Appendix C5.05

Section 2
River Swilly Crossing: Structures Options Report

River Swilly Crossing: Structures Options Report

TEN-T Priority Route Improvement Project, Donegal

TT_MGT0337-RPS-P3-ZZ-RP-S-BR0004
River Swilly Crossing: Structures Options Report
S3 P02

March 2022

Structures Options Report - Consultation STA-1a

Category 3

SCHEME NAME

Name and location	Ten-T Priority Route Improvement Project - Donegal

STRUCTURES

Name and nature of the Structure:	River Swilly Crossing
Structures Options Report	
Reference:	TT_MGT0337-RPS-P3-ZZ-RP-S-BR0004
Revision:	P02
Date:	04-03-2022

SUBMITTED BY:

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EXECUTIVE SUMMARY

STRUCTURE

Name:	River Swilly Crossing
Structure Ref No:	N56R005
Primary Function:	To carry the new 56 Mainline over the River Swilly,
Check Category:	3
Loading:	IS EN 1991-2 – LM1, LM2, LM3 (SV196)

PASSAGES

Primary:	N56
Secondary:	River Swilly

RECOMMENDATION

The outcome of the River Swilly Structures Options Report indicates that a 3-span varying depth post-tensioned concrete box girder bridge (Option 1) is considered the preferred option. It is recommended that Option 1 is taken forward to preliminary design and planning stage as the preferred option.

ESTIMATED COST

The estimated construction cost of the bridge and approach embankment is approximately €28.41m excluding VAT (2021).

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1 INTRODUCTION

1.1 Consultant's Brief

In November 2016, Donegal County Council appointed joint venture RPS/Barry Transportation as design consultants for the Trans-European Network - Transportation (TEN-T) Priority Route Improvement Project, Donegal. The project is divided into three sections as illustrated in Figure 1-1.

Section 1 – N15/N13 Ballybofey / Stranorlar Urban Region

Section 2 – N56/N13 Letterkenny to Manorcunningham

Section 3 – N14 Manorcunningham to Lifford / Strabane / A5 Link.

The three sections of the TEN-T Priority Route Improvement Project, Donegal are considered as one project.

The project is being implemented in accordance with the Transport Infrastructure Ireland (TII) Project Management Guidelines (PMGs), January 2019; superseding the NRA's 2010 Project Management Guidelines (PE-PMG-02004) and September 2017 updates which were used on the project up until the publication of the January 2019 PMGs. In the context of this Option Selection Report the 2019 PMGs have minor differences from the 2010 PMGs.

This report will focus on Section 2 and will cover a new multi-span bridge crossing the River Swilly to facilitate the new route east of Letterkenny.

1.2 Background to the Scheme

Much of the TEN-T road network in Donegal does not meet the current design standards for a National Primary road in terms cross-section, horizontal and vertical alignments, junctions, overtaking opportunities, drainage, etc. Given the strategic importance of the N13, N14 and N15 routes to Donegal providing connectivity to the rest of the island, a study into the condition of the existing infrastructure was undertaken as part of the Trans-European Transport Network Corridor Needs Study, Donegal in 2015. This study reviewed the TEN-T network in Donegal, assessing the network against various technical, non-technical, economic, traffic and safety criteria. The assessment comprised a site visit, journey time surveys and a desktop study for all parts of the TEN-T network in the county, except the N15 from south of Ballybofey to the county boundary, as numerous upgrades of this section have been completed in recent times.

Six sections of the TEN-T network in Donegal were identified and ranked in order of intervention priority due to deficiencies in the existing infrastructure provision. Three sections requiring the most immediate intervention (see Figure 1-4) form part of the TEN-T Priority Route Improvement Project, Donegal:

1. The N15/N13 Ballybofey/Stranorlar Urban Region

2. The N56/N13 Letterkenny to Manorcunningham

3. The N14 Manorcunningham to Lifford/Strabane/A5 Link.

In addition to the fact these routes are strategic, nationally significant connections from Letterkenny/Donegal to the rest of the island, they also provide connectivity between key towns in County Donegal – Letterkenny, Ballybofey/Stranorlar and Lifford. Consequently, a high volume of traffic uses these routes, which has an impact on these towns. As a result, the towns suffer from issues such as congestion and a poor environment for vulnerable road users, while traffic suffers from longer journeys and poor journey time reliability.

The prioritisation of these three sections is also necessary to ensure the development of the county in line with the Donegal County Development Plan, which has long established a need for intervention at the three areas in question. Furthermore, the National Development Plan also recognises that work on these links are required. All three locations have had previous projects progressed to varying degrees and as a result, have reserved corridors for new routes in the County Development Plan.

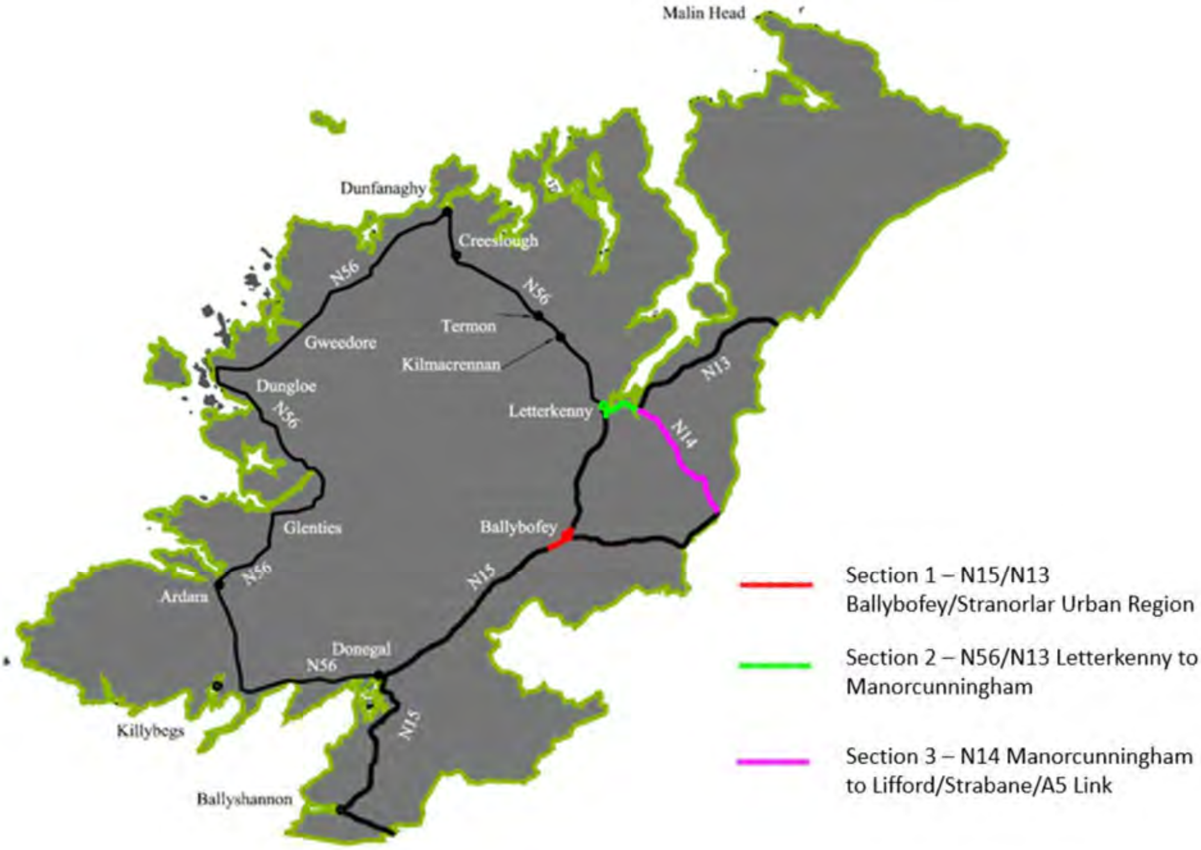


Figure 1-1: Donegal National Roads and Proposed Schemes

1.3 Previous Studies

Several reports and investigations have been previously carried out across the TEN-T network in Donegal. The fundamental reports are listed here:

- Constraints Studies – these outlined the constraints for the respective sections prior to identifying options:
  1. N14/N13 Junction (Manorcunningham) to Lifford Constraints Study; 2000; Mott MacDonald,
  2. N15 Ballybofey/Stranorlar Bypass Constraints Study (2000); McCarthy Hyder.

- Route Selection Reports – conclude with proposals for route options:
  1. N15 Ballybofey/Stranorlar Bypass Route Selection Report (2001); McCarthy Hyder,
  2. N14/N13 Junction (Manorcunningham) to Lifford Route Selection Report (2001); Mott MacDonald,
  3. N56 Letterkenny Relief Road Route Selection Report, (2010) Donegal County Council.

- Environmental Impact Statements:
  1. Environmental Impact Statement Ballybofey/Stranorlar Bypass (2007); McCarthy Hyder
  2. N14/N15 to A5 Link Environmental Impact Statement (2011).

- Other reports and assessments:
  1. N14 Four Lane Road at Letterkenny Feasibility Report Nov (2005); Michael Punch and Partners,
  2. Various Traffic Model Studies conducted by Jacobs,
  3. Traffic model reviews on the N14 conducted by RPS.

All three sections of the TEN-T Priority Route Improvement Project were previously advanced under separate projects to various stages of planning and design.

2 SITE LOCATION & CONSTRAINTS

There are a number of constraints to be considered in the study area, an overview of the constraints is presented below.

2.1 Site Location

The site of the proposed bridge is on the eastern side of Letterkenny town, Co. Donegal at the location where the proposed N56 Route crosses the River Swilly, see Figure 2-1. A structure's location map for Section 2 of the project is attached in Appendix 1. Each structure on the project has been assigned a structure reference based on the mainline carriageway route number, structure type (O for overbridge, R for river bridge etc) and chainage location, the Swilly Crossing's structure reference is therefore N56R005.

Figure 2-1: Site Location

2.2 Constraints

2.2.1 Proposed Alignment & Location

The proposed alignment and location of the new bridge is governed by the preferred option chosen at route selection stage and the location and path of the River Swilly.

2.2.2 River Swilly

The River Swilly provides a significant physical constraint due to the width of the watercourse. At the proposed crossing location the main channel width is approximately 49.4m and the depth from the channel bank to the river bed level is approximately 4.5m. The river is prone to flooding and there is a flood berm located on the southern bank at the proposed crossing location. The River Swilly is highly tidal in this area with the channel becoming quite shallow and faster flowing at low tide. The tidal nature of the proposed site would preclude floating bridge construction methods and material transportation via the river.

Figure 2-2: River Swilly

2.2.3 Land Requirements

The land on the east and west banks of the river are privately owned and it is intended to progress the scheme by means of Compulsory Purchase Order (CPO). The land to the east is primarily low-lying agricultural land, susceptible to flooding with deep alluvial deposits. The land on the western approach is higher and has had various uses, is currently a scrambler track. The tie-in to the existing national N56 route is located approximately 400m from the bridge crossing.

2.3 Environmental Constraints

2.3.1 River Swilly SAC

The primary environmental constraint at this location is the River Swilly which is designated part of the Lough Swilly Special Area of Conservation (SAC) (Site Code: 002287) and Special Protection Area (SPA) (Site Code: 004075), see Figure 2-3.

The lower reaches and estuarine element of the River Swilly and surrounding flood plains are designated under the Lough Swilly SAC which is designated for the following qualifying interests; Estuaries [1130], Coastal lagoons [1150], Atlantic salt meadows [1330], Old sessile oak woods with *Ilex* and *Blechnum* in the British Isles [91A0] and the Annex II species Otter (1355). The Lough Swilly SAC is designated for the following five qualifying features:

- Estuaries [1130]
- *Coastal lagoons [1150] (*priority habitat)
- Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*) [1330]
- Old sessile oak woods with *Ilex* and *Blechnum* in the British Isles [91A0]
- *Lutra lutra* (Otter) [1355]

Otter is a qualifying interest of the Lough Swilly SAC and may be found throughout the watercourses within the study area. The extent of otter habitat, in addition to the aquatic habitat, comprises a 10m riparian buffer (both banks). Therefore, watercourses and their riparian zone connected to the River Swilly within the study area are considered to provide potential habitat for otter.

The Lough Swilly SPA is designated for the following special conservation interests:

- Great Crested Grebe (*Podiceps cristatus*) [A005]
- Grey Heron (*Ardea cinerea*) [A028]

- Whooper Swan (*Cygnus cygnus*) [A038]
- Greylag Goose (*Anser anser*) [A043]
- Shelduck (*Tadorna tadorna*) [A048]
- Wigeon (*Anas penelope*) [A050]
- Teal (*Anas crecca*) [A052]
- Mallard (*Anas platyrhynchos*) [A053]
- Shoveler (*Anas clypeata*) [A056]
- Scaup (*Aythya marila*) [A062]
- Goldeneye (*Bucephala clangula*) [A067]
- Red-breasted Merganser (*Mergus serrator*) [A069]
- Coot (*Fulica atra*) [A125]
- Oystercatcher (*Haematopus ostralegus*) [A130]
- Knot (*Calidris canutus*) [A143]
- Dunlin (*Calidris alpina*) [A149]
- Curlew (*Numenius arquata*) [A160]
- Redshank (*Tringa totanus*) [A162]
- Greenshank (*Tringa nebularia*) [A164]
- Black-headed Gull (*Larus* (*Chroicocephalus ridibundus*) [A179]
- Common Gull (*Larus canus*) [A182]
- Sandwich Tern (*Sterna sandvicensis*) [A191]
- Common Tern (*Sterna hirundo*) [A193]
- Greenland White-fronted Goose (*Anser albifrons flavirostris*) [A395], and
- Wetland and Waterbirds [A999]

The Lough Swilly SPA is downstream of the proposed bridge crossing however it is within the flight path of commuting birds such as black headed gull and curlew upstream in the estuary outside of the SPA. The bridge structure may increase disturbance and interfere with natural flight lines/fly ways of SPA bird species thereby creating a barrier effect.

Greater lengths of embankment within floodplain, has potential for greater impact on the hydrological regime of the River Swilly Estuary and the structure and function of the SAC/SPA. Consequently, careful consideration of the environmental impact of the scheme shall be required particularly on birds, habitats, otter and hydrological functioning.

Figure 2-3: Lough Swilly SAC at Letterkenny

2.4 Archaeological and Cultural Heritage

A number of areas of high archaeological potential were identified following a review of the local topography, recorded archaeological records and locational data, historic cartographic sources and aerial mapping which was supplemented by observations in the field. These areas of high archaeological potential have been identified at 3 no. locations and have been abbreviated as Section 2 Area of Archaeological Potential_01 to 03 (S2-AAP01 to S2-AAP03). S2-AAP01 incorporates the proposed Swilly crossing location.

This area comprises the location for the offline relief road option proposed to service Letterkenny town at Ballyraine linked to the Port Road (N56) and N13. It consists of the estuarine lands associated with the River Swilly, the river itself, and associated banks. There is a site of a recorded ringfort DG53-026--- 'White Fort' on the northern banks of the river, as the ground begins to rise, as well as the location of a Battle site in the general northerly environs at this point (DG053-056---). Given the recorded archaeological resource as well as the attractive nature of the riverine environment for past human use and the potential for the presence of underwater archaeology, this area is deemed to be of high archaeological potential.

2.5 Landscape and Visual Impacts

The existing environment of the study area associated with Section 2 includes land between Connaghan's Bridge to the east, Trimragh to the north, Listellian to the south and the urban form of Letterkenny to the north-west. The landscape associated with the Section 2 study area and wider environs is dominated by the wide valley system associated with the River Swilly estuary and its adjacent floodplains. More elevated land to the south of the existing N13 road corridor and to the north and west of Letterkenny provides a sense of enclosure to the flat, estuarine landscape.

Overall it is considered that the landscape within the study area is of a medium sensitivity. Whilst much of the study area may be designated as High Sensitive Area, the landscape is heavily influenced by existing road networks, industrial built form and residential development such that the landscape has the capacity to accommodate a degree of change.

2.6 External Constraints & Design Parameters

2.6.1 Design Parameters – Geometric

The bridge will carry a Type 2 dual carriageway with a shared pedestrian/cycle facility in the verge over the River Swilly.

2.6.2 Design Parameters – Structural

The proposed structure shall be designed in accordance with Eurocodes and the TII Design Manual for Roads and Bridges (DMRB), which specify a design life of 120 years It will be designed for live loading in accordance with IS EN 1991-2, load models LM1 and LM3 (SV196). A structures Preliminary Design Report (PDR) will be prepared in accordance with TII DN-STR-03001 where all the relevant design parameters will be listed.

As the proposed structure will form a pedestrian link, the parapet height shall be a minimum of 1.25m high in accordance with TII DMRB requirements.

2.6.3 Stakeholders

There are a number of stakeholders to consider as part of the scheme. Stakeholders to the project include:

- TII as the funding body and the agency responsible for future maintenance of the structure.
- Donegal County Council as the asset owner and one of the bodies responsible for delivering the bridge.
- Office of Public Works – responsible for the hydraulic impact of the structure.

- Inland Fisheries Ireland and the National Parks and Wildlife Service for protection of the aquatic and terrestrial environments.
- Service providers with utilities in the vicinity (see section 2.5.5)
- Owner of the lands on each bank.

2.6.4 Utilities

The exact nature and location of buried services will be confirmed during site investigation works. There are several known utilities in the vicinity of the bridge:

- 110kv ESB overhead transmission line crossing the river to the west of the proposed crossing location
- 600mm gravity sewer along the northwest bank of the River Swilly
- Buried Eir Services.
- Buried watermain.

2.6.5 Hydraulic Constraints

The new structure will introduce the potential for a new hydraulic constraint in the river channel. The existing channel is very wide and the downstream tidal boundary 1:100-year flood level (1% AEP) is 3.43mOD. Joint probability of fluvial and coastal flooding scenarios is a consideration in Letterkenny due to the downstream tidal reach. It is important to determine whether the fluvial dominated or coastal dominated scenario is more extreme as well as determining the impact of the proposed development on the two scenarios. The 1:200 design event (0.5% AEP) was used in the modelling due to the tidal flooding mechanism, the downstream boundary condition for this scenario was peak of 3.52mOD. In this scenario, the water spills over the main channel into the overbanks and the water width is 82.1m, the depth of water at the crossing location during this event is 5.6m.

OPW recommends a minimum 300mm freeboard above the 100 year (1% AEP) level to the soffit of any new structure. All flood levels quoted include a 20% allowance for climate change as per OPW guidelines.

3 OPTIONS FOR PROPOSED CROSSING

Options for the crossing were developed by RPS Consulting Engineers considering the various constraints outlined in detail in Section 2 of this report.

3.1 Structural Forms Considered

In considering what the preferred solution may comprise, a variety of structural forms for the Swilly Crossing were considered in an initial scoping exercise with several of them being discounted for a number of reasons:

- A multi-span steel twin ladder deck or constant depth steel box girders with the main span launched from the south of the river to the north. Temporary intermediate supports to facilitate the launching operation would not be possible within the River Swilly and SAC. The main span of 104m was considered too long for launching without intermediate supports.

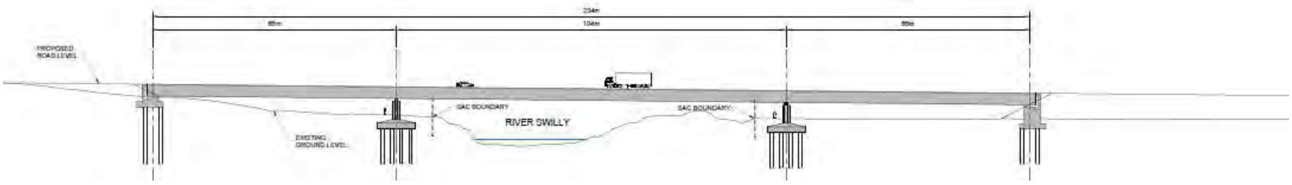


Figure 3-1: Launched ladder deck option

- A three-span varying depth steel multi-girder arrangement which would be lifted into position by crane was also considered. The length of the main span over the River Swilly was considered too long for this option to be viable.

