APPENDIX 4-6

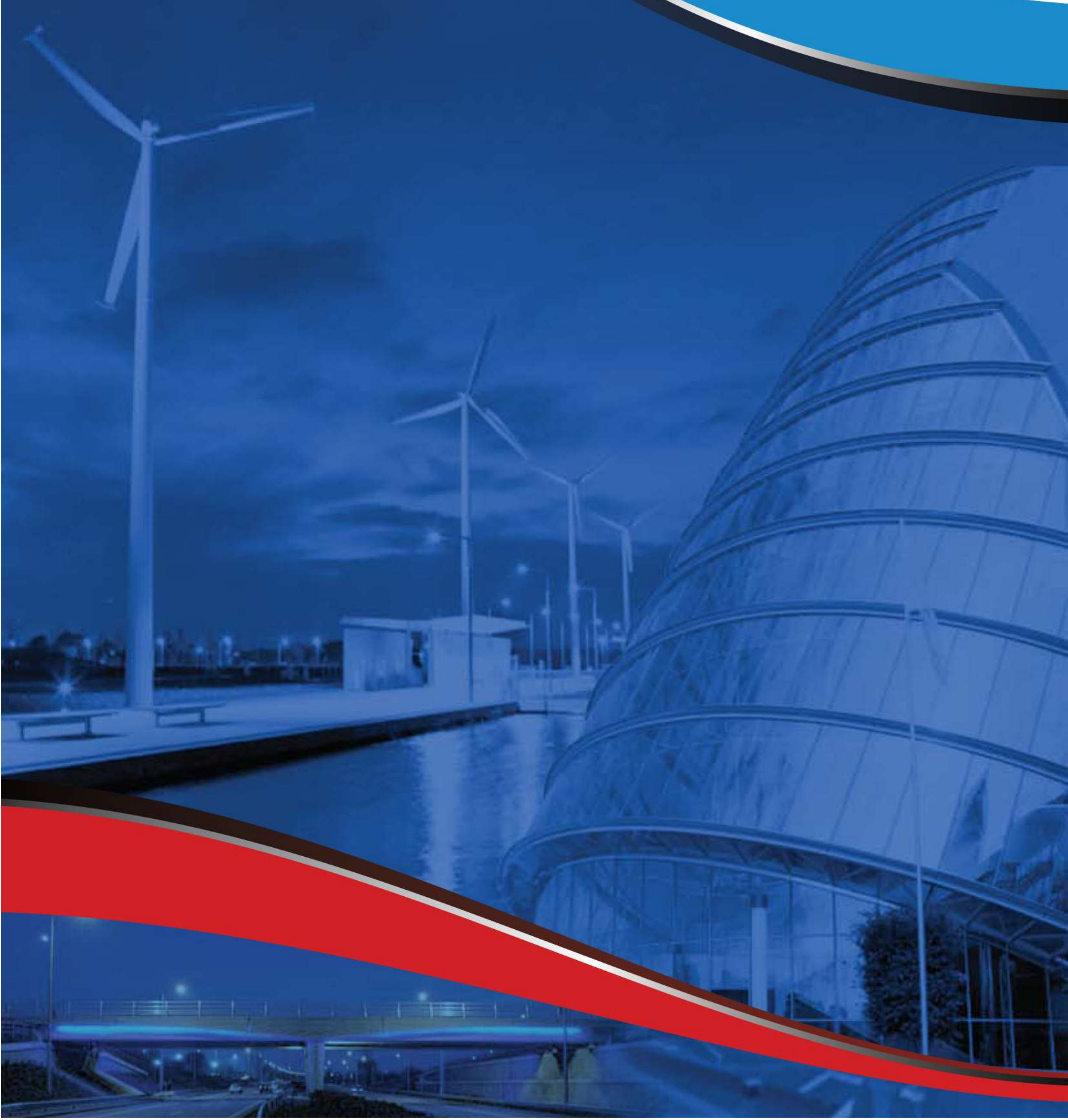
BRIDGE OPTIONS REPORTS

BRIDGE OPTIONS REPORT

MOYGADDY MASTERPLAN LANDS

Sky Castle Ltd
S665
19 August 2022

OCSC
O'CONNOR | SUTTON | CRONIN
Multidisciplinary
Consulting Engineers



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NOTICE

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1 INTRODUCTION

APPOINTMENT

O'Connor Sutton Cronin & Associates (OCSC) have been appointed by Sky Castle Ltd to carry out the design of the civil engineering services associated with the development of the proposed Maynooth Outer Orbital Road (MOOR) on lands at Moygaddy, Co. Meath, which is located northeast of the town of Maynooth, Co. Kildare.

SETTING

Maynooth environs is a large growth area, category II Town status located in south County Meath, and is an economically vibrant area with high-quality transport links to larger towns/cities. The Meath Development Plan 2021-2027 outlines the social, economic, and planning context for the Maynooth environ lands, setting the framework for the plan's policies and objectives. It has a core strategic vision that seeks to ensure that future growth is based on principles of sustainable development that meet the needs of residents per National and Regional guidelines. The environs of Maynooth is a Core Economic Area included in the Gateway Core Economic Area located on the M4 corridor. The wider Maynooth Environs Lands proposed land-use zoning includes A2 – New Residential, E1 – Strategic Employment Zones, G1 – Community Infrastructure, D1 – Tourism and H1 – High Amenity.

The delivery of the Maynooth Outer Orbital Route (MOOR) is critical to facilitating residential, high-end employment, tourist, and leisure development in the Maynooth environ lands and fulfilling the transport infrastructure needs in proximity to Maynooth University and Maynooth town.

