COLNE VALLEY VIADUCT
Specimen Design

Knight Architects

Code 1 - Accepted

hs2

C227-ATK-ST-REP-000-000011
Revision P01

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image: Hayes Davidson | Knight Architects

INTRODUCTION

HS2 passes through a diverse and continuously changing landscape. Structures along the route must respond to this diversity, becoming harmonious, memorable and fitting additions to their sites.

This is particularly true for the Colne Valley Viaduct, which due to its scale, visibility and the sensitivity of its site, forms one of the most important structures along the route. As such, it will become a beacon of HS2's design-quality to onlookers and passengers alike. It will portray the 'national-scale' of HS2's infrastructure whilst expressing its sensitive integration within the landscape.

The Colne Valley Viaduct offers an opportunity to celebrate the exceptional character of its surroundings, and demonstrate how HS2 structures can combine local distinctiveness with route-wide identity.

During the development of this Specimen Design the key principles of *HS2 Design Vision* document were followed and *Open Route Structures Design Approach* (HS2-HS2-AR-GDE-000-000005), *Landscape Design Approach* (HS2-HS2-EV-STR-000-000010) and *Bridge Design Requirements* (HS2-HS2-BR-STD-000-000004) documents were used as a guidance. The final aim of the process was to design a bridge that gives response to both the technical requirements of HS2 and the unique and sensitive nature of its location, in order to meet the aspirations for the viaduct stated by the High Speed Rail (London - West Midlands) Bill Select Committee of the House of Commons [1]:

"181. (...) the Colne Valley viaduct will be the most significant visible engineering feature of the HS2 Phase One route. It will have international significance and its design should reflect that. Having argued against a viaduct, local people deserve that its design be respectful and respectable (...) Sympathetically and imaginatively designed, the viaduct can become a suitable symbol for the country's future high-speed railway network."

This document outlines the design-approach behind the viaduct, and how it has been developed so as to address *HS2 Design Vision* three core values:

People, Place and Time

[1] High Speed Rail (London - West Midlands) Bill Select Committee of the House of Commons | Second Special Report of Session 2015-16 of 22 February 2016 | 4 Principal conclusions and recommendations | The Colne Valley, Hillingdon, Denham and environs | Viaduct design

image: Hayes Davidson | Knight Architects

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1 | SITE ANALYSIS

1.1 | HS2 Phase 1 Route

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1.2 | Colne Valley Viaduct Location

The Colne Valley Regional Park is located to the northwest of London, spanning Berkshire, Hertfordshire, Surrey and Hillingdon. It is predominantly formed from parkland, farmland and woodland, yet contains large reservoirs which surround the River Colne and the Grand Union Canal.

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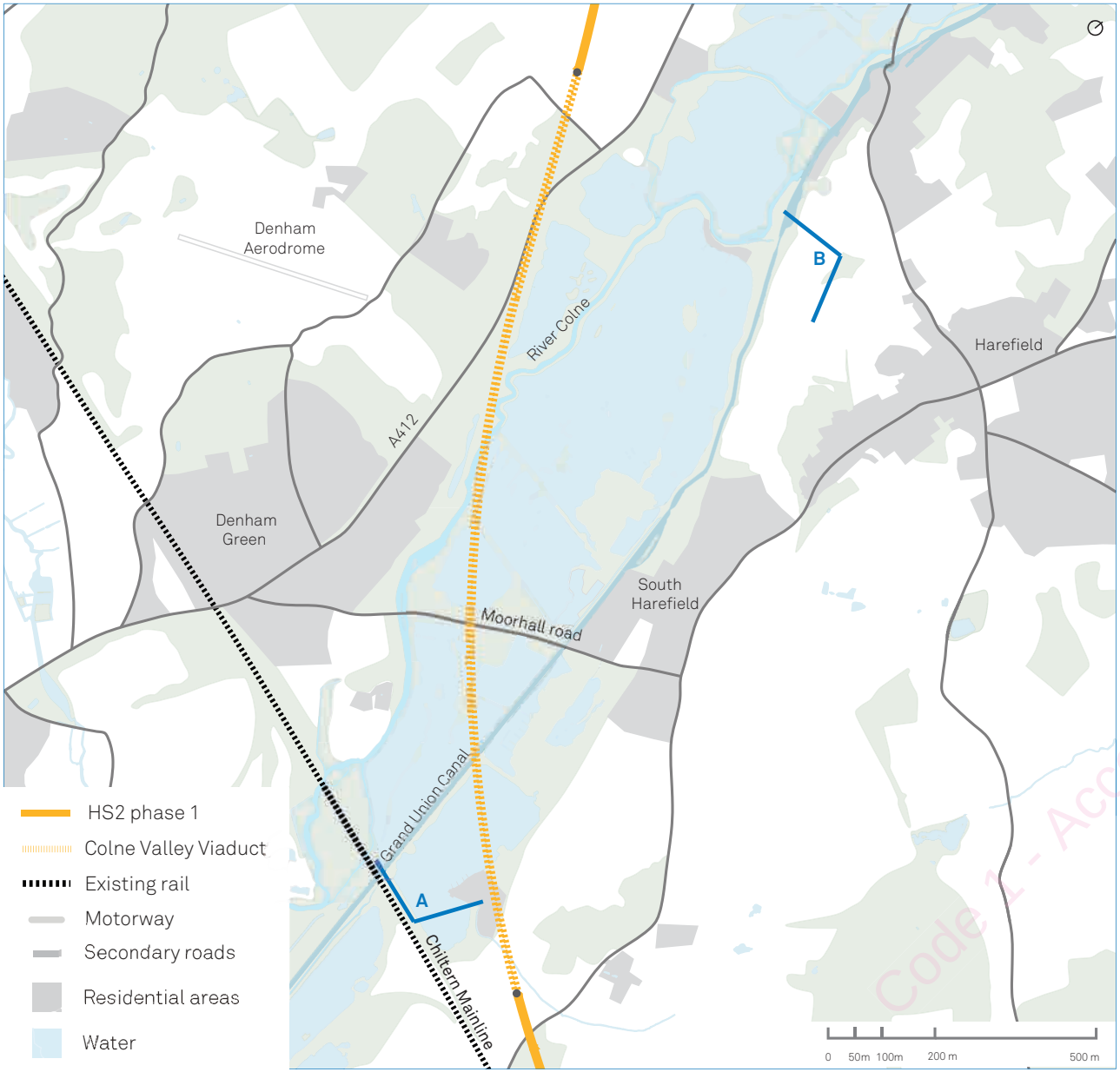
1.3 | Colne Valley Viaduct Area

The site itself sits alongside the existing railway line which runs into London Marylebone. It crosses multiple reservoirs, the Grand Union Canal as well as the A412 and Moorhall Road. The site's heritage stems from quarrying and agriculture, which have now given way, in large part, to recreational uses surrounding the reservoirs.



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View A

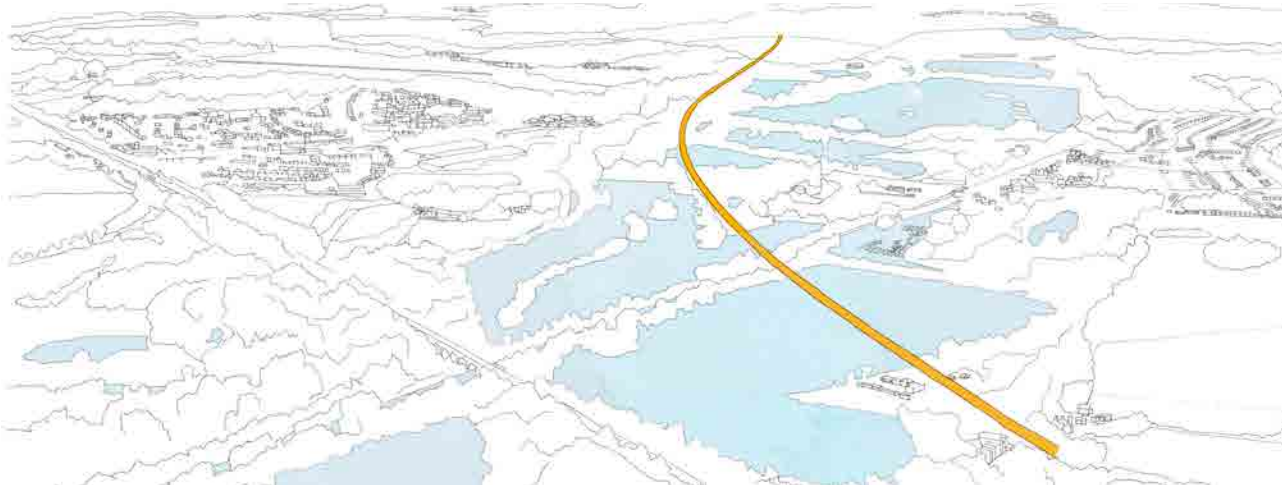

View B

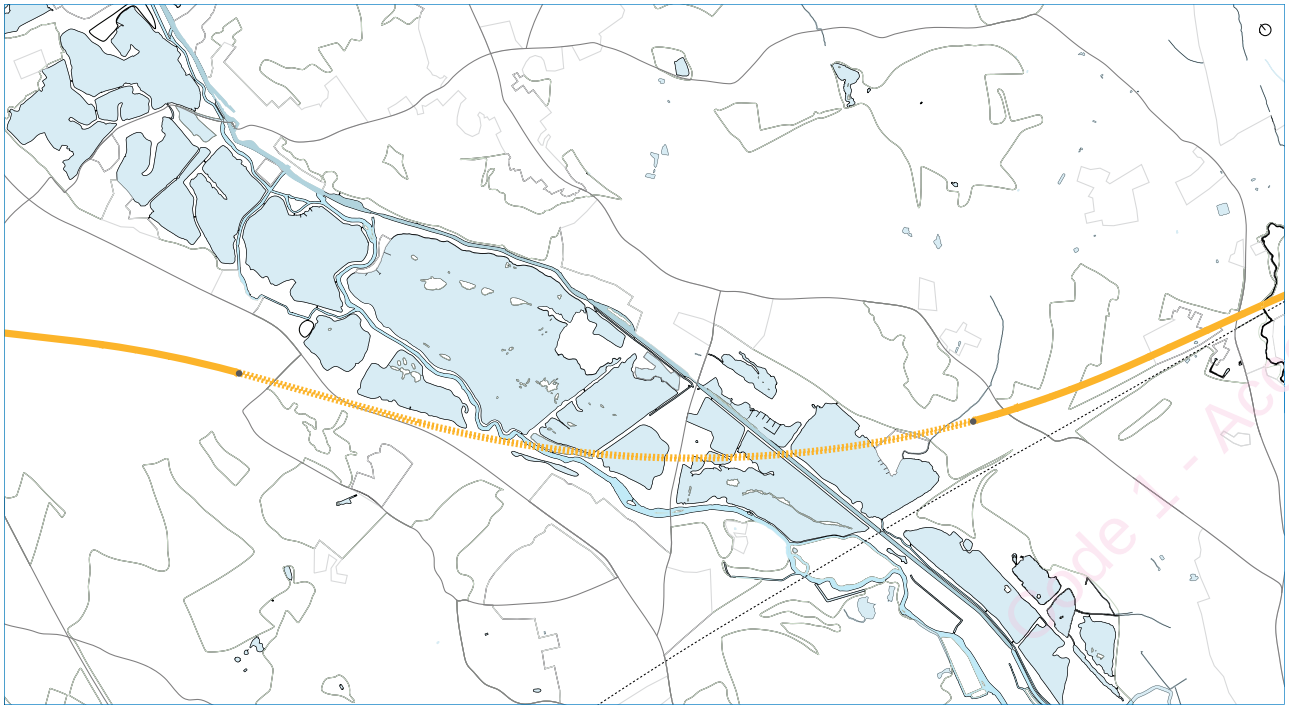
1.4 | Site Character

The immediate surroundings of the CVV can be broadly divided into two key landscape character areas: water and woodland. In order to successfully integrate within this landscape, it is important that the CVV responds specifically to the varied characteristics of these two areas.

Water Area

The water area is located above the reservoirs, and covers the majority of the length of the viaduct. Whilst the bodies of water are fragmented with roads, canals and the river, visually, they combine to create a consolidated character which will influence the design of the viaduct. Expanses of water provide open views to the surrounding vantage points.
The free-flowing movement of boats on the water and informal edges to the reservoirs is contrasted by the comparatively linear canal and river which bisect them. Trees following the lines of these water features demark these as two key axes which the viaduct should respond to.





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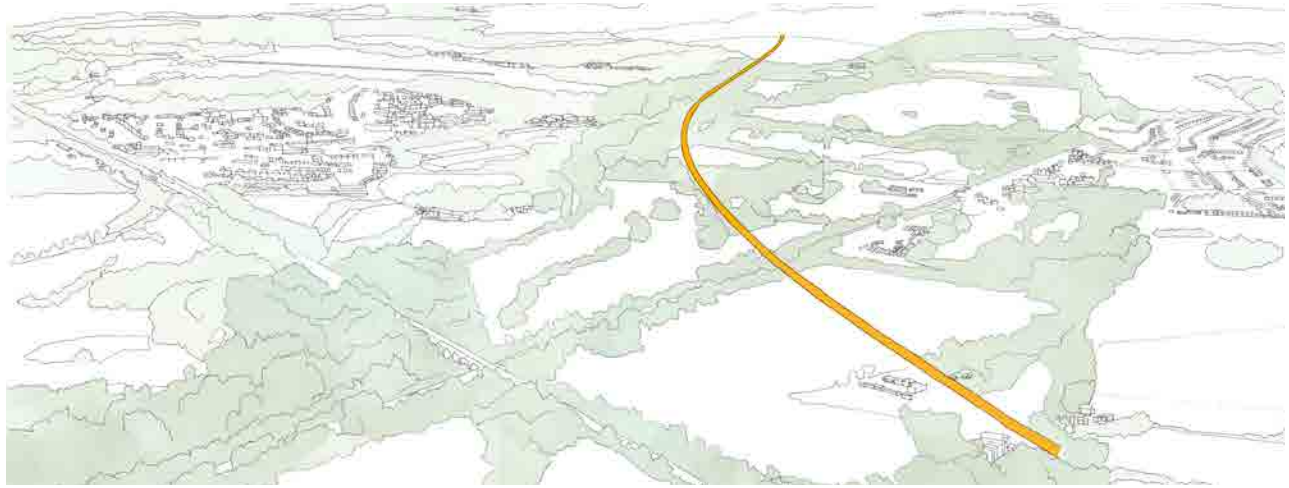

Woodland Area

By contrast to the openness of the water, the Woodland Character Area is defined by enclosure, with tree-lined roads permitting only restricted views of the structure which will pass through it. Whilst the woodland character area surrounds all edges of the water, it is primarily focused to the northwest of the water, with the CVV entering the Woodland after it has crossed the River Colne.

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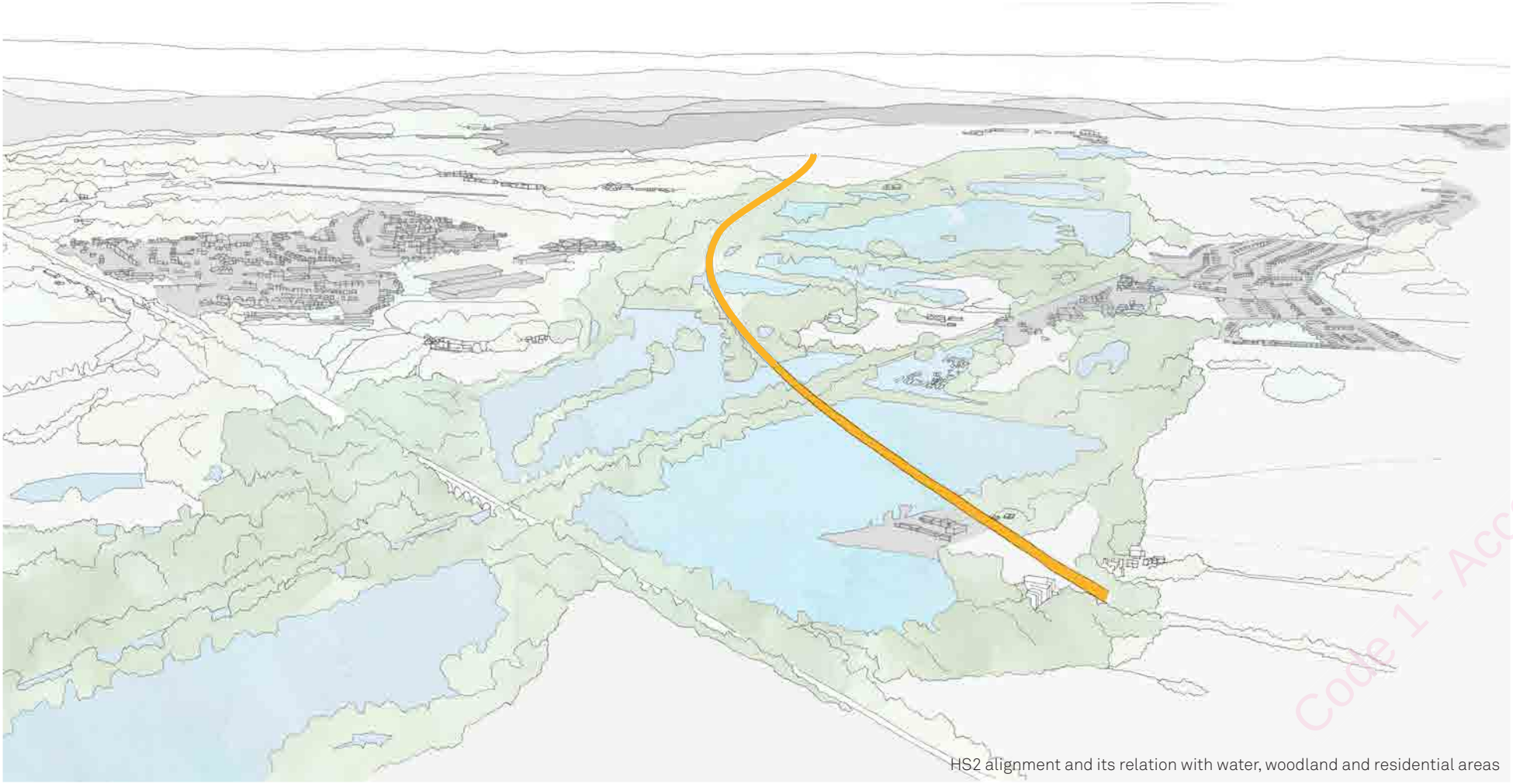

HS2 alignment and its relation with water, woodland and residential areas

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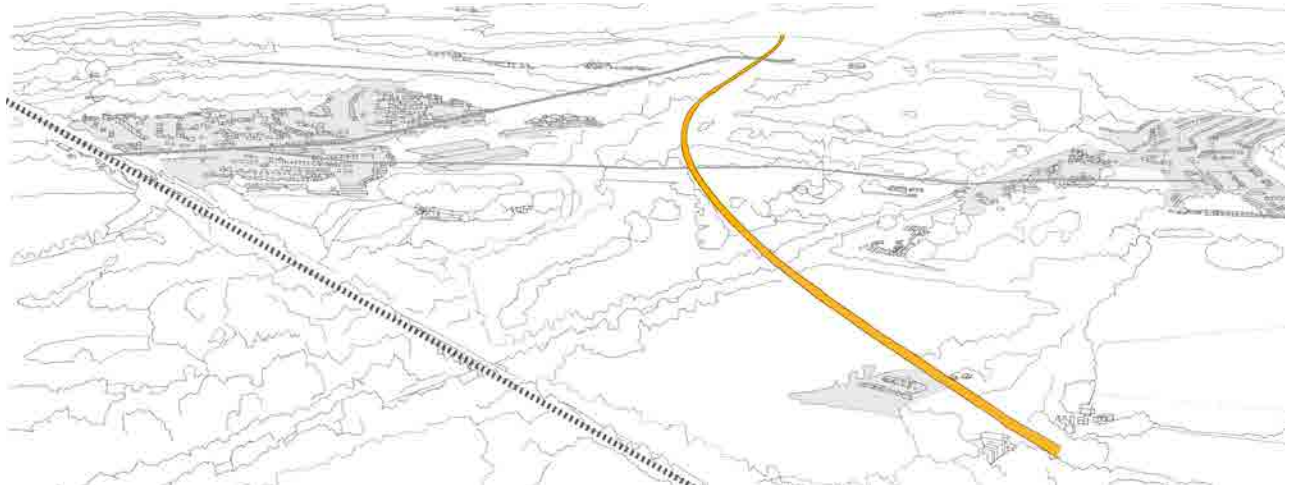
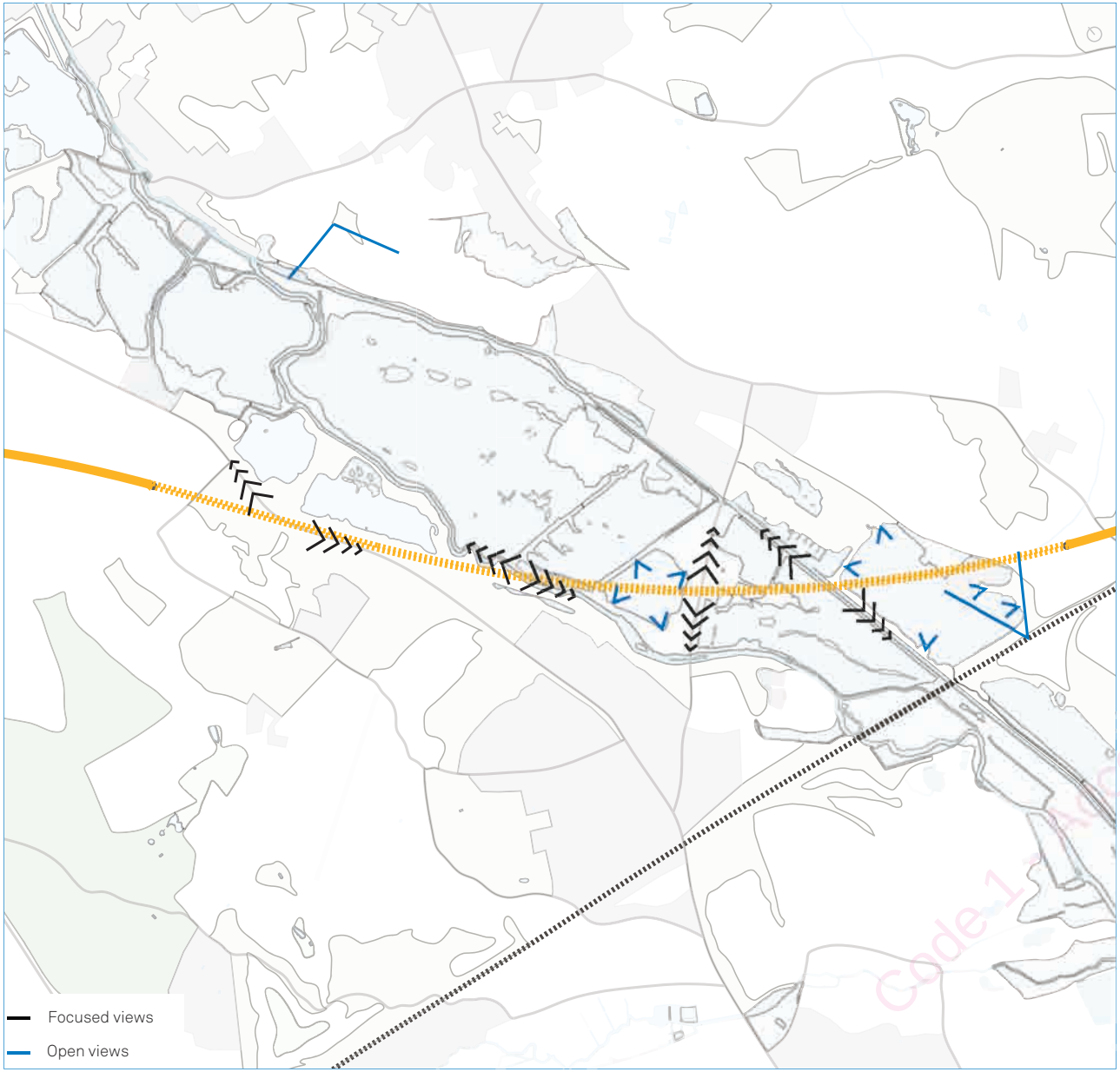
1.5 | Visibility



The CVV is most visible as it crosses the water character area. Here, the key viewpoints are from the elevated position of the existing railway line, as well the lower viewpoints surrounding the water's edge. Denham Green and Harefiled are the nearest settlements, but views from these locations are restricted by woodland. The A412, Moorhall Road and the Grand Union Canal all permit axial views of the structure, predominantly framed by trees.

1.6 | Key views

The CVV must respond to a wide range of viewpoints, separated between the two landscape character areas of water and woodland. The best vantage point is afforded from the existing railway, which will be both at speed and a reasonable distance away. By contrast, the low-level views from the footpaths and trails surrounding the water will permit a closer, and comparatively 'slower' experience of the viaduct at a primarily pedestrian-scale.



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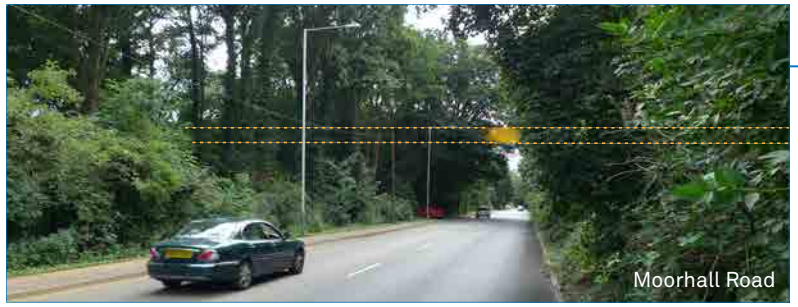
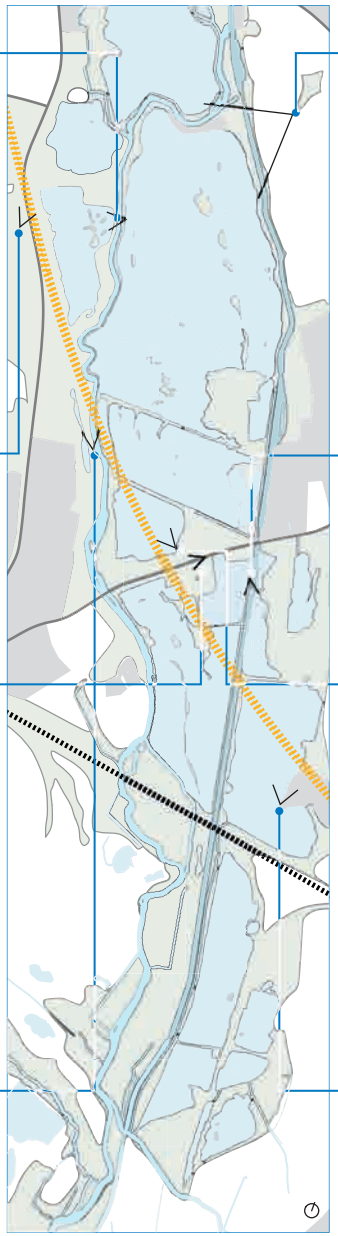




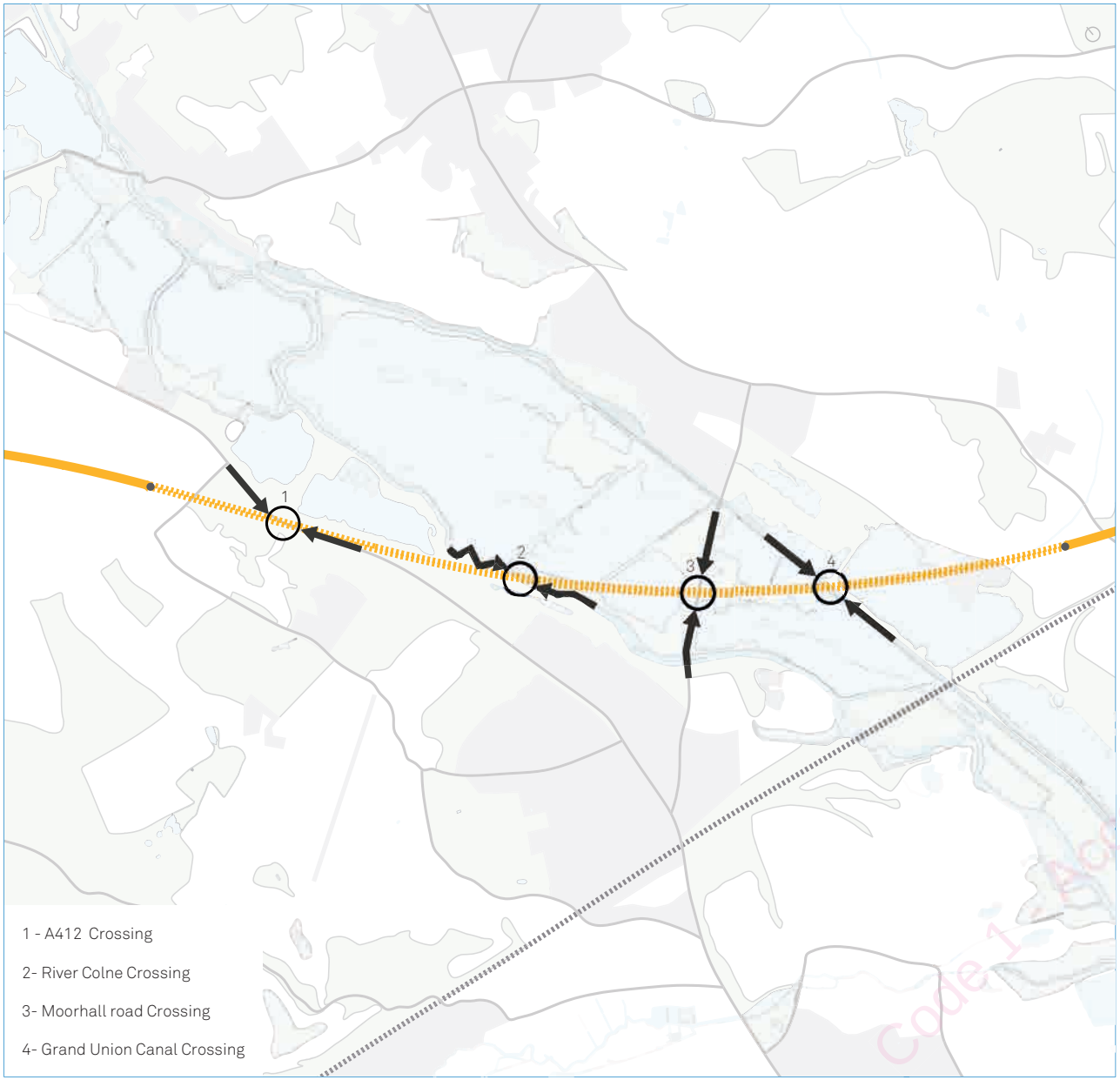
1.7 | Crossings

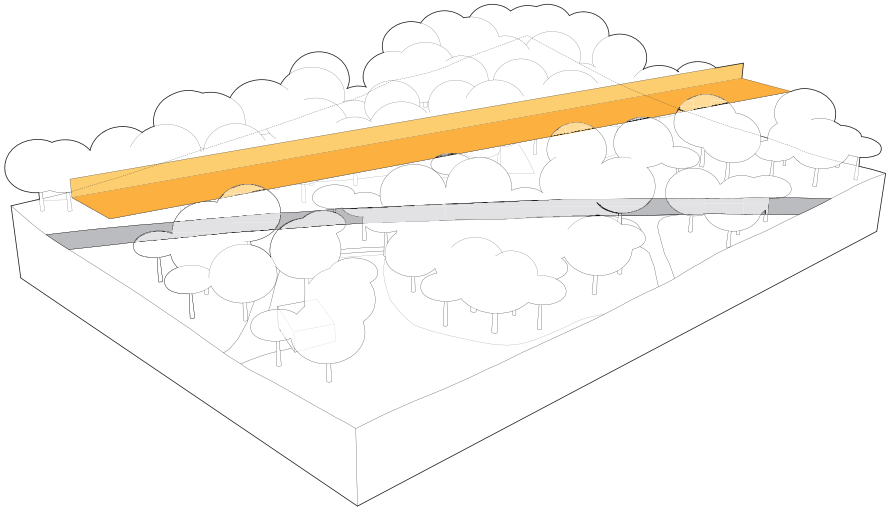
A key characteristic of a well-integrated structure is how it responds to the infrastructure beneath it. Beyond the challenge of responding to the axial views created at the road, canal and river crossings, the CVV must formally address these crossings in its structural arrangement. In order to form a positive addition to the site, as the CVV crosses over this range of existing infrastructure, its design must respond to the constraints that they create.

