PETER STEWART
CONSULTING P/L

A Review and Consideration

of the

Structural Condition

of the existing

Windsor Bridge

Final Review

Peter Stewart Consulting Pty Ltd P.O.Box 163, Pymble, NSW 2073 (02)98809552

Table of Contents

Peter Stewart Consulting Pty Ltd P.O.Box 163, Pymble, NSW 2073 (02)98809552

Peter Stewart Consulting Pty Ltd P.O.Box 163, Pymble, NSW 2073 (02)98809552

1. Executive Summary

This report addressed the completeness of the EIS and associated documentation submitted justifying the demolition of the existing Windsor Bridge based substantially on its current condition. Relevant 'Submissions' documentation was reviewed particularly in regard to the existing Windsor Bridge. Gaps in documentation were identified and further information sought to close those gaps. This was obtained through requests for information from RMS through the DP&I for information along with meetings to clarify the requirements as well as to receive submissions from RMS. External sources were also consulted for information. Once all documentation was received it was analysed to assess the justification for the demolition.

Windsor Bridge has several important heritage engineering features which demonstrate the innovative culture in our engineering profession dating back to 1875. These features are well stated in the documentation and should therefore serious consideration should be given their preservation in some form or another.

While the bridge is deteriorating from various ailments it is not about to collapse in the short term. Each ailment can be treated and this has been plainly demonstrated by RMS and others. It is acknowledged that it would be uneconomic and unrealistic to expect the existing bridge to satisfy current standards and codes as well as provide the desired level of service, especially as it was built in 1875 and upgraded in 1922 for far lessor loading. Strengthening by the RMS method would destroy most of the heritage value in the bridge.

The bridge can be refurbished at a cost such that it can function for the next 50 years with little ongoing maintenance. However this refurbishment would not permit the level of service required by RMS into the future hence the need for a new bridge. Refurbishment would permit alternative uses for the existing bridge such as either a pedestrian bridge or a load limited bridge (16 tonne). This reports shows that it would not be an exorbitant cost (approx. $12.5m) to bring the bridge up to an 'as new' condition for an alternative use.

It appears the optimum option is some combination between the RMS and the Pearson Wedgewood options which will be able to provide a viable option to refurbish and strengthen to carry T44 loading with a load factor of 2 which will be sustainable for the next 25 to 50 years, and not build a new bridge at this stage. Then at some time in the future a bypass alignment can be identified, approved and built which avoids all the damage to property, heritage values etc. So with a relatively modest expenditure (approx. $14.5m) the bridge can be serviceable for the next 50 years within which time an alternative route will have been identified and agreed.

It is clear however that the documentation does not show a strong resolve to preserve the existing bridge for an alternative use, with a continuing theme throughout the documentation that it will replaced by a new bridge. This was clear when a decision was main within the then RTA (now RMS) to replace the bridge sometime before 2003. Subsequent to this decision no expenditure on maintenance or repair of damaged fabric is evident except where public safety might be endangered. Despite this neglect it is remarkable that no great deterioration has taken place in the last 10 years.

Peter Stewart Consulting Pty Ltd P.O.Box 163, Pymble, NSW 2073 (02)98809552

There is no evidence that the management approach to bridge maintenance and repair changed as a result of either being listed on the RMS Section 170 Register or being classified as State Significant.

Assuming the new bridge proceeds subject to all the approvals it would be appropriate to determine alternative uses for the existing bridge. This would not only provide the community with an ongoing asset but also preserve the important heritage embodied in the bridge. Consultation with the community specifically on alternative uses may uncover an important contribution to the local social fabric and this should be explored.

In conclusion it would not be viable to upgrade the existing bridge to meet the level of service required for the future. However the bridge fabric should be refurbished with a view to undertaking work to satisfy alternative uses for the bridge for the next 50 years.

2. Document Status

Revision	Purpose	Date delivered	Reviewed by
-	Internal draft issued to client for review	18 April 2013	Andrew Beattie
22 May 13	Preliminary Draft issued to client	30 May 2013	Andrew Beattie
26 July 13	Final Draft issue to Client	26 July 2013	Andrew Beattie
14 Aug 2013	Final Draft	14 August 2013	
15 August	Final Review	16 August 2013	

3. The Project

The Department of Planning and Infrastructure (DP&I) is considering a major application for the Replacement of the existing Windsor Bridge. Roads and Maritime Services (RMS) acting as the proponent has prepared an Environmental Impact Statement for the Project [B1]. The DP&I are currently reviewing submissions [B2] from the public and stakeholders received as a result of the public exhibition of the project.

Note: Throughout this report the [ref] refers to the source document by Appendix and Number.

Peter Stewart Consulting has been engaged by DP&I to review the structural condition, engineering & other impacts in regard to the proposed demolition of the existing Windsor Bridge.

4. Scope of Brief for PSC [C]

PSC has been engaged by NSW Planning to review the EIS and other submissions to:

- Review the appropriate documentation provided by the Department with regard to relevant engineering guidelines, industry standards and legislation.
- Meet with Department representatives, proponent's/council/agency experts as necessary.
- Undertake a site visit
- Provide the Department written advice on the:
    - adequacy of the documentation, and if necessary, identifying gaps in the documentation;

Peter Stewart Consulting Pty Ltd P.O.Box 163, Pymble, NSW 2073 (02)98809552

  - adequacy and/or suitability of the proposed mitigation and/or management and/or protection measures if required;
  - assessment of the significance of the engineering impact; and
  - suggested remedial actions for the engineering issues identified
- Conduct peer reviews of other service providers work if required

After meeting with the Department on the 3rd April 2013 to confirm the brief the scope was further clarified to address the following:

1. Verify the justifications for demolition of the existing Windsor bridge are valid
2. Ascertain whether the conclusions can be supported
3. Assess what options are available
4. Assess what heritage items are worth preserving

5. Review Methodology

The methodology for this review is as follows:

- Meet with the Department and confirm the Scope of Works
- Review the documentation provided by the Department.
- Identify the key issues.
- Undertake a gap analysis of the documents and raise questions for the proponent
- Meet with Department representatives, proponent's/council/agency experts as necessary.
- Undertake a site visit
- Review and analyse responses from the department & proponent
- Address the initial issues and any new issues raised as a result of the process
- Advise the Department on the:
  - adequacy and/or suitability of the proposed mitigation and/or management and/or protection measures if required;
  - assessment of the significance of the engineering impact; and
  - suggested remedial actions for the engineering issues identified
- Provide a report to the DP&I

6. EIS [B1]

The following extracts from the EIS are relevant to this report and the red font sections are addressed specifically:

"The Project
Roads and Maritime Services NSW (RMS) is proposing to replace the existing bridge over the Hawkesbury River at Windsor. The proposal for bridge replacement includes the following key features (amongst others):

- *Removal and backfilling of the existing bridge approach roads.*
- *Demolition and removal of the existing road bridge, known as Windsor Bridge…"*

Peter Stewart Consulting Pty Ltd P.O.Box 163, Pymble, NSW 2073 (02)98809552

Why is it (the project) needed?

THE EIS (page xii) states

"There are a number of reasons why the project is needed. Critically, the structural piers and other parts of the existing Windsor Bridge are over 130 years old and are substantially deteriorated due to age and heavy use. The bridge requires extensive rehabilitation work if it is to be used and maintained into the future.

Speed restrictions are currently imposed due to the structural weakness of the bridge and it is inspected regularly to ensure public safety. A load limit may also need to be applied in the short term and ultimately closure of the bridge is expected in the longer term when ongoing maintenance can no longer provide a structurally adequate bridge.

The remaining safe life of the bridge cannot be accurately predicted due to deterioration, heavy use and risk of flooding, however RMS could need to close it anytime without notice to protect public safety if regular inspections identify considerable further structural weakness.

In addition to deteriorating with age, the existing bridge does not meet current engineering and road safety standards."

EIS Section: *1.1 The proposed project*

"Roads and Maritime Services NSW (RMS) is seeking approval under Part 5.1 of the Environmental Planning and Assessment Act 1979 (EP&A Act) to replace the existing bridge over the Hawkesbury River at Windsor (known as Windsor bridge). The existing bridge needs to be replaced as its structural integrity is deteriorating with age and it is no longer cost-effective to maintain.

EIS Section 1.2 Project Location & context

Parts of the existing bridge are 138 years old and are deteriorating as a result of age and heavy use. Elements of the bridge have deteriorated substantially and RMS has assessed that it is not practical to replace or repair these elements. The existing bridge and adjacent intersections no longer meet the demands of current peak hour traffic volumes or current road standards. The level of maintenance required to maintain adequate road safety is no longer cost effective and it is therefore regarded that the bridge has reached the end of its economic life."

EIS Section 3:

"3.2.1 Condition of existing bridge

Parts of the existing Windsor bridge are over 130 years old and are deteriorating due to age and heavy use. The bridge is regularly inspected to identify maintenance requirements and ensure safety for use, revealing ongoing and escalating maintenance issues. Technical inspection reports about the condition of the existing bridge are provided in ***Appendix C.*** *Inspections have shown that while the bridge is suitable for current vehicle and pedestrian use:*

- *Sections of the bridge below the water line are heavily corroded and substantial graphitisation of the cast iron has occurred on some piers. This has resulted in variable pier wall thickness but in places the piers have corroded so much that the wall thickness is very low (less than five millimetres). The average wall*

thickness from the underwater cores taken to date is about 15 millimetres (CTI, 2011). The original wall thickness was estimated to be about 30 millimetres.

- *Horizontal cracking is present in the pier columns, including both columns of the fifth pier from the southern bank. There is also a short vertical crack on the upstream column of the fifth pier from the southern bank, and there are vertical cracks in the brackets securing the upper end of the diagonal bracing to most piers. Such cracks would be expected to have a serious impact on the overall serviceability of the bridge (CDS, May 2011).*
- *There has been a 16 per cent deterioration in the stiffness of at least one of the bridge spans since 2003. The stiffness of a span determines the load it is able to support – and with deteriorating stiffness – load limits on the bridge may need to be implemented (Access: UTS, 2007).*
- *Bracing between the older cast iron column sections on three piers are undergoing considerable corrosion at the water-line and may require replacement or repair.*
- *The bridge deck has a number of issues including:*
  - *Extensive spalling, leaching, wide cracks and exposed and corroded steel reinforcement at the ends of the deck slab.*
  - *External beams – have severe spalling and carbonation of concrete, suspect quality of concrete, exposed and corroded steel reinforcement and loss of 50 per cent of beams seating area at the headstocks.*
  - *Internal beams – have minor spalling and carbonation of concrete, suspect quality of concrete, and loss of 20 per cent of beams seating area at the headstocks.*
  - *Deck joints – are old and do not allow expansion, have no compression seals and the sealed surfaces at the joints are cracked and bulged.*
  - *Headstocks - have severe spalling and carbonation of concrete, suspect quality of concrete and cracking.*

Overall the condition of the existing bridge is rated as poor and, while the bridge is suitable for current use, would need extensive rehabilitation works if it was to be used and maintained into the future (RTA, 2003 and 2005). Subsequent inspections (including underwater inspections) in 2012 that followed the March 2012 floods have not identified any further significant deterioration of the structure. Also if a new bridge was to be constructed downstream of the existing bridge, retaining the existing bridge would not be possible due to the risks of its failure during a flood event. Debris from the failed bridge may cause physical damage to the piers of a new downstream bridge or may become caught in the new bridge, damming floodwaters and putting unacceptable stresses on the structure of the new bridge."