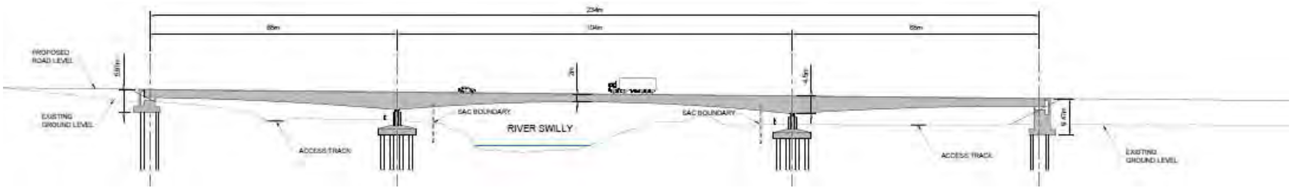


Figure 3-2: Craned multi-girder option

3.2 Viable Options

Following the initial scoping exercise, the following six options are proposed for further consideration:

- Option 1: 3-span varying depth post-tensioned concrete box girder,
- Option 2: 3-span varying depth steel box girders with steel orthotropic deck,
- Option 3: 5-span varying depth post-tensioned concrete box girder,
- Option 4: 9-span varying depth post-tensioned concrete box girder,
- Option 5: 2-span cable stayed steel plate girder,
- Option 6: Single-span varying depth post-tensioned concrete box girder.

General arrangement drawings of each option are included in Appendix 1.

3.2.1 Option 1 – 3-span varying depth post-tensioned concrete box girder

Option 1 is a 3-span concrete box girder. The girder depth varies from 5.3m at the intermediate supports to 2.3m away from the supports. This option achieves good symmetry and aesthetics and it would be similar in appearance to the Harry Blaney Bridge spanning Mulroy Bay in Co. Donegal. The span arrangement is 65m, 104m, 65m, giving a total length of 234m. The bridge consists of an in-situ, post tensioned concrete box girder structure, constructed via balanced cantilever method. The substructure consists of cast in-situ reinforced concrete piers and abutments supported by bored pile foundations. A significant construction site will be required to cater for the specialist balanced cantilever construction methodology of the varying depth spans and the traditional construction of the approach spans.

3.2.2 Option 2 – 3-span varying depth steel box girders with steel orthotropic deck

Option 2 has a similar span arrangement and substructure to Option 1. The superstructure is comprised of twin steel box girders with a steel orthotropic deck. This option is a similar structure to the Foyle Bridge in Co. Derry. The steel section would be lifted into position by a large crane. The girder depth varies from 4.5m at the supports to 2m away from the supports.

3.2.3 Option 3 – 5-span varying depth post-tensioned concrete box girder

Option 3 is similar to Option 1 with additional constant depth spans to the south over the floodplain. The 5-span arrangement is 65m, 104m, 65m, 65m, 65m giving a total length of 364m. The mains spans would again be constructed vis balanced cantilever method with the additional backspans being constructed by conventional methods. The viability and potential benefits of extending the structure is to reduce the potential flood risk of constructing approach embankments across the flood plain and also to make up for a fill material deficit in Section 2 of the project.

3.2.4 Option 4 – 9-span varying depth post-tensioned concrete box girder

Option 4 is an extension of option 3 with a 9-span arrangement of 65m, 104m, 65m, 65m, 65m, 55m, 55m, 55m, 55 giving a total length of 584m. Again the viability and potential benefits of extending the structure is to reduce the potential flood risk of constructing approach embankments across the flood plain and also to make up for the fill material deficit in Section 2 of the project.

3.2.5 Option 5 – 2-span cable stayed steel plate girder

This option comprises a single pylon cable stayed structure. The main span is 176m long and the overall length is 228.5m. The deck comprises two 2.5m longitudinal steel plate girders with intermediate transverse girders supporting an insitu reinforced concrete slab. The pylon foundation would require a significant piled foundation. This option would be highly visual and visible with a pylon which stands 90m high above the adjacent landscape. Landmark structures of this scale are not commonplace in Ireland.

3.2.6 Option 6: Single-span varying depth post-tensioned concrete box girder

Option 6 is effectively a single span bridge with a total length of 174m. The main length of this is a 104m main span with a varying depth multi cell post-tensioned concrete box. At either end of this main span is an extended sub structure which includes both pier and abutment. This substructure acts as a short end span with two foundations, a primary piled foundation under the pier and a shallow foundation with rock anchors under the abutment. The rock anchors would counteract the potential effect of abutment uplift associated with very short end spans on multi-span bridges.

4 TECHNICAL EVALUATION

4.1 Option 1 – 3-span varying depth post-tensioned concrete box girder

4.1.1 Option 1 – Advantages

This option provides a technical solution to satisfy the constraints outlined in Section 2 and all the requirements of the brief.

The span arrangement provides good overall symmetry and a structurally efficient ratio of back span to main span of 0.625 is achieved.

The varying depth girder means a reduced depth of structure at the midspan regions giving a more open aspect, improving aesthetics and structural efficiency and increasing clearance to the River Swilly.

The concrete deck structure means little to no maintenance requirements compared to a painted steel or cable stayed option.

4.1.2 Option 1 – Disadvantages

Balanced cantilever construction is a significant construction operation and is extremely specialised and not an everyday form of construction. Post tensioned concrete is also not a commonly used form of construction in Ireland so a very skilled and experienced Contractor will be required, most likely with international experience of similar forms of construction.

Construction of the side spans beyond the balanced cantilevers will most likely require conventional ground supported falsework as these cannot be constructed by cantilever methods.

The intermediate pier foundation locations are in proximity to the SAC on both sides of the river. Temporary works may be required to ensure excavations for the foundations do not encroach on the SAC.

4.2 Option 2 – 3-span varying depth steel box girders with steel orthotropic deck

4.2.1 Option 2 – Advantages

This option provides a technical solution to satisfy the constraints outlined in Section 2 and all the requirements of the brief.

The span arrangement provides good overall symmetry and a structurally efficient ratio of back span to main span of 0.625 is achieved.

The varying depth girder mean a reduced depth of structure at the midspan regions giving a more open aspect, improving aesthetics and structural efficiency and increasing clearance to the River Swilly.

The construction methodology of lifting the box girders in by crane is relatively well understood compared to the construction methodologies of the other options.

4.2.2 Option 2 – Disadvantages

The use of orthotropic steel decks is not commonplace in Ireland. The fabrications of the deck and varying depth steel boxes would also be complex and would have significant cost implications.

A very large crane will be required to allow the central sections of the main span over the River Swilly to be lifted into position without temporary intermediate supports. The crane would require multiple set up locations to lift in each of the approach spans.

As weathering steel is not suitable for use near marine environments the steel box girders and steel orthotropic deck would be fabricated from painted steel which means that maintenance painting will be required over the lifetime of the structure. The painted steel would require nominal maintenance over the first 20 years after which maintenance painting of the steel work will be required. It is expected that full repainting will be required after 25-30 years. This is a significant disadvantage as it would incur substantial additional maintenance costs but also increase the ongoing maintenance works required within the SAC.

The intermediate pier foundation locations are in proximity to the SAC on both sides of the river. Temporary works may be required to ensure excavations for the foundations do not encroach on the SAC.

4.3 Option 3 – 5-span varying depth post-tensioned concrete box girder

4.3.1 Option 3 – Advantages

This option provides a technical solution to satisfy the constraints outlined in Section 2 and all the requirements of the brief.

The span arrangement provides reasonable overall symmetry and a structurally efficient ratio of secondary span to main span of 0.625 is achieved.

The varying depth girder mean a reduced depth of structure at the midspan regions giving a more open aspect, improving aesthetics and structural efficiency and increasing clearance to the River Swilly.

The concrete deck structure means little to no maintenance requirements compared to a painted steel or cable stayed option .

The additional back spans reduce the amount of approach embankment fill required and may reduce potential flood risk associated with constructing embankments across the flood plain.

4.3.2 Option 3 – Disadvantages

Balanced cantilever construction is a significant construction operation and is extremely specialised and not an everyday form of construction. Post tensioned concrete is also not a commonly used form of construction in Ireland so a very skilled and experienced Contractor will be required, most likely with international experience of similar forms of construction.

Construction of the side spans beyond the balanced cantilevers and additional approach spans to the south will most likely require conventional ground supported falsework as these cannot be constructed by cantilever methods. This extension of the bridge to the south will have knock on effects on both construction costs and duration.

The intermediate pier foundation locations are in proximity to the SAC on both sides of the river. Temporary works may be required to ensure excavations for the foundations do not encroach on the SAC.

4.4 Option 4 – 9-span varying depth post-tensioned concrete box girder

4.4.1 Option 4 – Advantages

This option provides a technical solution to satisfy the constraints outlined in Section 2 and all the requirements of the brief.

The span arrangement provides a structurally efficient ratio of secondary span to main span of 0.625 is achieved.

The varying depth girder mean a reduced depth of structure at the midspan regions giving a more open aspect, improving aesthetics and structural efficiency and increasing clearance to the River Swilly.

The concrete deck structure means little to no maintenance requirements compared to a painted steel or cable stayed option .

Similar to Option 3 the additional back spans reduce the amount of approach embankment fill required and may reduce potential flood risk associated with constructing embankments across the flood plain.

4.4.2 Option 4 – Disadvantages

Balanced cantilever construction is a significant construction operation and is extremely specialised and not an everyday form of construction. Post tensioned concrete is also not a commonly used form of construction in Ireland so a very skilled and experienced Contractor will be required, most likely with international experience of similar forms of construction.

Construction of the side spans beyond the balanced cantilevers and additional approach spans to the south will most likely require conventional ground supported falsework as these cannot be constructed by cantilever methods. This further extension of the bridge to the south will have knock on effects on both construction costs and duration.

The intermediate pier foundation locations are in proximity to the SAC on both sides of the river. Temporary works may be required to ensure excavations for the foundations do not encroach on the SAC.

4.5 Option 5 – 2-span cable stayed steel plate girder

4.5.1 Option 5 – Advantages

An advantage of this option is the introduction of an iconic landmark structure into the landscape which can help to enhance the road user experience while also providing Letterkenny with a strong visual identifier that can be used to promote increased interest and tourism in the area.

Another advantage of this option is that the bridge footprint is moved further away from the SAC during construction and in the permanent case compared to the other multi-span options.

4.5.2 Option 5 – Disadvantages

There are several disadvantages associated with this form of bridge. The complexity in the design and construction would require highly skilled specialist consultants and contractors most likely with international experience of similar forms of design and construction.

The pylon of this bridge would require significant piled foundations. The increased scale of both the bridge superstructure and foundations and earthworks required for this bridge would have obvious knock-on effects on the expected cost and duration of the construction works and therefore the environmental impacts associated with the construction stage.

There will be increased inspection and maintenance requirements associated with monitoring and maintaining the cables on this form of bridge therefore increasing the whole life costs of the structure. Bearing and expansion joint maintenance and replacement will also be required like the other options. As weathering steel is not suitable for use near marine environments the steel girders of Option 5 would be fabricated from painted steel which means that maintenance painting will be required over the lifetime of the structure. This will be a challenging task due to the scale of the structure and the works being undertaken over the SAC and River Swilly.

High-level landmark bridges of this nature will generally be designed to have additional lighting along the cable and up lighting of the pylons. The high-level pylons, cables and lighting have potential negative impact on local wildlife and bird flight paths. They will also have highly negative impacts visually for local landowners.

4.6 Option 6 – Single-span varying depth post-tensioned concrete box girder

4.6.1 Option 6 – Advantages

This option provides a technical solution to satisfy the constraints outlined in Section 2 and all the requirements of the brief.

The varying depth girder mean a reduced depth of structure at the midspan regions giving a more open aspect, improving aesthetics and structural efficiency and increasing clearance to the River Swilly.

The concrete deck structure means little to no maintenance requirements compared to a painted steel or cable stayed option .

The primary advantage of this options is that it offers the shortest structure possible to span the River Swilly at the proposed crossing location.

4.6.2 Option 6 – Disadvantages

Option 6 is based on the M4 Liffey Bridge (Eirspan Structure ID KE-M04-037.10 & .20). This is not a typical bridge arrangement in Ireland. The atypical details of this structure add to the complexity of the design and construction. Although considered a single span option the substructures on either side of the River Swilly will effectively act as a back-span. There is difficulty and complexity in the construction of both the cantilever “main” span and the substructure/”backspans” as outlined in the following paragraphs.

Cantilever construction is a significant construction operation and is extremely specialised and not an everyday form of construction. Post tensioned concrete is also not a commonly used form of construction in Ireland so a very skilled and experienced Contractor will be required, most likely with international experience of similar forms of construction.

Ground anchor beams will connect the heads of the rock anchors at each abutment. Tie beams will join the piers and abutments. Movement joints will be located at each abutment. The main structural bearings will be located on the pile caps at the piers with additional sliding bearings under the ground anchor beams at the abutments.

The substructure locations are in proximity to the SAC on both sides of the river. Temporary works may be required to ensure excavations for the foundations do not encroach on the SAC.

The single span option will block riverbank access more than the other multi-span options this could impact otter movement. It also extends the length of embankment of embankment construction within the flood plain of the SAC compared to the other options. This increases the risk of impacts to water quality, flow regimes and potential wash through of the working zone if flooding was to occur during construction.

Option 6 restricts access to both sides so additional culverts for flood water conveyance would possibly be required.

Construction of access underpass box structures will also be required beyond the abutments to facilitate the access tracks required for bridge maintenance and emergency vehicle access. These tracks will pass through the backspans of the other options. The abutment underpasses will also be used by landowners for access and would be open to the public. Anti-social activity is often associated with box-underpass structures of this nature in or near urban areas.

4.7 Summary

The options being considered as viable for the Swilly Crossing are similar from a technical perspective, with the exception of Options 5, with associated advantages and disadvantages for each. It is likely that flood modelling of the various options, construction methodology and associated environmental impact, aesthetics and cost will dictate the preferred option.

5 ECONOMIC EVALUATION

5.1 Construction Costs

A summary of the estimated costs of each option is outlined below in Table 5-1. Further details are given in Appendix 3.

In considering the economic evaluation of the proposed options, it is also prudent to consider the out-turn cost certainty. The scale of the bridges proposed means some cost-uncertainty is associated with each of the options. It is also necessary to compare the estimated costs of constructing the approach embankments required from chainage 400 to chainage 1000 as these will vary significantly for the various bridge arrangements being considered.

Options 1, 3 and 4 have medium cost certainty due to the scale of the proposed bridges and the highly specialist nature of the balanced cantilever construction method.

Option 2 has medium cost certainty due to the unfamiliarity in the use of orthotropic steel decks and the potential difficulties with the material availability and fabrication of the varying depth steel boxes.

Options 5 has low cost certainty due to the scale of the bridge and the highly specialist nature of the cable stayed bridge construction.

Option 6 also has low cost certainty due to the atypical arrangement of the substructure and complex form of construction.

Table 5-1: Bridge Options Construction Cost Estimates

Option	Estimated Cost Ex. Vat for bridge construction	Out-turn Cost Certainty	Estimated Cost Ex. Vat for approach embankment	Total construction cost estimate
1: 3-span varying depth post-tensioned concrete box girder	€28.09m	Medium	€323k	€28.41m
2: 3-span varying depth steel box girders with steel orthotropic deck	€29.09m	Medium	€323k	€29.41m
3: 5-span varying depth post-tensioned concrete box girder	€43.71m	Medium	€235k	€43.95m
4: 9-span varying depth post-tensioned concrete box girder	€70.12m	Medium	0	€70.12m
5: 2-span cable stayed steel plate girder	€42.60m	Low	€331k	€42.93m
6: Single-span varying depth post-tensioned concrete box girder	€25.12m	Low	€411k	€25.53m

It should be noted that the above cost estimates are construction costs only, and do not include other scheme costs such as design, supervision, land acquisition, client costs etc. A significant increase in cost estimates across all options is seen when compared to earlier versions of this report. Following receipt of TII's comments on the original report and arising from recent significant fluctuations in market rates, inflation and cost increases during and exiting the COVID-19 pandemic a detailed exercise was undertaken to assess previous construction cost estimates. This included:

- Discussions with contractors, material suppliers and fabricators,
- A high-level breakdown of materials for each option,
- A review of recent tender prices received on large scale bridge projects.

RPS is satisfied that the construction cost estimates presented in Table 14-1 accurately represent today's construction cost.

The primary potential benefits of Options 3 and 4 were to reduce the potential flood risk of constructing approach embankments across the flood plain and an associated reduction in cost of constructing the shortened approach embankments given the fill material deficit in Section 2 of the project. Table 5-1 outlines that the reduction in construction cost of the shortened embankment in Options 3 and 4 is negligible in comparison to the overall costs of the bridge options construction. The viability of these options will therefore be dictated by the flood modelling and other associated environmental impacts.

5.2 Whole Life Costs

The whole life costs associated with routine maintenance, deck resurfacing and replacement of damaged parapets will be similar for all six options. Each option would have variations in their whole life costs associated with maintenance of other elements.

The whole life cost of Options 1, 3, 4 and 6 are favourable as the concrete superstructure will require less maintenance compared to the painted steel options.

As weathering steel is not suitable for use near marine environments the steel box girders and steel orthotropic deck of Option 2 would be fabricated from painted steel which means that maintenance painting will be required over the lifetime of the structure. The painted steel would require nominal maintenance over the first 20 years after which maintenance painting of the steel work will be required. It is expected that full repainting will be required after 25-30 years. This would incur significant costs.

Inspection of all box girder options and of the pylon of Option 5 would require internal inspection via confined space access into the interior of the boxes/pylon. Therefore, specialist access equipment would be needed to complete an interior inspection. Special access for exterior inspections which would be similar for all options.

Each option would have a different number of movement joints and bearings that would require inspection, maintenance and replacement over the lifetime. The post-tensioned concrete box options would be integral at the pier to the south of the river with two bearings at each of the remaining supports, the other options will have bearings at each support. The number of bearings at each option are as follows; Option 1 would have two bearings at three support (6 in total), whereas Option 2 would require four bearings at each support (16 in total); Option 3 would have two bearings at five support (10 in total), Option 4 would two bearings at nine support (18 in total). Option 5 will have two bearings at each support (6 in total). Option 6 will have 4 bearings at both piers and 4 at both abutments (16 in total), these bearings will require voids for access.

There will be increased inspection and maintenance requirements associated with monitoring and maintaining the cables on Option 5 therefore increasing the whole life costs of the structure significantly making it the least favourable. Similar to Option 2 as weathering steel is not suitable for use near marine environments the steel plate girders of Option 5 would be fabricated from painted steel which means that maintenance painting will be required over the lifetime of the structure. The painted steel would require nominal maintenance over the first 20 years after which maintenance painting of the steel work will be required. It is expected that full repainting will be required after 25-30 years. This would incur significant costs.

Option 1 is the most favourable in terms of whole life costs due to the scale and/or complexity of maintaining the other options.

6 AESTHETIC EVALUATION

The six bridge options considered are in steel or concrete. With the exception of Option 5, each option has taken an understated approach to the detailing. A visualisation model carried out by RPS will confirm the full landscape and visual assessment and visual impact of the new proposed bridge option as part of the Environmental Assessment of the scheme.