The viaduct should 'tread lightly' across this sensitive landscape; a significant challenge given that the range of typologies, alignments and context of these crossings varies dramatically beneath the viaduct.

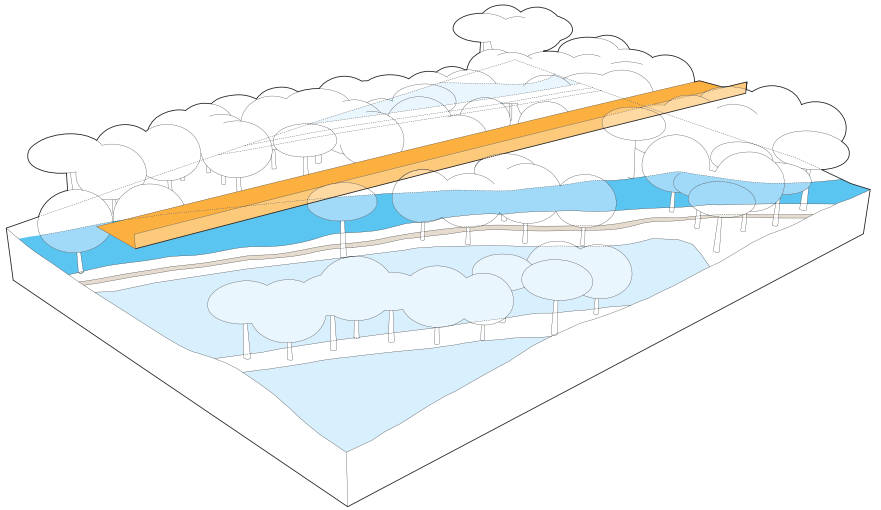
Most crossings are lined with trees (even in the Water Character Area) which serves to restrict views to the axis of the crossing itself. Alignments range from the perpendicular arrangement at Moorhall road, to the high-skew of the A412.

Whilst the visibility of crossings within the Woodland Character Area is limited (often to viewpoints on the road itself) the crossings of the Canal and River within the Water Character Area can be viewed from a variety of surrounding vantage points. At these locations the span arrangement, pier form and alignment are of critical importance in establishing a structure which actively responds to the specific features of the site below it.

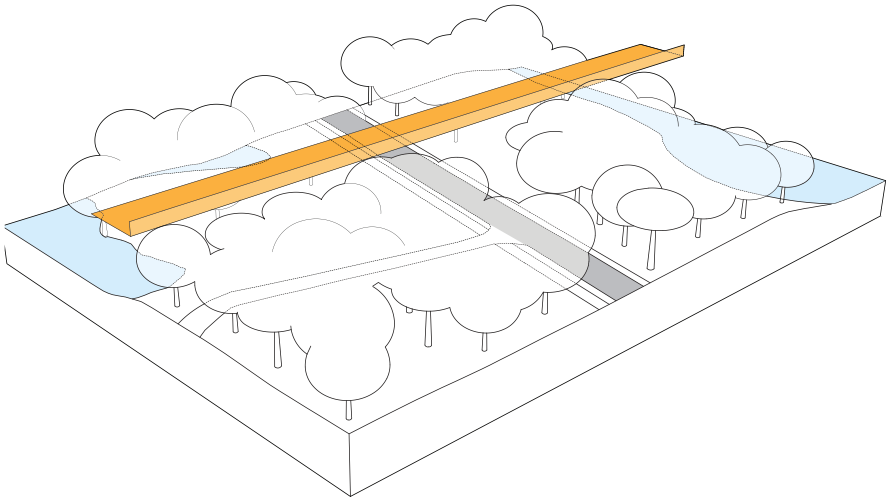




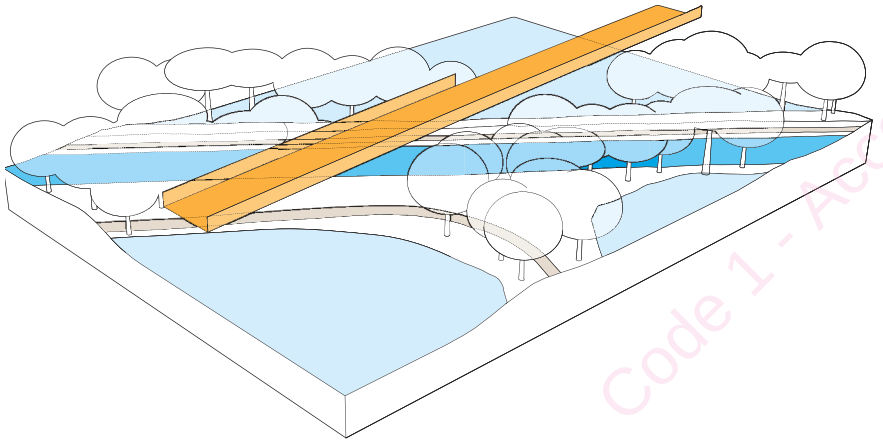
1. A412



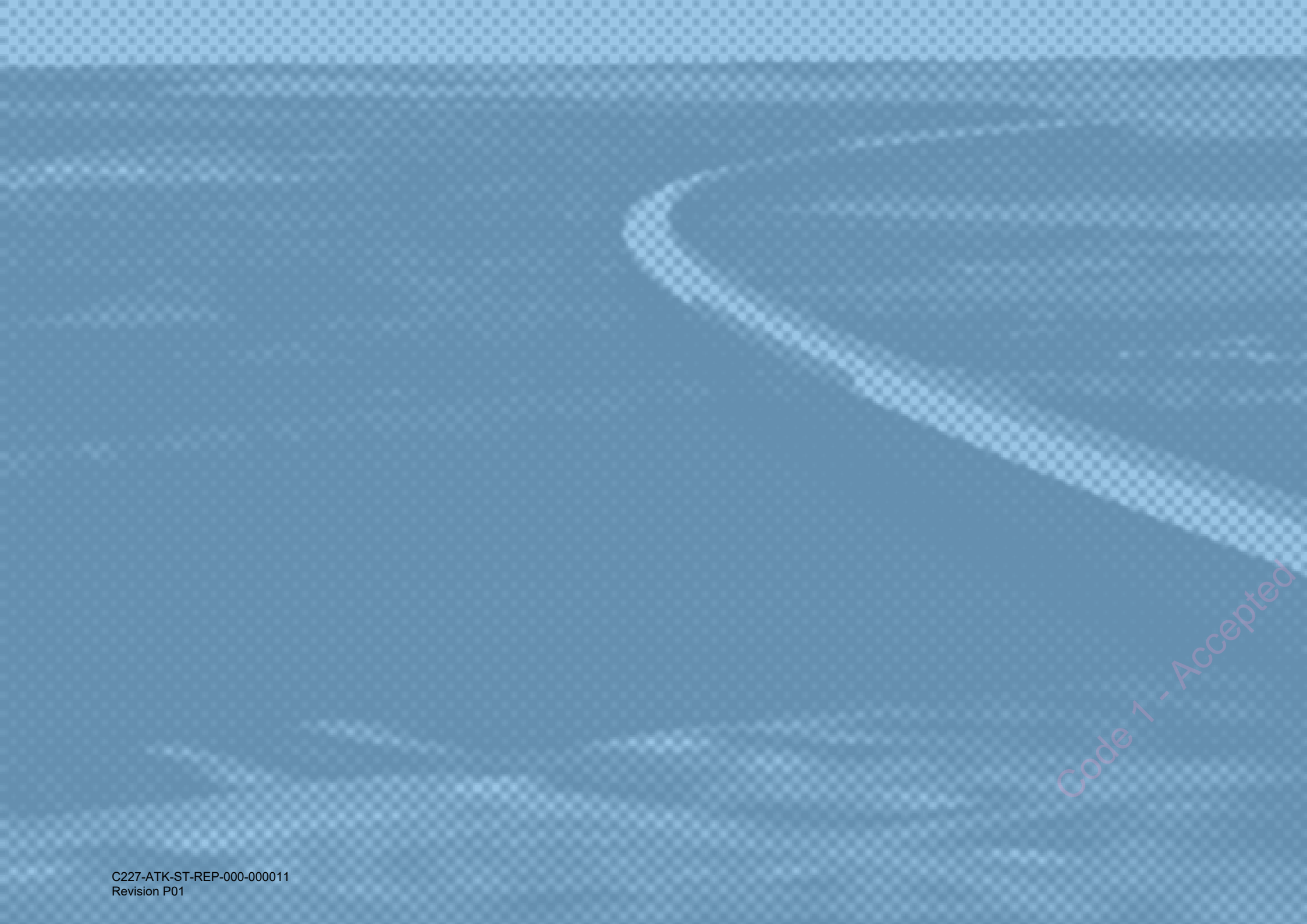
2. River Colne



3. Moorhall Road



4. Grand Union Canal

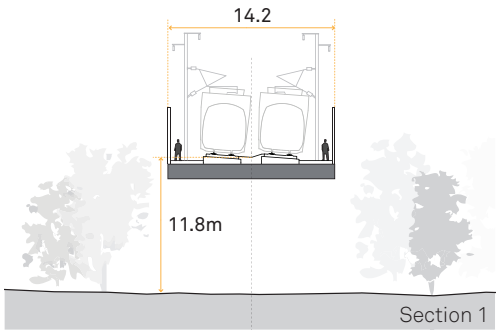


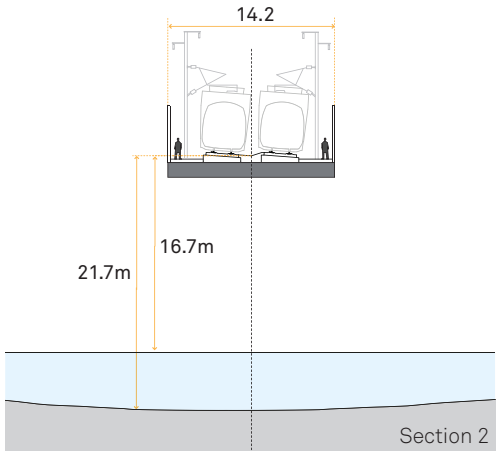
2 | HS2 CONSTRAINTS

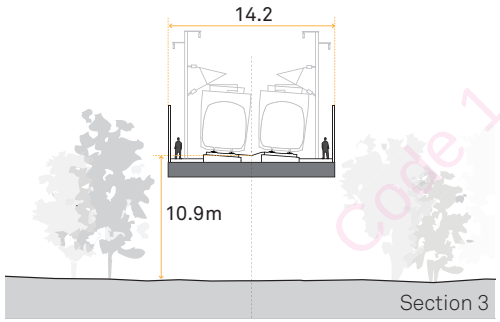
2.1 | Vertical alignment

Perhaps the biggest constraint on the design of the CVV is its vertical alignment. This low, relatively consistent alignment creates a challenging relationship between the structure and the ground below it. Proportions, span length and structural profiles all must be carefully considered so as to produce a fitting, elegant solution. This challenge is eased somewhat over the water, as reflections serve to increase the perception of height, allowing more light, transparency and even views through the structure.

In the Woodland Character Area, the low vertical alignment places the deck within the tree-line, which masks large portions of the structure from the majority of viewpoints. This alignment results in the viaduct passing 'through' rather than 'over' the woodland, which a successful design must respond to.







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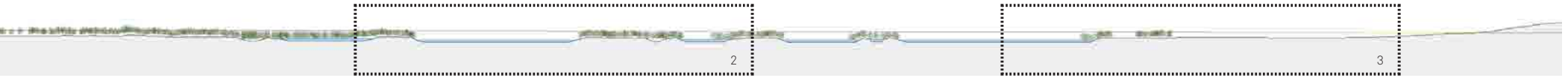
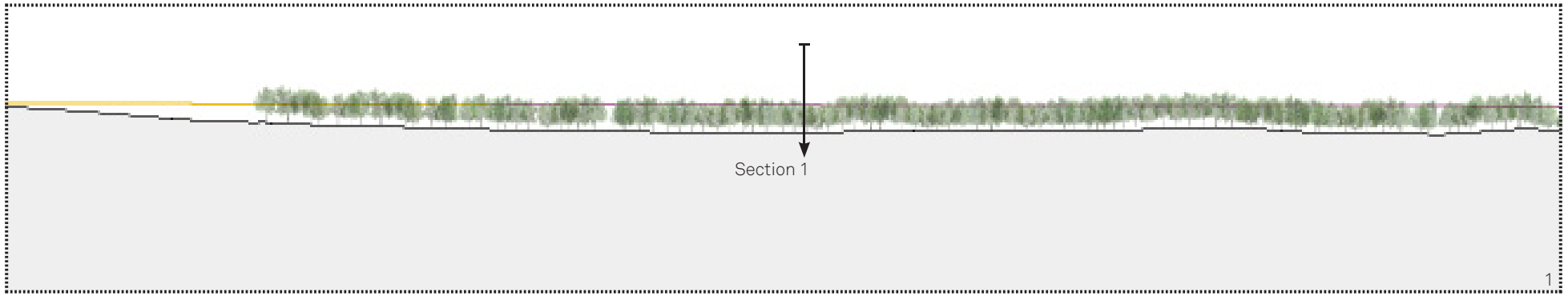
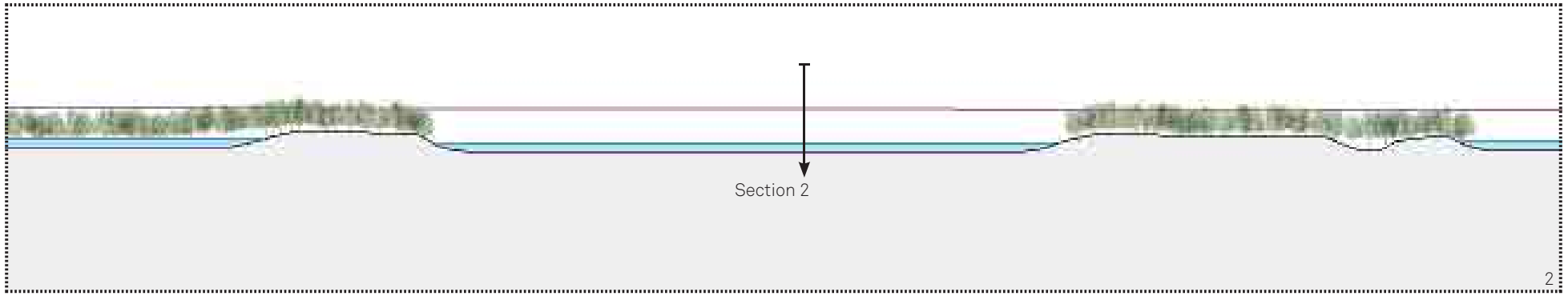
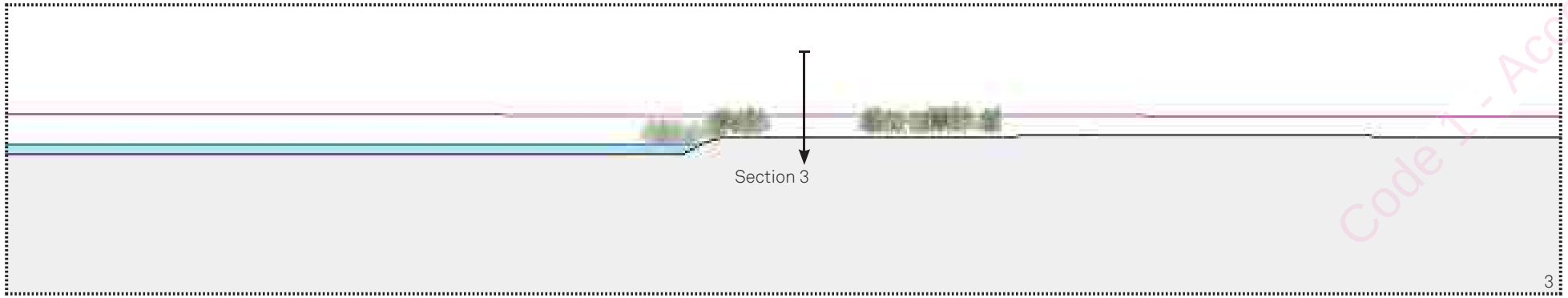




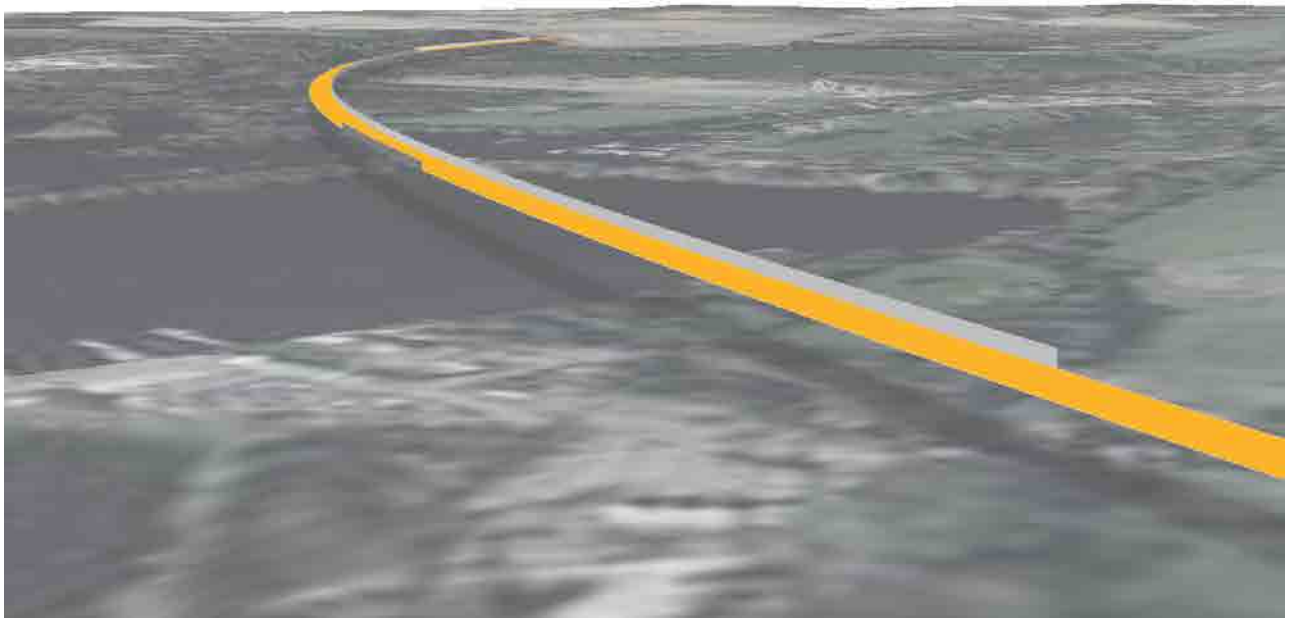


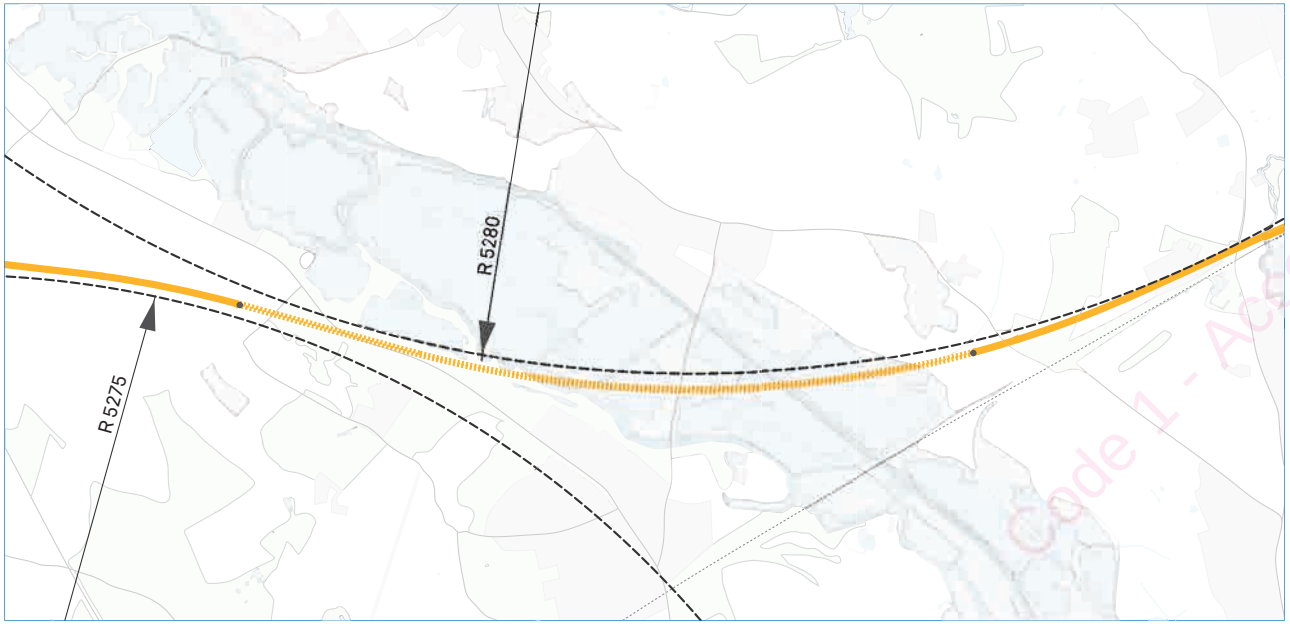


2.2 | Plan alignment

By contrast to the challenges of the vertical alignment, from an aesthetic standpoint the effect of the gently curved plan alignment is generally positive. However, the curve eliminates 'pure' elevational views, with neighbouring piers presenting different angles to most viewpoints. This, combined with a low-alignment can often produce a 'forest of columns' effect, which must be avoided. As such pier shaping and arrangement must carefully consider the plan-curve so as to achieve a well-co-ordinated, deliberate appearance.

If a successful pier arrangement is achieved, the eye will be drawn to lines of the deck. From most viewpoints, the plan curvature will generate a dynamic form, creating fluid, free-flowing lines that sit well within this natural setting. The viaduct's combination of length and plan curvature may also result in views of the structure for the passengers upon it. Even if only a brief glimpse is achieved, this will greatly enhance the passenger experience of the rail. The CVV provides one of the best opportunities for views of the open countryside for HS2 passengers. The experiences of speed, scale and 'journey' are all further enhanced if the structure (and even the train itself) can be a part of that view.



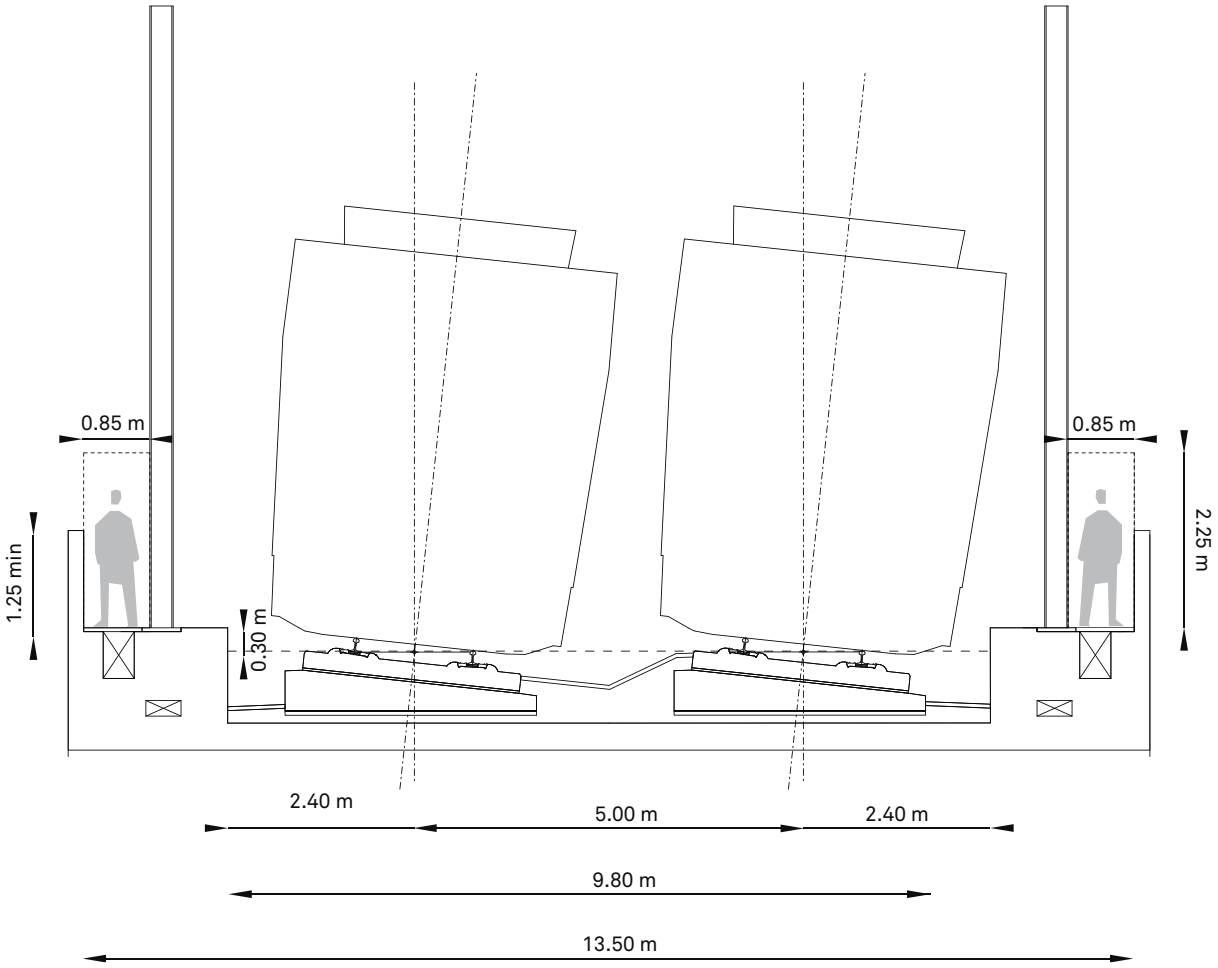


2.3 | Deck cross section

There are certain constraints to be taken in to account when it comes to sectional design. The viaduct cross section must host two rail tracks with a cant due to the curved horizontal alignment, and using slab track system. A derailment containment system must be used at both sides of the track area, and two evacuation and maintenance routes must be arranged at both edges of the deck.

Overhead lines are used for electrical power transmission to the vehicle, what means that OLE (Overhead Line Equipment) posts will be arranged at a certain longitudinal interval (40m to 60m) at both sides of the track area.

