URS

York Street Interchange

Stage 3 Buildability Assessment

Information Pack: Volume 1

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TABLE OF CONTENTS

1 INTRODUCTION

1.1 Report Structure

Volume 1 of this document comprises the main body of the information pack. Drawings referred to within Volume 1 are included as **Volume 2**, with appendices included as **Volume 3**.

1.2 Background

The York Street Interchange is proposed as a long-term major road improvement scheme to improve links from the A12 Westlink, "the Westlink" to the M2 Motorway, "the M2" and M3 Motorway, "the M3" in Belfast. The existing at-grade signalised York Street junction links the Westlink, the M2 and the M3 through a complex arrangement of traffic signals that interface with the surface street network that includes York Street, York Link, Great George's Street and Nelson Street. Road users currently experience long delays and congestion at peak periods travelling through this signalised gyratory system. The scheme is strategic in nature and is considered necessary in the longer term for the development of the Belfast Metropolitan Area (BMA) beyond 2015.

For the purposes of referring to the various road links within the interchange, a naming convention has been adopted as per Drawings **YSI-URS-XX-XX-DR-RE-IM000** and **YSI-URS-XX-XX-DR-RE-IM001**.

A location plan for the scheme is included as Drawing **YSI-URS-XX-XX-DR-RE-GE008**.

1.3 Development of the Scheme

URS was appointed by Transport NI in June 2008 to prepare a Design Manual for Roads and Bridges (DMRB) Stage 1 Scheme Assessment for the scheme to alleviate congestion in the vicinity of the York Street junction. The summary Preliminary Options Report published in March 2009 recommended the further investigation of the scheme and a subsequent DMRB Stage 2 Scheme Assessment of four solutions, termed Options. The DMRB Stage 2 Scheme Assessment was completed in December 2012 with the publication of the Preferred Options Report which identified the Preferred Option for the scheme. Following this announcement, a preliminary design of the scheme has been developed in more detail ahead of the completion of a DMRB Stage 3 Scheme Assessment and the preparation of draft Statutory Orders.

The Preferred Option identified represents a 3-dimensional solution that delivers grade separation at a location with significant engineering constraints, in particular the existing Lagan road bridge carrying the M3 and the Dargan rail bridge, operated by Translink, which cross through the study area. These and other engineering constraints affecting route alignments are identified on Drawing **YSI-URS-XX-XX-DR-RE-GE009**. In order to develop the Preferred Option, efforts were made to accurately identify and model the position of all known substructures into a 3D model using as-built records and available survey information.

1.4 Scope of the Assessment

The scope of the assessment by the appointed buildability adviser, Gareloch Construction, will include:

- the review of engineering drawings to identify potential show-stoppers
- the identification of key construction issues and possible mitigation measures
- the review of TTM phasing drawings (to inform QUADRO modelling)

- the development and issue of feasible construction programmes
- the identification of value engineering opportunities
- the identification of key residual risks with regard to construction
- assisting the project team to summarise the overall assessment findings.

2 EXISTING CONDITIONS

2.1 Road Network

The extent of the existing road network is as shown on Drawing **YSI-URS-XX-XX-DR-RE-GE005**.

Within the study area, the routes comprising the existing strategic road network include the A12 Westlink, the M2 motorway and the M3 motorway. The existing surface streets of York Street, Great George's Street, Nelson Street, Garmoyle Street and Whitla Street further comprise the extent of the trunk road network within the area.

A number of existing structures at the location form engineering constraints for the works, as shown on Drawing **YSI-URS-XX-XX-DR-RE-GE009**. These engineering constraints include:

- the Lagan Bridge carrying the M3 motorway
- the Dargan Bridge carrying Translink operated railway and associated ramp structures
- the existing depressed section of the Westlink
- the existing North Queen Street bridge
- the existing Dock Street bridge
- the existing Galway House multi-storey development at York Street.

Further details on the existing structures are provided in **Section 2.2**.

The existing pavement construction on the majority of routes can be considered to be of flexible construction. It should be noted that a section of the existing Westlink carriageway is of rigid composite construction, with a continuously reinforced concrete (CRC) slab underlying asphalt binder and surfacing courses from the western abutment of North Queen Street Bridge. The extents of this existing CRC slab are shown on Drawing **YSI-URS-XX-XX-DR-RE-ST004**.

It should be noted that the Westlink, M2 and M3 motorways are operated and maintained by Highway Management (City) Limited under the terms of its DBFO Contract with Transport NI. Under the terms of the DBFO Contract, the concessionaire will not be liable for reductions in lane availability due to temporary traffic management for the proposed scheme.

2.2 Structures

2.2.1 *Overview*

A number of existing structures exist within the extents of the scheme. These structures are identified on Drawing **YSI-URS-XX-XX-DR-RE-ST002**. Summary descriptions of the identified structures are included below.

2.2.2 ***Lagan Bridge***

The Lagan Bridge was constructed between 1991 and 1994 as part of the Cross-Harbour Links contract. The main bridge comprises a viaduct structure with associated ramp structures which cross over numerous city streets and the River Lagan, supporting the M3 motorway. The bridge deck for the structure generally comprises of post-tensioned precast concrete box segments and is supported in turn on reinforced concrete piers. The piers are supported on piled foundations.

2.2.3 ***Dargan Bridge***

The Dargan Bridge operated by Translink was constructed as part of the same works contract as the Lagan Bridge and comprises a viaduct structure which crosses over both city streets and the River Lagan. The bridge supports a single track railway line with passing points, opening to twin tracks on the main river span. The bridge is of similar construction to the Lagan Bridge, with the deck comprising of a series of post-tensioned precast concrete box segments supported on reinforced concrete piers and piled foundations.

2.2.4 ***Dock Street Bridge***

Dock Street Bridge is a continuous four span precast composite concrete simply supported structure carrying twin 7.3m wide carriageways (the M2). The bridge is straight, with spans of 10.4m, 16.5m, 16.5m and 12.6m in a south to north direction. The bridge was constructed between 1981 and 1982, with the north-bound (western) carriageway subsequently widened in 1991. The bridge deck comprises precast pre-stressed M4 concrete beams supporting a cast in-situ concrete slab. At the internal supports, the deck is supported on in-situ concrete crosshead beams which are, in turn, supported on individual reinforced concrete columns. These columns are supported on piled foundations. At each end of each internal support, the last two columns are connected by reinforced concrete infill walls to enhance the resistance of the columns to vehicle impacts. The end supports comprise reinforced concrete abutments, which are piled. The crosshead beams and end diaphragms are post tensioned transversely. The structural connection between the original deck and the widened section is between the deck slabs only. There is no transverse post tensioning of the deck between the end diaphragms.

2.2.5 ***North Queen Street Bridge***

North Queen Street Bridge is a single span precast composite concrete simply supported structure carrying twin 7.3m wide carriageways (the Westlink) with a 2.550m wide central reservation and 2.5 metre wide footways on each side. The bridge is skewed at an angle of 23 degrees and has a skew span of 22.2m between bearing centres. The bridge deck comprises 24 No. precast pre-stressed M6 concrete beams supporting a cast in-situ concrete slab. The deck is supported on in-situ concrete abutments by 24 No. bearing pads. The abutments are carried on reinforced concrete spread footings. Record drawings for the structure are dated circa 1980 and it is thought that the bridge was constructed in the early 1980s.

2.2.6 ***Dock Street Rail Bridge***

The Translink operated railway bridge at Dock Street was constructed as part of the Cross-Harbour Links contract along with the Lagan and Dargan Bridges. It is a two span structure with varying skew and cross-section along its length. The structure comprises two longitudinal steel box girders with intermediate transverse cross-girders. Precast deck planks formed permanent formwork to the cast in-situ deck, which supports the rail ballast. The steel box girders are supported in the centre by two reinforced concrete piers, but insufficient record

information exists to determine the nature of the foundation structure. However, it can be reasonably assumed that piled foundations have been used in a manner akin to the adjacent Dock Street road bridge.

2.2.7 ***Whitla Street Subway***

Whitla Street subway was originally constructed in the 1980s as part of the M2 motorway. The structure comprises a reinforced concrete box section, supported on raked piled foundations. The original structure was widened in 1991 on the western side in accompaniment to the construction of the Dargan Bridge.

2.2.8 ***Clifton Street Bridge***

Clifton Street Bridge was constructed in 1979 as part of the original Westlink construction. It comprises a single 21.5m span over the Westlink carriageway. The bridge deck comprises 25 No. precast M5 beams at 1.02m centres, supporting a cast in-situ concrete slab. The deck is supported on in-situ concrete abutments by 25 No. bearing pads, with the abutments carried on reinforced concrete spread footings.

2.2.9 ***Westlink Retaining Walls***

The outer retaining walls on the Westlink depressed section at Clifton Street are of reinforced concrete construction and are of an inverted T type. Record drawings suggest that the walls have spread footings and bear directly onto placed fill. The retained height varies from approximately 2m to 5m over the length of the walls, with a typical stem width of 500mm.

2.2.10 ***Little George's Street Retaining Wall***

The retaining wall at Little George's Street forms the land boundary to the rear of existing domestic properties. The wall is of an inverted T type, with a reinforced concrete stem of approximately 450mm in width. The wall comprises a series of panels with a stepped top of wall profile, with a brick outer skin provided on exposed faces. The retained height varies from approximately 1m to 2m over the length of the wall. The wall has spread footings and bears directly onto underlying strata.

