Australasian
Corrosion
Consultants

HERITAGE VICTORIA

BARWON OVOID SEWER AQUEDUCT
Breakwater, Victoria

REHABILITATION TRIALS



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Executive Summary

Australasian Corrosion Consultants Pty Ltd was commissioned by Heritage Victoria to carry out trials on realkalization and cathodic protection electrochemical repair systems and compare them against conventional patch repairs. The aim of the project was to develop a preliminary Scope of Works and Cost Estimate of the 3 repair systems to enable Heritage Victoria to develop a program for formulating a repair using one of the tested techniques.

Repair trials under this project have been undertaken on sections of the major chords and minor stays of the structure using **Realkalization** and **Cathodic Protection**. Previous repairs have been undertaken on the structure using **Conventional Patch Repairs** and the 3 techniques are considered the only feasible options for the repair of the structure.

The ovoid pipe has not been included in the repair trials at this stage. The pipe is in relatively good condition compared to the rest of the Aqueduct structure and the large scale electro-chemical repair based protection of the pipe may not be warranted. We recommend some further investigation of the ovoid pipe, combined with some trial repairs using various CP or realkalization techniques before finally recommending the preferred repair and protection system for this element.

Comparison of the three repair systems:

Conventional Patch Repairs are a proven technique for the repair of carbonated concrete:

The advantages are:

- An excellent life expectancy for the areas repaired (50 years plus).

The disadvantages are:

- The repair is expensive, partly because of the structural support required during the concrete removal and replacement.
- The repair system is only carried out on the spalled and delaminated areas and the remaining unrepaired sections of the structure will continue to corrode and spall.

The budget developed in this report totals

- $14.9m for an average of only 17% of the concrete surface area of the structure.
- $2.2m on a rolling 5 yearly interval maintenance repair program for ongoing corrosion.

Realkalization trial repairs proved effective in areas but insufficient levels of realkalization were achieved in some locations.

The advantages are:

- Economical repair over the life of the repair.
- Reduced structural support required during the concrete removal and replacement.

The disadvantages are:

- The system requires all spalling and delaminated concrete to be repaired prior to applying the realkalization treatment.
- Has a short history in Australia and the life of the system internationally has not been well documented.

The budget developed in this report totals

- $13.5m for the realkalization based repair (all concrete areas excluding ovoid pipe)
- A further provision for future repairs of $2.0m on a 10 year rolling interval.

Cathodic Protection (CP) based repairs proved effective with the trial repairs meeting Australian and International criteria for the corrosion protection of the reinforcement.

The advantages are:

- Economical repair over the life of the repair.
- Reduced structural support required during the concrete removal and replacement.
- Has a long history in Australia and internationally with a service life of 30 years plus.
- Use of internal anodes in the larger elements i.e. chords allows for some of the concrete repairs to be staged over an extended period. (Staging has not been considered in the budget).

The disadvantages are:

- The surface based concrete repairs are required prior to installing titanium ribbon surface anodes in the smaller elements.
- Periodic monitoring of the cathodic protection system is required.

The budget developed in this report totals

- $13.3m for the CP based repairs (excluding ovoid pipe).
- Monitoring the Cathodic protection system at $18K pa plus an allowance of $20K pa for maintenance of the system.

Cost comparison summary (over 50 years):

Repair system	Initial cost	Ongoing cost	Total over 50 years
Conventional patch repairs	$ 14.9m	$ 22m	$ 36.9m
Realkalization	$ 13.5m	$ 10m	$ 23.5m
Cathodic Protection	$ 13.3m	$ 1.9m	$ 15.2m

Recommendations

Based on the investigation and trial works undertaken, we recommend the **Cathodic Protection** based repair as the preferred and most economical repair method for the Aqueduct Structure. The CP based approach could be utilized in a staged manner, with repair to one tower or all towers progressively. There is also the possibility of installing CP systems initially and delaying some of the concrete repairs to future years.

While the structural stability of the structure is beyond the scope of this report, from the estimated rates of corrosion we expect there will be continued deterioration of the structure. If there are significant delays in undertaking Catholic Protection and repairs, propping the ends of the tower spans may be necessary to reduce the dead load on these critical elements. This would obviously need structural engineering input.

1. Background

The Barwon Ovoid Sewer Aqueduct was constructed over the Barwon River in 1913-1915. The aqueduct carries the now de-commissioned ovoid reinforced concrete sewer pipe across the Barwon River from Leather St in Breakwater to Tannery Lane in Marshall. The length of the aqueduct is approximately 756 metres. The structure is owned by Barwon Water.

The aqueduct consists of 56 reinforced concrete trusses which cantilever from 14 concrete towers. The gap between the ends of the trusses is bridged by girders. In addition to the ovoid pipe the aqueduct also carries a walkway.

The steel reinforced elements of the aqueduct trusses were constructed using the "Considere" method for reinforced concrete which uses spirally wound reinforcement to increase the compressive strength of the truss elements.

Following several rehabilitation trials by others since 1991, ACC were commissioned by Heritage Victoria to trial realkalization and cathodic protection electrochemical repair systems and compare them against conventional patch repairs. The aim of this project was to develop a preliminary Scope of Works and Cost Estimate of the 3 repair systems to enable Heritage Victoria to develop a program for formulating a repair using one of the tested techniques.

Scope of Work

The Scope of Work agreed to for this project was to:

- Carry out a condition assessment of 1st Section of the Barwon Sewer Aqueduct.
- Supply, install and trial a limited realkalisation system and carry out a suitability assessment.
- Supply, install and trial a limited cathodic protection system and carry out a suitability assessment.
- Prepare a preliminary scope of works and budget for the repair of the structure using the systems trialled and also using conventional patch repair.

2. Investigations and Trials 2009

The objective of this project is to test the technical and economic performance of realkalization and cathodic protection systems against conventional patch repairs as part of repair techniques for the Barwon Ovoid Sewerage Aqueduct.

Access to the Barwon Ovoid Sewer Aqueduct in 2009 was limited due to OH&S concerns. Barwon Water, the owner of the structure, has in place an embargo which prohibits any person entering the area within the fenced area or anywhere on the structure itself. Following negotiations between interested parties it was agreed that ACC could access the structure by "boom" lift only and they were provided with a key to access the site in November 2008. As a consequence to the limited access ACC revised their program to conduct the trials on the east side of Tower 1 only, as the west side could not be approached with the boom. Further the detailed visual condition survey was modified because the delamination (drummy) test could not be carried out on the western side of the structure or on the aqueduct towards the river crossing. The visual survey was carried out on the following sections:

- General visual of the whole of the structure from the security fence perimeter.
- A detailed visual from the security fence on the following sections
    - Tower 1 eastern side.
    - Tower 2 eastern and western sides
    - Tower 3 eastern side
    - Tower 7 eastern side
    - Tower 8 eastern side
    - Tower 9 eastern side northern portion

The trials repairs undertaken were all carried out on the south- eastern side of Tower 1, as marked on figure 1.

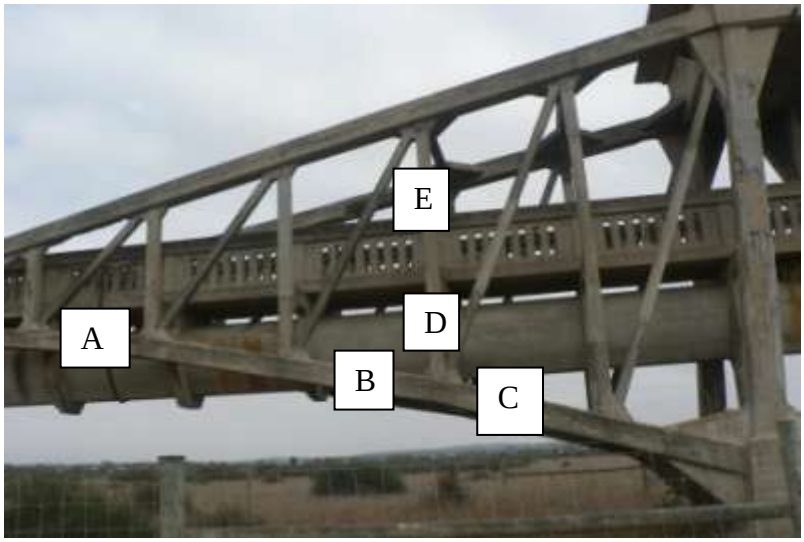


Figure 1

Trial locations on Tower 1 South - A, C & D – Realkalization; B & E - CP

2.1.Investigation

A diagnostic investigation of the structure was carried out on a limited number of elements on the Aqueduct only. The scope of the investigation included the following:

- Visual inspection and delamination testing
- Cover to reinforcement measurement
- Reinforcement Continuity Testing
- Equipotential mapping using the Galva Pulse system
- Carbonation analysis
- Inspection of reinforcement at breakout locations

2.1.1. Visual inspection

The aim was to record the extent of visible deterioration such as concrete cracks, spalls, delamination and other surface defects. The visual inspection was performed on all elements of Towers No 1, 2, 3, 7, 8 and 9 and the spans between the towers. The ovoid pipe was not included in the inspection. The results are recorded in Appendix B.

The results of this inspection in comparison to the 1991 investigation shows the defects on Tower 2 have increased by 4% and Tower 3 by 26% which generally gave the range over which the Aqueduct has deteriorated since 1991.

2.1.2. Concrete Cover Survey

The thickness of concrete cover to reinforcing steel was determined using a microprocessor-controlled reinforcement bar locater in accordance with ACC's Test Method Statement No 5 and by physical measurement of concrete cover at locations of exposed reinforcement.

The bottom chord of the structure contains 8 No ¾" (~20mm) longitudinal main bars with No.4 wire (~6mm) ligatures spiralled around them forming a round cage. Structure stay No. 2 contained 6 No ⅜" (~10mm) longitudinal bars and No. 5 wire (~5mm) spiralling wound ligature which also formed a round steel cage. The chords and vertical stays have been formed square in section and therefore the covers vary significantly. Further the steel in the vertical stay was found to be placed off centre within the section.

The minimum covers measured to the main bars were approximately 60mm and to the ligatures 36mm.

2.1.3. Reinforcement Continuity Testing

The in-situ continuity characteristic of the reinforcement was determined by DC resistance testing in accordance with ACC's Test Method Statement No 1.

The steel reinforcement is not electrically continuous between all longitudinal bars and the ligature wire in the bottom chord or the vertical stay. Resistance between the main bars of the major chord and in the minor vertical stay were commonly between 20 to 30 ohms, where the standard requires less than 2 ohms. Therefore all steel will need to be bonded together before any electrical treatment can be applied. This can most easily be done by welding in 6mm rod around the main bars.



Figure 2

2.1.4. Potential and Resistance Mapping

The level of corrosion activity affecting embedded reinforcement was determined by half-cell potential mapping and the relative ease with which current can flow through the concrete was ascertained by resistance mapping. The mapping was performed using the Galva Pulse system for potential and resistance mapping. All detailed results are included in Appendix A.

The corrosion potentials were measured and analysed in accordance with ASTM-C876-80 "Standard Test Method for Half Cell Potentials of Uncoated Reinforcing Steel in Concrete" The Standard provides a very general guide for classification of Half-Cell potential values based upon probability for corrosion. This guideline is presented in the following table:

POTENTIAL	PROBABILITY OF CORROSION
More positive than -0.20 volts	< 5%
-0.200 to -0.350 volts	About 50%
More negative than -0.350 volts	> 95%

Table 1

The analysis is presented in graphical format and colour coded to show the area of the test which fall into the three categories given in table 1.

2.1.4.1. Trial test Area "B"

Test area "B" at location shown in figure 1 was selected to trial the discrete anode cathodic protection system. The potential analysis was carried out in the form of a graph and is shown in figure 3. The graph shows the probability of corrosion is 50% for the test area with a small area considered to have a corrosion probability of 90%.

The same area was surveyed for concrete resistance. The results analysed are shown in figure 4 which indicates significantly resistance variation over the test area.

Equipotential. Aqua B

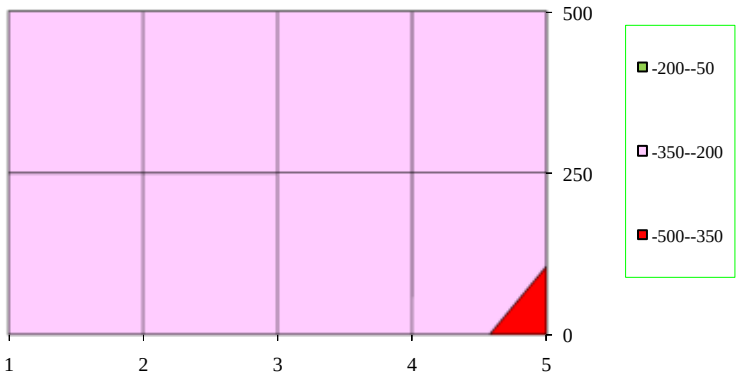


Figure 3

Resistance. Aqua B

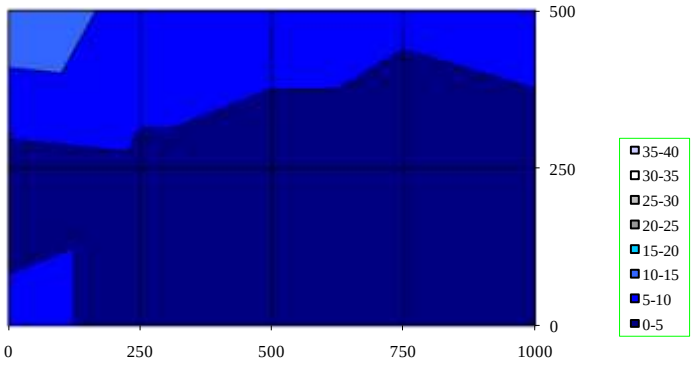


Figure 4

2.1.4.2. Trial test Area "C"

Test area "C" at location shown in figure 1 was selected to trial the realkalization process. The potential analysis as a graph is shown in figure 5. The graph shows the probability of corrosion for the whole area tested is 50%.