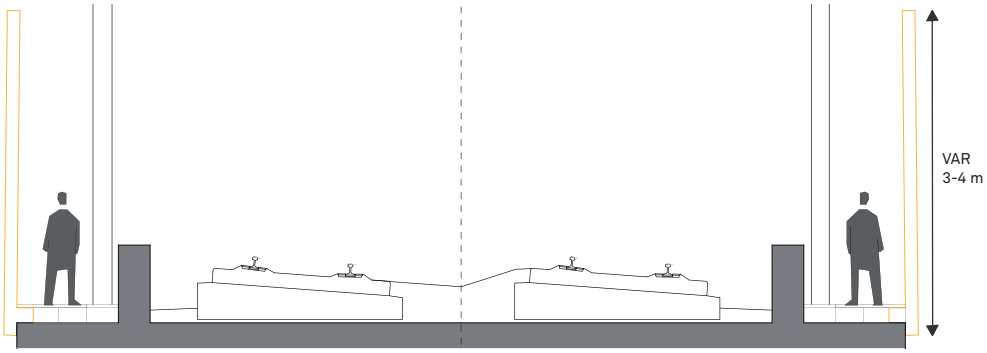
Noise barriers are required along most of the length of the viaduct, at least on one side of the deck, its height varying from 3m to 4m. A protection barrier is needed on the edges of the deck.

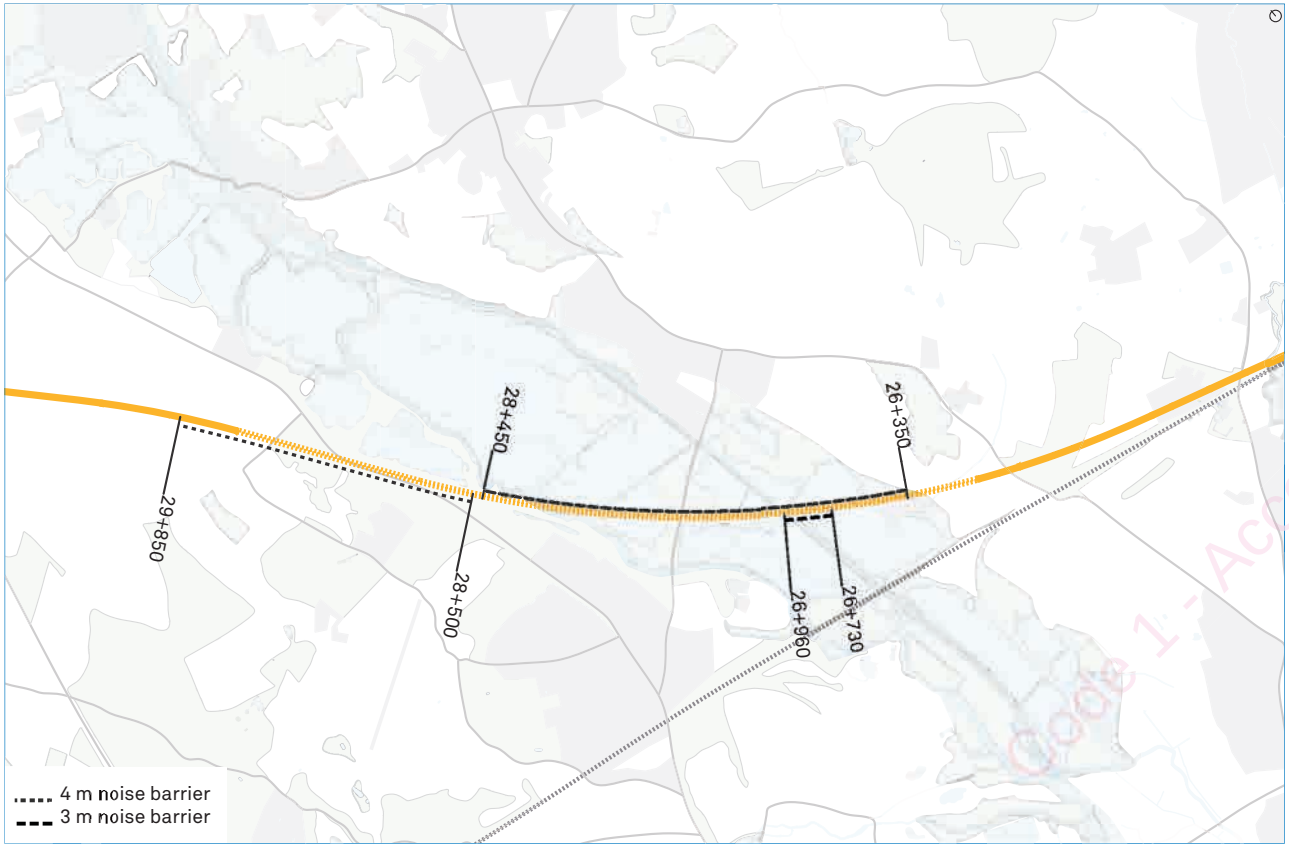


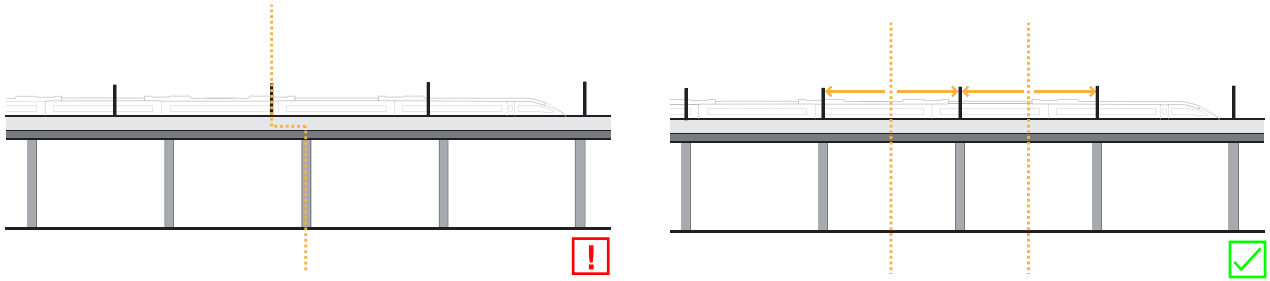
Noise Barrier

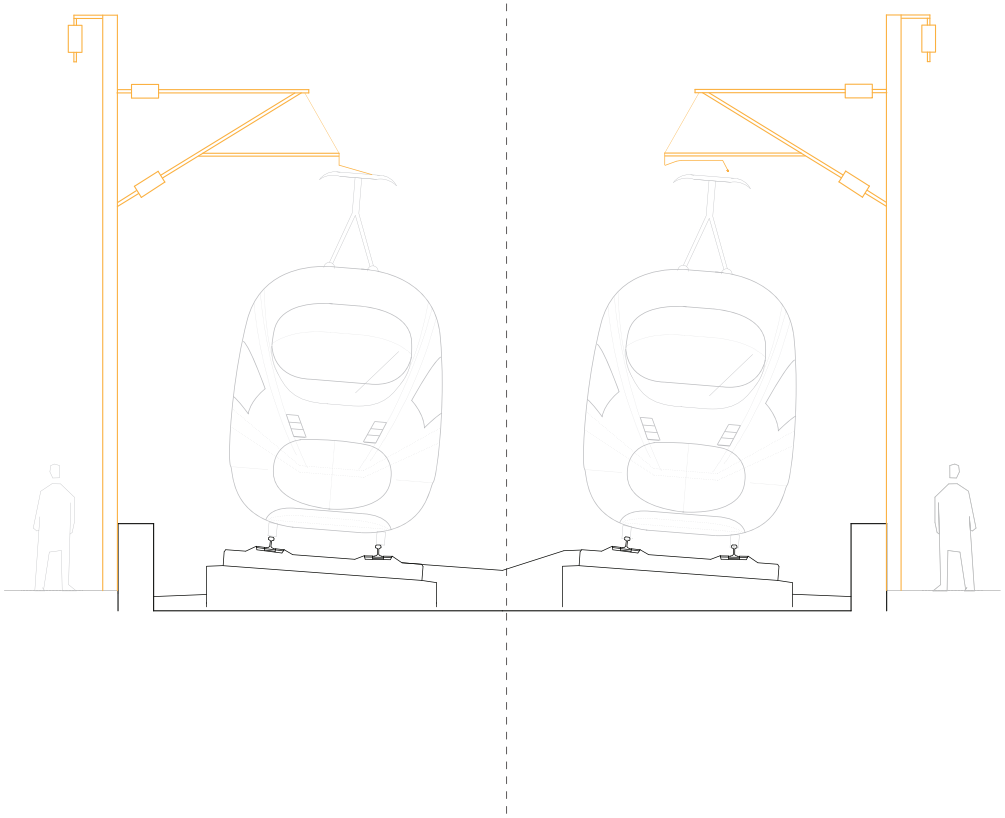
Having just exited a tunnel, the CVV offers an exciting opportunity to provide dramatic, open views to passengers on the rail, allowing the diverse changes in the landscape to be perceived. Across the route, these elevated vantage points are relatively rare and great care must be taken to not unnecessarily obstruct them with noise barriers. The location, height and design of the barriers must seek to combine functional performance with transparency; to reduce noise whilst maximising views.

In addition to the consideration of the view 'from' the CVV, the consideration of noise barriers' impact on views 'of' the viaduct is of critical importance. The flowing, understated lines that could be achieved in the primary structure can all too easily be broken with poorly designed barriers placed on top of it. As many of the viewpoints of the viaduct are from below, the transverse position of the barriers is just as important as the longitudinal; barriers which are placed in close proximity to the rail have less impact on the appearance of the structure. Once the broad position, height and design of the barriers is established, its components must also be carefully co-ordinated so that the noise barrier appears as a logical, integral element of the CVV design. Of particular importance in this regard is the transition at either end of noise barrier sections; abruptly starting and stopping the barriers creates a disruptive pattern that detracts from the structure below.









OLE

Whilst the design of the OLE posts themselves falls outside the scope of this document, their appearance will have a significant impact on the appearance of the CVV structure. As such, we would suggest that OLE post design on the CVV aims to be:

Bespoke: It is recommendable that the OLE posts are bespoke to the CVV and not appear to be a composition of 'off the shelf' elements with a multitude of joints and proprietary components,

Minimalistic: Their silhouette will be highly visible and as such it should be as slender as possible

Consistent: Their spacing and design should be consistent and co-ordinated across the CVV, as changes in either disrupt the rhythm of the structure below.

3 | DESIGN ASPIRATIONS

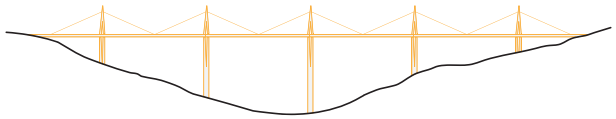
3.1 | Beacon structure

The Colne Valley Viaduct is one of the most important structures on the HS2 route, set within one of the most sensitive landscapes. As such, it must represent the very best in contemporary design. It will form a 'beacon' of HS2, and therefore must convey the route-wide aspiration to create a fitting, elegant and long-lasting piece of national infrastructure.

Given the design aspiration for a 'beacon structure', there are broadly two design methodologies one can use to achieve one – Prominence, or Elegance. A prominent viaduct would take the form of a tall, eye-catching design, usually with above-deck structure. High vertical alignments such as those across deep valleys lend themselves to this approach, where massive forms can remain aesthetically pleasing due to the proportions offered by the vertical scale of the crossing.

By contrast, a beacon structure can also be achieved through Elegance. Here, careful detailing, slender proportions and keenly designed components can produce a structure that forms a beacon via a reductive, rather than an additive approach. This methodology is best suited to the low vertical alignment of the CVV, where issues of deck depth, span length, structural proportions and transparency are valued over height.

Prominence



Elegance

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The low vertical alignment both literally and figuratively leaves less room for elaborate design. Whereas tall, prominent structures can readily accommodate elaborate eye-catching designs, low-lying solutions should strive for understated simplicity if they are to be considered elegant.

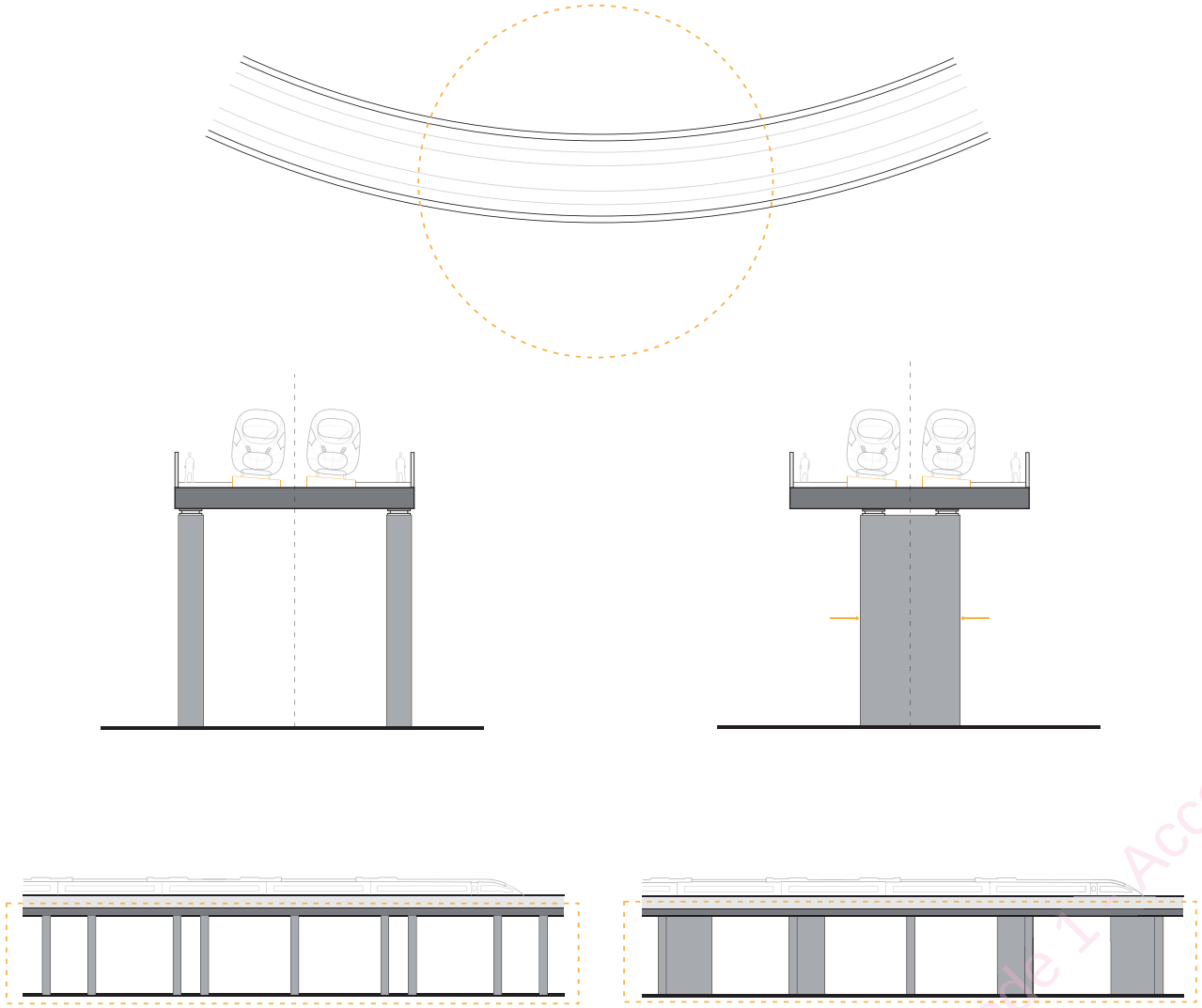
A High Viaduct can be easily visible and legible. It also may offer more options in terms of height vs span ratio choice. It is much easier to get an internationally recognised Beacon Structure with a high alignment than with a low one.

A Low Viaduct is less likely to be visible and legible (especially in woodland areas). It offers less design versatility in terms of height vs span ratio. Achieving an internationally recognised Beacon Structure with a low alignment is challenging.

Given the low-alignment, the aspiration must be for an ‘extraordinary’ viaduct. This is intended both in the hyperbolic sense of achieving an exceptional structure, but also in the very literal sense of designing something out-of-the-ordinary. An ‘ordinary’ structure will not be specific to the Colne Valley, nor will it be commensurate with the importance of this scheme.

3.2 | Uncluttered Rhythm

One of the primary influences on an elegant design is what happens below the deck. The curved plan-alignment of the CVV will require careful alignment of the piers in order to ensure that their arrangement is logical, simple and fitting. 'Twin Piers' which each pick up a bearing will read as two separate objects. This is not suitable to a curved alignment where their rhythm will create interference patterns that will create a cluttered appearance. As such, piers should be 'singular' in their design; either 'leaf' style elements or 'V' piers. In doing so, their arrangement and rhythm will be more easily read from the variety of surrounding viewpoints, and the viaduct will appear to 'tread lightly' across this sensitive landscape.



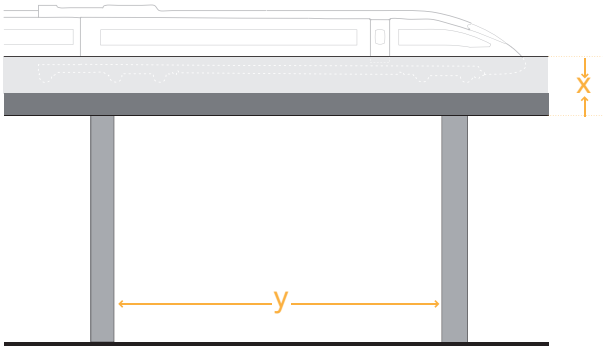
3.3 | Proportions

An elegant viaduct, particularly one with a low vertical alignment, must be well proportioned. The proportions of the CVV should address the following three constraints:

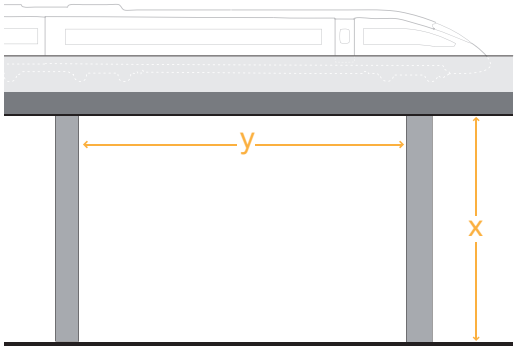
Span to Depth Ratio: it is important that the structure appears to be 'working' – the CVV must not appear to be an ordinary structure. This visual perception is usually based on the span to depth ratio, with overly short spans detracting from the drama and elegance of the structure. Whichever structural system is used, it must appear to be keen, efficient, even an extraordinary design which positively portrays the forces running through it.

Deck Depth to Clearance Ratio: A low viaduct must strive to maximise the clearance that remains underneath it. Views, landscape permeability and light all benefit from greater clearance. This distance will be viewed against the structural depth. A well-proportioned ratio between the two will ensure the viaduct delicately and respectfully crosses the landscape.

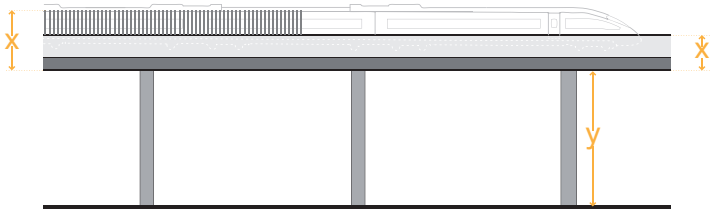
Width to Clearance: Visually, structures which are wide in the transverse direction need to have more clearance. This is to the same end as a good depth to clearance ratio – light, views and permeability are worsened by structural width. Moreover, the width dramatically impacts the bearing locations, and in turn the pier size. Wide piers block views and increase the visual mass. Split piers increase the transparency but at the cost of adding clutter.



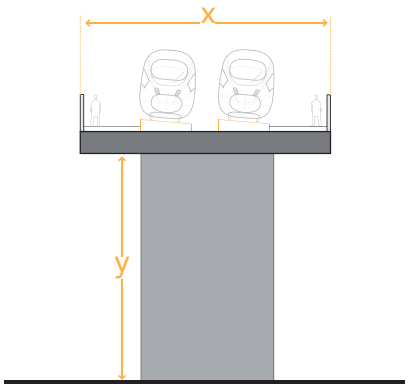
Span to Depth Ratio



Clearance to span



Deck Depth to Clearance Ratio



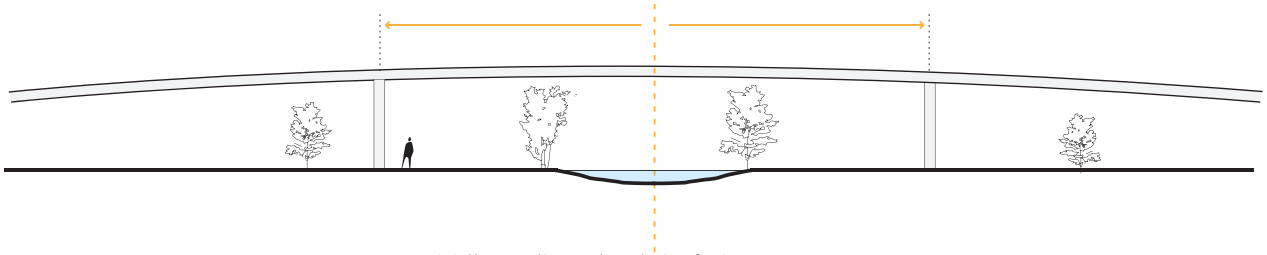
Width to Clearance

3.4 | Respond to character areas

As established previously, the site can broadly be divided into ‘Woodland’ and ‘Water’ character areas, which the viaduct should respond to. The comparative openness of the water is suited to longer spans, with the enclosure provided by the woodland permitting shorter spans. Reflections over the water require careful consideration to be given to the soffit, which will be readily visible from many vantage points.

Pier form may also benefit from changing to suit the specific characteristics of each area.

Whilst other elements of the structure will change across the landscape character areas, the deck edge will likely benefit by remaining consistent. This will give continuity across the viaduct, providing a steady datum, against which other structural changes can be read.



Well-coordinated and pier fitting arrangement

Responds sensitively to the existing context beneath

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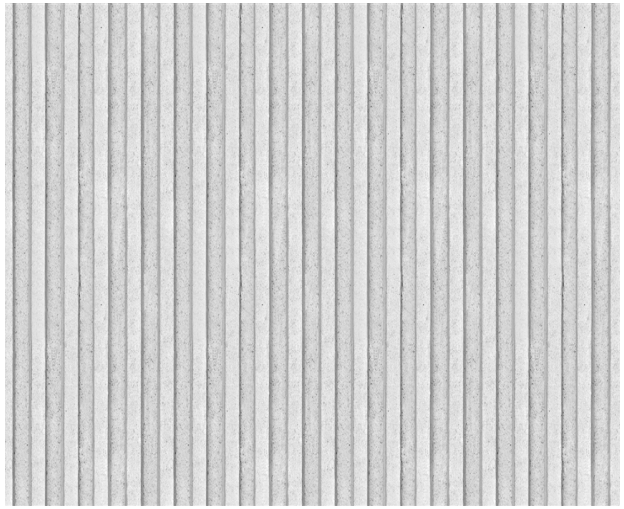
3.5 | Quality

The CVV will be viewed at a variety of distances and speeds, and the quality of materials and detailing must respond to this. An understated, elegant solution must be exceptionally well detailed if it is to be perceived as an extraordinary structure. It must be long-lasting, of the highest quality, and provide a material finish that is suited to the close proximity that can be achieved from many of the viewpoints on and surrounding the water.

Particularly below-deck, the structure must be designed with a 'pedestrian-scale' in mind. Whilst this is indeed a large piece of railway infrastructure, it will form a critical component of the pedestrian environment beneath it. Piers will touch the water, provide access around them for walking routes, and the soffit's relatively low height will make it easily visible. As such, all elements that face the pedestrian environment must be of a quality, scale and texture commensurate with the up-close and low-speed scrutiny it will be subject to.

Quality in this project is related to overall geometric design, choice of materials (light grey concrete for the structure, and transparent acrylic sheets and stainless steel for noise barrier, as an example), use of texture for some of the surfaces (some areas of deck and piers with recessed patterns), how these materials are treated during construction (concrete finish, welding smoothness in steelwork, etc.), and the design of details (recessed stripes to direct water in a controlled way on the deck sides, or drainage conduit-pier coordination, for example).

Good concrete colour and finish must be an aspiration in the construction of this bridge. The use of granulated blast furnace slag along with the cement can help to achieve a light colour, minimising the embodied carbon



Adding texture to some deck surfaces and to some piers helps from drainage, volume-breaking and pedestrian-scale addressing points of view

Transparency in noise barriers is a key design feature, both to minimise the visual impact of the viaduct in the landscape and to allow passengers to enjoy the views when crossing along the Colne Valley

Stainless steel profiles in the noise and protection barrier reinforce the architectural quality of the bridge and minimise maintenance

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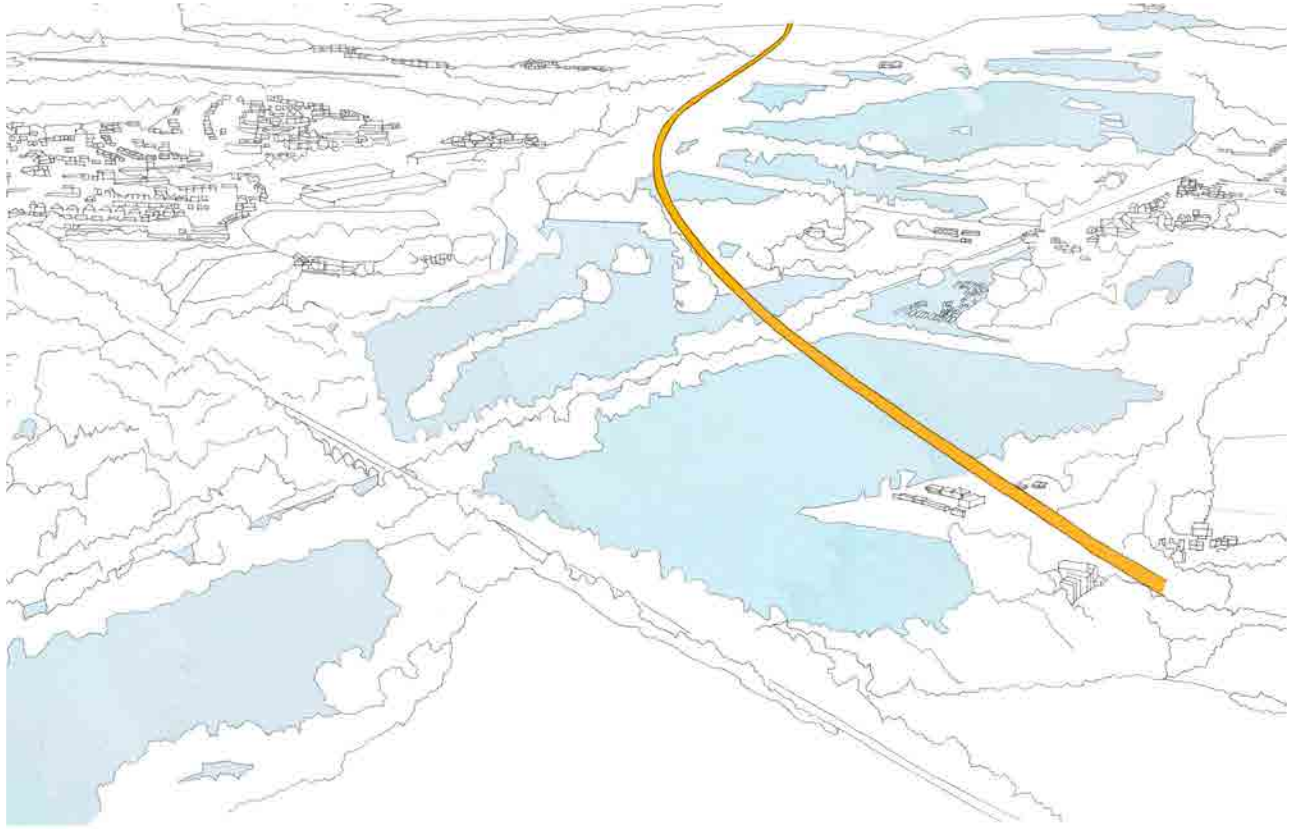
3.6 | Conclusions

For the CVV to be considered a fitting structure, which has been sensitively designed with the landscape in mind, it must directly address the features which it crosses. This is achieved to some extent by responding to the specific characteristics of the woodland and the water. However, the existing infrastructure also must be referenced. The Grand Union Canal, the River Colne, as well as the different roads and pathways should be acknowledged in the design. This could be as simple as ensuring that these structures are positioned centrally within spans, or could extend to having their presence highlighted by 'feature' spans.

Careful consideration of these linear features, combined with a wider-scale understanding of the character of the water and woodland will ensure that the CVV is a fitting addition to the landscape.