2.2.11 ***Great George's Street Retaining Walls***

The retaining wall at Great George's Street is of an inverted T type, with a reinforced concrete stem of approximately 450mm in width. The wall comprises a series of panels with a profiled top of wall level with brick facings provided on exposed faces. The retained height varies from approximately 1m to 2m over the length of the wall. The wall bears directly onto underlying strata.

2.3 Services

Within the York Street area there exists a dense network of existing utilities infrastructure. The known major utility providers were contacted. This was to establish firstly if they had apparatus within the study area and secondly, if they did, information on location, type of apparatus etc., was also sought. A C2 Preliminary Enquiries letter was sent to the various utility providers in accordance with the NIRAUC Agreement.

The scheme study area is located to the North of Belfast city centre. Given the developed nature of the site, there is an extensive network of underground utility services which includes telecommunications ducts, sewerage, water mains, storm drainage pipes, electricity cables and gas mains. Information such as existing utilities infrastructure locations, sizes of pipes and mains and duct arrangements has been received. These utilities are mainly located within

existing footpaths but are also located within the existing carriageway. The utility infrastructure present within the area serves not only the adjacent residential, commercial and industrial development but similarly sized developments and substantial development in areas beyond the study area.

Due to the high number and high density of services within the scheme area, separate utility drawings have been provided to show each of the individual utility provider's apparatus and the existing services layout is depicted/illustrated/represented in the following drawings:

- **YSI-URS-XX-XX-DR-UT-0021** - Existing NI Water Utilities Infrastructure
- **YSI-URS-XX-XX-DR-UT-0022** - Existing BT Utilities Infrastructure
- **YSI-URS-XX-XX-DR-UT-0023** - Existing Cable and Wireless Utilities Infrastructure
- **YSI-URS-XX-XX-DR-UT-0024** - Existing Motorway Communications Utilities Infrastructure
- **YSI-URS-XX-XX-DR-UT-0025** - Existing Eircom Utilities Infrastructure
- **YSI-URS-XX-XX-DR-UT-0026** - Existing Mobile Telecoms Utilities Infrastructure
- **YSI-URS-XX-XX-DR-UT-0027** - Existing NI Electricity Utilities Infrastructure
- **YSI-URS-XX-XX-DR-UT-0028** - Existing Street Lighting Utilities Infrastructure
- **YSI-URS-XX-XX-DR-UT-0029** - Existing Phoenix Natural Gas Utilities Infrastructure
- **YSI-URS-XX-XX-DR-UT-0030** - Existing Virgin Media Utilities Infrastructure**.**

Significant diversions of utilities infrastructure would be required as a result of the construction of the scheme. From information supplied by the service authorities it is evident that the majority of service utilities to be diverted are located in five main areas of York Street, Nelson Street, Great George's Street, York Link and in the vicinity of Duncrue Street.

An assessment of the diversions required has been carried out based on the data received from the utility providers. No provision has been made for the possibility of preferred upgrades to existing infrastructure which may be requested by any of the utility providers.

In developing the scheme design as part of the DMRB Stage 3 Scheme Assessment, a geophysical survey contract was awarded to verify the records held by the various utility providers. A series of electronic trial holes were completed at a number of specified locations, with a series of 3-dimensional cross-sections prepared to illustrate the nature and location of detected services. This information was used in the development of associated service diversion proposals, as described in **Section 3**.

2.4 Drainage

The existing road network in the vicinity of the scheme generally drains via traditional kerb and gullies which discharge into either dedicated storm sewers or combined storm water and foul water sewerage (combined sewers). The site predominantly drains to an existing 1500mm diameter combined sewer in Corporation Street. This can be seen on Drawing No **YSI-URS-XX-XX-DR-UT-0021**. It should be noted that the accuracy of locations of apparatus shown is dependent on the information that has been sourced and that the information illustrated in the drawing is approximate.

The proposed design road edge detail would be primarily that of combined kerb and drainage units which discharge to longitudinal carrier drainage pipes at certain connection points. This method would be used in any underpasses or elevated structures and in relatively flat areas of

the scheme. Road drainage gullies which feed a longitudinal collector pipe would also be considered as a method of road drainage in other areas of the scheme.

Although the existing scheme area drains to the existing 1500mm diameter combined sewer in Corporation Street, consultation to date with Northern Ireland Water has highlighted their policy to remove storm water from their combined system, where possible. Therefore the proposed drainage design for the scheme incorporates a pumped drainage outfall to the River Lagan. It has been assumed that existing NI Water disused culverts in Gamble Street can be used to connect the outfall pipeline into, as this would reduce the overall length of the proposed pipeline and avoid the need to construct an outfall structure to the River.

The proposed drainage solution also involves connecting relatively minor road drainage catchment areas into existing storm and combined sewers where it would be difficult to connect these to the proposed pump station and where proposed road drainage levels would permit such connections.

2.5 Ground Conditions

Solid and Drift geology maps for the area indicate that the site is underlain by drift deposits comprising quaternary alluvium and glacial deposits from the Pleistocene Period to the present. The estuarine alluvium thickness is shown to be at least 10m, particularly along the study area. The map indicates that the geology of the site consists of Sherwood Sandstone Group (formerly the 'Bunter Sandstone') of the Triassic Period. The bedrock formation consists of sandstone, silty sandstone and mudstone alternations.

Previous borehole records were obtained from the Belfast Cross Harbour Road and Rail Links Site Investigation contract and the following soil and rock lithologies were identified in the following stratigraphic order:

- Made Ground
- Estuarine Alluvium (Sleech) and Peat
- Alluvial Deposits
- Glacial Deposits
- Sedimentary rock alternations.

These boreholes suggest ground water level variation between depths of 0.5m to 2.5m below ground level (bgl). It is also anticipated that groundwater level is subject to tidal influence. **Table 2.3.1** summarises in-situ test results in stratigraphic order.

To complement this and other sources of historical ground investigation information, a Ground Investigation contract was completed as part of the DMRB Stage 3 Scheme Assessment process. This additional information has confirmed the extents of sleech deposits underneath the majority of the site and importantly, its western extents under York Street. Contour maps of the underlying strata have been developed and are included as **Appendix A**.

As part of the Ground Investigation contract, an intrusive survey was carried out at base C22 to verify the extents of the underlying pile cap. The surveyed location of the pile cap has been used to further refine the 3d substructure model.

3 RESTRICTIONS ON WORKING AND ACCESS

3.1 Road Closures

For the purposes of this buildability assessment, it should be assumed that all existing traffic movements are to be maintained through the works during the period of 6am to 10pm, Monday to Saturday and the period of 11am to 10pm on Sundays.

Outside of these periods, lane and full closures (limited or otherwise) will normally be considered permissible.

It is recognised that full closures may be required within these periods for specific works activities. Where such full closures are considered necessary, their extent and likely duration should be presented to the team for consideration.

3.2 Railway Possessions

With regard to the construction of overbridges above the Dargan Bridge, it should be assumed that possessions of the railway track will only be permissible for the period of 12am to 5.30am, Monday to Friday, the periods of 12am to 6am and 11pm to 12am on Saturday and the period of 12am to 8.30am on Sundays.

3.3 Land Made Available

For the purposes of this buildability assessment, it is assumed that the areas of land identified on Drawing **YSI-URS-XX-XX-DR-RE-LA003** will be vested by Transport NI and made available to the successful contractor for the construction of the permanent works.

3.4 Potential Haul Routes

For the purposes of the disposal of unsuitable material and haulage of fill material, routes to the nearest commercial landfill sites in the vicinity of the site are identified on Drawings **YSI-URS-XX-XX-DR-RE-GE006** and **YSI-URS-XX-XX-DR-RE-GE007**.

4 WORKS DESCRIPTION

4.1 Roadworks

4.1.1 *Overview*

A plan of the proposed layout is included as Drawing **YSI-URS-XX-XX-DR-RE-GE002**, with profiles of the various links also included as Drawings **YSI-URS-XX-XX-DR-RE-GD001 to 010** inclusive.

A summary of the key link alignments is provided in Sections 4.1.1 to inclusive.

4.1.2 *Westlink to M2 (Link No. 1)*

The link commences at the back of the existing Clifton Street north-bound on-slip, with online widening of the Westlink and North Queen Street Bridge (BR-001) on the northern side to facilitate a new weaving section arrangement. This requires demolition and replacement of existing retaining walls adjacent to the Westlink and North Queen Street. West of BR-001, the link lowers into a depressed section underneath the new York Street to York Road (Link No. 11).

To facilitate the online widening, it is necessary to increase the slope on the existing Westlink embankment. To avoid works to replace the existing Little George's Street retaining wall, a strengthened earthwork (EB-001) is proposed on the northern side of the link between BR-001 and BR-002B for a distance of approximately 100m. Construction of this strengthened earthwork will require a suitable working platform for piling operations and this will, in turn, require temporary removal of a significant portion of the existing embankment.

To provide sufficient headroom to BR-002B, the link is lowered by approximately 3m below existing ground level. An underpass structure is proposed, with a single lane diverge to the M3. As the link approaches the Dargan Bridge, it rises to match levels on the existing M2 on-slip, with approximately 400mm cover provided to the underlying pile caps. The link then matches the existing alignment on the on-slip to provide a 2-lane lane gain onto the north-bound M2 foreshore.