6.1 Option 1 – 3-span varying depth post-tensioned concrete box girder

Option 1 consists of 3 spans of varying depths. Structurally efficient and architecturally pleasing ratios of backspans to main span of 0.625 are achieved and the structure has excellent symmetry.

The bridge deck's varying depth arched profile offers a pleasing elevation aesthetic on both the main and back spans while the bridge achieves the required clearances to the SAC and River Swilly. The depth of structure combined with the low vertical alignment results in a limited aspect ratio with the structure appearing heavy and close to the ground. Transverse deck cantilevers will overhang and shadow the main structural members, somewhat disguising the structural depth of the bridge, giving a slimmer, less intrusive appearance in elevation.

A concrete box girder offers clean lines and is known to be aesthetically pleasing when viewed from close by or from underneath with no fussy details on display and a consistency of materials across the girder, deck slab and substructure.

6.2 Option 2 – 3-span varying depth steel box girders with steel orthotropic deck

Option 2 consists of 3 spans of varying depths. Structurally efficient and architecturally pleasing ratios of backspans to main span of 0.625 are achieved and the structure has excellent symmetry.

The bridge deck's varying depth arched profile offers a pleasing elevation aesthetic on both the main and back spans while the bridge achieves the required clearances to the SAC and River Swilly. The depth of structure combined with the low vertical alignment results in a limited aspect ratio with the structure appearing heavy and close to the ground. Transverse deck cantilevers will overhang and shadow the main structural members, somewhat disguising the structural depth of the bridge, giving a slimmer, less intrusive appearance in elevation.

The twin painted steel box girders offer relatively clean lines and an aesthetically pleasing when viewed from close by or from underneath.

6.3 Option 3 – 5-span varying depth post-tensioned concrete box girder

Option 3 consists of 3 spans of varying depths and 2 constant depth approach spans. The varying depth spans achieve good aesthetics while the bridge achieves the required clearances to the SAC and River Swilly.

Structurally efficient and architecturally pleasing ratios of secondary spans to main span of 0.625 are achieved. The additional spans to the south make this option long and less symmetrical than Options 1 and 2.

The depth of structure combined with the low vertical alignment results in a limited aspect ratio with the structure appearing heavy and close to the ground at the 3 main spans. Transverse deck cantilevers will overhang and shadow the main structural members, somewhat disguising the structural depth of the bridge, giving a slimmer, less intrusive appearance in elevation. The additional southern backspans reduce the amount of embankment fill within the flood plain giving an overall more open aspect.

A concrete box girder offers clean lines and is known to be aesthetically pleasing when viewed from close by or from underneath with no fussy details on display and a consistency of materials across the girder, deck slab and substructure.

6.4 Option 4 – 9-span varying depth post-tensioned concrete box girder

Option 4 consists of 3 spans of varying depths and 5 constant depth approach spans. The varying depth spans achieve good aesthetics while the bridge achieves the required clearances to the SAC and River Swilly.

Structurally efficient and architecturally pleasing ratios of secondary spans to main span of 0.625 are achieved. The additional spans to the south make this option extremely long with little symmetry.

The depth of structure combined with the low vertical alignment results in a limited aspect ratio with the structure appearing heavy and close to the ground at the 3 main spans. Transverse deck cantilevers will overhang and shadow the main structural members, somewhat disguising the structural depth of the bridge, giving a slimmer, less intrusive appearance in elevation. The additional southern backspans reduce the amount of embankment fill within the flood plain giving the overall most open aspect of all the options.

A concrete box girder offers clean lines and is known to be aesthetically pleasing when viewed from close by or from underneath with no fussy details on display and a consistency of materials across the girder, deck slab and substructure.

6.5 Option 5 – 2-span cable stayed steel plate girder

An advantage of this option is the introduction of an iconic landmark structure into the landscape which can help to enhance the road user experience while also providing Letterkenny with a strong visual identifier that can be used to promote increased interest and tourism in the area.

An asymmetrical single pylon cable-stayed bridge with main span of 176m and reinforced concrete A-frame pylon would be visually striking. The superstructure could be clad in a GRP enclosure to improve aesthetics by offering simplicity and consistency of materials across the soffit of the bridge.

High-level landmark bridges of this nature will generally be designed to have additional lighting along the cable and up lighting of the pylons. The high-level pylons, cables and lighting have potential negative impact on local wildlife and bird flight paths. They will also have highly negative impacts visually for local landowners particularly at the northern end of the crossing where they would be in close proximity to the high-level pylon.

6.6 Option 6 – Single-span varying depth post-tensioned concrete box girder

Option 6 consists of a primary varying depth span. The appearance of such a long single span gives the structure a striking appearance with excellent symmetry. The bridge deck's varying depth arched profile offers a pleasing elevation aesthetic while the bridge achieves the required clearances to the SAC and River Swilly.

The depth of structure combined with the low vertical alignment results in a limited aspect ratio. Transverse deck cantilevers will overhang and shadow the main structural members, somewhat disguising the structural depth of the bridge, giving a slimmer, less intrusive appearance in elevation. The shorter structure means the approach embankments are extended thus creating a less open appearance compared to the other options.

A concrete box girder offers clean lines and is known to be aesthetically pleasing when viewed from close by or from underneath with no fussy details on display and a consistency of materials across the girder, deck slab and substructure.

6.7 Summary

Although aesthetics can be regarded as somewhat subjective, this is not the case when it comes to symmetry and slenderness of the structure in midspan regions. Therefore, it is clear that symmetrical and varying depth options are more aesthetically pleasing. The clean lines of a box girder are also desirable for locations such as the Swilly Crossing where there are close up views of the structure from the underside.

Consultation with TII on previous schemes has confirmed that a curved soffit or varying depth girder is preferred for multi-span bridges of this scale.

Therefore, it can be concluded that the symmetry and varying depth soffit of Option 1 has a clear aesthetic advantage over the other options. Option 2 would also be an aesthetically pleasing option with a similar arrangement to Option 1 however the twin box and more complex details of the deck soffit are seen as slightly less desirable compared to the single concrete box. Option 3 and 4 have similar details to Option 1 but are less desirable as they are very long structures with less symmetry although do offer the most open aspect across the flood plain of all the options. The main span aesthetics of Option 6 are satisfactory and similar to Option 1, however the closed in appearance of the extended approach embankments make it less desirable.

Option 5 has the potential to be an iconic landmark structure which would be aesthetically pleasing however the proposed crossing location is not considered suitable for such a high level, large structure.

7 DURABILITY AND MAINTENANCE

A summary of the maintenance considerations for each option is outlined in Table 7-1.

Table 7-1: Maintenance Considerations

Option	Maintenance Considerations
Option 1: 3-span varying depth post-tensioned concrete box girder	The exposed concrete faces of Option 1 will require nominal maintenance over its entire lifespan. Concrete is recognised as being a durable material with little maintenance required. Specialist access equipment is required to access the box girder internal cells to facilitate future inspection and maintenance. Other elements such as deck surfacing will need maintenance and replacement after 20 years. Bridge bearings and movement joints will need to be inspected and maintained regularly and replaced after 50 and 20 years respectively. This option has 6 bearings in total that will need inspection, maintenance and replacement. To facilitate these works permanent access will be required to the piers and abutments.
Option 2: 3-span varying depth steel box girders with steel orthotropic deck,	As weathering steel is not suitable for use near marine environments the steel box girders and steel orthotropic deck of Option 2 would be fabricated from painted steel which means that maintenance painting will be required over the lifetime of the structure. The painted steel would require nominal maintenance over the first 20 years after which maintenance painting of the steel work will be required. It is expected that full repainting will be required after 25-30 years. Specialist access equipment is required to access the box girder internal cells to facilitate future inspection and maintenance. Other elements such as deck surfacing will need maintenance and replacement after 20 years. Bridge bearings and movement joints will need to be inspected and maintained regularly and replaced after 50 and 20 years respectively. This option has 16 bearings in total that will need inspection, maintenance and replacement. To facilitate these works permanent access will be required to the piers and abutments.
Option 3: 5-span varying depth post-tensioned concrete box girder	The exposed concrete faces of Option 3 will require nominal maintenance over its entire lifespan. Concrete is recognised as being a durable material with little maintenance required. Specialist access equipment is required to access the box girder internal cells to facilitate future inspection and maintenance. Other elements such as deck surfacing will need maintenance and replacement after 20 years. Bridge bearings and movement joints will need to be inspected and maintained regularly and replaced after 50 and 20 years respectively. This option has 10 bearings in total that will need inspection, maintenance and replacement. To facilitate these works permanent access will be required to the piers and abutments.
Option 4: 9-span varying depth post-tensioned concrete box girder	The exposed concrete faces of Option 4 will require nominal maintenance over its entire lifespan. Concrete is recognised as being a durable material with little maintenance required. Specialist access equipment is required to access the box girder internal cells to facilitate future inspection and maintenance. Other elements such as deck surfacing will need maintenance and replacement after 20 years. Bridge bearings and movement joints will need to be inspected and maintained regularly and replaced after 50 and 20 years respectively. This option has 18 bearings in total that will need inspection, maintenance and replacement. To facilitate these works permanent access will be required to the piers and abutments.

Option 5: 2-span cable stayed steel plate girder.	As weathering steel is not suitable for use near marine environments the steel girders of Option 5 would be fabricated from painted steel which means that maintenance painting will be required over the lifetime of the structure. The painted steel would require nominal maintenance over the first 20 years after which maintenance painting of the steel work will be required. It is expected that full repainting will be required after 25-30 years. There will be increased inspection and maintenance requirements associated with monitoring and maintaining the cables. Specialist access equipment and personnel will be required for this and to access the interior of the pylon to facilitate future inspection and maintenance. Other elements such as deck surfacing will need maintenance and replacement after 20 years. Bridge bearings and movement joints will need to be inspected and maintained regularly and replaced after 50 and 20 years respectively. This option has 6 bearings in total that will need inspection, maintenance and replacement. To facilitate these works permanent access will be required to the piers and abutments.
Option 6: Single -span varying depth post-tensioned concrete box girder	The exposed concrete faces of Option 6 will require nominal maintenance over its entire lifespan. Concrete is recognised as being a durable material with little maintenance required. Specialist access through the voided sub-structure is required to access the box girder internal cells to facilitate future inspection and maintenance. Other elements such as deck surfacing will need maintenance and replacement after 20 years. Bridge bearings and movement joints will need to be inspected and maintained regularly and replaced after 50 and 20 years respectively. This option has 16 bearings in total that will need inspection, maintenance and replacement. To facilitate these works permanent voids and confined space access will be required to the piers and abutments.

8 HYDRAULIC CONSIDERATIONS

Flood modelling was undertaken considering a coastal event of 0.5% AEP combined with a fluvial event of 50% AEP in order to produce a joint return period of 0.5% AEP for a coastal dominated scenario. Conversely, a fluvial event of 1% AEP was combined with a coastal event of 50% AEP for a joint return period of 1% AEP for a fluvial dominated scenario. It was apparent that the 0.5%AEP coastal dominant event was more extreme than the 1.0%AEP fluvial dominant and so was brought forward to the flood impact study.

The flood extents output by the model showed an increase in inundated flood areas from the existing to proposed scenarios. Flood mitigation is proposed for the scheme in the form of flood relief culverts and flood compensation areas.

Flood compensation areas are proposed in order to increase flood volume storage locally. The flood compensation areas have been reduced to 1.0mOD (between 500mm and 1600mm deeper than existing ground level) and together they provide approximately 28,000m^3 of storage. Two flood relief culverts are proposed for the flood plain on the southern approach to the crossing location. These culverts would be required for bridge Options 1, 2, 5 and 6. Option 3 would only require the southernmost culvert while Option 4 would require neither due to the extended bridge lengths for these options.

The model outputs indicate that the flood compensation areas and culverts effectively mitigate the impacts of the proposed route alignment on flood impact locally. The modelling also confirms that with the mitigation in place the Swilly Crossing will introduce a negligible hydraulic constraint into the River Swilly channel. There is therefore little preference between the various proposed bridge options from a hydraulic/flooding impact point of view. The options do not include a footprint within the river and all options maintain additional setback to the river channel on both banks. All six options achieve suitable clearance to the River Swilly.

Temporary flood mitigation measures may be required during construction to protect the hardstanding working areas from flooding as well as control dewatering and run-off during all stages of construction to avoid direct discharge to the river. This may include the construction of temporary bunds around the edges of hardstanding areas, geotextile layers installed beneath hardstanding areas as well as measures such as settling ponds to treat water to remove suspended solids prior to controlled discharge to the river. These measures would be required during the entire construction stage of the bridge.

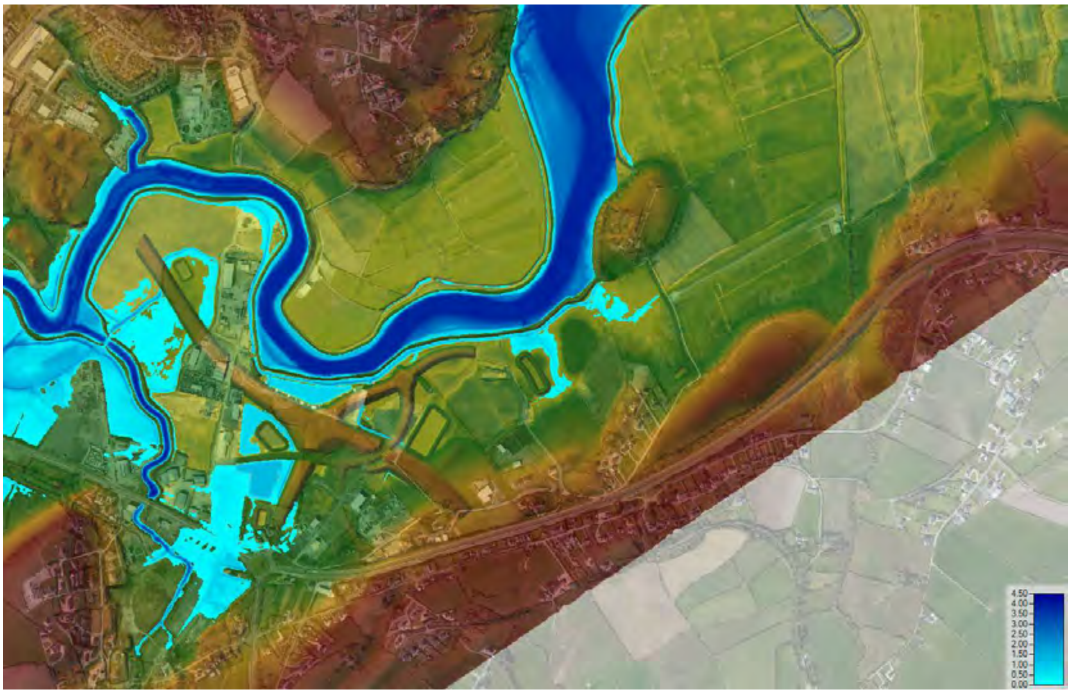


Figure 8-1: Proposed Scenario Model with Flood Mitigation

9 ENVIRONMENTAL EVALUATION

As the location of the proposed development is within the Lough Swilly SAC and upstream of the Lough Swilly SPA, there is potential for adverse environmental impacts with all options, particularly during the construction phase. These impacts will need to be fully mitigated in order to reach a conclusion of “no adverse effect” at Stage 2 (Natura Impact Statement) of the Appropriate Assessment. It should also be noted that in-stream works will not be required or permitted for any of the proposed bridge options. The construction footprint of the bridge needs to be viewed collectively with the construction footprint of the temporary and permanent drainage infrastructure which will also be located adjacent to the SAC/SPA; which includes proposed discharge into the Swilly Estuary.

A summary of the environmental preference ranking for each option is outlined in **Table 9-1**.

Table 9-1: Environmental Considerations

Name	Feedback	Option 1 Rating	Option 2 Rating	Option 3 Rating	Option 4 Rating	Option 5 Rating	Options 6 Rating
Population and Human Health	There are no residential properties in the vicinity of the crossing so there is no existing local resident population which could be potentially directly affected. The potential direct impact of all options on local resident population is equally nil for all. For the wider population of Letterkenny and beyond all six bridge options will provide equally for route connections / travel demands. There are existing working populations / local businesses at each side of the river crossing. All six bridge options and the adjoining road have similar landtake requirements on both sides of the river. It would appear from the information provided however that any differences would be minor, and accordingly there would be very little difference in direct impact on businesses. The duration of construction of the bridge and associated traffic travelling through neighbouring residential / business areas has potential to cause inconvenience and impact on established amenities. These are impacted by the nature of the construction and in particular with volumes of fill required for embankments affecting associated traffic numbers. On this basis Option 1 would have a medium construction duration (27mths) with likely relatively high construction traffic; Option 2 would have low-medium duration (24mths) and high construction traffic; Option 3 would likely be medium - high duration (32mths) and comparatively lower traffic; Option 4 the highest duration (38mths) but with lower construction traffic; Option 5 medium duration (30ths) and relatively high traffic; and Option 6 would have the shortest construction duration (21mts) but potentially highest levels of construction traffic given the scale of embankment. The bridge will also be used by visitors to the area including tourist traffic. All options will provide the same level of connectivity for visitor / tourist traffic. Having the most visually striking design, Option 5 has greater potential to act as a landmark structure to visitors and tourists in particular, but also to the local resident population of Letterkenny.	intermediate (4th)	intermediate (3rd)	Intermediate (5th)	Least preferred (6th)	Preferred (1st)	Intermediate (2nd)

Name	Feedback	Option 1 Rating	Option 2 Rating	Option 3 Rating	Option 4 Rating	Option 5 Rating	Options 6 Rating
	Overall, the operational impacts of the various options on population are similar for all six options, with the potential for option 5 to deliver a landmark structure having a slightly more positive potential impact than the other options. Thereafter the construction impacts do give rise to a distinct order of preference, with shorter options being preference even though it may have high levels of traffic within that period.						
Biodiversity (Terrestrial)	Option 1 & Option 2: Greater lengths of embankment within floodplain, therefore greater potential for barrier effects to local wildlife and species listed as part of the Lough Swilly SAC/SPA. Option 3 and Option 4: During the construction stage, freespan bridge construction activities have the greater potential for pollutants to enter the Swilly and will take longer than embankment construction, with potentially greater disturbance to wildlife. However, at operational stage as freespan structures present less of a barrier to the movement of wildlife. Option 4: has the least amount of embankment within the flood plain therefore less of a barrier to movement of wildlife. Option 5 (Cablestay): Close proximity to Lough Swilly SPA and within the flightpaths of commuting birds such as black headed gull and curlew upstream in the estuary outside of the SPA. Likely to increase disturbance and interfere with natural flight lines/fly ways of SCI bird species thereby creating a barrier effect. Option 6: This option has the greatest extent of embankment within the floodplain, in combination with the post tensioned box structure, has the potential to cause the greatest barrier to the movements of otter.	Intermediate (3rd)	Intermediate (3rd)	Intermediate (2nd)	Preferred (1st)	Least preferred (5th)	Least preferred (4th)
Biodiversity (Aquatic)	Option 1 & Option 2: Greater lengths of infill (grade embankment) within floodplain, therefore greater potential for sediment export to Lough Swilly SAC/SPA during construction. Infill on floodplain represents negative impact on hydromorphology through alteration of floodplain function, although culverts through the embankment will	Intermediate (3rd)	Intermediate (3rd)	Preferred (1st)	Intermediate (2nd)	Intermediate (4th)	Least preferred (5th)