ADMINISTRATIVE JURISDICTION

The proposed development is located primarily in the jurisdiction of Meath County Council (MCC), and therefore the Maynooth Outer Orbital Route design and the associated civil engineering services were carried out with reference to the following:

- Meath County Development Plan 2021-2027;
- Maynooth Environs Local Area Plan 2014 (incorporated into adopted MCDP);
- Regional Spatial and Economic Strategy for the Eastern and Midland Region (2019);

Even though Maynooth Environs is situated in the Meath County Council administrative area, the Maynooth Environs Local Area Plan contains an objective to liaise with Kildare County Council in the identification, design, reservation and delivery of the section of the Maynooth Outer Relief Road located within the administrative area of Meath County Council. The administrative area of Kildare County Council is located immediately adjacent to the LAP environs lands and some infrastructure improvements will be located within the Kildare County Council (KCC) administrative area. Therefore, the design will also be conducted with due regard to:

- Maynooth LAP
- Kildare County Development Plan
- Maynooth Traffic Management Plan

STUDY AREA

The subject site is located on the southernmost extent of County Meath, as shown in Figure 1, aligning with the county boundary to Co. Kildare. It is approximately 1.5km north of the town of Maynooth, Co. Kildare, which forms part of a larger strategic landbank on zoned lands known as Maynooth Environs. The site is immediately bound by:

- R157 Maynooth – Dunboyne Road, to the east;

- Agricultural lands, to the north and west; and
- River Rye Water, to the south;

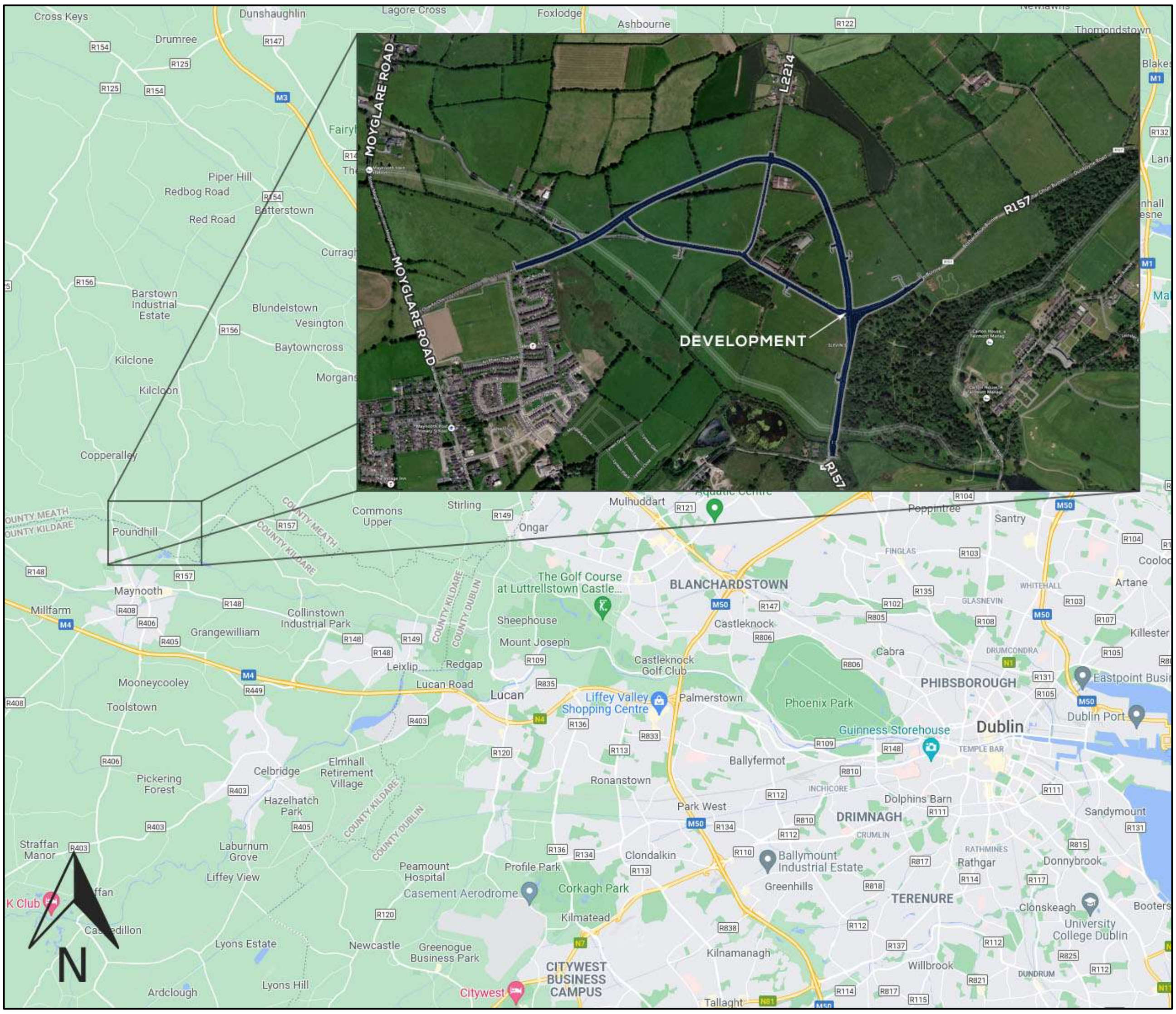

Figure 1: Development Locality Plan

BRIDGE STRUCTURES

There are five bridge structures required within the project's extent. Two bridge structures carry a regional road and a shared pedestrian/cyclist laneway, and three structures carry a shared pedestrian/cyclist laneway only. These are referred to as 'road' bridges and 'pedestrian' bridges for the remainder of the report. All bridge structures will be built to facilitate the phased development. This Options Report has been prepared per TII standard DN-STR-03001 Appendix B.