4.1.3 *M2 to Westlink (Link No. 2)*

The link commences with a two-lane lane drop from the M2 motorway on approach to the existing Dock Street Bridge, with the link passing on a proposed overbridge structure over Dock Street (BR-004). The link continues to drop below existing ground level in an underpass (UP-001A) underneath Dock Street to M3 (Link No. 6), Westlink to M3 (Link No. 3) and the existing Lagan and Dargan Bridges. A pinch point is encountered when passing under the Lagan Bridge, where clearances to existing bridge substructure are between 400-500mm.

To facilitate this alignment, a number of existing properties will require demolition, including the existing Roads Service depot at Corporation Street. At its lowest point, the finished road level on the link is approximately 9m below existing ground level. The link rises upon departure from the pinch point, passing under the York Street to York Road link (Link No. 11) carried on BR-002A and rises to tie in with existing levels at North Queen Street Bridge, where widening of the existing bridge (BR-001) is required on the southern side. This requires works to demolish and replace existing retaining walls on North Queen Street. In a similar manner to the Westlink to M2 link (Link No. 1), it is proposed to steepen the side slopes on the existing Westlink embankment. To do this, whilst avoiding the need to replace the existing Great George's Street retaining wall, it is proposed to create a strengthened earthwork (EB-001). The construction of this strengthened earthwork will again require the excavation of part of the existing Westlink embankment to form a suitable platform for piling operations. West of the widened BR-001, a lane drop is maintained to Clifton Street, with two lanes continuing south-bound on Westlink.

It should be noted that the feasibility of the proposed underpass structure underneath the Lagan and Dargan Bridges was specifically examined as part of the DMRB Stage 2 Scheme Assessment process. In developing the solution for the underpass, discussions were held with industry specialists to fully consider buildability issues and a copy of the summary report prepared is included as **Appendix B**.

4.1.4 *Westlink to M3 (Link No. 3)*

The Westlink to M3 link (Link No. 3) commences as a single lane diverge from the Westlink to M2 alignment (Link No. 1) that passes under BR-002B in an underpass structure (UP-002B). At its lowest point, the finished road level in the underpass is approximately 3m below existing ground level. To the west of BR-002B, the link rises to provide 400mm cover to existing underlying pile caps of the Dargan and Lagan Bridges. The link is carried over UP-001A on the proposed Bridge BR-003. A lane gain from Dock Street (Link No. 6) converges with the link, with the two resulting lanes continuing onto the existing on-ramp structure.

4.1.5 ***M3 to Westlink (Link No. 4)***

The link commences on the existing Lagan Bridge off-ramp structure, with white lining used to reduce the overall number of lanes on the existing embankment to two. On approach to the Dargan Bridge, a new link is created in an offline position that passes between existing bridge piers at approximately ground level. West of Dargan Bridge, the link drops below existing ground level in an underpass (UP-001B) with a low point located to the east of BR-001A. On approach to BR-002A the link rises and is approximately 3.6m below existing ground level as it passes under the bridge. The link continues to rise to join the M2 to Westlink (Link No. 2) alignment west of BR-002A with a lane gain arrangement.

4.1.6 ***Westlink to York Street (Link No. 5)***

The link comprises a lane drop from the Westlink to M2 alignment (Link No. 1), with a single lane drop opening to two lanes on approach to a new signalised junction with the York Street to York Road alignment (Link No. 11). The alignment is initially in cutting relative to existing ground level, before rising to approximately 4.2m above existing ground level at its junction with York Street. The existing Little George's Street retaining wall is maintained within the layout, with the extent of the existing boundary wall from house nos. 39 to 47 (odds) inclusive also retained within the layout. However, on approach to York Street, the section of existing boundary wall to the north of the link requires demolition and replacement with a new retaining wall (RW-007).

4.1.7 ***Dock Street to M3 (Link No. 6)***

The new link provides a direct connection from Dock Street to the M3, with some horizontal and vertical realignment of the existing link required to facilitate a two-way section away from its junction with York Street to facilitate access to a future development opportunity site (Link No. 39). From this junction arrangement, a single lane continues to create a lane gain with the Westlink to M3 link (Link No. 3), passing over UP-001A via BR-003. A new retaining wall (RW-025) is proposed to support the raised alignment.

4.1.8 ***M3 to York Street (Link No. 7)***

The link commences with a single lane diverge from the M3 to Westlink link (Link No. 4) and is at existing ground level as it passes under the Dargan Bridge at a new left-in/left-out junction with Nelson Street (South) (Link No. 12). The link subsequently rises to meet the raised alignment of York Street (Link No. 11) and is approximately 2.3m above existing ground level at the junction between the links.

4.1.9 ***York Street to York Road (Link No. 11)***

The works comprise a vertical and horizontal realignment of York Street to provide headroom for new bridges BR-002A and BR-002B over the proposed underpasses. The vertical realignment of the link starts on approach to the proposed junction with the M3 to York Street link (Link No. 7), with the link raised by approximately 1.8m at the junction, supported by new retaining walls RW-006, RW-028, RW-031 and RW-033. The link continues to rise to a maximum of approximately 5m above existing ground level and is supported by retaining walls RW-032 and RW-034 between BR002A and BR-002B, before lowering back to tie in with existing levels at a position adjacent to the current entrance to Cityside Retail Park (Link No. 28). A new retaining wall RW-007 will be required adjacent to existing Cityside complex to support the raised alignment, with a new signalised access provided for Yorkgate Business Park (Link No. 27). This will require works at street level to widen York Street on the eastern

side (through narrowing of the adjacent footway) to provide the necessary central traffic island widths.

4.1.10 ***York Street (South) to M2 (Link No. 15)***

The link commences at a signalised junction with Link No. 11 with two lanes provided on a downhill gradient under the Dargan Bridge, with a minimum of 400mm cover to existing bases. The link rises to merge into the M2 foreshore at Dock Street Bridge (BR-005), which will be widened to accommodate the link on its western side. The link will be supported by retaining walls RW-020 and RW-021 on its approach to the structure. On approach to the widened bridge, the two lanes on the link reduce to provide a single lane gain onto the M2 foreshore (Link No. 1).

4.1.11 ***Duncrue Street to Westlink (Link No. 31)***

The new link provides a parallel merge arrangement onto the M2 to Westlink link (Link No. 2), commencing from a new signalised junction arrangement at the M2/Duncrue Street offslip (Links Nos 32 and 29). In order to provide the link within the space available, it is proposed to cut into the existing M2 embankment, with the M2 supported in lieu by a new retaining wall RW024. The finished road level on the link is approximately 2m below the existing M2 adjacent to this retaining wall. The link rises as it continues south, with widening of Whitla Street subway (BR-006) required on its eastern extent (including associated replacement of wingwalls) to accommodate the new link. Widening of the subway has implications for a number of service corridors that are located within the existing underpass structure, significantly a number of 110kV cables that will require substitute connections, diversion and protection for the duration of the works. It is expected that given the nature of these electrical supply cables and cooling systems, the lead-in times for these operations could be quite significant for the overall construction programme.

4.1.12 ***Works to other Surface Streets***

Other works required by the scheme include the stopping up of Nelson Street (Link No. 12) and its conversion to permit two-way running, requiring works at the junction of Dunbar Link (Link No. 63) and Nelson Street (Link No. 12) to provide a signal controlled right-turning movement. Local regarding of the existing accesses onto York Street will be required to accompany the raised alignment of York Street (Link No. 11). Further works will be required to regrade Little York Street (Link No. 22) into the revised alignment of the M3 to York Street alignment (Link No. 7). In order to provide access to the isolated portion of land between Links A and D, it is proposed to construct a new access road (Link No. 38) underneath the Lagan Bridge and Dargan Bridge, with connection onto Corporation Street via a priority junction. In order to provide the new Duncrue Street to Westlink (Link No. 31), it will be necessary to realign the existing Nelson Street north (Link No. 29) requiring works at the Dock Street junction (Link No. 10) and at its junction with Whitla Street (Link No. 33).

Consultations with the Transport NI Traffic Information and Control Centre (TICC) have led to the identification of indicative gantry locations to service the extension of the Managed Route system on the M1/Westlink onto the M2 foreshore as far as Nelson Street. With regard to infrastructure works within the extent of the scheme it is expected that a minimum of three new access gantries will be required along with associated control cabinets and transmission links.

4.2 Structures

4.2.1 *Overview*

The scheme will require the construction of several significant structures, summarised below:

- four major underpasses, up to 10 metres deep
- two twin span pre-stressed beam bridges, one highly skewed
- a single span bridge supported on the walls of the largest underpass
- a three span bridge carrying traffic over the Dock Street junction
- two existing bridges to be widened, with parapet improvements
- seventeen retaining walls, several subject to collision loading and/or acting as flood protection walls.
- an extension to a pedestrian underpass
- a services culvert
- three overhead sign gantries
- structures associated with pumping stations required for scheme drainage
- strengthening works to the foundations of Lagan Road Bridge.

Potential design options were identified for each of the structures, each option being defined by the following basic features:

- structural type
- type of foundation
- span arrangements
- number and type of supports
- choice of materials.

