Appendix 2 – Viaduct Structure Design Statement

Transport Scotland

A82 Pulpit Rock Improvement

Viaduct Structure Design Statement

August 2010

Prepared for:

Table of Contents

1 Introduction

1.1 Project Background

The A82 Pulpit Rock Improvement Scheme is intended to remove the traffic lights and associated bottleneck in the road network at Pulpit Rock, on the shores of Loch Lomond. The Scheme provides improvements over a length of approximately 380m. It is a partly offline structural solution, providing a new viaduct which runs in parallel to the loch shoreline for approximately 180m. North of the new viaduct the existing carriageway is widened by a combination of cutting into the existing rock headland and provision of a new embankment section. The improvements to the existing road will extend approximately 180m to the north of the new structure. Tie-in works will be required in advance of the start and end of the Scheme covering approximately 20m at each location.

The proposed Scheme consists of the following elements:

- Viaduct structure
- Road embankment
- Rock cut

1.2 Scope and Objective of Report

This report summarises the development and evolution of the structural forms considered for the proposed viaduct structure at Pulpit Rock, along with consideration of the landscape and visual context for the scheme. The finalised proposal for the viaduct's structural form and minimum design requirements to be progressed at Detailed Design stage are specified. It is noted that the proposals for the road embankment and rock cut treatment are described separately in the Landscape and Visual Assessment Chapter of the Environmental Statement.

1.3 Scheme Site Constraints

The site is particularly constrained, with the Loch on one side and a large rock outcrop on the other. With the existing road geometry potentially restricting access to and from the site, the possibility of utilising the Loch for both access and construction purposes was considered. Use of a floating work platform, similar to those used in both river and marine locations, was investigated and informally discussed with a Contractor experienced in the use of such systems. Background research confirmed that two potential commercial systems are currently available. It was therefore assumed that a floating work platform could be utilised to aid the construction process and avoid some of the site constraints. It is recognised that using a floating work platform will introduce certain restrictions and limitations. However, it is felt that the benefits of using such a system outweigh any negatives.

1.4 Main Drivers in the Development of the Structural Form

The aesthetic appearance of the viaduct structure was one of the main issues influencing the outline design of the viaduct. In addition to this, due to the impact on local communities and users of the A82 an important objective was to minimise the duration of full road closures and traffic disruption. Also, given the local site constraints, the buildability and construction methods were an important consideration. Therefore, in no particular order, the main drivers considered in the development of the schematic structural form for the viaduct structure were:

- Buildability
- Cost
- Aesthetics/ Landscape and Visual Impact
- Material Selection
- Extent of road closure required for construction
- Scheme geometry/ Road alignment
- Future maintenance requirement
- Compliance with the relevant Codes and Standards

This report primarily deals with material selection, aesthetic considerations and engineering requirements. It should be noted that this report deals only with the design considerations for the viaduct structure. The landscape treatment of the rock cut is addressed in the Landscape and Visual chapter of the Environmental Statement.

2 Landscape and Visual Context

The scheme is located in a National Scenic Area and within the Loch Lomond and Trossachs (LLT) National Park. Pulpit Rock itself is a Scheduled Monument. The A82 is an important tourist route and the view of the Loch from the A82 is one of the iconic views of Scotland.

A full Landscape and Visual Assessment has been carried out separately under the EIA process and is reported in the Environmental Statement. Site visits have been undertaken to check the landscape and visual issues. Views from the road and footpaths, including the West Highland Way and publicly accessible areas, have been recorded. Also, the view from the Loch by boat, which gives a broader indication of the effects on the wider landscape setting, has been taken into account. A number of viewpoints and photomontage locations to be included in the Landscape and Visual Assessment have been agreed with the LLT National Park Authority.