2 DESCRIPTION OF STRUCTURES AND OPTIONS CONSIDERED

SITE LOCATION

The proposed development is bounded by the River Ryewater to the south, and farmland to the north. A Site-Specific Flood Risk Assessment has determined that the development is located without a flood zone. Refer to the separate SSFRA OCSC report, S665-OCSC-1C-XX-RP-C-0009, and JBA Consulting's Flood Risk Assessment report on the Moygaddy Masterplan for details. The conclusions in these reports have been considered in the road alignment and hence, the geometry and type of bridge structures.

Refer to the figure below for the location of Applicant-owned lands, in the Maynooth Environs area, in which the new bridge structures are to be provided, along with local watercourses. A total of 5nr.bridge structures are to be provided through the Maynooth Environs area, to facilitate the provision of the new Maynooth Outer Orbital Route (MOOR) and improvements to pedestrian and cycle connectivity throughout.

Figure 2: Site Location and Local Watercourses

BRIDGE STRUCTURES

A total of 5 nr. bridge structures are to be provided through the Maynooth Environs area, to facilitate the provision of the new Maynooth Outer Orbital Route (MOOR) and improvements to pedestrian and cycle connectivity throughout.

Refer to the figure below for the location of the proposed bridge structures.

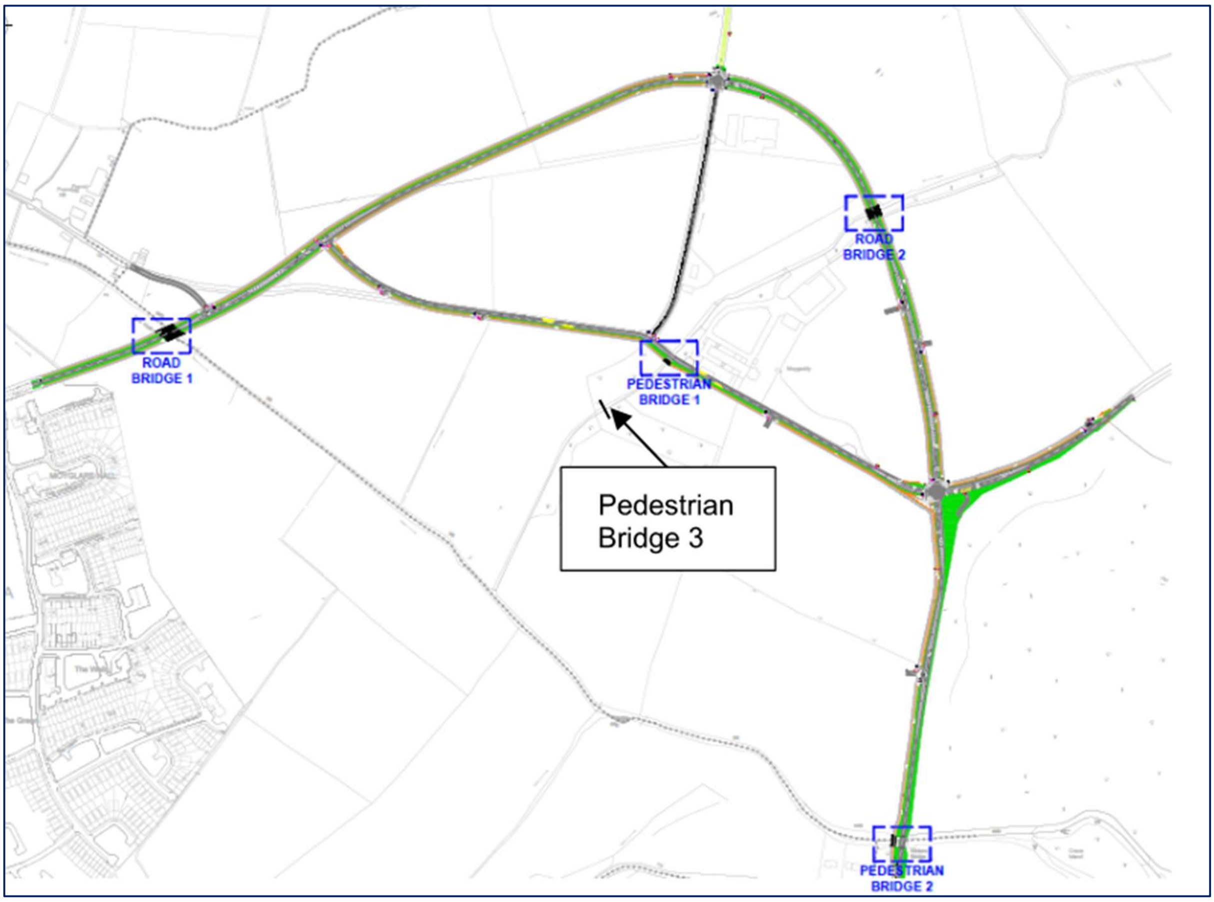

Figure 3: Location of Bridges

The noted bridges are summarised as follows:

ROAD BRIDGE 1

This is to comprise a 50m span across the River Rye Water, and link west Maynooth to the proposed new MOOR, which shall include pedestrian and cycle facilities and extension of water main assets to serve new development in Maynooth Environs. The elevation and cross-section of this bridge is shown in the figure below.