The same area was surveyed for concrete resistance. The graphed results are shown in figure 6 which indicates a relatively even spread of resistance over the test area with a high resistance in a relatively small area.

Equipotential. Aqua C

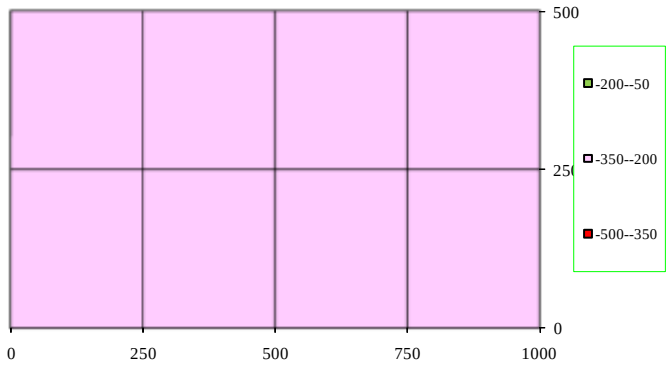


Figure 5

Resistance. Aqua C

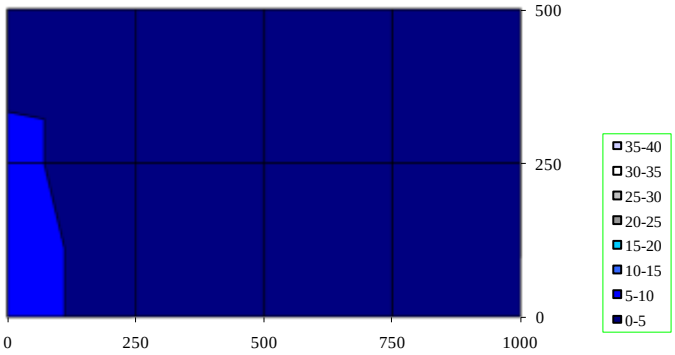


Figure 6

2.1.4.3. Trial test Area "D"

Test area "D" at location shown in figure 1 was selected to trial the realkalization process on the smaller vertical stay. The potential analysis was carried out in the form of a graph and is shown in figure 7. The graph shows the probability of corrosion is 50% for 75% of the test area and 25% of the area has a corrosion probability of 90%.

The same area was surveyed for concrete resistance. The analysed results are shown in figure 8 and indicated a low resistance over most of the test area.

Equipotential. Aqua D

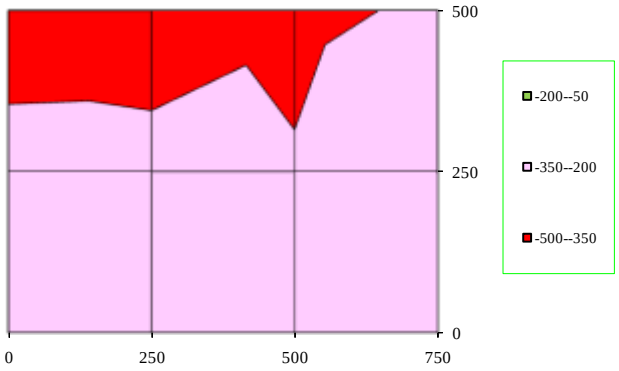


Figure 7

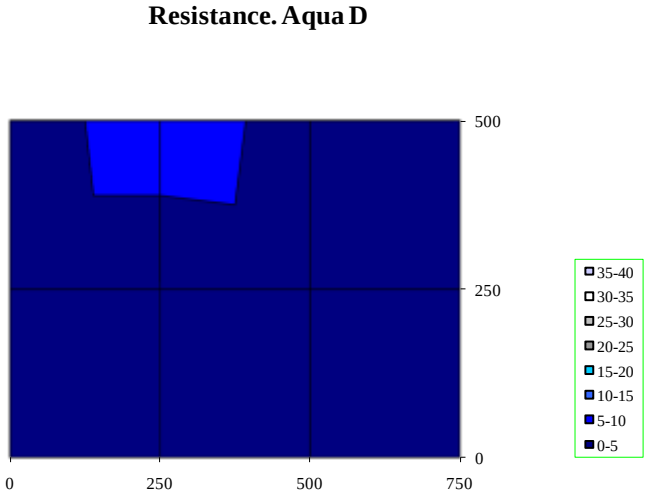


Figure 8

2.1.5. Corrosion rate measurement

The rate of corrosion was measured using the Galva Pulse system at the same time as the potential measurements were taken. The measurement was carried out without sensor control in this instance due to the high concrete resistance found in all test sites.

A published criterion by Broomfield for a system without sensor control is given as:

No corrosion expected: $I_{corr} < 0.2$ µA. cm^{-2}

Corrosion possible in 10 to 15 years: I_{corr} 0.2 to 1.0 µA cm^{-2}

Corrosion expected in 2 to 10 years: I_{corr} 1.0 to 10 µA cm^{-2}

Corrosion expected in 2 years or less: $I_{corr} > 10$ µA cm^{-2}

The corrosion rates were measured in zones “B”, “C” and “D” and are shown in table 2. When assessing the results against the corrosion rate criteria, a very high rate of corrosion is occurring in all zones, however the rates in zone “B” is less than half of those measured in zones “C” and “D”.

All corrosion rate values are given in µA/cm^2

Zone	Test 1	Test 2	Test 3	Test 4
“B”	17.53	9.82	8.32	7.95
“C”	47.77	23.90		
“D”	32.40			

Table 2

The measured corrosion rates were further analysed to estimate the loss of steel section and likelihood of further concrete cracking given the configuration of the test site, depth of cover, reinforcement bar size and layout etc. The measured results were used to calculate the corrosion rate in accordance with Faraday’s Law as shown below.

Calculation of Corrosion Penetration Rate

$$CR = \mathrm{K}_1 * \frac{i_{corr}}{\rho} * EW$$

Where:

CR is given in mm/yr, i_{corr} in µA/cm^2 as measured.
K_1 = 3.27 x 10^{-3}, mm g/µA cm yr.
ρ = density of carbon steel = 7.81 g/cm^3.
EW = Equivalent weight for carbon steel = 27.92.

The steel area is set by the test instrument in reinforcement bar size. The area was adjusted to account for the changing bar sizes and the configuration of the steel within the chord and stay elements. The revised estimated area was used to adjust the corrosion rate (i_{corr}) and the corrosion penetration rate calculated using the adjusted i_{corr}. The results of the calculations are show in table 3 for all measured sites.

Zone	Test ID	Measured corrosion rate i_{corr} (µA/cm^2)	Instrument set to test area bar = 16mm Ø length = 7cm (cm^2)	Estimated CR test area (cm)	Adjusted corrosion rate i_{corr} (µA/cm^2)	Corrosion Penetration Rate (CR) (mm/yr)	Corrosion Penetration Rate (CR) (µm/yr)
"B"	**Test 1**	17.53	35.2	359.1	1.7	0.020	20
	Test 2	9.82	35.2	359.1	1.0	0.011	11
	Test 3	8.32	35.2	359.1	0.8	0.010	10
	Test 4	7.95	35.2	359.1	0.8	0.009	9
"C"	**Test 1**	47.77	35.2	359.1	4.7	0.055	55
	Test 2	23.9	35.2	359.1	2.3	0.027	27
"D"	**Test 1**	32.4	35.2	381.0	3.0	0.035	35

Table 3

The corrosion rate tests show that the measurements on the chord element steel may range from 9 to 55µm/yr in the test areas and the single test on the stay at 35µm/yr. Therefore to lose 10% of the chord reinforcement steel section at the rate estimated requires more than 34 years and for the stay 26 years if the protection offered by the concrete remains valid.

With regard to further cracking Broomfield suggests section loss of 10µm is sufficient to cause cracking. It can be seen that at the measured corrosion rates cracking followed by delamination and spalling will occur in the areas which currently appear sound including at the lowest measured values of 9µm/yr within 2 years. When cracking, delamination and spalling does occur the steel will be subjected to atmospheric corrosion rates.

The Australian Standard "Guide to the protection of iron and steel against exterior atmospheric corrosion" AS2312-2002 gives a corrosion rate of 18µm/yr for steel in the atmosphere in a similar location as the Aqueduct. At this rate, it will require more than 100 years before 10% of section area is lost.

The corrosion rate analysis indicates the major reinforcement steel bars are losing sufficient section to be of concern. The corrosion rate analyse does not take into

consideration corrosion rates in areas such as crevices which hold moisture for long periods of time, micro climates or drainage systems which may be appreciably higher.

2.1.6. Carbonation Testing

Modified phenolphthalein indicator solution was used to determine the depth to which concrete has become carbonated. The test was performed in accordance with ACC's Test Method Statement No. 8. Carbonation has the effect of lowering concrete pH. The indicator solution is designed to change colour on contact with concrete with a pH more than 9.5 to 10.

The carbonation tests in visually solid concrete found a depth of carbonation of 60mm occurred in zone "A"; however a depth of only 12mm was measured in zone "B". These results confirm earlier reports on the cause of the deterioration.

2.1.7. Inspection of the reinforcement at the breakouts

The condition of the steel reinforcement is shown in figure 2. These show that the ligature wire on the chords has been lost in the delaminated areas however the main longitudinal bars have suffered little section loss. The reinforcement in the vertical stays displayed similar losses.

2.2.Trials

2.2.1. Electrical Continuity

Continuity was established by exposing the main bars in the main chord and the vertical stay by creating a transverse slot in the cover concrete to the steel and by installing crimp lugged cables screwed to the main bars as shown in figure 2.

Welding a continuity bar could be utilized establishing full electrical continuity to facilitate electrochemical protection in the future. This was not done due to the fire risk in the dry grass below the structure at the time of this installation.

It is expected that two continuity locations per chord per half span will be required for the major chord elements, with one continuity connection per minor stay element.

2.2.2. Realkalization System

The Aqueduct's reinforced concrete suffers mainly from Carbonation of the concrete, where the normally high alkalinity of the concrete protects the reinforcing steel from corrosion. With the carbonation extending well past the reinforcing steel, a conventional repair would require all of the carbonated concrete around the steel to be removed and replaced, an impossibly expensive and laborious operation.

Realkalization restores the original alkalinity of the concrete, by passing a direct current through the concrete generating alkalinity at the reinforcement surface as shown diagrammatically in figure 9. Also, an alkaline solution is "forced" into the concrete via electro-osmosis, completing the restoration of the alkaline nature of the original concrete.

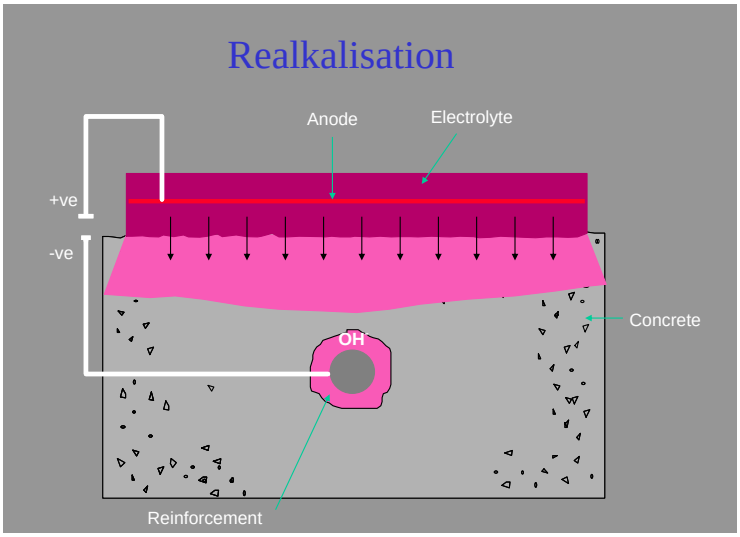


Figure 9

Realkalization is normally a short term treatment of less than 7 days duration, with current density in the order of 1 A/m^2 concrete surface. Realkalization must be completed on sound concrete, so that surface repairs are required over spalled or delaminated areas and crack repairs are required before the treatment. Reinforcement electrical continuity is required prior to undertaking the realkalization process.

The areas intended for treatment were 1m lengths of the bottom and top chord elements, plus a 0.5m length of the smaller vertical "truss" element.

2.2.3. The realkalization trials

Due to the restricted time and access available, the realkalization trials needed to be undertaken on non-spalling structure locations, as the time required for patch repair works to be completed and cured would be prohibitive given the access methods available. Selection of suitable sound locations on the major chords resulted in both areas being on the lower chord on the South-east side of Tower 1. The vertical stay section formed the trial location of the minor elements. The selected locations are shown in figure 1.

The realkalization was undertaken by using fibrous (woollen) fabric wrapped around the concrete, with the titanium or ribbon mesh anode placed outside the initial material. Another layer of woollen fabric was then placed over the anode, with plastic strapping firmly placed around the arrangement to keep the system in good contact with the concrete. (see photographs below). The "Soak-it" hoses are then positioned over the trial areas to keep the test area wet with the alkaline solution.

	
Test site D, bottom chord wrapped in wool blanket and covered in Titanium mesh anode	Anode is encapulated in woolen cloth
 \	
Test site D with soak-it hose placed.	Test site D (left) and C (right) prior to wrapping in plastic.

The realkalization areas are saturated with the alkaline solution prior to wrapping the systems in plastic to keep them continually damp. The header tank is placed above the trial sites with the flow of solution to the sites controlled by an adjustable tap.

	
Test site C & D wrapped with plastic, with header tank for the solution	Test site A prior to wrapping in plastic.

The Realkalization trial areas were energized on 26/2/09 as detailed in Appendix A. Due to the restriction of battery power only, lower current than ideal was applied to the trial locations initially, with increased batteries allowing voltage increases as detailed in the results.

The ideal current density for realkalization is approximately 1 Amp/m2 concrete. Accordingly, the ideal current for realkalization trial areas A & C was 1.6 A, with the small trial area D being 0.3 Amp. As detailed in Appendix A, these currents were generally not achievable with the 48 volts available requiring the duration of the trial to be extended to closely achieve the recommended amp-hour application.