EIS Section: 11.1 Justification

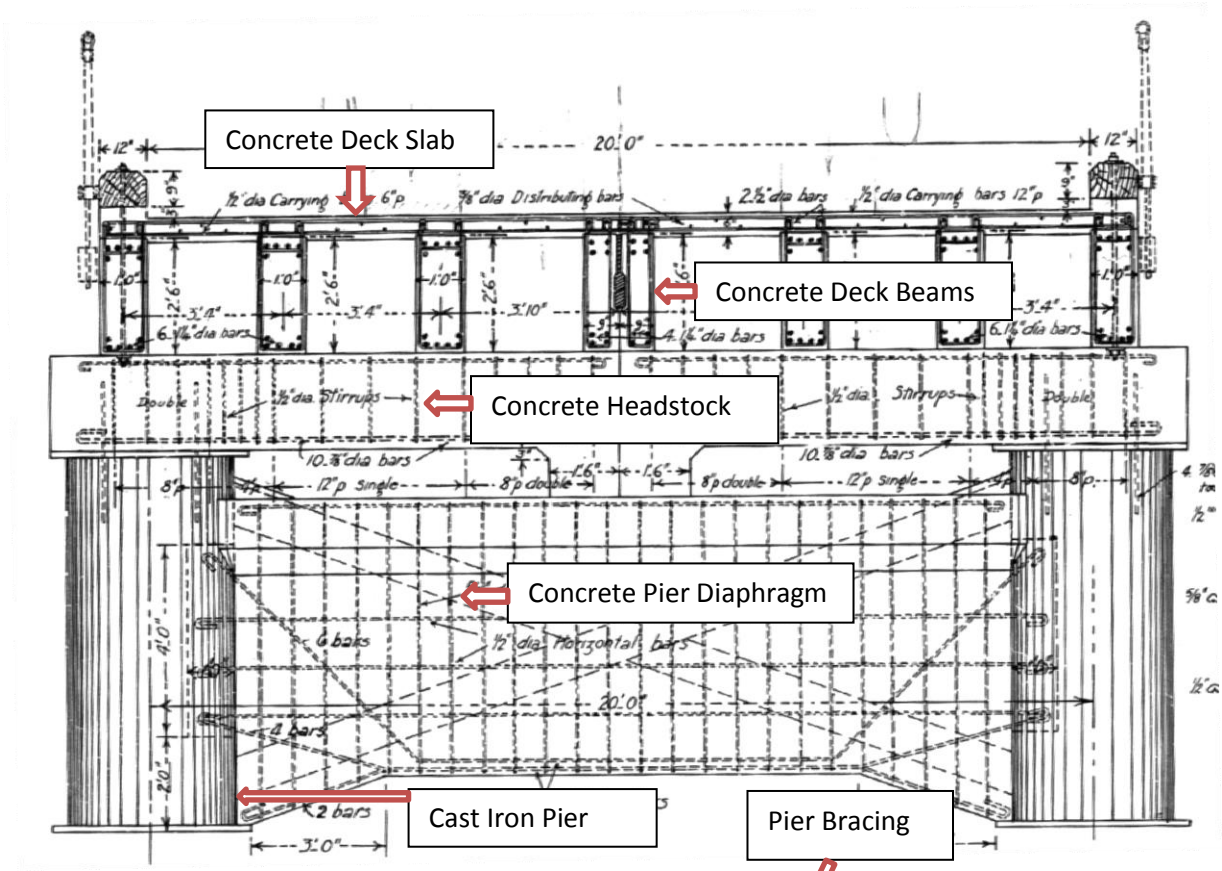
11.1.1 Project justification

"Windsor bridge provides an important link for communities on each side of the Hawkesbury River in the Windsor locality, as well as an important regional link between western Sydney, the Blue Mountains and the Hunter region. Around 19,000 vehicles use the bridge each day, with around seven per cent of these being heavy vehicles. The nearest alternative bridge crossing of the Hawkesbury is located around 10 kilometres away at Richmond, requiring a road detour of around 20 kilometres to drive between the southern and northern sides of the river at Windsor. There are a number of reasons why a replacement river crossing at Windsor is required including:

Peter Stewart Consulting Pty Ltd P.O.Box 163, Pymble, NSW 2073 (02)98809552

- *Deterioration in the condition of the existing bridge – Elements of the existing bridge are over 130 years old and substantially deteriorated.*
- *The existing bridge and approach roads do not meet current engineering and safety standards.*
- *The existing bridge has a lower flood immunity than the surrounding roads.*
- *The poor current and future traffic performance and capacity of the existing bridge and intersections.*"

In reference to the justification for demolition of the bridge the above statements from the EIS in **red** are dealt with in this report. The following nomenclature is adopted:



Peter Stewart Consulting Pty Ltd P.O.Box 163, Pymble, NSW 2073 (02)98809552

7. Documentation

The documentation reviewed for the purposes of this report are itemised in Appendix B.

8. Communications

Communications such as meetings have been held with the Department and RMS to obtain/clarify information contained in the documents.

Date	Location	Type of communication	Purpose	Comment
3rd April	DP&I	Meeting	Intro & Briefing	Elaborated on the scope of work
18th April	RMS N Sydney	Meeting	RMS presentation, Q & A	Background information on bridge condition, options & costings
10th May	RMS N Sydney	Meeting	RMS Responses to DP&I questions	Discussion on rehabilitation & costs; future maintenance costs
12th July	DP&I	Meeting	Status update	New queries raised/exchanged info

9. Site Visit

The writer conducted a site inspection on the 23rd April 2013. Photo record is included in Appendix E.

10. Advice on Documentation

- Adequacy of the documentation, and if necessary, identifying gaps in the documentation;
- Adequacy and/or suitability of the proposed mitigation and/or management and/or protection measures if required;
- Assessment of the significance of the engineering impact; and
- Suggested remedial actions for the engineering issues identified

The following sections address the adequacy or otherwise of the documentation (Refer Appendix B); the adequacy or suitability of the proposed measures; the engineering significance and remedial actions proposed.

11. Key Issues

Sections 12,13,14,15 &16 address the key issues associated with the condition of the existing bridge.

12. Condition of Bridge

"…the structural piers and other parts of the existing Windsor Bridge are over 130 years old and are substantially deteriorated due to age and heavy use. The bridge requires extensive rehabilitation work if it is to be used and maintained into the future."

It is acknowledged that all things deteriorate with age and bridges are no exception, however they can still perform the function for which they were initially intended if they are

appropriately maintained. The deterioration is primarily due to neglect of the bridge over many decades, but most noticeably in the last two decades. Also, whilst it is acknowledged that there is 'heavy use' of the bridge, this fact alone does not seem to be the cause of the deterioration having considered all the investigations and reports. Heavy use may mean overloaded vehicles but RMS indicated in their response to question [D13] "Why are illegal loads being allowed across the existing bridge if it lowers the load factor?" that "*Illegal loads are not allowed on the bridge. A decision was made in 2003 to continue with General Access vehicles (ST42.5) and Restricted Access Vehicles (BD62.5) and in 2011 to allow Higher Mass Limits (ST45.5 and BD68) subject to a range of measures including:*

- *A detailed inspection and monitoring regime*
- *Measures to ensure over mass and oversized vehicles do not cross the bridge"*

This is confirmed in 2008 by RMS in their Bridge Assessment & Evaluation Report conclusions [B4V1.8]. This report also contemplates the bridge will be replaced in 2010.

Based on this response we can only conclude that heavy use does not mean overloaded vehicles but rather increased traffic. However this alone is not the cause of bridge deterioration as no report or document indicates this as a cause.

- Current state of the bridge.
  "Overall the condition of the existing bridge is rated as poor". Whilst the bridge suffers from many ailments each impacting on the integrity of the bridge, the bridge is safe for current use. In 2010 Inspection and Structural Assessment by UTS [B4V2.12] stated that *"If RMS intends to decommission bridge in the near future, bridge in its present condition and loading will be safe for some time."*
  In February 2013 the RMS report [B4V2.16]on the performance of the bridge recommended *"the higher mass limit (HML) six axle articulated truck with maximum GVM of 45.5t (ST45.5) and HML nine axle truck with maximum GVM of 68t (BD68) be allowed to cross the bridge subject to the following conditions:*
  - *Regularly monitor the graphitisation of pier columns*
  - *Regularly monitor the bridge deck where spans are in poor condition*
  - *Remove any spalled concrete which could be a danger to public"*

There are many reports, investigations, assessments and estimates regarding the condition of the bridge particularly over the last 10 years. [B4V1 and V2]

- **Gaps in documentation:**

The conclusion that the whole bridge is in a poor condition is not supported by the level 2 Inspection Report Ratings [B8]. There is no linkage provided between the condition of the various elements and the overall condition. If it is assumed that the condition of the bridge is equivalent to the worst element then again the argument is thin as only 2.1% of the reinforced concrete beams is categorised as condition 4 or 'poor'.

The reports address several main issues impacting the condition of the bridge which are:

Peter Stewart Consulting Pty Ltd P.O.Box 163, Pymble, NSW 2073 (02)98809552

- **Carbonisation**

Basics: Carbonisation is a reaction of carbon dioxide with concrete which commences at the concrete surface and progressively reduces the alkalinity of the concrete. As the carbonisation advances through the concrete it reaches the reinforcement and the reinforcement protection against corrosion is destroyed. As the reinforcement corrodes it expands and the concrete around it then cracks and 'spalls' or falls away.

This is most noticeable on the beam soffits, particularly on the exterior or most exposed beams. The rate of carbonisation is very slow and is estimated at 1mm/year although this is dependent on many factors.

Extent: The extent of spalled, cracked or delaminated concrete has been estimated by GHD in 2003 [B4V1.2] at 250m2 [B4V1.2Appendix E pg. 8] of surface area (~10% of deck under-surface area). Note GHD advised that damage is likely to increase with time as the carbonation front advances. The rate of increase will depend on several factors but will be influenced by the neglect of bridge maintenance actions, which is the current situation. RMS should undertake a new survey comparable to the GHD survey in 2003 to gauge the deterioration over the last 10 years.

The scuppers are a significant cause of concrete deterioration as the beam and slab concrete adjacent to the scuppers repeatedly becomes wet and then dry.

Recommendations: GHD Oct 2003 recommended Re-alkalisation (A process used to arrest carbonisation) as it is deemed the most technically appropriate repair and the most cost effective repair option over the future service life of 25 years. RMS Inspection & Assessment Report Dec 2003 [B4V1.3] stated *"The structure assessed to be in poor condition"* and *"The recommendation of the report was to replace the bridge within 5 years"* based on the extensive repairs identified in the inspection & durability reports.

GHD also provided an estimate of cost to re-alkalise the total exposed area of 2360m2 which included the soffit and sides of the beams & headstocks (but not the abutments) of $2.75m in Dec 2009 [B4V2.9]. This GHD report recommended as follows: *"Re-alkalisation is recommended as the most technically appropriate repair method…..and more cost effective repair over a future service life of 25 years".*

The Technical Review of the Alternative Refurbishment [B3] correctly noted that "*Re-alkalisation would be expected to provide a long term solution greater than 50 years that would not require reapplication of the re-alkalisation provided the anti-carbonation coating was properly maintained (i.e. reapplication of the anti-carbonation coating every 10-12 years)*"

RMS cited Wardell Road Bridge Rehabilitation Project [D5] as a local example of re-alkalisation of the bridge. On further enquiry with Marrickville Council this bridge, built in 1924, had 314m2 re-alkalised 12 years ago and no additional maintenance has been required since that treatment. The structure was also treated with an anti-carbonating coating. This is not a standard coating as it takes into account the elevated alkalinity of the concrete after treatment.