2.1.1 Existing Landscape Setting

Loch Lomond is contained within a large scale rugged glaciated U-shaped valley with mountainous ridges on either side and a number of summits, notably Ben Vorlich, form a backdrop to the Loch. This location forms the wider landscape setting for the Pulpit Rock scheme. There are some scattered natural rock outcrops adjacent but slopes are typically well wooded with large bands of coniferous plantations and deciduous woodland. The bottom of the valley leading to the Loch is clothed with dense semi-natural broadleaved woodland extending to the shoreline, where there is very little break in the tree cover. The existing road threads through the tree belt on the shoreline and is well screened when viewed from the water in summer but is much more visible in winter.

2.1.2 Local Setting

The A82 skirts the west bank of the Loch above the shoreline. The Glasgow to Fort William West Highland Railway Line, constructed in the nineteenth century, runs parallel to the A82 at a higher level, curving to the south and west of Pulpit Rock. The section of the A82 which forms the scheme is approximately 400m in length.

The rock outcrop adjacent to Pulpit Rock forms a significant promontory into the Loch with vertical and overhanging faces. The A82 runs around the edge of the promontory on the Loch side. The sloping faces of the rock outcrop support some mature vegetation and there is also self seeded mature vegetation growing on the Loch side of the road. There is a steep sloping stone rubble edge to the Loch that was originally built to support the road.

Along much of the length of the scheme the edge to the Loch is not heavily engineered and looks relatively natural owing to the use of natural materials and colonisation by self seeding vegetation. The rock outcrop has previously been cut back to accommodate the A82 and there is an old stone retaining wall adjacent to the west side of the road for part of the section around the promontory. There is also a section of stone and concrete retaining wall below the level of the road going down to the shoreline further to the south. The upper section of this retaining wall forms a low stone wall adjacent to the carriageway on the Loch side.

When viewed externally, tree cover (a mix of oak, birch, ash and sycamore) appears to be unbroken from the shore to the top of the rock outcrop with a bare section at the top. However the trees on the shoreline screen bare vertical and overhanging rock faces behind. These faces will be exposed when the trees are removed for construction. The natural rock faces are grey/brown and the existing retaining walls above and below the road have a similar colour to the natural rock. They are also blended into the slope with vegetation and moss/lichen growth.

2.1.3 Visibility

The visibility of the scheme is discussed in the Landscape and Visual Assessment Chapter of the Environmental Statement. The overall visibility of the scheme is relatively restricted by topography, bends in the road and, in summer, by vegetation. However the site can be seen with increasing distance from a wide area, from the Loch, the West Highland Way and from the hillsides and summits on the eastern shores of the Loch. The moving vehicles make the road a more visible element in the landscape, especially in winter.

The visibility of individual elements of the site and therefore the scheme varies with the location of the viewer. The types of views can be categorised as:

- External - looking towards the site/scheme from varying distances. Important features are the surrounding context, background and foreground and different angles of view;
- Internal - looking from the site/scheme while travelling along the A82. The view is influenced most strongly by material, structure and detailing; and
- Sequential - changing aspect during approach. This combines the context and different angles of view and also the detailing which varies with distance from the site/scheme and the angles of view.

The view from the A82 by road users (including residents, business users and tourists) is the most significant and important view in terms of the number of receptors and the close proximity of the visible elements of the scheme. These receptors would have both sequential and internal views. Important elements would be the treatment of the rock cutting and the design of the viaduct superstructure and parapets, although the design of the substructure would be visible in some sequential views.

Other viewpoints and receptors include a small number of residential receptors, boat users including passengers on the ferry at Ardlui, railway passengers, other recreational receptors including walkers on the West Highland Way, hills and mountains and wild campers.

All of these receptors would view the scheme externally from varying distances. The important elements would be the appearance of the viaduct, the rock cutting and how both elements fit into the landscape. With increasing distance from the scheme it is the overall profile rather than the detailing which will be visible, and visibility will be affected by varying weather and light conditions.

2.1.4 Aesthetic Considerations

The area affected by the scheme is a relatively small element in the wider landscape when viewed from a distance. However, it is in a prominent position and the removal of trees for construction, especially those on the shoreline, would create a noticeable scar. It would expose the rock face and make the proposed viaduct more prominent, at least in the short term. At year 15 it is not expected that the trees on the shore will have grown up to their present heights or thickness and the proposed viaduct will have restricted the growth of trees in this section of the scheme. Overall, the scheme could form a significant feature in the landscape.