Note that the trial area A, only achieved approximately one-third the current of the similar sized area C. The concrete resistance of area C was shown to be low as indicated in figure 6. Other sections of this chord contained high and variable concrete resistance as shown in figure 4. Therefore the concrete resistance at area A may have been high resulting in a lower current being applied.

The trials were decommissioned on 10/3/09 and cored concrete samples were immediately taken to examine the extent of realkalization. The extent of realkalization achieved varied considerably across the trial locations. In all test areas, sample sites were found showing complete realkalization from the surface to full depth. However, each site also had areas of partial realkalization, where part depth realkalization only was achieved, as illustrated below.



Core drilling the realkalization test site C for testing of realkaliztion depth



Test site C, top side, indicating complete realkalization.

	
Test site A, top side, with excellent realkalization	Test site D, side near base. Result indicates incomplete realkalization possibly due to high concrete resistance.

We believe the range of realkalization achieved illustrates that the process itself works well, but the variation in the extent of realkalization is a real concern. The likely reasons for the partial depth realkalization in some areas are summarized as follows:

- The uniform realkalization of the elements requires the concrete to be uniformly damp with the solution. The shape and slopes of the elements results in difficulty in keeping all areas damp.
- Keeping the fabric in contact with the concrete is difficult, especially on the underside of the chords where gravity tends to pull the system away from the concrete. Further development of the realkalization method may assist in this area.
- Variations in resistivity (resistance) in the concrete as measured in the preliminary investigation, resulting in variations of the current and extent of realkalization achieved.

Despite the above, we conclude that realkalization of the elements of the aqueduct is feasible, given further development of the method and system for the structure. Further trialling should be undertaken to eliminate the variations in the extent of realkalization before adopting the system on a large scale. Realkalization using a one molar solution of potassium bicarbonate for 130Amp/hour per square meter should be sufficient to achieve full depth realkalization.

2.2.4. Cathodic Protection System

Cathodic Protection uses a small continuously applied direct current to stop the corrosion process. The current causes a net current flow onto the reinforcing steel turning off existing corrosion cells, "Polarizing" the reinforcement, repelling corrosion inducing chloride ions and generates alkalinity at the Reinforcement surface similarly to Realkalization.

We proposed a trial using "Internal" anodes, where the anodes are placed centrally in the element in drilled holes of approximately 30mm diameter. The current passed from the anodes to the reinforcement is therefore from the inside to the outside of the concrete element as shown in figure 10.

This results in the major advantage of this form of CP, in that the concrete repair of the elements, by far the greatest cost of the restoration project, is not required to be completed for the system to be effective. The CP current will protect any steel reinforcement in contact with sound concrete, so that only the exposed surface of the reinforcement at spalled areas will not be protected. When the spalled areas are subsequently repaired with cementitious repair mortar, protective currents will flow to all surfaces of the bar, giving complete protection.

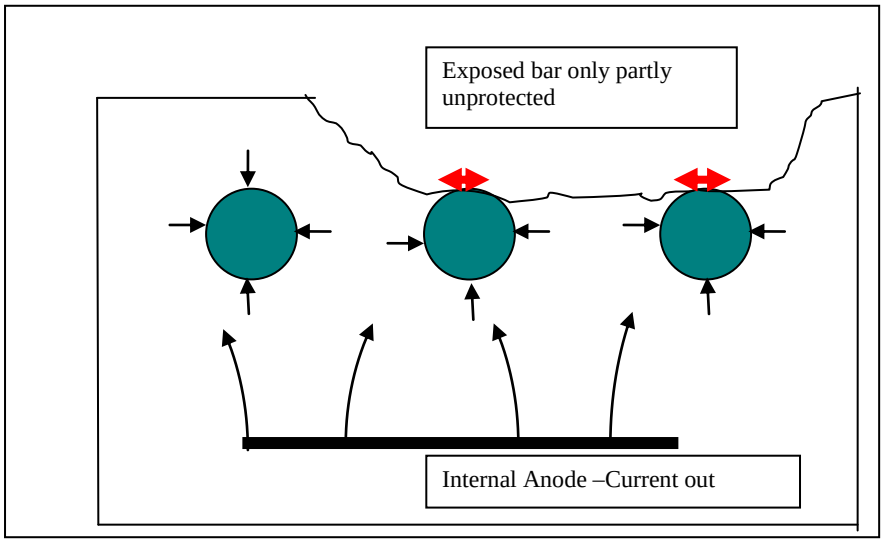


Figure 10

This system therefore allows the application of the CP system and the protection of the reinforcing steel in all major elements of the structure without having to complete the major cost operation of the concrete repair.

2.2.5. Cathodic Protection Trials Cathodic Protection- Internal Anode Trial

The CP trial was installed in a 1m length of the bottom chord element, Test Site B shown in figure 1, with the area selected to include some delaminated and spalled areas so as to demonstrate the system's application without first completing concrete repair. The internal anodes were placed at an average spacing of 200mm in 25mm diameter drilled holes. The anodes consisted of 2 layers of Elgard 150 ribbon anode 300mm long. The anodes were then connected in series with a positive cable. The arrangement is illustrated in the photographs below.

	
Test site B. Internal anodes are installed in drilled holes into the centre of the chord, at 200mm centres. Note exposed (spalled) section of concrete	Test site B. Internal anodes are connected in series and connected to positive power supply. Spalled concrete area cleaned of loose rust and treated with 2-3mm of repair mortar for "temporary" repair.

A typical minor vertical stay was the second CP test area located as shown in figure 1. Due to the small scale of the element, a longitudinal ribbon anode was installed in a slot on the mid section of the stay for a length of 1 m. The anode was an Elgard 150 titanium ribbon. The photographs below illustrate this arrangement.

	
Test site E, ribbon anode installed in slot on southern face of vertical stay	Test site E showing reference electrode installed on eastern face.

Both CP systems were energized on 25/2/09 through the 12 Volt battery powered CP controllers, with the batteries charged through a solar panel. The CP systems were monitored over a 3 month period, until the final monitoring on 5/6/09. All results are detailed in Appendix A and are summarized below.

System	Lower Chord Test Site B	Vertical Stay Test Site E
Ref. Natural Potential (mV)	-374	-225
CP Current applied (mA)	18	8
CP Voltage applied (V)	7.2	7.0
Instant off potential (mV)	-707	-718
4 hour decay (mV)	104	110
24 hour decay (mV)	153	133
Protection criterion achieved 100 mV Decay	YES	YES
Design Current (min) required Per Metre element (mA)	18	8
Anode arrangement (subject to final design)	Internal anode 200mm spacing 3.6mA/anode	Single ribbon 8mA/m

As detailed above, the main chord reinforcement was protected by internal anodes placed at a 200mm longitudinal spacing passing an average of 3.6mA per anode (18mA /m chord). The minor vertical stay was protected by a single ribbon anode longitudinally placed and passing 8mA /m. This information will be valuable in completing the design of a CP system to protect the structure and it is likely that a system similar to that trialled, with appropriately designed anodes, will be effective in protecting the elements of the Aqueduct.

3. Repair options

3.1. Conventional Repairs

3.1.1. Scope of Works

Conventional (Patch) repairs involve the removal of contaminated (carbonated) concrete from around the reinforcement, cleaning and repair of the reinforcement and replacement of the concrete with a new repair mortar.

The difficulty with this type of repair is the large degree of structural support required to stabilize the Aqueduct during the repair. In addition, assuming the patch repairs are only undertaken in visually defective areas (spalling), future deterioration of the non-repaired sections will continue requiring ongoing access and repair. The patch repair budget below is based on repair to all currently spalling areas, averaging only 17% of the concrete surface area, leaving 83% of the concrete surface unrepaired and continuing to corrode and spall.

3.1.2. Budget

The estimate for full depth patch repair is attached in Appendix B1 (ii). In this spreadsheet, the repair quantities are derived from the visual surveys undertaken on Tower 2 & 3, detailed in the Tower 2 & 3 worksheets. These surveys compare the surface area deterioration with that undertaken in the 1991 surveys enclosed in the Taywood – Maunsell report (1991). The cost of surface only repairs ($1500/m2 for electro-chemical EC repairs) for tower 2 & 3 are calculated in Appendix B1 (i) and these figures are used at the increased rate of $3000/m2 for full depth repairs.

Appendix B1(iii) then uses the 1991 repair budgets for each tower to approximate the relative condition of the towers today, including a 26% increase factor for the increased extent of repairs in 2009. This estimate gives a predicted $4.0m for the patch repair costs of all 14 towers.

To this base figure, we have added the costs of access, structural support, site establishment, supervision and margin to arrive at the $14.9m budget for the works. (Note- this budget is to repair spalling areas only, an average of 17% of the concrete surface area. The remaining 83% of the concrete that is not repaired will continue to deteriorate)

As the non-repaired areas will continue to spall, we have added the ongoing repair estimate of 15% of the original costs per 5 years, giving a $2.23m cost (5 yearly). The estimate of these ongoing costs must be considered as speculative.

3.2. Realkalization Repair

3.2.1. Scope of Works

The realkalization based repair requires the surface based patch repair (to the rebar, but not behind) of the concrete prior to the realkalization treatment. Accordingly, the budget for the realkalization treatment includes the surface based concrete repair costs.

The realkalization itself is estimated for all concrete elements excluding the ovoid pipe, which is considered separately.

3.2.2. Budget

The budget for the realkalization and surface repair is detailed in Appendix B1 (ii). The worksheet details the estimate of the surface areas of all elements in a typical tower (excluding the pipe). The calculation then estimates the materials, labour, access etc to calculate the realkalization cost of $675K per tower, or $9.5m for all 14 towers. Added to this is the surface concrete repair estimate from worksheet (i) $4.0m to give the final budget of $13.4m for the realkalization based repair.

As full realkalization is not expected in all areas and the life of realkalization is not proven, we suggest an additional allowance of 15% of the repair cost $2.0m is allowed on a 10 yearly interval for future repairs.

3.3. Cathodic Protection Repair

3.3.1. Scope of Works

The cathodic protection works again requires the similar extent of surface based concrete repairs to that for realkalization. As suggested earlier, CP using internal anodes does give the opportunity to stage the works with some concrete repair completed in future years. This staging possibility is not considered in the following budgets.

The scope of the CP is to protect all elements of the structure (except the ovoid pipe) using long life titanium anodes (50 year plus design life). The system is powered by solar cells with the control systems (and solar cells) placed inside the top of each tower (out of view). An alternative system using a mains power supply is expected to be a similar cost. The budget includes for the control systems to be remotely monitored via a web (www) based system.

3.3.2. Budget

The budget for the CP based repair is detailed in Appendix B1 (iv). The cost of the CP materials and labour is built in a separate spreadsheet named Appendix B2, which calculates the cost of the CP at $665K per tower. In Appendix B1 (iv) this figure is added to the surface concrete repair estimate to arrive at the total budget of $13.3m for the CP of all 14 towers.

Cathodic Protection requires monitoring and maintenance and we have made a separate allowance for

Annual monitoring and reporting	$18K pa
Annual maintenance	$20K pa

3.4. River Crossings- Special Consideration

The river crossings add significantly to the difficulty of the repair works for all repair options. Towers 9, 10, 11 & 12 are the river crossing towers, with towers 10 & 11 on the island.

The river spans complicate both the access and propping of the tower sections. The propping or structural support during repair will need to be considered by structural engineers prior to works in these areas. Similarly, the access to the river spans requires further consideration as there are several options possible, including the use of booms and/or increased levels of traditional scaffolding.

The full consideration of options to address the additional propping and access to the river spans is beyond the scope of this report. We suggest an additional budget allowance is made for the river crossing spans in the order of $200K in total.

3.5. Timing considerations

From our observed rates of corrosion, we expect there will be continued deterioration of the structure, with continued spalling of cover concrete from all elements. This will result in an increasing risk of falling concrete.

The rate of continuing corrosion was addressed in section 2.1.5 of this report, and concludes that cracking will likely occur in most sound concrete areas within 2 years based on the measured corrosion rates. Spalling and delamination of the currently sound elements will follow the cracking, but may be in the order of 10 to 15 years before significant delamination occurs. The cost of future rectification will be mainly linked to the area of delamination and spalling., that is, if there are significant delays in undertaking repairs, costs will be higher because of the larger proportion of the structure with delamination and spalling.

The risk of deteriorating structural stability of elements of the structure is a matter for structural engineering input, beyond the scope of this report. In discussions with structural engineers Ken McLeod and Dick van der Molen, it is understood that the lower chord elements are likely the most critical elements as the corrosion proceeds. The spiral ligatures that are most affected by the corrosion to date are important especially in these lower chord compression elements. However, to limit the risk of any structural collapse, the ends of the tower spans can be simply propped to reduce the dead load on these critical elements. This work is recommended to proceed to limit the structural collapse risk. Engineering input is required to determine the method of propping. Propping becomes more difficult on the river spans of the structure.

4. Conclusions

The aqueduct structure suffers from carbonation initiated corrosion which has reached the depth of the reinforcement in the large majority of the surface, resulting large scale spalling and delamination of the concrete. The large extent of the corrosion has been confirmed with equipotential mapping and rate of corrosion found to be significant using the Galva Pulse instrument.

Repair trials under this project have been undertaken on sections of the major chords and minor stays of the structure with **Realkalization** and **Cathodic Protection**. Previous repairs have been undertaken on the structure using **Conventional Patch Repairs** and these 3 techniques are considered the only feasible options for the repair of the structure.

Conventional Patch Repairs are a proven technique for the repair of carbonated concrete with an excellent life expectancy for the areas repaired (50 years plus). Patch repairs are expensive, partly because of the structural support required during the concrete removal and replacement, with the budget developed in this report totalling $14.9m for an average of only 17% of the concrete surface area of the structure. The major disadvantage of this repair system is that the remaining unrepaired sections of the structure will continue to corrode and spall, requiring ongoing repairs, budgeted in this report in the order of $2.2m on a rolling 5 yearly interval.