In most cases, several technical solutions presented themselves in which case the choice of the preferred solution was influenced by the following factors:

- disruption to the road network during construction
- appearance and environmental impact
- desire to maintain the appearance of a “family” of structures within the scheme
- safety and ease of construction
- foundation conditions
- road geometry
- future maintenance
- capital and whole life cost.

The preferred solution for each structure was developed and is presented in the drawings included for each structure in **Volume 2**. A reference plan for the various structures is included as Drawing **YSI-URS-XX-XX-DR-SE-ST001**.

All new works shall be designed to the Eurocodes, with their associated National Annexes and Published Documents. Existing structures shall be assessed either qualitatively, in accordance with BA 16 of the DMRB, or quantitatively in accordance with BD 21 and BD 44 of the DMRB. Wherever it can be demonstrated that loads applied to the existing structure have not increased, a qualitative assessment shall be considered adequate. If loading applied to an existing structure is increased, a quantitative assessment shall be undertaken.

A major consideration in the Stage 3 design development has been the requirement to minimise disruption to the road network during construction. Buildability and any temporary traffic management requirements have been considered in detail. Another challenge associated with the project is the poor ground. This means that the majority of structures require piling. This in itself makes limiting the disruption to existing roads more challenging, due to the logistics of installing piles. Many of the structures on the scheme are reinforced concrete retaining walls. Time could be saved constructing these walls if precast retaining walls were used. However, as the ground conditions on the scheme generally necessitate piled foundations, there is a challenge associated with the interface between standard precast cantilever retaining walls and piles. One option available is to use precast stem and cope units and only adopting in-situ concrete for the foundation slabs. Another alternative would be to form a piled slab using in-situ concrete and to place a complete precast concrete retaining wall unit on top of it. Clearly, for the tallest sections of retaining wall on the scheme, precast units are unlikely to be practical for lifting, or transportation. In addition, the joints between precast units often provide pathways for water leakage.

The structures drawings presented with this report do not specify either in-situ or precast forms of construction. The preferred solution will be dependent on the cost-savings associated with reduced lane occupations and the successful Contractor's preference.

The design adopted for each of the structures is discussed briefly in the following sections.

4.2.2 *BR-001 – North Queen Street Bridge Extension*

The following summary should be read in conjunction with Drawings **YSI-URS-BR-01-DR-SE-00001** and **YSI-URS-BR-01-DR-SE-00002**.

The existing North Queen Street Bridge carries the Westlink alignment over North Queen Street. It is a single span pre-stressed beam bridge with in-situ concrete deck. The beams are supported on elastomeric bearings on reinforced concrete abutments. A run-on slab is provided at the west side of the bridge, where deck movements due to thermal effects are accommodated by shear distortion in the bearings. The proposed Westlink cross-section is wider than the existing bridge, requiring it to be extended northwards and southwards by approximately 4 metres and 2.5 metres respectively. It is envisaged that the extensions shall be formed from reinforced concrete abutments dowelled into the existing abutments, with pre-stressed beams and an in-situ deck to match the existing structure. As settlement has already occurred beneath the existing bridge foundations, piled foundations are proposed beneath the extensions to prevent differential settlement.

The existing Westlink alignment needs to be retained during construction of the extensions and it is envisaged that this will be achieved using sheet-piling. The extent of disruption to the Westlink depends on whether piling platforms can be formed to allow piling rigs to work from the side of the Westlink rather than directly on it. Formation of these platforms would require disruption to the roads and pedestrian routes below the Westlink (North Queen Street, Great George's Street and the stairs and footpath area north-west of the bridge). The existing police station wall may facilitate forming a piling platform at the south-west corner of the bridge, potentially providing support to the south extent of the piling platform. At the north-east corner of the bridge a sheet pile wall will need to be installed from the Westlink, to allow extension of

the bridge abutment. It is envisaged that this will be undertaken after the bridge has been extended southwards, to increase the space for re-configuration of lanes over the bridge.

Disruption to Great George's Street and North Queen Street would also occur during installation of permanent piles for the extensions.

A detailed construction sequence is defined on the drawings for this bridge.

4.2.3 ***BR-002A – York Street Underbridge (South)***

The following summary should be read in conjunction with Drawing **YSI-URS-BR-2A-DR-SE-0001**.

Bridge BR-002A carries York Street (Link No. 11) over underpasses UP-001A and UP-001B. It is integral with the diaphragm walls used to form the underpasses.

The bridge has a skew of 21 degrees with a total skewed length of approximately 34m. It has two spans, each formed from pre-stressed concrete beams with a reinforced concrete deck slab. Due to the modest skew and length, this bridge is required to be integral by the DMRB, hence the lack of movement joints or bearings in the design.

At the internal support, the diaphragm wall is continued up to existing ground level. This is attractive from a construction perspective because it allows underpasses UP-001A and UP-001B to be constructed separately. Above existing ground level, discrete columns are provided. This gives the structure a more open appearance, which is desirable from a driver comfort perspective. The columns will be formed from 20 equal facets to improve their aesthetics. The aesthetics could be further improved by breaking down the central diaphragm wall after the underpasses were formed. Full height columns could then be constructed, which would open the structure up further, although there would clearly be cost implications associated with this. This would also result in a very tall retaining wall east of the bridge. Currently it is assumed that the central diaphragm wall will not be broken down. The cross head at the column tops shall not protrude below the soffit of the beams and shall be integral. This is preferable to downstands below the beam soffits from an aesthetics perspective.

The upper part of the abutments and the deck are above ground level. They shall be formed after the underpass has been excavated and temporary props have been removed. This prevents the deck from acting as a prop in the short term (although in the long term, creep effects will result in a degree of propping action). The lack of propping is advantageous, because there would otherwise be a differential in stiffness at the ends of the bridge, which would apply significant loads to the underpass walls. While joints could be provided to accommodate differential movements, this would not be attractive in terms of sealing the underpass against groundwater ingress. Providing bearings was considered, because thermal movements and shrinkage of the deck would also apply significant loads to the underpass walls. However, it was judged that the magnitudes of displacements are such that the underpass walls could accommodate the associated load effects. Integral structures have significant benefits in terms of whole life cost and are likely to be Transport NI' preference.

Disruption associated with the construction of this bridge will be modest, and likely to coincide with closures required for the construction of underpass UP-001A.

4.2.4 ***BR-002B– York Street Underbridge (North)***

The following summary should be read in conjunction with Drawing **YSI-URS-BR-2B-DR-SE-0001**.

Bridge BR-002B carries York Street (Link No. 11) over underpasses UP-002A and UP-002B. It is supported on the diaphragm walls used to form the underpasses.

Bridge BR-002B has two spans, which are formed from pre-stressed concrete beams with a reinforced concrete deck slab. It has a skew of approximately 45 degrees with a total skewed length of approximately 50m. Due to the high skew, it is not practical for the bridge to be integral, nor is it required to be by the DMRB; consequently, bearings are provided at the abutments and the columns. Movement joints are also required at each abutment. Inspection galleries are provided to allow access to the bearings and movement joints.

The articulation arrangement shall allow for thermal, shrinkage and live load induced movements of the deck and any deflection of the supporting diaphragm/ bored pile walls. The geometry of the abutments shall facilitate bearing replacement.

To minimise the construction depth, the beams shall be placed at closer than normal spacing, and higher grade concrete shall be used. The beams are sized to be the same as BR-002A, which has a significantly shorter span. This retains a constant beam depth when both bridges are viewed from the Westlink.

At the internal support, the diaphragm walls are continued up to existing ground level. This is attractive from a construction perspective because it allows underpasses UP-002A and UP-002B to be constructed separately. Above existing ground level, discrete columns are provided. This gives the structure a more open feel, which is desirable from a driver comfort perspective. The columns will be formed from 20 equal facets to improve their aesthetics. The aesthetics could be further improved by breaking down the central diaphragm wall after the underpasses were formed. Full height columns could then be constructed, which would open the structure up further, although there would clearly be cost implications associated with this. This would also result in a very tall retaining wall east of the bridge. Currently it is assumed that the central diaphragm walls will not be broken down. The cross head at the column tops shall not protrude below the soffit of the beams and shall be integral. This is preferable to downstands below the beam soffits from an aesthetics perspective.

Disruption associated with the construction of this bridge will be modest, and likely to coincide with closures required for the construction of underpass UP-01A.

4.2.5 *BR-003 – Underpass UP-001A Roof Slab*

The following summary should be read in conjunction with Drawing **YSI-URS-BR-03-DR-SE-0001**.

Bridge BR-003 carries the Westlink to M3 (Link No. 3) and Dock Street to M3 (Link No. 6) interchange links over underpass UP-001A. It is supported on the diaphragm walls which form the underpass UP-001A.

BR-003 is a single span portal structure which is integral with the diaphragm/bored pile walls of the underpass. It has a span of 13 metres and the deck is formed from in-situ reinforced concrete. Pre-stressed beams were considered but dismissed, on the basis that the limited headroom beneath existing structures would make crane operation problematical.

The bridge is approximately 55 metres wide, extending beyond the width required to support the link roads; this additional width is required to prop the underpass walls over the extent of the underpass coinciding with the foundations of the existing Dargan and Lagan bridges. Propping the underpass over this significant length minimises ground movements in the vicinity of these important structures. The additional width also safeguards against dropped items from the Dargan or Lagan bridges landing in the underpass.