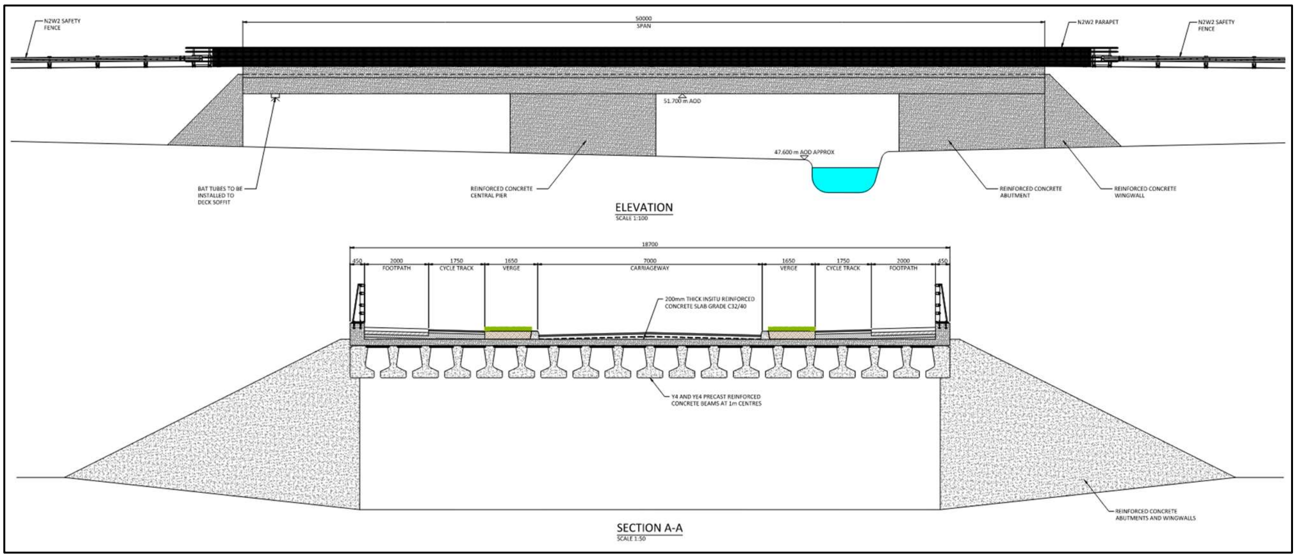

Figure 4: Road Bridge 1 Cross-Section and Elevation

ROAD BRIDGE 2

This is to comprise a short-span vehicular bridge, as part of the new MOOR, including pedestrian and cycle facilities. The elevation and cross-section of this bridge is shown in the figure below.

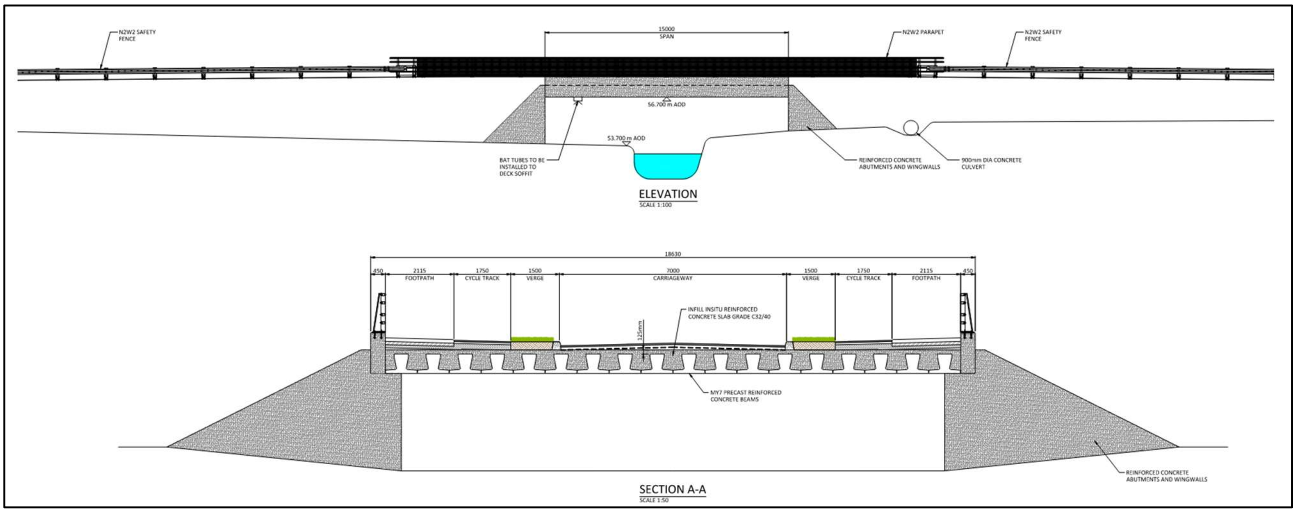

Figure 5: Road Bridge 2 Cross-Section and Elevation

PEDESTRIAN BRIDGE 1

This is a new pedestrian and cycle bridge structure that will be erected adjacent to the downstream side of the existing vehicular bridge at this location, which spans the Blackhall Little stream (also known as the Moygaddy Stream). It is to be a standalone, independent structure. The elevation and cross-section of this bridge is shown in the figure below.