Realkalization trial repairs proved effective in areas but insufficient levels of realkalization were achieved in some locations. Reasons of this variability have been proposed in the report and further trialling may conclude that the system could be utilized as the major repair system for the Aqueduct. The system requires all spalling and delaminated concrete to be repaired (surface based patch repair) prior to applying the realkalization treatment. The budget for the realkalization based repair totals $13.5m (all concrete areas excluding ovoid pipe) with a further provision for future repairs of $2.0m on a 10 year rolling interval.

Cathodic Protection (CP) based repairs proved effective with the trial repairs meeting Australian and International criteria for the corrosion protection of the reinforcement. The surface based concrete repairs (similar to repairs for realkalization) are required prior to installing titanium ribbon surface anodes, but if the internal anodes are utilized (for major chords and other large elements) some of the concrete repairs could be staged over an extended period. (Staging has not been considered in the budget). The budget developed for the CP based repairs totals $13.3m (all concrete areas excluding ovoid pipe) with an additional estimate of Monitoring the CP at $18K pa plus $20K pa for maintenance of the system.

5. Recommendation

Based on the investigation and trial works undertaken, we recommend the **Cathodic Protection** based repair as the preferred and most economical repair method for the Aqueduct Structure. The CP based approach could be utilized in a staged manner, with repair to one tower or all towers progressively. There is also the possibility of installing the CP systems initially and delaying some of the concrete repairs to future years.

The ovoid pipe has not been included in the repair budget using CP at this stage. The pipe is in relatively good condition compared to the rest of the Aqueduct structure and the large scale CP based protection of the pipe may not be warranted. We recommend some further investigation of the ovoid pipe, combined with some trial repairs using various CP or realkalization techniques before finally recommending the preferred repair and protection system for this element.

If there are significant delays in undertaking Catholic Protection and repairs, propping the ends of the tower spans to reduce the dead load on these critical elements is recommended. The system of propping would need to be designed by a structural engineer.

Appendix A
Investigation and Trial Results

FORCE Technology GalvaPulse

Aqua zone B

Ag/Cl calibrated to CuCuSO4 70 mV

Potential in mV

Y/X	0	250	500	750	1000
500	-282	-284	-310	-296	-309
250	-208	-280	-336	-314	-335
0	-243	-311	-333	-335	-361

Resistance in kohm

Y/X	0	250	500	750	1000
500	14	8	8	6	7
250	3	4	2	2	3
0	6	4	3	4	3

FORCE Technology GalvaPulse

Aqua B

Potential in mV to AgCL electrode

Y/X	1	2	3	4
1	-258	-266	-257	-259

Corrosion Current in uA/cm2 without guard ring

Y/X	1	2	3	4
1	17.5298	9.8193	8.3185	7.9455

Resistance in kohm

Y/X	1	2	3	4
1	4	3	3	2

FORCE Technology GalvaPulse

Aqua Zone C

AgCl electrode calibrated to CSE 70 mV

Potential in mV

Y/X	0	250	500	750	1000
500	-287	-296	-289	-261	-272
250	-272	-305	-287	-284	-279
0	-253	-292	-272	-274	-272

Resistance in kohm

Y/X	0	250	500	750	1000
500	1	0	0	1	3
250	7	0	0	1	2
0	9	0	0	0	1

Spacing 250mm

FORCE Technology GalvaPulse

Aqua C

Potential in mV to AgCL electrode

Y/X	1
2	-206
1	-195

Corrosion Current in uA/cm2 without guard ring

Y/X	1
2	23.9038
1	47.7746

Resistance in kohm

Y/X	1
2	1
1	2

FORCE Technology GalvaPulse

Aqua zone D

AgCl electrode calibrated to CSE 70 mV

Potential in mV

Y/X	0	250	500	750
500	-400	-414	-370	-336
250	-314	-311	-343	-276
0	-276	-285	-291	-274

Resistance in kohm

Y/X	0	250	500	750
500	1	9	2	4
250	0	0	1	2
0	0	0	1	1

agcl 70mV

FORCE Technology GalvaPulse

Aqua D

Potential in mV to AgCL electrode

Y/X	1
1	-241

Corrosion Current in uA/cm2 without guard ring

Y/X	1
1	32.4003

Resistance in kohm

Y/X	1
1	2

Realkalisation trial applied currents

Circuit ID:		A		C		D	
Location:		Lower cord southern end		Lower cord near tower		On vertical stay	
Area (m^2)							
Circuit cabling :		Structure steel	Anode	Structure steel	Anode	Structure steel	Anode
Cable colour:		Brown	Orange	Pink	Blue	Pink	Purple

Realkalisation outputs

Date	Time	Current (Amps)	Charge (A-hrs)	Current (Amps)	Charge (A-hrs)	Current (Amps)	Charge (A-hrs)
26/02/2009	8:30	0.121		0.526		0.22	
27/02/2009	9:00	0.092	2.208	0.401	9.624	0.164	3.936
27/02/2009	16:00	0.224		0.976		0.4	
28/02/2009	8:30	0.05		0.17		0.031	
28/02/2009	13:00	0.304	7.296	1.034	24.816	0.188	4.512
1/03/2009	10:00	0.04		0.136		0.025	
1/03/2009	11:00	0.3	7.2	1.023	24.552	0.186	4.464
3/03/2009	10:30	0.3	14.4	0.96	46.08	0.221	10.608
4/03/2009	12:00	0.25	6	0.855	20.52	0.156	3.744
5/03/2009	10:00	0.371	8.904	1.6	38.4	0.105	2.52
6/03/2009	Realkalisation off on arrival, system repaired and re-energised						
7/03/2009		0.374	8.976	1.43	34.32	0.143	3.432
8/03/2009		0.432	10.368	1.64	39.36	0.164	3.936
9/03/2009		0.402	9.648	1.5	36	0.155	3.72
Treatment Amp Hour			75		274		41
10/03/2009	Realkalisation system de-energised						

Cathodic protection trials results

Circuit ID:	B	E
Location:	Lower Chord	Vertical Stay
		

Anode current injection tests

Circuit ID:	B			E		
Location:	Lower Chord			Vertical Stay		
Applied voltage:	6.3 volts			6.3 volts		
	Anode ID	Current (mA)	Comments	Anode ID	Current (mA)	Comments
	A1	5.2	Pass	Strip	30	Pass
	A2	2300	Fail			
	A3	6.7	Pass			
	A4	7.8	Pass			
	A5	5.6	Pass			
	A6	12	Pass			

Cathodic protection potentials

Base/Native potentials			-374			-225
Circuit ID	B			E		
Circuit cabling :	Structure steel	Anode	Reference Electrode	Structure steel	Anode	Reference Electrode
Cable colour:	Black	White	Red	Green	Blue	Lt Blue
Results	ON Potential (mV)	Instant Off Potential (MV)	Applied Current (mA)	ON Potential (mV)	Instant Off Potential (MV)	Applied Current (mA)
25/02/2009	-570		21	-390		10
26/02/2009	-610		18	-424		6
27/02/2009	-572	-490	18	-468	-293	12
1/03/2009	-538	-482	12.5	-429	-295	5
2/03/2009	-538	-490	13.5	-461	-329	6
3/03/2009	-547	-500	14	-493	-355	7
4/03/2009	-527	-461	12 adjusted to 16	-439	-241	4 adjusted to 8
5/03/2009	-589	-514	15	-498	-270	7
6/03/2009	Cathodic protection off on arrival, system repaired & restored.					
7/03/2009	-574	-520	16	-508	-332	8
8/03/2009	-554	-506	15	-473	-300	8
9/03/2009	-591	-513	16	-574	-332	8
10/03/2009	-526	-462	17	-653	-326	8
7/04/2009	-612	-547	17	-797	-586	7
8/04/2009		-461			-422	
24 hour decay		86			164	
15/05/2009	-579	-538	10	-794	-626	6.5
16/05/2009		-478	reset to 18		-493	reset to 8
24 hour decay		60			133	
5/06/2009	-924	-707	17	-971	-718	7
5/06/2009		-603			-608	
4 hour decay		104			110	

Appendix B
Visual Assessment

GEELONG AND DISTRICT WATER BOARD
OVOID SEWER BRIDGE

TOWER No. 1

Element Description	Condition Rating (Code)	Damage Rating (% Surface Area)	Member Area (m2)	Extent of Defects (m2)	Cost Estimate ($)	Remarks
TOP CHORD N.E.	3	70	30.00	15.00		
BOTTOM CHORD N.E.	3	20	31.00	7.00		
0-0' N.E.	1	10	14.40	2.00		
1-1' N.E.	0	0	2.90	0.00		
2-2' N.E.	0	0	2.60	0.00		
3-3' N.E.	1	10	2.10	0.20		
4-4' N.E.	1	10	1.70	0.20		
5-5' N.E.	0	0	1.30	0.00		
6-6' N.E.	1	10	1.00	0.20		
0-1' N.E.	1	10	46.00	0.50		
1-2' N.E.	0	0	3.70	0.00		
2-3' N.E.	3	15	3.10	0.70		
3-4' N.E.	1	10	2.50	0.60		
4-5' N.E.	3	35	2.10	0.70		
5-6' N.E.	0	0	1.80	0.00		
TOP CHORD S.E.	1	10	30.00	2.00		
BOTTOM CHORD S.E.	3	15	31.00	3.00		
0-0' S.E.	0	0	14.40	0.00		
1-1' S.E.	0	0	2.90	0.00		
2-2' S.E.	0	0	2.60	0.00		
3-3' S.E.	0	0	2.10	0.00		
4-4' S.E.	0	0	1.70	0.00		
5-5' S.E.	0	0	1.30	0.00		
6-6' S.E.	0	0	1.00	0.00		
0-1' S.E.	0	0	4.60	0.00		
1-2' S.E.	0	0	3.70	0.00		
2-3' S.E.	0	0	3.10	0.00		
3-4' S.E.	0	0	2.50	0.00		
4-5' S.E.	0	0	2.10	0.00		
5-6' S.E.	2	25	1.80	0.50		
TOP CHORD N.W.						
BOTTOM CHORD N.W.						
0-0' N.W.						
1-1' N.W.						
2-2' N.W.						
3-3' N.W.						
4-4' N.W.						
5-5' N.W.						
6-6' N.W.						
0-1' N.W.						
1-2' N.W.						
2-3' N.W.						
3-4' N.W.						
4-5' N.W.						
5-6' N.W.						
TOP CHORD S.W.						
BOTTOM CHORD S.W.						
0-0' S.W.						
1-1' S.W.						
2-2' S.W.						
3-3' S.W.						
4-4' S.W.						
5-5' S.W.						
6-6' S.W.						
0-1' S.W.						
1-2' S.W.						
2-3' S.W.						
3-4' S.W.						
4-5' S.W.						

GEELONG AND DISTRICT WATER BOARD
OVOID SEWER BRIDGE

TOWER No. 1

Element Description	Condition Rating (Code)	Damage Rating (% Surface Area)	Member Area (m2)	Extent of Defects (m2)	Cost Estimate ($)	Remarks
5-6' S.W.						
N1-1						
N2-2						
S1-1						
S2-2						
TOWER TOP (WALLS)	3	20	31.00	5.00		
TOWER TOP (SOFFIT)	3	30	11.40	2.00		
TOWER BASE	3	30	53.90	3.00		
EXPANSION JOINT						
WALKWAY SOFFIT			98.80	90.00		
WALKWAY : 0-10m	1/0/2/0	75/0/20/0	20/36/14/18	2.00		
:10-20m	1/0/0/0	40/0/0/0	20/36/14/18	2.00		
:20-30m	1/0/0/1	50/0/0/5	20/36/14/18	1.00		
:30-40m	1/0/2/1	10/0/40/20	20/36/14/18	1.00		
:40-50m	1/1/1/1	10/20/25/20	20/36/14/18	1.00		
PIPE SUPPORT BRACK:						
1	3		5.31			
2	1		5.31			
3	3		5.31			
4	2		5.31			
5	3		5.58			
6	3		5.58			
7	2		8.33			
8	2		8.33			
9	3		8.33			
10	2		8.78			
11	3		9.33			
12	3		7.25			
13	2		7.25			
14	2		9.33			
15	3		8.78			
16	3		8.33			
17	2		8.33			
18	2		8.33			
19	3		5.58			
20	4		5.58			
21	3		5.31			
22	3		5.31			
SEWER PIPE						
				TOTAL	0	