Mitigation in the form of careful design could have a significant influence on how the scheme fits in to the landscape and how it is perceived by receptors. The main elements of the scheme which will be most prominent are the proposed rock cut and viaduct. The landscape and visual assessment and mitigation measures with regards to the rock cut are addressed in the Landscape and Visual chapter of the Environmental Statement.

Therefore consideration of the following principles has informed the viaduct structure aesthetic design development:

- The design and detailing should be of high quality appropriate to the location of the site within the National Scenic Area;
- Aesthetic considerations should be integral to the design and relate to the general form of the scheme and how individual components contribute to the whole;
- Views of the landscape from the viaduct should be maximised;
- Where possible, the profile of the viaduct should allow the landscape setting to be appreciated from all agreed viewpoints;
- Whether a bold or subtle solution is taken forward, a ‘simple’ structure that frames the landscape and provide a good landscape contrast is preferable to a ‘complex’ option;
- The colour of the viaduct should be given due consideration, to provide appropriate contrast with the landscape tones; and
- Retain existing vegetation, minimising the footprint and hard surfaces where possible to set the scheme within the landscape.

It was agreed from the outset that the design of the viaduct could be approached in three ways;

1. Make it as invisible as possible to hide it in the landscape,
2. Make it as distinctive as possible to contrast and stand out in the landscape,
3. Make it as simple and elegant as possible to complement the landscape.

Given the location of the viaduct structure and the existing landscape context of a National Scenic Area and National Park it was determined early in the design consideration that it was not possible to hide or screen the structure and therefore either approach 2 or 3 should be taken forward.

3 Development of the Schematic Design

3.1 Design Development

A number of design and technical review meetings were held with representatives from Scott Wilson Roads, Structures and Environmental sections to consider the scheme aesthetics, material choice, buildability and construction methods.

Due to the Scheme's rural setting and landscape context, the initial design ethos developed around a concept that a simple, unobtrusive structure would be most appropriate, so as to not detract or distract from the natural landscape. For this reason, use of structural forms such as cable-stay bridges and bow-string arches were ruled out and the provision of a simple beam and slab structure was proposed.

For ease of reporting, the design progression can be described in relation to different elements of the viaduct structure, namely the superstructure (that part of the structure which directly supports traffic and includes deck, slab and girders), the substructure (that part of the structure i.e. piers and abutments, which supports the superstructure and which transfers load to the foundations) and the foundations.

3.2 Consideration of Alternative Structural Forms

3.2.1 Superstructure

Engineering/ Buildability Considerations

For beam and slab structures, various options were considered in regard to material choice for construction. Materials that are commonly used include:

- In-situ concrete;
- Precast concrete;
- Painted steel; and
- Weathering steel.

Taking into account the site location and constraints, two options were considered for the superstructure:

- Precast concrete beams with a reinforced concrete deck slab; and
- Composite braced pair steel girders with a reinforced concrete deck slab.

There are advantages and disadvantages to both options. A precast beam option may prove easier to transport to site and lift into place, but would require temporary works to ensure individual beam stability until the deck slab or diaphragm beams were constructed. The time required to place all the precast concrete beams is also likely to be greater than that required to place steel girders.

A steel girder deck is likely to be self-stabilising if braced-pair girders are provided. They are also likely to be quicker to place than a number of individual precast concrete beams.

However, as such girders would require to be lifted in pairs, there would likely be an increase in the weight to be lifted at any one time. This may lead to a larger crane and associated construction plant being required.

Of the other material choices noted above, use of a purely in-situ concrete structure was discounted due to environmental risks from leaking grout and the extent of formwork and falsework that would be required to support the deck during the construction process. It should be noted however that this does not rule out the option for part of the structure to be constructed from in-situ concrete.

Use of precast concrete box elements was ruled out due to the site topography. It was felt that this was an unsuitable and uneconomic form of construction for this location and for the short overall length of the viaduct.