Name	Feedback	Option 1 Rating	Option 2 Rating	Option 3 Rating	Option 4 Rating	Option 5 Rating	Options 6 Rating
	mitigate (in an already very modified environment). No difference between these options. Option 3 and Option 4: Infill (grade embankment) is set back on TR by 195m & 350m, respectively. It is noted that freespan bridge construction activities have greater potential for pollutants to enter the Swilly and take longer than construction from the embanked infill. However, at operational stage, infill on floodplain technically represents negative impact on hydromorphology through alteration of floodplain function. Option 4 with least amount of infill on the flood plain technically has least potential for hydromorphology impact, although embankment culverts mitigate floodplain function effects, so this is less of a consideration. Option 5 (Cable stay): Close proximity of infill/embankment and large concrete pours close to Lough Swilly SAC, with elevated risk of pollutant export during construction, plus hydromorphological impact during operation. Option 6: This option has the greatest extent of infill within the floodplain, in combination with the post tensioned box structure involving large concrete pours near the SAC channel and greatest impact on hydromorphology.						
Land and Soils	The feedback is based on length of earthworks	intermediate (3rd)	Intermediate (3rd)	intermediate (2nd)	Preferred (1st)	intermediate (4th)	least preferred (5th)
Air and Climate	Pilling is a carbon-intensive process, so any design option that could minimise the need for piling would be beneficial. Embankments are preferrable, particularly if they can be constructed using site-won material (minimise transport distances for importing fill to site, etc.). However, it's hard to be specific as a lot could depend on whether the bridge design uses low-carbon concrete mix, precast v. in situ columns, use of steel (steel manufacturing is energy intensive) so a lot of variables. Many of these won't be known until a contractor is appointed and has selected their suppliers.	n/p	n/p	n/p	n/p	n/p	n/p

Name	Feedback	Option 1 Rating	Option 2 Rating	Option 3 Rating	Option 4 Rating	Option 5 Rating	Options 6 Rating
	In general, embankment wins over pilling, assuming both designs require similar amounts of materials and construction efforts otherwise. Too many variables in the design to assign a clear preference until detailed design. All will have similar construction stage impacts (slight variations depending on materials and methods required).						
Noise	In each case the road/bridge are in the same location so operational phase noise is not a differential. Construction noise can impact significantly on residential and commercial premises. The nearest residences are at Thorndale north of the proposed bridge and Ballyraine Park and Orchard Grove on the western side of the N56. Commercial premises include The Mount Errigal Hotel, Rossan College and the Ballyraine Park Health Centre, where patients may be visiting for treatment during the day and the Donegal ETB Training centre with workshops and classrooms. These commercial premises will have a degree of noise sensitivity. Construction such as piling for the bridge foundations are likely to be the most disruptive activity and could continue intermittently for an extended period of months. Any option that lessens piling works will be preferred. As the sensitive receptors are on the west bank of the river this is the critical consideration from a noise point of view. From the drawings it is not specified which will require more piling west of the river. Options 1, 2, 3 and 4 appear around equal, Option 5 looks to be more extensive and option 6 appears to have a single support. The preferences are indicated on this basis but are not strong arguments in favour of or against any option as the construction activity will be for a finite period with no long-term impacts.	Intermediate (2nd)	Intermediate (2nd)	Intermediate (2nd)	Intermediate (2nd)	Least preferred (3rd)	Preferred (1st)
Material Assets (Agriculture)	The less landtake the better	n/p	n/p	n/p	n/p	n/p	n/p

Name	Feedback	Option 1 Rating	Option 2 Rating	Option 3 Rating	Option 4 Rating	Option 5 Rating	Options 6 Rating
Material Assets (Non-Agriculture)	The less landtake the better - all appear to be similar, however. Utilities should be able to be moved to allow for bridge construction. No preference.	n/p	n/p	n/p	n/p	n/p	n/p
Cultural Heritage	The road alignment footprint and tie-in layout to the west riverbank is the same for all options, save Option 6 where the main alignment is in closer proximity to the river bank. The western bank area is adjacent to a recorded ringfort DG053-026--- ('White Fort') which appears to have been removed or heavily disturbed/modified by the existing dirt bike track on the site. Any potential impact on sub-surface archaeology is the same for all options (save for Option 6 - greater footprint) and so there is no preference in that regard. All options are clear span and the River Swilly bed will not be impacted – therefore there are no underwater archaeological impacts and so there are no preferences based on this. The bridging options tie-in/cross the Bunagee and 'Milk Isle' area – there are no recorded archaeological or built heritage items located at this area. However the proximity to the river, the fording point at the Port Bridge area to the west, and its accessibility provided out to the lough beyond at the east/northeast, would have been favourable and it is deemed an area of archaeological potential in this regard. There are references to a brick works at Milk Isle in the Schools Folklore Collection but this is not indicated on any of the historic maps. As such any overall preferences come down to overall road alignment footprint extent on the east side of the bridge span connections, and those with least footprint (and therefore least ground disturbance during construction) would be considered more favourable.	Least preferred (4th)	Least preferred (4th)	Less Preferred (2nd)	Preferred (1st)	Least Preferred (3rd)	Least preferred (5th)

Name	Feedback	Option 1 Rating	Option 2 Rating	Option 3 Rating	Option 4 Rating	Option 5 Rating	Options 6 Rating
Landscape & Visual	Option 1 (Post tensioned Box Girder): Reduced 'floating road' element (234m total length) with increased embankment when compared with Option 3 or Option 4 within the valley landscape. Embankments can be greened to provide 'fit' Decking depths slightly increased when compared with Option 2 – 'thicker' bridge. Option 2 (Box Girder / Orthotropis Steel deck): Reduced 'floating road' element (234m total length) with increased embankment when compared with Option 3 or Option 4 within the valley landscape. Embankments can be greened to provide 'fit'. Decking depths reduced slightly when compared with Option 1. Option 3 (Post tensioned Box Girder): Increased 'floating road' element when compared with Option 1, Option 2 and Option 3. Perceived visual block created by floating road element across valley landscape. Reduced embankments – though these can be greened to provide fit Option 4 (Post tensioned box girder): Increased 'floating road' element (584m total length) when compared with Option 1, Option 2, Option 3 and Option 6. Option 5 (Cable Stay): Could be viewed as a positive development / identified as a new gateway feature e.g. similar to the 'Dry Arch' roundabout or the Boyne Bridge on M1 south between Belfast and Dublin. Option 6 (Post tensioned Box): Visible extent of bridge deck reduced – (104m total length). Embankments can be 'greened' to reduce visible impact.	Intermediate (3rd)	Preferred (2nd)	Intermediate (3rd)	Least preferred (4th)	Least preferred (5th)	Preferred (1st)
	Overall	**3rd**	**2nd**	**1st**	**1st**	**5th**	**4th**

10 HEALTH & SAFETY CONSIDERATIONS

10.1 Traffic Management During Construction

All of the options will be constructed offline from the current existing alignment of the N14 and N56 so traffic management requirements for the bridge construction will be minimal.

10.2 Safety During Construction

In-stream works are not required or permitted for any of the proposed options.

All options will require access to the land to the north and south of the River Swilly during the construction stage, works platforms in these areas will be the responsibility of the Contractor/PSCS.

All options require piled foundations, which limits the size of excavations needed for foundations. Piling operations and construction of pile caps will be constructed from constructed areas of hardstanding.

In addition to the general obligations and duties under the Safety, Health and Welfare at Work Act 2005, the consultant carrying out the detailed design of the proposed crossing will also undertake the duties of Project Supervisor Design Process (PSDP) and prepare a Preliminary Safety & Health Plan for the works. The works will also be designed taking account of the principles of prevention.

It is envisaged that the appointed contractor will be experienced in bridge construction and will be appointed Project Supervisor Construction Stage (PSCS) for the duration of the works.

10.3 Safety in Use

All options are currently shown with minimum 1.25m high vehicle and pedestrian parapets. These systems have been widely used and climbing can be prevented by providing an inward incline on the parapet posts.

Inspection of the bridge superstructure can be undertaken safely from the bridge itself, from the ground below the bridge and from the river using boat access when required. Inspection of abutments and bearings can be undertaken from ground level and appropriate access for inspection will be provided in the design.

The likely significant maintenance operations required during the life span of the bridge will vary depending on the chosen option. These are summarised in Section 7. The primary maintenance operation for each option will be the replacement of expansion joints and bearings. Each maintenance operation required are commonplace in the industry and management of the related health and safety issues is well understood.

11 CONSTRUCTION & BUILDABILITY

All options considered are readily constructible by a contractor suitably experienced in bridge construction of this scale and form. No issues have been identified that would not be inherent in comparable bridge schemes completed elsewhere in Ireland or the UK.

Each option will require bored pile foundations down to rock meaning a large piling rig and crawler crane will require access to both sides of the river. Areas of hardstanding will be required throughout the proposed bridge location to facilitate the piling process and will need to be maintained throughout the construction stage. Conventional construction of the reinforced concrete substructure will also require plant such as concrete lorries and pumps to operate throughout the site on both sides of the river. Construction time has been accounted for in the following sections for the additional approach embankments that would be required for the various options.

11.1 Option 1 - 3-span varying depth post-tensioned concrete box girder

Balanced cantilever construction is a significant construction operation and is extremely specialised. Post tensioned concrete is also not a commonly used form of construction in Ireland so a very skilled and experienced Contractor will be required, most likely with international experience of similar forms of construction.

Construction of the side spans beyond the balanced cantilevers will most likely require conventional ground supported falsework as these cannot be constructed by cantilever methods.

The intermediate pier foundation locations are in proximity to the SAC, temporary works may be required to ensure excavations for the foundations do not encroach on the setback zones.

In total Option 1 will take approximately 24 months to construct.

11.2 Option 2 - 3-span varying depth steel box girders with steel orthotropic deck

Option 2 will be lifted into place in sections by crane. A very large crane will be required to allow the central sections of the main span over the River Swilly to be lifted into position without temporary intermediate supports. Multiple crane set ups would be required to lift in the various sections, the areas of hardstanding would need to be extended to facilitate the crane set ups and girder assembly. A smaller crane could be used to lift in the northern and southern end span sections.

It is likely that some intermediate temporary supports will be required (outside of the SAC) during the lifting operation, to support one end of the pier sections prior to lifting in the central sections.

Although a very large crane will be required, this is a relatively well understood construction methodology. However the size of the steel boxes along with the length of the main span due to the width of the river and SAC at the proposed crossing location, will require a complex and difficult lifting operation. Consideration was given to whether the sections could be lifted up from below from a barge or pontoon/jetty however although the Swilly may be "navigable" for barges to pass on high tides the area is highly tidal with the channel becoming quite shallow and faster flowing at low tide so unsuitable for a barge to remain in place for a duration of work. Similarly a moored/anchored pontoon adhered to the tidal mud flats as tides fill and recede would not be acceptable to the NPWS and so was not considered further.

The intermediate pier foundation locations are in proximity to the SAC, temporary works may be required to ensure excavations for the foundations do not encroach on the setback zones.

In total Option 2 will take approximately 24 further months to construct.

11.3 Option 3 - 5-span varying depth post-tensioned concrete box girder

Balanced cantilever construction is a significant construction operation and is extremely specialised. Post tensioned concrete is also not a commonly used form of construction in Ireland so a very skilled and experienced Contractor will be required, most likely with international experience of similar forms of construction.

Construction of the side spans beyond the balanced cantilevers will most likely require conventional ground supported falsework as these cannot be constructed by cantilever methods.

The main span intermediate pier foundation locations are in proximity to the SAC, temporary works may be required to ensure excavations for the foundations do not encroach on the setback zones.

In total Option 3 will take approximately 32 months to construct.

11.4 Option 4 - 9-span varying depth post-tensioned concrete box girder

Balanced cantilever construction is a significant construction operation and is extremely specialised. Post tensioned concrete is also not a commonly used form of construction in Ireland so a very skilled and experienced Contractor will be required, most likely with international experience of similar forms of construction.

Construction of the side spans beyond the balanced cantilevers will most likely require conventional ground supported falsework as these cannot be constructed by cantilever methods.

The main span intermediate pier foundation locations are in proximity to the SAC, temporary works may be required to ensure excavations for the foundations do not encroach on the setback zones.

In total Option 4 will take approximately 38 months to construct.

11.5 Option 5 - 2-span cable stayed steel plate girder

This option would require a combination of complex construction methodologies. The main pylon would require significant piled foundations far greater than any of the other options. The reinforced concrete A-frame pylon would be constructed via travelling/climbing formwork. The main span could be assembled to the north of the northern abutment and launched across the river to its final position. Temporary cable stays connected to the pylon would facilitate the launching operation.

To further reduce the potential impact on the SAC and SPA during the construction stage of Option 5 it could be a specific contract requirement that, following steel superstructure installation, the reinforced concrete deck is constructed over the river completely from on top of the bridge rather than from the ground. This could be done with precast or in-situ concrete and would involve starting at the ends of the bridge and lifting or pouring one section at a time, allowing it to come up to sufficient strength before moving further along to repeat the process. This will add significantly to the programme but could be done from north and south concurrently with a fast-setting concrete mix design to reduce construction time as much as possible.

In total Option 5 will take approximately 30 months to construct.

11.6 Option 6 - Single-span varying depth post-tensioned concrete box girder

This is not a typical bridge arrangement in Ireland. The atypical details of this structure add to the complexity of the design and construction. Cantilever construction is a significant construction operation and is extremely specialised. Post tensioned concrete is also not a commonly used form of construction in Ireland so a very skilled and experienced Contractor will be required, most likely with international experience of similar forms of construction.

Construction of the end/span substructure including ground beams for the rock anchor heads, tie beams between the piers and abutments and the various voids and access chambers would be done first. The main span would then be constructed via cantilever, with the substructure/"backspan" acting as the counterweight.

The main structural bearings will be located on the pile caps at the piers with additional sliding bearings under the ground anchor beams at the abutments.

The substructure locations are in proximity to the SAC, temporary works may be required to ensure excavations for the foundations do not encroach on the setback zones.

Construction of access underpass box structures will also be required beyond the abutment north and south to facilitate the access tracks required bridge maintenance and emergency vehicle access. These tracks will pass through the backspans of the other options.

In total Option 6 will take approximately 21 months to construct.

12 GROUND CONDITIONS

A ground investigation for the proposed Swilly Crossing area has been completed comprising geophysical surveys, cone penetration tests, boreholes and trial pits. The Geophysical Survey Report, investigation logs and an indicative location drawing based on Bridge Option 4 are available in Appendix 2.

The geophysical survey on the northwestern bank of the river consisting of 2D resistivity, seismic refraction and MASW was undertaken as intrusive investigations were not permitted due to the proximity of the Special Area of Conservation.

All investigation logs indicate upper strata of soft silts and clays which increase in stiffness with depth to between approximately 12m and 16m below ground level. This stratum increases in strength at shallower depths further away from the riverbank, with medium strength soils encountered at approximately 9m below ground level close to the river and 4.5m further away. The silts and clays are underlain by gravel, with occasional lenses of peat and sand, and bedrock is encountered between 18 and 25m below ground level to the southeast of the bridge.

Ground investigations to date indicate that all proposed options will require piled foundations to be constructed down to the gravel strata at a minimum. It is not envisaged at this time that further detailed ground investigations will materially alter the proposed type of bridge foundation.

It is expected that for all proposed options a 0.5m depth of topsoil and soft material will need to be excavated and replaced with a suitable fill such as Clause 804 to create areas of hardstanding for access and construction of foundations, piers, abutments and bridge superstructure.

13 CONSULTATION WITH RELEVANT AUTHORITIES

There are a significant number of stakeholders in the scheme as outlined in section 2.6.5. To date, both formal and informal consultations have been held with a number of authorities and private landowners.

The scheme will be subject to the planning permission process which includes a statutory consultation process with prescribed bodies. This will act as the primary medium for formal consultation with the majority of the relevant authorities. The remainder will be consulted with during preliminary design stage.

14 CLIMATE ASSESSMENT

Section 15 outlines the ranking of each of the options under the various criteria considered in this report, during the options design process discussion with TII Structures highlighted the need to consider the Carbon Footprint and Climate Assessment of the highest ranked options. As Option 1, 3-span varying depth post-tensioned concrete box girder, Option 2, 3-span varying depth steel box girders with steel orthotropic deck, and Option 6, single-span varying depth post-tensioned concrete box girder, were emerging as the most favourable options these three were considered for a detailed quantitative climate assessment based on the options design. The report and results of this assessment are included in Appendix 4 and summarised below. Options 3, 4 and 5 have been assessed qualitatively based on the results of the quantitative assessment of Options 1, 2 and 6.

The climate assessment used the TII Carbon Tool, which is TII's proprietary software for carrying out carbon assessments on road and rail infrastructure projects. The tool uses a combination of default assumptions and user-defined inputs to generate an estimated, carbon footprint for the project. The results of the quantitative comparison assessment of Options 1, 2 and 6 are set out in Table 14-1.

Table 14-1: Total Carbon Emissions by Life Cycle Stage (kgCO2e)

Option	Before Use (kgCO2e)			Use (kgCO2e)	Total (kgCO2e)
	Pre-Construction	Embodied Carbon	Construction Activities	Use	
Option 1 - 3-span Concrete Box	162.56	4,932,249.28	363,480.00	270,891.11	5,566,782.95
Option 2 - 3-span Steel boxes with steel deck	162.56	5,350,896.91	363,480.00	270,891.11	5,985,430.59
Option 6 - Multicell Single Span Concrete Box	87.65	3,991,942.40	335,520.00	201,402.24	4,528,952.29

Option 6 is the preferred option from a climate perspective. This is mainly due to the lower embodied carbon of the materials associated with the bridge construction. Option 2 uses steel extensively in its superstructure design. Steel, as a material, has a high carbon footprint due to the energy required in extracting raw materials, processing and manufacturing the final product. Additionally, the type of structural steel used in bridge building is usually imported from other countries due to lack of manufacturing in Ireland. This adds higher transport emissions to the embodied carbon footprint, compared to sourcing materials closer to the site.

Comparatively, Option 6 relies mostly on structural concrete in its construction. This can be sourced within Ireland, which lowers transport emissions. More importantly, structural concrete has a lower carbon footprint than steel, even when rebar is included. Option 1 uses similar design principles and materials to Option 6 but has a larger deck area and therefore greater quantity of bridge materials. Option 6 does require additional approach earthwork embankments. Section 2 of the scheme has a deficit of material. Options 6 will therefore increase the import of material, road haulage and operations associated with construction of the approach embankments, this has not been accounted for in the figures in Table 14-1. Subsequently Option 1 has a marginally higher carbon footprint than Option 6. The use of concrete over steel is the main reason why Options 1 and 6 have a lower carbon footprint than Option 2. However as displayed in table 14-1, the results for each option are relatively similar.

Of the other options, Option 4, although similar in form to Option 1, is the least desirable option from a climate assessment perspective given it's enormous scale and quantity of materials required. Option 5 is the next least desirable, again due to the quantity of both steel and concrete required to construct the cable stayed steel plate girder signature bridge. Option 3 is a similar form to Option 1 but has a larger climate impact due to the increase in length and therefore materials required for the 5-span varying depth post-tensioned concrete box girder.

15 OVERALL EVALUATION OF PROPOSED OPTIONS

15.1 Evaluation of Options

The six proposed Swilly Crossing options were assessed under various headings as set out below in Table 15-1 and as discussed in previous sections of this report. The options were ranked 1-6 against each criterion in terms of preference, with 1 being the most desirable option for that criterion and 6 being the least desirable option for that criterion.