GEELONG AND DISTRICT WATER BOARD
OVOID SEWER BRIDGE

TOWER No. 2

Element Description	Condition Rating (Code)	Damage Rating (% Surface Area)	Member Area (m2)	Extent of Defects (m2)	Cost Estimate ($)	Remarks
TOP CHORD N.E.	1	25	30.00	2.25		
BOTTOM CHORD N.E.	1	50	31.00	4.65		
0-0' N.E.	1RM3	50	14.40	1.44		
1-1' N.E.	1/RM	25	2.90	0.15		
2-2' N.E.	3	75	2.60	0.39		
3-3' N.E.	3	100	2.10	0.42		
4-4' N.E.	2	75	1.70	0.26		
5-5' N.E.	0	50	1.30	0.13		
6-6' N.E.	R0	0	1.00	0.00		
0-1' N.E.						
1-2' N.E.						
2-3' N.E.						
3-4' N.E.						
4-5' N.E.						
5-6' N.E.						
TOP CHORD S.E.	4	75	30.00	6.75		
BOTTOM CHORD S.E.	3	100	31.00	9.30		
0-0' S.E.	3RM3	20	14.40	0.58		
1-1' S.E.	R0	0	2.90	0.00		
2-2' S.E.	R0	0	2.60	0.00		
3-3' S.E.	R0	0	2.10	0.00		
4-4' S.E.	R0	0	1.70	0.00		
5-5' S.E.	R0	0	1.30	0.00		
6-6' S.E.	R0	0	1.00	0.00		
0-1' S.E.	R0	0	4.60	0.00		
1-2' S.E.	R0	0	3.70	0.00		
2-3' S.E.	R0	0	3.10	0.00		
3-4' S.E.	R0	0	2.50	0.00		
4-5' S.E.	R0	0	2.10	0.00		
5-6' S.E.	R0	0	1.80	0.00		
TOP CHORD N.W.	2	100	30.00	9.00		
BOTTOM CHORD N.W.	3	5	31.00	0.46		
0-0' N.W.	R0	0	14.40	0.00		
1-1' N.W.	R0	0	2.90	0.00		
2-2' N.W.	R0	0	2.60	0.00		
3-3' N.W.	R0	0	2.10	0.00		
4-4' N.W.	R0	0	1.70	0.00		
5-5' N.W.	R0	0	1.30	0.00		
6-6' N.W.	R0	0	1.00	0.00		
0-1' N.W.	R0	20	4.60	0.14		
1-2' N.W.	R0	0	3.70	0.00		
2-3' N.W.	R0	0	3.10	0.00		
3-4' N.W.	R0	0	2.50	0.00		
4-5' N.W.	R0	0	2.10	0.00		
5-6' N.W.	R0	0	1.80	0.00		
TOP CHORD S.W.	1	30	30.00	2.70		
BOTTOM CHORD S.W.	3	20	31.00	1.86		
0-0' S.W.	3	20	14.40	0.58		
1-1' S.W.	R0	0	2.90	0.00		
2-2' S.W.	R0	0	2.60	0.00		
3-3' S.W.	R0	0	2.10	0.00		
4-4' S.W.	R0	0	1.70	0.00		
5-5' S.W.	R0	0	1.30	0.00		
6-6' S.W.	R0	0	1.00	0.00		
0-1' S.W.	R0	0	4.60	0.00		
1-2' S.W.	R0	0	3.70	0.00		
2-3' S.W.	R0	0	3.10	0.00		
3-4' S.W.	R0	0	2.50	0.00		
4-5' S.W.	R0	0	2.10	0.00		

GEELONG AND DISTRICT WATER BOARD
OVOID SEWER BRIDGE

TOWER No. 2

Element Description	Condition Rating (Code)	Damage Rating (% Surface Area)	Member Area (m2)	Extent of Defects (m2)	Cost Estimate ($)	Remarks
5-6' S.W.	R0	0	1.80	0.00		
N1-1						
N2-2						
S1-1						
S2-2						
TOWER TOP (WALLS)	3	20	31.00	3.00		
TOWER TOP (SOFFIT)	3	30	11.40	4.00		
TOWER BASE	3	20	53.90	3.00		
EXPANSION JOINT	3	100				
WALKWAY SOFFIT	3	75	98.80	70.00		
WALKWAY :50-60m	1/0/1/1	40/0/20/30	20/36/14/18	2.00		
:60-70m	3/0/0/1	60/0/0/5	20/36/14/18	2.00		
:70-80m	3/2/1/1	20/10/10/50	20/36/14/18	2.00		
:80-90m	1/0/0/1	20/0/0/30	20/36/14/18	2.00		
:90-100m	1/1/0/1	30/20/0/20	20/36/14/18	2.00		
:100-110m	2/1/1/1	25/10/20/10	20/36/14/18	2.00		
PIPE SUPPORT BRACK:						
23	3	75	5.31	0.32		
24	2	75	5.31	0.32		
25	4	100	5.31	0.42		
26	3	100	5.31	0.42		
27	3	75	5.58	0.33		
28	3	75	5.58	0.33		
29	3	80	8.33	0.53		
30	2	50	8.33	0.33		
31	4	100	8.33	0.67		
32	2	25	8.78	0.18		
33	2	25	9.33	0.19		
34	0	-	7.25	0.00		
35	1	25	7.25	0.15		
36	3	75	9.33	0.56		
37	4	100	8.78	0.70		
38	3	100	8.33	0.67		
39	3	100	8.33	0.67		
40	3	50	8.33	0.33		
41	4	100	5.58	0.45		
42	3	75	5.58	0.33		
43	3	75	5.31	0.32		
44	2	25	5.31	0.11		
SEWER PIPE						
				TOTAL	0	

otal from 1991 hardcopy but all figures match in the cost estimate column therefore the totals on the hardcopy must be incorrect or approximate

GEELONG AND DISTRICT WATER BOARD
OVOID SEWER BRIDGE

TOWER No. 3

Element Description	Condition Rating (Code)	Damage Rating (% Surface Area)	Member Area (m2)	Extent of Defects (m2)	Cost Estimate ($)	Remarks
TOP CHORD N.E.	3	40	30.00	6.00		
BOTTOM CHORD N.E.	4	30	31.00	5.00		
0-0' N.E.	3	40	14.40	3.00		
1-1' N.E.	3	20	2.90	1.50		
2-2' N.E.	3	50	2.60	2.00		
3-3' N.E.	1	10	2.10	0.50		
4-4' N.E.	3	30	1.70	1.50		
5-5' N.E.	1	-	1.30	-		
6-6' N.E.	0	-	1.00	-		
0-1' N.E.	R0		4.60			
1-2' N.E.	1		3.70			
2-3' N.E.	R0		3.10			
3-4' N.E.	R0		2.50			
4-5' N.E.	R0		2.10			
5-6' N.E.	3	20	1.80	0.50		
TOP CHORD S.E.	2	50	30.00	6.00		
BOTTOM CHORD S.E.	3	25	31.00	4.00		
0-0' S.E.	4	80	14.40	8.00		
1-1' S.E.	3	20	2.90	1.00		
2-2' S.E.	3	30	2.60	1.50		
3-3' S.E.	0	50	2.10	0.21		
4-4' S.E.	3	10	1.70	1.00		
5-5' S.E.	3	20	1.30	1.00		
6-6' S.E.	1	-	1.00	-		
0-1' S.E.	3	20	4.60	0.50		
1-2' S.E.	0	0	3.70	0.00		
2-3' S.E.	3	25	3.10	1.00		
3-4' S.E.	3	5	2.50	0.50		
4-5' S.E.	3	10	2.10	0.00		
5-6' S.E.	2	10	1.80	0.00		
TOP CHORD N.W.						
BOTTOM CHORD N.W.						
0-0' N.W.						
1-1' N.W.						
2-2' N.W.						
3-3' N.W.						
4-4' N.W.						
5-5' N.W.						
6-6' N.W.						
0-1' N.W.						
1-2' N.W.						
2-3' N.W.						
3-4' N.W.						
4-5' N.W.						
5-6' N.W.						
TOP CHORD S.W.						
BOTTOM CHORD S.W.						
0-0' S.W.						
1-1' S.W.						
2-2' S.W.						
3-3' S.W.						
4-4' S.W.						
5-5' S.W.						
6-6' S.W.						
0-1' S.W.						
1-2' S.W.						
2-3' S.W.						
3-4' S.W.						
4-5' S.W.						

GEELONG AND DISTRICT WATER BOARD
OVOID SEWER BRIDGE

TOWER No. 3

Element Description	Condition Rating (Code)	Damage Rating (% Surface Area)	Member Area (m2)	Extent of Defects (m2)	Cost Estimate ($)	Remarks
5-6' S.W.						
N1-1						
N2-2						
S1-1						
S2-2						
TOWER TOP (WALLS)	3	60	31.00	10.00		
TOWER TOP (SOFFIT)	3	40	11.40	5.00		
TOWER BASE	3	10	53.90	2.00		
EXPANSION JOINT	-	20				
WALKWAY SOFFIT	3	25	98.80	5.00		
WALKWAY : 110-120m	3/0/2/1	100/0/50/5	20/36/14/18			
:120-130m	3/1/3/1	100/30/75/10	20/36/14/18			
:130-140m	1/3/1/1	20/75/20/15	20/36/14/18			
:140-150m	1/3/1/1	25/80/20/20	20/36/14/18			
:150-160m	1/3/1/1	20/75/25/20	20/36/14/18			
PIPE SUPPORT BRACK:						
45	3	25	0.11	0.11		
46	3	50	0.21	0.21		
47	4	75	0.32	0.32		
48	4	100	0.45	0.45		
49	4	100	0.45	0.45		
50	4	100	0.67	0.97		
51	3	50	0.33	0.33		
52	3	75	0.50	0.50		
53	3	25	0.18	0.18		
54	4	75	0.56	0.56		
55	4	50	0.29	0.29		
56	3	50	0.29	0.29		
57	3	50	0.37	0.37		
58	3	75	0.53	0.53		
59	4	75	0.50	0.50		
60	2	50	0.33	0.33		
61	4	100	0.67	0.67		
62	4	75	0.33	0.33		
63	4	50	0.22	0.22		
64	3	75	0.32	0.32		
65	3	80	0.34	0.34		
66	3	50	0.21	0.21		
SEWER PIPE						
				TOTAL		

GEELONG AND DISTRICT WATER BOARD
OVOID SEWER BRIDGE

TOWER No. 7

Element Description	Condition Rating (Code)	Damage Rating (% Surface Area)	Member Area (m2)	Extent of Defects (m2)	Cost Estimate ($)	Remarks
TOP CHORD N.E.	2	15	30.00	3.00		
BOTTOM CHORD N.E.	3	20	31.00	3.00		
0-0' N.E.	4	60	14.40	7.00		
1-1' N.E.	-		2.90	-		
2-2' N.E.	1		2.60	-		
3-3' N.E.	3		2.10	1.00		
4-4' N.E.	0		1.70	-		
5-5' N.E.	0		1.30	-		
6-6' N.E.	0		1.00	-		
0-1' N.E.	3		4.60	1.00		
1-2' N.E.	0		3.70	-		
2-3' N.E.	3	10	3.10	0.50		
3-4' N.E.	3	10	2.50	0.50		
4-5' N.E.	1		2.10	-		
5-6' N.E.	0		1.80	-		
TOP CHORD S.E.	3	20	30.00	5.00		
BOTTOM CHORD S.E.	3	25	31.00	10.00		
0-0' S.E.	3	60	14.40	6.00		
1-1' S.E.	1		2.90	-		
2-2' S.E.	0/R0		2.60	-		
3-3' S.E.	1		2.10	-		
4-4' S.E.	1		1.70	0.50		
5-5' S.E.	2		1.30	0.50		
6-6' S.E.	2-3		1.00	0.50		
0-1' S.E.	3	25	4.60	2.00		
1-2' S.E.	3		3.70	2.00		
2-3' S.E.	3		3.10	0.25		
3-4' S.E.	-		2.50	-		
4-5' S.E.	-		2.10	-		
5-6' S.E.	-		1.80	-		
TOP CHORD N.W.						
BOTTOM CHORD N.W.						
0-0' N.W.						
1-1' N.W.						
2-2' N.W.						
3-3' N.W.						
4-4' N.W.						
5-5' N.W.						
6-6' N.W.						
0-1' N.W.						
1-2' N.W.						
2-3' N.W.						
3-4' N.W.						
4-5' N.W.						
5-6' N.W.						
TOP CHORD S.W.						
BOTTOM CHORD S.W.						
0-0' S.W.						
1-1' S.W.						
2-2' S.W.						
3-3' S.W.						
4-4' S.W.						
5-5' S.W.						
6-6' S.W.						
0-1' S.W.						
1-2' S.W.						
2-3' S.W.						
3-4' S.W.						
4-5' S.W.						

GEELONG AND DISTRICT WATER BOARD
OVOID SEWER BRIDGE

TOWER No. 7

Element Description	Condition Rating (Code)	Damage Rating (% Surface Area)	Member Area (m2)	Extent of Defects (m2)	Cost Estimate ($)	Remarks
5-6' S.W.						
N1-1						
N2-2						
S1-1						
S2-2						
TOWER TOP (WALLS)	3	40	31.00	10.00		
TOWER TOP (SOFFIT)	4	100	11.40	10.00		
TOWER BASE	3	5	53.90	2.00		
EXPANSION JOINT	1	20				
WALKWAY SOFFIT	4	80	98.80	50.00		
WALKWAY : 330-340m	1/0/2/1	60/0/50/50	20/36/14/18	2.10		50%-70%
:340-350m	1/3/3/1	30/75/80/10	20/36/14/18	3.45		
:350-360m	0/3/2/1	20/75/25/20	20/36/14/18	2.86		
:360-370m	1/3/3/1	50/75/80/20	20/36/14/18	3.89		
:370-380m	2/3/3/1	70/40/80/30	20/36/14/18	3.38		
PIPE SUPPORT BRACK:						
133	3	75	5.31	0.32		
134	0	0	5.31	0.00		
135	4	100	5.31	0.42		
136	3	50	5.58	0.22		
137	3	75	5.58	0.33		
138	2	50	8.33	0.33		
139	1	25	8.33	0.17		
140	0	0	8.33	1.00		
141	3	75	8.78	0.53		
142	3	75	9.33	0.56		
143	2	25	7.25	0.15		
144	3	50	7.25	0.29		
145	3	75	9.33	0.56		
146	1	25	8.78	0.18		
147	1	25	8.33	0.17		
148	3	50	8.33	0.33		
149	2	50	8.33	0.33		
150	2	50	5.58	0.22		
151	0	0	5.58	0.00		
152	3	75	5.31	0.32		
153	3	25	5.31	0.11		
154	2	25	5.31	0.11		
SEWER PIPE	4	35	216.00	3.78		
				TOTAL		