Before

After

The process had no adverse impact on the appearance of the bridge (good for heritage) and only a few sporadic half road closures. Design was by GHD. [B11]

Actions to date:

Removal and repairs of spalls has been going on for some 10 years by RMS but ONLY where they pose a safety risk to the public. RMS advised on 16th May in response to the question [D6] "What, if any, interventions to the bridge have taken place to reinstate the fabric of the bridge in the last 10 years? Note: not maintenance but refurbishment tasks" stated *"no specific interventions have taken place to reinstate the fabric of the bridge, although activities such as removal of spalling continue as part of bridge maintenance"*

No re-alkalisation has been undertaken despite GHD recommendations in 2003.

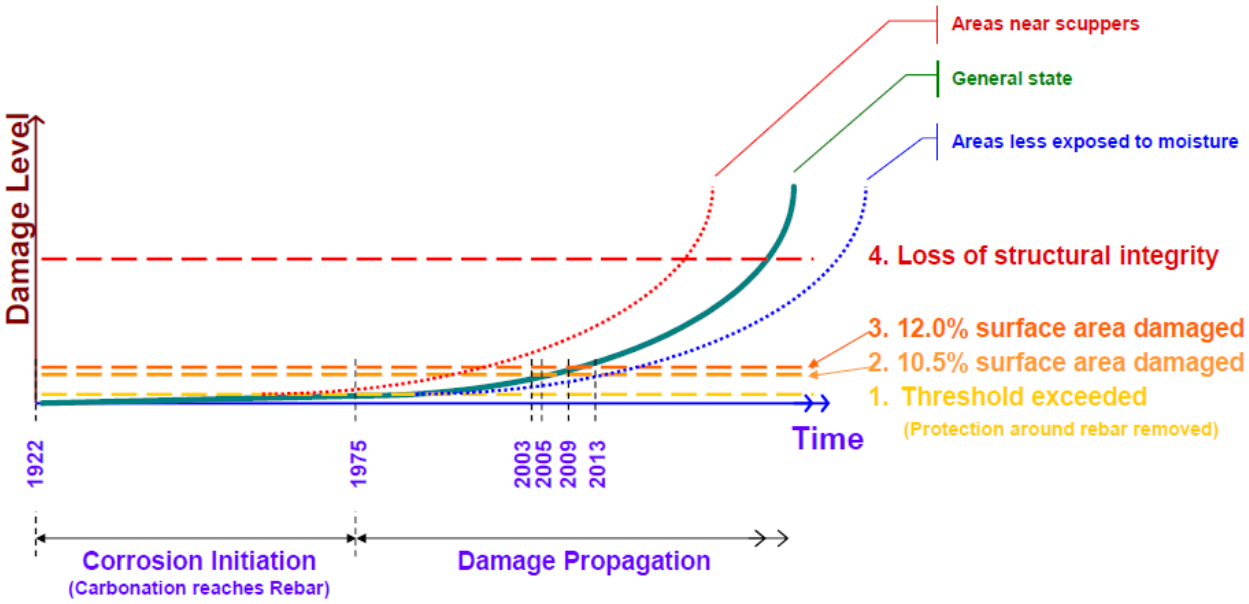
Is it still a condition that would warrant demolition of the bridge?

If left untreated this condition would in itself warrant the demolition of the bridge. It appears the RMS has left it untreated as a result of the recommendation in December 2003 to replace the bridge in 5 years. It is noted that the replacement bridge may not be operational for ~10 years plus and not the 5 years stated in the recommendation. This raises questions about the approach to maintaining the fabric of the bridge.

- **Gaps in documentation:**

RMS provided a Concrete Damage Model – Carbonation in their presentation of 18th April 2013. This indicated corrosion initiation in 1975 and the rate of damage accelerating rapidly from 2003

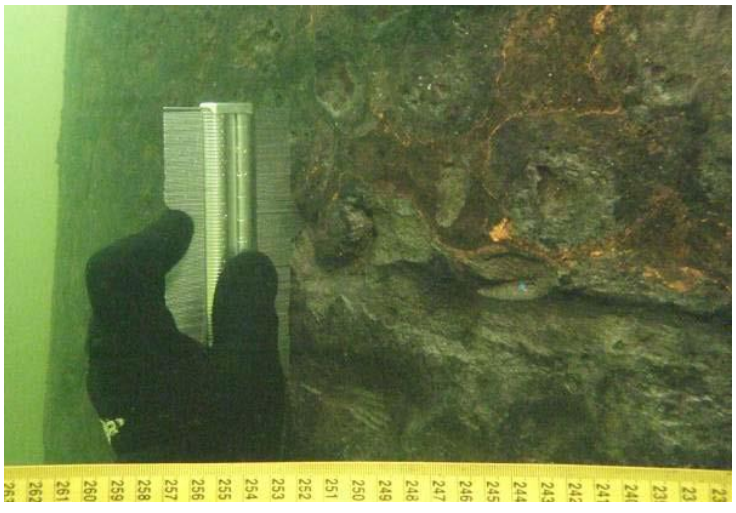
onwards. On enquiry this chart is based on Dr Phil Bamforth entitled 'A new approach to Durability Design Using Risk Analysis' [B10]. See chart below:



The date of corrosion initiation is not substantiated by RMS and the curves seem somewhat arbitrary without any backup calculations. For 2009, the chart seems to indicate a more extreme acceleration of deterioration (12%) than that observed in the inspection of 2009 (2.1%) (see Section 14 on Maintenance below).

- ***Graphitisation***

Basics: Graphitisation is form of deterioration of cast iron (as used in the piers) in which the metallic components are converted to corrosion products leaving the graphite intact which has no structural strength.



Extent: RMS first identified this in 2005 (CTI Underwater Graphitisation Survey [B4V1.5]) [D18]. CTI assessed the above water condition of the piers to be excellent. CTI identified graphitisation in piers 1, 5, 7 and 9. However *"there was no discernible pattern to the distribution of the residual wall thickness."* CTI subsequent survey (July 2011) [B4V2.15] indicated that *"the condition of the columns …reveals that graphitisation has advanced to significant proportions. Indications are that in places there are more than 20mm of graphitised material present."* This leaves an average structural thickness of 15mm which is roughly 50% of the original thickness. So graphitisation has corroded the caissons at a rate of approx. 15mm in 138 years or 0.11mm/year. It is evident that this is a very slow process.

Recommendations: From CTI 2005 report *"Should the bridge still be structurally adequate, further graphitisation of immersed surfaces can be prevented by installing impressed current cathodic protection to the columns, designed in accordance with AS 2832.3."* Other recommendations centre on monitoring the situation particularly after flooding.

Actions to date:

No action has been taken to rectify this condition.

Is it still a condition that would warrant demolition of the bridge?

Due to the very slow rate of deterioration it would not warrant demolition of the bridge for some considerable time. It is also evident that the process can be arrested or prevented either by installing an impressed current or jacketing the damaged sections. However, if left untreated graphitisation could become an issue for the structural integrity of the bridge piers.

- **Gaps in documentation:**

The underwater inspections have not clearly stated whether all piers are subject to graphitisation. RMS makes the assumption in their presentation of the 18th April that all piers are affected. Other piers may be affected but the extent will vary from pier to pier. The most affected piers seem to have been identified. Treatment may only be needed on the severely affected piers in the light of the fact that this is a very slow process and the refurbishment should only consider extending the life by 50 years.

- **Pier caisson cracks**

Basics: Severe cracking may have a serious impact on the overall serviceability and integrity of the bridge depending on where the cracks occur and their rate of growth.

Extent: Pier caisson cracks (vertical & horizontal) observed in Pier 5 and to a lesser extent in Pier 6 are documented in the CDS Underwater Inspection Report of June 2011 [B4V2.15]. Horizontal cracks are present in these three columns including both columns of pier 5. RMS first identified these cracks in 2011 through the CDS inspection [D9]. Underwater inspections later in 2011 concluded there was no evidence that the cracks have widened or shifted since previous survey 2 months before. The report went on to say *"It appears the cracks are not new and have been present for quite some time, at least a few decades and possibly longer"*. The cause of the cracks is unknown.

Recommendations: A detailed structural analysis to determine the impact of the cracking on the bridge's capacity. That underwater inspection is undertaken after every major flood event.

Action to date:

RMS has advised of only one underwater inspection having been undertaken to date... after the 2012 flood. [D8]

No action has been taken to rectify this condition although performance load tests have been carried out to verify the structure is safe. (Endurance Consulting October 2012)[B4V2.14]

Is it still a condition that would warrant demolition of the bridge?

The cracks have been there for decades and during that time the bridge has been subjected to severe flooding (overtopped approximately 64 times in 100 years) as well as increases in traffic volumes. The bridge has not exhibited any signs that it is about to fail. The condition of the piers is not a reason alone to demolish the existing bridge, due to the rehabilitation methods available to retain the structure.

NB This should be read in conjunction with the deck joints section below for if the bridge structure is changed in the way it distributes the forces then it may well become structurally unsafe. This is because currently the loads in the piers are primarily compression loads due to the locked up nature of the joints. The longitudinal forces caused by braking or thermal movements are transferred through the locked up joints primarily to the ends of the structure where the abutments resist the forces. If the deck joints are opened up as part of a repair process then the piers will have to resist greater horizontal forces which they may not be able to do due to graphitisation and cracking (certainly pier 5 is severely weakened as it cracked completely around its circumference). Reference: RMS diagram slide 20 from their presentation of the 18th April. [B5]

- **Gaps in documentation:**

There is no indication of cracks in other piers as the underwater inspections have been commissioned to assess graphitisation only. By chance in doing this they have discovered these cracks. Other piers may be cracked but this is unknown at this time.

- **Deck Joints**

Basics: Deck joints are there to ensure the correct articulation of the bridge and transfer longitudinal braking and thermal loads to ground via the piers and abutments.

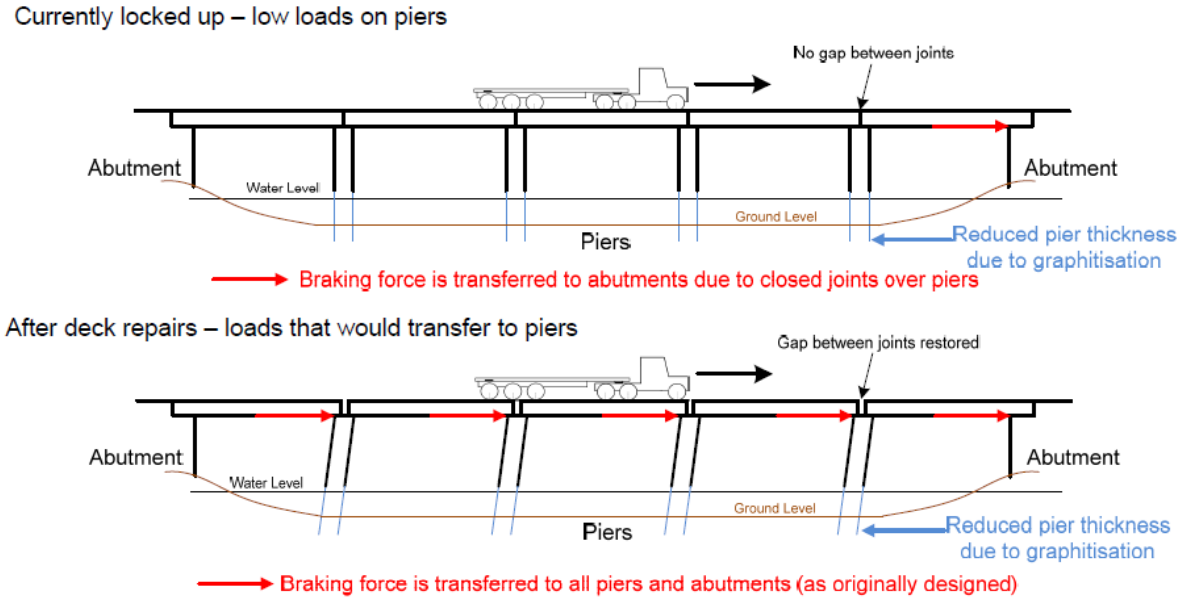
Windsor Bridge: The connection between the precast deck units and the pier headstocks is by way of dowelled connections. The 48mm dowels occur at each end of each girder of the deck units. No detail of the dowel connection between the precast panels and the headstock has been sighted. It is also noted that no bearings or bearing pads have been inserted between the precast units and the pier headstocks thus resisting any movements at the joints.