Table 15-1: Bridge Options Assessment Matrix

Criterion	Description	Ranking – 1 Most Desirable (Least Impact)	2	3	4	5	Ranking – 6 Least Desirable (Most Impact)
1	Bridge Aesthetics	Option 1	Option 2	Option 5	Option 6	Option 3	Option 4
2	Structural Efficiency	Option 1	Option 2	Option 6	Option 3	Option 4	Option 5
3	Hydraulics/Flooding Impact	-	-	-	-	-	-
4	Foundation Requirements	Option 2	Option 1	Option 6	Option 3	Option 5	Option 4
5	Construction & Buildability	Option 1	Option 2	Option 3	Option 6	Option 4	Option 5
6	Maintenance & Whole Life Costs	Option 1	Option 3	Option 6	Option 4	Option 2	Option 5
7	Environmental Impact	Option 3/4	Option 2	Option 1	Option 6	Option 5	-
8	Construction Health and Safety	Option 1	Option 6	Option 2	Option 3	Option 4	Option 5
9	Capital Cost	Option 6	Option 1	Option 2	Option 5	Option 3	Option 4
10	Risk	Option 1	Option 3	Option 6	Option 2	Option 4	Option 5
11	Climate Assessment	Option 6	Option 1	Option 2	Option 3	Option 5	Option 4

The scores for each option are added and the option with the lowest overall score is the most desirable option when assessed against the criteria listed in Table 15-1 above. The minimum possible score is 11 and the maximum possible score is 66. The results are shown in Table 15-2 below. The criteria are not weighted, and so if the scores are close between a number of options, consideration may be given to weighting some of the more important criteria.

Table 15-2: Bridge Options Assessment Results

Option	Score	Ranking
1	15	1
2	27	2
3	34	4
4	49	5
5	52	6
6	28	3

16 CONCLUSIONS & RECOMMENDATIONS

16.1 Conclusion

It is clear from the preceding chapters there are a significant number of competing constraints that need to be carefully balanced to ensure that the optimum solution to meet the brief is proposed.

In assessing the preferred option, the constraints highlighted in Chapter 2 have been carefully considered and a number of feasible options were evaluated. These options were developed into a shortlist of six options for assessment in this options report under a number of criteria. Based on the evaluation undertaken in Section 15, Option 1 is considered the preferred option as it has significantly outscored all of the other options. While Option 6 has the lowest capital costs and marginally the best climate assessment ranking, Option 1 ranks higher in Environmental Impact, Buildability and Maintenance and Whole Life Costs which were concluded to deserve an equal weighting to capital costs and climate assessment. While the hydraulic modelling undertaken concluded that all options considered will have a negligible effect on flooding, the inclusion of Option 1's backspans will also give it an advantage over Option 6 in terms of conveyance for any unforeseeable future flooding events.

Furthermore Option 1 most adequately addresses the constraints which can be simplified to the following points:

- The structure is considered safe and useable for all users,
- The structure is cost effective,
- The option is buildable,
- The structure provides sufficient headroom and clearance to the River Swilly channel.
- It has aesthetic merit with minimal negative visual impact on the local landscape,
- The development has minimal impact on the local environment and the SAC.

16.2 Recommendation

The outcome of the River Swilly Structures Options Report indicates that a 3-span varying depth post-tensioned concrete box girder bridge (Option 1) should be considered as the preferred option. It is recommended that Option 1 is taken forward to preliminary design and planning stage as the preferred option.

17 DRAWINGS & DOCUMENTS

17.1 Bridge Option Drawings

Table 17.1 lists the Swilly Crossing Options drawings included in Appendix 1 of this report.

Table 17-1: Bridge Drawings

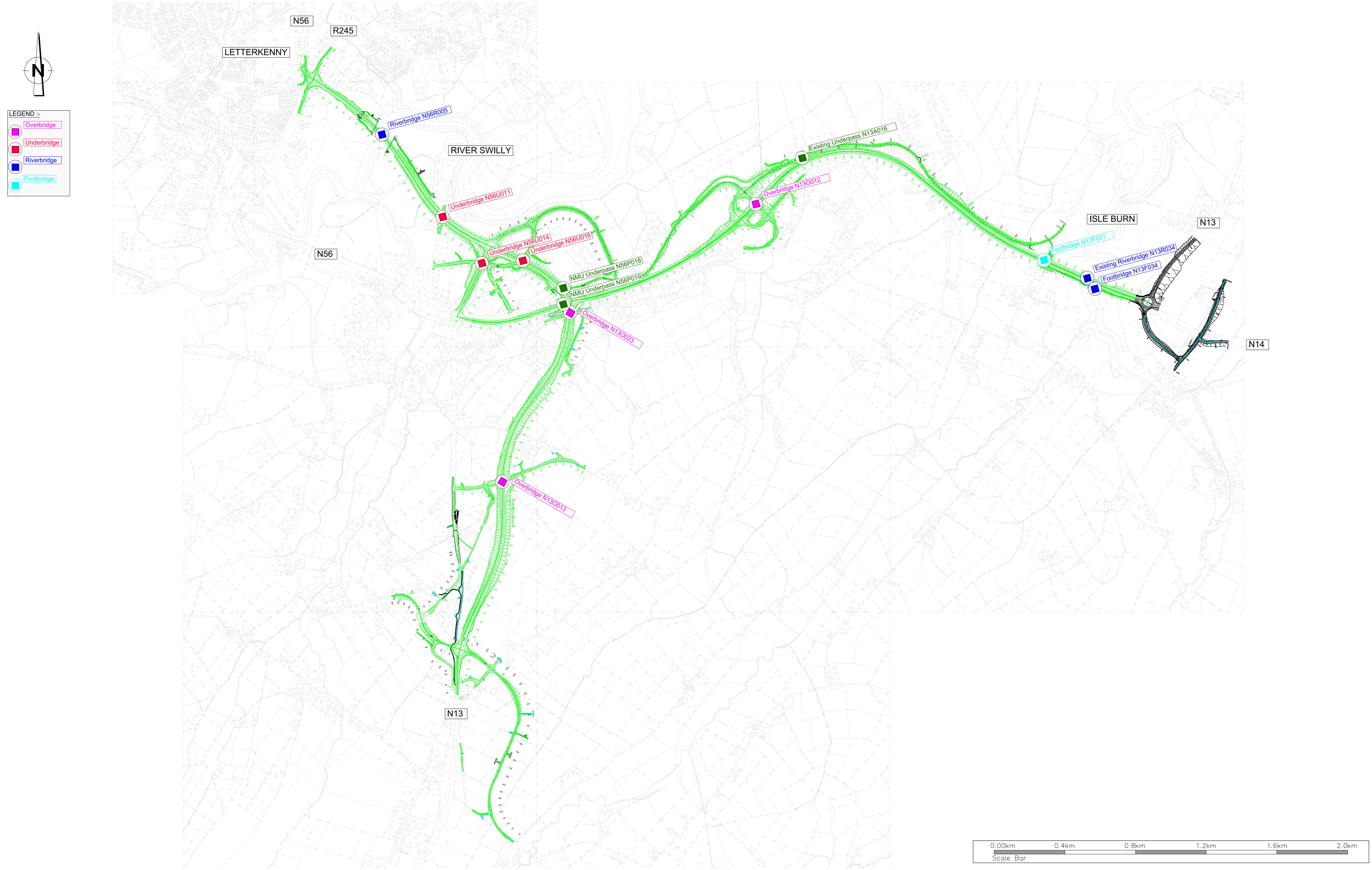
Drg. No.	Rev	Title
TT_MGT0337-RPS-P3-S2-DR-C-BR0102	P02	Section 2 Bridge Locations
TT_MGT0337-RPS-P3-S2-DR-C-BR0131	P02	River Swilly Crossing Bridge Option - 1
TT_MGT0337-RPS-P3-S2-DR-C-BR0136	P02	River Swilly Crossing Bridge Option - 2
TT_MGT0337-RPS-P3-S2-DR-C-BR0132	P02	River Swilly Crossing Bridge Option - 3
TT_MGT0337-RPS-P3-S2-DR-C-BR0135	P02	River Swilly Crossing Bridge Option - 4
TT_MGT0337-RPS-P3-S2-DR-C-BR0133	P02	River Swilly Crossing Bridge Option - 5
TT_MGT0337-RPS-P3-S2-DR-C-BR0137	P02	River Swilly Crossing Bridge Option - 6

17.2 Documents

The Appendices to this Report are:

- Appendix 1 Location Map & Bridge Options Drawings
- Appendix 2 Geotechnical Information
- Appendix 3 Cost Estimate
- Appendix 4 Climate Assessment

APPENDIX 1: LOCATION MAPS & BRIDGE OPTIONS DRAWINGS



LOCATION PLAN

(Scale 1 : 10,000)

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Rev.	Date	Drawn	Description	Chk'd	Appr.
P04	12.11.21	DC	ISSUE FOR REVIEW & COMMENT	JM	EC
P03	15.10.21	DC	ISSUE FOR REVIEW & COMMENT	JM	EC
P02	05.09.21	PH	ISSUE FOR REVIEW & COMMENT	JM	EC
P01	04.05.21	PH	ISSUE FOR REVIEW & COMMENT	JM	EC

Project Title: TEN-T Priority Route Improvement Project, Donegal
Section 1 - N15/N13

Drawing Title: SECTION 2 BRIDGE LOCATION

Status: S3

Designed: JM	Date: Nov.'20	Model File Identifier: TT_MGT0337-RPS-P3-S2-DR-C-BR0102	Rev: P04
Drawn: DC	Scale @ A1: As Shown		
Approved: EC	@ A3: Half	File Identifier: TT_MGT0337-RPS-P3-S2-DR-C-BR0102	
Checked: AO'B	Sheet: 01 of		

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PLAN

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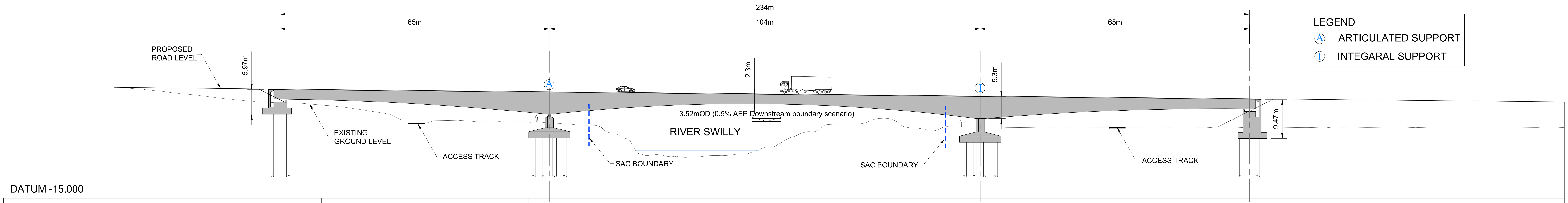

CHAINAGE	350.00	400.00	450.00	500.00	550.00	600.00	650.00	700.00
PROPOSED LEVEL	11.763	11.258	10.762	10.263	9.762	9.263	8.763	8.263
EXISTING LEVEL	11.585	7.491	3.328	-4.387	2.116	1.977	2.037	2.111

LONG SECTION

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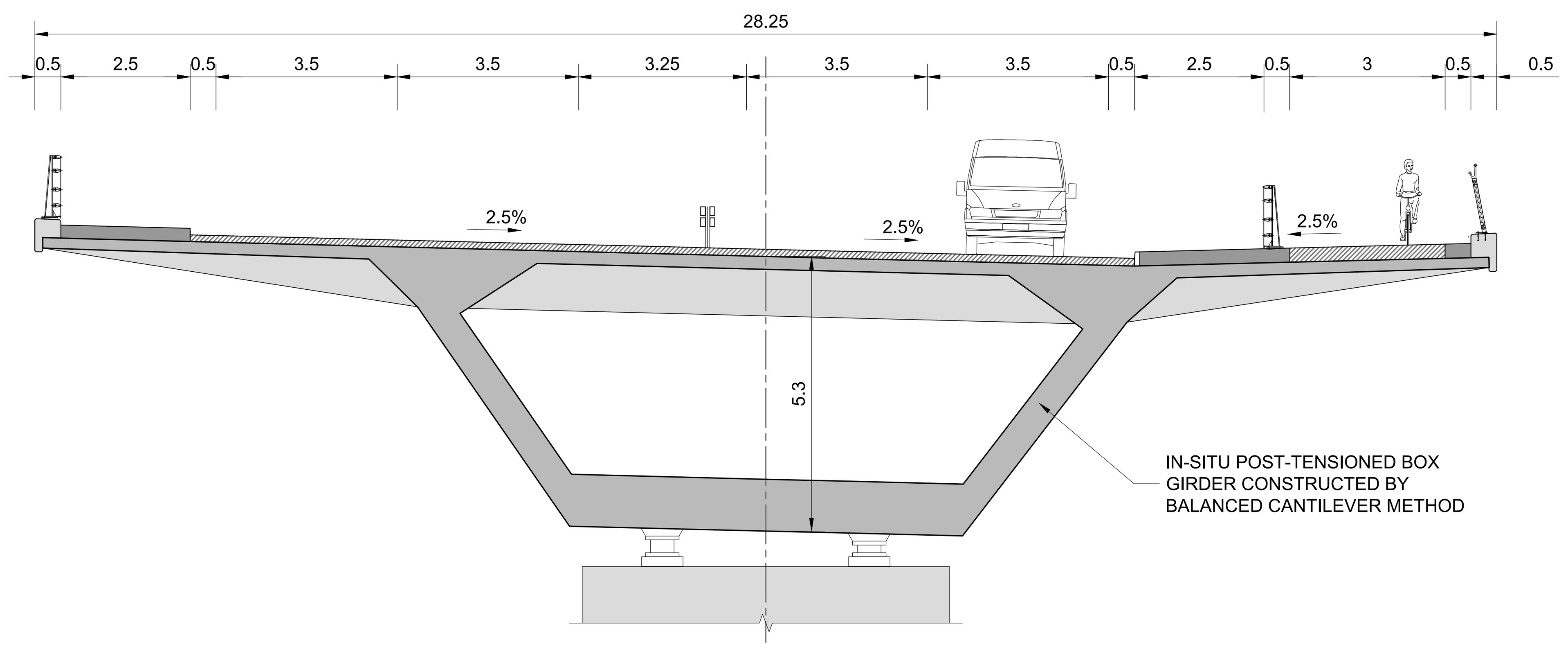

CROSS SECTION @ ARTICULATED PIER SUPPORT

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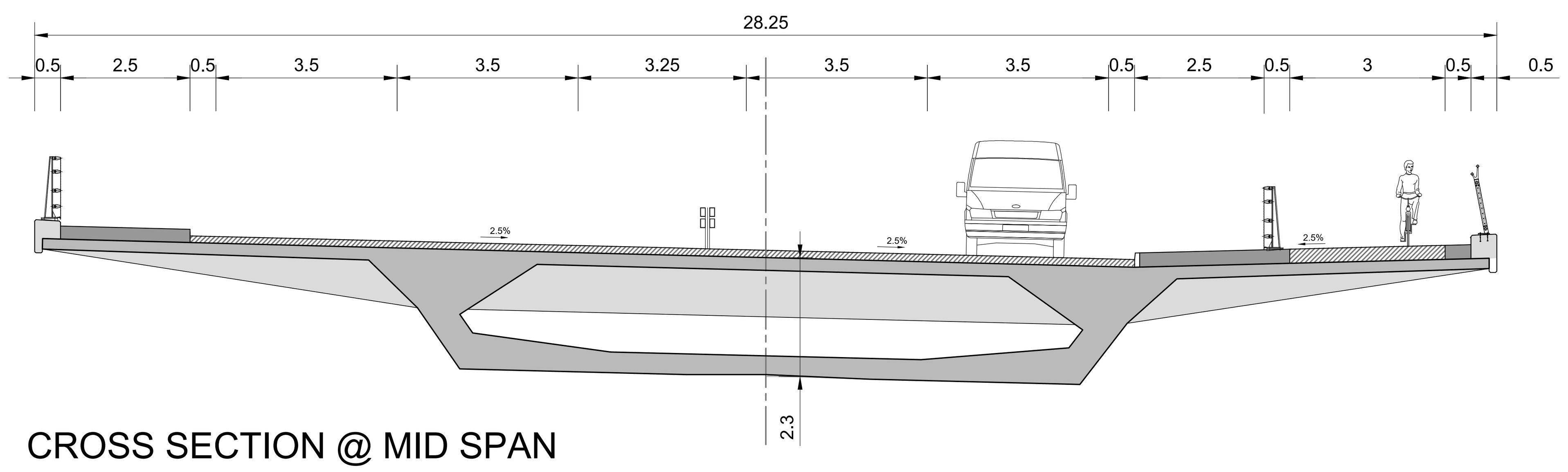

CROSS SECTION @ MID SPAN

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Rev.	Date	Drawn	Description	Chk'd	Appr.
S3 P02	Oct.'21	DC	ISSUE FOR REVIEW & COMMENT	TP	EC
P01	10.09.21	PH	ISSUE FOR REVIEW & COMMENT	JM	EC

Project Title: TEN-T Priority Route Improvement Project, Donegal
Section 2 - N56/N13 Letterkenny to Manorcunningham

Drawing Title: RIVER SWILLY CROSSING
BRIDGE OPTION - 1 (POST TENSIONED BOX GIRDER)

Status: S3

Designed: JM | Date: FEB 2021
Drawn: PH | Scale @ A1: AS
Approved: EC | @ A3: AS
Checked: JM | Sheet: 01 of 01

Model File Identifier: N/A

File Identifier: TT_MGT0337-RPS-P3-S2-DR-C-BR0131

Rev: P02

PLAN
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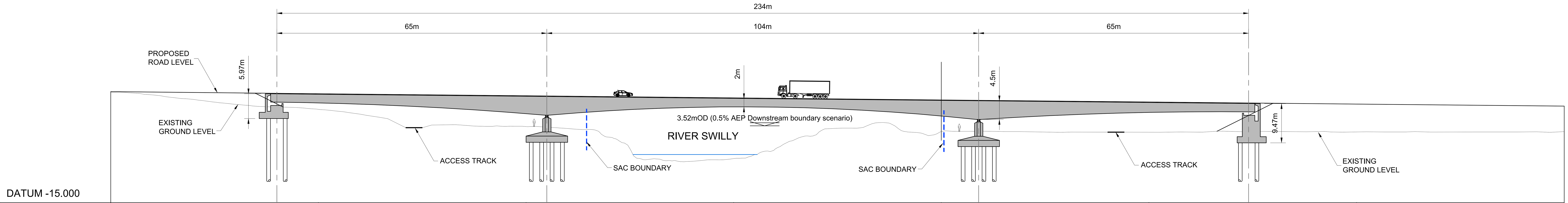

CHAINAGE	350.00	400.00	450.00	500.00	550.00	600.00	650.00	700.00
PROPOSED LEVEL	11.763	11.258	10.762	10.263	9.762	9.263	8.763	
EXISTING LEVEL	11.585	7.491	3.328	-4.387	2.116	1.977	2.037	