GEELONG AND DISTRICT WATER BOARD
OVOID SEWER BRIDGE

TOWER No. 8

Element Description	Condition Rating (Code)	Damage Rating (% Surface Area)	Member Area (m2)	Extent of Defects (m2)	Cost Estimate ($)	Remarks
TOP CHORD N.E.	1	12	30.00	3.00	1530	
BOTTOM CHORD N.E.	1	5	31.00	1.50	0	
0-0' N.E.	3	25	14.40	2.00	7344	
1-1' N.E.	3	25	2.90	1.00	500	
2-2' N.E.	1	0	2.60	-	500	
3-3' N.E.	0	0	2.10	-	0	
4-4' N.E.	0	0	1.70	-	500	
5-5' N.E.	RM0	10	1.30	0.50	0	
6-6' N.E.	4	100	1.00	1.00	680	
0-1' N.E.	3	25	4.60	1.00	587	
1-2' N.E.	3	10	3.70	0.50	500	
2-3' N.E.	0	0	3.10	-	0	
3-4' N.E.	1	0	2.50	-	500	
4-5' N.E.	1	5	2.10	0.50	500	
5-6' N.E.	1	5	1.80	1.00	0	
TOP CHORD S.E.	1	15	30.00	1.00	0	
BOTTOM CHORD S.E.	3	20	31.00	4.00	0	
0-0' S.E.	3	20	14.40	3.00	4896	
1-1' S.E.	1	5	2.90	0.50	500	
2-2' S.E.	1	5	2.60	0.50	707	
3-3' S.E.	1	5	2.10	0.20	500	
4-4' S.E.	0	-	1.70	-	0	
5-5' S.E.	0	-	1.30	-	0	
6-6' S.E.	0	-	1.00	-	0	
0-1' S.E.	0	-	4.60	-	500	
1-2' S.E.	0	-	3.70	-	500	
2-3' S.E.	1	-	3.10	-	500	
3-4' S.E.	1	-	2.50	-	500	
4-5' S.E.	3		2.10	0.50	0	
5-6' S.E.	0		1.80	-	0	
TOP CHORD N.W.			30.00			
BOTTOM CHORD N.W.			31.00			
0-0' N.W.			14.40			
1-1' N.W.			2.90			
2-2' N.W.			2.60			
3-3' N.W.			2.10			
4-4' N.W.			1.70			
5-5' N.W.			1.30			
6-6' N.W.			1.00			
0-1' N.W.			4.60			
1-2' N.W.			3.70			
2-3' N.W.			3.10			
3-4' N.W.			2.50			
4-5' N.W.			2.10			
5-6' N.W.			1.80			
TOP CHORD S.W.			30.00			
BOTTOM CHORD S.W.			31.00			
0-0' S.W.			14.40			
1-1' S.W.			2.90			
2-2' S.W.			2.60			
3-3' S.W.			2.10			
4-4' S.W.			1.70			
5-5' S.W.			1.30			
6-6' S.W.			1.00			
0-1' S.W.			4.60			
1-2' S.W.			3.70			
2-3' S.W.			3.10			
3-4' S.W.			2.50			
4-5' S.W.			2.10			

GEELONG AND DISTRICT WATER BOARD
OVOID SEWER BRIDGE

TOWER No. 8

Element Description	Condition Rating (Code)	Damage Rating (% Surface Area)	Member Area (m2)	Extent of Defects (m2)	Cost Estimate ($)	Remarks
5-6' S.W.			1.80			
N1-1			6.28			
N2-2			6.28			
S1-1			6.28			
S2-2			6.28			
TOWER TOP (WALLS)			31.00			
TOWER TOP (SOFFIT)			11.40			
TOWER BASE			53.90			
EXPANSION JOINT						
WALKWAY SOFFIT			98.80			
WALKWAY : 380-390m			20/36/14/18			
:390-400m			20/36/14/18			
:400-410m			20/36/14/18			
:410-420m			20/36/14/18			
:420-430m			20/36/14/18			
:430-440m			20/36/14/18			
PIPE SUPPORT BRACK:						
155	3		5.31			
156	3		5.31			
157	2		5.31			
158	2		5.58			
159	1		5.58			
160	1		8.33			
161	3		8.33			
162	3		8.33			
163	0		8.78			
164	3		9.33			
165	3		7.25			
166	3		7.25			
167	3		9.33			
168	3R0		8.78			
169	2		8.33			
170	1		8.33			
171	1		8.33			
172	1		5.58			
173	3		5.58			
174	2		5.31			
175	2		5.31			
176	3		5.31			
SEWER PIPE			216.00			
				TOTAL		

GEELONG AND DISTRICT WATER BOARD
OVOID SEWER BRIDGE

TOWER No. 9

Element Description	Condition Rating (Code)	Damage Rating (% Surface Area)	Member Area (m2)	Extent of Defects (m2)	Cost Estimate ($)	Remarks
TOP CHORD N.E.	3	20	30.00	3.00		
BOTTOM CHORD N.E.	3	15	31.00	3.00		
0-0' N.E.	3	20	14.40	2.00		
1-1' N.E.	R0	25	2.90	-		
2-2' N.E.	3	30	2.60	1.00		
3-3' N.E.	3	30	2.10	2.00		
4-4' N.E.	3	20	1.70	2.00		
5-5' N.E.	0	-	1.30	-		
6-6' N.E.	3R	10	1.00	0.50		
0-1' N.E.	3	10	4.60	0.50		
1-2' N.E.	1	10	3.70	0.50		
2-3' N.E.	0	-	3.10	-		
3-4' N.E.	3	20	2.50	1.50		
4-5' N.E.	3	30	2.10	1.50		
5-6' N.E.	1	5	1.80	-		
TOP CHORD S.E.			30.00			
BOTTOM CHORD S.E.			31.00			
0-0' S.E.			14.40			
1-1' S.E.			2.90			
2-2' S.E.			2.60			
3-3' S.E.			2.10			
4-4' S.E.			1.70			
5-5' S.E.			1.30			
6-6' S.E.			1.00			
0-1' S.E.			4.60			
1-2' S.E.			3.70			
2-3' S.E.			3.10			
3-4' S.E.			2.50			
4-5' S.E.			2.10			
5-6' S.E.			1.80			
TOP CHORD N.W.			30.00			
BOTTOM CHORD N.W.			31.00			
0-0' N.W.			14.40			
1-1' N.W.			2.90			
2-2' N.W.			2.60			
3-3' N.W.			2.10			
4-4' N.W.			1.70			
5-5' N.W.			1.30			
6-6' N.W.			1.00			
0-1' N.W.			4.60			
1-2' N.W.			3.70			
2-3' N.W.			3.10			
3-4' N.W.			2.50			
4-5' N.W.			2.10			
5-6' N.W.			1.80			
TOP CHORD S.W.			30.00			
BOTTOM CHORD S.W.			31.00			
0-0' S.W.			14.40			
1-1' S.W.			2.90			
2-2' S.W.			2.60			
3-3' S.W.			2.10			
4-4' S.W.			1.70			
5-5' S.W.			1.30			
6-6' S.W.			1.00			
0-1' S.W.			4.60			
1-2' S.W.			3.70			
2-3' S.W.			3.10			
3-4' S.W.			2.50			
4-5' S.W.			2.10			

GEELONG AND DISTRICT WATER BOARD
OVOID SEWER BRIDGE

TOWER No. 9

Element Description	Condition Rating (Code)	Damage Rating (% Surface Area)	Member Area (m2)	Extent of Defects (m2)	Cost Estimate ($)	Remarks
5-6' S.W.			1.80			
N1-1			6.28			
N2-2			6.28			
S1-1			6.28			
S2-2			6.28			
TOWER TOP (WALLS)			31.00			
TOWER TOP (SOFFIT)			11.40			
TOWER BASE			53.90			
EXPANSION JOINT						
WALKWAY SOFFIT			98.80			
WALKWAY :440-450m			20/36/14/18			
:450-460m			20/36/14/18			
:460-470m			20/36/14/18			
:470-480m			20/36/14/18			
:480-490m			20/36/14/18			
PIPE SUPPORT BRACK:						
177	4		5.31			
178	3		5.31			
179	2		5.31			
180	2		5.58			
181	2		5.58			
182	1		8.33			
183	1		8.33			
184	3		8.33			
185			8.78			
186			9.33			
187			7.25			
188			7.25			
189			9.33			
190			8.78			
191			8.33			
192			8.33			
193			8.33			
194			5.58			
195			5.58			
196			5.31			
197			5.31			
198			5.31			
SEWER PIPE			216.00			
				TOTAL		

Appendix B1
Repair Budgets

GEELONG AND DISTRICT WATER BOARD
OVOID SEWER BRIDGE

TOWER No. 2

Element Description	Condition Rating (Code)	Damage Rating (% Surface Area)	Member Area (m2)	Extent of Defects (m2)	Cost Estimate ($)	Remarks
TOP CHORD N.E.	1	25	30.00	2.50	3750	
BOTTOM CHORD N.E.	1	50	31.00	4.65	6975	
0-0' N.E.	1RM3	50	14.40	2.00	3000	
1-1' N.E.	1/RM	25	2.90	1.00	1500	
2-2' N.E.	3	75	2.60	2.00	3000	
3-3' N.E.	3	100	2.10	2.00	3000	
4-4' N.E.	2	75	1.70	2.00	3000	
5-5' N.E.	0	50	1.30	0.13	195	
6-6' N.E.	R0	0	1.00	0.00	0	
0-1' N.E.					0	
1-2' N.E.					0	
2-3' N.E.					0	
3-4' N.E.					0	
4-5' N.E.					0	
5-6' N.E.					0	
TOP CHORD S.E.	4	75	30.00	10.00	15000	
BOTTOM CHORD S.E.	3	100	31.00	5.00	7500	
0-0' S.E.	3RM3	20	14.40	1.00	1500	
1-1' S.E.	R0	0	2.90	0.00	0	
2-2' S.E.	R0	0	2.60	0.00	0	
3-3' S.E.	R0	0	2.10	0.00	0	
4-4' S.E.	R0	0	1.70	0.00	0	
5-5' S.E.	R0	0	1.30	0.00	0	
6-6' S.E.	R0	0	1.00	0.00	0	
0-1' S.E.	R0	0	4.60	0.00	0	
1-2' S.E.	R0	0	3.70	0.00	0	
2-3' S.E.	R0	0	3.10	0.00	0	
3-4' S.E.	R0	0	2.50	0.00	0	
4-5' S.E.	R0	0	2.10	0.00	0	
5-6' S.E.	R0	0	1.80	0.00	0	
TOP CHORD N.W.	2	100	30.00	10.00	15000	
BOTTOM CHORD N.W.	3	5	31.00	3.00	4500	
0-0' N.W.	R0	0	14.40	3.00	4500	
1-1' N.W.	R0	0	2.90	0.00	0	
2-2' N.W.	R0	0	2.60	0.00	0	
3-3' N.W.	R0	0	2.10	0.00	0	
4-4' N.W.	R0	0	1.70	0.00	0	
5-5' N.W.	R0	0	1.30	0.00	0	
6-6' N.W.	R0	0	1.00	0.00	0	
0-1' N.W.	R0	20	4.60	0.14	210	
1-2' N.W.	R0	0	3.70	0.00	0	
2-3' N.W.	R0	0	3.10	0.00	0	
3-4' N.W.	R0	0	2.50	0.00	0	
4-5' N.W.	R0	0	2.10	0.00	0	
5-6' N.W.	R0	0	1.80	0.00	0	
TOP CHORD S.W.	1	30	30.00	2.00	3000	
BOTTOM CHORD S.W.	3	20	31.00	2.00	3000	
0-0' S.W.	3	20	14.40	0.58	870	
1-1' S.W.	R0	0	2.90	0.00	0	
2-2' S.W.	R0	0	2.60	0.00	0	
3-3' S.W.	R0	0	2.10	0.00	0	
4-4' S.W.	R0	0	1.70	0.00	0	
5-5' S.W.	R0	0	1.30	0.00	0	
6-6' S.W.	R0	0	1.00	0.00	0	
0-1' S.W.	R0	0	4.60	0.00	0	
1-2' S.W.	R0	0	3.70	0.00	0	
2-3' S.W.	R0	0	3.10	0.00	0	
3-4' S.W.	R0	0	2.50	0.00	0	
4-5' S.W.	R0	0	2.10	0.00	0	

GEELONG AND DISTRICT WATER BOARD
OVOID SEWER BRIDGE

TOWER No. 2

Element Description	Condition Rating (Code)	Damage Rating (% Surface Area)	Member Area (m2)	Extent of Defects (m2)	Cost Estimate ($)	Remarks
5-6' S.W.	R0	0	1.80	0.00	0	
N1-1				2.00	3000	
N2-2				2.00	3000	
S1-1				2.00	3000	
S2-2				2.00	3000	
TOWER TOP (WALLS)	3	20	31.00	3.00	4500	
TOWER TOP (SOFFIT)	3	30	11.40	4.00	6000	
TOWER BASE	3	20	53.90	3.00	4500	
EXPANSION JOINT	3	100			0	
WALKWAY SOFFIT	3	75	98.80	70.00	105000	
WALKWAY :50-60m	1/0/1/1	40/0/20/30	20/36/14/18	2.00	3000	
:60-70m	3/0/0/1	60/0/0/5	20/36/14/18	2.00	3000	
:70-80m	3/2/1/1	20/10/10/50	20/36/14/18	2.00	3000	
:80-90m	1/0/0/1	20/0/0/30	20/36/14/18	2.00	3000	
:90-100m	1/1/0/1	30/20/0/20	20/36/14/18	2.00	3000	
:100-110m	2/1/1/1	25/10/20/10	20/36/14/18	2.00	3000	
PIPE SUPPORT BRACK:						
23	3	75	5.31	0.32	480	
24	2	75	5.31	0.32	480	
25	4	100	5.31	0.42	630	
26	3	100	5.31	0.42	630	
27	3	75	5.58	0.33	495	
28	3	75	5.58	0.33	495	
29	3	80	8.33	0.53	795	
30	2	50	8.33	0.33	495	
31	4	100	8.33	0.67	1005	
32	2	25	8.78	0.18	270	
33	2	25	9.33	0.19	285	
34	0	-	7.25	0.00	0	
35	1	25	7.25	0.15	225	
36	3	75	9.33	0.56	840	
37	4	100	8.78	0.70	1050	
38	3	100	8.33	0.67	1005	
39	3	100	8.33	0.67	1005	
40	3	50	8.33	0.33	495	
41	4	100	5.58	0.45	675	
42	3	75	5.58	0.33	495	
43	3	75	5.31	0.32	480	
44	2	25	5.31	0.11	165	
SEWER PIPE						
				TOTAL	241995	

. from 1991 hardcopy but all figures match in the cost estimate column therefore the totals on the hardcopy must be incorrect or approximate