It would be helpful to have the RMS detail of the dowel joints.

From the diagonal cracking at the beam ends it appears the dowels are locked up. Cracks have been created by the restraint imposed by the dowels which has resisted the naturally occurring thermal movements associated with expansion & contraction.

Extent: Deck joints are in poor condition which can be clearly seen from photographs. Ironically it may be unwise to repair them to their original design as it would change the load transfer of forces (as mentioned above).

Currently as the joints are 'locked up' the forces from vehicle braking is transferred through the deck to the abutments and not transferred through the piers. (See reproduced RMS diagram below) [B5]



The braking load test undertaken on the bridge supports the theory that the bridge is locked up with negligible bending stresses recorded in the piers under the tests indicating that the horizontal forces are being shared by all the piers or being transferred to the abutments. This is fortuitous as the piers, which would otherwise transfer these braking loads, are in a condition whereby they may not be able to withstand the full braking forces (particularly Pier 5 which has significant circumferential cracking of its cast iron caisson).

Recommendations: In December 2003 the RMS Report [B4V1.3] recommended introducing compressed seal joints. RMS state that leaving the bridge 'locked up' has a number of risks. *"One of the risks is significant wide cracks at ends of beams originating from dowel bars connecting beams to pier headstocks. As a risk mitigation RMS is regularly monitoring these cracks"*

Actions to date:

No action has been taken to repair the joints. These repairs should not be done until the cracked piers (piers 5 and 6) have been repaired by providing them with a structural steel jacket as strengthening.

Is it still a condition that would warrant demolition of the bridge?

No, but the timing of repairing the joints could negatively influence the existing condition. It will be difficult to remove and replace the dowels as this will involve coring out the existing dowels and installing sleeves into the headstocks for the new dowels such that the bridge is able to move or rotate to avoid building up the stresses that cause the cracks. The process of coring may cause significant damage to the beams and headstock as it may of necessity cut through existing reinforcement. Other solutions should be identified and investigated such that an alternative load path for the induced forces on the dowels is created as part of the refurbishment works. This would remove the potential for further cracking at the dowels.

- **Gaps in documentation:**

More information on the existing jointing arrangements would be desirable.

- ***Cracking***

Basics: Cracking impacts on the integrity of the structure and its durability (cracks promote corrosion which undermines the structural strength and life of the structure)

Extent: Coinciding with the deck joints mentioned above concrete cracking has occurred at dowel locations in ~25 beam ends (roughly 16%). Cracking also occurs in the headstocks.

Recommendations: Repairs recommended in RMS Report from December 2003. [B4V1.3]

Actions: Maintenance records provided by RMS make no reference to crack repairs having been undertaken.

Is it still a condition that would warrant demolition of the bridge?

These by themselves do not warrant demolition of the bridge. However, if left untreated corrosion of the reinforcement at the beam ends will undermine the integrity of the structure.

- **Gaps in documentation:**

None

- **Overall Condition including cumulative effects of above deterioration**

The best way of assessing the cumulative effects of all the above deteriorations is through load testing. Performance load testing was carried out in August 2006 [B4V1.7] and *"concluded that the bridge in 'as is' condition is capable of carrying General access Vehicle (semi-trailer) St42.5 and Restricted Access Vehicle (B-doubles) BD62.5 in the short term until the planned replacement of the bridge…".*

In 2010 Inspection and Structural Assessment by UTS [B4V2.12] stated that *"If RMS intends to decommission bridge in the near future, bridge in its present condition and loading will be safe for some time."*

In February 2013 the RMS report [B4V2.16] on the performance of the bridge recommended *"the higher mass limit (HML) six axle articulated truck with maximum GVM of 45.5t (ST45.5) and HML nine axle truck with maximum GVM of 68t (BD68) be allowed to cross the bridge subject to the following conditions:*

- *Regularly monitor the graphitisation of pier columns*
- *Regularly monitor the bridge deck where spans are in poor condition*
- *Remove any spalled concrete which could be a danger to public"*

- **Gaps in documentation:**

Only as noted in the various subsections above.

- **Conclusion**

While the bridge is deteriorating from various ailments it is not about to collapse in the short term. Each ailment can be treated and this has been plainly demonstrated by RMS and others. However If left untreated the bridge condition would deteriorate and the bridge would eventually fail. It appears the RMS has left it untreated as a result of the recommendation in December 2003 to replace the bridge in 5 years. Ten years have elapsed since that decision and a new operational bridge could still be up to 5 years away. This raises concerns about the bridge integrity especially if the refurbishment of the fabric of the bridge is not carried out in the near future.

13. Interventions to arrest deterioration

A number of reports, tests and investigations have been commissioned each with specific recommendations for arresting the deterioration of the bridge have been produced (see Appendix B4). Recommendations have been made to deal with the major causes of deterioration, namely:

No	Cause of Deterioration	Date	Recommendation	Source	Ref [B4]	Comment
1	Carbonisation	Oct 2003	Re-alkalisation	GHD	V1.2	Not done. If done would be cost effective for 50 years. Should re-survey to determine rate of deterioration due to carbonation.
2	Graphitisation	Apr 2005	Cathodic protection	CTI	V1.5	Not done but see 4 below
3	Spalling	Jan 2010	Conventional patch repair & coating	RMS	V1.10	Only repaired where public safety risk exists
4	Pier Cracking	May 2011	Structural Analysis and jacketing	CTI	V2.15	Not done – but if done would effectively treat 2 above
5	Deck joints	Dec 2009	Installation of deck joints	GHD	V2.9	Not done

Interventions are notable by their absence since the recommendation to replace the bridge in 5 years was made by RMS in December 2003. In answer to the DP&I question [D6]: What, if any, interventions to the bridge have taken place to reinstate the fabric of the bridge in the last 10 years? Note: not maintenance but refurbishment tasks. RMS has responded *"No specific interventions have taken place to reinstate the fabric of the bridge, although activities such as removal of spalling continue as part of bridge maintenance."*

These major causes of deterioration continue unabated as there have been no interventions to arrest their advance despite many recommendations about actions that should be taken.

14. Maintenance

"The existing bridge needs to be replaced as its structural integrity is deteriorating with age and it is no longer cost-effective to maintain".

Past & Current maintenance activities: Evidence presented by RMS would indicate little has been done since the decision to build a replacement bridge.

- From the RMS maintenance reports it is clear that repairs were not being undertaken due to the impending replacement of the bridge. Example: Maintenance Inspection Report January 2009 states *"No repair required due to bridge replacement in the near future*". In July 2011 the inspection report states *"Due to the extra push for replacement now any RMA repairs to spalling HAVE NOT been listed"*
- From the RMS presentation [B5]: Slide 5 Windsor Bridge Management Strategy the Action: 2003-2013:RTA/RMS level 2 Inspections every two years indicates the Key Outcomes as:
    - Maintenance activities as per Level 2 reports
    - Level 3 inspection and structural assessment in 2003 [B4V1.2]
    - Removal of spalling concrete to minimise risk to public

It is noted that despite the BIS being in operation since 1994 no maintenance activity records have been presented for the period 2003 – 2013 leading to the conclusion that the

RMS decision that the bridge is due for replacement no maintenance activities should be performed on the bridge unless it is a risk to the public.

RMS Level 2 Inspection Records [B8] received indicate the following:

Element	Date of Inspection	Condition 1	Condition 2	Condition 3	Condition 4	Element Health Rating	Element Condition Index
Concrete Deck Slab	Aug 2002	1068				As-built	100
	Jan 2003	1068				As-built	100
	July 2005	1068				As-built	100
	Jan 2007	1018	25	25	0	Fair	97.7
	Jan 2009	1018	25	25	0	Fair	97.7
	July 2011	1018	25	25	0	Fair	97.7

Element	Date of Inspection	Condition 1	Condition 2	Condition 3	Condition 4	Element Health Rating	Element Condition Index
Concrete Pier Headstock	Aug 2002	335	0	15	0	Fair	97.1
	Jan 2003	335	0	15	0	Fair	97.1
	July 2005	335	10	5	0	Fair	98.1
	Jan 2007	335	10	5	0	Fair	98.1
	Jan 2009	335	10	5	0	Fair	98.1
	July 2011	335	10	5	0	Fair	98.1

Element	Date of Inspection	Condition 1	Condition 2	Condition 3	Condition 4	Element Health Rating	Element Condition Index
Concrete Reinforced Beam	Aug 2002	2330	40	20	0	Fair	98.9
	Jan 2003	2330	40	20	0	Fair	98.9
	July 2005	2330	0	40	20	Poor	98.0
	Jan 2007	2300	20	30	40	Poor	97.2
	Jan 2009	2300	20	20	50	Poor	97.1
	July 2011	2300	20	20	50	Poor	97.1

Conclusions from the above inspections are:

- From RMS Bridge Inspection Records the Reinforced Concrete Beams are the primary guiding element in determining the condition of the whole bridge. In 2003 these were rated 'fair' in the level 2 inspection with zero per cent categorised as Condition 4 'Advanced Deterioration'. In 2005 20m2 or 0.8% of the beam area reached Condition 4 and whole element was re-categorised as 'poor' as a result. In 2007 40m2 or 1.6% reached Condition 4 and by 2009 50m2 or 2.1% was categorised at Condition 4. The last report received in July 2011 has maintained that 2.1% is at Condition 4. It is difficult to accept that the condition of the whole bridge is rated as

poor based on a 'poor' rating for the RC beams due to only 2.1% being in an advanced deterioration state.

- RMS in the "Concrete Damage Model – Carbonation" indicated that by 2009 10.5% of the surface would be damaged [B5]. The model clearly presents a pessimistic outlook when compared against the actual inspection results.

Maintenance Expenditure

- RMS advises in answer to DP&I questions that maintenance activities on Windsor Bridge between 1994 and 2002 totalled $57,347[D16]. [Average $6371.89 per year or $6.10/m2/year]. Since then RMS has advised on spall removal on 30 Nov 2009 costing $1021 and collision damage repair on 30 April 2010 of $3032.
- RMS have provided maintenance history in document entitled "Routine Maintenance Windsor Bridge 1994 – 2001" in which the total maintenance cost is $83,994.42 [average $10,500/year or $10.06/m2/year] with a "payment still required of $75,663.21" which doesn't appear to have been spent as there is no date completed against the items [B8]. Note this amount doesn't align with advice given in the dot point above. As this latter response is more detailed I will assume it is correct.
- The Grants Commission received information from the RTA in 2008 that the "annual maintenance cost RTA bridge structures is $19.70/m2. Total program expenditure figures for 2008-09 indicate total bridge expenses averaging $45.26/m2". This would confirm that even before the decision to replace the bridge was made that the RTA was not spending anything like enough ($10.06/m2/year) on the routine maintenance of Windsor Bridge.
- There is no evidence that the change of status (listing on the s.170 register of the Heritage Act 1977) changed the approach to maintenance of the bridge particularly reinforced by the obvious neglect of maintenance.

