVER THE RIVER BARWON
GEELONG WATERWORKS & SEWERAGE TRUST.

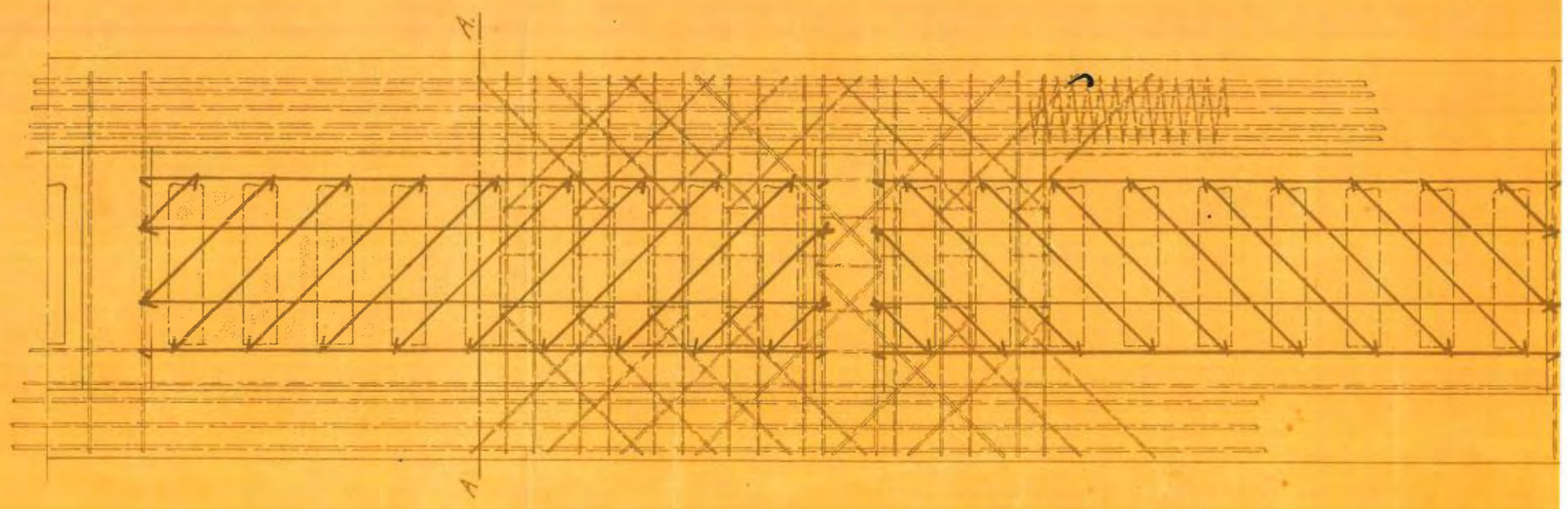
SCALE ¼ IN. & 1½ INS TO ONE FOOT.

Copies of Drawings supplied to W. & S. Trust 19/9/13





SECTION A–A.