GEELONG AND DISTRICT WATER BOARD
OVOID SEWER BRIDGE

TOWER No. 3

Element Description	Condition Rating (Code)	Damage Rating (% Surface Area)	Member Area (m2)	Extent of Defects (m2)	Cost Estimate ($)	Remarks
TOP CHORD N.E.	3	40	30.00	6.00	9000	
BOTTOM CHORD N.E.	4	30	31.00	5.00	7500	
0-0' N.E.	3	40	14.40	3.00	4500	
1-1' N.E.	3	20	2.90	1.50	2250	
2-2' N.E.	3	50	2.60	2.00	3000	
3-3' N.E.	1	10	2.10	0.50	750	
4-4' N.E.	3	30	1.70	1.50	2250	
5-5' N.E.	1	10	1.30	0.50	750	
6-6' N.E.	0	10	1.00	0.20	300	
0-1' N.E.	R0		4.60		0	
1-2' N.E.	1		3.70		0	
2-3' N.E.	R0		3.10		0	
3-4' N.E.	R0		2.50		0	
4-5' N.E.	R0		2.10		0	
5-6' N.E.	3	20	1.80	0.50	750	
TOP CHORD S.E.	2	50	30.00	6.00	9000	
BOTTOM CHORD S.E.	3	25	31.00	4.00	6000	
0-0' S.E.	4	80	14.40	8.00	12000	
1-1' S.E.	3	20	2.90	1.00	1500	
2-2' S.E.	3	30	2.60	1.50	2250	
3-3' S.E.	0	50	2.10	0.21	315	
4-4' S.E.	3	10	1.70	1.00	1500	
5-5' S.E.	3	20	1.30	1.00	1500	
6-6' S.E.	1	10	1.00	0.50	750	
0-1' S.E.	3	20	4.60	0.50	750	
1-2' S.E.	0	0	3.70	0.00	0	
2-3' S.E.	3	25	3.10	1.00	1500	
3-4' S.E.	3	5	2.50	0.50	750	
4-5' S.E.	3	10	2.10	0.00	0	
5-6' S.E.	2	10	1.80	0.00	0	
TOP CHORD N.W.		90	30.00	27.00	40500	
BOTTOM CHORD N.W.		6	31.00	1.86	2790	
0-0' N.W.		20	14.40	2.88	4320	
1-1' N.W.		75	2.90	2.18	3262.5	
2-2' N.W.		50	2.60	1.30	1950	
3-3' N.W.		50	2.10	1.05	1575	
4-4' N.W.		100	1.70	1.70	2550	
5-5' N.W.		0	1.30	0.00	0	
6-6' N.W.		100	1.00	1.00	1500	
0-1' N.W.		75	4.60	3.45	5175	
1-2' N.W.		60	3.70	2.22	3330	
2-3' N.W.		25	3.10	0.78	1162.5	
3-4' N.W.		25	2.50	0.63	937.5	
4-5' N.W.		75	2.10	1.58	2362.5	
5-6' N.W.		75	1.80	1.35	2025	
TOP CHORD S.W.		70	30.00	21.00	31500	
BOTTOM CHORD S.W.		30	31.00	9.30	13950	
0-0' S.W.		90	14.40	12.96	19440	
1-1' S.W.		30	2.90	0.87	1305	
2-2' S.W.		20	2.60	0.52	780	
3-3' S.W.		50	2.10	1.05	1575	
4-4' S.W.		20	1.70	0.34	510	
5-5' S.W.		100	1.30	1.30	1950	
6-6' S.W.		60	1.00	0.60	900	
0-1' S.W.		25	4.60	1.15	1725	
1-2' S.W.		30	3.70	1.11	1665	
2-3' S.W.		25	3.10	0.78	1162.5	
3-4' S.W.		50	2.50	1.25	1875	
4-5' S.W.		50	2.10	1.05	1575	

GEELONG AND DISTRICT WATER BOARD
OVOID SEWER BRIDGE

TOWER No. 3

Element Description	Condition Rating (Code)	Damage Rating (% Surface Area)	Member Area (m2)	Extent of Defects (m2)	Cost Estimate ($)	Remarks
5-6' S.W.		50	1.80	0.90	1350	
N1-1		50	6.28	3.14	4710	
N2-2		50	6.28	3.14	4710	
S1-1		50	6.28	3.14	4710	
S2-2		50	6.28	3.14	4710	
TOWER TOP (WALLS)	3	60	31.00	10.00	15000	
TOWER TOP (SOFFIT)	3	40	11.40	5.00	7500	
TOWER BASE	3	10	53.90	2.00	3000	
EXPANSION JOINT	-	20			0	
WALKWAY SOFFIT	3	25	98.80	5.00	7500	
WALKWAY : 110-120m	3/0/2/1	100/0/50/5	20/36/14/18	30.00	45000	All walkway
:120-130m	3/1/3/1	100/30/75/10	20/36/14/18	0.00	0	inc
:130-140m	1/3/1/1	20/75/20/15	20/36/14/18	0.00	0	inc
:140-150m	1/3/1/1	25/80/20/20	20/36/14/18	0.00	0	inc
:150-160m	1/3/1/1	20/75/25/20	20/36/14/18	0.00	0	inc
					0	
PIPE SUPPORT BRACK:					0	
45	3	25	0.11	0.11	165	
46	3	50	0.21	0.21	315	
47	4	75	0.32	0.32	480	
48	4	100	0.45	0.45	675	
49	4	100	0.45	0.45	675	
50	4	100	0.67	0.97	1455	
51	3	50	0.33	0.33	495	
52	3	75	0.50	0.50	750	
53	3	25	0.18	0.18	270	
54	4	75	0.56	0.56	840	
55	4	50	0.29	0.29	435	
56	3	50	0.29	0.29	435	
57	3	50	0.37	0.37	555	
58	3	75	0.53	0.53	795	
59	4	75	0.50	0.50	750	
60	2	50	0.33	0.33	495	
61	4	100	0.67	0.67	1005	
62	4	75	0.33	0.33	495	
63	4	50	0.22	0.22	330	
64	3	75	0.32	0.32	480	
65	3	80	0.34	0.34	510	
66	3	50	0.21	0.21	315	
SEWER PIPE						
				TOTAL	333127.5	

GEELONG AND DISTRICT WATER BOARD
OVOID SEWER BRIDGE

Tower Surface Area of Elements

Element Description	Member Area (m2)
TOP CHORD N.E.	30.00
BOTTOM CHORD N.E.	31.00
0-0' N.E.	14.40
1-1' N.E.	2.90
2-2' N.E.	2.60
3-3' N.E.	2.10
4-4' N.E.	1.70
5-5' N.E.	1.30
6-6' N.E.	1.00
0-1' N.E.	4.60
1-2' N.E.	3.70
2-3' N.E.	3.10
3-4' N.E.	2.50
4-5' N.E.	2.10
5-6' N.E.	1.80
TOP CHORD S.E.	30.00
BOTTOM CHORD S.E.	31.00
0-0' S.E.	14.40
1-1' S.E.	2.90
2-2' S.E.	2.60
3-3' S.E.	2.10
4-4' S.E.	1.70
5-5' S.E.	1.30
6-6' S.E.	1.00
0-1' S.E.	4.60
1-2' S.E.	3.70
2-3' S.E.	3.10
3-4' S.E.	2.50
4-5' S.E.	2.10
5-6' S.E.	1.80
TOP CHORD N.W.	30.00
BOTTOM CHORD N.W.	31.00
0-0' N.W.	14.40
1-1' N.W.	2.90
2-2' N.W.	2.60
3-3' N.W.	2.10
4-4' N.W.	1.70
5-5' N.W.	1.30
6-6' N.W.	1.00
0-1' N.W.	4.60
1-2' N.W.	3.70
2-3' N.W.	3.10
3-4' N.W.	2.50
4-5' N.W.	2.10
5-6' N.W.	1.80
TOP CHORD S.W.	30.00
BOTTOM CHORD S.W.	31.00
0-0' S.W.	14.40
1-1' S.W.	2.90
2-2' S.W.	2.60
3-3' S.W.	2.10

GEELONG AND DISTRICT WATER BOARD
OVOID SEWER BRIDGE

Tower Surface Area of Elements

Element Description	Member Area (m2)
4-4' S.W.	1.70
5-5' S.W.	1.30
6-6' S.W.	1.00
0-1' S.W.	4.60
1-2' S.W.	3.70
2-3' S.W.	3.10
3-4' S.W.	2.50
4-5' S.W.	2.10
5-6' S.W.	1.80
N1-1	10.00
N2-2	10.00
S1-1	10.00
S2-2	10.00
TOWER TOP (WALLS)	31.00
TOWER TOP (SOFFIT)	11.40
TOWER BASE	53.90
EXPANSION JOINT	
WALKWAY SOFFIT	98.80
WALKWAY :50-60m	50.00
:60-70m	50.00
:70-80m	50.00
:80-90m	50.00
:90-100m	50.00
:100-110m	50.00
PIPE SUPPORT BRACK:	
1	5.31
2	5.31
3	5.31
4	5.31
5	5.58
6	5.58
7	8.33
8	8.33
9	8.33
10	8.78
11	9.33
12	7.25
13	7.25
14	9.33
15	8.78
16	8.33
17	8.33
18	8.33
19	5.58
20	5.58
21	5.31
22	5.31
SEWER PIPE	
	1109.18

(i) Aqueduct CP & Realkalization Concrete Repair Summary

Repairs for CP and Realkalization are "surface" patch repairs, where delamianted and spalled concrete is removed and replaced but sound concrete behind or over corroding reinforcement is not required to be removed. Accordingly, far less concrete is required to be removed, allowing the strcuture to be repaired with a minimum of structural weakening.
This repair assessment is based on a detailed visual assessment of Towers 2 & 3 (attached in the adjacent worksheets) with the 1991 repair asesment used as a relative guide for the condition of each tower

Tower	1991 Repair Assessment	Detail CP Repair 2009	% increase	CP Repair Estimate 2009	
1	114000		26	143253	
2	233000	241995	4	241995	
3	265000	333128	26	333128	
4	245000		26	308700	
5	283000		26	356580	
6	252000		26	317520	
7	236000		26	297360	
8	174000		26	219240	
9	231000		26	291060	
10	256000		26	322560	
11	252000		26	317520	
12	223000		26	280980	
13	154000		26	194040	
14	311000		26	391860	
	3229000		26	**4015795**	Total surface patch repair estimate for CP and Realkalization

(ii) Patch Repair Estimate

Full depth patch repair is estimated to be approximately double the cost for surface based repairs.
The following calculation uses the CP based surface repair cost x 2 to estimate the full depth patch repair cost
In addition, additional falsework and support costs are added to structuarally support the tower

Tower	1991 Repair Assessment	Detail CP Repair 2009	% increase	CP Repair Estimate 2009	Full depth repair
1	114000		26	143253	$286,506
2	233000	241995	4	241995	$483,990
3	265000	333128	26	333128	$666,256
4	245000		26	308700	$617,400
5	283000		26	356580	$713,160
6	252000		26	317520	$635,040
7	236000		26	297360	$594,720
8	174000		26	219240	$438,480
9	231000		26	291060	$582,120
10	256000		26	322560	$645,120
11	252000		26	317520	$635,040
12	223000		26	280980	$561,960
13	154000		26	194040	$388,080
14	311000		26	391860	$783,720
	3229000		26	**4015796**	**$8,031,592**

Full Depth patch Repair Estimate Item	Qty	Unit	Rate	Amount	
Full depth patch repair	1	No	$8,031,592	$8,031,591.66	
Structural support during repair	14	No	65000	$910,000.00	
Access	14	No	55000	$770,000.00	
Prop span	14	No	10000	$140,000.00	
Site establishment	14	No	12000	$168,000.00	
Supervision - Daily	14	No	75000	$1,050,000.00	
Supervision - Senior	14	No	36000	$504,000.00	
Contingency	14	No	25000	$350,000.00	
				$11,923,591.66	
Contractor Margin (??)	25%			$2,980,897.92	
Total				**$14,904,489.58**	Total
5 yearly additional patch repair costs	**15%**			**$2,235,673.44**	

GEELONG AND DISTRICT WATER BOARD
OVOID SEWER BRIDGE

(iii) Realkalization Estimate

Realkalization costs are based on the surface area of concrete to be treated, with the rate per m2 calculated below

The concrete repair costs for realkalization are similar to the CP concrete repair costs (surface repairs), with these costs included from worsheet (i)

Realkalization Estimate					
	Qty	**Unit**	**Rate**	**Amount**	**Notes**
Materials	1109	m2	105	116,445	Titanium $60, Chemical $10, Other $35
Labour Install	1980	manhours	100	198,000	6 man days per 30m2 (major cord)= 1.8MH/m2x 1100
Labour Monitor (7 days)	143	manhours	100	14,300	4 mh per 30m2= 0.13mh/m2 x 1100
Labour remove	277	manhours	100	27,725	1.5 man day per 30m2
Continuity	1	item	6000	6,000	
Access - Fixed scaffold	1	item	12000	12,000	
Access - Scissor lift	80	day	300	24,000	
Prop span	1	item	5000	5,000	
Site establishment	4	months	2000	8,000	
Supervision- Daily	85	day	800	68,000	
Supervision- Senior	20	day	1800	36,000	
Contingency	1	item	25000	25,000	
SUB-Total				540,470	
Margin (contractor??)			0.25	135,118	
Realkalization Estimate (per tower)			**Total**	**675,588**	
Realkalization Estimate all tow	14	No	675588	9,458,225	
Surface Concrete Repair (from	1	No	4015795	4,015,795	
Total Realkalization Repair Budget				**$13,474,020**	**Total Realkalization Based Repair Estimate**

Allowance for Future Repairs (15% each 10 years) **$2,021,103**

GEELONG AND DISTRICT WATER BOARD
OVOID SEWER BRIDGE

(iv) Cathodic Protection Estimate

CP installation costs are calculated in detail in Appendix B2 (a)

The concrete repair costs for CP are included from worsheet (i)