Estimates of future maintenance tasks. RMS provided a table of projected maintenance costs at the meeting of the 16th May 2013 over the next 25 and 50 years. Discounting routine maintenance activities (mill and re-sheet; routine inspections by boat) which should take place no matter what structure is there the following expenditures were determined from RMS data:

Activity	Comment	Cycle	After 25 years	After 50 years
Anti-carbon+wet jet		10	$1,060,127	$3,616,848
Re-alkalisation	Done in year 0	50		
Concrete patching		10	$3,245,286	$11,071,987
Dowel joints		35		$3,686,645
Scuppers		25		$266,596
Total (Future Value)			**$4,305,413**	**$18,642,076**
Equivalent maintenance expenditure per square metre of deck per year				
Rate per m2/year	Future dollars		$165/m2/year	$714.32/m2/year
In today's dollars	NPV@4%		$1,614,877	
Rate per m2/year	**Today's dollars**		**$61.88/m2/year**	See note below

NB: Based on Bridge deck area 1043.9m2

Peter Stewart Consulting Pty Ltd P.O.Box 163, Pymble, NSW 2073 (02)98809552

Summary:

- Proposed spend over the next 25 years is $61.88/m2/year in today's dollars
- Recent maintenance expenditure (over the years 1994 to 2001) was equivalent to $10.06/m2/year.[B8]
- From 2001 to 2013 this has dropped to be almost negligible (RMS have not provided any records of maintenance costs for the period 2002 to 2013)
- If indeed RMS retained the ownership of the bridge they would need to spend significantly more than they are doing at present to prevent the structure deteriorating to a point where it self-destructs.[D11 and D12]
- One cannot help deduce that the proposed maintenance spend is presented to support the argument that the bridge is not cost effective to maintain. History shows that RMS does not spend anything like this amount on the bridge.
- Certainly if appropriate routine maintenance was being applied the current state of severe deterioration would not be evident.

    - **Gaps in documentation:**
    - Maintenance records from 2003 to 2013
    - Information on how State Significance of this structure impacted maintenance activities

15. Practical Refurbishment Methods

"Elements of the bridge have deteriorated substantially and RMS has assessed that it is not practical to replace or repair these elements"

Practical is defined in the Collins English Dictionary to be:

1. Of, involving, or concerned with experience or actual use; not theoretical
2. Of or concerned with ordinary affairs
3. Adapted or adaptable for use
4. Of, involving, or trained by practice
5. Being such for all useful or general purposes; virtual

The most appropriate in the context of rehabilitation of the existing Windsor Bridge is a combination of 1 and 3 being a solution which is feasible, realistic and pragmatic.

RMS definition of practical relates to 'cost effectiveness' and the 'poor level of service' [D1 and D2] rather than the dictionary understanding of practical in regard to the rehabilitation solutions. They also cited the disruption due to the partial closure of the bridge during rehabilitation activities.

We have two methods to rehabilitate the bridge but by RMS' definition these solutions are not 'practical' by way of cost effectiveness and level of service.

The two repair methods are not comparable as they do not provide a structure capable of carrying the same loads or providing the same 'level of service'. Some of the comments made by RMS re the alternative method are not valid because the two different repair methods are trying to achieve different objectives.

This raises the question as to what is the objective of the refurbishment.

- **Refurbishment Objective**

The objective should be to refurbish the existing bridge for alternative local uses assuming there will be a new bridge meeting current standards for heavy loads and through traffic.

Various suggestions have been made:

1. RMS Durability Investigation Report Jan 2010 [B4V2.10] quoted *saying "RTA is considering maintaining the bridge for pedestrian use"*
2. ex RTA State Chief Bridge Designers proposal along with enhancements proposed by the Technical Review would be load limited to <20tonne as the proposal would only provide a load factor of 1.87 on current traffic loadings (42.5t semi-trailers and 62.5t B-double vehicles) [B12]
3. RMS proposal which proposes strengthening to provide the required load factor of 2 for current legal maximum loads or the T44 standard.

On this basis the comments on the refurbishment options are:

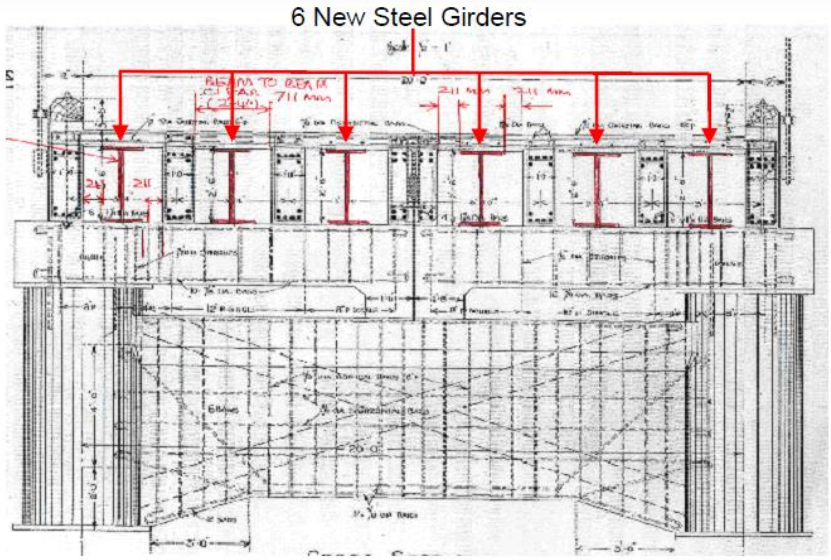
1. The RMS refurbishment would provide a structure capable of complying with all the latest standards and load factors even though a new bridge is to be constructed mainly for the through traffic. In other words it would include refurbishment & strengthening. This seems wasteful at best considering a new bridge will be built at some stage.
2. The Alternative (ex RTA State Chief Bridge Designers) refurbishment would provide a structure capable of a lighter loading more suited to local traffic and certainly assumes a new bridge will be constructed. This proposal would return the bridge to 'as new' condition with a load factor of 1.87 based on current loading (42.5t semi-trailers and 62.5t B-double vehicles)
3. For code compliance (load factor=2) the precast beams need to be enhanced for bending strength and this could be done using carbon fibre laminates bonded to the beam soffits, subsequent to repairing all spalling and re-alkalisation for treating carbonation.
4. The bridge may be retained for a lesser loading (local traffic, pedestrians etc.) and RMS have advised that the bridge could be refurbished to meet light traffic loading (<20tonnes). This would be acceptable if a comprehensive risk management strategy is put in place.
5. RMS advised that rehabilitation (without strengthening for T44 loading) would cost around $14m (2011 dollars) [D10].
6. If this amount is spent on the bridge now then there will only be routine ongoing maintenance.
7. The repair method should be such that the heritage is still preserved and visible and not concealed otherwise the heritage value is lost.

- **Review of Proposed Methods:**

Review whether proposed methods of repair are 'practical'

- **RMS method**

[Method Statement Pg. 3 Rehabilitation Report][B4V1.6]



- This method requires the closing of one lane for the duration of installation of steel beams as lifting and access points are required in the deck.
- This method requires considerable work at height which is a safety issue.
- Steel beams would be installed in sections requiring two splices per span which are made from below the existing deck. Splice design would need careful consideration as external top flange splice plates would be undesirable as they could become load concentration points. This is due to the tight tolerances associated with this method.
- Beam splices would need to be made at height in a tight clearance and
- Such that the top flange bears continuously under the deck soffit (Sketches show steel beam is a tight fit over the headstocks (approx. 60mm clearance)…leading to concerns about how the gap between the beams and the deck will be grouted using the stated method).
- Jacking the deck off the beam will be difficult to achieve the desired load distribution between the concrete beams and steel beams.
- Maintenance of the concrete deck becomes even more problematic as access is heavily restricted by the steel beams.
- This method whilst possible is not very practical and will cause significant impacts to the traffic and long term maintenance.
- A full constructability assessment will reveal better less intrusive methods of achieving this repair method. For example there are ways to install the steel beams which would not require closing half the road.
- This method has not been considered further as it is not deemed necessary to strengthen the existing bridge to meet current standards when a new bridge is proposed.

Peter Stewart Consulting Pty Ltd P.O.Box 163, Pymble, NSW 2073 (02)98809552

- **Alternative method (ex RTA State Chief Bridge Engineers)**
    - RMS commissioned a Technical Review of the Alternative Refurbishment Methodology [B3] which addressed amongst other things the practicality of the proposed Alternative method
    - This method relies upon undertaking the majority of the work from below the deck using a fully equipped barge.
    - This review stated "*The proposal to rehabilitate the Windsor Bridge using steel jackets and deck concrete patch repairs is considered technically viable provided future maintenance is undertaken"*
    - The review made a number of recommendations (pg. 13 of the report) which would make the proposal acceptable but more costly than originally anticipated. These should be adopted along with the option to patch & repair plus re-alkalisation should be adopted to extend the life beyond 50 years.
    - New scupper arrangements are required to prevent water splashing onto the precast deck beams
    - This method requires only minor traffic impacts involving short closures during off peak times (e.g. for Deck joint repairs and waterproofing during night closures)
    - This method could be enhanced if the load factor of 2 is required for current legal loadings through using carbon fibre strengthening in conjunction with re-alkalisation of the deck concrete.

- **Impact on heritage of repair methods**
    - RMS method
        - Will have noticeable impacts on the heritage value of the structure which would be mainly visual (Primarily the steel beams and to a lesser extent the pier jackets)

    - Alternative method
        - Will have minor impacts on the heritage value of the structure which would be mainly visual (Pier jackets only just above low water level).

These are two different methods proposed are constructible although the RMS approach is more complex and has greater impacts than the Alternative. They are, to different degrees, practical and hence not a reason to demolish the bridge. Being practical doesn't mean that they are easy to construct or indeed that they have no impacts on various stakeholders.

The decision to replace the bridge made in 2005 coincides with the approach not to spend any more money on a bridge that is assumed will be demolished.

Peter Stewart Consulting Pty Ltd P.O.Box 163, Pymble, NSW 2073 (02)98809552

- **Gaps in documentation:**

The design and construction methodology of the RMS option appears to have not been given a lot of thought as little or no basic design or methodology has been provided.

16. Refurbishment Cost

It is worth analysing the latest cost estimates pertaining to the Refurbishment to permit loading <20t with minimal ongoing maintenance.

On the 18th April 2013 RMS presented a slide (24) of refurbishment costs [B5]. RMS indicated that, excluding the steel beams, this represented a minimum cost to refurbish the bridge no matter whether it is used for pedestrians or local traffic. This is summarised in the table below:

Item No	Item Description	Source	Quantity	Cost in May 2005	Comment
1	Deck joints, deck slab & beam repairs, deck drainage, sealing of deck surface	GHD Repair cost estimate February 2005 [B4V1.4 Appendix A]		$394,650	
2	Repairs and re-alkalisation of concrete, protective coating & access/temp works		Spall repair 300m2 Re-alkalisation 2360m2	$1,576,600	$400/m2
3	Repairs to diaphragm walls		42m2	$126,000	
4	Repairs to steel bracings			$33,500	
5	Miscellaneous items			$31,000	
6	Strengthening cast iron piers with jacketing	RTA Bridge Section Report May 2005 [B4V1.6]		$3,600,000	Estimate. See note 2 below.
7	**Sub total**			**$5,761,750**	
8	Design & Project Management	[B5]	30%	$1,728,525	
9	Contingencies	[B5]	40%	$2,304,700	
10	**Total in 2005 dollars**			**$9,794,975**	**$9,383/m2** See Note 1 below
11	CPI factor from 2005 to 2013	Rateinflation.com	1.277	$2,705,025	
12	**Total in 2013 dollars**		**1043.9m2**	**$12,500,00**	**$11,975/m2**

Comments:

1. This is not an unusually large expenditure to refurbish a bridge if you compare with other bridge structures [D4] around the state that RMS have refurbished in recent times such as
    a. Swansea ($10,059/m2 between 2007 and 2012);
    b. Hinton ($8,696/m2 between 2004 and 2010) and
    c. Junction ($15,808/m2 in 2006).