At this initial stage, no differentiation was made between painted and weathering steel options.

Use of crossheads was also considered, although not preferable from an aesthetic viewpoint, they potentially ease the construction of the deck structure by allowing individual beams to be placed and potentially reduce the amount of temporary works required. Crossheads could be precast to minimise on-site construction time. This would require the use of temporary works to support the crossheads whilst the in-situ concrete connection was formed.

Aesthetic Considerations

With regards to the superstructure, it was initially proposed that, as the structure could not be screened within the landscape, a bold approach should be taken to provide a 'chunky' structure that would become a feature in the landscape. From this, options were considered to curve or arch the soffit. However, the concept of a chunky deck would only work aesthetically should the proportionality with the substructure be in tune. Options for the bridge deck were considered alongside larger diameter single piers and twin piers of varying diameter. Considerations of the interplay between the superstructure and substructure resulted in two varying approaches, either a chunky deck and superstructure with large diameter single or twin piers or alternatively a finer superstructure supported on slender twin piers. The final design for the superstructure was determined alongside the design for the substructure and this is addressed in aesthetic considerations for substructure reported below.

Another important aesthetic consideration tied to the superstructure design was that of the parapets, as it was considered that the design of the parapet could contribute significantly to the visual appearance of the viaduct. It is noted that the Highways Agency Accepted EN 1317 Compliant Road Restraint Systems (available from the HA website) contains a number of parapet systems that may be used. Originally the parapets proposed were of a vertical 'standard' design but it was decided that a range of parapets should be considered from both a visual and engineering perspective. Of the parapet options considered, it was proposed to progress with a parapet system containing smoothly rounded design elements to provide a more visually appealing alternative to more conventional parapets. The slight arc in the parapet was considered to fit well in the landscape and provide a softer, shaped finish for external views of the viaduct structure and for users viewing out to the loch.

3.2.2 Substructure

Engineering/ Buildability Considerations

For the piers, various options were examined. These included:

- Single column piers
- Leaf piers
- Twin column piers

Single columns were initially considered, utilising either a single column with a crosshead or a 'Y' shaped column. It was felt that use of a 'Y' shaped column would not be appropriate to the location of the proposed structure, as the adjacent Loch bank level rises and falls. This would make the columns appear to be of differing heights and could look aesthetically untidy. The provision of a single 'plain' column with a crosshead would require the column to be significantly larger than that provided for twin columns. It is also likely that additional temporary works would be required during construction to stabilise the deck.

Leaf piers were briefly considered but ruled out on aesthetic grounds, as it was felt they would look 'heavy' in comparison with the proposed deck structure and would not be in keeping with the scenic setting.

Twin columns were considered in conjunction with a crosshead. As two points of support are provided, the columns can be slimmer than a single column, lending a potentially more elegant aesthetic.

In order to limit works required in the existing road envelope, the provision of a bankseat type abutment was proposed. The abutments will be required to contain the expansion joints for the viaduct. It is proposed that sliding bearings be provided in these location; either free-sliding or sliding-guided as appropriate.

Aesthetic Considerations

Initially, there was concern over a possible 'forest of columns' effect with a twin column substructure and the visual impact associated with this. Therefore it was recommended that either single column piers (even if with larger diameter) or fewer piers spaced further apart should be considered. The use of a single column pier was initially discounted due to its poor torsional restraint to the superstructure and, due to this constraint, options for spacing the piers further apart were investigated. The structural concept for the viaduct structure was further developed to reduce the number of piers required, reducing the potential 'forest of columns' effect that was previously a concern. This was achieved by considering larger span lengths, which also had the benefit of providing a finer more elegant superstructure .

3.2.3 Foundations

Phase 1 ground investigation (GI) works reported steeply sloping and potentially soft Loch bed soil deposits overlying a sloping rock layer. The soil deposits vary in depth depending upon location but are typically around 4m deep and slope at around 45 degrees at the south side of the scheme.

The steepness of the ground profile effectively rules out the use of pad foundations and strongly suggests that piled foundations are the most appropriate solution for the scheme.