Note the annual CP monitoring and maintenace costs

Cathodic Protection Installation (from App B2 (a)	1	No	665680	665680
CP Estimate (per tower)			**Total**	**665,680**
CP Estimate all towers	14	No	665680	9,319,520
Surface Concrete Repair (fromsheet (i)	1	No	4015795	4,015,795
Total CP Repair Budget				**$13,335,315**

Monitoring CP (ANNUAL) $18,000
Maintenance (ANNUAL) $20,000

Appendix B2
CP BUDGETS

Appendix B2-CP budget.xls

Ian Godson & Associates

1/4 span (one half of one side of a span)

Bottom chord

length across		height		length of member		section 1			section 2			section 3			section 4		
ft	m	ft	m	ft	m	a	b	c	a	b	c	a	b	c	a	b	c
64.0	19.5	10.0	3.1	64.8	19.8	16.0	3.5	16.4	16.0	2.9	16.3	16.0	2.3	16.2	16.0	0.6	16.0

sum

a	b	c
64.0	9.2	64.8	19.8

top chord

length across		height		length of member		
ft	m	ft	m	ft	m	
64.0	19.5	13.5	4.1	65.4	19.9	step size top
						1.7

cross member #1

distance from top across

ft	m	height ft	height m	length of member ft	length of member m	length on paper	ratio paper/calc
8.0	2.4	21.0	6.4	22.5	6.9	92.0	13.4

cross member #2

distance from top across

ft	m	height ft	height m	length of member ft	length of member m		
8.0	2.4	17.7	5.4	19.4	5.9	73.0	12.3

cross member #3

distance from top across

ft	m	height ft	height m	length of member ft	length of member m		
8.0	2.4	14.5	4.4	16.6	5.1	60.0	11.9

cross member #4

distance from top across

ft	m	height ft	height m	length of member ft	length of member m		
8.0	2.4	11.4	3.5	13.9	4.2	52.0	12.3

cross member #5

distance from top across

ft	m	height ft	height m	length of member ft	length of member m		
8.0	2.4	8.6	2.6	11.7	3.6	44.0	12.3

cross member #6

distance from top across

ft	m	height ft	height m	length of member ft	length of member m		
8.0	2.4	5.8	1.8	9.9	3.0	38.0	12.6

vertical member #1

length

ft	m	tower support ft	tower support m		
19.3	5.9	21.3	6.5	average	12.5

vertical member #2

length

ft	m
16.0	4.9

Appendix B2-CP budget.xls

Ian Godson & Associates

1/4 span (one half of one side of a span)

Bottom chord																						
length across			height		length of member		section 1			section 2			section 3			section 4					
ft	m		ft	m	ft	m	a	b	c	a	b	c	a	b	c	a	b	c			
64.0	19.5		10.0	3.1	64.8	19.8	16.0	3.5	16.4	16.0	2.9	16.3	16.0	2.3	16.2	16.0	0.6	16.0			

vertical member #3
length
ft m
12.8 3.9

vertical member #4
length
ft m
9.7 3.0

vertical member #5
length
ft m
6.9 2.1

vertical member #6
length
ft m
4.1 1.2

main vertical support
height
ft m
21.5 6.6

cross members (1/2 length) 2 of
ft m ft m
5.9 1.8 5.5 1.7

pipe support1 3.3
length
ft m
6.3 1.9

pipe support2
length
ft m
5.9 1.8

pipe support3
length
ft m
5.5 1.7

pipe support4
length
ft m
5.1 1.6

pipe support5
length
ft m
4.7 1.4

pipe support6

Appendix B2-CP budget.xls

Ian Godson & Associates

1/4 span (one half of one side of a span)

Bottom chord																							
length across			height			length of member			section 1			section 2			section 3			section 4					
ft	m		ft	m		ft	m		a	b	c	a	b	c	a	b	c	a	b	c			
64.0	19.5		10.0	3.1		64.8	19.8		16.0	3.5	16.4	16.0	2.9	16.3	16.0	2.3	16.2	16.0	0.6	16.0			
length																							
ft	m																						
4.3	1.3																						
pipe support7																							
length																							
ft	m																						
3.9	1.2																						
pipe support8																							
length																							
ft	m																						
3.5	1.1																						
pipe support9																							
length																							
ft	m																						
3.1	0.9																						

	1/4	One Span	totals	
Upper Boom Length	19.94639955	79.7856		
Lower Boom Length	19.76671077	79.06684	158.8524	boom
Xmember1	6.854022542	27.41609		
Xmember2	5.910991641	23.64397		
Xmember3	5.0542895	20.21716		
Xmember4	4.240961483	16.96385		
Xmember5	3.574982242	14.29993		
Xmember6	3.006724593	12.0269	114.5679	x members
Veritcal member 1	5.89221875	23.56888		
Veritcal member 2	4.871104167	19.48442		
Veritcal member 3	3.91353125	15.65413		
Veritcal member 4	2.955958333	11.82383		
Veritcal member 5	2.100052083	8.400208		
Veritcal member 6	1.244145833	4.976583	83.90804	Vertical members
Pipe Support 1	1.931666667	7.726667		
Pipe Support 2	1.807760417	7.231042		
Pipe Support 3	1.683854167	6.735417		
Pipe Support 4	1.559947917	6.239792		
Pipe Support 5	1.436041667	5.744167		
Pipe Support 6	1.312135417	5.248542		
Pipe Support 7	1.188229167	4.752917		
Pipe Support 8	1.064322917	4.257292		
Pipe Support 9	0.940416667	3.761667	51.6975	Pipe Supports
OB1	1.807760417	7.231042		
OB2	1.683854167	6.735417		
UB1	1.807760417	7.231042		
UB2	1.683854167	6.735417	27.93292	lateral beams
main tower support	6.506666667	26.02667	26.02667	main tower
total	115.7463636	462.9855		

			Cost
Internal Anodes required for Major Chords			
Upper Chord Length (m)	80		
Lower Chord Length (m)	80		
Tower Supports (m)	26		
Total Major Chord length (m)	186		
Allowance	1.1		
Internal anode spacing (m)	0.2		
No. of Anodes	1023	Anode costs	$30,690.00

Ribbon anode length required for minor chords			
Vertical Support length (m)	84		
Cross Member Length (m)	115		
Walkway Support Length (m)	84		
Lateral Beam Length (m)	28		
Total Minor Chord Length (m)	311		
Allowance	1.1		
Length Required	342.1	Ribbon anoc	$5,131.50

CP Materials per Span

Internal Anodes	ribbon anode length (m)	Conductor bar length (m)	connections	Reference Electrodes	
1023	2012	642	100	15	
$30.00	$15.00	$11.00	$60.00	$350.00	cost per unit
$30,690.00	$30,185.00	$7,060.90	$6,000.00	$5,250.00	totals

Materials budget
$79,185.90

Conductor Bar Length Required	
Bar #1(for internal anodes)	
Upper Chord Length (m)	80
Lower Chord Length (m)	80
Tower Supports (m)	26
Total Major Chord length (m)	186
Allowance	1.15
Length Required	213.9

Conductor Ba	$2,352.90		
Bar #2 (for ribbon anodes)			
Upper Chord Length (m)	80		
Lower Chord Length (m)	80		
Total Major Chord length (m)	160		
Allowance	1.5		
Length Required	240	Conductor E	$2,640.00

Unit costs

Internal Anodes ($/each	$30.00
Ribbon Anodes($/m)	$15.00
Conductor bar ($/m)	$11.00
Postive Connections ($e	$60.00
Negative Connections ($	$60.00
Reference Electrodes ($	$350.00

Walkway base and sides.				
Base	1.5			
Sides x 2	2.5			
Total width	4			
Length	52.8	176		0.3
Total area	211.2			
Ti ribbon @ 200mm	1056	$15,840.00		
Conductor	75	$825.00		

Tower base & top			
Base (3 x2 + 7x2)x1.5	30	m2	
Top (6x2 +3 X2)1.5 + 18	48		
Total Area	78		
Ti ribbon @ 250mm	312	$4,680.00	
Conductor	60	$660.00	

0	Pipe hangers		
	Length	4	
	Span	53	
	Spacing	2.4	
	No per span	22.08333333	
	Ti ribbon	88.33333333	$1,325.00
	Conductor	53	$583.00

Connections Required			
For Internal Anodes			
Bottom Chords	8		
Top Chords	8		
Tower Supports	4		
Allowance	1.1	Connections cost	
positive	22		$1,320.00
negative	22		$1,320.00
total	44		$2,640.00

For Ribbon anodes			
Bottom Chords	8		
Top Chords	8		
Allowance	1.1		
positive	17.6		
negative	17.6	Connections cost	
total	35.2		$1,056.00
			$1,056.00
			$2,112.00

Reference Electrodes Required		
Major Chords (excluding tower su	4	
Minor Chords	4	
tower supports	2	
		Reference Electrodes cost
Allowance	1	
total	10	$3,500.00

Total Cost
$49,066.40

Grout Usage m^3								
Internal Anodes (tower supports)	Internal Anodes (horizontal major chords)	Conductor Bar	Ribbon	total grout	Allowance	grout cost per L	Cost	
0.005605387	0.030661944	0.3114	0.3078	0.655467	1.3	$6,666.67	$5,680.72	
					0.852108			

gout cost per L	$6.67	
per m^3	$6,666.67	

Internal Anodes
Horizontal Chords 160 of

Grout per anode

diameter of hole (m)	area(m^2)	fraction through	width of	width of me	length of ho	volume of materia	volume of material (L)
0.03	0.000706858	0.666666667	16	0.406667	0.271111	0.000191637	0.1916372

Tower Supports 26 of

Grout per anode

diameter of hole (m)	area(m^2)	fraction through	width of	width of me	length of ho	volume of materia	volume of material (L)
0.03	0.000706858	0.666666667	18	0.4575	0.305	0.000215592	0.2155918

Ribbon 311 m
Grout per m

strip size(mm)	strip size(m)	Area (m^2)
30	0.03	0.0009

Conductor bar 346 m
Grout per m

strip size(mm)	strip size(m)	Area (m^2)
30	0.03	0.0009

all summed in man hours 1 Man hour Assumed at $100

	Units	Man hours Per Unit	cost
Internal anodes	1023	0.5	$51,150
Ribbon	2012.333333	1	$201,233
Conductor Bar	641.9	1	$64,190
Connections	100	2	$20,000
reference electrode	15	2	$3,000
Junction Box	3	3	$900
Transformer Rectifier	1	24	$2,400
cabling	1	80	$8,000
		totals	$350,873

Cathodic Protection Installation Cost Budget

Excludes Concrete Repair

Quantities
From earlier worksheets

CP Materials per Span

Internal Anodes	ribbon ano	Conductor ba	connection	Reference	Electrodes
1023	2012.333	641.9	100	15	
30	15	11	60	350	cost per unit
30690	30185	7060.9	6000	5250	totals

Estimate- CP Supply and Install

	Qty	Unit	Supply Rate	Supply	labour Rate	labour Amount
Internal Anodes	1023	No	30	30690	60	61380
Ribbon anodes	2012	m	15	30185	60	120740
Conductor bar	642	m	11	7060.9	20	12838
Connections	100	No	60	6000	60	6000
Reference	15	No	350	5250	120	1800
Junction boxes	3	No	700	2100	500	1500
T/R	1	No	22000	22000	2000	2000
Solar/Batteries	1	Item	8000	8000	2000	2000
Cabling	1	Item	8000	8000	5000	5000
Grout	4	m3	4000	16000		0
Sundry materials	1	Item		10000		15000
				145285.9		228258 Sub-total labour
Supply (carried over)						145286 Sub-total materials
Continuity						6000
Access - Fixed scaffold	1	item			12000	12000
Access - Scissor lift	80	day			300	24000
Prop span						5000
Site establishment	4	months			2000	8000
Supervision- Daily	85	day			800	68000
Supervision- Senior	20	day			1800	36000
SUB-Total						532544
Margin (contractor??)					0.25	133136
TOTAL CP (EXCL REPAIR)						665680

5 Man crew for 85 days

Appendix C
DEFINITIONS

Definitions

- **Tower –** For the purpose of this trial and costing of the repairs a tower section includes all of the concrete tower pier above the ground level and one half of the span emanating on either side of the tower but excludes the ovoid pipe.
- **Span –** The elements of the span includes the trusses, the central girder forming the footway and the ovoid pipe hangers.
- **Truss –** The trusses are the cantilevered sections out from the towers and consist of the triangular frame each made up of an upper and lower chord, stiffened by vertical and diagonal members referred to in the report as stays.
- **Chord –** The chord members have been constructed of reinforced concrete using the Considere system.
- **Stay –** The stays are the vertical and diagonal reinforced concrete elements between the chords and have been constructed using the Considere system.
- **Mixed Metal Oxide Anode –** A MMO anode is a length of narrow titanium ribbon coated with a mixed metal oxide. The width of the ribbon is directly related to the current capacity of the anode per unit length. The mixed metal oxide has the ability to discharge a high electrical current over a long period of time. The consumption of the metal coating is a function of the current discharged and time and is commonly known as Faraday loss; hence the Faradic loss of the coating is extremely low for this type of anode.
- **Internal anode –** An internal anode is a short length of MMO anode placed within a chord element by drilling a hole into the centre of the chord, filling the hole with cementitious grouting and pushing the anode into the grouted hole. The anode is located in such a way that the protection current flows from the centre of the element out to the surrounding reinforcing steel.
- **Ribbon Anode –** A ribbon anode is a length of MMO anode placed in the surface concrete of the stays. The anode is installed by saw cutting 2 parallel lines anode width apart at a depth of approximately 20mm, removing the concrete between the saw cuts to form a slot, placing a layer of grout into the slot, placing the ribbon anode firmly into the grout and grout back filling to surface level.
- **ACC Test Method Statement No. 1** – To determine by electrical measurement the in-situ continuity characteristics of reinforced concrete structures.
- **ACC Test Method Statement No. 5** – To determine by electromagnetic measurement the depth and layout of the steel reinforcement within a reinforced concrete structure
- **ACC Test Method Statement No. 8** – To determine the depth that carbonation has progressed into a concrete structure by field test method