In the vicinity of BR-003, the proposed diaphragm walls of underpass UP-001A are close to the piled foundations of the existing Lagan Bridge. Taking account of normal construction tolerances there should not be a clash between the proposed diaphragm walls and the existing foundations albeit the theoretical clearances are small. However, there is a possibility that the existing piles were not placed within tolerance, which could result in the new diaphragm wall clashing with the existing piles. If left un-checked, this could result in damage to the Lagan Bridge. The current scheme includes strengthening works to the foundations of the Lagan Bridge. These works shall ensure that damage to the existing Lagan Bridge piles closest to the proposed underpass would not result in the strengthened foundations becoming non-code compliant. The proposed strengthening works are discussed in detail later in this report.

4.2.6 ***BR-004 Dock Street Overbridge***

The following summary should be read in conjunction with Drawing **YSI-URS-BR-04-DR-SE-0001**.

Bridge BR-004 carries the M2 to Westlink (Link No.2) over the Dock Street junction.

Bridge BR-004 has 3 spans and is formed from pre-stressed concrete beams with a reinforced concrete deck slab. It has a skew of approximately 20 degrees with a total skewed length of approximately 80m. Due to its length, the bridge is not required to be integral by the DMRB. Consequently, bearings are provided at the abutments. Movement joints are also required at each abutment to accommodate thermal movements. Inspection galleries are provided to allow access to the bearings and movement joints for inspection and replacement. The articulation arrangement shall allow for thermal, shrinkage and live load induced movements of the deck. The geometry of the abutments shall facilitate bearing replacement.

At the internal supports, full height columns shall be provided. These shall be integral with the deck, minimising maintenance requirements at these locations, in the midst of a busy junction. The columns shall be 1.5m diameter and will be formed from 20 equal facets to improve their aesthetics and discourage graffiti. The location of the columns is determined by the traffic islands below. This has resulted in the outermost pre-stressed beams being offset transversely a significant distance from the columns below, with the result that the diaphragm at the columns has to cantilever significantly from the columns to support the outer beams. The stresses applied to the diaphragm are further increased by the 34m length of the central span and the 26m length of the longest end span. Currently, it is not clear that such a diaphragm will be practical from a structural engineering perspective without a downstand below beam soffit level. As there is sufficient clearance to the roads below, the current design shows a downstand crosshead at the columns. This may not be as aesthetically attractive as a no-downstand solution, but offers a robust engineering solution, which is preferred at this stage in the design development. The downstand also removes the requirement for temporary works to support the beams, which would be attractive from a traffic management perspective. Further calculations at detailed design stage may confirm that the downstand is not required, but the associated temporary works are unlikely to be attractive, considering traffic management.

Piled foundations are required at this bridge. A single line of piles was considered for the column foundations, in an attempt to minimise disruption to the Dock Street junction. However, twin lines of piles are more efficient structurally, allowing smaller piles, smaller piling rigs, reduced placing time and less disruption. The single line of pile options would also result in a flexible structure during construction, requiring temporary works to limit deflections. These temporary works would also have implications for traffic management.

4.2.7 ***Bridge BR-005 - Dock Street Bridge Extension***

The following summary should be read in conjunction with Drawing **YSI-URS-BR-05-DR-SE-0001**.

The existing Dock Street Bridge carries the M2 north-bound and M2 south-bound over Dock Street. It is a four span bridge, with a pre-stressed beam deck supported on bankseats at each end, with columns for internal supports. Piled foundations are provided throughout. Pre-stressing has been used to form crossheads at the columns, with soffit levels in line with the soffit of the pre-stressed beams. The original bridge was extended westward in the 1990's.

The proposed re-alignment of the M2 south-bound requires the bridge to be extended further westwards. This will be achieved by extending the already once extended abutments and internal supports, removing the existing cope and extending the existing pre-stressed beam deck by The following summary should be read in conjunction with Drawing **YSI-URS-RW-01-DR-SE-0001**.

approximately 6.3 metres, with similar beams. There will be significant disruption to Dock Street during this construction work, with some disruption to the M2 also. A single night-time, complete closure of Dock Street shall be required for erection of the pre-stressed beams. Aside from this complete closure, careful phasing of the works, sheet piling and traffic management (including contraflows) may be used to ensure a minimum of one lane shall remain open in each direction at all other times.

4.2.8 ***Bridge BR-006 – Whitla Street Subway Extension***

The following summary should be read in conjunction with Drawing **YSI-URS-BR-06-DR-SE-0001**.

Currently the Whitla Street subway passes beneath the M2, providing pedestrian access between York Street and Nelson Street and Whitla Street. The proposed re-alignment of the M2 results in it widening at this location, requiring the subway to be extended. The subway also carries numerous services, including water, gas and electricity, buried between dividing walls, beneath the footpath of the subway.

It is proposed that the extension be made by continuing the piled reinforced concrete box structural form of the existing structure. Dowels shall be used to ensure a structural connection between the existing and new structures.

Disruption to the M2 during construction shall be minimised by sheet piling along the edge of the current M2 alignment, from a piling platform formed adjacent to Nelson Street using gabions or similar temporary works. Once the sheet piling is established, the existing retaining walls will need to be removed before constructing the new works.

4.2.9 ***Retaining Wall RW-001***

The following summary should be read in conjunction with Drawing **YSI-URS-RW-01-DR-SE-0001**.

Retaining wall RW-001 provides retention to the soil supporting the north side of the proposed widening of the Westlink as it approaches Bridge BR-001 from the west. The wall reaches 5.6 metres in height and is approximately 73 metres long.

Over the majority of its length, where it is sufficiently removed from the existing Westlink retaining walls, the proposed wall is a standard piled reinforced concrete cantilevered retaining wall. Wherever the new wall approaches the existing wall sheet piling will be required to

prevent undermining of the existing wall. This shall require the formation of a piling platform and closures to the pedestrian footpath at this location. Towards the east end of the wall, where it interfaces with bridge BR-001, the base geometry will be reversed so that its toe is larger than its heel. This allows the wall to be constructed without demolishing the existing wall. Sheet piling will be required at this location to avoid undermining the existing retaining wall

It is likely that the existing retaining walls will require demolition down to a level sufficient to allow the new Westlink alignment to pass over them without formation of hard-spots.

4.2.10 ***Retaining Wall RW-002***

Retaining wall RW-002 comprises the south-west wingwall to BR-001. Construction works associated with the wall are described on Drawings **YSI-URS-BR-01-DR-SE-00001** and **YSI-URS-BR-01-DR-SE-00002**.

4.2.11 ***Retaining Wall RW-004***

The following summary should be read in conjunction with Drawing **YSI-URS-RW-04-DR-SE-0001**.

Retaining wall RW-004 has two functions. Firstly it acts as an earth retaining wall, allowing for the differences in levels between diverging underpasses UP-001A and UP-002B; secondly, it acts as a continuation of the concrete safety barrier VCSB-001 as it approaches the divergence.

The proposed wall is a reinforced concrete piled retaining wall, designed to resist collision loading. It is approximately 40 metres long and up to 2 metres high.

There is potential for collision loading to be applied from either side. Consequently, it would be optimum from a structural efficiency perspective for the design to be symmetrical. However, an asymmetric design is proposed, so that the larger heel can be constructed under a lane occupation necessitated for the construction of the neighbouring underpasses. Sheet piling, combined with a modest toe, will minimise disruption to the other underpass which would remain open. The wall is tapered over the likely collision height to allow the design of the wall to be as for a concrete parapet, in accordance with TD19/06 and BS 6779.

4.2.12 ***Retaining Wall RW-005***

Retaining Wall RW-005 is a new section of wall joining the existing Great George's Street retaining wall to the southern retaining wall of UP-001B. The proposed structure will be a reinforced concrete cantilevered retaining wall on piled foundations, with a brickwork cope and facing to complement the appearance of the existing Great George's Street retaining wall.

4.2.13 ***Retaining Wall RW-006***

The following summary should be read in conjunction with Drawing **YSI-URS-RW-06-DR-SE-0001**.

At the junction between York Street (Link No. 11) and the M3 to York Street link (Link No. 7), the proposed road alignment is at a higher level than the existing road. This requires retaining walls to be formed, to allow existing properties to remain accessible. Retaining wall RW-006 bounds the south-east corner of the proposed junction. It is an approximately 64 metres long reinforced concrete cantilevered retaining wall on piled foundations, with a maximum height of about 3 metres. The wall carries a metal parapet and is designed to resist collision loading. The proposed wall will maintain the footpath giving access to the existing buildings along the

south-east corner of the junction. It is inevitable that there will be some disruption to access to these buildings and pedestrian access along these roads during construction works. In addition, there will be a requirement to close a single lane on both York Street and Great George's Street while the wall is constructed.

4.2.14 ***Retaining Wall RW-007***

The following summary should be read in conjunction with Drawing **YSI-URS-RW-07-DR-SE-0001**.

Retaining wall RW-007 retains the west side of the proposed York Street (Link No. 11) road alignment and part of the Westlink to York Street (Link No. 5). The wall starts from the end of the existing brick boundary wall to the rear of nos. 39-47 (odds) inclusive of Little George's Street and runs parallel to the York Street (Link No. 11) alignment until to a location near the revised access arrangement to Cityside Retail Park (Link No. 28).