Reporting from Phase 2 GI is still to be completed, but it is expected to confirm that piled foundations are the most appropriate solution.

3.2.4 Summary

Initially the schematic design proposed a concrete beam and slab deck with typical spans of approx 20m, sitting on a concrete substructure consisting of crossheads supported by twin column piers with piled foundations.

The design developed through consideration of both the superstructure and substructure as interconnected elements and involved multidisciplinary working to ensure a range of options were considered and assessed.

The aesthetic considerations moved from that of proposing a 'chunky' structure which was a bold feature in the landscape to a concept of a more elegant refined structure which is described more fully in section 4. The wider spans create order and rhythm and is therefore considered more aesthetically pleasing.

3.3 Technical Review

Following the above design iterations, a Technical Review was held within Scott Wilson to confirm assumptions and decisions made to date on the Scheme. The evolution of the design as detailed above was examined and alternative structural options discussed and considered.

The outcome was that steel girders were perceived to have benefits over concrete beams, with twin composite trapezoidal box girders considered the most appropriate option. The benefits of a box girder solution include:

- Larger spans and span / depth ratios are possible, leading to a more slender, elegant structure;
- Larger spans require fewer intermediate supports, reducing the 'forest of columns' effect and the impact of construction activities on the Loch banks;
- A box girder superstructure is torsionally stiff, which is a more structurally efficient solution to fit the significant plan curvature of the road;
- The girders can be fabricated in straight lengths and angled in plan at the splice points to accommodate the curvature of the road;
- Smaller number of beams reduces the number of supports and bearings required, leading to a less cluttered appearance and easier maintenance;
- Smooth clean lines are possible on the box surface as no external stiffeners are required;
- Sloping webs give box girders visual appeal. The increased contrast in light falling on the deck edge and shadow falling on the side of the box girder can suggest a more slender appearance for the structure; and
- Possibility of making boxes watertight and floating them to site could aid construction.

Material choice was also discussed. It was proposed that to minimise future maintenance requirements, use of weathering steel would be preferred over painted steel.

The proposed design has been reviewed and approved by Transport Scotland Structures Department at a design review meeting. In addition a meeting was also held with Transport

Scotland’s Aesthetic Advisor who approved the design and suggested the use of wire mesh on the parapet to enhance the views from the road and de-urbanise the look of the structure.

4 Proposed Structural Form

4.1 Proposed Viaduct Structure

The proposed viaduct structure which has emerged from the design process comprises six-span steel twin trapezoidal box girders acting compositely with a reinforced concrete deck slab, supported on reinforced concrete abutments and twin plain circular columns at each pier location. The girders will be in weathering steel. The structure will be supported on piled foundations, which will likely require to be constructed within sheet-piled cofferdams within both the Loch and the Loch bank.

A parapet system containing smoothly rounded design elements is proposed to complement the structure. It also offers the motorist low intrusion into their field of vision and therefore maximises the views of the landscape through the bridge.

A general arrangement drawing showing the outline proposed viaduct structure is presented in Appendix A.

4.2 Preliminary Outline Construction Sequence

The Scheme provides a partly offline structural solution incorporating a multi-span viaduct structure with piled foundations. It is proposed to construct the offline section of the viaduct structure first, to minimise delays and closures of the existing road. Once the offline section of the viaduct structure has been completed, it is proposed that the new rock cut at the north end of the scheme will be constructed. Work will then commence on construction of the tie-ins to the north and south of the viaduct structure. Embankment works to the north of the structure are also proposed to be carried out at this stage.

4.3 Other Issues for Consideration

A number of Detailed Design issues have been identified and these will require to be developed further prior to construction:

- Cope cross section shape could be altered to create a more coherent form with the proposed parapet system;
- Careful detailing will be required to avoid staining from weathering steel run-off;
- Controlled Permeability Formwork (CPF) could be used to minimise marine growth on pier columns. The use of CPF may also prevent staining from weathering steel run-off;
- A limitation on structural depth allowed will be required to ensure that the box soffits and bearings will have at least the minimum freeboard above high water level;
- Curving the box girders in plan could be specified for aesthetic reasons. It should be noted that there would be cost and fabrication implications if curved boxes were adopted; and
- The use of precast concrete elements should be encouraged to reduce the construction time on site.