2. Based on these figures it would not be cost prohibitive to refurbish the bridge, thus not a solid justification to demolish it.
3. RMS Bridge Section Internal memo estimate for 'pedestrian use' in February 2010 was $12m in 2010 dollars which compares favourably.[B4V2.11]
4. Pier Jackets. The RMS figure is purely an approximate cost estimate based on experience [B4V1.6pg6] and not on the latest RMS standard estimating practice or market rates. Arenco who compete in the market place have costed the supply & installation of steel plate jacketing of the piers in Sept 2012. This was based on providing 20no 3.35m average length jackets (37.3tonnes). The Technical Review [B3] commissioned by RMS suggested some enhancements to the proposal increasing the jacket lengths such the toe would be 0.5m below river bed level and the top just above low water mark. This would increase the jacket length to 5.5m average so that the steel jacket tonnage increases to 75 tonne. The annulus was to be grouted (11.4m3). These are considered sound suggestions. Arenco's original quote was for just under $1million for the jacketing. With the design enhancements this increases to $2.1 million taking into account the extra jacketing and grouting. Some of the allowances for design, environmental protection and containment etc. seem light. However these are assumed to amount to 20% ($420,000). The contingency for marine work should be closer to 60% so this adjustment is included as well. This has not been added to the RMS estimate as it is judged to be very conservative in the first place. Table below summarises comparison between RMS and adjusted costing based on Arenco costing of the pier jackets:

Item Description	RMS Jacket Cost	Price adjusted
Supply & Install Jackets	$3,600,000	$2,100,000
Environmental as above	included	$420,000
Sub total		**$2,520,000**
RMS Costs	$50,000	$50,000
Design & Project management 30%	$1,080,000	$756,000
Contingency 40%	$1,440,000	
Contingency 60%		$1,512,000
Total	**$6,170,000**	**$4,838,000**

This difference of $1.3m would indicate the overall refurbishment has every opportunity of being delivered for around $11 million which is not exorbitant.

If the objective is to refurbish and strengthen the bridge to provide sufficient level of service for a T44 loading with a factor of safety of 2 then there is time to re-evaluate the optimum alignment for the bypass. To refurbish and strengthen (carbon fibre strips) the bridge to carry T44 loading may be the optimum option and can be achieved for approximately $14.5million. This would provide an operational life of between 25 and 50 years.

17. Flood damage

"Also if a new bridge was to be constructed downstream of the existing bridge, retaining the existing bridge would not be possible due to the risks of its failure during a flood event. Debris from the failed bridge may cause physical damage to the piers of a new downstream

bridge or may become caught in the new bridge, damming floodwaters and putting unacceptable stresses on the structure of the new bridge."

- Review potential for damage to new bridge if existing bridge retained
    - Should not be a concern if the existing bridge is maintained properly after refurbishment to 'as new' condition
    - Only a concern if maintenance is not adequate

Note that in 100 years the bridge has been overtopped in floods 64 times [D7] without structural elements being severed to cause downstream damage.

18. Heritage value

EIS proposes in 7.1.5: "*The 1874 bridge will be dismantled in a manner that allows its construction methods and evolution to be appropriately documented as an archival record prior to, and during its demolition."*

The specific key elements of the existing bridge with heritage significance are:

- Precast Reinforced Concrete Beams (Earliest use of precast concrete girders in NSW and is unique)
- Cast iron caissons designed to resist the severe flooding (first use in a road over river crossing as previously only used in railway bridges)
- Elements used to raise the deck 2.4m
- Methodology involving maintaining the trafficability of the bridge during construction of the precast deck

- This is a heritage landmark that contributes to the social & economic life of Windsor. It would be a great loss to demolish this state significant structure. However if the decision is made to demolish then it is paramount that these key heritage aspects are preserved in a way that the people of Windsor and visitors to Windsor can continue to appreciate and enjoy long into the future.

19. Response to the Issues

- Demolish
    - Scrap completely and keep archival record
    - Keep one span by retaining the end span adjacent to Windsor and demolish the rest of the bridge after making appropriate archival records.
    - Keep one span & erect on land as record of heritage after making appropriate archival records
    - Keep key heritage elements of bridge and display on land appropriately after making appropriate archival records
- Retain
    - Upgrade to meet current standards (assumes no new bridge is required)
    - Refurbish to carry loading for local traffic, pedestrians & cyclists (separate local and through traffic) say 16 tonne
    - Refurbish and strengthen (Carbon fibre process) for T44 loading

Peter Stewart Consulting Pty Ltd P.O.Box 163, Pymble, NSW 2073 (02)98809552

20. Requirements of the brief

Requirement of the brief	Major points to note	Conclusions
Review the appropriate documentation provided by the Department with regard to relevant engineering guidelines, industry standards and legislation.	• Relevant Documentation has been received from DP&I • The documents have been reviewed in regard to engineering guidelines, industry standards and legislation as appropriate	This requirement has been satisfied
Meet with Department representatives, proponent's/council/agency experts as necessary.	Several meetings have been held with DP&I and RMS	This requirement has been satisfied
Undertake a site visit	Site visited on 23rd April 2013	This requirement has been satisfied
Provide the Department written advice on the: • adequacy of the documentation, and if necessary, identifying gaps in the documentation;	Where gaps in documentation have been identified questions have been submitted to the Department for a response, either from the Department or RMS.	This requirement has been substantially satisfied
Provide the Department written advice on the: • adequacy and/or suitability of the proposed mitigation and/or management and/or protection measures if required;	Advice has been provided to the Department on the suitability of the proposed management measures by way of this report	This requirement has been satisfied
Provide the Department written advice on the: • assessment of the significance of the engineering impact	Advice has been provided to the Department on the significance of the engineering impact by way of this report	This requirement has been satisfied
Provide the Department written advice on the: • suggested remedial actions for the engineering issues identified	Advice has been provided to the Department on suggested remedial actions for the engineering issues by way of this report	This requirement has been satisfied

Peter Stewart Consulting Pty Ltd P.O.Box 163, Pymble, NSW 2073 (02)98809552

Requirement of the brief	Major points to note	Conclusions
Conduct peer reviews of other service providers work if required	Not required	
Verify the justifications for demolition of the existing Windsor bridge are valid	Assessment of the justifications for the demolition of the existing bridge have been done and presented in this report.	This requirement has been satisfied
Ascertain whether the conclusions can be supported	Assessment of the conclusions and whether they can be supported has been done and presented in this report	This requirement has been satisfied
Assess what options are available	Assessment of the available options has been done and presented in this report	This requirement has been satisfied
Assess what heritage items are worth preserving	Assessment of the heritage items worth preserving has been done and presented in this report	This requirement has been satisfied

21. Key outcomes and conclusions

The condition of the existing bridge is such that it is not in a dire condition and could relatively economically be refurbished and strengthened. However, it is in danger of accelerated deterioration though neglect of maintenance. It is not proposed to refurbish & strengthen the bridge to carry the future traffic volumes & loads and hence meet the RMS desired level of service, standards and specifications. It is assumed that a new bridge will provide for the future needs. Refurbishment/strengthening options would permit alternative uses for the existing bridge. So the remaining options for the existing bridge are:

1. Refurbish to a condition & retain existing bridge for pedestrians and cyclists only and/or retain for Sunday morning markets as well as for pedestrians and cyclists
2. Refurbish to 'as new' condition & retain existing bridge for local traffic only (with 16 tonne weight restrictions applied)
3. Refurbish and strengthen (Carbon fibre process) for T44 loading with a compliant load factor of 2.

It appears the optimum option is some combination between the RMS and the Pearson Wedgewood options which will be able to provide a viable option (3 above) for the next 25 to 50 years and hence not build a new bridge at this stage. Then at some time in the future a bypass can be built which avoids all the damage to property, heritage values etc. So with a relatively modest expenditure the bridge can be serviceable for the next 50 years within which time an alternative route will have been identified and agreed.

Peter Stewart Consulting Pty Ltd P.O.Box 163, Pymble, NSW 2073 (02)98809552

22. Appendices

- **Appendix A: Glossary of terms**

Term	Meaning
Abutment	The end support of a bridge
Access	The driveway by which vehicles and/or pedestrians enter or leave property adjacent to a road
Beam seating area	The area on a headstock upon which the beam sits
Bridge Deck	The surface of the bridge including road and pedestrian/cyclist pathway
Bracing	Steel members used to brace or support the main structure
BIS	Bridge Information System
Caisson	A caisson is a watertight retaining structure used for the foundations of a bridge pier and is normally cylindrical.
Carbonation of concrete	Carbon dioxide in the air diffuses into concrete and reacts with alkalis within the concrete. This leads to corrosion of embedded reinforcement in the concrete which then expands causing the bridge concrete to bulge and crack.
Compressed seal joints	This is a type of joint installed in the deck surface to permit expansion & contraction of the bridge deck
Concrete	A mixture of fine and coarse aggregate, water, cement and admixtures.
Condition Categories	See Appendix B6 for RMS description of condition categories
Constructability assessment	Review of the construction method to optimise time, cost, safety and other key indicators.
Contingencies	An allowance for the unforeseen or unpredictable depending on the level knowledge of the project details at the time.
Deck Joints	Joints are installed in the deck surface to permit expansion & contraction of the bridge deck
De-laminated concrete	A form of deterioration of concrete caused by corrosion of reinforcing steel. The corroded steel expands thus cracking the concrete and causing it to separate in laminations or thin slices.
Design Standard	Identified particular standards used in the design
Dowel joints	This a form of expansion/contraction control at a structure joint. These control the point from which expansion/contraction occurs.
EIS	Environmental Impact Statement
Foundation	The soil or rock upon which a structure rests
Girders	A type of support beam
Graphitisation	Leaching of cast iron in slightly acidic water which leads to corrosion & weakening
Headstocks	A structure that sits on top of bridge piers that supports the bridge deck and superstructure.
In situ	An operation carried out on a material in its final position
Inspection Levels	RMS Maintenance Inspections. See Appendix B6 for RMS description of inspection levels.
Level of service	A qualitative measure describing operational conditions within a traffic stream and their perception by motorists and/or passengers
Locked up joints	Joints which for various reasons are not able to move as originally intended in response to expansion/contraction or braking forces.

Peter Stewart Consulting Pty Ltd P.O.Box 163, Pymble, NSW 2073 (02)98809552

Maintenance	Performing routine actions which keep the structure in working order (known as scheduled maintenance) or to prevent trouble from arising (preventive maintenance).
Pier	An intermediate support in a bridge having more than one span. Part of the substructure supporting the superstructure and transferring the loads to the foundations
Pier Diaphragms	Concrete structure to transfer or distribute loads from the deck to the piers
Re-alkalisation	Re-alkalisation is a method of restoring the natural alkalinity in concrete to halt steel reinforcement corrosion. This is achieved by increasing the concrete pH level to a value greater than 10.5 which is sufficient to restore and maintain a passive oxide film on the steel.
Refurbishment	The state of being restored to its former condition (as new). To restore to good condition, operation, or capacity
Rehabilitation	The state of being restored to its former condition (as new). To restore to good condition, operation, or capacity
Reinforced Concrete	Concrete strengthened within its mass by reinforcing steel bars, mesh or steel fibres.
Reinforcement	Bars, or mesh, usually steel, embedded in concrete for the purposes of resisting particular stresses e.g. tensile, temperature related etc.
RMS	Roads and Maritime Services NSW (formerly Roads and Traffic Authority)
RTA	(former) Roads and Traffic Authority (now RMS)
Scupper	An opening to allow drainage of water
Steel Jackets	Fabricated steel jacket to reinforce the damaged pier caissons by wrapping around the pier like a collar.
Section 170 register	A register established in accordance with section 170 of the Heritage Act 1977 to record all heritage items in the ownership or under the control of RMS (or other state government agencies)
Soffit	The underside of the bridge deck
Spalling	Natural deterioration of concrete due to carbonation
Span	The distance between centres of adjacent supports of a bridge
Substructure	In a bridge, the piers, headstocks and abutments (including wing walls) which support the superstructure
Superstructure	The part of the bridge structure which is supported by the piers, headstocks and abutments.