LONG SECTION
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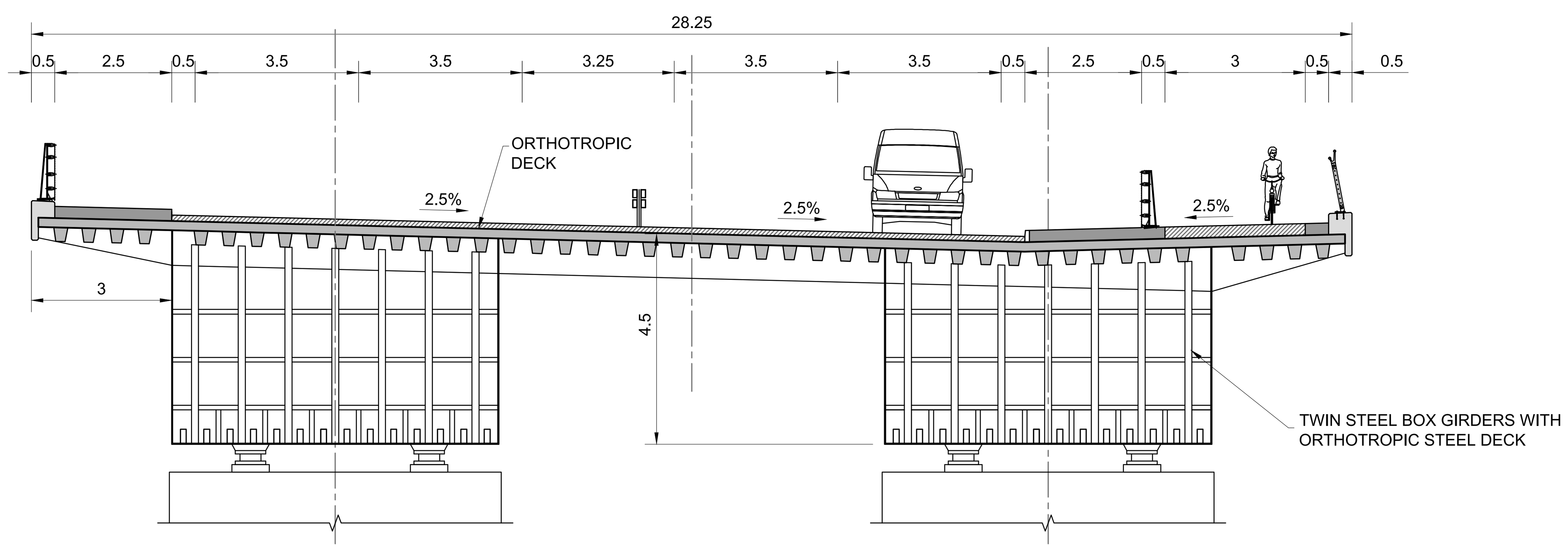

CROSS SECTION @ PIER
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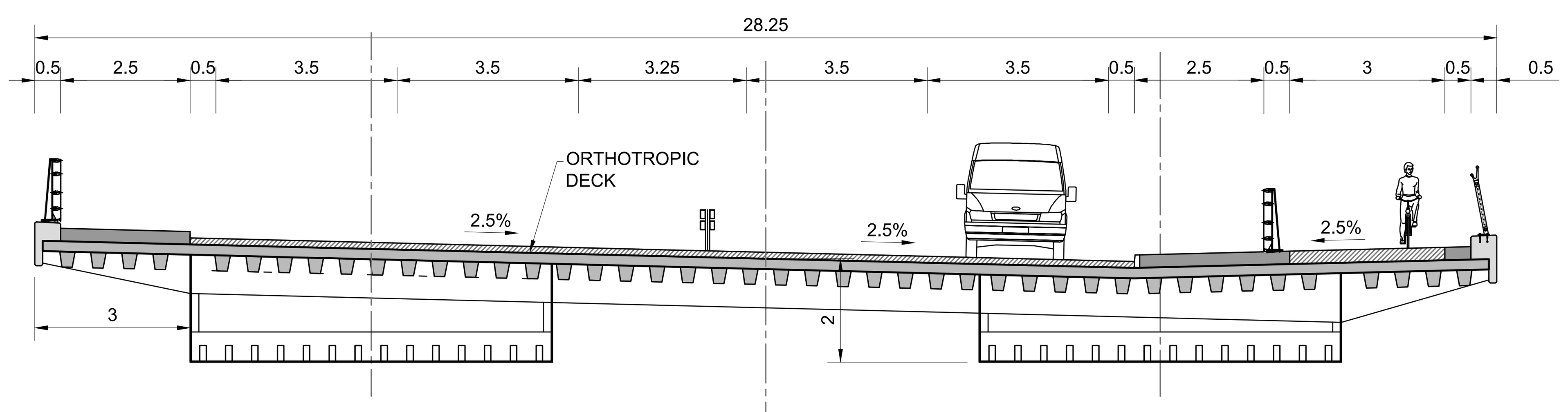

CROSS SECTION @ MID-SPAN
Scale: 1/100 @ A1, 1/200 @ A3

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Rev.	Date	Drawn	Description	Chk'd	Appr.
S3 P02	Oct.'21	DC	ISSUE FOR REVIEW & COMMENT	TP	EC
P01	09.09.21	PH	ISSUE FOR REVIEW & COMMENT	JM	EC

Project Title: TEN-T Priority Route Improvement Project, Donegal
Section 1 - N15/N13

Drawing Title: RIVER SWILLY CROSSING
BRIDGE OPTION - 2 (BOX GIRDERS WITH ORTHOTROPIC STEEL DECK)

Status: S3

Designed: JM	Date: FEB 2021	Model File Identifier: N/A	Rev: P02
Drawn: PH	Scale @ A1: AS		
Approved: EC	@ A3: AS	File Identifier:	
Checked: JM	Sheet: 01 of 01	TT_MGT0337-RPS-P3-S2-DR-C-BR0136	

PLAN
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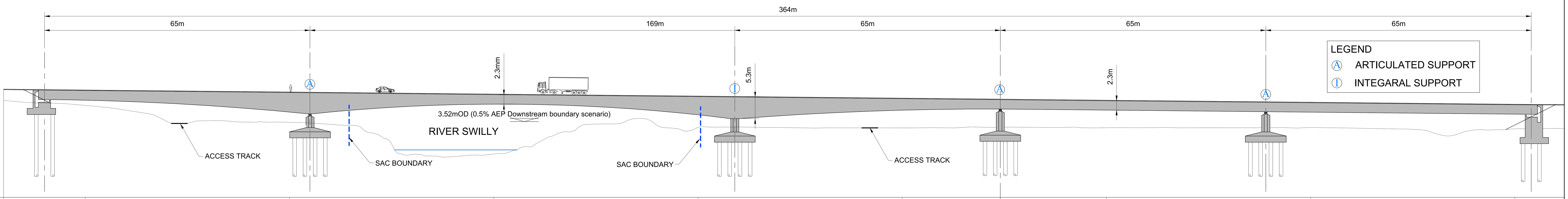

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EXISTING LEVEL	8.696	7.491	3.328	-4.387	2.116	1.977	2.037	2.111	1.743

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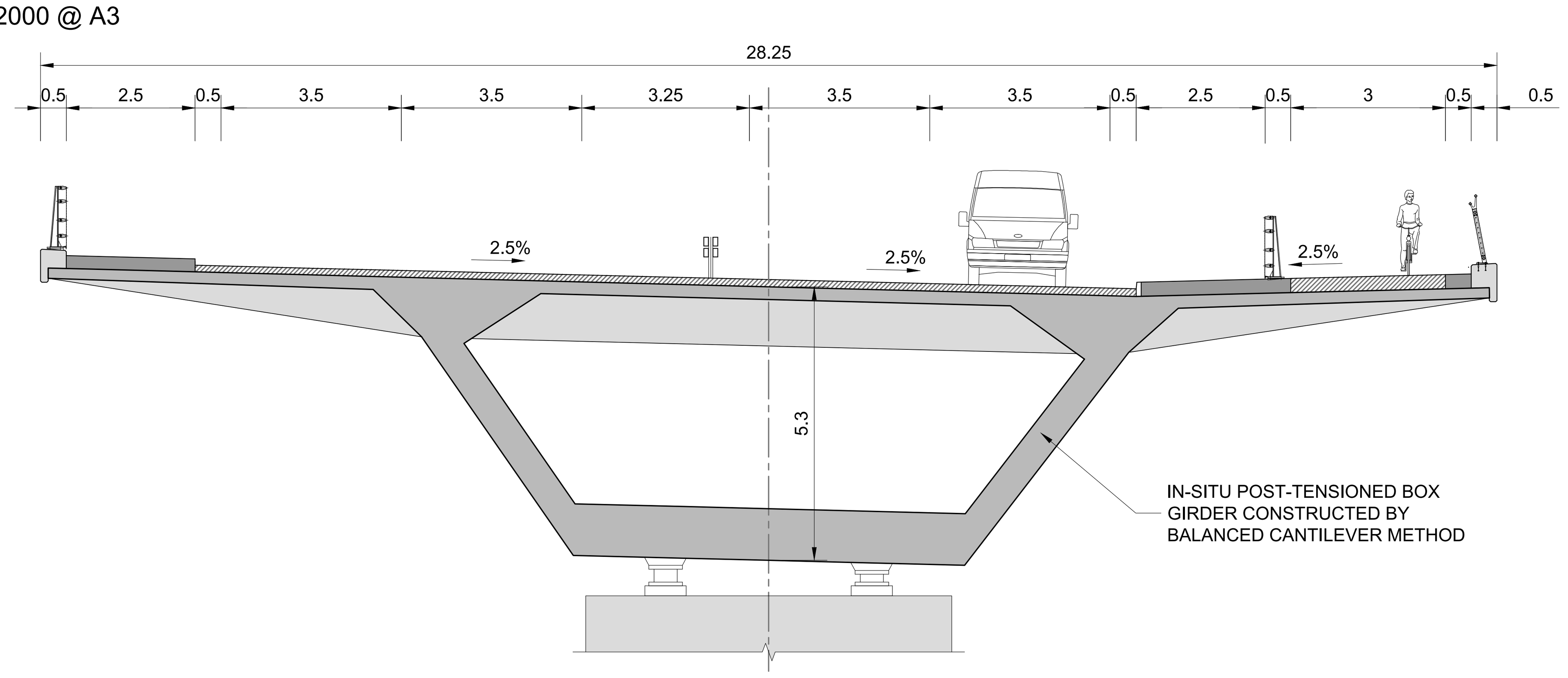

CROSS SECTION @ ARTICULATED PIER SUPPORT
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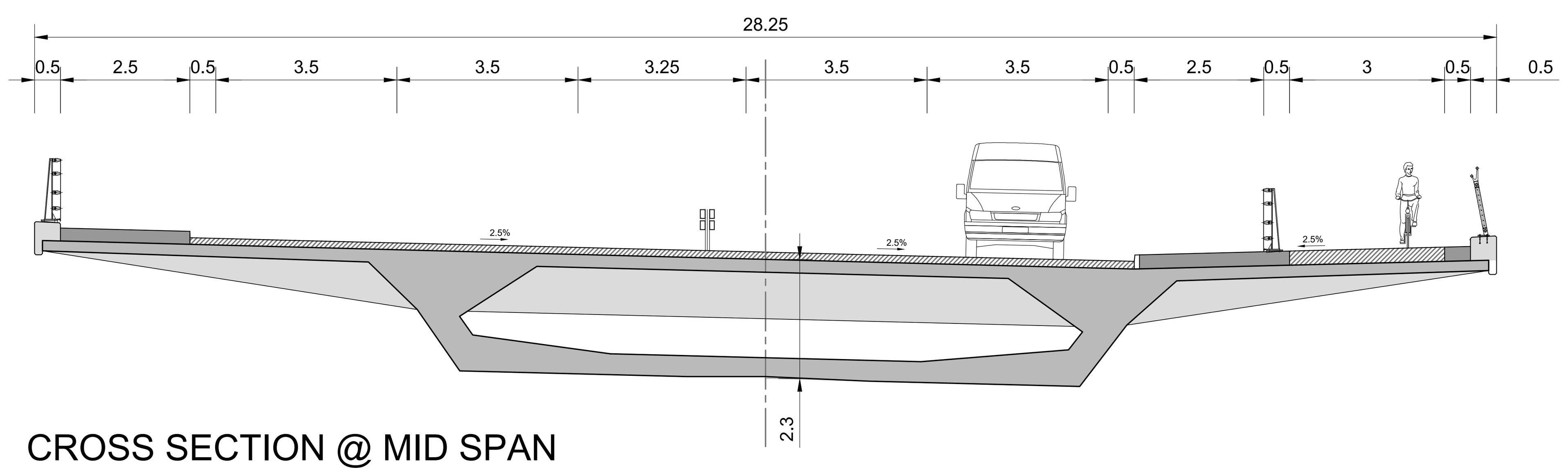

CROSS SECTION @ MID SPAN
Scale: 1/100 @ A1, 1/200 @ A3

\\gaitw-btp-f01\Work_Transport\MGT0337 - Ten-T Priority Route Imp - Donegal\8.0 Drawings\Phase 3\BR\TT_MGT0337-RPS-P3-S2-DR-C-BR0131_BR0132.dwg

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P01	10.09.21	PH	ISSUE FOR REVIEW & COMMENT	TP	EC

Project Title: TEN-T Priority Route Improvement Project, Donegal
Section 2 - N56/N13 Letterkenny to Manorcunningham

Drawing Title: RIVER SWILLY CROSSING
BRIDGE OPTION - 2 (POST TENSIONED BOX GIRDER)

Status: S3

Designed: JM
Drawn: PH
Approved: EC
Checked: TP
Date: FEB 2021
Scale @ A1: AS
@ A3: AS
Sheet: 1 of 1
Model File Identifier: N/A
File Identifier: TT_MGT0337-RPS-P3-S2-DR-C-BR0132
Rev: P02

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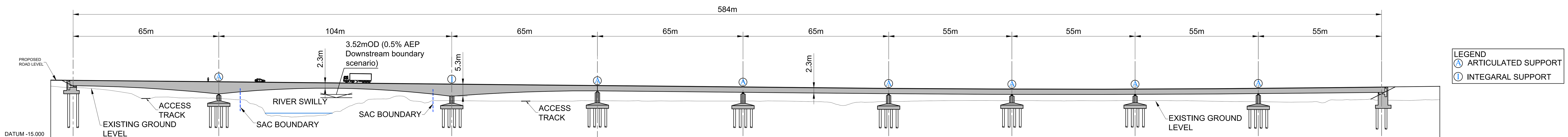

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PROPOSED LEVEL	12.460	11.258	10.762	10.263	9.762	9.263	8.763	8.263	7.770	7.758	7.406	7.611	8.069	8.603
EXISTING LEVEL	8.696	7.491	3.328	-4.387	2.116	1.977	2.037	2.111	1.743	2.248	2.150	1.901	2.044	2.621

LONG SECTION
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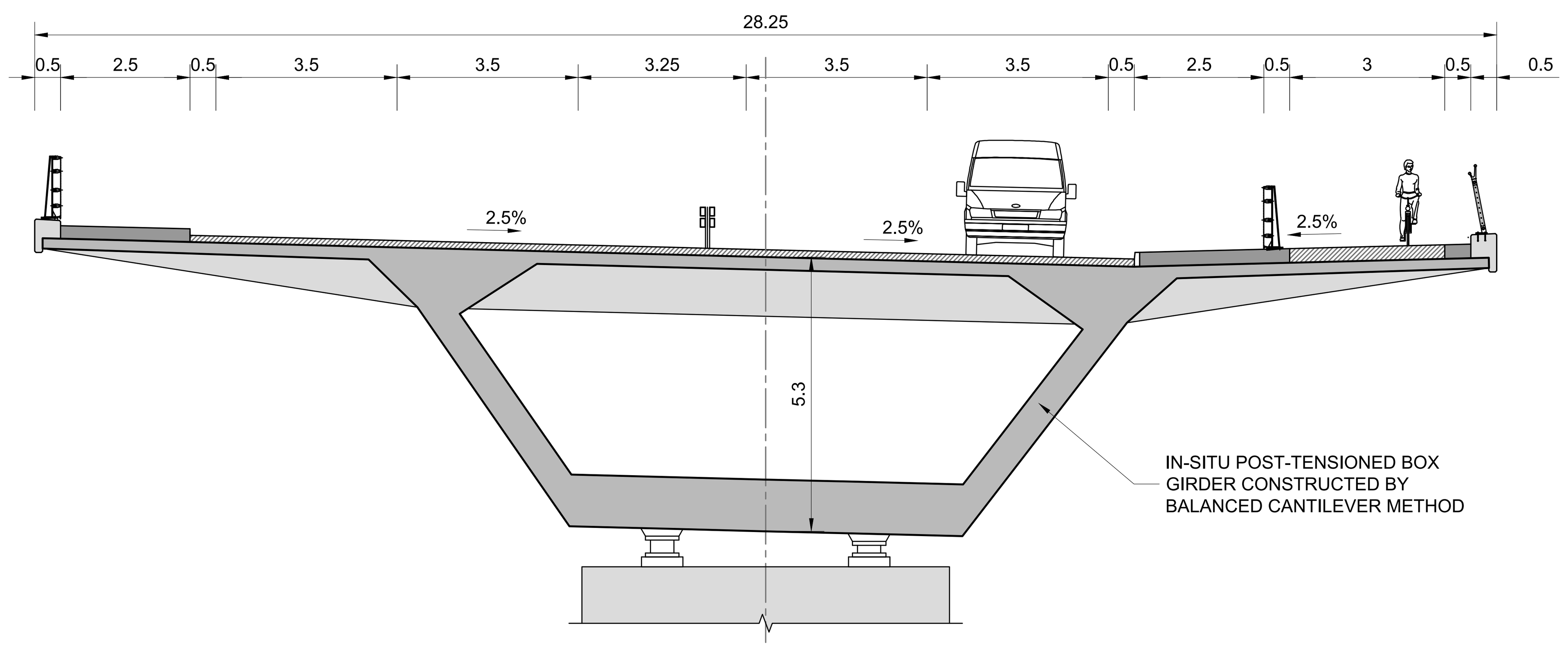

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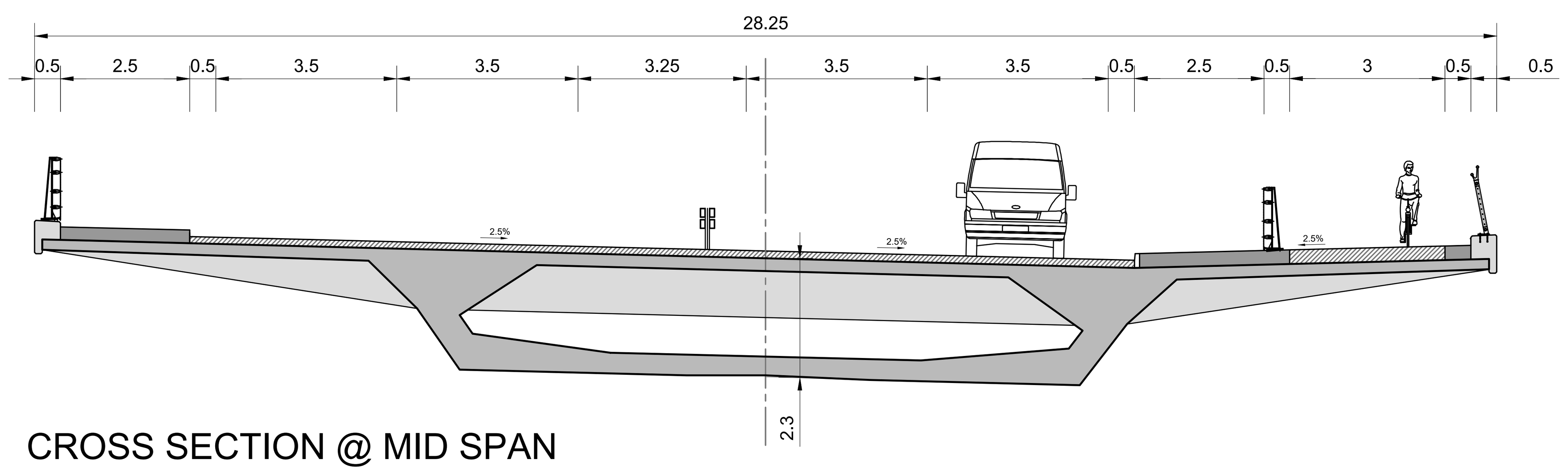