4.4 Structural Requirements to be Considered at Detailed Design

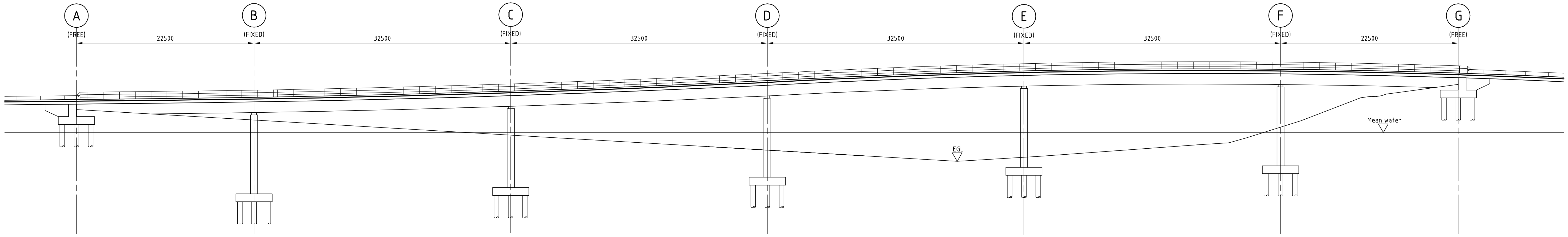
It is expected that the requirements listed below will form the initial basis for the Employer's Requirements for the viaduct section of the Scheme. It is noted that alternative contract options and types are available to Transport Scotland.

It is anticipated that the contractor for the improvement works will be appointed through a Design and Build contract and, as such, the detailed design of the viaduct structure will be undertaken at this time. To ensure compliance with the Environmental Statement the design should adhere to the following minimum requirements;

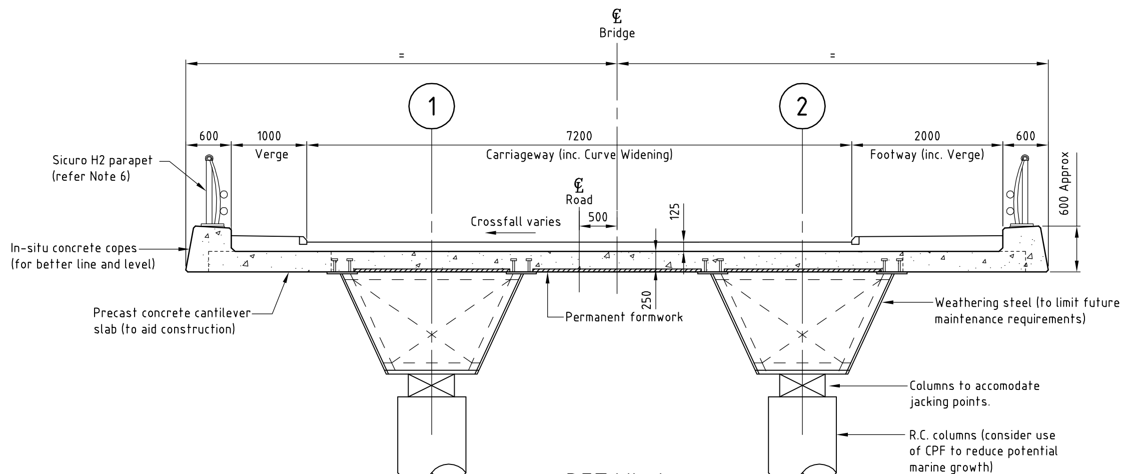
- Maximum number of two columns per pier.
- The structure is expected to be a 6 span viaduct of approx. 175m overall length with the four internal spans of equal length.
- A parapet system, utilising tubular hollow sections to provide smoothly rounded design elements, with wire mesh infill panels is to be provided. The parapet system should be in keeping with the scenic setting of the scheme and be deemed to have appropriate aesthetic merit
- Twin trapezoidal box girders to be adopted, formed from weathering steel.
- Concrete elements are to be pre-cast where possible to minimise environmental risks from in-situ concrete works on site.
- Deck copes are to be formed from in-situ concrete, to ensure a smooth line and level.
- Use of controlled permability formwork, or similar, to be considered for pier columns to minimise potential staining from marine growth.