The wall is a reinforced concrete cantilever retaining wall with piled foundations. It has a retained height of up to 5.1 metres, with an approximate length of 145 metres.

4.2.15 ***Retaining Wall RW-017***

The following summary should be read in conjunction with Drawing **YSI-URS-RW-17-DR-SE-0001**.

Retaining wall RW-017 retains the east side of the embankment carrying the link road between the M2 and Westlink (Link No. 2) on its southern departure from Bridge BR-004. Earthworks could have been used to reduce the height of the wall, but the full height walls were selected to maximise the level ground available at finished ground level for future development.

RW-017 is a reinforced concrete cantilevered retaining wall on piled foundations. It reaches a height of 8.4m, over a length of 117 metres. The wall is bound at its north end by Bridge BR-004 and at its south end by Underpass UP-001A. At the interface between RW-017 and UP-001A, the wall is detailed to provide flood water retention up to 3.9mAOD. This shall prevent water from entering the underpass in the event of a 1in 200 year coastal flood event. Ground strengthening shall be required beneath the embankment behind the retaining wall.

Reinforced soil walls were considered as an alternative form of construction. These were rejected due to Transport NI concerns regarding wash-out of soil during an extreme flooding event. Voided box solutions were also considered but not developed further, in favour of a more traditional solution. It may be economical to use lightweight aggregate to form the abutment. This will depend on the savings in piled ground strengthening compared to the cost of the aggregate.

4.2.16 ***Retaining Wall RW-018***

The following summary should be read in conjunction with Drawing **YSI-URS-RW-18-DR-SE-0001**.

Retaining wall RW-018 retains the west side of the embankment carrying the link road between the M2 and Westlink (Link No. 2) on its southern departure from Bridge BR-004. Earthworks could have been used to reduce the height of the wall, but the full height walls were selected to maximise the level ground available at finished ground level for future development.

RW-018 is a reinforced concrete cantilevered retaining wall on piled foundations. It reaches a height of 8.2m, over a length of 105 metres. The wall is bound at its north end by Bridge BR-004 and at its south end by Underpass UP-001A. At the interface between RW-018 and UP-001A, the wall is detailed to provide flood water retention up to 3.9mAOD. This shall prevent water from entering the underpass in the event of extreme flooding. Ground strengthening shall be required beneath the embankment behind the retaining wall.

Reinforced soil walls were considered as an alternative form of construction. They were rejected due to Transport NI concerns regarding wash-out of soil during an extreme flooding event. Voided box solutions were also considered but not developed further, in favour of a more traditional solution. It may be economical to use lightweight aggregate to form the abutment. This will depend on the savings in piled ground strengthening compared to the cost of the aggregate.

4.2.17 ***Retaining Wall RW-020***

The following summary should be read in conjunction with Drawing **YSI-URS-RW-20-DR-SE-0001**.

RW-020 has two functions. Firstly it provides earth retention to accommodate the difference in level between two neighbouring roads:

- the east-bound link between the Westlink and the M2 heading north
- the link between the north-bound York Street and the M2 heading north.

RW-020 also acts as a safety barrier between the two roads.

The wall is a reinforced concrete cantilever retaining wall, on piled foundations. It is approximately 155 metres long with a maximum height of roughly 4.5 metres.

The tapered geometry of the top of the wall allows it to be designed to be compliant with TD19/06 and BS 6779. Although collision loading can be applied from both sides, the wall is designed with its heel pointing North West. Although this is not the most structurally efficient arrangement in terms of resisting collision loads, which can be applied from either side, the selected geometry will minimise disruption to the existing slip road from York Street to the M2 during construction.

4.2.18 ***Retaining Wall RW-021***

The following summary should be read in conjunction with Drawing **YSI-URS-RW-21-DR-SE-0001**.

RW-021 provides retention to the proposed York Street (South) to M2 slip road (Link No. 15). It is a reinforced concrete cantilevered retaining wall on piled foundations. It interfaces with Bridge BR-005 at its northern end. The wall is approximately 130 metres long, typically 2-3 metres high, but rising to 6 metres where it ties into Bridge BR-005.

There is sufficient space to construct the wall with minimal disruption to the M2, apart from where it interfaces with Bridge BR-005. At Bridge BR-005 sheet piling is required to form the extension to the abutments. A minor extension to the sheet pile wall shall provide sufficient retention for the construction of retaining wall RW-021.

However, ground strengthening works may be required in this area, to support the widening of the embankment. The construction of the ground strengthening works may necessitate further sheet piling, possibly requiring more significant disruption to the M2.

4.2.19 ***Retaining Wall RW-022***

The following summary should be read in conjunction with Drawing **YSI-URS-RW-22-DR-SE-0001**.

RW-022 retains the proposed embankment supporting the M2 to Westlink and Duncrue Street to Westlink alignments (Link Nos. 2 and 31 respectively). It is adjacent to Nelson Street and passes beneath the northern span of Bridge BR-004, adjacent to the north abutment of the bridge.

RW-022 is a reinforced concrete cantilever retaining wall on piled foundations. It approaches 10 metres in height and is approximately 186 metres long. At the south end of RW-022, it curves beneath Bridge BR-004, in front of its north abutment. There is potential for a clash between the foundations of Bridge BR-004 and the foundations of RW-022 at this location that will require further consideration at detailed design stage.

At the north end of RW-022, the wall interfaces with underpass BR-006. The wall also gets closer to the existing M2 alignment. To form the northern end of the wall will require a lane occupation to the M2.

Disruption to the existing Nelson Street during construction shall be minimised by sheet piling as close as possible to the toe of the wall, without hampering construction, but there will be a reduction in available carriageway width.

Reinforced soil was considered as an economical alternative, but this was rejected due to Transport NI concerns regarding wash out under extreme flood conditions.

4.2.20 ***Retaining Wall RW-024***

The following summary should be read in conjunction with Drawing **YSI-URS-RW-24-DR-SE-0001**.

RW-024 retains the M2 (Link No. 2) and Duncrue Street to Westlink (Link No.31) alignments at the northern extent of the scheme. It requires approximately 100 metres of piled reinforced concrete cantilever retaining wall, with a retained height of up to 2.8 metres.

Sheet piling is required, coupled with a hard shoulder closure on the M2, to allow construction of the wall while minimising disruption to the M2. This will require a piling platform, but there is sufficient space between the M2 and Duncrue Street for this to be achieved without disruption to Duncrue Street.

4.2.21 ***Retaining Wall RW-025***

The following summary should be read in conjunction with Drawing **YSI-URS-RW-25-DR-SE-0001**.

RW-025 has two functions. It acts as a flood wall, preventing coastal flooding from entering the underpasses, and it also provides parapet edge protection to the proposed Dock Street to M3 alignment (Link No. 6) It is a reinforced concrete cantilever retaining wall formed on piled foundations. It will be constructed during a closure of Nelson Street, associated with its re-alignment, so there are no unusual construction challenges. The wall reaches a height of 5.1m, with a total length of 84.5 metres.

Where the stem of the wall extends above 3.9mAOD a metal parapet is proposed, to reduce collision loading. However, where the wall acts as a water retaining structure, clearly a solid

reinforced concrete flood wall is required, and this doubles as a reinforced concrete parapet, resisting collision loading.

4.2.22 ***Retaining Wall RW-026***

The following summary should be read in conjunction with Drawing **YSI-URS-RW-26-DR-SE-0001**.

RW-026 is located just south of Bridge BR-003 and acts as a flood wall, preventing coastal flooding entering the underpasses from its east side. It is a reinforced concrete cantilevered wall on piled foundations. The heel and toe switch sides to avoid the limit of land made available. Away from this limitation, the heel and toe are arranged to minimise lane occupation requirements. Where the retaining wall crosses Culvert CU-001, a horizontal structural stiffener is provided to transmit loads (particularly collision loads) across the culvert. A water-tight joint shall be provided between the culvert and the retaining wall.

The construction of this wall will require a single lane closure to the existing M3 on-slip, with sheet piles used to minimise the size of the closure. Sheet piling will also be required to ensure works remain within the limit of land made available.

4.2.23 ***Retaining Wall RW-027***

The following summary should be read in conjunction with Drawing **YSI-URS-RW-27-DR-SE-0001**.

Retaining wall RW-027 mirrors retaining wall RW-026, providing flood protection to the west side of the M3 on-slip, just south of Bridge BR-003. It crosses Culvert CU-001, and comes close to the planned strengthening works to one of the Lagan road bridge foundations.

The wall is a reinforced concrete cantilevered retaining wall on piled foundations. Where the retaining wall crosses Culvert CU-001, a horizontal structural stiffener is provided to transmit loads (particularly collision loads) across the culvert. A water-tight joint shall be provided between the culvert and the retaining wall.

The use of sheet piling during construction of this retaining wall will remove the need for closures to the Nelson Street to M3 south-bound slip road.

4.2.24 ***Retaining Wall RW-028***

The following summary should be read in conjunction with Drawing **YSI-URS-RW-28-DR-SE-0001**.