- **Appendix B Documentation**

1. Windsor Bridge Replacement Project Environmental Impact Statement Volume 1- Main Report. Nov 2012
2. Submissions CD containing submissions 1 to 94 plus Agency submissions
3. RMS Submissions Report April 2013
4. RMS Bridge Rehabilitation Reports Volumes 1 and 2
5. RMS Presentation: Bridge over Hawkesbury River at Windsor 18th April 2013
6. RMS Responses to comments raised by DP&I's Independent bridge condition review 16th May 2013 (see Appendix D) including RMS Bridge Inspection Policy appendices C and D and Inspection Levels
7. RMS response to Windsor Bridge DPI comments 17th May 2013
8. RMS Attachment A Routine Maintenance Records 1994-2001 Windsor Bridge 17th May 2013
9. RMS Ongoing OM DPI response sent 21st May 2013 on Maintenance Costs
10. A New Approach to Durability Design Using Risk Analysis by Dr Phil Bamforth Nov 1998
11. Marrickville Report on Upgrade of Wardell Road Bridge over Cooks River, Dulwich Hill, NSW
12. Email from Ray Wedgwood 29 May 2013

Items 1 to 3 may be accessed through the Department of Planning & Infrastructure website:

http://majorprojects.planning.nsw.gov.au/index.pl?action=view_job&job_id=4951

Items 4 to 12 are attached by way of a memory stick

- **Appendix C Invitation to Tender**

NSW GOVERNMENT | Planning & Infrastructure

Contact: Contracts Team
Phone: 02 9860 1518
Fax: 02 9895 7670
Email: slrmail@planning.nsw.gov.au

11 FEB 2013

File: 13/02614

Mr P Stewart
Peter Stewart Consulting
6 Karoo Ave
East Lindfield NSW 2070

peter@peterstewartconsulting.com.au

Dear Mr Stewart

DoPI 2013/54 Invitation to Tender: Windsor Bridge Engineering Analysis Project

The Department of Planning invites your organisation to tender for the above project. Essentially, the services of a suitably qualified and experienced service provider are required to provide expert advice in the field of engineering analysis to review relevant sections of the Windsor Bridge project.

Scope of Work

1. Review the appropriate documentation provided by the Department with regard to relevant engineering guidelines, industry standards and legislation.
2. Meet with Department representatives, proponent's/council/agency experts as necessary.
3. Undertake a site visit
4. Provide the Department written advice on the:
   - adequacy of the documentation, and if necessary, identifying gaps in the documentation;
   - adequacy and/or suitability of the proposed mitigation and/or management and/or protection measures if required;
   - assessment of the significance of the engineering impact; and
   - suggested remedial actions for the engineering issues identified
5. Conduct peer reviews of other service providers work if required

This project will be undertaken on a time and expenses based contract. Would you please provide a tender which includes up to 75 hours work to be undertaken over a five month period up until 30 June 2013.

Tender Requirements

Your organisation is invited to provide a written tender (an email response with attachment is acceptable) to perform the above scope of works. The tender should include a completed *Value of Financial Offer form* (template attached) summarising your tender price and if successful, your organisation will be engaged under the Corporation's *Professional Services Contractor Agreement* (template attached).

23-33 Bridge Street, Sydney NSW 2000 or GPO Box 39, Sydney NSW 2001
Tel (02) 9860 1518 Fax (02) 9895 7670 Website: www.planning.nsw.gov.au ABN 38 755 709 691

Would you please ensure the tender is provided on company letterhead (with ABN identified), is dated and contains the following:

1. a signature from an authorised representative from your organisation
2. the timeline or program for deliverables
3. copies of current Insurance Certificates of Currency for the insurance categories and amounts specified overleaf
4. confirmation your organisation agrees to be engaged under the Corporation's *Professional Services Contractor Agreement*
5. a completed Conflict of Interest declaration
6. a completed *Value of Financial Offer Form* which provides the following details:
   - an upper limiting fee (inc GST) for the project
   - the number and type of meetings costed in the tender
   - a breakdown of hourly rates per task
   - the hourly rates payable to the person/people proposing to undertake the work
   - the cost per person per task
   - the position/role of the person/people proposing to undertake the work; and
   - details of any disbursements sought.
7. a Safety Work Methods Statement satisfying Occupational Health & Safety requirements

Insurance Certificate of Currency Requirements

- Workers Compensation
- Public Liability – a minimum of **$10m**
- Professional Indemnity – a minimum of **$5m**

Please forward your tender to slrmail@planning.nsw.gov.au by **10am on Thursday 14 February 2013.**

If you require clarification of any the above information, please contact the Contracts team on slrmail@planning.nsw.gov.au or on (02) 9860 1518.

Yours sincerely

Lyn Corkett
Contracts Management Coordinator

Attachments

- ***Conflict of Interest Declaration***
- ***Professional Services Contractor Agreement template***
- ***Value of Financial Offer Form template***

23-33 Bridge Street, Sydney NSW 2000 or GPO Box 39, Sydney NSW 2001
Tel (02) 9860 1518 Fax (02) 9895 7670 Website: www.planning.nsw.gov.au ABN 38 755 709 681

- **Appendix D Questions & Answers**

Bridge Engineer Issue	RMS Response
1. From EIS Volume 1 Section 1.1: Please explain the fundamental statement behind the need to demolish the existing bridge "…and it is no longer cost effective to maintain" [note: no evidence received in regard to maintenance tasks or their cost].	Bridge deterioration is discussed in Section 3.2.1 of the EIS and Sections 2.15.3 of the Submissions Report/PIR. Further information (including complete copies of investigation reports) have been provided to the Department separately and in responses to the Department's general questions on 6 May 2013, with summaries of each report provided in Appendix G of the Submissions Report/PIR. RMS formed the view that it is no longer cost effective to maintain the existing bridge based on its demonstrated poor condition, the substantial cost to rehabilitate the structure to ensure it is able to be maintained, and the resulting poor level of service that the structure would provide into the future (not meeting current standards and T44 design loading). In respect of pure maintenance costs, additional information will be provided separately to the department.
2. From EIS Volume 1 Section 1.2 Page 2 Second paragraph: Please justify the statement that "…RMS has assessed that is not practical to replace or repair these elements" when indeed there are at least two practical solutions described (one by RMS and one by Ray Wedgewood & Brian Pearson.	There are a number of feasible rehabilitation methodologies that were considered for the bridge, however RMS assessed that rehabilitation is not practical for the same reasons as those identified above, as well as other factors such as the need for total or partial closure during rehabilitation.
3. From EIS Volume 1 Section 4.1.4 Page 34 Disadvantage #2: Damage to replacement bridge should existing bridge fail in a flood event. Assuming the existing bridge is refurbished and properly maintained explain how this event could happen.	The existing bridge, proposed around 35 metres upstream of the new bridge, would comprise an additional waterway obstruction during flood events. Depending on the magnitude of flood there is a risk of very high debris loading on the existing bridge which could, in turn, have possible adverse effects on the new bridge. Even if the existing bridge is refurbished some level of risk would still remain. There are few examples of bridges being washed away in flood events. One such example is the Bridge over Page River at Gungy which was washed away around 2000.
4. The following details are requested for the Swansea, Junction and Hinton Bridges that have undergone refurbishment works: a) Nature of refurbishment works; b) Cost of refurbishment works (total cost and cost per m^2); and c) Duration of refurbishment works.	A detailed response to this can be found in the attachment.
5. The above information should also be provided for Marrickville Council's bridge over the Cooks River which was discussed at our recent meeting (18/4/13).	RMS has limited information about this bridge (which is not an RMS asset) beyond the information provided in the presentation. Marrickville Council should be contacted for more detailed information. (Suggested contact David Matheson – Coordinator Civil Works 8595 2454)

Bridge Engineer Issue	RMS Response
6. What, if any, interventions to the bridge have taken place to reinstate the fabric of the bridge in the last 10 years? Note: not maintenance but refurbishment tasks.	No specific interventions have taken place to reinstate the fabric of the bridge, although activities such as removal of spalling continue as part of bridge maintenance.
7. How often has the bridge been closed due to flooding in the last 100 years?	The bridge has been closed 64 times with the most recent closure in February 2012
8. How many underwater inspections have been taken after these floods? Please provide details of who did the inspection and when? Only one has been cited.	One - after the 2012 flood. The inspection report was provided as part of the earlier package provided to the Department.
9. What year did RMS first identify the cracks in the piers?	2011
10. If a new bridge is to be built for the majority of through traffic and the existing bridge is to be retained, why should the existing bridge need to meet current loading standards? If not, to what standard should/could the bridge be refurbished to?	The bridge could be refurbished to meet light traffic loading (<20 tonnes) or could be strengthened to meet T44 standard. The former could continue to carry only light traffic and/or pedestrians and cyclists. The latter would allow longer/heavier vehicles. While the cost of refurbishing and strengthening the existing bridge was estimated to be around $18M in 2011 dollars, rehabilitation without strengthening could be undertaken for around $14M (2011 dollars). (These costs would have escalated to around $20M and $15M for 2013, respectively). Both would require ongoing operation and maintenance costs. Further details on operation and maintenance costs will be provided separately to the Department.
11. Who will own and maintain the existing bridge if it is retained?	RMS would seek to have the local council own and manage the asset.
12. If it is to be retained will RMS rehabilitate it at their cost, to meet RMS standards, before handover to the new owner?	This would be subject to future management arrangements and operating standards. Funding has not been allocated for the rehabilitation of an orphan structure
13. Why are illegal loads being allowed across the existing bridge if it lowers the load factor?	Illegal loads are not allowed on the bridge. A decision was made in 2003 to continue with General Access Vehicles (ST42.5) and Restricted Access Vehicles (BD62.5), and in 2011 to allow Higher Mass Limits (ST45.5 and BD68) subject to a range of measures including: · A detailed inspection and monitoring regime · Measures to ensure over mass and oversized vehicles do not cross the bridge
14. Please advise the details of a Level 2 inspection and a Level 3 inspection.	RMS' bridge inspection regime includes four levels of inspections. An extract of the RMS Bridge inventory, inspection and condition rating policy is attached providing detailed information on each.
15. Please advise maintenance activities from the database created in 1994 onwards. Particular reference should be made to spall removal & repair (quantify) and other repairs to the fabric of the bridge.	Records of these maintenance activities were provided in Attachment A of the package of RMS responses to the Department's general questions (provided on Monday 6 May). There is limited available information on RMS' bridge information system, however spalling removal is known to have cost $1021 on 30 November 2009 and collision damage repair on 30 April 2010 cost $3032.