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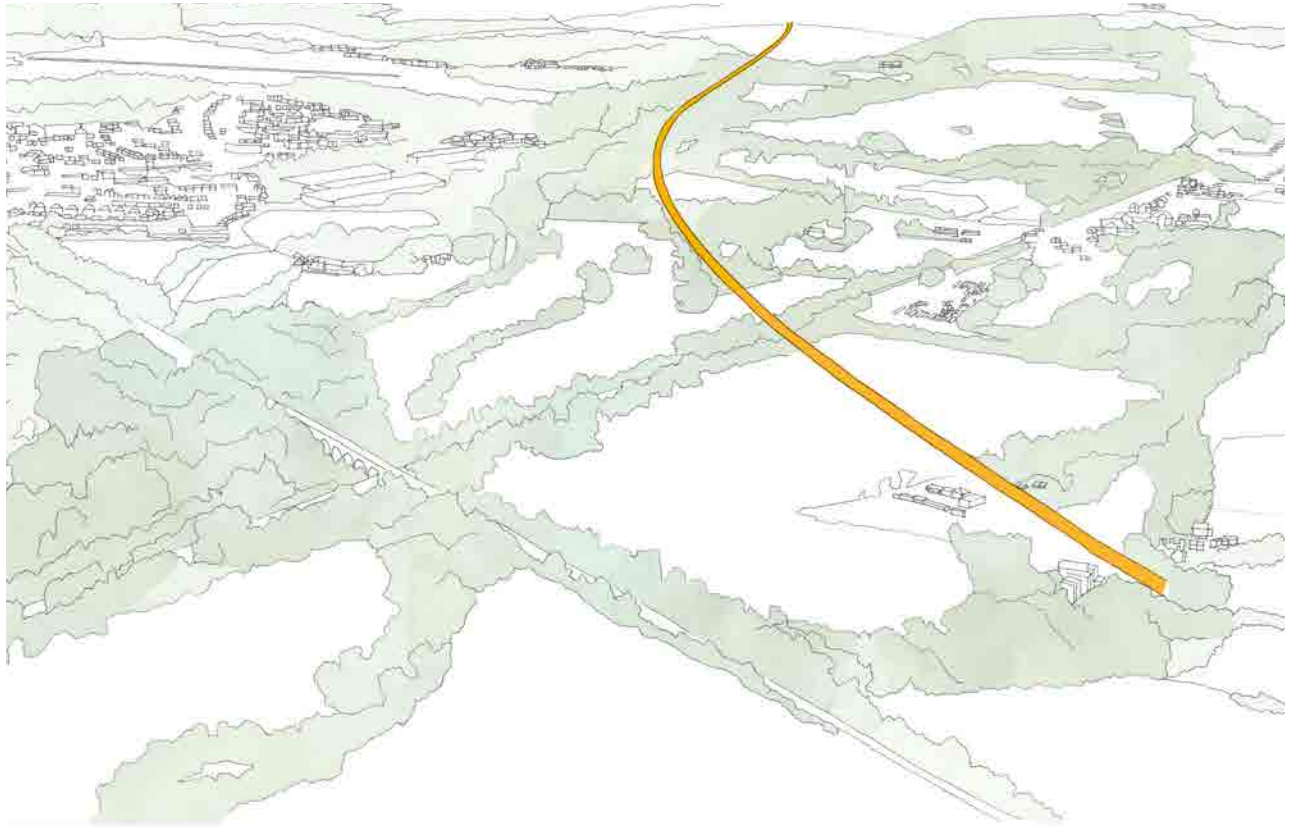
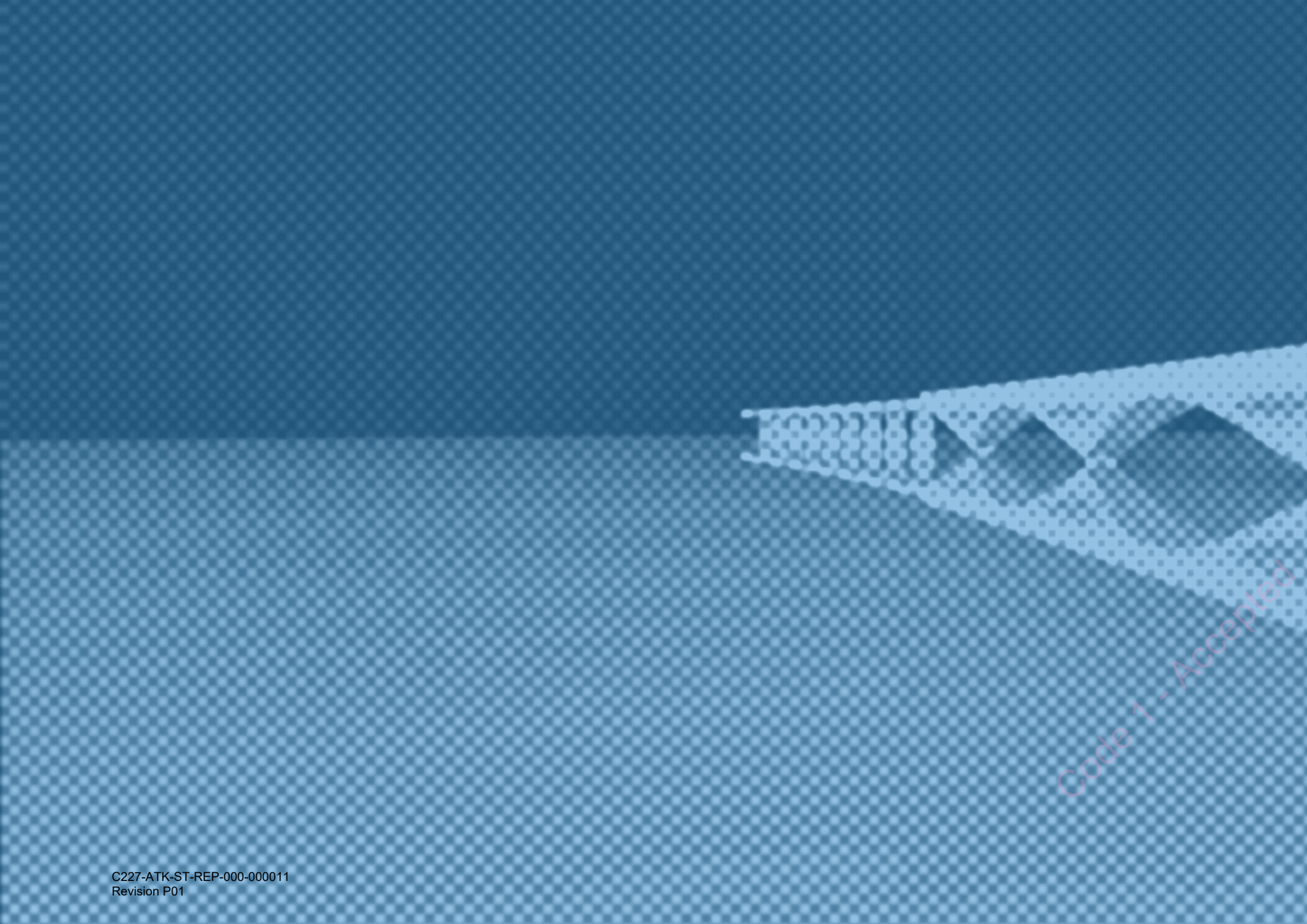




4 | OPTIONS APPRAISAL

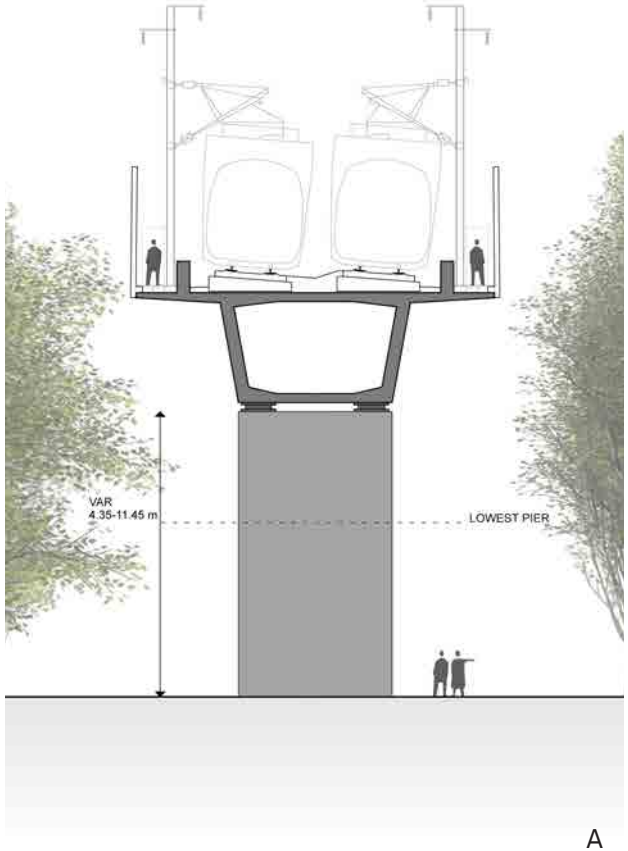
4.1 | Deck Section Appraisal

Having established the design aspirations set out in the previous chapter, concept design options can now be assessed against them. In order to best address the separate constraints and opportunities of the Woodland and the Water Character Areas, options will focus on them separately.

Many of the proportional constraints (span to depth, depth to clearance, etc.) are most restrictive in the Woodland Character Area. As such, the cross-sectional design of the deck and piers should be designed with a focus on this area so as to address the most constrained sections of the viaduct.

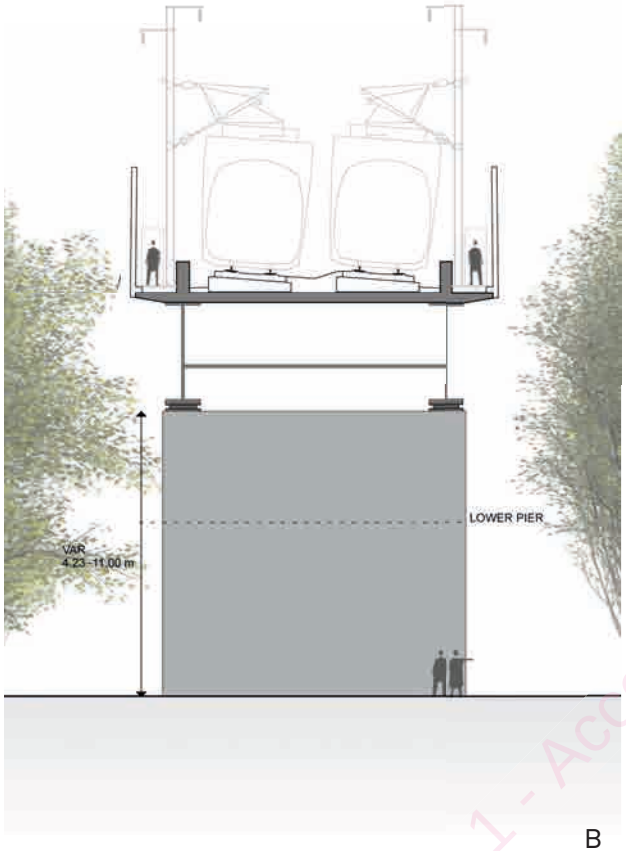
Within this area, the cross-section of the deck, its influence on the bearing location and in turn the pier width is of critical importance. As mentioned previously, there is a visual aspiration to increase the clearance underneath the deck. At several locations (such as over roads) this desire is reinforced with a functional clearance constraint.

A traditional arrangement would position the vast majority of the structure below the level of the deck (A). This reduces the clearance and also 'stacks' elements such as robust kerbs, noise barriers, parapets and catenary structures on top of the structural depth, which leads to a further increase in the total perception of deck depth (structure + components above). Using a 'through' structure arrangement has the benefit of moving a proportion of the structure above the deck. This improves the clearance below, and also allows certain elements



A

Elegance ☒
Well Proportioned (Deck to Clearance) ☒
Uncluttered, Minimalist Piers ☑
Positive Passenger Experience (Views) ☑



B

Elegance ☒
Well Proportioned (Deck to Clearance) ☒
Uncluttered, Minimalist Piers ☒
Positive Passenger Experience (Views) ☑

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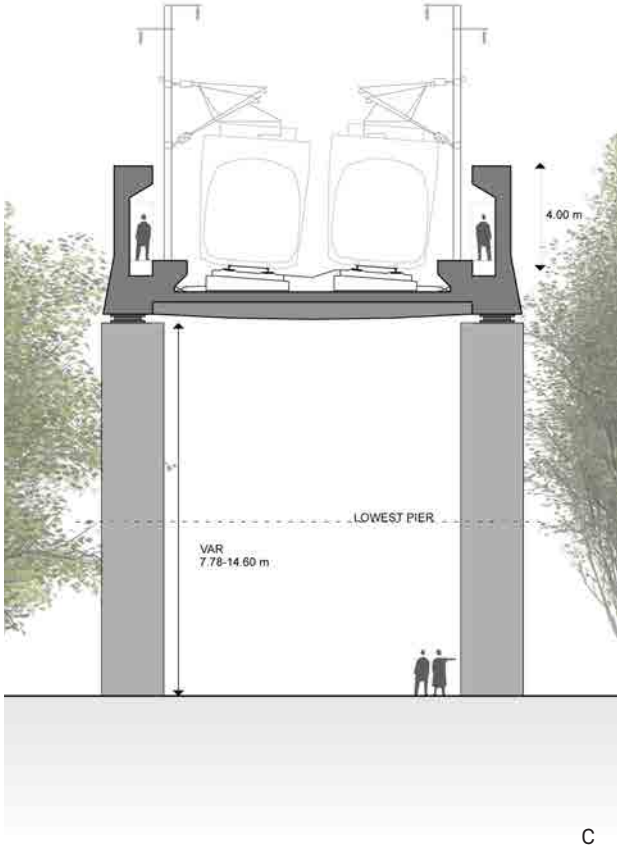
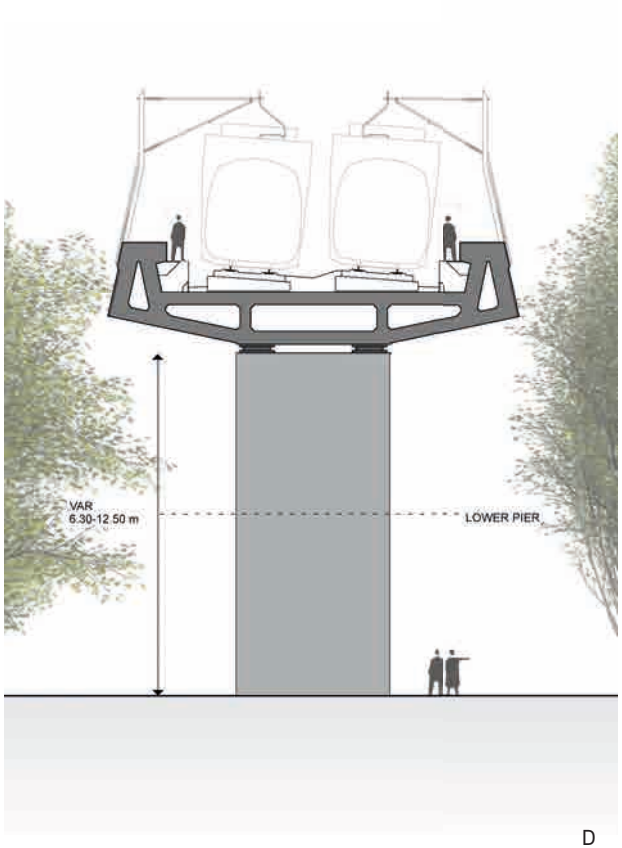


C

- Elegance ✗
- Well Proportioned (Deck to Clearance) ✓
- Uncluttered, Minimalist Piers ✗
- Positive Passenger Experience (Views) ✗



D

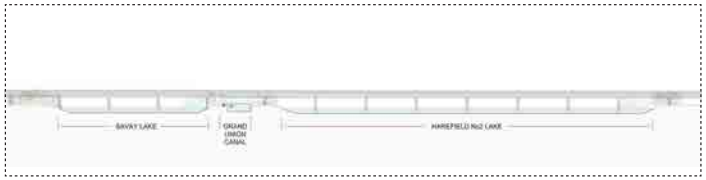
- Elegance ✓
- Well Proportioned (Deck to Clearance) ✓
- Uncluttered, Minimalist Piers ✓
- Positive Passenger Experience (Views) ✓

(noise barriers, kerbs, escape platforms etc.) to exist within/behind this structural makeup, further reducing the visual depth of the 'total' deck build-up.

Of course, if this structure rises to the point where it begins to block the views of the passengers, any benefit achieved in views 'of' the structure is eliminated with a negative effect on views 'from' the structure.

Next, is the deck's influence on the transverse distance between bearings. Traditional through structures force the bearings to the edge of the deck, which results in either twin-piers (C), wide leaf piers (similar to B) or cantilevered piers. These piers either appear overly large and block views, or produce an irregular pattern which clutters the appearance of the viaduct, and as such are not suitable for the CVV.

The proposed solution is option (D), which combines above and below deck structure with enough torsional stiffness in order to maintain a close bearing proximity beneath the deck. The result is a structure with a good 'total depth' to clearance ratio, which masks certain elements behind the structure, and permits transversely-slender piers beneath.

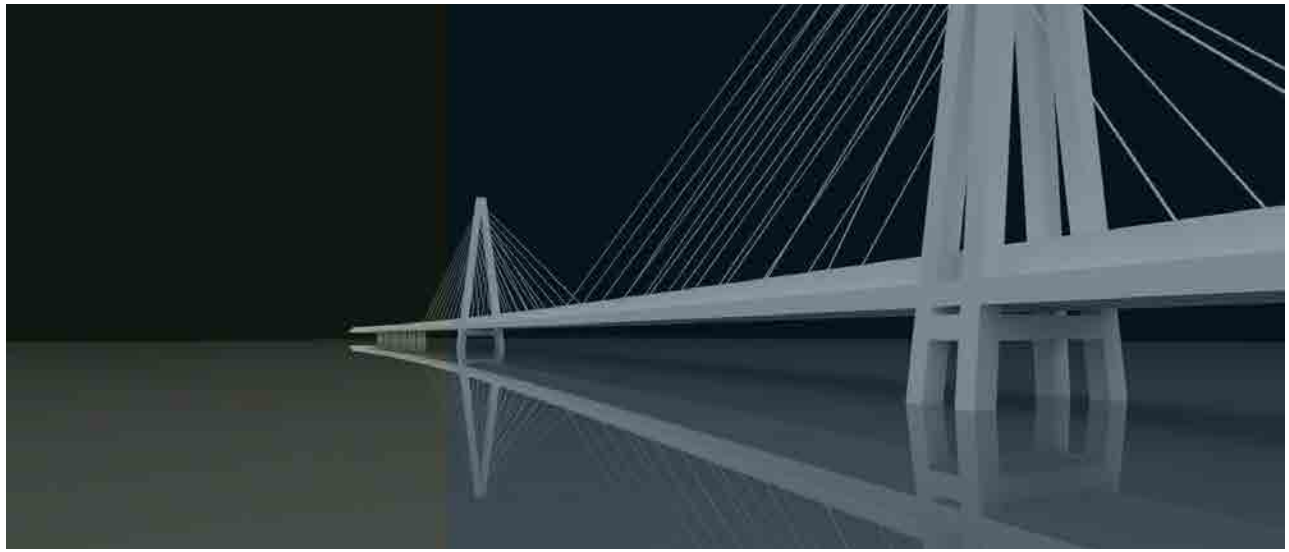


4.2 | Option Appraisal

1. Multispan continuous beam with a box girder with cantilevers (or U-shaped) constant depth cross section

Perhaps the most basic design would take the form of a continuous beam viaduct with consistent 60m spans. The constant depth deck would comprise of either a box girder and cantilevers, or a U-shape.

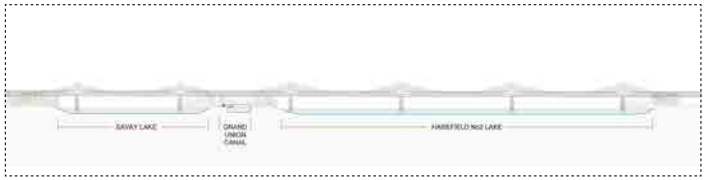
Whilst this structure would be suitable for certain HS2 crossings, it is not commensurate with the importance of the CVV, nor does it positively respond to the diverse, sensitive landscape below. Whilst moving to a U-shaped cross-section would improve the proportions and clearance below, it does little to respond to the site, and certainly falls short of an 'extraordinary', elegant structure.



4.2 | Option Appraisal

2. Multispan cable-stayed viaduct

A multi-(350m)-span cable-stayed viaduct would certainly fall into the 'prominent' category of design aspiration. Whilst a solution such as this would be well-suited to lofty arrangements such as Millau, the low-alignment creates a poorly-proportioned structure which is completely out of scale with the Colne Valley. This viaduct design, even if beautifully sculpted, would not fit this landscape, is incompatible with the use of Denham Aerodrome (the towers will interfere with the departure and landing corridors) and on the limit of what could be technically achieved for a HSR viaduct.



4.2 | Option Appraisal

3. Extradosed Spans Over Main Lakes

This solution (as well as the four following ones), respond separately to the Woodland and Water Character Areas. Either across the whole viaduct, or specifically over the Woodland Area, all four utilise a U shaped deck cross section in order to maximise clearance below, as well as position non-structural elements within the structural depth. Whilst simple, shorter spans suit the Woodland areas, longer spans are used for the Water Character areas to respond to the open views.

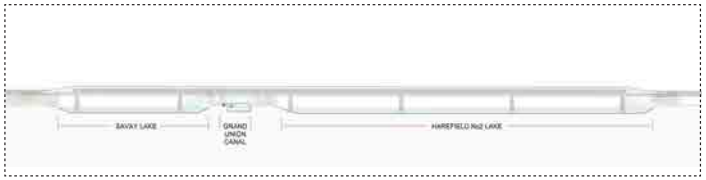
This extradosed option is designed with 115m-long spans over the water, with a cross-section that departs from the U-shaped one utilised in its shorter woodland spans. The extradosed arrangement requires support at the edge of the deck, which negatively impacts the pier form below as discussed previously.

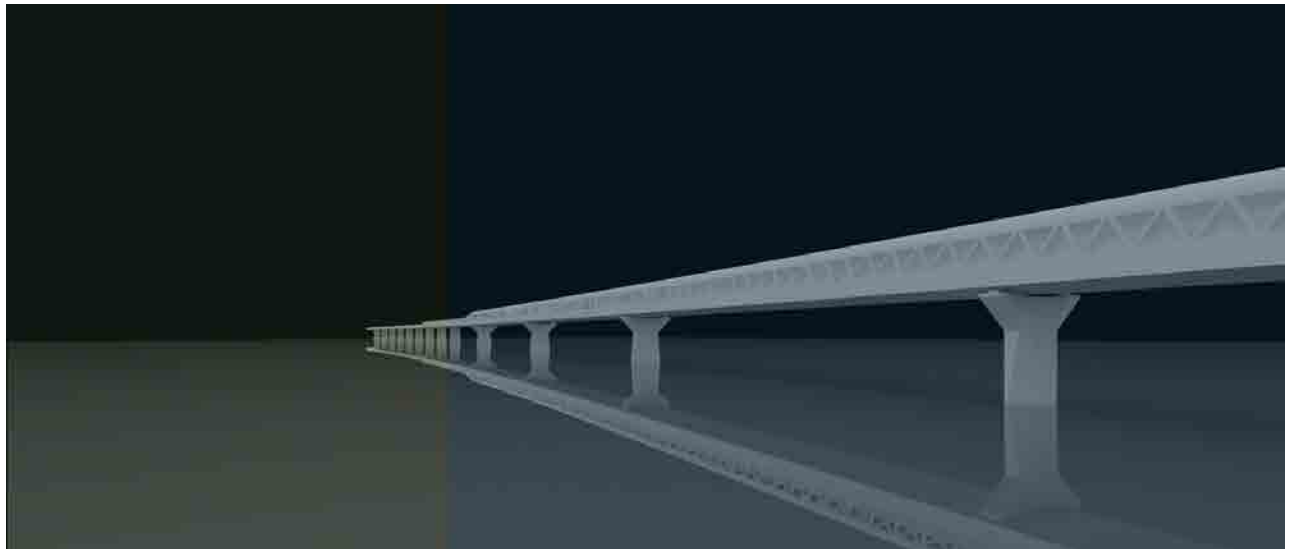
The layout is a natural progression of the previous cable-stayed solution, reducing both the span length and the tower height, ultimately producing a viaduct with a more suitable scale. Whilst certainly eye-catching, the harsh lines and utilitarian form does not produce an elegant response to this natural setting.

4.2 | Option Appraisal

4. Multispan beam with variable depth spans (above rail) over main lakes

In this fourth option, the main 115m-long spans over the water have variable depth, with a cross-section that departs from the U-shaped one used in the shorter woodland spans. The variable depth profile is formed as an extension to the side girders, which offers opportunities to create interesting forms that respond to the character of the site. However, the structural form is highly complex, and the above-deck waves may restrict views for the passenger. Furthermore the external structure would require wide piers, adding mass and clutter below the deck.

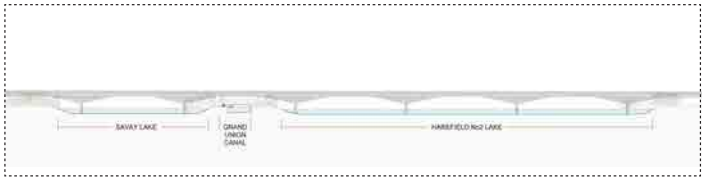


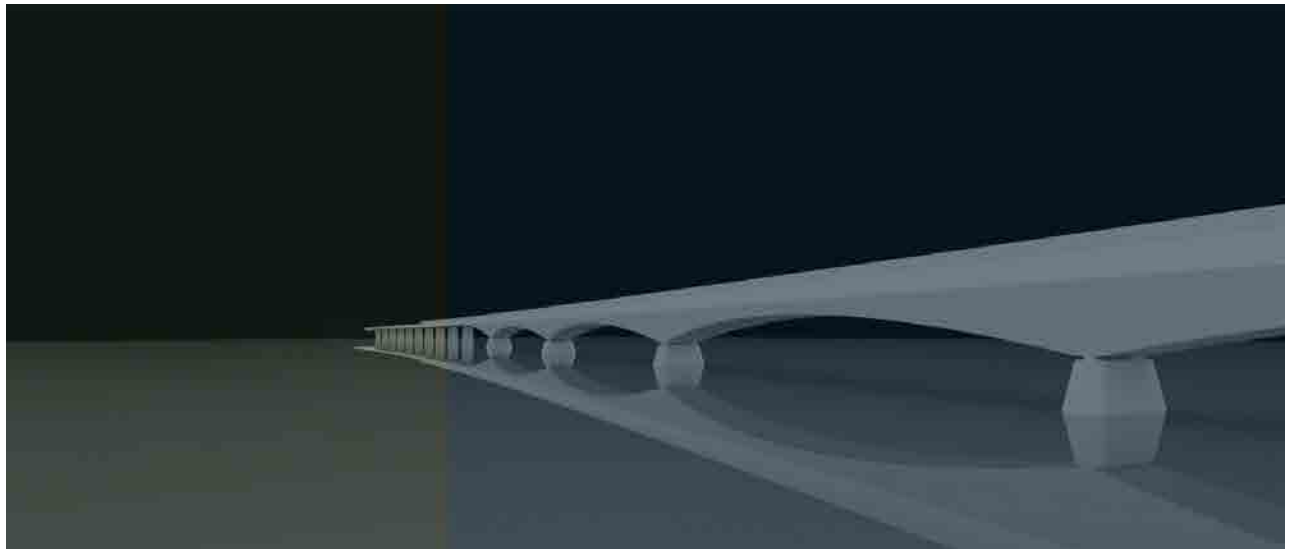


4.2 | Option Appraisal

5. Multispan beam with constant depth tubular cross section over main lakes

In this fifth solution a tubular cross-section with side trusses is used across the water to achieve 115m spans. Pushing structural depth wholly above deck results in a depth of more than 9.5m. This would be obstruct open views of the countryside for the passenger, and whilst the clearance below the deck is high, the visual mass of the deck is too great. Again, the externally-located structure results in the necessity for hammer-head or double piers below, which counteracts the advantages brought by the high clearance.

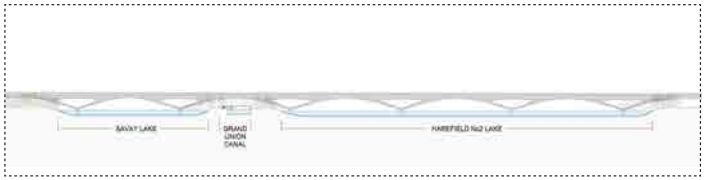


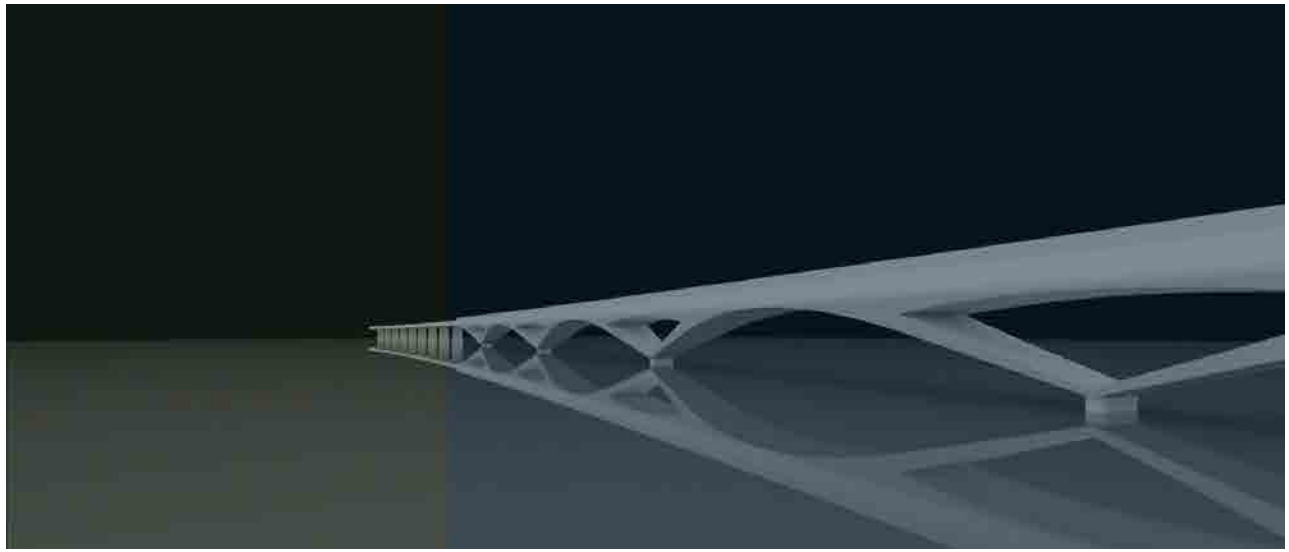


4.2 | Option Appraisal

6. Multispan beam with variable depth spans (below rail) over main lakes

This sixth solution seeks to increase the spans across the water by utilising a conventional variable depth deck, with the whole structure below rail, in order to reach the main 115m long spans. This goes some way to responding to the water environment, as well as utilising reflections. This solution also helps to visually link the deck to the piers, adding clarity to the arrangement when viewed from oblique angles. The more centrally located bearings also reduces the cross-sectional width of the piers, enabling the structure to tread more 'lightly' across the landscape. However, the mass of the beams over the supports creates a heavy structure that is too dominant to be considered elegant.