RW-028 retains the proposed raised York Street (Link No. 11) and Great George's Street (Link No. 17) road alignments at the junction between the two roads. The walls are of modest height, but are required to provide collision resistance, so are significant structures. The walls border the existing car park, which is to be retained. They reach a maximum height of approximately 2 metres, with a length of approximately 41 metres.

Where the walls have significant soil retention they are formed from reinforced concrete cantilevered retaining walls on piled foundations. Once the degree of retention is small, the structure changes to piled parapet ground beams, with their design primarily associated with resisting collision loading.

Due to the limited retained height relative to existing road levels, the walls can be constructed without lane occupations either to York Street or Great George's Street, provided this is done

before the road alignment is raised. Once the road alignment has been raised, they will clearly be retaining significantly more.

4.2.25 ***Retaining Wall RW-029***

The following summary should be read in conjunction with Drawing **YSI-URS-RW-29-DR-SE-0001**.

RW-029 retains the proposed embankment supporting the M2 to Westlink (Link No. 2), north of Bridge BR-006, adjacent to Nelson Street.

RW-029 is a reinforced concrete cantilever retaining wall on piled foundations. It approaches 6 metres in height and is approximately 80 metres long. At the south end of RW-029, it interfaces with underpass BR-006.

Construction of this wall will require modest occupations to the M2 and Nelson Street to allow installation of sheet piles, which are required to minimise disruption to traffic during construction.

4.2.26 ***Retaining Wall RW-030***

RW-030 is a proposed flood wall located to the nearside of the York Street (South) to M2 (Link No. 15) to prevent coastal flooding from entering Underpass UP-001A. The wall will be of modest height given projected flood levels at the location and so is anticipated to be a reinforced concrete cantilevered wall, similar to RW-026.

4.2.27 ***Retaining Walls RW-031 to RW-034***

Retaining walls RW-031 to RW-034 inclusive are proposed to limit the extents of proposed ground improvements at York Street. The walls will be of similar form to adjacent retaining walls and therefore are anticipated to be formed by reinforced concrete cantilevered walls on piled foundations.

4.2.28 ***Services Culvert CU-001***

This services culvert provides the main route for services to pass beneath the M3 on-slip from Nelson Street and the Westlink. It carries significant, gas, electric and telecommunications services.

Despite its simple structural form, this structure is possibly the most challenging in terms of construction, due to implications for the road network.

The structure is formed from three reinforced concrete boxes, formed from lightweight aggregate concrete, to facilitate lifting of the structures. The three boxes are placed side by side, with access manholes at both ends. Sumps are provided at the lower ends of the boxes to facilitate pumping out in the event of flooding. The boxes are founded on pile caps at either end, with the boxes spanning longitudinally between the pile caps – placing piles beneath the road will not be practical within the duration of the closures. Elastomeric bearings support the boxes on the pile caps during installation, to be grouted up once the road is reinstated.

The proposed construction sequence is detailed on the drawings provided in Appendix **. In summary, the foundations are off-line, and with the use of temporary works, can be constructed without disruption to the roads network. The boxes will also be constructed off-line at a suitable location for a high capacity mobile crane to lift them into position. There is sufficient space for construction of the boxes, and a high capacity mobile crane, North-East of the final location of the culvert. During the first night closure, the existing road will be

excavated with heavy plant. The three boxes will be lifted into position before temporary backfilling and re-instatement of the road surface. On the following night, another closure will be required to properly compact the backfill around the culverts and permanently reinstate the road surfacing.

4.2.29 ***Services Culvert CU-002***

In a similar manner to Culvert CU-001, an additional service corridor crossing is required at the M3 off-slip. It is proposed that the form of this crossing will take the form of one or several new culverts of a similar form and construction to CU-002.

4.2.30 ***Services Culverts CU-003 and CU-004***

Several services require diversion from York Street as part of the proposed works, to avoid the new diaphragm walls installed as part of the various underpasses. Given the number, complexity and lead-in times of such service diversions, it is proposed to undertake these service diversions at the onset of the contract, or potentially, as part of an advance works contract. As the contractor will then be required to construct the various ground improvements around the diverted services, there is a risk of accidental damage. Given the importance of the services to the surrounding areas, it is considered that this is not a risk that the service providers will be willing to accept unless a more pro-active form of protection is in place. Accordingly, it is proposed to construct a number of additional service culverts (CU-003 and CU-004) through which the diverted services will be routed, providing a more substantial form of protection. It is envisaged that these culverts will be of reinforced concrete construction, with precast sections expected to be promoted by the contractor to speed construction. The culverts will be constructed below existing ground level and are not anticipated to require their own piled foundations, subject to confirmation at detailed design stage. The culverts will then be covered by reinforced concrete slabs as part of the proposed ground improvements works as described in **Section 4.3.35**.

A typical section for the proposed culverts is included on Drawing **YSI-URS-XX-XX-DR-UT-0031**.

4.2.31 ***Variable Concrete Step Barrier VCSB-001***

The following summary should be read in conjunction with Drawing **YSI-URS-VC-01-DR-SE-0001**.

A variable (height) concrete safety barrier (VCSB) shall be provided in the central reserve of the Westlink, west of retaining wall RW-004, extending to the most westerly extent of the scheme, west of Bridge BR-001. The purpose of the structure is to prevent errant vehicles from crossing the central reserve, and also to accommodate very modest differences in road levels either side of the VCSB. It replaces the existing safety barrier which will not be compliant with modern codes.

These structures are formed directly on top of road make-up by specialist contractors. Constructing the VCSB shall require lane occupations to the Westlink in both directions.

4.2.32 ***Underpasses UP-001A, UP-001B, UP-002A and UP-002B***

The following summary should be read in conjunction with the following Drawings:

- **YSI-URS-UP-1A-DR-SE-00001**
- **YSI-URS-UP-GE-DR-SE-00001**
- **YSI-URS-UP-1B-DR-SE-00001**

- **YSI-URS-UP-2A-DR-SE-00001**
- **YSI-URS-UP-2B-DR-SE-00001.**

The link from the M2 to Westlink (Link No. 2) will be depressed below existing ground level and several existing and proposed road and rail bridges in Underpass UP-001A. In addition, the link from M3 to Westlink (Link No. 4) will be depressed below existing ground level and a number of existing and proposed bridges to meet with Underpass UP-001A at a position underneath BR-002A.

As noted previously, due to the constrained nature of the site and the proximity of existing and future bridge substructure, the structural form of Underpass UP-001A has been subject to specific assessment, as summarised in the report included for information in **Appendix B**

Owing to the constraints on cross-section and headroom, it is proposed to use low-headroom diaphragm walling to construct the part of UP-001A that passes underneath the Lagan Bridge and Dargan Bridge. Away from this identified pinch point, it is accepted that a future contractor has the option of exploring other forms of embedded retaining wall, however, it is considered that given the costs of mobilising such specialist plant from a typically overseas location, a contractor is likely to use diaphragm walling throughout the scheme, switching to full height diaphragm walling plant away from areas subject to headroom restrictions.

Accordingly, the proposed structural form for all underpasses is that of diaphragm walls as shown on the associated drawings, with an inner box or U-frame as appropriate. As shown on the drawings, tie-down piles may be required in a number of areas to pin down the underpass base slabs. An internal drainage membrane system is proposed to deal with any groundwater that may seep into the system, which will discharge into the main pumping station arrangement. A single pumping station is proposed to cater for stormwater run-off from all four underpasses. Underpasses UP-002A, UP-002B and UP-001B will drain by gravity into a single wet well adjoining Underpass UP-001A. This will require several crossings through the diaphragm walls by carrier drains, which require routes above the base slab within the watertight section of the underpass. Accordingly, the formation level of the base slab has been lowered to ensure that all road drainage is carried within the inner frame of the underpass, to provide a sealed drainage system. In order to protect the underpasses from coastal flooding, the above ground “stems” of the retaining walls shall be extended to a level of 3.9mAOD.

4.2.33 ***Lagan Bridge Foundation Strengthening FS-001***

Two of the piled foundations of the Lagan Bridge are close to the proposed diaphragm walls of underpass UP-001A. There is a concern that the new diaphragm walls could clash with the existing piles of the Lagan Bridge, potentially damaging them and compromising the code compliance of the Lagan Bridge. Calculations show that on the assumption that the existing Lagan Bridge piles were placed in accordance with standard tolerances, and the proposed diaphragm walls will also be constructed to tolerance, there would be 165mm of clearance assuming worst possible directions of out of tolerance etc. However, although unlikely, it is possible that the existing piles, and/or the new diaphragm walls, could be out of tolerance.

Bearing in mind the importance of the Lagan Bridge, it is recommended to remove the risk of the structural integrity of its foundations being compromised. This can be achieved by strengthening the Lagan Bridge foundations such that they remain code compliant in the event of the rows of piles closest to the diaphragm walls being rendered ineffective.

The proposed strengthening works comprise barrettes, or mini-piles, offset from the existing foundation piles, and the proposed diaphragm walls. These are joined by an inverted

reinforced concrete u-frame which partially encapsulates the existing foundation slab. Vertical load transfer is achieved by a combination of a modest nib and dowels fixed into the existing base acting in shear. The aggregate to the face of the existing pile cap will also be exposed to enhance interface shear resistance through concrete cohesion and granular interlock. The tendency for the strengthening works to open up, due to the eccentricity of the piles from the edge of the existing pile cap, is resisted both by u-frame action of the strengthening works, and dowels acting in direct tension.