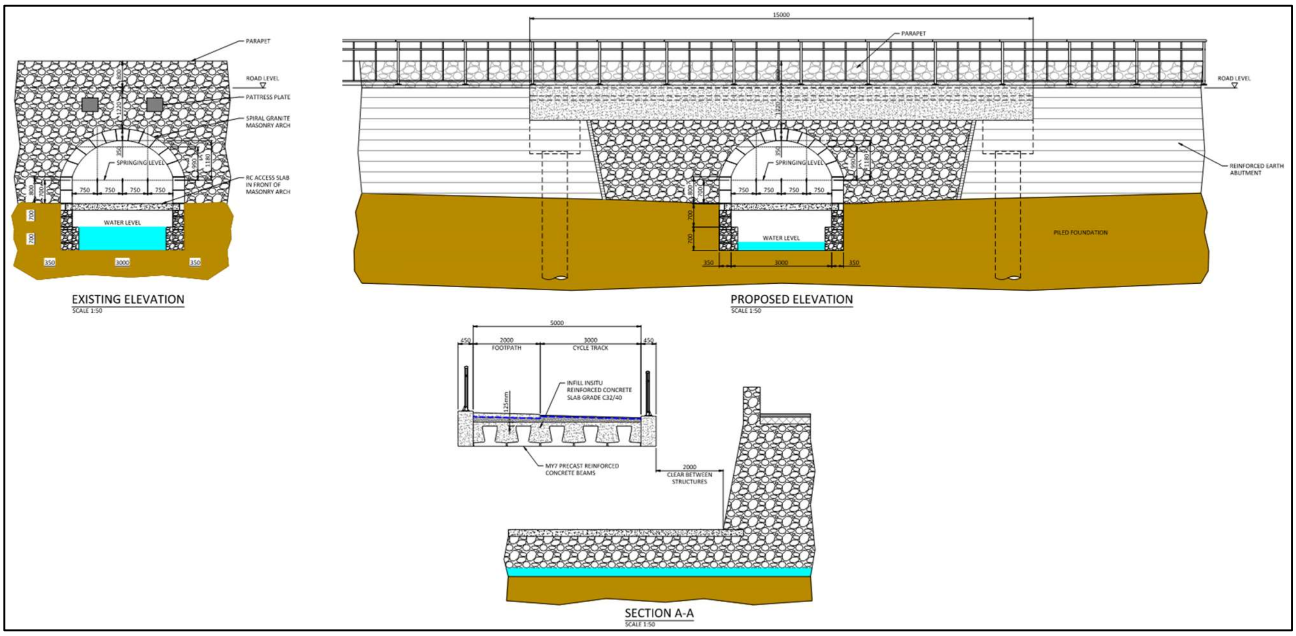

Figure 6: Pedestrian Bridge 1 Cross-Section and Elevation

PEDESTRIAN BRIDGE 2

This is a new pedestrian and cycle bridge structure that will be erected adjacent to the upstream/western side of the existing Kildare Bridge at this location and is to be a standalone, independent structure, that shall also support new water main assets. New wastewater rising mains shall also be installed underground, adjacent to this bridge structure, to its west. The elevation and cross-section of this bridge is shown in the figure below.

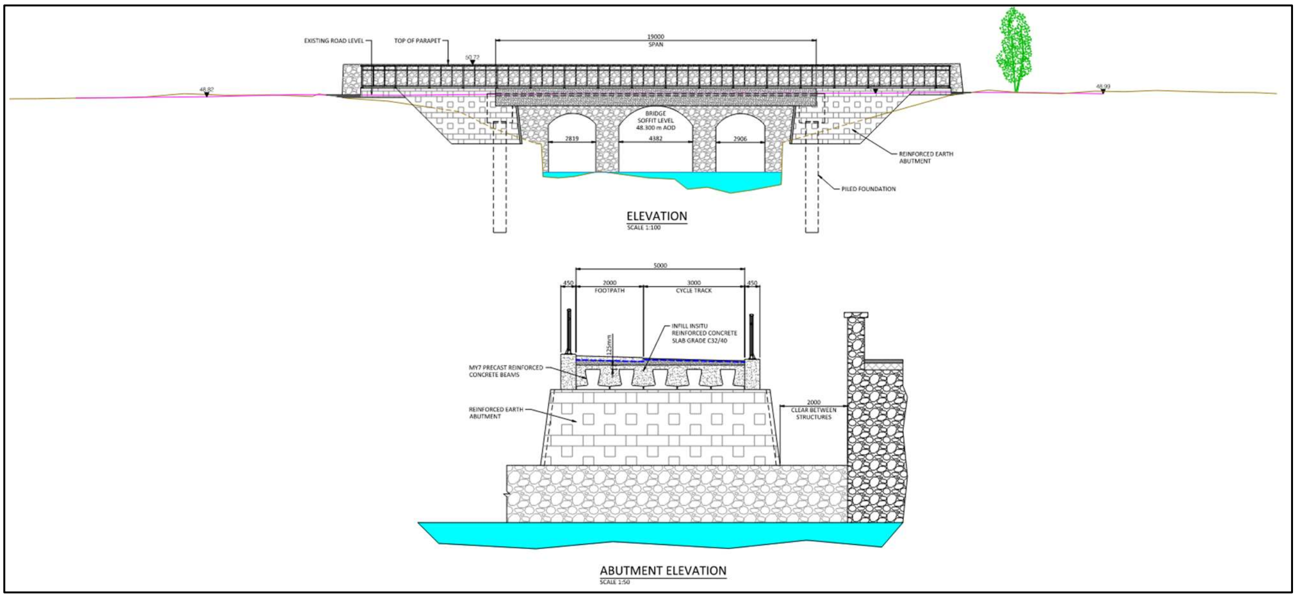

Figure 7: Pedestrian Bridge 2 Cross-Section and Elevation

PEDESTRIAN BRIDGE 3

A new pedestrian and cycle bridge structure is to be provided as part of the Strategic Housing Development scheme, over the Blackhall Little / Moygaddy Stream, linking the residential units with the proposed scout's den and creche. The new bridge structure will also support a gravity wastewater pipe, to facilitate a connection over to the location of the proposed strategic wastewater pumping station. The elevation and cross-section of this bridge will be similar to Pedestrian Bridge 1, shown in Figure 6.

FUNCTION OF THE STRUCTURES

The function of the structures is to carry motorists, pedestrians and cyclists over the two watercourses, the River Rye and the Modgaddy stream, that dissect the proposed development. The structures are to have little or no impact on the adjacent flood plain and properties. A freeboard of 600mm between the design flood level and the minimum bridge soffit level has been adopted. The location of bridge supports will be located outside of the flood plain where practically possible. The purpose of this report is to discuss the various options of structural form to minimise the impact on the surrounding environs.

ALIGNMENTS AND CROSS-SECTIONS

The vertical and horizontal alignments are designed by OCSC. They are in accordance with TII standard DN-GEO-03031 Rural Road Link Design. A design speed of 60 kph is adopted for the development. The road bridge design consists of a 7m wide single carriageway with a hard paved verge, footpath and cycle track. The pedestrian bridges are 5m wide between parapets and have a 2m wide footpath and a 3m wide cycle track.