4.2 | Option Appraisal

7. Multispan variable depth arched spans with v-shaped piers over main lakes

The last option is an evolution of option 6, where the whole structure is kept below deck, combining a variable depth deck (with parabolic variation) and V shaped piers, holistically conceived as a single body with the appearance of a sequence of arches narrowing when closer to the water. Minimising the area in contact with the water, so as to tread lightly across this sensitive landscape, is one of the key benefits of this design. Furthermore, whereas option 6 appeared overly heavy above the piers, large perforations maintain views and landscape 'flows' through. The combination of subtle arches, structural lightness and exceptional proportions creates a structure which is a fitting addition to the landscape. Further refinement of the detailing will offer the opportunity to create an extraordinary contextual structure, which becomes a beacon through its elegance.

Option 1

- Extraordinary ✗
- Fits the Landscape ✗
- Appropriate Scale ✓
- Elegance ✗
- Responds to Landscape Character Areas ✗
- Responds to Landscape Constraints ✗
- Positively Utilises Reflection ✗
- Well Proportioned !
- Uncluttered ✓
- Addresses Varied Views ‘of’ the Viaduct ✗
- Positive Passenger Experience ✓
- Maintains Views & landscape flow ‘through’ Legible ✗
- Structurally Achievable ✓
- Buildability ✓

Option 2

- Extraordinary ✓
- Fits the Landscape ✗
- Appropriate Scale ✗
- Elegance ✗
- Responds to Landscape Character Areas ✗
- Responds to Landscape Constraints ✗
- Positively Utilises Reflection !
- Well Proportioned ✗
- Uncluttered ✓
- Addresses Varied Views ‘of’ the Viaduct ✓
- Positive Passenger Experience ✓
- Maintains Views & landscape flow ‘through’ Legible ✓
- Structurally Achievable ✗
- Buildability ✗

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Option 3

Extraordinary	✓
Fits the Landscape	!
Appropriate Scale	✓
Elegance	✗
Responds to Landscape Character Areas	✓
Responds to Landscape Constraints	✓
Positively Utilises Reflection	✗
Well Proportioned	✗
Uncluttered	✗
Addresses Varied Views ‘of’ the Viaduct	✓
Positive Passenger Experience	✗
Maintains Views & landscape flow ‘through’ Legible	✓
Structurally Achievable	!
Buildability	✓

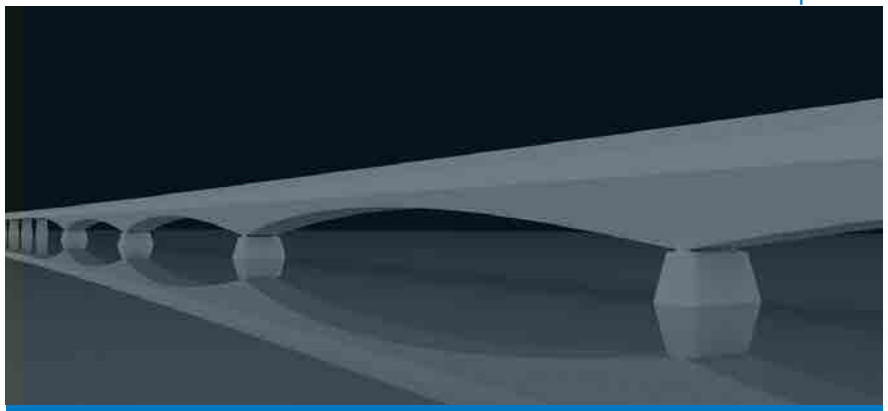
Option 4

Extraordinary	✓
Fits the Landscape	✓
Appropriate Scale	✓
Elegance	✗
Responds to Landscape Character Areas	✓
Responds to Landscape Constraints	✓
Positively Utilises Reflection	✗
Well Proportioned	✓
Uncluttered	!
Addresses Varied Views ‘of’ the Viaduct	✓
Positive Passenger Experience	✗
Maintains Views & landscape flow ‘through’ Legible	✓
Structurally Achievable	✓
Buildability	✓

Option 5

- Extraordinary ✓
- Fits the Landscape ✗
- Appropriate Scale !
- Elegance ✗
- Responds to Landscape Character Areas ✗
- Responds to Landscape Constraints ✓
- Positively Utilises Reflection ✗
- Well Proportioned !
- Uncluttered !
- Addresses Varied Views ‘of’ the Viaduct ✗
- Positive Passenger Experience ✗
- Maintains Views & landscape flow ‘through’ Legible ✗
- Structurally Achievable ✓
- Buildability ✓

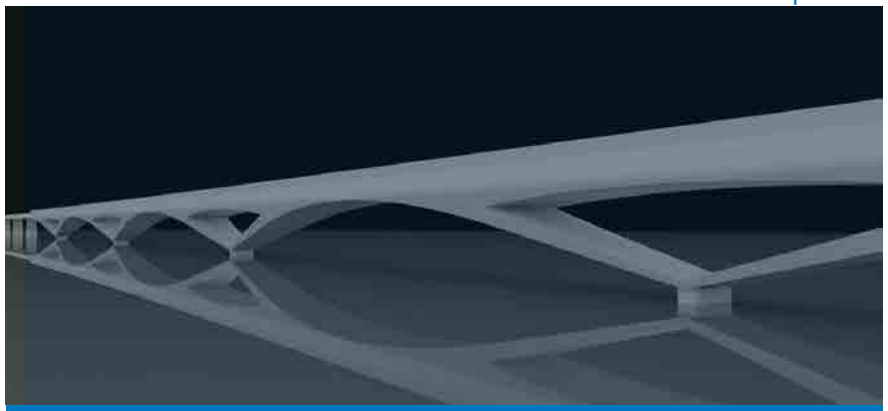
Option 6



- Extraordinary ✗
- Fits the Landscape ✓
- Appropriate Scale ✓
- Elegance ✗
- Responds to Landscape Character Areas ✓
- Responds to Landscape Constraints ✓
- Positively Utilises Reflection ✓
- Well Proportioned ✗
- Uncluttered ✓
- Addresses Varied Views ‘of’ the Viaduct ✗
- Positive Passenger Experience ✓
- Maintains Views & landscape flow ‘through’ Legible !
- Structurally Achievable ✓
- Buildability ✓

4.3 | Conclusion

Option 7



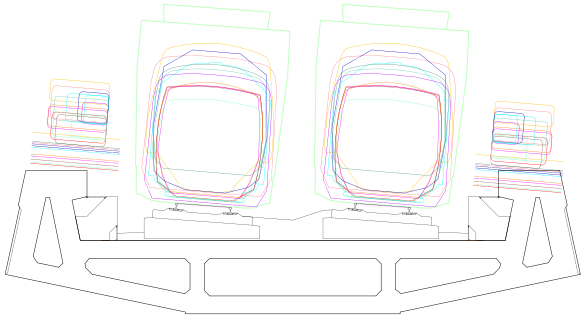
- Extraordinary ✓
- Fits the Landscape ✓
- Appropriate Scale ✓
- Elegance ✓
- Responds to Landscape Character Areas ✓
- Responds to Landscape Constraints ✓
- Positively Utilises Reflection ✓
- Well Proportioned ✓
- Uncluttered ✓
- Addresses Varied Views 'of' the Viaduct ✓
- Positive Passenger Experience ✓
- Maintains Views & landscape flow 'through' Legible ✓
- Structurally Achievable ✓
- Buildability ✓

5 | SPECIMEN DESIGN

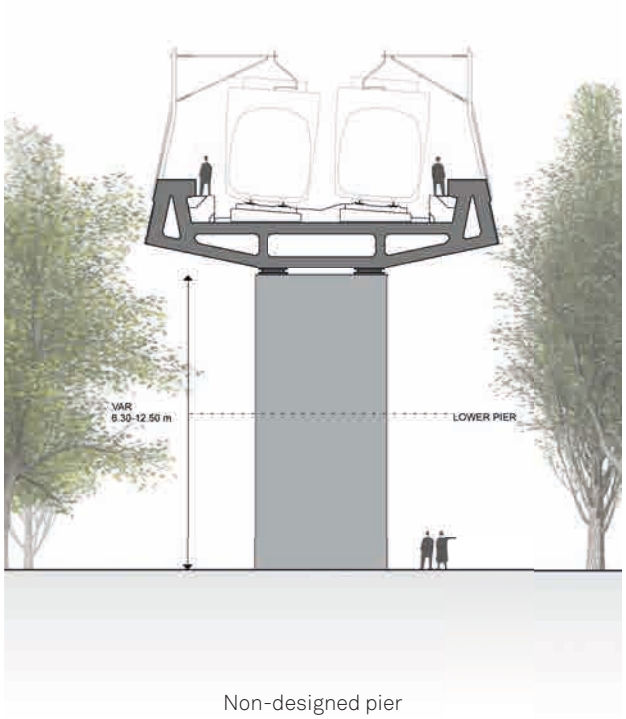
5.1 | Deck

The combination of some above-deck structure and torsional stiffness creates a deck that actively responds to the HS2 constraints, whilst maintaining good clearance below, as well as offering an opportunity for a consistent design element across the varied conditions of the CVV.

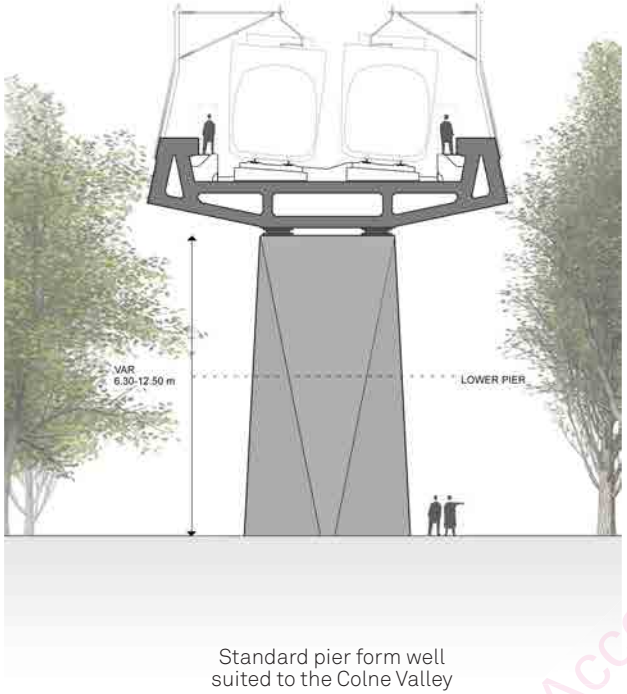
Applying a subtle taper to the piers, as well as simple ‘creases’ to their face, creates a standard form which is well suited to the Colne Valley. The cross-sectional distance between the deck edge and the bearings also serves to cast the pier into shadow, drawing attention to the crisp edge of the deck, adding lightness to the appearance of the structure in both the water and woodland areas.



Deck cross section showing, in colours, the envelope of potential trains to be used for the line and, over the side box girders, the position of their windows and floor levels. The design of the deck guarantees one of the key points of the design: the structure doesn’t obstruct the views of the Colne Valley from the vehicle



Non-designed pier



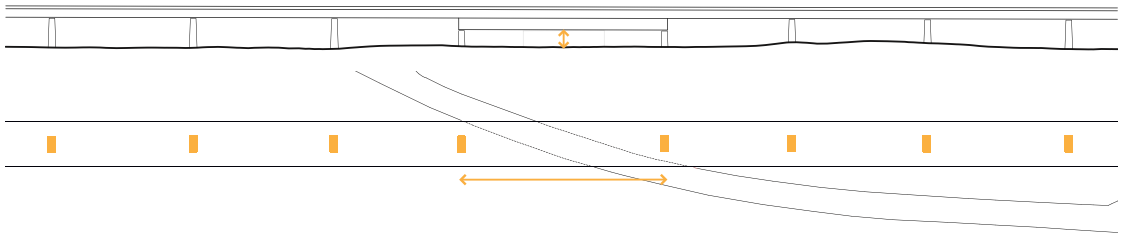
Standard pier form well suited to the Colne Valley

Elevation of deck and piers in a woodland area

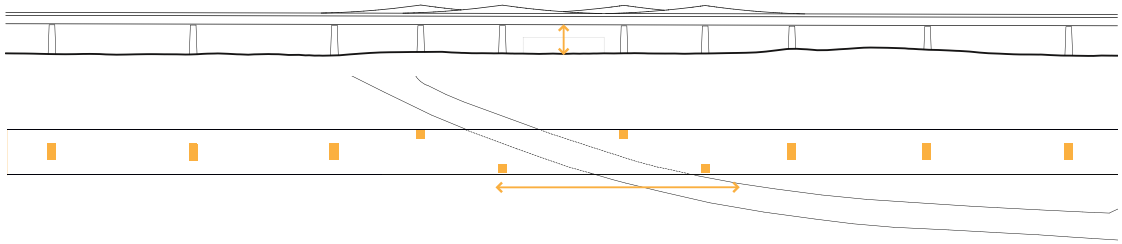
Deck and piers in woodland areas

5.2 | A412 Crossing

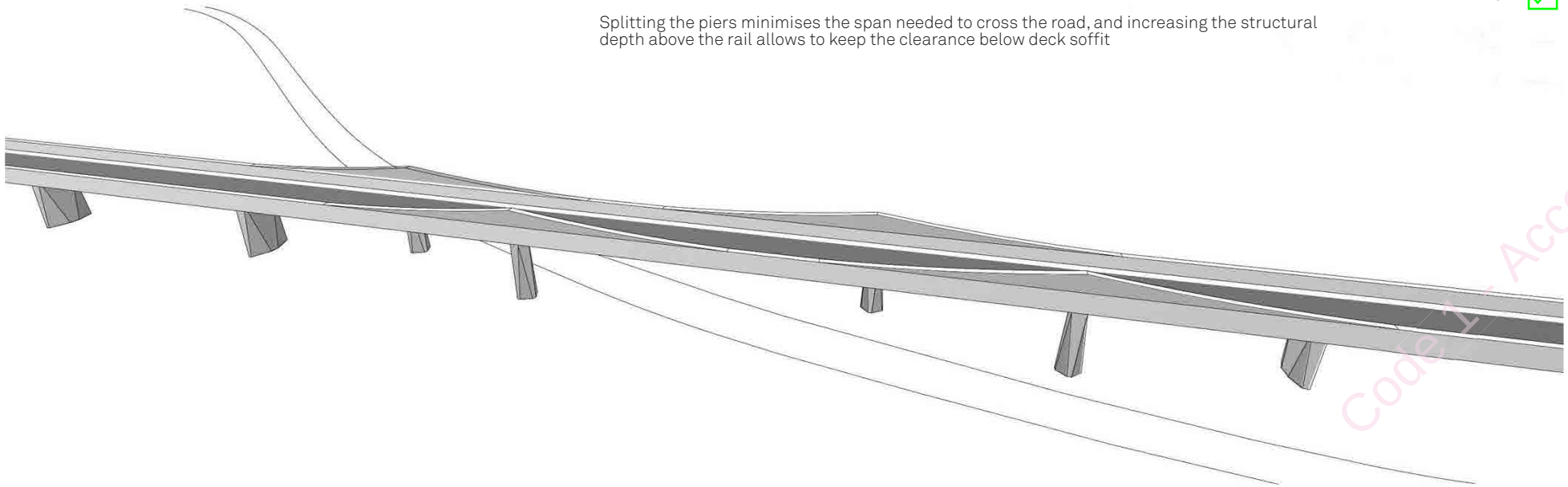
The high-skew of the A412 crossing forces a different solution than the standard Woodland spans. Here, the piers must split, and the increased span requires a greater structural depth. Simply stepping the beam depth down below the deck would reduce the clearance, and push the vertical alignment of the rail up. Instead, it is proposed to use and option akin to that seen for water option 4. By increasing the structural depth above the rail, the clearance below remains high. Whilst this solution was not highly successful for the multi-span arrangement over the water, it addresses this single crossing well, and makes a positive feature out of a challenging arrangement.



Just increasing the span would mean a deeper deck and a potential headroom restriction



Splitting the piers minimises the span needed to cross the road, and increasing the structural depth above the rail allows to keep the clearance below deck soffit



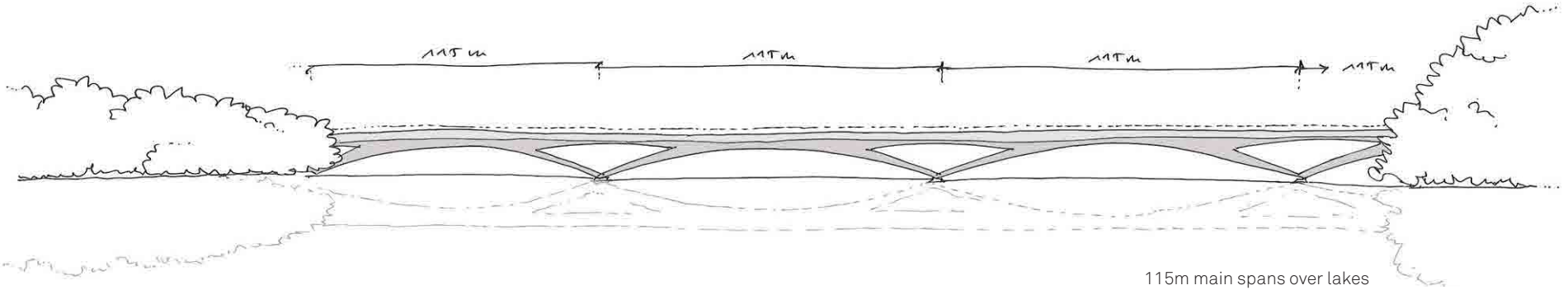
A412 skewed crossing s showing deck cross sections

A412 skewed crossing

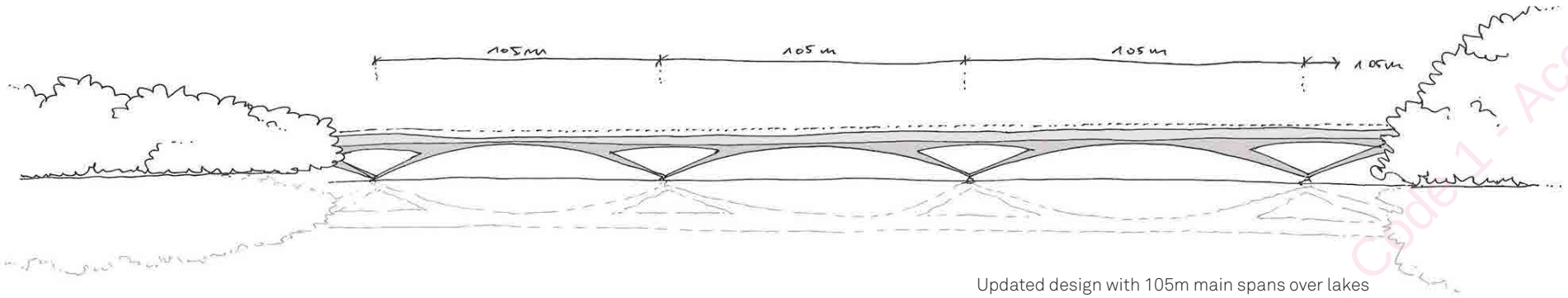
5.3 | Water Span Arrangement

Whilst the general aim of achieving long spans on the water section is desired, it has been found that a slight reduction in span, from 115m to 105m results in a much better arrangement. The proposed 105m spans formally address both the lakes, and the canal below, and creates a structure which is both more legible and more deliverable.

Elevation over Korda Lake with 105m main spans

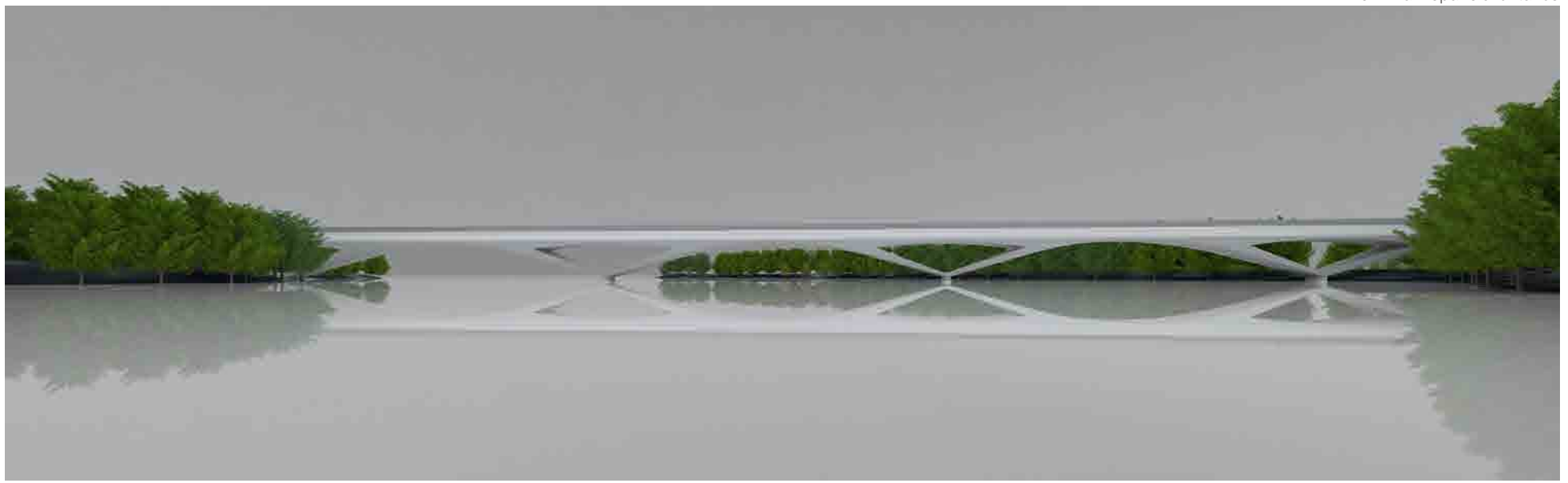


115m main spans over lakes



Updated design with 105m main spans over lakes

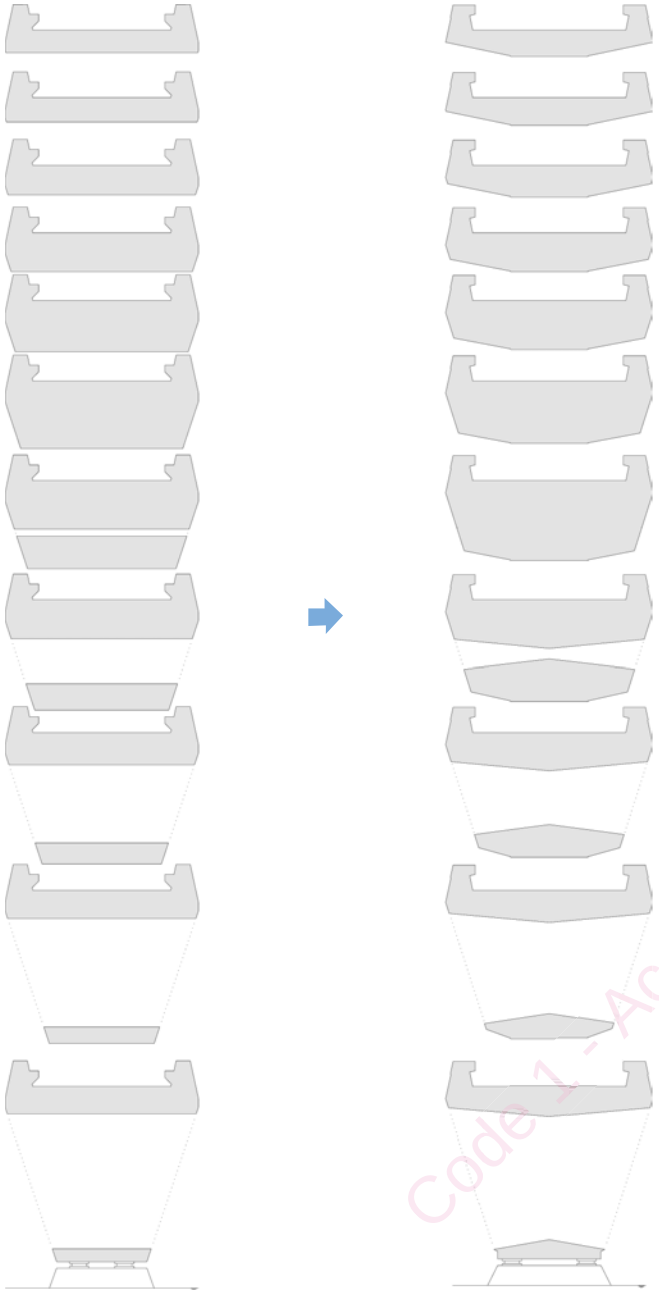
115m main spans over lakes

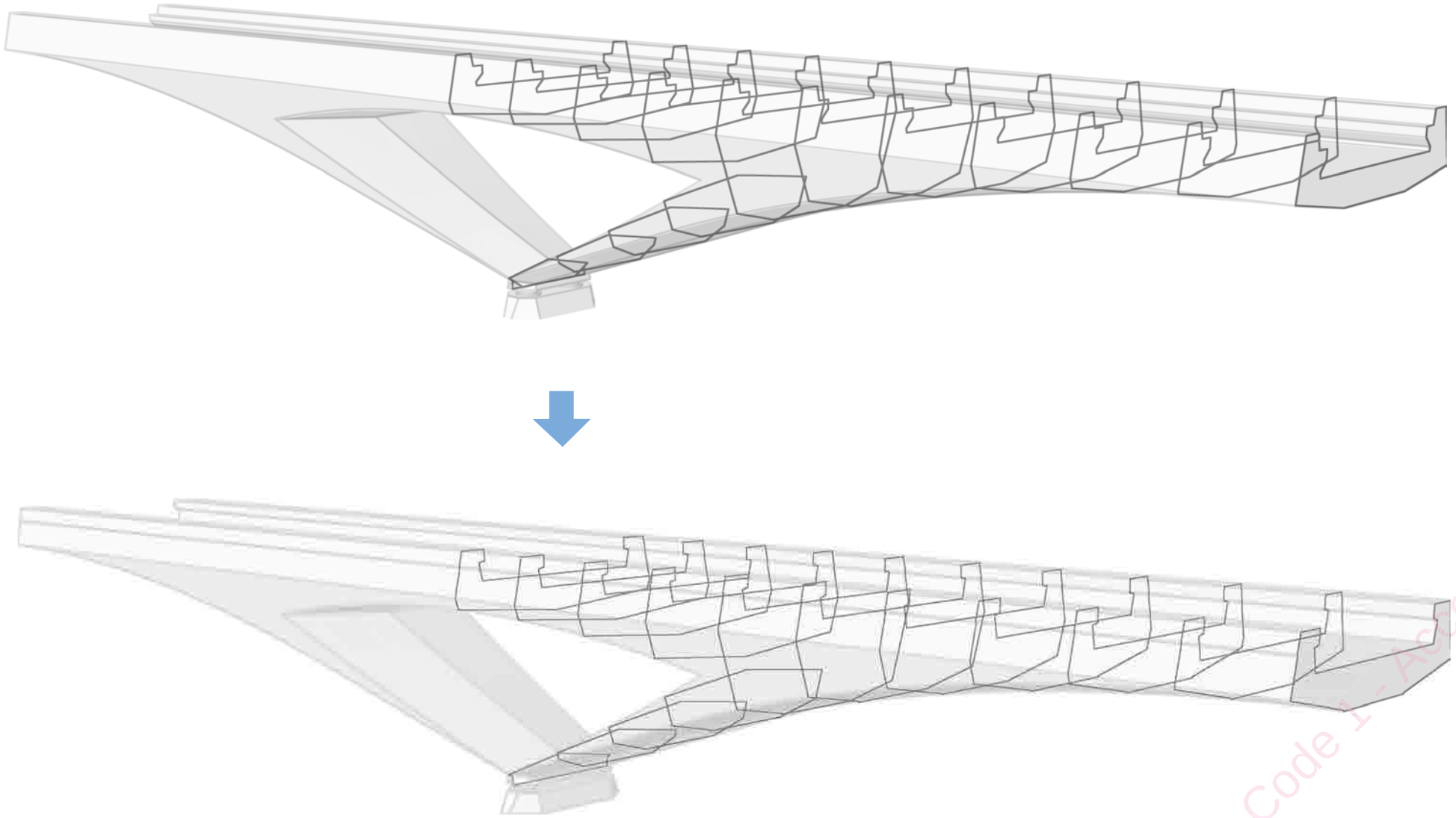


Updated design with 105m main spans over lakes

5.4 | Cross Section Shaping

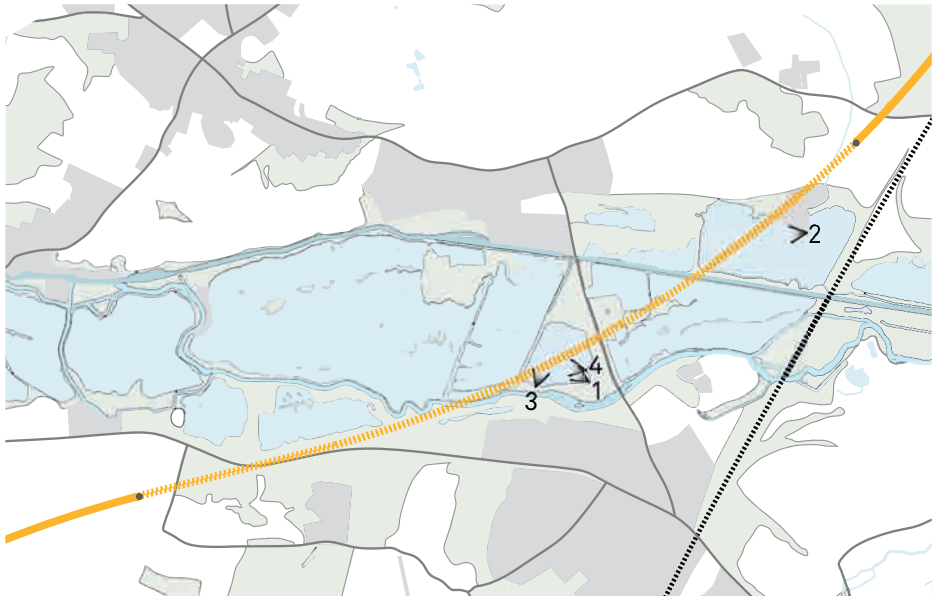
For this elegant structure to become a beacon, it must be exceptionally detailed. Part of this is to ensure that its key features are refined designs which add to the interest and quality of the crossing. The parametrically refined forms facet the deck soffit and the internal faces of the triangular cells, increasing the visual slenderness without reducing their mechanical properties.