Appendix A Outline General Arrangement Drawing

THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED AND ONLY WRITTEN DIMENSIONS SHALL BE USED



ELEVATION A-A
SCALE 1:250



DETAIL A
(1:50)

Suggested Construction Sequence:

Site Setup

1. Establish floating work platforms and associated works (safety boats, etc)
2. Establish traffic management
3. Carry out site clearance works

Construct Offline Works

4. Install temporary works for structural foundations (sheet pile cofferdams, access measures, etc)
5. Install piles
6. Construct pilecaps
7. Construct pier columns
8. Place box girders
9. Construct deck

Construct New Rock Cut

10. Establish full road closure
11. Excavate existing material and install rock anchoring, shotcreteing and finishing works for rock cut, as required

Construct Online Tie-in Works

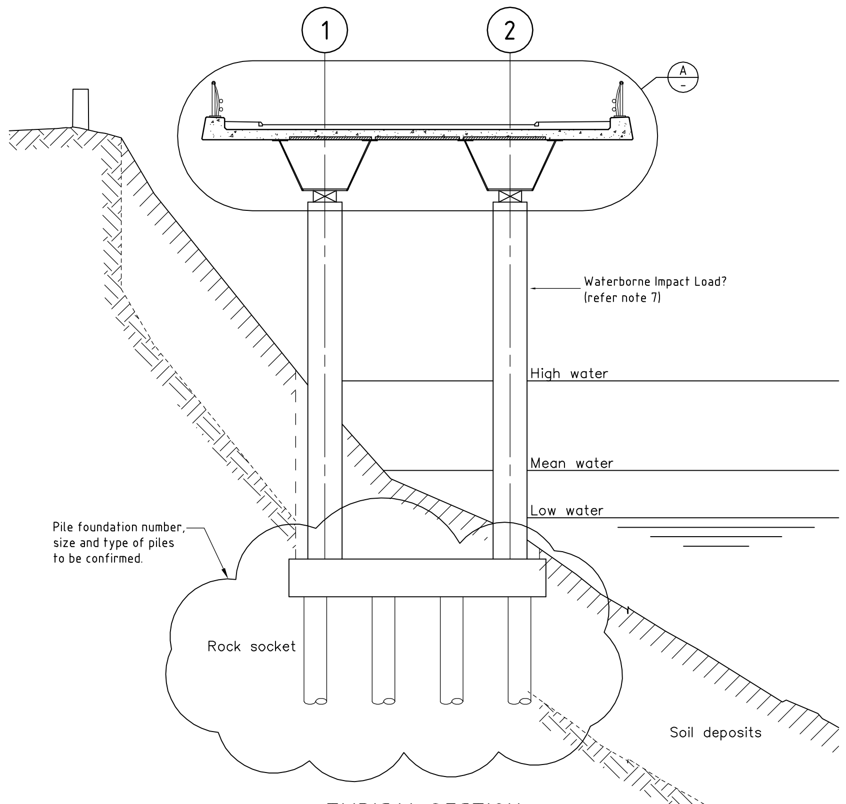
12. Install temporary works for remaining structural foundations (sheet pile cofferdams, access measures, etc)
13. Install piles
14. Construct pilecaps
15. Construct pier columns and abutments
16. Place box girders
17. Construct deck
18. Construct new earthworks

Finishing Works

19. Fix parapets, expansion joints, safety fences and other required fixings
20. Place road surfacing (inc. waterproofing)
21. Complete landscaping works
22. Remove traffic management and open road to the public

NOTES

1. Do not scale from this drawing.
2. All dimensions are in millimetres unless noted otherwise.
3. All levels are in metres AOD unless noted otherwise.
4. Details are referenced thus :
   Detail Reference
   Drawing Number - blank if shown on this drawing
5. Use of C40/50 concrete and S355 weathering steel assumed.
6. Parapet type to be confirmed. Provision of Sicuro H2 parapet system may require a Departure from Standard for parapet height.
7. The possibility of waterborne impact loading on the structure should be considered. If it is deemed a risk, potential impact vessel weights and speeds will require to be determined.