A challenge associated with the strengthening works is that the proposed road alignment is not far above the existing foundations. As there is a requirement for the strengthening works to act as a u-frame above the existing pile cap, it is likely that there will be only 120mm of surfacing on top of the pile cap. This could present a hard spot in the new road alignment. To prevent this, run-on slab type geometry is proposed, combined with a slab spanning between the strengthening works and the underpass walls.

Clearly the strengthening works are required to be in place before construction of the sections of diaphragm walls close to the existing foundations. It is proposed that the strengthening works are undertaken during phase 3 of the Stage 2 temporary traffic management plan for Option C, but before the section of diaphragm walling close to the existing foundations is formed.

4.2.34 ***Strengthened Earthworks EB-001 and EB-002***

Works to widen the Westlink and BR-001 will require the side slopes on the existing Westlink embankments to be increased to remain within the existing land boundary. This places additional overburden on the existing embankment retaining walls at Little George's Street (EB-001) and Great George's Street (EB-002). Structural assessments of the construction of the existing walls have confirmed that these existing retaining walls would require replacement on this basis. Therefore, given the level of disruption such works would create on adjacent residential premises, alternative solutions were explored. Of the options considered, the option selected for both EB-001 and EB-002 is that of a reinforced soil solution, with slopes of up to 70 degrees, supported on an independent piled slab, such that the overburden of the embankment is carried on a separate structure, resulting in no additional increase in loading on the existing retaining walls.

A typical section for the proposed solution at EB-001 is included as Drawing **YSI-URS-XX-XX-DR-RE-EW201**.

In order to construct the reinforced soil solutions and associated piled slabs, it will be necessary to excavate parts of the existing embankment to form a platform of up to 5.5m width on each side. This will require temporary works as necessary, potentially in the form of sheet piling, to provide support to the remaining sections of embankment. From a review of the topography of the site, it would appear that such works can be carried out using lane closures on the Westlink north-bound and south-bound carriageways, however, this will require the temporary relocation, or reduction, in lane availability on the Westlink during construction.

4.2.35 ***Strengthened Earthworks EB-003 to EB-009***

Given the poor underlying ground conditions, the formation of the various embankments within the scheme presents significant challenges for settlement control in particular. To overcome this, it is proposed that a number of strengthened earthworks (EB-003 to EB-009) inclusive will be formed through the construction of load transfer platforms under areas of fill. It is proposed that such platforms will be formed through rigid inclusions (piles) driven or bored through the underlying strata. Load transfer slabs spanning between pile caps will then provide the necessary stable platform for embankment construction.

All areas of strengthened earthworks are expected to be of a similar form of construction, as illustrated for EB-003, EB-004 and EB-005 on Drawings **YSI-URS-XX-XX-DR-RE-EW101** and **YSI-URS-XX-XX-DR-RE-EW102** and for EB-007 on **YSI-URS-XX-XX-DR-RE-EW103**.

The works associated with construction of these transfer platforms will require access for piling and the construction of slabs in the vicinity of the existing York Street which will in turn require multiple temporary traffic management arrangements in a confined location, with the maintenance of the north-bound connection from York Street to York Road during the works presenting a significant challenge. As described in **Section 4.4.29**, it is proposed to construct a number of services culverts through several of the identified areas of strengthened earthworks to provide protection during construction of the load transfer platforms. This will in turn create challenges for the construction of the piles and slabs within the space available under temporary traffic management arrangements.

4.3 Service Diversions

The proposed Service Routes for the scheme are set out on Drawing No. **YSI-URS-XX-XX-DR-UT-00011**. The construction of underpasses for the proposed Westlink to M2 (Link No. 1), M2 to Westlink (Link No. 2), Westlink to M3 (Link No. 3) and M3 to Westlink (Link No. 4) interchange links would lead to existing services within York Street and Nelson Street being severed.

Service Routes A, B and C have been proposed to accommodate the temporary/permanent service diversions required within York Street (Link No. 11). Service Route A (Pink Corridor), located to the west of the proposed underpass walls, would comprise of a service corridor approximately 7.5m wide and would be used to house several significant utilities currently located within York Street including a BT 12-way and 355mm Ø trunk water main. It should be noted that BT have indicated that due to the significance of their apparatus in York Street, which includes fibre optic cables, York Street apparatus diversions could take 9 months to a year to complete.

Within Service Route A on the Westlink to York Street link (Link No. 5), a piled load transfer platform is proposed to support the associated embankment due to poor ground conditions within the area. It is proposed that the services in this corridor would be placed within concrete box culvert CU-003 to provide protection during piling operations, as shown in cross and long sections included on Drawings **YSI-URS-XX-XX-DR-UT-00031** and **YSI-URS-XX-XX-DR-UT-00038**.

Service Routes B (Purple Corridor) and C (Yellow Corridor) are available for additional ducting and may be used for permanent service diversions upon completion of the York Street overbridges. These routes may be incorporated into the York Street overbridges via ducting provision within the bridge structure or within the bridge deck.

Service Route D (Green Corridor) has been proposed to accommodate a link between Great George's Street (Link No. 17) and Dock Street (Link No. 10). This can accommodate, for example, any services within Nelson Street which may be severed by the proposed underpass diaphragm walls. Service Route D will comprise of a service corridor approximately 5m wide and will follow the alignment of the proposed access road to the drainage pumping station and continue north within Culvert CU-001 (2 No. box culverts and 1 No. pipe culvert) which will provide protection during the construction of Underpass (UP-001A). These diversions will tie in to the existing services at appropriate locations within the Dock Street area.

Service Route E (Peach Corridor) has been proposed to provide a link between Service Route A on York Street and Service Route D. Due to the proposed locations of structural foundations (walls and a piled embankment slab) and also owing to proposed changes in level and

alignment along the proposed Great George's Street, service diversions are also proposed in Culvert CU-004 including, for example those needed to accommodate a 600mm ø combined sewer and a 315mm ø MP (4 bar) gas main diversion.

Service Route F (Brown Corridor) has been proposed to accommodate service diversions required within Nelson St and Duncrue Street, north of Dock Street. This route includes the diversion of a 7 bar IP gas main, as well as the diversion of high voltage 110kV transmission electricity cables apparatus which currently is located within the Whitla Street underpass. NIE have indicated that the lead in times for ordering the specific 110kV cables required for the diversion are approximately 1 year. Protection of existing services will be required to facilitate the construction of the extension of the Whitla Street underpass (BR-006).

Existing services drawings are provided as Drawing Nos. **YSI-URS-XX-XX-DR-UT-00021** to **YSI-URS-XX-XX-DR-UT-00030** inclusive.

4.4 Road Drainage

The proposed drainage design for the scheme is set out on Drawing No. **47037827-DR-SK-028**.

It is proposed that where higher level road drainage outfall connections can be achieved and where it could prove difficult to connect these outfalls to the proposed pump station, connections to existing and proposed sewerage would be acceptable.

Due to the underpass elements of the scheme, which have finished levels well below the drainage outfall levels, a drainage pumping station will be required. The proposed catchment area which will drain to the pumping station has been further enlarged to facilitate an approach which seeks to maximise storm-water separation from the existing sewerage network, following consultations with the sewer network operator; NI Water. At this stage of the design it is proposed that the pumping station wet well and valve chambers will be housed within structures which will be formed integral with the diaphragm walls of UP-001A A preliminary suitable size of the pump station wet well has been established as shown on Drawing No **47037827-DR-SK-022**. The preliminary design is as follows:

- submersible type pumps to be located within the wet well.
- four pumps are to be provided; one low flow duty, one low flow assist, one high flow duty and one high flow assist pump
- the total output required with pumps operating in parallel is 970 l/s at an estimated total head of 18m.

A rising main outfall pipeline is proposed which will discharge storm-water entering the pumping station wet well, which emanates from the upstream road scheme catchment areas. The current design proposals are to connect this outfall to an abandoned combined sewer overflow (CSO) culvert which currently passes beneath Gamble Street. The design levels of this proposed rising main are at considerable depth below existing ground level in order to pass beneath existing constraints along its route as illustrated on Drawing Nos. **47037827-DR-SK-024** and **47037827-DR-SK-025**. Twin rising mains are required; a 350mm diameter main to be provided downstream of the low flow pumps and a 700mm diameter downstream of the high flow pumps. It is proposed that these will be accommodated within a single outer conduit of 1800mm diameter which will be formed using trenchless techniques such as pipe-jacking or micro-tunnelling. The proposed length of the rising mains are approx. 450 metres and a long section of their route is illustrated on Drawing No **47037827-DR-SK-027**. Three separate temporary chambers/structures will be required to enable significant changes in direction of the outer conduit to be constructed using trenchless techniques. It has

been envisaged within the design that these temporary chambers may be constructed using segmental shafts formed using precast concrete units by caisson method. Locations of temporary shafts, proposed sizes and approximate working areas are also shown on Drawing Nos. **47037827-DR-SK-024** and **47037827-DR-SK-025.**

The existing abandoned CSO (rectangular culvert size clear opening = 2.6m x 1.6m) is subject to regular tidal ingress (invert level at connection to Belfast Harbour = -0.805mAOD) and therefore construction of the pumping station connection structure to the CSO will need to take due cognisance of this constraint.