CROSS SECTION @ MID SPAN
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\\gslw-btp-f01\Work_Transport\MGT0337 - Ten-T Priority Route Imp - Donegal\6.0 Drawings\Phase 3\BRITT_MGT0337-RPS-P3-S2-DR-C-BR0135.dwg

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P01	09.09.21	PH	ISSUE FOR REVIEW & COMMENT	JM	EC

Project Title: TEN-T Priority Route Improvement Project, Donegal
Section 1 - N15/N13

Drawing Title: RIVER SWILLY CROSSING
INDICATIVE BRIDGE OPTION - 4 (POST TENSIONED BOX GIRDER)

Status: S3

Designed: JM
Drawn: PH
Approved: EC
Checked: JM

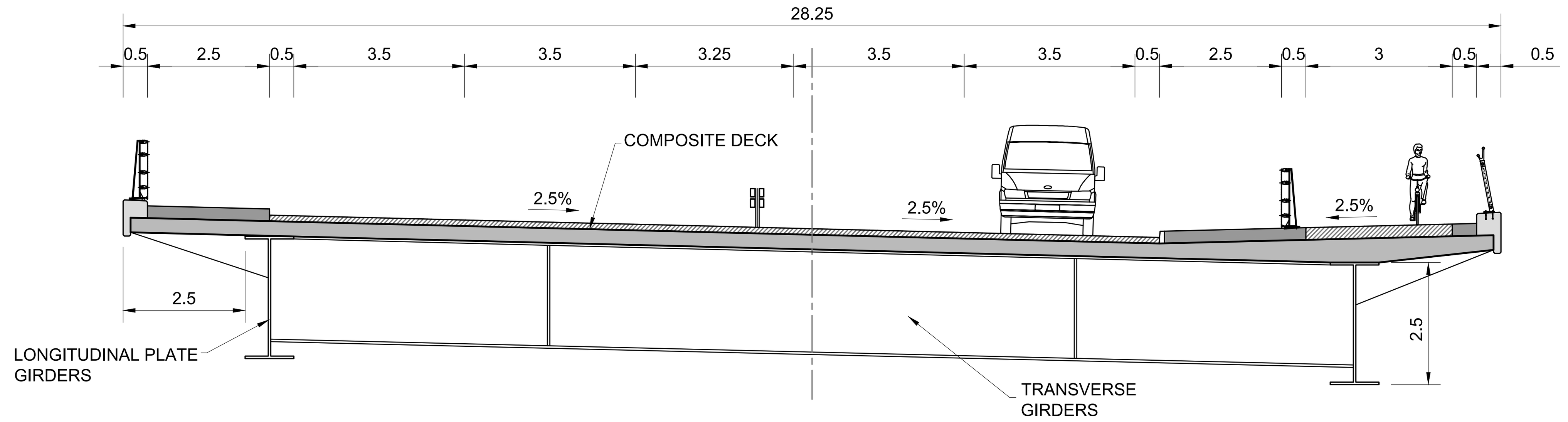
Date: FEB 2021
Scale @ A1: AS
@ A3: AS
Sheet: 01 of 01

Model File Identifier: N/A
File Identifier: TT_MGT0337-RPS-P3-S2-DR-C-BR0135

Rev: P02

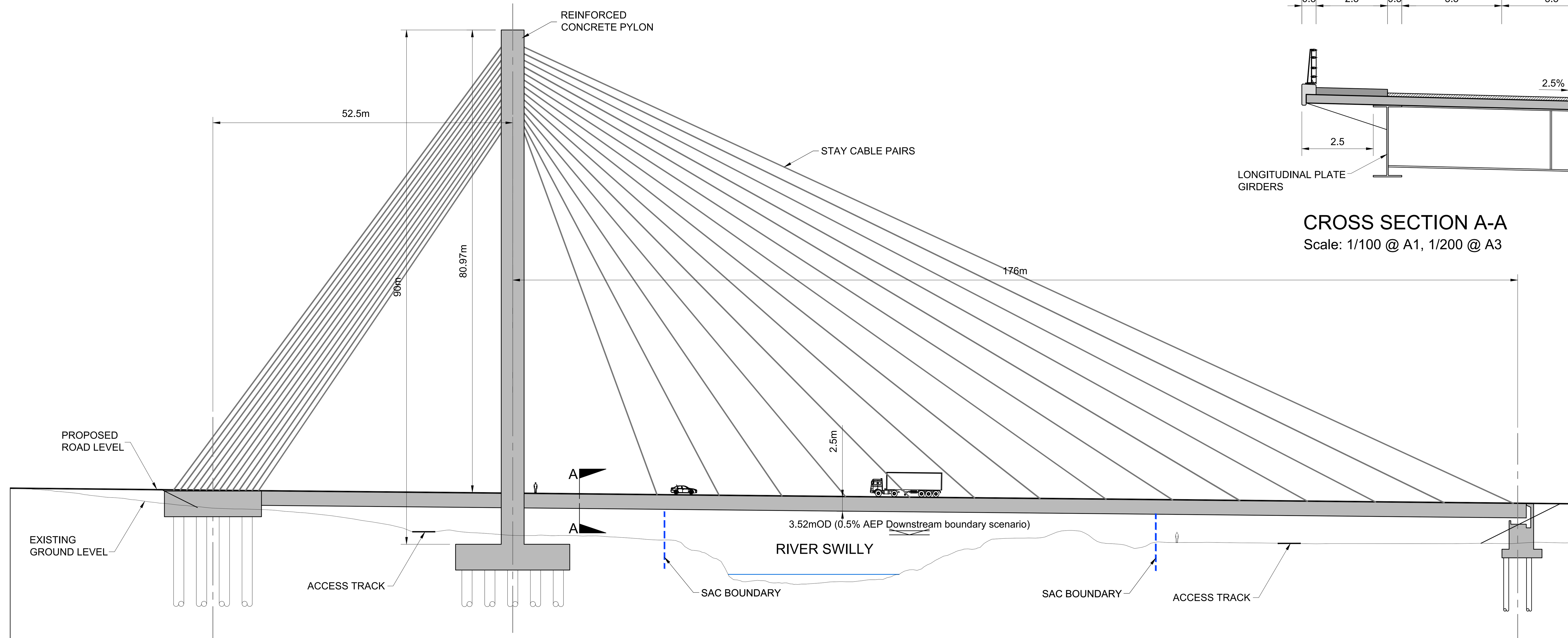
PLAN

Scale: 1/1000 @ A1, 1/2000 @ A3



CROSS SECTION A-A

Scale: 1/100 @ A1, 1/200 @ A3



DATUM -15.000

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PROPOSED LEVEL	11.763	11.258	10.762	10.263	9.762	9.263	8.763	8.263
EXISTING LEVEL	11.585	7.491	3.328	-4.387	2.116	1.977	2.037	2.111

LONG SECTION

Scale: 1/500 @ A1, 1/1000 @ A3

\\galw-btp-f01\Work_Transport\MGT0337 - Ten-T Priority Route Imp - Donegal\8.0 Drawings\Phase 3\BR\TT_MGT0337-RPS-P3-S2-DR-C-BR0133.dwg

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Rev.	Date	Drawn	Description	Chk'd	Appr.
S3 P02	Oct.'21	DC	ISSUE FOR REVIEW & COMMENT	TP	EC
P01	09.09.21	PH	ISSUE FOR REVIEW & COMMENT	JM	EC

Project Title: TEN-T Priority Route Improvement Project, Donegal Section 1 - N15/N13

Drawing Title: RIVER SWILLY CROSSING BRIDGE OPTION - 5 (CABLE STAY)

Status: S3

Designed: JM
Drawn: PH
Approved: EC
Checked: JM

Date: FEB 2021
Scale @ A1: AS
@ A3: AS
Sheet: 01 of 01

Model File Identifier: N/A

File Identifier: TT_MGT0337-RPS-P3-S2-DR-C-BR0133

Rev: P02

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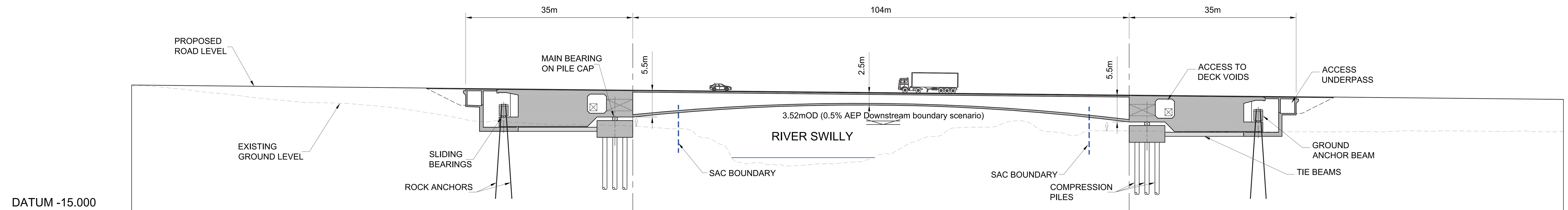

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PROPOSED LEVEL	11.763	11.258	10.762	10.263	9.762	9.263	8.763
EXISTING LEVEL	11.585	7.491	3.328	-4.387	2.116	1.977	2.037

LONG SECTION
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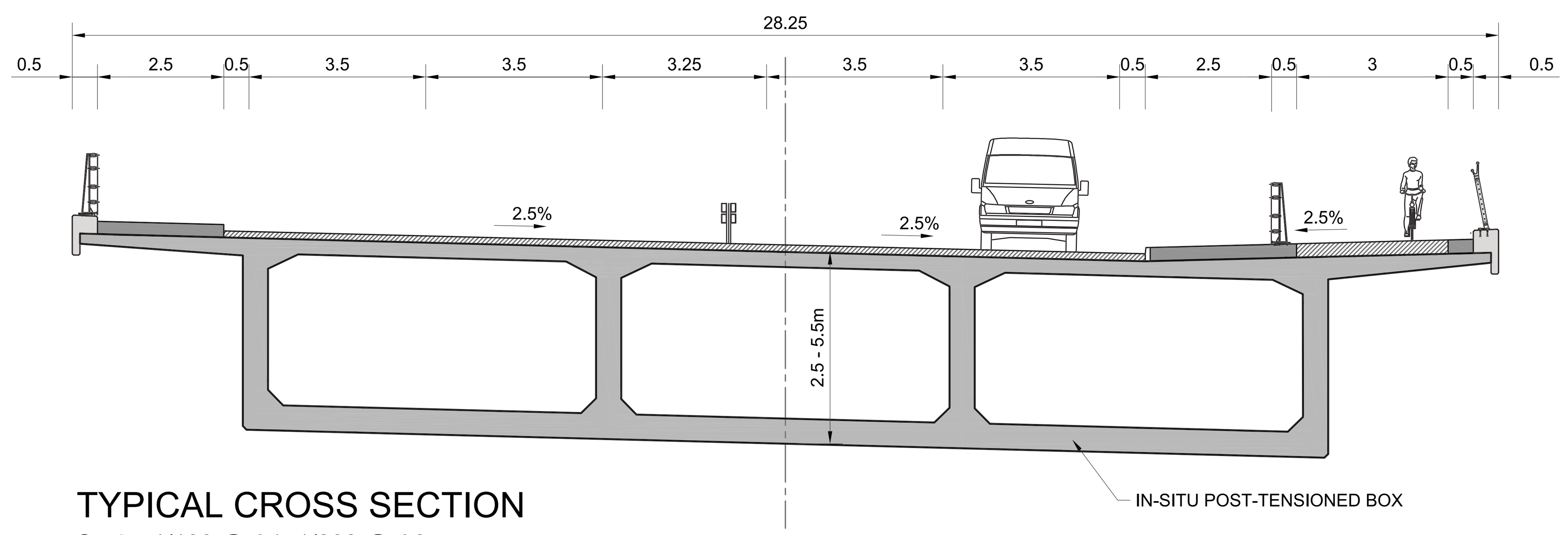

TYPICAL CROSS SECTION
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\\galw-btp-f01\Work_Transport\MGT0337 - Ten-T Priority Route Imp - Donegal\8.0 Drawings\Phase 3\BR\TT_MGT0337-RPS-P3-S2-DR-C-BR0137.dwg

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S3 P03	Dec.'21	DC	ISSUE FOR REVIEW & COMMENT	JM	EC
S3 P02	Oct.'21	DC	ISSUE FOR REVIEW & COMMENT	JM	EC
P01	09.09.21	PH	ISSUE FOR REVIEW & COMMENT		EC

Project Title: TEN-T Priority Route Improvement Project, Donegal
Section 2 - N56/N13 Letterkenny to Manorcunningham

Drawing Title: RIVER SWILLY CROSSING
BRIDGE OPTION - 6 (POST TENSIONED BOX)

Status: S3

Designed: JM
Drawn: PH
Approved: EC
Checked: JM

Date: FEB 2021
Scale @ A1: AS
@ A3: AS
Sheet: 01 of 01

Model File Identifier: N/A
File Identifier: TT_MGT0337-RPS-P3-S2-DR-C-BR0137

Rev: P03

APPENDIX 2: GEOTECHNICAL INFORMATION

TEN-T

Co. Donegal

Geophysical Survey

Report Status: Draft

MGX Project Number: 6400

MGX File Ref: 6526d-005.doc

30th October 2020

Confidential Report To:

Irish Drilling Ltd.
Old Galway Road
Pollroebuck
Loughrea
Co. Galway

Report submitted by :
Minerex Geophysics Limited

Unit F4, Maynooth Business Campus
Maynooth, Co. Kildare, W23X7Y5
Ireland
Tel.: 01-6510030
Email: info@mgx.ie

Issued by:

Author: John Connaughton (Geophysicist)

Reviewer: Hartmut Krahn (Senior Geophysicist)

Minerex Geophysics Limited

Subsurface Geophysical Investigations

EXECUTIVE SUMMARY

1. Minerex Geophysics Ltd. (MGX) carried out a geophysical survey consisting of 2D-Resistivity, seismic refraction (p-wave) and MASW (s-wave) surveying for the ground investigation for the TEN-T project in County Donegal.
2. The survey was done at eight separate locations.
3. The main objectives of the survey were to determine the ground conditions under the site, determine the depth to rock and the overburden thickness and to estimate the strength/stiffness/compaction of overburden and the rock quality.
4. The 2D-Resistivity data was displayed with a scale ranging from low resistivity clay and silt overburden to high resistivity sand and gravel and also rock at depth.
5. The seismic refraction data was modelled with a four-layer model.
6. Layer one is described as soft or loose topsoil, soil or made ground. Layers 2 and 3 are subdivided into three material types using the 2D-Resistivity data while Layer 4 is divided in two types.
7. Layer 2 is described as firm to stiff or medium dense to dense overburden. Layer 3 is interpreted as either very stiff to hard or very dense overburden or poor to fair weathered rock while layer 4 is described as slightly weathered to fresh rock.
8. The shallowest good to very good rock is found at Area C and at the structure at CH1900 – 1250 as shallow as 1.5 – 2 m. Weathered rock may be even shallower in some areas.
9. The good rock layer is not found within the survey depth in Areas A, D & E where layer 3 is the deepest layer modelled. It is interpreted as primarily very consolidated overburden rather than weathered rock.
10. This report will be reviewed and finalised after the complete direct ground investigation data has been received.

CONTENTS

List of Tables, Maps and Figures:

1. INTRODUCTION

1.1 Background

Minerex Geophysics Ltd. (MGX) carried out a geophysical survey for the TEN-T Project in Co. Donegal. The survey consisted of 2D-Resistivity, seismic refraction (p-wave) and MASW (s-wave) measurements. The survey was commissioned by Irish Drilling Ltd.

The survey was done at eight separate locations:

Location	**Townland**	**Design Feature**
Area A	Drumcarn/Drumoghill	Side Road Underbridge
Area B	Moondooey Lower	Side Road Underbridge
Area C	Drumbeg	Side Road Underbridge
Area D	Drumboe Lower	Side Road Overbridge
Area E	Ballyraine	Side Road Overbridge
River Swilly Crossing North	Drumany/Dromore	Bridge
Structure at CH 1900 – 2150	Ballyholey Far	Bridge
River Finn Crossing North	Carrickdawson	Bridge

The survey employed various geophysical methods that complement each other and improve the interpretation. The role of geophysics as a non-destructive fast method is to provide a geological interpretation in areas where access for direct ground investigations was limited at specific locations. The survey was aimed at investigating the ground stability and to determine the general geology in particular locations.

1.2 Objectives

The main objectives of the geophysical survey were:

- To determine the ground conditions under the site
- To determine the depth to rock and the overburden thickness
- To estimate the strength/stiffness/compaction of overburden materials and the rock quality
- To determine the type of overburden and rock
- To detect lateral changes within the geological layers
- To determine the s-wave velocity and to calculate the small strain shear modulus G_{max}

1.3 Site Description

The survey was carried out at eight locations across Donegal stretching from Ballybofey in the South to Letterkenny in the North. Most profiles were carried out in grass fields. Area D consisted of two profiles which crossed the L1214 road. Area A consisted of two lines which were carried out on the verge of the N14 while the profiles at CH 1900 – 2150 crossed a small local access road. There was a stream crossing the lines in Area C.

1.4 Geology

As the survey is spread over a wide area, the geology varies between the survey locations. The bedrock geology is generally metamorphic rock types such as marble, quartzite and psammites while the overburden consists of till derived from metamorphic rock and alluvium near rivers and streams. A description of the geology (GSI, 2020) for each area is given in Table 2 attached to this report.

1.5 Report

This report includes the results and interpretation of the geophysical survey. Maps, figures and tables are included to illustrate the results of the survey. More detailed descriptions of geophysical methods and measurements can be found in GSEG (2002), Milsom (1989) and Reynolds (1997).

The description of soil and rock and the use of geotechnical terms (like soft, stiff, dense etc) follows the standards (Eurocode 2007, BSI 2015). Geophysical parameters are used to determine these terms by using guidelines and from experience. The geophysical survey has been acquired, processed, interpreted and reported on in accordance with these guidelines.

The client provided maps of the site and the digital version was used as the background map in this report. Elevations were surveyed on site and are used in the vertical sections.

The interpretative nature and the non-invasive survey methods must be taken into account when considering the results of this survey and Minerex Geophysics Limited, while using appropriate practice to execute, interpret and present the data, give no guarantees in relation to the existing subsurface.

2. GEOPHYSICAL SURVEY

2.1 Methodology

The methodology consisted of using 2D-Resistivity, Seismic Refraction and MASW surveying across all proposed lines. Some proposed very short lines such as lines 6 and 7 at the River Swilly Crossing North were extended to allow meaningful data to be collected. The results from MASW profiles 3 – 5 at the River Swilly Crossing North site are 11.5 m short as the river stopped the profiles from being extended past the start of the proposed line as is required to acquire the data. It was not possible to carry out MASW profiles across the road at Area D as this would have required the closure of the road. At Area C, the MASW profiles were stopped at the river as the noise from the river and the sudden elevation change would interfere with the collection of surface wave information.

At Area B, Line 2 was diverted along a local road as the proposed line crossing the road would not have been feasible. At Area C, Line 19 was curved around a derelict house and large mound of topsoil which obstructed the proposed line.

The survey locations are indicated on Maps 1a and 1b. The lines, locations and parameters are tabulated in Table 1 attached to this report.

2.2 2D-Resistivity (ERT)

2D-Resistivity lines were surveyed with electrode spacing of 3 m, up to 64 electrodes per set-up and a maximum length of 189 m per set-up. The readings were taken with a Tigre Resistivity Meter, Imager Cables, stainless steel electrodes, laptop and ImagerPro acquisition software.