TYPICAL SECTION
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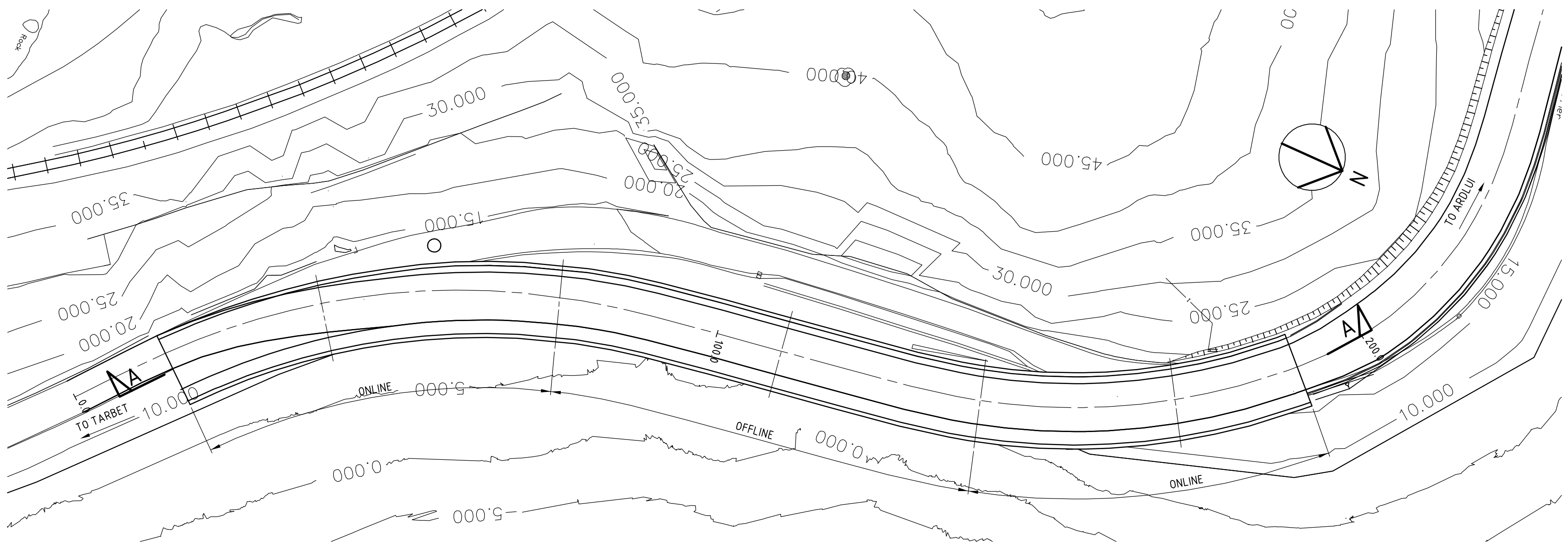

PLAN
SCALE 1:500

Revision Details	By / Check	Date	Suffix
Land side verge width corrected.	GMcF / GMcF	23.07.10	D
Span arrangement corrected. Foundation detail amended.	GMcF / GMcF	04.06.10	C
Notes amended	GMcF / GMcF	26.05.10	B
General revision	JMcC / GMcF	25.05.10	A

Drawing Status: PRELIMINARY

Job Title: A82 PULPIT ROCK IMPROVEMENTS

Drawing Title: PRELIMINARY GENERAL ARRANGEMENT

Scale at A1: AS SHOWN

Drawn	Approved
JMcC	AHWB

Stage 1 check	Stage 2 check	Originated	Date
GMcF		APRIL10	

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