Cross section shaping of the main spans

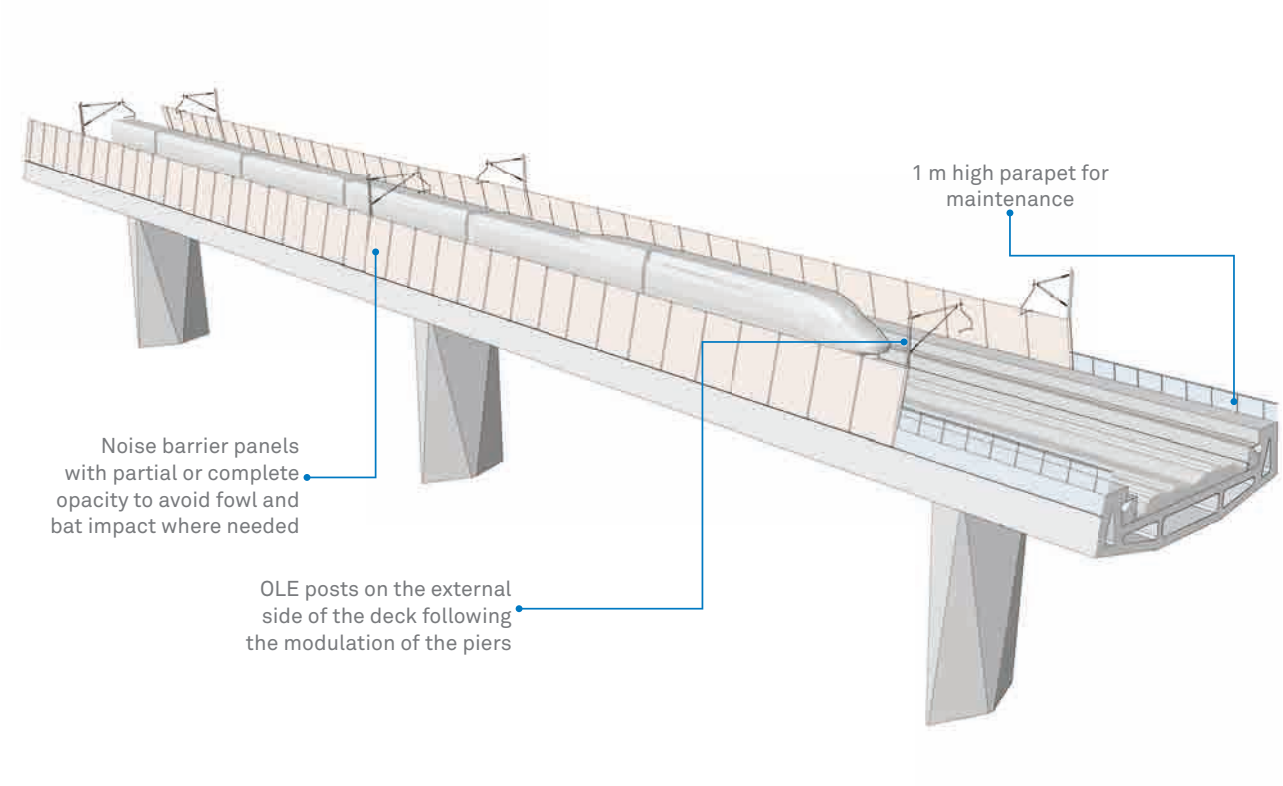
5.4 | Cross Section Shaping | render sketches



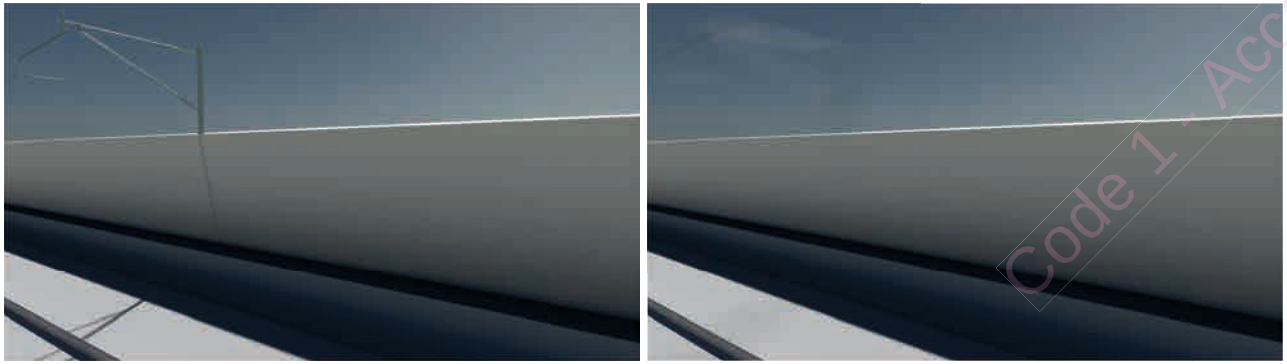
5.5 | Additional Elements

For any viaduct to be considered elegant, it must provide a holistic solution, which addresses the requirements of both the rail and the landscape. Even if the structure itself is beautiful, additional elements placed on top of it run the risk of adding clutter.

As such, the proposal is for a holistic edge-condition, which – with a single system – incorporates the noise barrier, parapet, fowl and bat protection and the OLE posts. As opposed to large 'frames' which abruptly start and stop, and thus disrupt the rhythm of the structure below, the proposal is for a series of vertical elements which subtly modulate across the viaduct. Their triangular cross section gives the system a transparent appearance when seen from the distance by CVRP visitors, and their arrangement and slenderness will make them almost invisible for HS2 users looking through the train window (see images). The envelope created by the system is consistent regardless of whether a noise barrier is needed or not, with its angle dividing the external face of the deck into two, increasing its visual slenderness.



What a HS2 user would see from the window of the train if a solid noise barrier is arranged (static image on the left and train running at a speed of 340km/h on the right). Users wouldn't even notice they are crossing the Colne Valley



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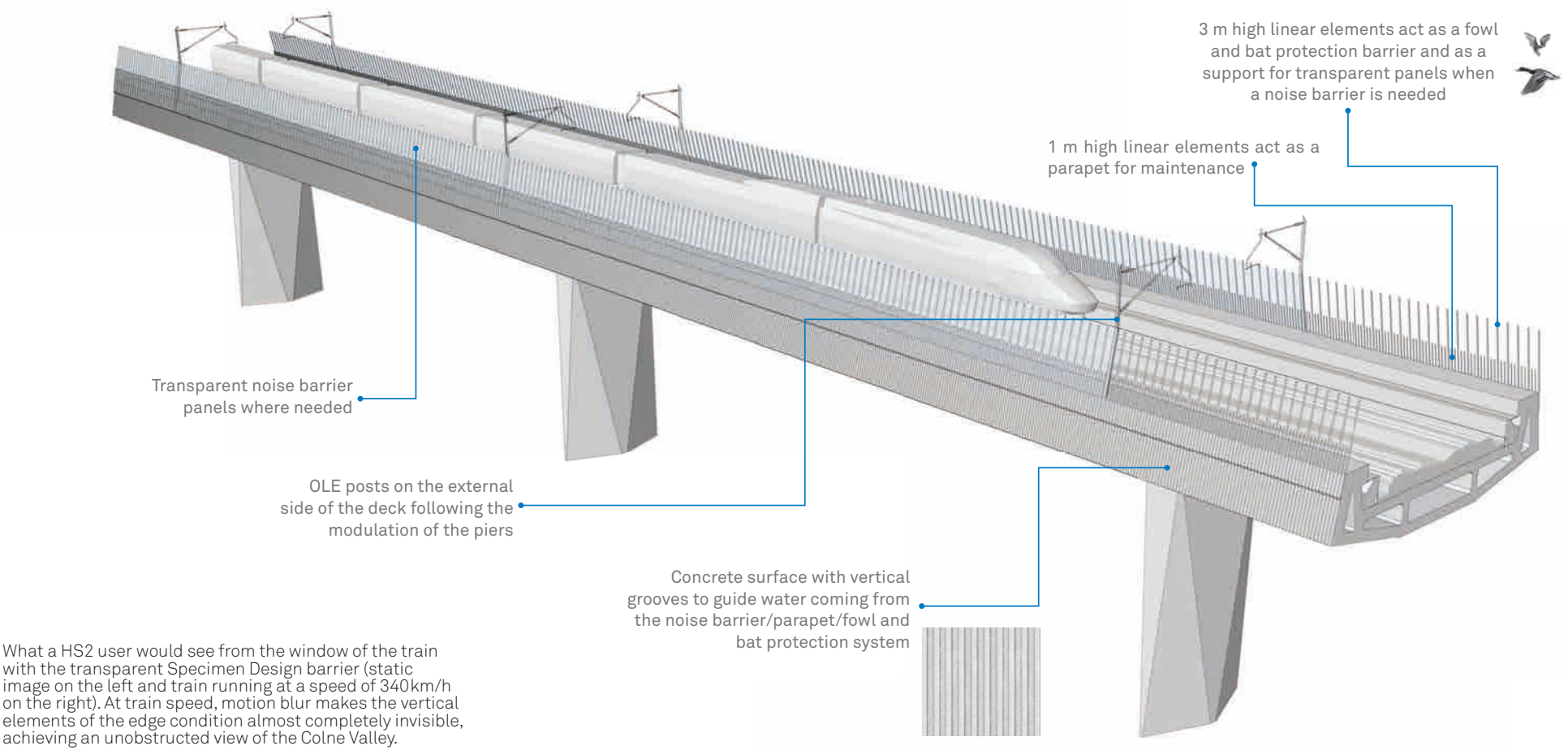
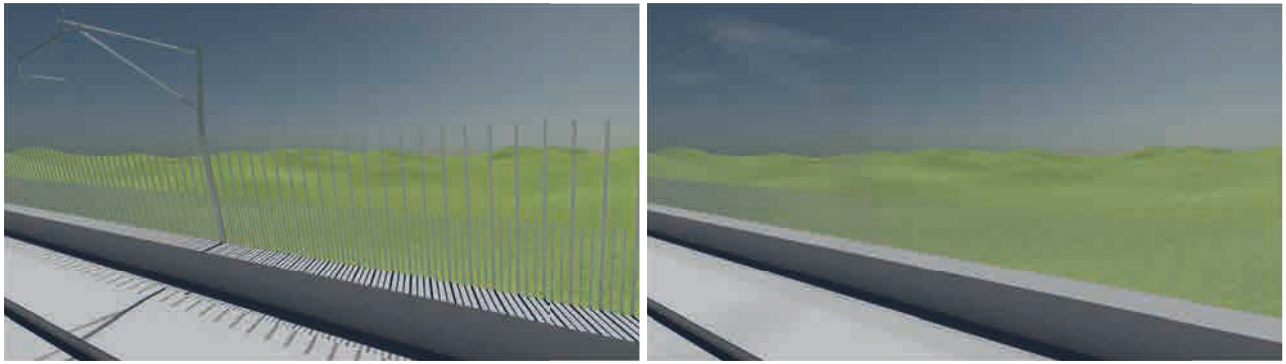


What a HS2 user would see from the window of the train with the transparent Specimen Design barrier (static image on the left and train running at a speed of 340km/h on the right). At train speed, motion blur makes the vertical elements of the edge condition almost completely invisible, achieving an unobstructed view of the Colne Valley.

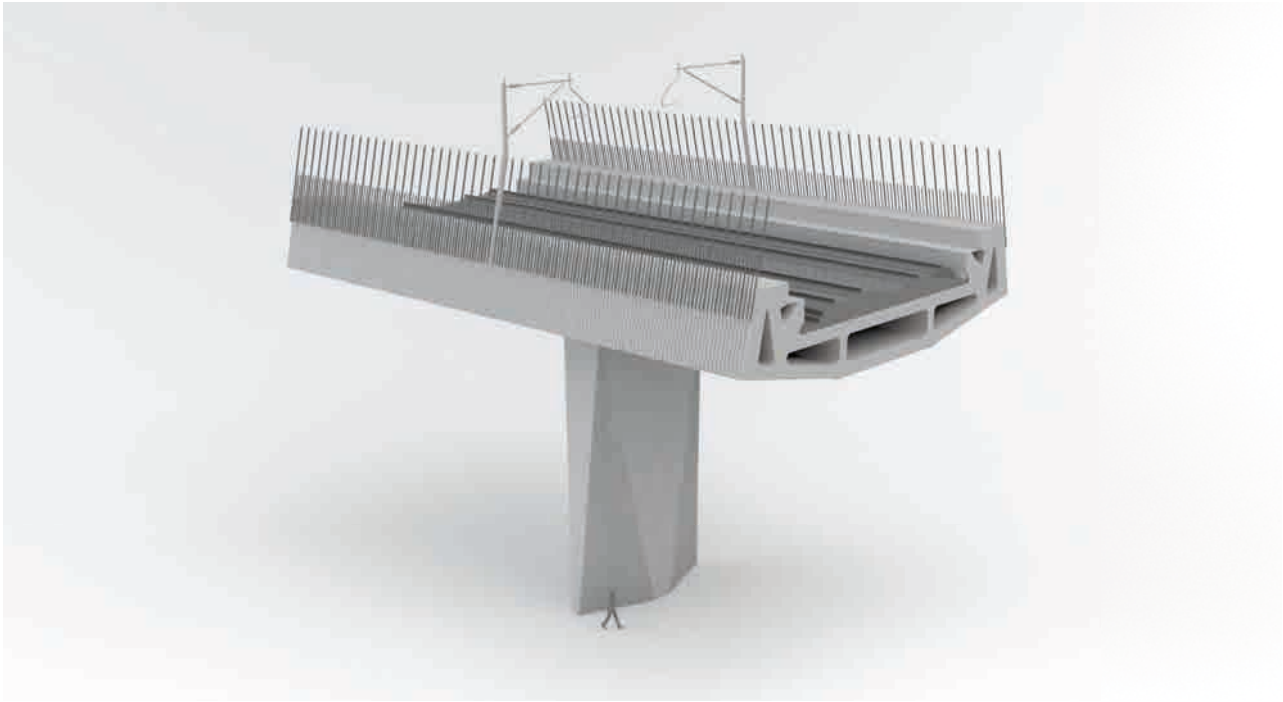


5.6 | Pier Detailing

The piers of the viaduct have an elegant, subtly tapered and faceted design. The fact that every support is made up by a single body, instead of the two columns that would be typically used together with U-shaped cross sections, means that they will be compact and cast in shadows, avoiding the pier-forest effect. Facets break their volume and create attractive shade contrasts varying with the daytime, season, and position of the viewer. These are key features of the design, defining a high quality that suits the viaduct design aspirations.

This design shouldn't be affected by a visible drainage system. Drainage conduits should be located inside the concrete body of the piers, using two pipes: a rigid fixed one and a flexible removable one inside the former, which can be accessed and replaced from the deck voids or the top of the deck.

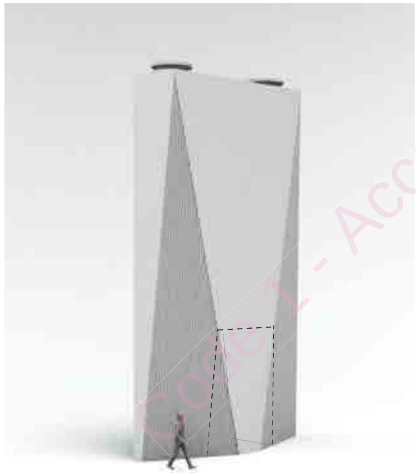
This general design approach can be enhanced in some specific areas improving the material finish with the addition of texture when they can be seen in close proximity by pedestrians, and locally and exceptionally modifying their geometry adding an aperture when they are close to towpaths and walking across the piers can contribute to a better user experience. The texture approach defined in this Specimen design complements the pier design, with simple vertical recessed lines on the triangular faces whose basis are located at ground level. It adds a balanced degree of complexity and interest to the untextured design while enhancing its natural geometric features, intensifying facet contrast.

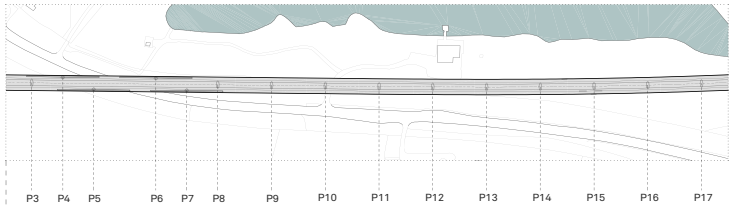


Original

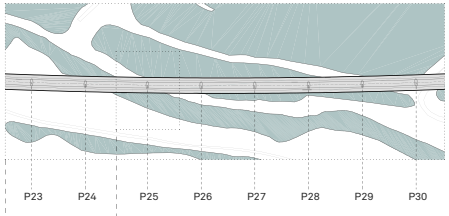
Textured

Aperture approach



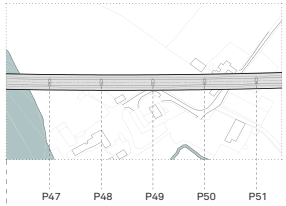


Area 1



Potential special pier with an aperture

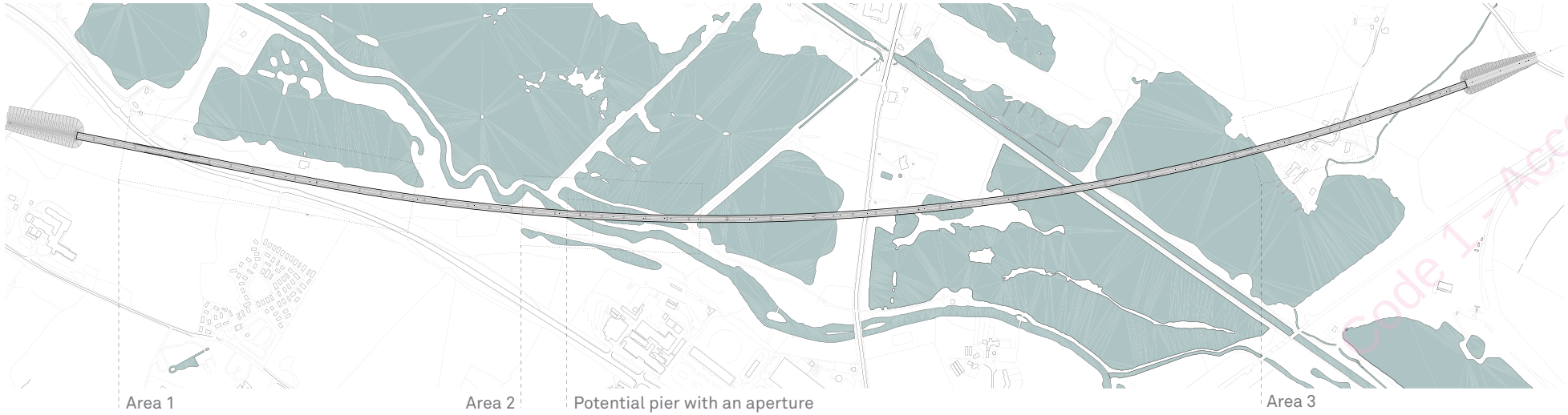
Area 2



Area 3

Three areas where texture can contribute to enhance the original untextured pier design have been identified and are defined in the bottom plan-view diagrams. Area 1 includes the piers in the proximity of the Water Ski Lake, a bridge stretch that runs parallelly to the A412 and a pathway. Area 2 is a woodland section where the viaduct runs along a towpath aligned with the River Colne and the lake known as Long Pond. It is probably the area of the bridge with the most exposed piers for people moving at low speed. An aperture in one of the piers of this group (highlighted in the diagrams) can be beneficial in order to maximise the functionality of the existing towpath. Area 3, East of Harefield Nº2 Lake, includes the last group of piers that may be visible from a short distance by pedestrians.

Location of areas where textured piers may be beneficial to improve the experience below deck, and location of potential pier with an aperture. In the top figures, these areas are shown in more detail.



Area 1 Area 2 Potential pier with an aperture Area 3

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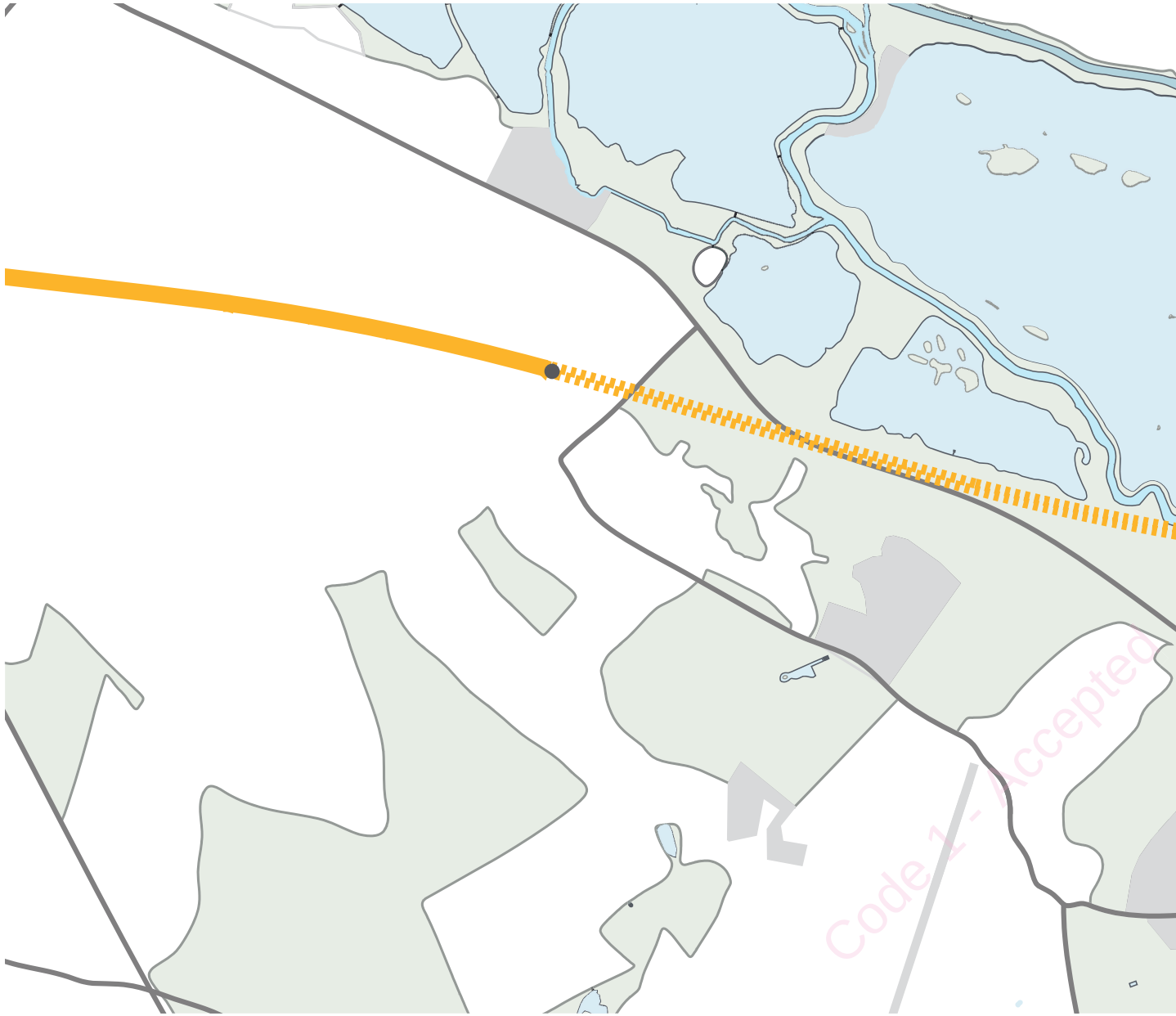
5.7 | Virtual images

The following virtual images show four key views of the viaduct crossing Harefield Nº2 and Korda Lakes. The key features of the Colne Valley Viaduct Specimen Design, described along this document, can be appreciated in this pictures: elegance, subtlety, legibility, harmonious and sculpted concrete shapes, respect for the water bodies being crossed (minimum concrete volume in contact with the water), transparency, use of reflection, care for detail, holistic design of viaduct and edge condition, etc.

The images show an extraordinary contextual structure, perfectly suited to the Colne Valley, which will become a beacon through its elegance.



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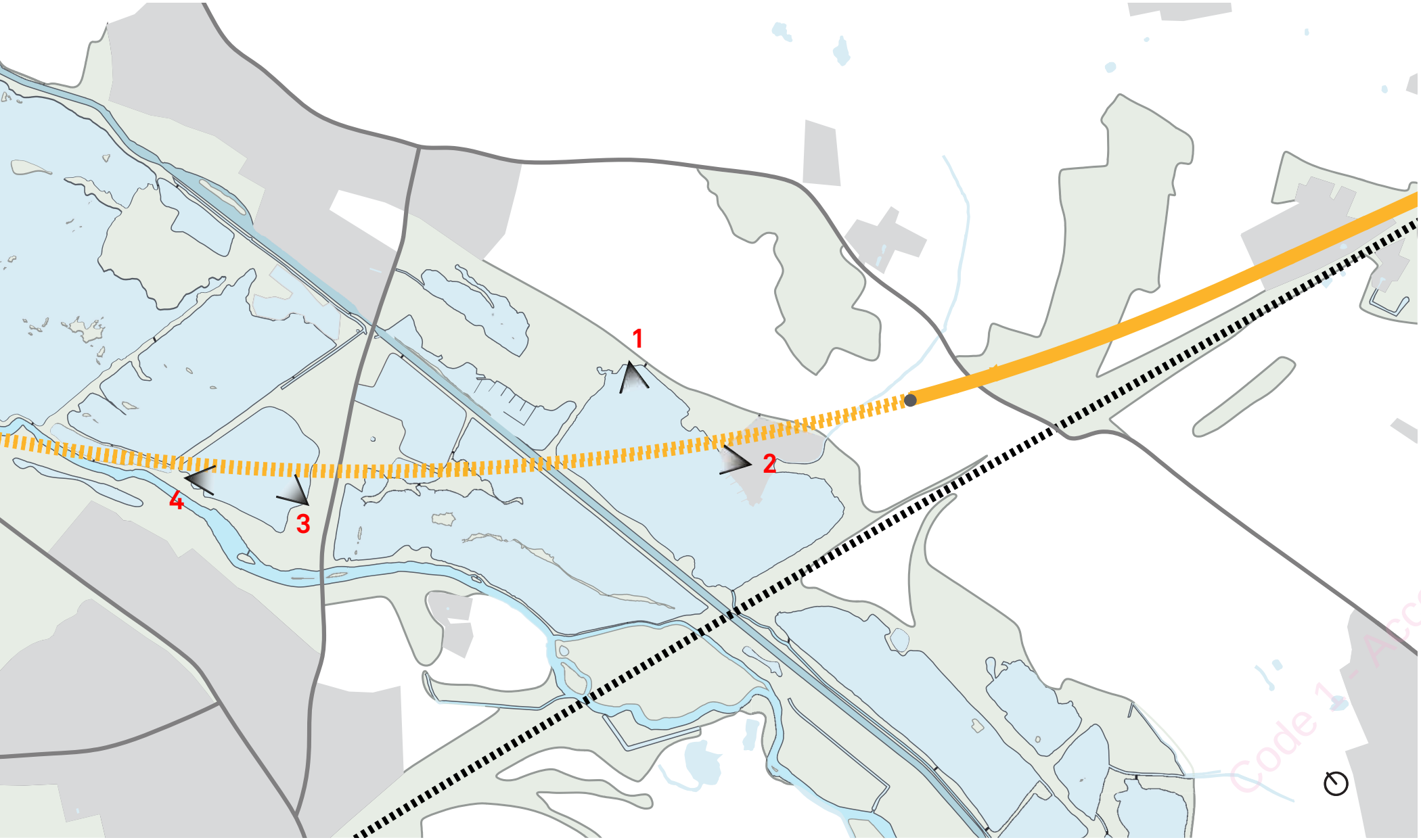

Image 1. Harefield No2 Lake

image: Hayes Davidson | Knight Architects

image: Hayes Davidson | Knight Architects

Image 2. Harefield No2 Lake

Image 3. Korda Lake

image: Hayes Davidson | Knight Architects

image: Hayes Davidson | Knight Architects

Image 4. Korda Lake

The Specimen Design has been developed interacting with the HS2 Colne Valley Regional Park Panel (CVRPP) and the HS2 Independent Design Panel at different stages of the work. Both panels provided very valuable input that was taken into account to produce this Specimen Design.