GROUND CONDITIONS

A number of percussion boreholes, rotary cores, dynamic probes and trial pits have been undertaken on the site. The existing ground strata consist of a brown overlaying a black sandy gravelly clay which is consistent in the Leinster region. Occasional cobbles are present in the clay, which is limestone in origin. The underlying bedrock consists of strong limestone interbedded with strong calcareous mudstone.

STRUCTURE OPTIONS

Three options have been explored for the development:

1. In-situ reinforced concrete bridge deck.

2. Precast reinforced concrete bridge deck.
3. Composite steel girder and in-situ bridge deck.

All options are integral in their abutments to minimise future maintenance requirements and adhere to the TII standards. The abutments are formed of reinforced concrete which sits on bored concrete piles in all instances.

The evaluation of the options considered in the remainder of this report relates to the road bridges only. The pedestrian bridge options are identical in nature but have a narrower bridge deck. i.e the options for the pedestrian bridge deck construction are in-situ reinforced concrete, precast beams and an in-situ deck, and a steel girder with an in-situ deck. The evaluation of the options and the recommendation in the following chapters are applicable to both road ridges and pedestrian bridges.

3 TECHNICAL EVALUATION

OPTION 1 – IN-SITU REINFORCED CONCRETE BRIDGE DECK

A reinforced concrete bridge deck continuous over pier supports (where applicable) and integral at the abutment bank seats and a voided deck. For a span length of 25m, the depth of the deck is approximated at 1.25m.

The technical advantages of this option are:

- The supports are outside the width of the flood plain, eliminating the risk of scouring and an effect on the existing hydrology.
- Integral construction removes the need for bearings and expansion joints at deck level.
- Concrete will require minimal future maintenance over the river.
- The geometry of the structure on plan and elevation is easily manipulated

The technical disadvantages of this option are:

- The construction of in-situ concrete options required significant falsework and formwork over the river.
- There is a significant time required in steel fixing, with less quality control than is typically available for precast construction, leading to long-term durability and maintenance issues.
- There are multiple pours required leading to cold-formed joints and potential water ingress locations at small void locations.

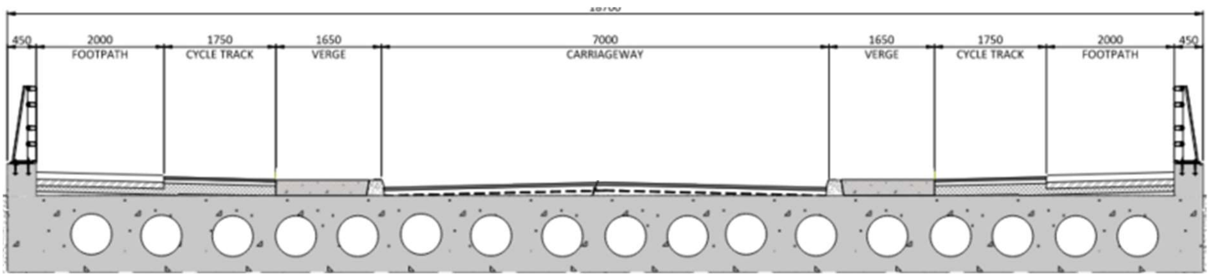

Figure 8: Reinforced Concrete In-situ Deck

OPTION 2 – PRECAST REINFORCED CONCRETE BRIDGE AND IN-SITU DECK

A precast concrete bridge deck is simply supported at abutment and pier locations with an in-situ deck. All structures are integral at the abutment bank seats. For a span length of 25m, the depth of the deck is approximated at 1.20m.

The technical advantages of this option are:

- The supports are outside the width of the flood plain, eliminating the risk of scouring and an effect on the existing hydrology.
- Integral construction removes the need for bearings and expansion joints at deck level.
- Concrete will require minimal future maintenance over the river.
- Falsework and formwork are largely reduced in comparison to an in-situ option.
- Quality control is factory controlled.
- Steel fixing and shuttering on-site are significantly reduced, as are the hazards and risks associated with the works, and construction over a watercourse.
- The available span lengths for precast products will suffice for all bridge structures, bringing the economy to the scheme from repetition.

The technical disadvantages of this option are:

- The single-span option is not as efficient as the two-span option of Option 1 (Applicable at 1no. structure only)
- The heavy lifting of prefabricated elements

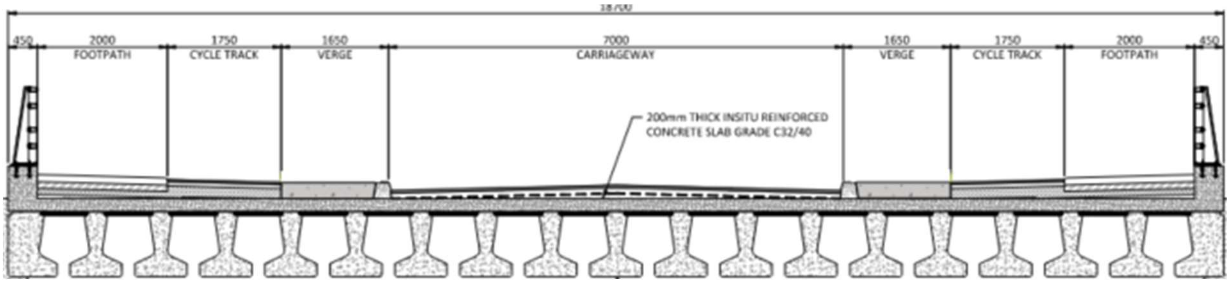

Figure 9: Precast Beams and In-situ Deck

OPTION 3 – COMPOSITE STEEL GIRDER AND IN-SITU DECK

A steel girder bridge beam arrangement with an in-situ deck. All structures are to be integral at the bridge abutments. The bridge is continuous over the pier supports where applicable (1no. road bridge structure) The overall depth of the girder and RC deck is approximately 1.2m, 1.0m girder depth and 200mm RC deck.