ELEVATON of CENTRAL GIRDER at POINT OF SUPPORT

Existing Reinforcement shewn dotted
Additional Rods shewn full

DESIGNED BY STEEL ARC GIRDER
REINFORCED CONCRETE ARCH AND
CONCRETE APPROACHES

CARLSONS

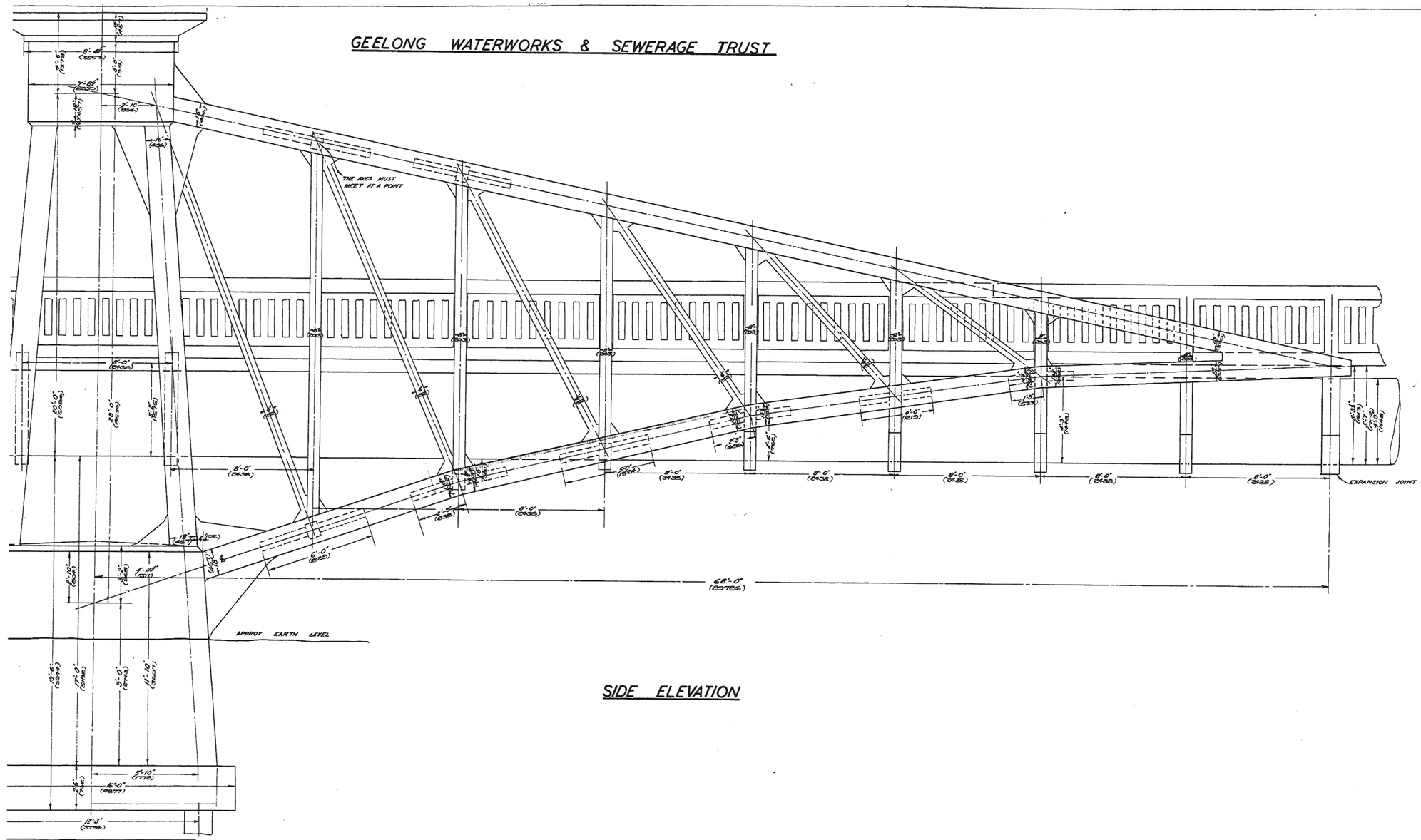
NOTE— DISTRIBUTION OF REINFORCEMENT IN UPPER BOOMS ARC SUBJECT TO ALTERATION

SCALE 3/32 TO ONE FOOT

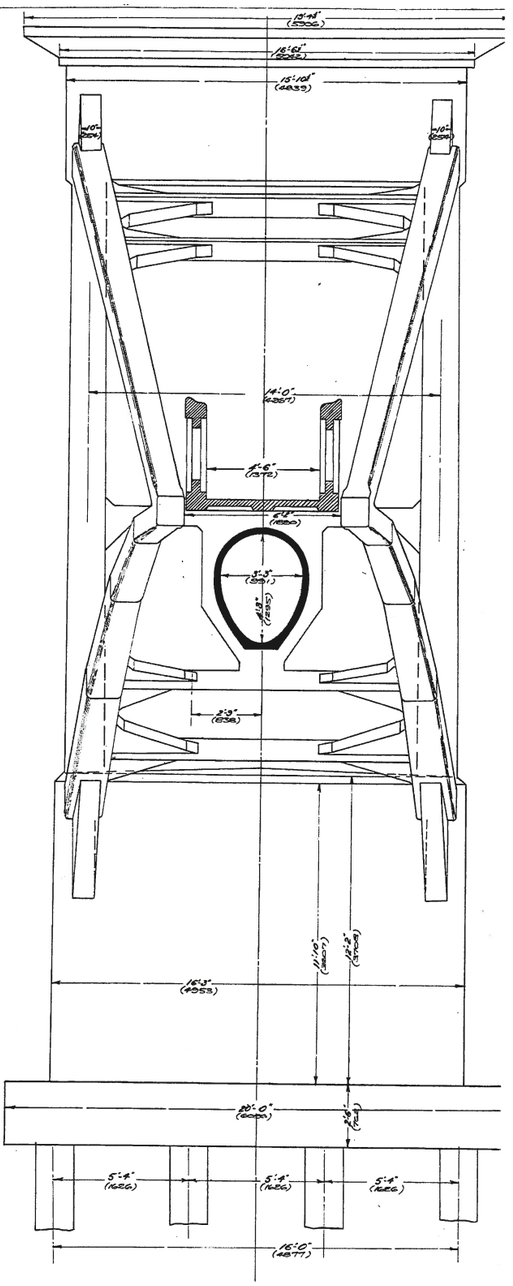
END ELEVATION

SIDE ELEVATION

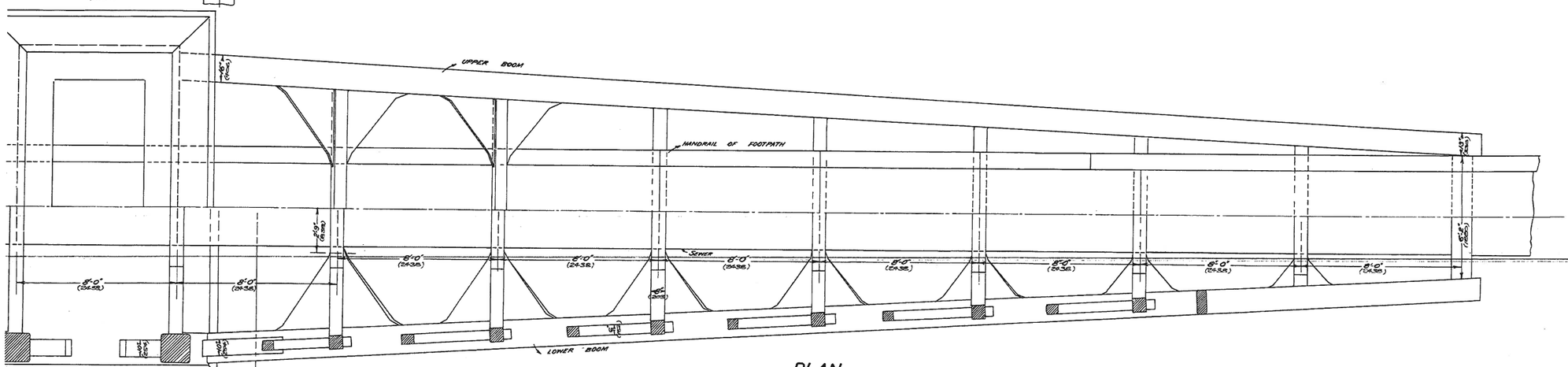
GEELONG WATERWORKS & SEWERAGE TRUST



SIDE ELEVATION



END ELEVATION



PLAN

TRACED OFF ORIGINAL BLUE PRINT
BY G.R. PLUMMER 23-8-1956

GHD

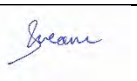
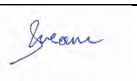
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Document Status – DRAFT

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
0	H.Blythe & P. Selby-Smith	D.Wearne D.Young		D.Wearne		19/05/17
1	H. Blythe & P. Selby-Smith	D. Wearne		D. Wearne		14/09/17

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