Apart from other informal meetings, conversations and comments from individual members of the panels, the following presentations and workshops took place:

Colne Valley Regional Park Panel

18/10/2016 - CVRP viaduct – specimen design workshop (at South Bucks District Council Offices in Denham) > Presentation of the design approach

02/11/2016 - CVRPP Meeting No. 9 - Workshop Specimen Design (at South Bucks District Council Offices in Denham) > Presentation at the end of the options appraisal

30/11/2016 - CVRP viaduct - specimen design workshop (at HS2 Sanctuary Building (Department for Education) Offices in London) > Presentation close to the end of the design stage

Design Panel

12/12/2016 - HS2 Design Panel to discuss the Colne Valley viaduct (at Canada Square Offices in London) > Presentation close to the end of the design stage
Both panels offered strong support for the content of the specimen design and the design approach. Specifically, both panels highlighted:

- The engagement and transparency with stakeholders all along the process.
- The sensitivity to the context of the overall design.
- How the viaduct changes in span and geometry depending whether it is above water, woodland or roads, keeping design coherence and elegance at the same time.
- How the intermediate cross-section successfully balances noise reduction with views from the train.
- The elegantly proportioned shapes of the main spans over water bodies and the variable depth span over the A412.
- Having taken into account the reflective properties of the water bodies as a relevant design parameter.
- The design of the parapet and noise barrier, and how the system becomes a fowl and bat protection barrier in the areas noise protection isn't needed. The intent to use ribbing to control water flow and staining, and to add texture was also welcome.

Both panels encouraged to think on the user experience of the Colne Valley Park visitors when designing the viaduct. Some aspects of the design are directly consequences of this input as, for example: the use of longer spans with arched shapes in the more visible areas, having an uncluttered pier arrangement with a single concrete body (instead of two columns) with refined shapes and dimensions, using textured surfaces when piers can be potentially in close proximity with pedestrians, and allowing the possibility of locally creating apertures to allow visitors to cross the piers when they are close to towpaths.

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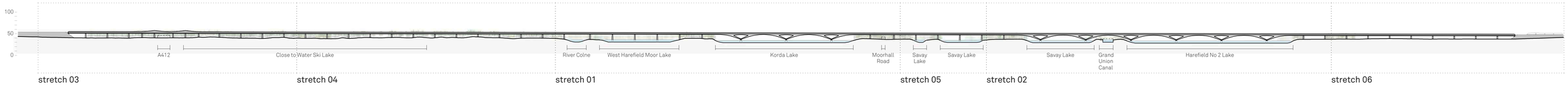
APPENDIX A | SPECIMEN DESIGN DRAWINGS



Elevation | Whole Scheme
1/4500

Plan | Whole Scheme
1/4500

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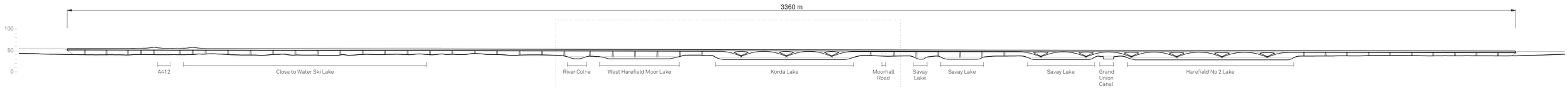
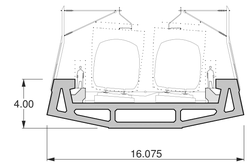
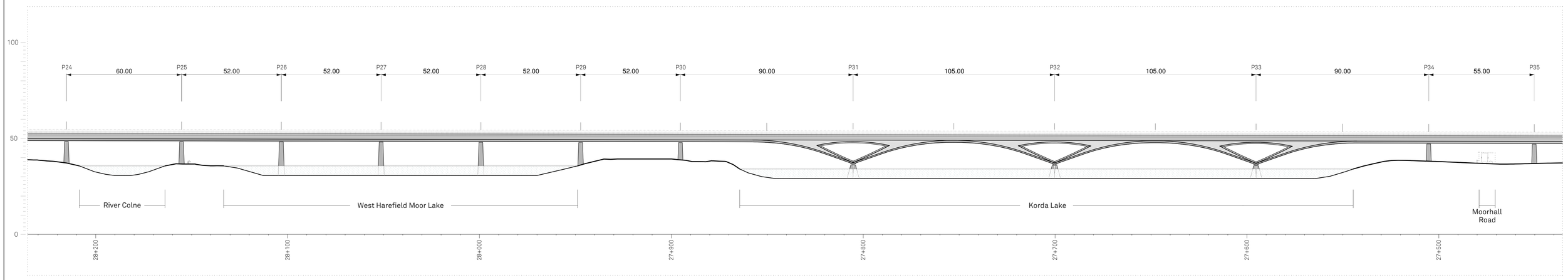
Scale: 1:4500 at A1
Title: Overall Scheme Definition
Stage: -
Date: 20/02/17
Number: KA102/001
Rev: 0



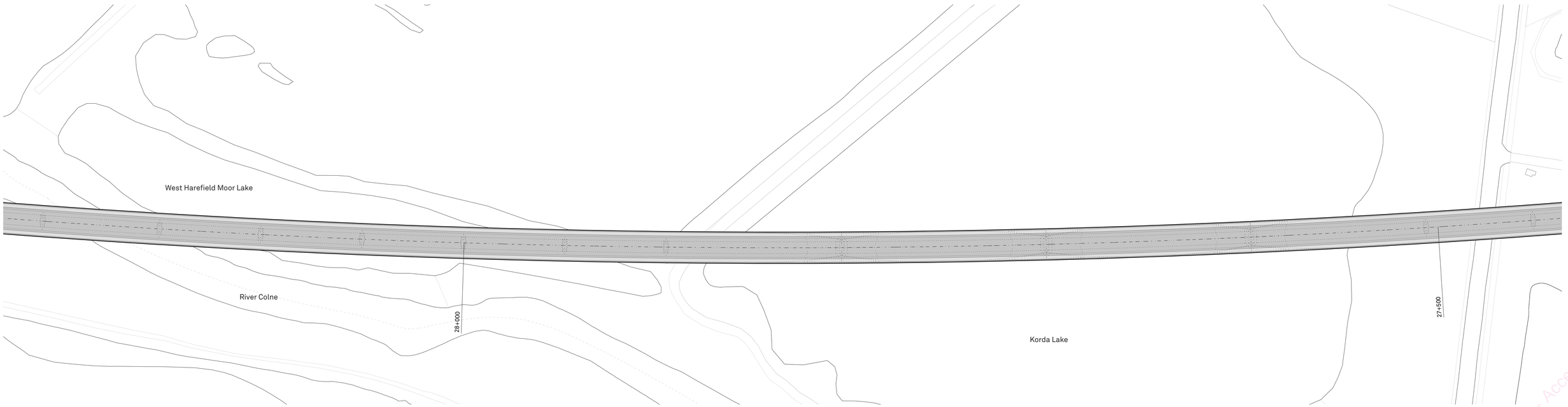
Elevation | Whole Scheme
1/4500



Typical Cross Section
1/250



Elevation | Stretch 01
1/1000



Plan | Stretch 01
1/1000

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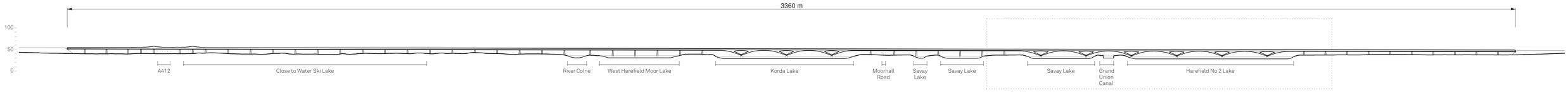
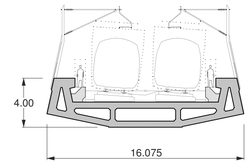
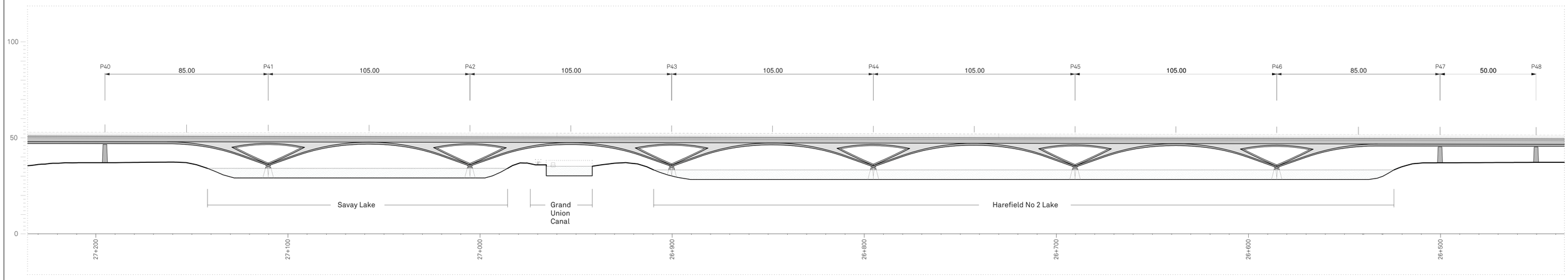
Stage:	**Date:**	**Number:** / **Rev:**
-	20/02/17	KA102/002 / 0



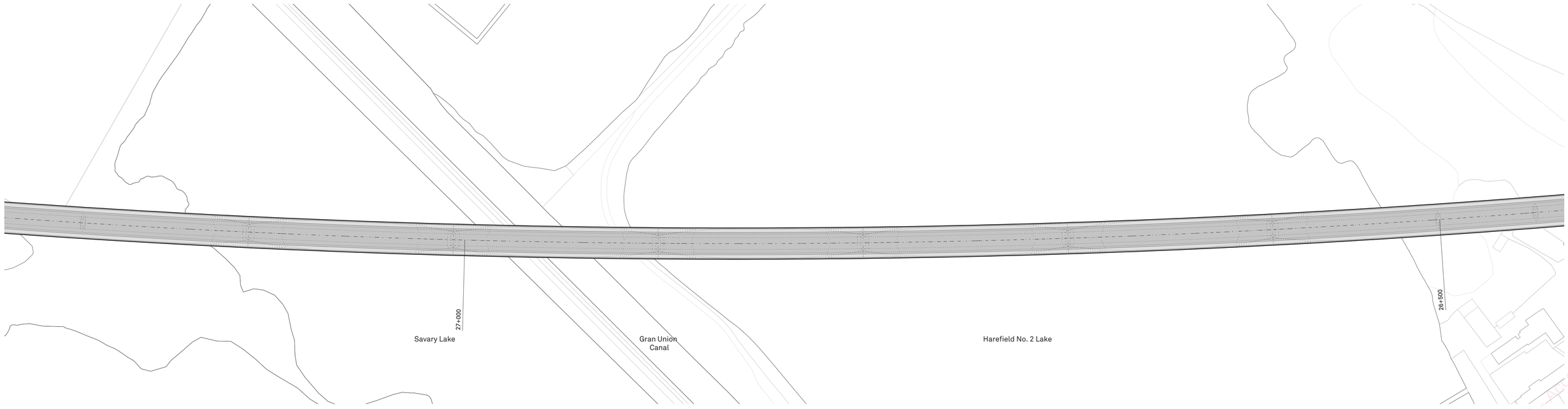
Elevation | Whole Scheme
1/4500



Typical Cross Section
1/250



Elevation | Stretch 02
1/1000



Plan | Stretch 02
1/1000

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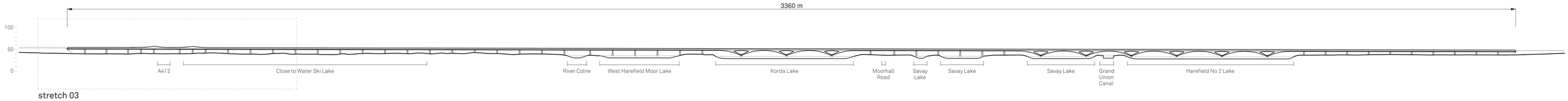
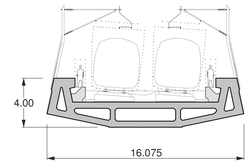
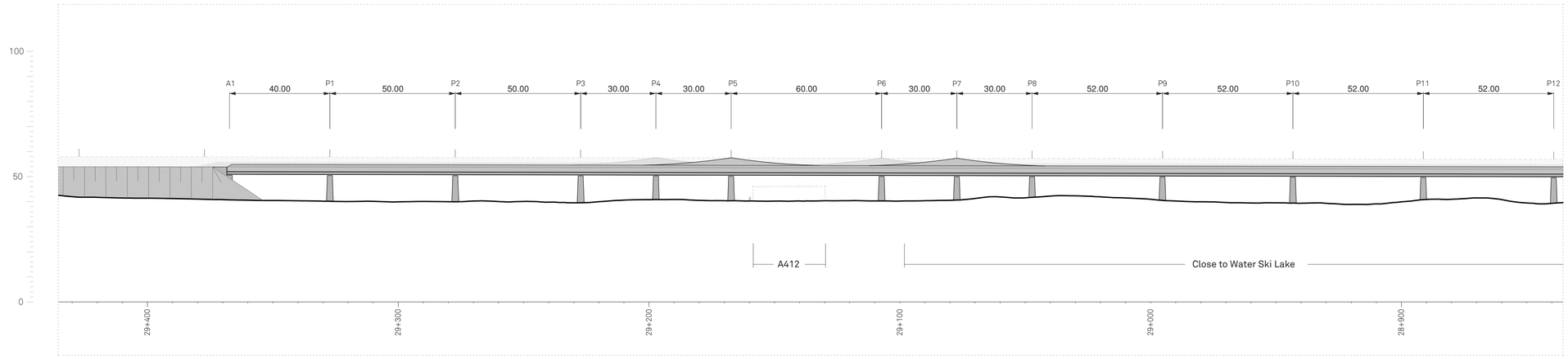
Title: General Definition 02/05
Stage: -
Date: 20/02/17
Number: KA102/003
Rev: 0



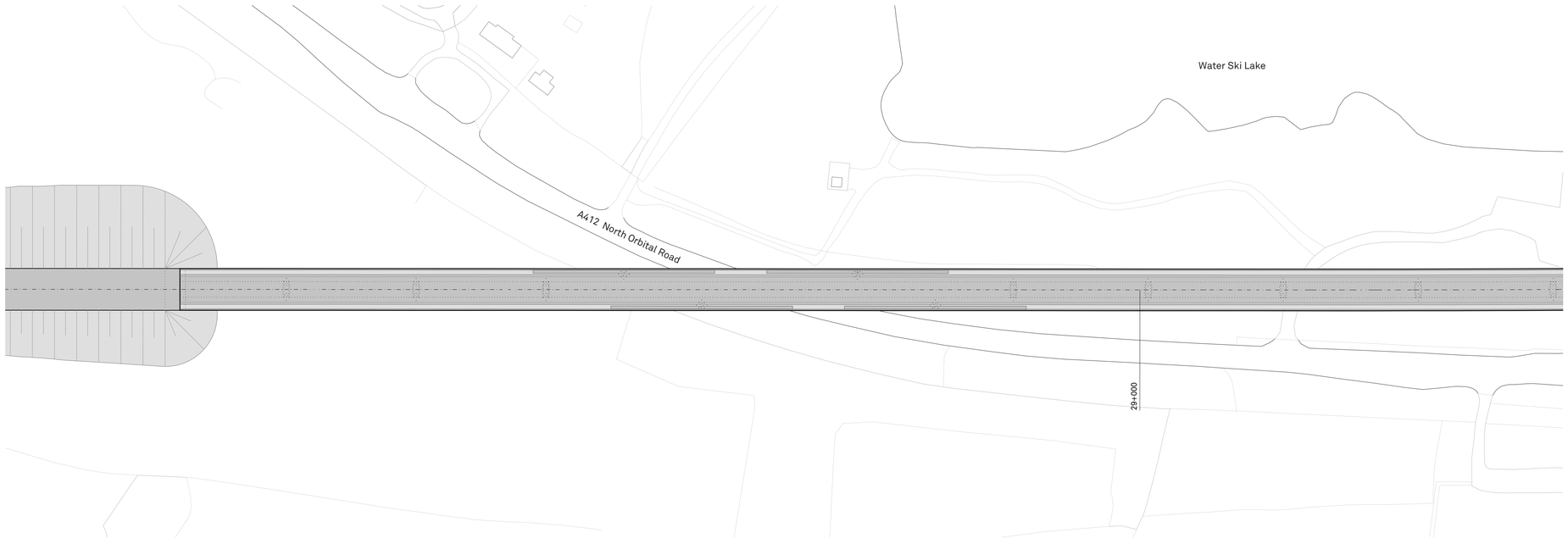
Elevation | Whole Scheme
1/4500



Typical Cross Section
1/250



Elevation | Stretch 03
1/1000



Plan | Stretch 03
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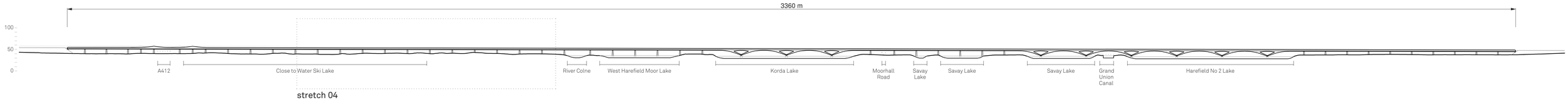
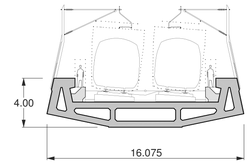
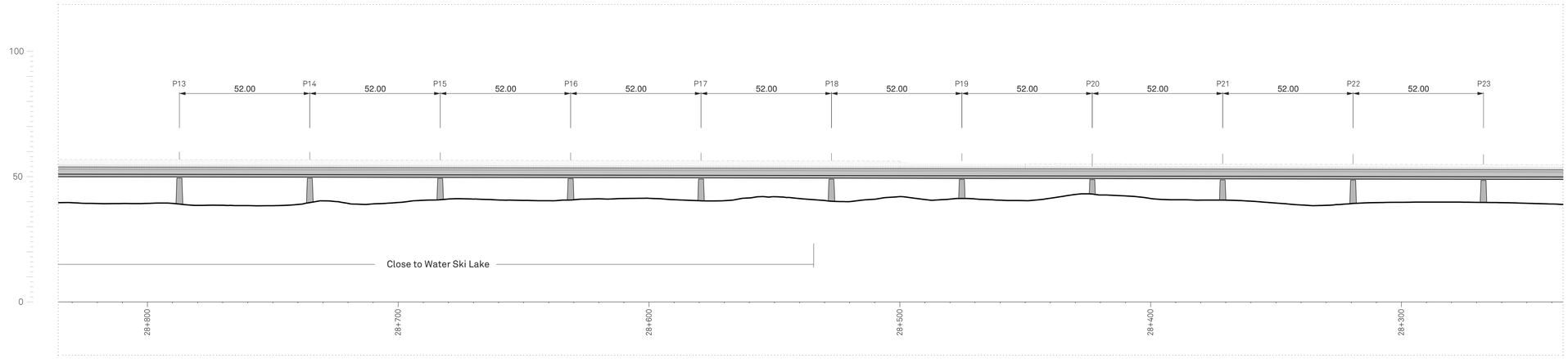
Stage:	**Date:**	**Number:** / **Rev:**
-	20/02/17	KA102/004 / 0



Elevation | Whole Scheme
1/4500



Typical Cross Section
1/250



Elevation | Stretch 04
1/1000

Plan | Stretch 04
1/1000

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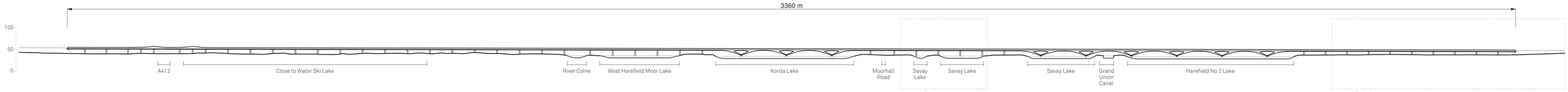
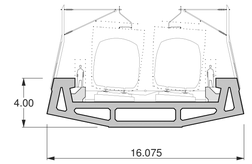
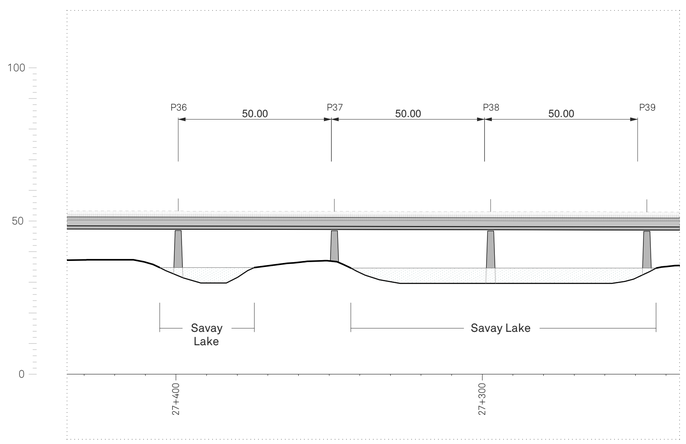
Stage:	**Date:**	**Number:** / **Rev:**
-	20/02/17	KA102/005 / 0



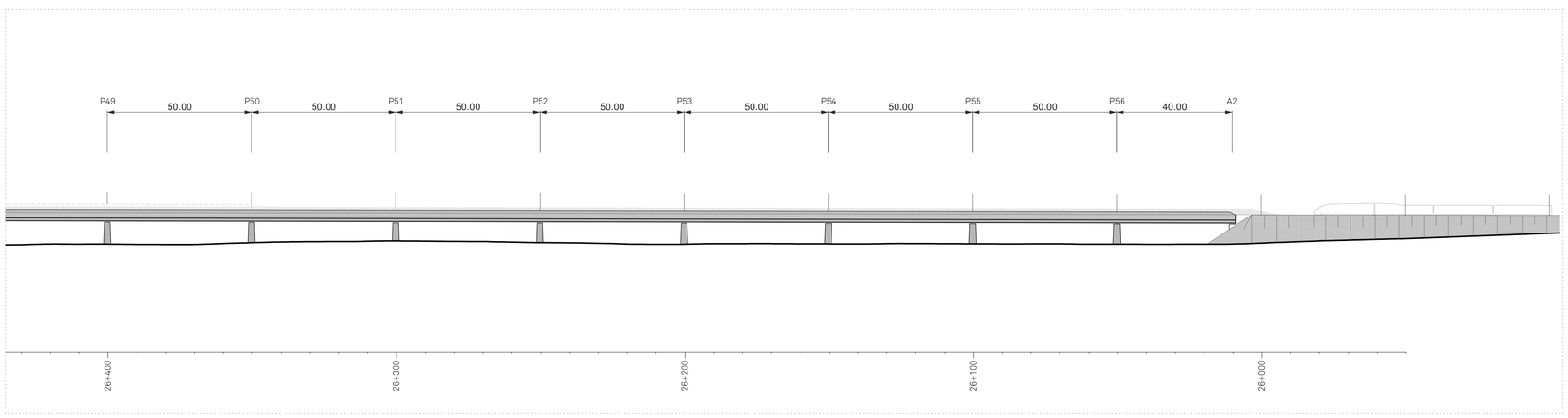
Elevation | Whole Scheme
1/4500



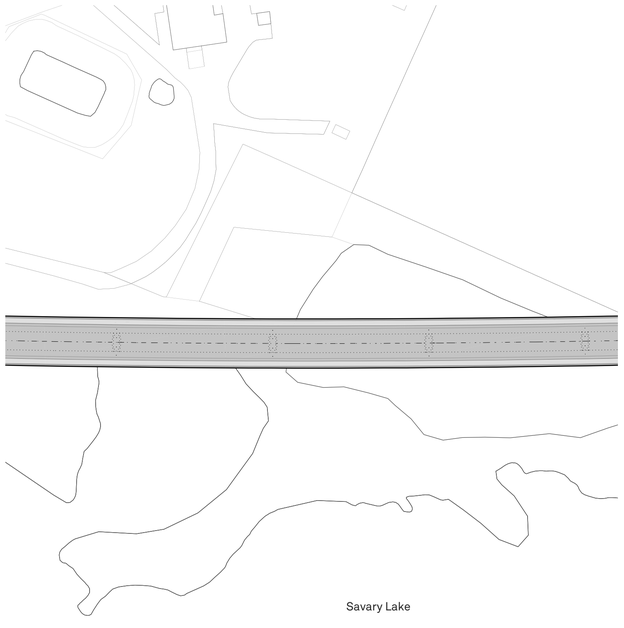
Typical Cross Section
1/250



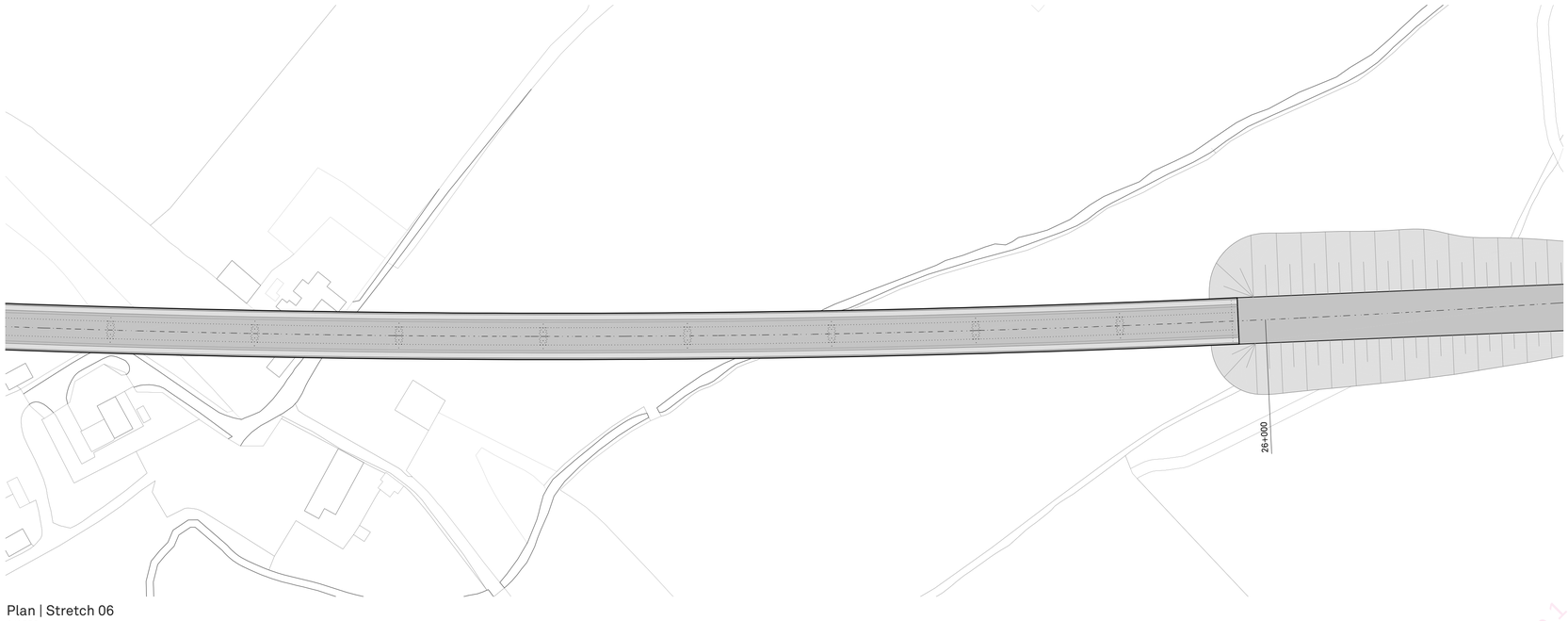
Elevation | Stretch 05
1/1000



Elevation | Stretch 06
1/1000



Plan | Stretch 05
1/1000



Plan | Stretch 06
1/1000

Rev:	Date:	Comments:

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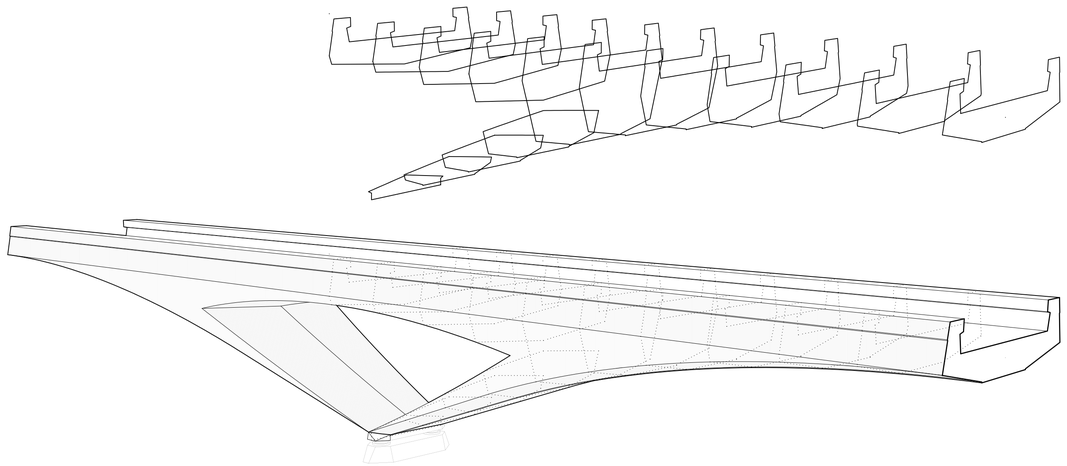
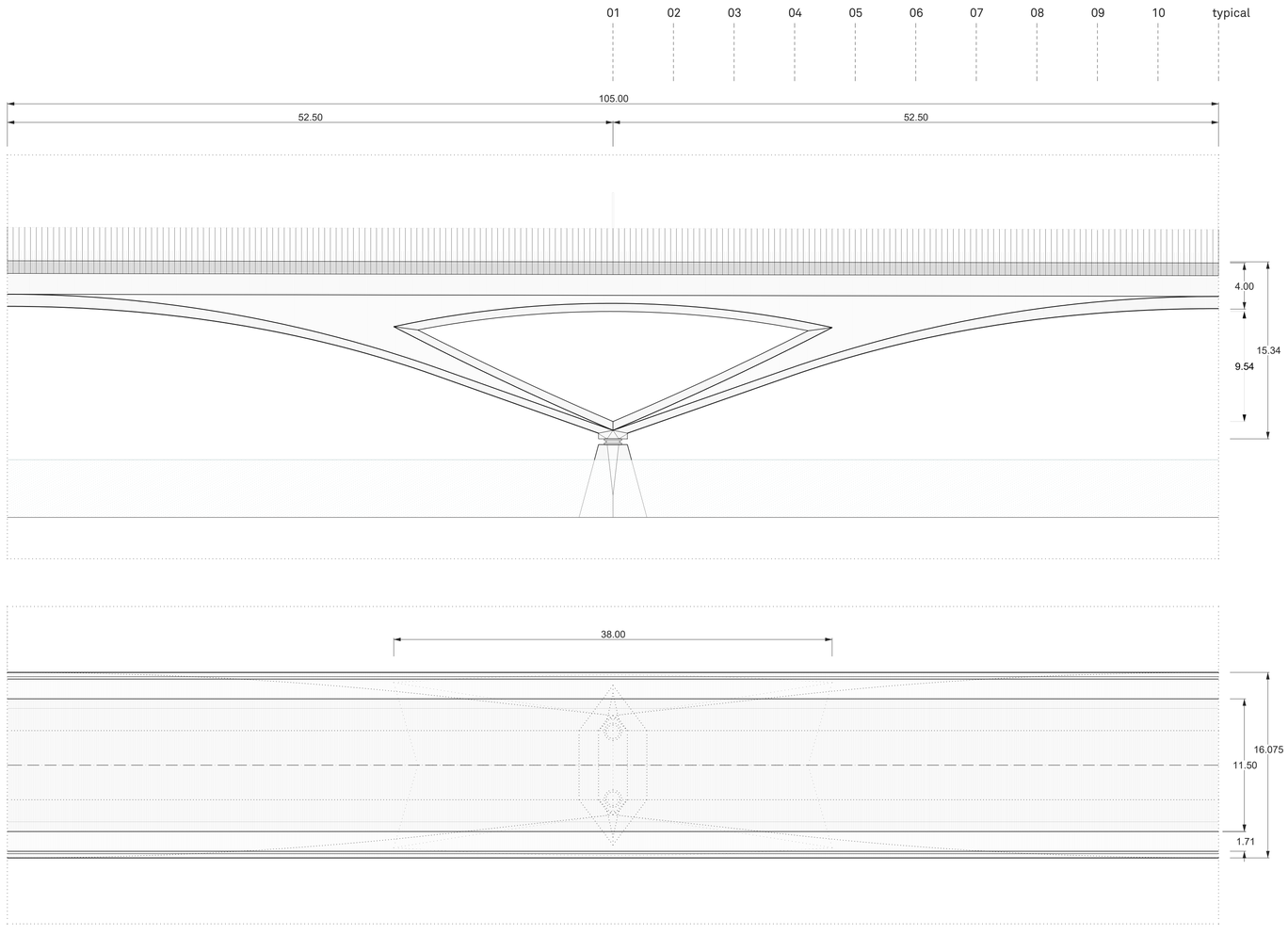
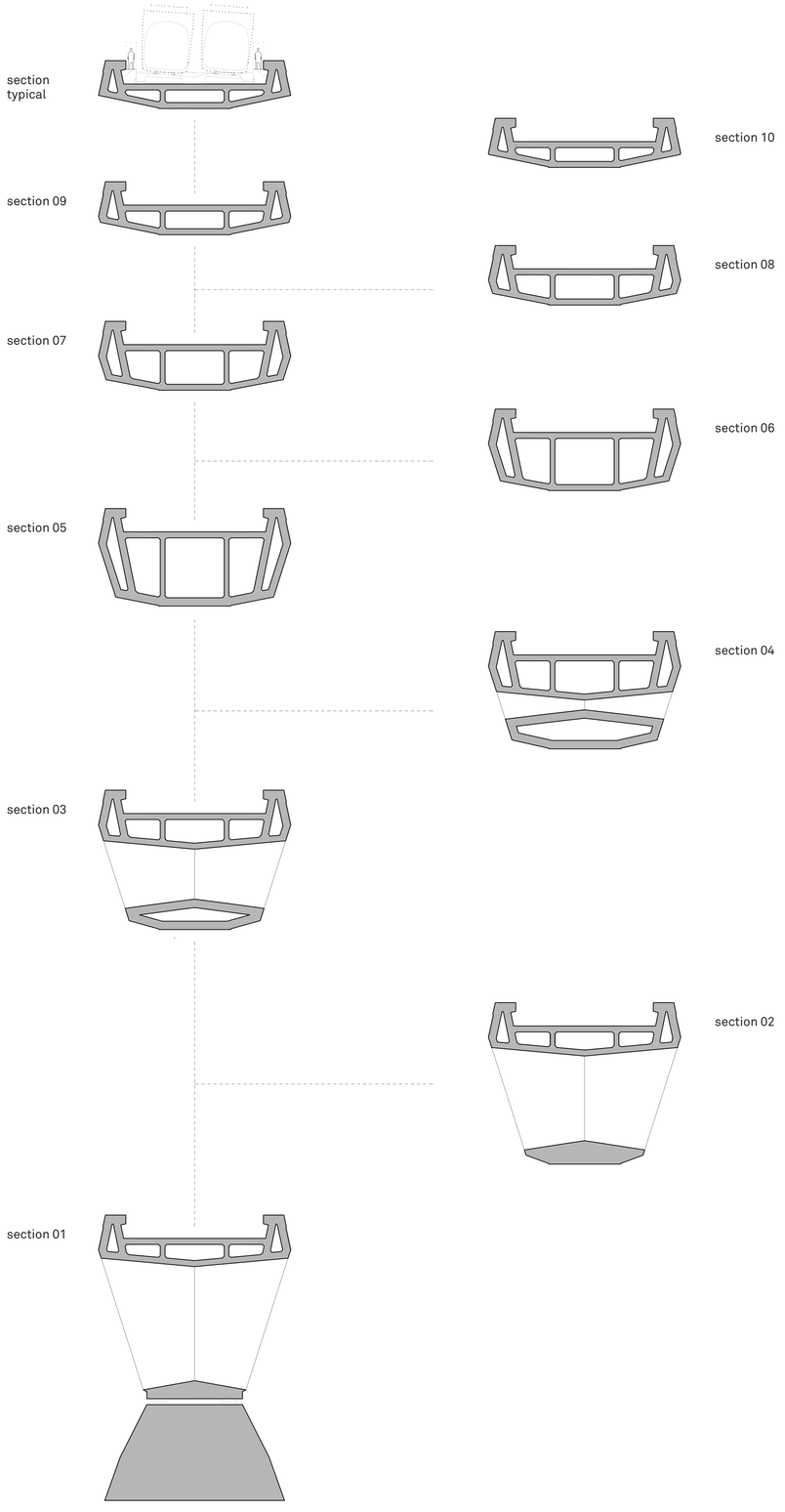
Project: Colne Valley Viaduct
Scale: 1:4500 | 1:250 | 1:1000 at A1
Title: General Definition 05/05
Stage: -
Date: 20/02/17
Number: KA102/006
Rev: 0



Perspective | Main Span



Plan | Main Span
1/250



Cross Sections | Main Span
1/250

Rev:	Date:	Comments:

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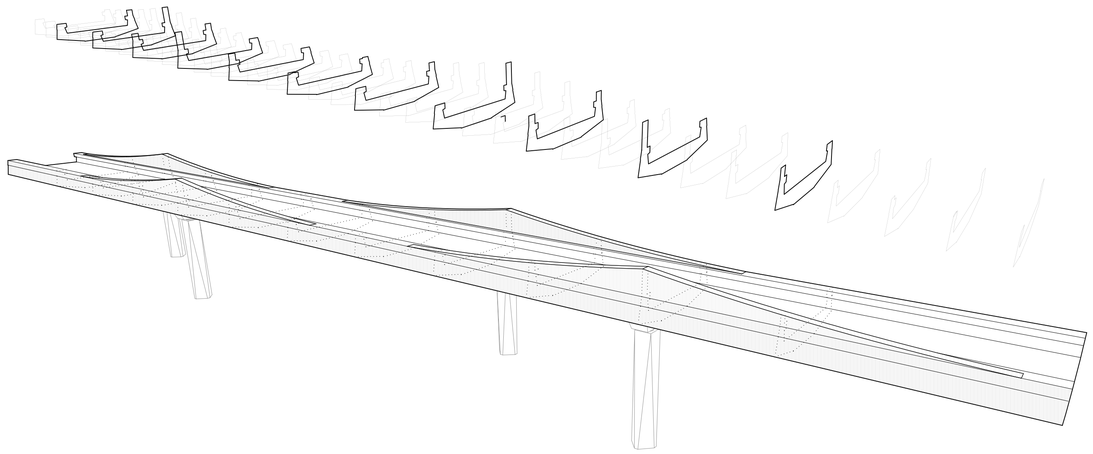
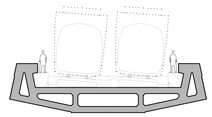
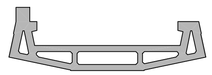
Project:	Scale:	Title:
Colne Valley Viaduct	1:250 at A1	Main Span Geometry Definition
Stage:	**Date:**	**Number:** / **Rev:**
-	10/02/17	KA102/007 / 0



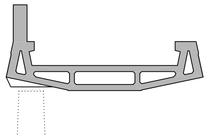
Perspective | Special Span over A412



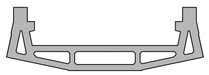
section typical



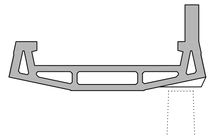
section 01



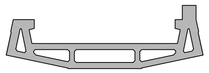
section 02



section 03

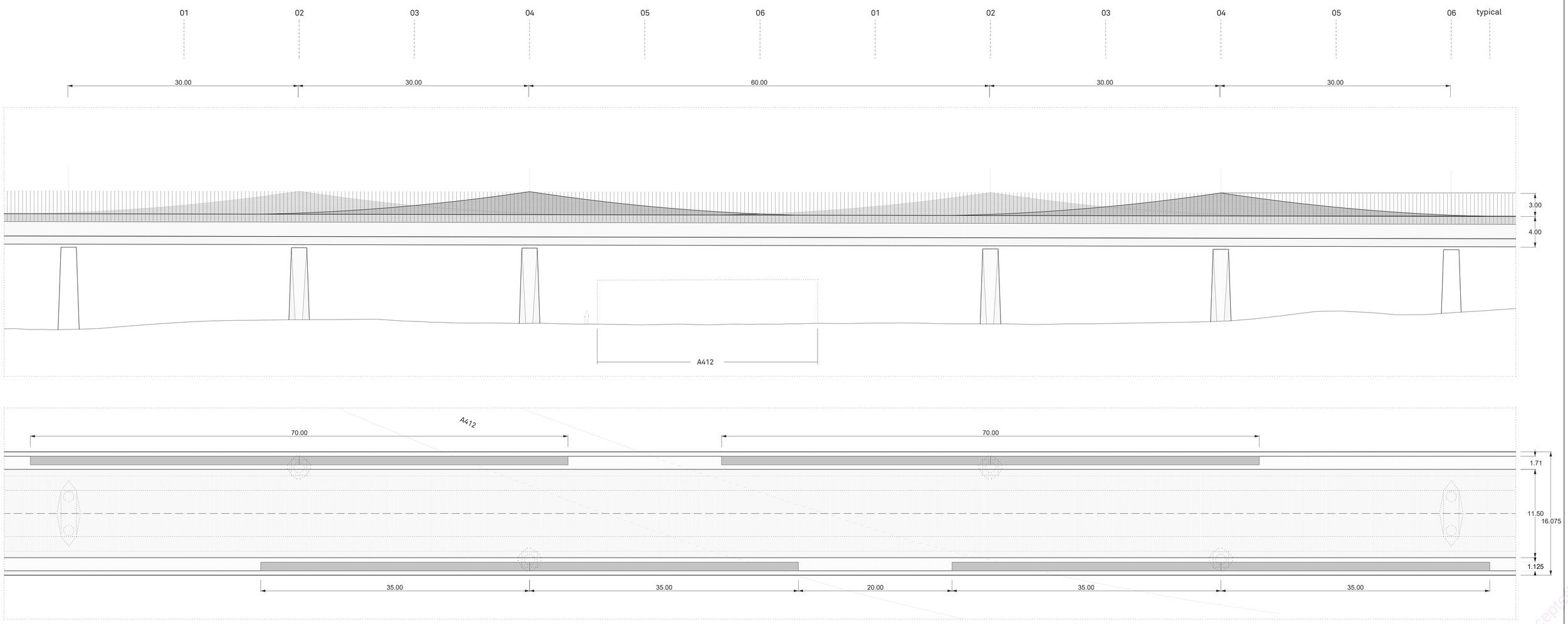


section 04



section 05

section 06



Plan | Special Span over A412

1/250

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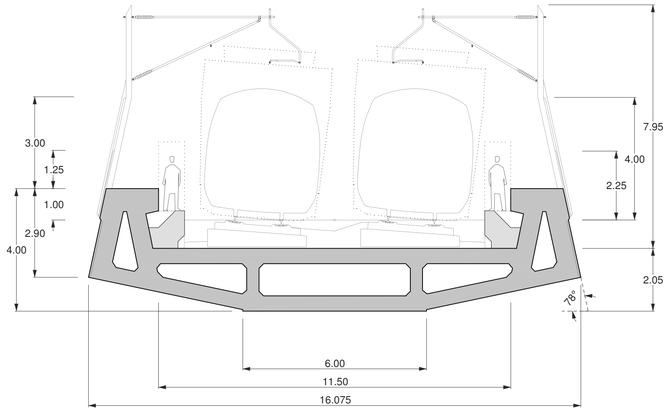
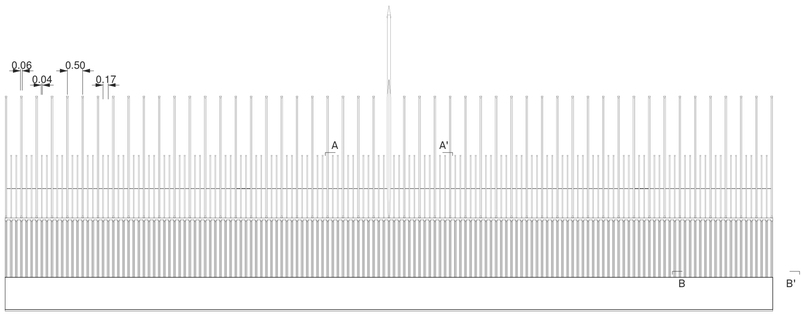
DO NOT SCALE FROM DRAWING

Project:	Scale:	Title:
Colne Valley Viaduct	1:250 at A1	Special Span over A412 Geometry Definition

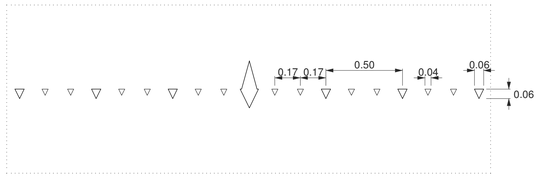
Stage:	Date:	Number:	Rev:
-	10/02/17	KA102/008	0



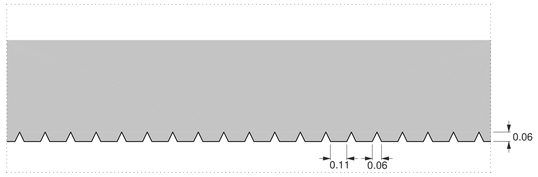
Cross Section | Typical
1/100



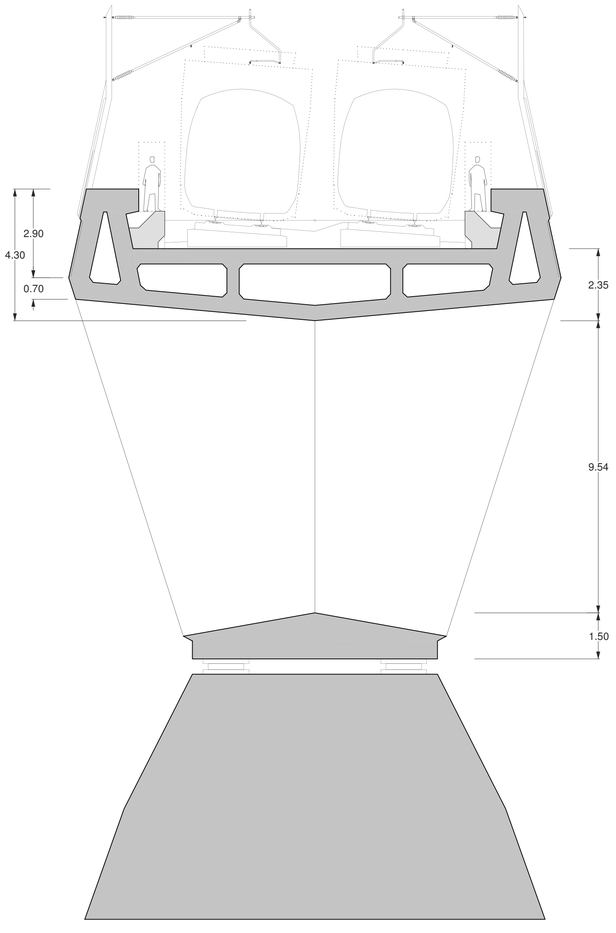
Elevation | Typical
1/100



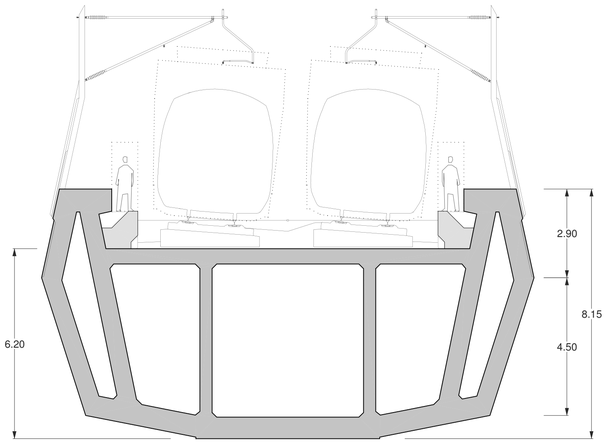
Section AA' | Parapet Elements
1/50

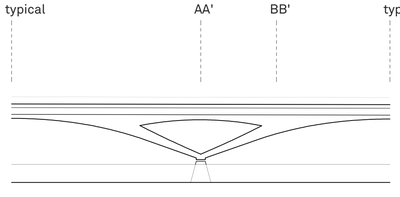


Section BB' | Texture Concrete
1/50

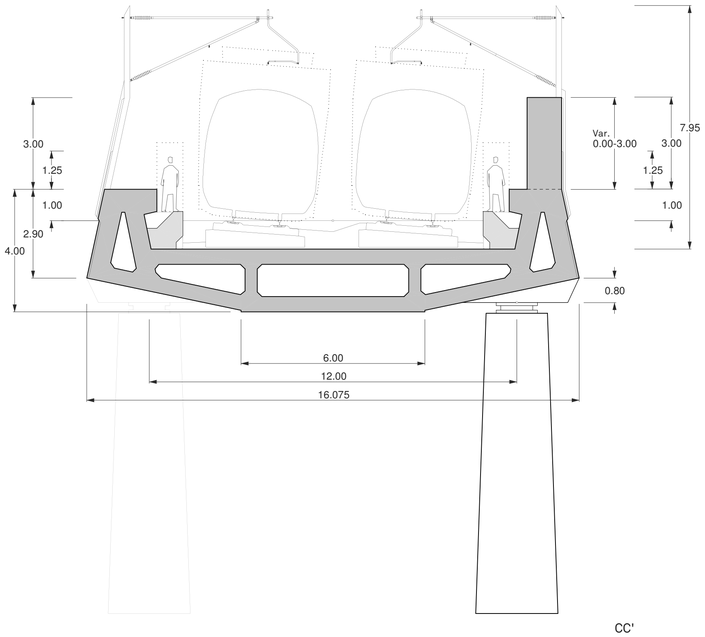


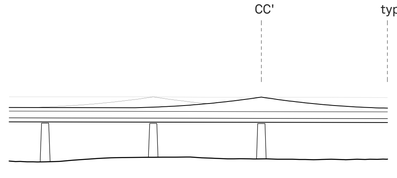
Cross Sections AA' and BB' | Main Span
1/100





Cross Sections | Main Span





Cross Sections | Special Span over A412

Cross Section CC' | Special Span over A412
1/100

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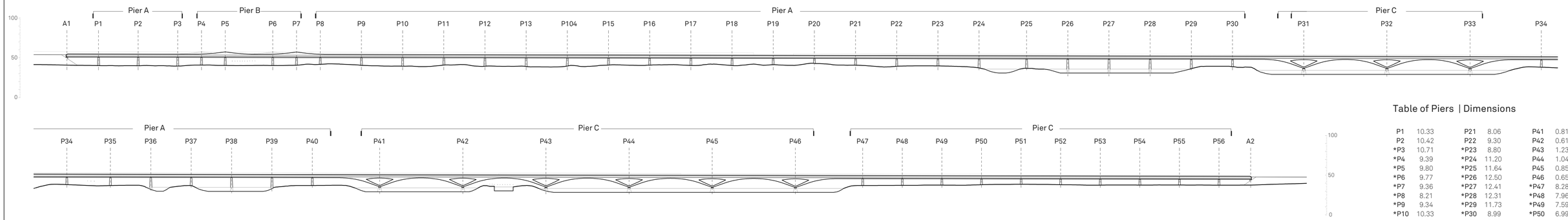
Project:	Scale:	Title:	
Colne Valley Viaduct	1:100 at A1	Details Cross Sections	
Stage:	**Date:**	**Number:**	**Rev:**
-	10/02/17	KA102/009	0

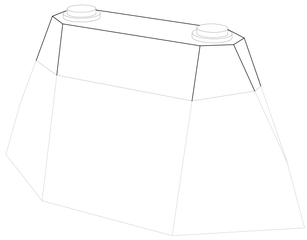


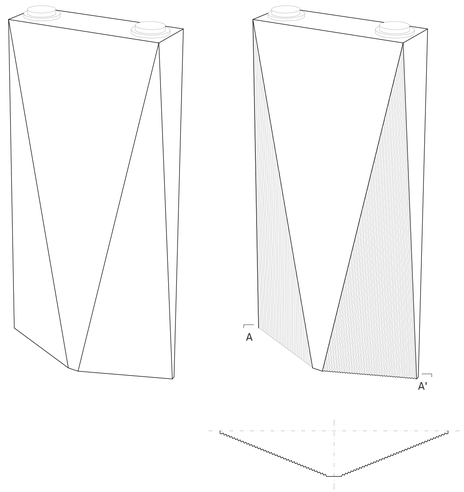
Elevation Whole Scheme | Piers guide
1/2500

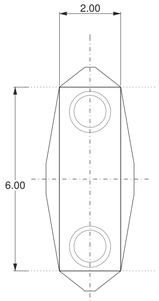
Table of Piers | Dimensions

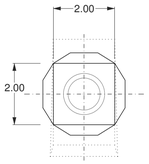
P1	10.33	P21	8.06	P41	0.81
P2	10.42	P22	9.30	P42	0.61
*P3	10.71	*P23	8.80	P43	1.23
*P4	9.39	*P24	11.20	P44	1.04
*P5	9.80	*P25	11.64	P45	0.85
*P6	9.77	*P26	12.50	P46	0.65
*P7	9.36	*P27	12.41	*P47	8.28
*P8	8.21	*P28	12.31	*P48	7.96
*P9	9.34	*P29	11.73	*P49	7.59
*P10	10.33	*P30	8.99	*P50	6.99
*P11	8.86	P31	2.09	*P51	6.28
*P12	10.18	P32	1.89	P52	6.78
*P13	10.43	P33	1.70	P53	7.25
*P14	9.74	P34	9.32	P54	7.05
*P15	8.50	P35	10.05	P55	6.93
*P16	8.51	P36	12.13	P56	6.98
*P17	8.73	P37	10.02		
P18	8.81	P38	12.09		
P19	7.62	P39	11.99		
P20	5.74	P40	9.51		

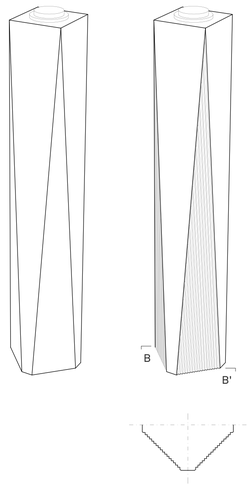
Note:
All the piers marked * will potentially incorporate textured faces to the original design, as indicated below.

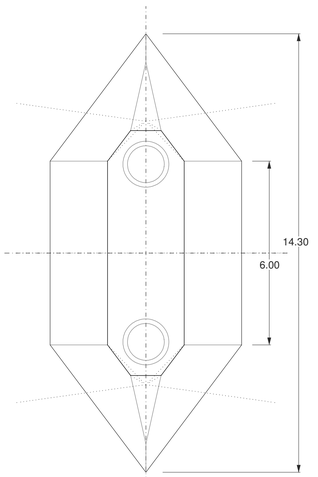






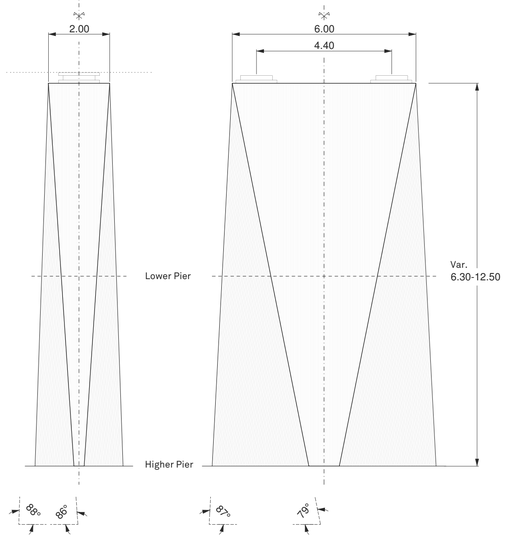


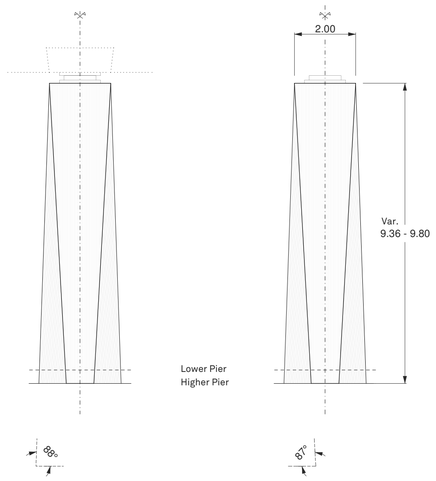


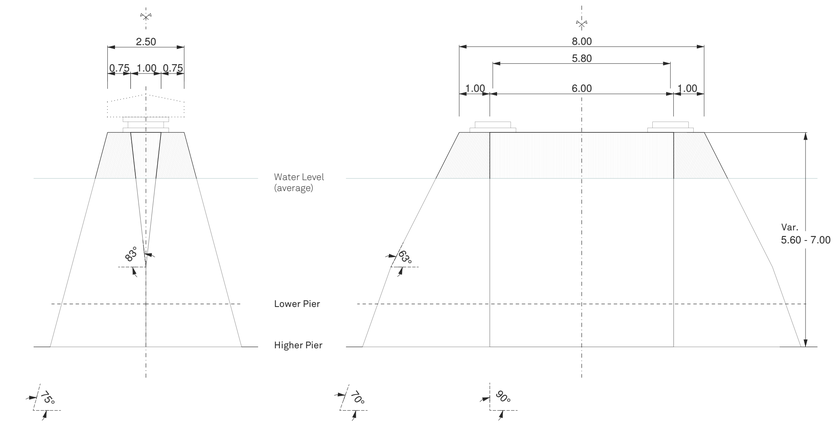


Section AA' | Textured Pier
1/100

Section BB' | Textured Pier
1/100







Pier A | Plan, Elevations and Perspective
1/100

Pier B | Plan, Elevations and Perspective
1/100

Pier C | Plan, Elevations and Perspective
1/100

Note:
All dimensions are referenced to either terrain or average water surface.

Rev:	Date:	Comments:

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DO NOT SCALE FROM DRAWING

Project:	Scale:	Title:
Colne Valley Viaduct	1:2500 | 1:100 at A1	Details Pier Definition
Stage:	**Date:**	**Number:** / **Rev:**
-	10/02/17	KA102/010 / 0