The technical advantages of this option are:

- The supports are outside the width of the flood plain, eliminating the risk of scouring and an effect on the existing hydrology.
- Integral construction removes the need for bearings and expansion joints at deck level.
- The structure is lightweight in comparison with a concrete alternative.
- The girders are fabricated and assembled off-site

.

The technical disadvantages of this option are:

- Maintenance - The steel girders will require a paint protection system which will need to be maintained over a period of 120 years, in an area of difficult access over a watercourse.
- The economy is achieved with spans in the vicinity of 25-45m, as opposed to the 15-25m spans required for this development.

- Structural steel availability is low with a large lead in times due to import requirements. Concrete and reinforcement are locally and readily available.

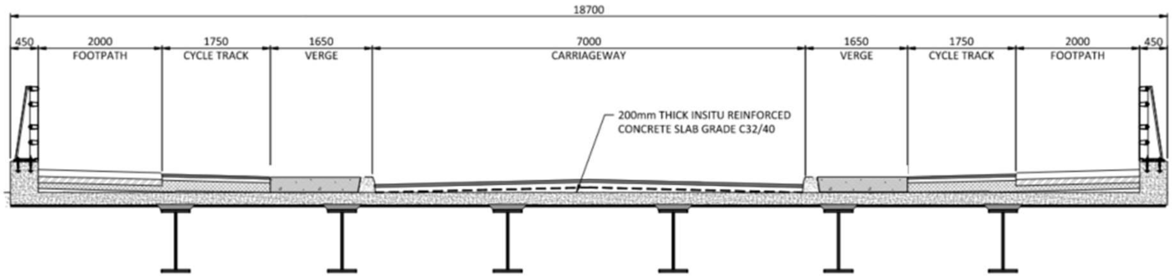

Figure 10: Composite Steel Girder and In-situ Deck

4 ECONOMIC EVALUATION

At this early stage in the project, it is difficult to calculate a precise value for each structural option, particularly with the inflation in construction products witnessed in recent years. As all substructure is the same for all options, the costs below are based upon the superstructure bridge deck only. The figures below are based on Road Bridge 1, which consists of a two-span deck totalling 50m in length, and 18.7m in width.

OPTION 1 – IN-SITU REINFORCED CONCRETE BRIDGE DECK

The in-situ deck will require falsework in the floodplain/watercourse, steel fixing and shuttering. The supports remain consistent across all options. The rate used to calculate the deck construction is €1200 / m2. Note, that the rate includes costs for falsework, reinforcement, concrete, pavement installation, waterproofing, and parapet install. The total cost is 50m x 18.7m x 1200 = **€1,122,000**

OPTION 2 – PRECAST REINFORCED CONCRETE BRIDGE AND IN-SITU DECK

The precast beams will be manufactured and lifted on-site. The in-situ deck will be constructed on top of the permanent shuttering planks, eliminating any falsework in the watercourse. The current rate for the precast beams is €450 per metre. The number of beams per span is 18no. The rate used to calculate the deck construction is €625 / m2. Note, that the rate includes costs for lifting operations, reinforcement, concrete, pavement installation, waterproofing, and parapet install.

Construction Cost: Precast Beams = 18no. x 2no. spans x 25m per beam x €450 = €405,000
Deck Construction = 50m x 18.7m x 625 = €584,375
Total Cost = **€989,375**

OPTION 3 – COMPOSITE STEEL GIRDER AND IN-SITU DECK

The steel girder option requires a paint protection system to be applied to the beams prior to site installation. The rate for structural steel supply including the paint protection system is €3000 per tonne. The cross-sectional area per girder is 0.06m2 allowing 10% for connections. There are 6no. girders are required to take the deck cross-section. Note, that the cost does not include future maintenance requirements.

Construction Cost: Steel Girders = 6no. x 2no. spans x 25m per beam x €3000/tonne x 7.85 t/m3 x 0.06 m2/girder = €423,900
Deck construction (as before) = €584,375
Total Cost = **€1,008,275**

The land take requirement and substructure are the same for all three options.
Option 2 is the cheapest option and has very low future maintenance costs. The cost of falsework and reinforcement tonnage contribute significantly to the total construction cost of Option 1, making it the most expensive option. Although Option 3 is not much more expensive than Option 1, the future maintenance costs over the design life of the steel girder option are viewed as a substantial additional cost, ranging in the hundreds of thousands.

5 AESTHETIC EVALUATION

The aesthetics of the bridge structures is an important aspect to consider. The scale and diversity of the development will create various viewing angles for all structures. However, a balance is required between function, value, constructability, and aesthetics. Due to the traditional structural nature of each bridge option, the aesthetics will be inherently similar i.e. a beam and slab solution. The optimisation of the aesthetic between the three options is achieved by reducing structural depth, creating a slim, clean line visual for the viewer and reducing the impact on its surroundings. Another consideration is the view of the structure for the road user, pedestrian and cyclist, so pavement type and parapet aesthetic are important considerations.

OPTION 1 – IN-SITU REINFORCED CONCRETE BRIDGE DECK

The in-situ deck is estimated as 1.25m in depth, while this is only fractionally deeper than the alternatives, it will have the greatest impact on the surroundings. There is an option to create a cantilevered narrow edge than can support the footway and parapet on the road bridges, however, this is difficult to form, shutter and steel-fix over a watercourse.

OPTION 2 – PRECAST REINFORCED CONCRETE BRIDGE AND IN-SITU DECK

The precast beam option is 1.2m in depth. There is an option to precast an edge beam with a curved or tapering soffit which can create a shadow effect which appears to make the deck shallower to the eye. Forming the edge beam is a controlled factory process and it can easily be dropped into position and tied in with the in-situ deck pour. Various options can be considered at tender and detailed design stages.