Bridge Engineer Issue	RMS Response
16. Please advise costs for the maintenance activities undertaken from 1994 to present.	As discussed in responses to DP&I comments made on 6 May 2013, maintenance costs for particular assets on the RMS database are only available until 2002 at which point the system began recording on a region/area basis. From 1994 until 2002 maintenance activities for Windsor Bride totaled $57,347.
17. Has RMS considered a solution where the deck joints are permanently 'locked up' such that the braking loads are transferred to the abutment?	This has not been considered by RMS and is not considered to be a practical design solution or possible to design for. Currently the bridge is operating with the joints **'**locked up**'** but this has number of risks. One of the risks is significant wide cracks at ends of beams originating from dowel bars connecting beams to pier headstocks. As a risk mitigation RMS is regularly monitoring these cracks.
18. Please confirm that graphitisation was first identified in 2005 by CTI	Confirmed
19. Please confirm cracks in some cast iron piers were first identified in 2011 by CDS	Confirmed
20. Please provide a source for the Concrete Carbonisation Damage Model	Bamforth P, 1998 *New approach to durability design using risk analysis*, Concrete Institute, Perth
21. Please advise in regard to the steel beam strengthening how this will reduce maintenance activities. (Steel beams are difficult to access and the concrete beams become harder to access).	The steel beam option is for strengthening the bridge to carry T44 design load and not for reducing maintenance activities. However this option is easy to construct and would be more cost effective to maintain in comparison to a concrete alternative as it has been established that the deterioration of bridge deck is due to carbonation of concrete.
22. Re-alkalisation options were discussed at a meeting with RMS on 10 May 2013	During the meeting RMS and the Department discussed re-alkalisation options considered by RMS including the total area of bridge proposed for re-alkalisation. The Department questioned whether re-alkalisation could be undertaken on more of the bridge than currently proposed and whether this would reduce the ongoing maintenance costs. The re-alkalisation option considered by RMS is applicable only to concrete girders and headstocks (at a total surface area of 2400 sq. m approximately). This area is about 85% of the total surface area of the girders and headstocks. Once this is done, it is considered that there will be no further concrete patching required in the future and no further re-alkalisation required for the next 50 years.
23. At the dept.'s meeting with RMS, it was asked whether removal of the shared path on the proposed replacement bridge would influence cost.	The meeting prompted discussion about the cost of refurbishing and maintaining the existing bridge for pedestrian and cyclist use only. The capital cost-saving implications of deleting the proposed shared user path from the design of the bridge were sought with a view to whether this could be considered a partial offset to the cost of the refurbishment and maintenance of the existing bridge (should the existing bridge be retained for pedestrians and cyclists an additional shared user path would not be necessary on the proposed new bridge).

Bridge Engineer Issue	RMS Response
	At the time RMS noted that the savings would be generally associated with materials as the set up costs of the project would be common with only minor associated cost savings.
24. Item 4: Could you please provide a copy of the information to be presented relating to rehabilitation options (based on dept.'s email of 2/5/13) and also a copy of the updated tables for ongoing maintenance (25, 50, 100 year)	In response to item 4 below, please find attached a revised version of the operation and maintenance cost table included in the 18 April presentation. As discussed, the table was only included in that presentation to illustrate the considerable 100 year cost to maintain. That particular table was not used to inform any aspect of the project development process nor in any of the assessment documentation. Its only use on the project is limited to the presentation and in hindsight it was probably not the best tool to illustrate the point and should have been excluded from the presentation. Notwithstanding, RMS has reviewed and revised the detail in the table. In critically evaluating the items in the table RMS recognises there is some uncertainty around the frequency with which re-dowelling would be required. As such, two tables have been prepared – one that provides for re-dowelling at 35 year intervals and a second that assumes re-dowelling would not be required beyond the initial re-dowelling undertaken during bridge rehabilitation (therefore included in the capital cost only). The tables have also been amended to provide 25, 50 and 100 year summaries. This will assist in demonstrating the effect of escalation over time, which is significantly more pronounced at 100 years. It is questionable whether there is merit in including a 100 year horizon, particularly given the structure is unlikely to meet this life. It should also be noted that these costs assume rehabilitation including re-alkalisation.
25. Could you please explain the condition ratings (1-5) that are used in the tables in the Level 2 inspection reports 2002 - 2012 (Page 21 onwards in Attachment A of your email received on 6 May 2013)?	Explanations of the ratings are provided in the Element Definitions section of RTA Bridge Inspection Procedure Manual, Second Edition 2007. A link to the document is found below. The description for each of the condition ratings (sometimes 1-4 other times 1-5) differs for each of the elements. They are described on pages identified as Definitions -2 to Definitions – 47. These are found from page 36 of the pdf.
26. Has RMS been provided with a copy of the independent quote for rehabilitation of the existing bridge by Arenco (commissioned by Pearson & Wedgewood)?	Please find a copy of the Arenco quote attached noting the following (as explained in Section 4.4.2 of the Submissions Report/PIR): • The proposed construction methodology is unlikely to be acceptable for safety and environmental reasons. Rather than all superstructure works being undertaken from a barge, a purpose built platform would need to be constructed and installed to provide a safe working location and to capture all debris from the concrete removal process. The platform would be

Bridge Engineer Issue	RMS Response
	moved from span to span as the works progressed across the bridge. This platform was not included in the cost estimate for the alternative bridge refurbishment. • The cost estimate was not based on the latest standard RMS and market rates. • The costing methodology did not follow the methodology in RMS's Project Estimation Manual and substantially underestimated the contingency requirements and incidental costs. All cost estimates prepared and presented by RMS comply with their Project Estimation Manual. Further, additional costs over the actual construction costs would likely include: • Contingency for additional works (due to age of the structure and the difficulty in inspecting all components) • Heritage and environmental planning approval and compliance costs. • Design costs • RMS costs • Some environmental management works • Community liaison and information during construction.
RMS responses to key issues raised in DP&I covering letter of review of Submissions Report/Preferred Infrastructure Report 17th May	
a) Underwater Bridge Inspection 09/05/2011 – 20/05/2011 (EIS - Appendix C) Page 12 of this report states that "more sample pictures are in the file 'B 415 Windsor Bridge photos' in the attached DVD". A digital copy of these photos is requested. Page 48 of this report states that "all core holes were photographed and the pictures are contained in the attached folder 'B415 Core holes' " A copy of these photos is also requested.	USB stick containing copies of these photos is attached to this package in Attachment A.
b) Inspection and Structural Assessment Report for Windsor Bridge (EIS - Appendix C) Page 4 states that "the visual inspection was not comprehensive due to the lack of adequate lighting at the time of testing" and "that the RTA of NSW had already performed such an inspection". Details of the then RTA visual	Copies of all available inspections have been included in the attached reports contained in Attachment A.

Bridge Engineer Issue	RMS Response
inspection are requested, including a copy of any records.	
c) EIS Section 3.2.1 Condition of Existing Bridge The first dot point in this section of the EIS compares the current average wall thickness of the piers (15mm) compared to the original wall thickness which is thought to be 30mm (based on available drawings). This original wall thickness appears inconsistent with Appendix C which states that the original wall thickness (based on site observations) is 25mm (Graphitisation Investigation Windsor Bridge, Page 1). Further, Page 20 states that the original wall thickness (based on core samples) is between 22mm and 38mm but "most samples falling between 22mm and 29mm". The report goes on to say "the results are lower than the indications on drawing which suggested a 30mm wall thickness". Additionally technical paper 1 (Historic Heritage, page 4) notes the piers are as thin as 18 mm compared to about 40 mm when new. Clarification is sought for the thickness of the original pier wall and likelihood of being uniform.	The rate of graphitisation is highly variable, hence the different ranges reported in respective investigations. The most detailed investigation into graphitisation was undertaken by CTI in 2011 and involved every pier. The earlier 2005 study only investigated select piers. As identified in the CTI (2011) report the original wall thickness is likely to be 22mm to 29mm – around 25 mm on average.
d) The Graphitisation Investigation dated 13 July 2011 (Appendix C of EIS Volume 1) states that the graphitisation 'phenomenon is being explored in a parallel report on graphitisation in other bridges in Hunter and Northern regions.' A copy of this report is requested. How does the structural condition of the existing Windsor Bridge compare to other bridges that may be experiencing graphitisation in the Hunter and Northern regions? Further, how does the structural condition of the existing Windsor Bridge compare to rail bridges that may be experiencing graphitisation. Do similar graphitisation reports exist for rail bridges? It is noted that the pile design of Windsor Bridge is more commonly used on rail bridges.	A copy of the report "Graphitisation Investigation Hunter Bridges" prepared by CTI Consultants in August 2011 is attached to this package in Attachment A. Graphitisation of other bridges is not as severe as Windsor Bridge. RailCorp has three bridges with cast iron piers in water. None are currently considered to have graphitisation problems although its presence has been recorded in examinations. With respect to country rail network bridges no records were available for consideration.
27. RMS provided a Concrete Damage Model – Carbonation in their presentation of 18th April 2013. This indicated corrosion initiation in 1975 and the rate of damage accelerating extremely rapidly from 2003 onwards. On enquiry this chart is based on Dr Phil Bamforth entitled 'A new approach to	Information not yet available/provided

Peter Stewart Consulting Pty Ltd P.O.Box 163, Pymble, NSW 2073 (02)98809552

Bridge Engineer Issue	RMS Response
Durability Design Using Risk Analysis'. The date of corrosion initiation is not verified by RMS and the curves seem somewhat arbitrary without any backup calculations. Please ask RMS to justify the date for corrosion initiation and the calculations for the percentage areas damaged with corresponding dates. These should be correlated to the reference article.	
28. The underwater inspections submitted have not determined whether ALL piers are subject to graphitisation. Ask RMS if they have any documentary evidence to show which piers are subject to graphitisation and if so to what extent.	Information not yet available/provided
29. Does RMS have a detail of the dowel joints between precast deck panels and pier headstocks? Please supply as built drawings of joints or failing that design drawings of joints.	Information not yet available/provided
30. What is the current area subject to spalling/carbonation equivalent to the 250m2 identified in 2003?	Information not yet available/provided
31. What is the ongoing cost of essential maintenance on the existing bridge?	Information not yet available/provided

- **Appendix E Site Visit**

The site visit was undertaken by the writer on the 23rd April 2013 and a photographic record was made of the visit. The assessment is purely on a visual basis and as no water transport was available the inspection was carried out from the banks of the Hawkesbury River. The photos were taken starting on the North side and then the South side.

The following was noted from the inspection of the bridge:

- The outer concrete beams were in a worse condition when compared to the inner beams
- The scuppers (deck drainage outlets) were a primary source of the moisture causing deterioration of the bridge
- There were joint cracks over the headstocks as a result of longitudinal forces between deck and headstock at the dowel locations.
- The quality of the concrete looked suspect on several headstocks and on at least one diaphragm.
- The caissons above the water level appeared in good condition
- The inner concrete beams appeared in good condition
- The deck joints display cracking across the roadway
- The diaphragms are in good condition generally
- Specific comments are made at each photo.
- Span numbers are from South to North (Hence span 11 is the most Northerly)

Span 11

Peter Stewart Consulting Pty Ltd P.O.Box 163, Pymble, NSW 2073 (02)98809552

Span 10 and 9 beyond

Looking South

Span 9

Peter Stewart Consulting Pty Ltd P.O.Box 163, Pymble, NSW 2073 (02)98809552

Diaphragm showing poor quality concrete

Span 10

Scupper impact on concrete and external beams showing greater weathering

Span 10

Headstock reinforcement showing perhaps as a result of insufficient concrete cover

Span 2

External beams are clearly showing greater weathering on the east side as well.

Other beams look good.

Span 2 looking North

Peter Stewart Consulting Pty Ltd P.O.Box 163, Pymble, NSW 2073 (02)98809552

Span 2

External beams showing greater deterioration

Span 1

Headstock reinforcement showing perhaps as a result of insufficient concrete cover

Span 1

Looking North

Peter Stewart Consulting Pty Ltd P.O.Box 163, Pymble, NSW 2073 (02)98809552

Peter Stewart Consulting Pty Ltd P.O.Box 163, Pymble, NSW 2073 (02)98809552