OPTION 3 – COMPOSITE STEEL GIRDER AND IN-SITU DECK

The composite steel and in-situ deck will be 1.2m deep. The cantilevered deck is a natural visual line for a narrow element, creating the least impact on the surrounding area. Over the lifetime of the structure, significant maintenance will be required for the steelwork, unless this is undertaken in a timely manner, any paint flaking or corrosion pitting can become a detrimental aesthetic.

6 MAINTENANCE REQUIREMENT EVALUATION

The maintenance requirements for a bridge structure can be the largest cost over its design life if not fully considered in the concept. They can largely overweigh the initial construction cost if not 'designed out' effectively, and in instances, lead to the requirement of a complete structural replacement. The key items to consider in the maintenance of a bridge are materials, bearings, joints, and workmanship. The three options proposed are integral structures, hence, bearings and expansion joints have been designed out of any future maintenance requirements. Resurfacing and waterproofing of the RC deck are common to all three options, so they are not further considerations.

OPTION 1 – IN-SITU REINFORCED CONCRETE BRIDGE DECK

The maintenance costs for the in-situ option will be low. The risk with the in-situ pour in the quality of workmanship and cover to reinforcement. Any areas that do not achieve the required cover, due to lower quality control associated with on-site works, may be subject to reinforcement corrosion and concrete spalling over time.

OPTION 2 – PRECAST REINFORCED CONCRETE BRIDGE AND IN-SITU DECK

The precast option has the least maintenance costs if any. The quality control of the reinforcement and tendon fixing for the precast beams will reduce the risk of corrosion and spalling in the future. The high grade of concrete strength, typically C50/60 will also increase the resistance to penetrating chlorides, carbonation and freeze-thaw attack.

OPTION 3 – COMPOSITE STEEL GIRDER AND IN-SITU DECK

The composite steel and in-situ deck will require a maintenance schedule for the girders. The paint system is likely to require a full refurbishment after approx. 25 years. This will be a substantial cost in the design life of the structure requiring access and encapsulation over the watercourse.

7 FURTHER CONSIDERATIONS

HYDRAULIC CONSIDERATION

A flood study has been undertaken for the entire scheme. The flood plains have been considered in the calculation of the bridge spans, flood levels and clear heights to the bridge soffit, which remains constant for all three options. For this report, the hydraulic criteria do not impact the three options considered.

HEALTH AND SAFETY CONSIDERATIONS

Other than standard construction-related health & safety issues, the primary health and safety concern with the construction of this bridge is working adjacent to and over a river.

Option 1, the in-situ deck, requires considerable falsework over the watercourse. Shuttering, fixing and casting the deck will be time-consuming and labour intensive, giving a high potential for incidents.

Option 2, the precast concrete beam option, requires the lifting of heavy precast elements. However, once the main beams are in position, precast panels are laid across the beams from a safe working platform for the in-situ works, which are considerably less intense than Option 1 with regard to reinforcement size and quantity. The prefabrication of the precast beams reduces the time for construction on site, which is a significant reduction of risk for the scheme.

Option 3, the steel girder and in-situ deck offer similar health and safety benefits as Option 2. There is slightly more time and consideration in the cantilevered deck edge which is likely to be cast in situ, hence falsework supported off the main beams is required. However, a proprietary product may be available to attach to the main girder prior to lifting in, or perhaps the cantilevered deck may be offered as precast, both can be considered at the detailed design stage.

CONSTRUCTION AND BUILDABILITY

The construction and buildability of a bridge over a river are critical considerations. The use of precast beams in Option 2 and the prefabricated steel members in Option 3 give them a distinct advantage over Option 1, which requires falsework over the river to carry out the in-situ construction.

While Options 2 and 3 do not require falsework over the river, they do require significant transport and crane operations to install the heavy precast/prefabricated elements. There is very good access to the development from the eastern side via N4 and regional roads from Leixlip and Maynooth.

Option 1, while of relative standard construction has some complex falsework requirements over the river. There will also be restrictions on the time of year that construction can take place due to fisheries and flood considerations. Option 2 is a standard form of construction which has been commonly used in Ireland in recent decades and as such would be the most straightforward from a buildability perspective. Similarly, Option 3 is a simple form of construction, but consideration has to be given to forming the deck, which is not as straightforward as Option 2 as previously described.

GROUND CONDITIONS

The ground strata are formed of topsoil underlaid by clay. The brown/black clay varies in stiffness with depth and can be described as typical conditions across the North Leinster region. Beneath the clay a very strong limestone bedrock is present. As all bridge options are integral piled solutions that extend to bedrock, the ground conditions do not affect the three options presented.

8 RECOMMENDATION

In addition to whole-life costs, the most critical technical considerations in evaluating the options proposed for these bridges are:

- Construction over a watercourse
- Maintenance considerations

Option 1 has the highest cost and most complex construction requirements. There is higher health and safety, constructability and environmental risk associated with the in-situ works over a watercourse. There are greater time and labour requirements for the workforce on-site. The maintenance costs and aesthetics are similar for both concrete options.

Option 2 has the lowest cost and maintenance requirements and simplest construction requirements. The aesthetics can be altered via a precast edge beam at the detailed design stage if required. The health and safety and constructability aspects of the proposal are advantageous over all the other options. There are economic benefits from repetition in the prefabrication of standardised precast beams for all bridge locations across the development. Alternative solutions such as girders will vary in plate thicknesses and depths, while in-situ decks will require differing reinforcement sizes and additional design and construction timeframes.

Option 3, while construction cost is competitive with the other options, has a large cost implication due to future maintenance requirements. The construction sequence is relatively simple and there are reduced health and safety risks due to prefabrication off-site. The narrow deck profile will give the impression of a 'light' design in comparison to a concrete alternative.

Based on the points above, Option 2 appears to offer the best solution for the bridge structures required within this development.

9 VERIFICATION

This report was compiled and verified by:

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