In sealed tarmac/concrete/hard standing areas small holes (12 mm) were drilled to place the electrodes in them and saline water was added to make a good electrical connection.

During 2D-Resistivity surveying, data is acquired in the form of linear arrays using a suite of metal electrodes. A current is injected into the ground via a pair of electrodes while a potential difference is measured across a second pair of electrodes. This allows for the recording of the apparent resistivity in a two-dimensional arrangement below the line. The data is inverted after the survey to obtain a model of subsurface resistivities. The generated model resistivity values and their spatial distribution can then be related to typical values for different geological materials.

The penetration depth of a resistivity set-up increases towards the centre where it reaches an approx. value of 1/6th of the array length.

2.3 Seismic Refraction

Seismic refraction lines were surveyed with geophone spacing of 3 m and 24 geophones per set-up resulting in a 69 m length per set-up. The recording equipment consisted of a 24 Channel GEOMETRICS ES-3000 engineering seismograph with 4.5 Hz vertical geophones. The seismic energy source consisted of a hammer and plate. A zero-delay trigger was used to start the recording. Normally 7 shot points per p-wave set-up were used.

Some set-ups were acquired in longer continuous lines using common shot points between set-ups and concatenating into longer lines at the processing stage.

In the seismic refraction survey method, a p-wave is generated by a source at the surface resulting in energy travelling through surface layers directly and along boundaries between layers of differing seismic wave velocities. Processing of the seismic data allows geological layer thicknesses and boundaries to be established.

Seismic Refraction generally determines the depth to horizontal or near horizontal layers where the compaction/strength/rock quality changes with an accuracy of 10 – 20% of depth to that layer. Where low velocity layers or shadow zones are present (e.g. below solid ground surface) or where layers dip with more than 20 degrees angle the accuracy becomes much less.

The seismic refraction set-ups with 69 m individual length have a reasonable penetration depth of around 15m. An internationally accepted maximum depth estimate for a seismic refraction set-up is 1/6 of the set-up length including off-shots. The depth penetration varies according to the velocity structure of the subsurface. In this report we used a depth of 10m bgl. where the seismic modelling was ended as deeper modelling becomes less meaningful.

2.4 2D-MASW (Multichannel Analysis of Surface Waves)

The seismic shear wave velocity was determined by active 2D-MASW surveying. MASW (Multi-Channel Analysis of Surface Waves) determines the bulk seismic shear wave velocity versus depth. The velocities are used to determine the small strain shear modulus and to compute other geotechnical parameters.

The MASW arrays consisted of a 1 m geophone spacing and a 24 channels set-up, resulting in an individual array length of 23m. Shots were carried out 8m after the last geophone in the array. The whole set-up was then advanced by 8m and the process repeated across the full survey line.

The recording equipment consisted of a 24 Channel GEOMETRICS GEODE engineering seismograph with 4.5 Hz vertical geophones. The seismic energy source consisted of a hammer and plate. A zero-delay trigger was used to start the recording.

Each set-up provides information for the middle of the geophone array. The displayed results therefore cover the distance from 11.5 m after the first geophone of the first array and 11.5 m before the last geophone of the last array. Table 1 shows the total length of the set-ups from the first geophone in the first array along a line to the last geophone of the final array. It is therefore 23 m longer than the displayed line on Map 1 which shows the locations of the midpoints of the MASW arrays.

The depth surveyed by the MASW method depends more on the ground itself rather than on the geophone spacing. The ground conditions determine the frequency of surface waves spreading through the subsurface. The frequency and the surface wave velocity determine the survey depth. The geophone spacing of 1m used for this survey ensures that all relevant wave form data can be captured. A low velocity ground (like very soft and soft ground) will give a shallow shear wave depth section while a high velocity ground (like shallow rock) will give a deeper section.

Many constraints exist for the MASW method and the main factors on this site that affect the methods are strong vertical velocity gradients and changing velocity structure and layer thicknesses along the lines.

2.5 Site Work

The data acquisition was carried out between the 28th of September and 8th of October 2020. The weather conditions were varied throughout the acquisition period. Health and safety standards were adhered to at all times. While working on roadways the area was clearly highlighted by the use of warning signs and cones and a traffic management system was in place.

The locations and elevations were surveyed with a Carlson NR3 RTK-GPS to accuracy < 0.05 m.

3. RESULTS AND INTERPRETATION

The interpretation of geophysical data was carried out utilising the known response of geophysical measurements, typical physical parameters for subsurface features that may underlay the site, and the experience of the authors.

The interpretation is based on the methods of 2D-Resistivity and Seismic Refraction while the MASW data is given some additional information where the ground conditions are favourable for the method. It must be considered that the first two methods work everywhere on this site while the MASW method is very dependent on having suitable ground conditions.

3.1 2D-Resistivity (ERT)

The 2D-Resistivity data was positioned and inverted with the RES2DINV inversion package. The programme uses a smoothness constrained least-squares inversion method to produce a 2D model of the subsurface resistivities from the recorded apparent resistivity values. Three variations of the least squares method are available and for this project the Jacobian Matrix was recalculated for the first three iterations, then a Quasi-Newton approximation was used for subsequent iterations. Each dataset was inverted using seven iterations resulting in a typical RMS error of <3.0%. The resulting models were colour contoured with the same resistivity scale for all lines and they are displayed as cross sections (Figure 1).

Resistivities are characteristic for certain overburden and rock types. If there is a high content of clay minerals (which are electrically conductive) then the overburden resistivity will be lower than as if there is a high content of clastic grains like sand or gravel. The purer the clay and the lower the sand/gravel content the lower the resistivity. The water content in the overburden also influences the resistivities but generally the clay content has a larger effect.

Within bedrock types like marble, quartzite and psammite, high resistivities indicate a fresh strong unweathered rock. As the weathering in the rock increases the resistivity gets lower because of weathering products, remineralisation of rock and infill of cracks, faults and voids with clay and water. Weathering within rock is typically indicated by lower resistivity values in the cross sections.

The resistivities cover a range typical for materials from clay rich overburden (low resistivities) to fresh strong unweathered bedrock (high resistivities). The ranges have been taken into the consideration for the interpretation. Low resistivity values (<180 Ωm) typically indicate overburden with high clay content. Medium values (180 to 1500 Ωm) show gravelly clay overburden and weathered bedrock. High resistivities (>1500 Ωm) indicate unweathered bedrock types like marble, quartzite and psammite or clean sand and gravel in overburden.

3.2 Seismic Refraction

The seismic refraction data was positioned and processed with the SEISIMAGER software package to give a layered model of the subsurface. The number of layers has been determined by analysing the seismic traces and between 2 and 4 layers were used in the models. All seismic lines were subject to a standardised processing sequence which consisted of a topographic correction which was based on integrated elevation data, first break picking, tomographic inversion, travel-time computation via ray-tracing and velocity modelling. Residual deviations of typically 0.4 to 1.8 msec RMS have been obtained for each line. Following each processing stage QC procedures were adhered to. The resulting layer boundaries are shown as thick lines overlaid on the 2D-Resistivity cross sections (Figures 1a – 1h). The average seismic velocities obtained within the layers are annotated on the sections as bold black numbers.

The p-wave seismic velocity is closely linked to the density of subsurface materials and to parameters like compaction, stiffness, strength and rock quality. The higher the density of the subsurface materials the higher the seismic velocity. Similarly, for the other parameters it is generally valid that a more compacted, stiffer and stronger material will have a higher seismic velocity. For rock, the seismic velocity is higher when the rock is stronger, less weathered and has a higher quality. If the rock is more weathered, broken or fractured then the seismic velocity will be reduced compared to that of intact fresh rock.

Because of the above relationship, the seismic refraction method and seismic velocities are suitable to investigate ground where the layers get denser, more compacted and stronger with depth. A disadvantage is that some materials may have the same seismic velocity. Very stiff to hard or very dense highly consolidated overburden and a weathered rock can have the same seismic velocity range (as is the case in the layer 3 below).

The modelled seismic data has created the following layered ground model:

Layer 1 has seismic velocities of 100 - 300 m/s. This overburden would be topsoil, soil or made ground with a soft or loose stiffness or compaction.

Layer 2 was modelled with a velocity range of 800 - 1600 m/s. The velocity indicates overburden material with firm to stiff or medium dense to dense strength or compaction.

Layer 3 velocities of 1800 - 2600 m/s indicate weathered rock or very stiff to hard or very dense overburden.

Strong rock (Layer 4) is indicated by seismic velocities of >3000 m/s.

3.3 Interpretation of Resistivity and Seismic Refraction

Table 3 below summarises the interpretation. The stiffness or compaction and the rock strength or quality have been estimated from the seismic velocity. The estimation of the excavatability for the bedrock has been made according to the caterpillar chart published in Reynolds (1997). The geotechnical assessment for rippability will have to take factors like rock type and jointing into account and the estimation in this report is solely based on the seismic velocities.

Interpreted cross sections are shown in Figure 2a – 2h. The interpretation has been made from all available information. For overburden layers and the top of the rock the seismic refraction data has been used because jumps in the seismic refraction velocities are the best method to delineate layer boundaries. The resistivity models have been used, within the seismic refraction layers, to delineate three generalised overburden types and to indicate weathering of rock. Along short sections where only one data type is available an interpolation for the interpreted layers was made.

Table 3: Summary of Interpretation

Layer	**General Seismic Velocity Range (m/sec)**	**General Resistivity Range (Ohmm)**	**Stiffness/ Compaction or Rock Strength/ Quality**	**Interpretation**	**Estimated Excavation Method**
1	100 - 300	Any	Soft or loose	Topsoil, Soil or Made Ground	Diggable
2a	800 - 1600	<180	Firm to stiff	Clay or Silt Overburden	Diggable
2b	800 - 1600	180 - 1500	Firm to stiff	Gravelly Clay Overburden	Diggable
2c	800 - 1600	>1500	Medium dense to dense	Sand and Gravel Overburden	Diggable
3a	1800 - 2600	<180	Very stiff to hard	Clay or Silt Overburden	Diggable
3b	1800 - 2600	180 - 1500	Very stiff to hard Or poor to fair Rock	Gravelly Clay Overburden or Weathered Metamorphic Rock	Diggable or rippable to marginal rippable
3c	1800 - 2600	>1500	Poor to fair Rock	Weathered Metamorphic Rock	Breaking & Blasting
4b	3000 - 4500	180 - 1500	Good to very good Rock	Slightly Weathered Metamorphic Rock	Breaking & Blasting
4c	3000 - 4500	>1500	Good to very good Rock	Metamorphic Rock	Breaking & Blasting

3.4 2D-MASW (Multichannel Analysis of Surface Waves)

The MASW data was positioned, processed, analysed and modelled with the SURFSEIS6 software packages. The objective is to obtain a model of shear wave velocity versus depth and to calculate the small strain shear modulus G_{max} from the shear wave velocities (using an assumed density of 2000 kg/m^3 typical for overburden). This is achieved for individual shot records acquired along a line and the results are then combined and displayed as a 2D-Contour image on cross-sections (Figures 3a – 3h).

Following processing steps are done to achieve this:

1. Edit the shot point geometry and display the shot points for each array set-up along a line.
2. A dispersion curve (phase velocity versus frequency plot or dispersion image) is computed.
3. The quality is analysed and only acceptable data is used in the next steps.
4. For each shot the maximum amplitude at each frequency of the dispersion image is selected and then saved.
5. An elevation file using the elevations surveyed at the centre of each array is imported into the program.
6. An initial model of shear-wave velocity Vs versus depth is computed from the saved picks.
7. An inversion is carried out to create the final V_s curve (Shear wave versus depth).
8. The small strain shear modulus (also named Gmax) for each shot point and depth is computed by using a density of 2000 kg/m^3 typical for highly consolidated overburden (Eq. 1)

   (Eq. 1) $G = V_s^2 * \rho * 10^{-6}$

   where G = Shear Modulus (MPa)

   V_s = Seismic Shear Wave Velocity (m/s)

   ρ = Density (kg/m^3)
9. The values for shear velocity (m/s) and small strain shear modulus (in MPa) are then gridded and contoured versus the distance on the line and the depth.
10. The contour section for shear wave velocity and small strain shear modulus are then displayed with a colour scale that ranges from 100 – 1200 m/s for the shear wave velocities and from 20 – 2880 MPa for the shear modulus on Figures 3a – 3h.

The surface waves and dispersion curves produced on this site were ranging from bad to good. Changes can occur between adjacent shot points (8 m apart), or even within a geophone layout. The quality can be seen in the seismic waveforms (surface wave fan) and in the overtone data.

Good data was obtained where the ground is laterally relatively homogeneous and has a gradual velocity increase with depth.

Bad data occurs where the ground does not allow surface waves to propagate. If there are no surface waves then it is obvious that the surface wave method cannot be applied. This case happens when there are no velocity increases with depth (deep rock, homogeneous overburden), where the velocity increases too much (shallow rock), where there are sudden large jumps in velocity with depth (layer boundaries), at topographical changes and deep ditches or road crossings.

The model depth depends on the frequency and wavelength of the surface wave. MASW deriving values at ground level would require an indefinitely high frequency which is not possible. The colour contours start at the depth of the shallowest model values derived from the software. This leaves a data ‘gap’ between the ground surface and the top of the model. The deeper penetration into rock is not realistic as the jump in density and velocity from overburden to solid rock would not accommodate surface waves (this is what the seismic refraction method is used for).

The relationship between shear wave velocities and material stiffness is summarised below:

Shear Wave Velocity Vs Range in m/s	**Material Stiffness**
< 150	Soft
150 to 300	Firm
300 to 500	Stiff
> 500 m/s	Very Stiff

4. RESULTS AND INTERPRETATION BY LOCATION

In this chapter each of the eight survey areas is discussed.

4.1 Area A

Two lines were surveyed at area A on either side of the N14 Road. Possible outcropping rock or boulders were observed at the start of profile 8 along the embankment beside the road in the west. The models show a very thin layer of topsoil underlain by 4 – 7.5 m layer of overburden or weathered rock. It is likely this layer consists primarily of overburden towards the east where the resistivities are lower and weathered rock towards the northwest where the possible outcrop or boulders was observed and there are higher resistivities. Good rock is found at a depth of 5 – 8 m below ground level across both lines.

The MASW data was poor at the start of line 8 but became better towards the east which conforms with the interpretation of weathered rock to the northwest and overburden to the east. Line 9 shows similar MASW results but with better data from the start of the line.

4.2 Area B

Lines in Area B were surveyed in a single field in the townland of Moondooey Lower. The seismic refraction models show a three-layer model with no good rock being encountered to a depth of 15m. The 2D-Resistivity data shows homogeneous resistivities to depth which indicates little change in the subsurface composition. Low resistivities at depth in the NE of both lines indicate seismic Layer 3 consists primarily of very stiff to hard or very dense overburden with a high clay content rather than weathered rock.

The MASW data was generally good across these lines with information to a depth of 10 m in most places. Results indicate increasing stiffness of materials with depth with very stiff material within seismic Layer 3.

4.3 Area C

The survey in the townland of Drumbeg was carried out in fields on either side of a local road off the N14. In the field to the north the line was diverted around an old cottage and mound of topsoil. Both lines crossed a stream which flows south near the east side of the lines.

High seismic velocities indicate shallow rock across both lines. The layers used are layers 1, 3b, 4b and 4c. Soft and loose topsoil is between 0.5 and 3 m deep and is thickest in the SW on the higher ground. Layer 3b likely contains weathered rock and is between 1 and 4.5 m thick. The top of the good to very good rock layer is found between 2 and 6 m below ground level.

The MASW data in this area was poor and no surface waves were detected. This is due to the shallow rock found throughout this location.

4.4 Area D

Two lines were surveyed crossing a local road in the townland of Ballyholey Far. The seismic models used 2 – 3 layers and the 2D-Resistivity data shows little change with depth in subsurface composition. No good rock was encountered and it is likely layer 3 is composed of very stiff to hard clay rich overburden and very dense gravelly clay.

The MASW survey was not possible across the road which means there is a gap in the data through the middle of both lines. Where MASW data was acquired it shows a gradual stiffening of overburden material with depth from stiff to very stiff.

4.5 Area E

Lines in Area E were carried out primarily in one field just to the west of the N14 in Carrickdawson. Line 13 extended into a second field to the north. There was a ditch with flowing water between the fields. The ground was very wet and marshy at the time of surveying.

The 2D-Resitivities data shows low resistivities to depths of up to 15 m. The seismic refraction data was modelled with 2 – 3 layers. No good rock was encountered. The model is interpreted as deep clay rich overburden primarily very stiff or hard material. The GSI online geological maps indicate this overburden is alluvium.

The MASW data was good in this area and shows deep overburden increasing from stiff to very stiff with depth.

4.6 River Swilly Crossing North

Five lines were surveyed in Ballyraine along the floodplain, north of the River Swilly. The river is tidal in this area and the riverbed shows significant mud along the bank. Lines 3 – 5 were surveyed perpendicular to the river, starting close to the riverbank while lines 6 and 7 were surveyed parallel to the river. Lines 3 - 5 show shallow high resistivities towards the NW with very low resistivities near the surface close to the river. Line 7 was located close to the river. This line shows very low resistivities to depth. This is likely due to interference from saline water in the river rather than an indication of rock change. Line 6 was carried out away from the river on higher ground and shows medium to high resistivities throughout.

The seismic models were modelled with 4 layers. The topsoil layer is between 1 and 2.5 m thick across all lines. Layer 2 is between 1.5 and 3.5 m thick. This layer is predominantly sand and gravel on the higher ground to the NW and changes to clay and silt rich alluvium towards the river. Layer 3 is between 1 and 4.5 m thick and most likely consists primarily of weathered rock. The top of the good to very good rock is between 3.5 and 8.5 m below ground level.

The MASW data usefulness varies across the profiles due to changes in layer thicknesses. The models become better away from the river and show a gradual increase in stiffness into the rock layer.

4.7 Structure at CH 1900 - 2150

The survey at Drumany/Drumore consisted of two lines which crossed a small local access road. The field SW of the road was a grass field which rose towards the south. The land NE of the road was overgrown and marshy with standing water in a number of places.

The 2D-Resistivity data shows medium - high resistivities near the surface and at depth. The resistivities vary from medium to high laterally at all depths with the highest conductivities found in the middle of the lines. The seismic refraction models were modelled with a thee layer model.

The soft or loose topsoil layer is thin with a maximum thickness of 1 m. Layer 2, interpreted as medium dense to dense gravelly clay and clean sand and gravel, is generally very thin but is up to 5 m thick, particularly to the SW at the higher ground. Layer 3 is between 1 and 10 m thick and is interpreted as primarily weathered metamorphic rock. This layer is thickest towards the SW and is thin towards the NE. Layer 4 is described as good to very good slightly weathered or fresh metamorphic rock. The top of this layer is 1.5 and 11 m below ground level and is shallowest in the NE.

The MASW data shows that no surface waves were detected on the NE end of the lines due to the shallow rock. The surface waves become better towards the SW where they show increased overburden stiffness with depth.

4.8 River Finn Crossing North

Five profiles were carried out across two fields north of the River Finn near Ballybofey in the townland of Drumboe Lower. The seismic refraction data was modelled with a 3-layer model for all profiles. The top two layers are described as soft or loose topsoil and medium dense to dense sandy gravelly clay or sand and gravel. This is underlain by slightly weathered to fresh metamorphic rock at a depth of 4.5 – 6.5 m below ground level.

MASW data shows the overburden consists of primarily stiff material.

5. CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are made:

- The geophysical surveys were carried out at eight separate locations across the TEN-T scheme which showed varied geology from deep clay rich overburden to shallow good rock.
- Online geological maps indicate the underlying rock consists of various metamorphic rock types such as marble, quartzite and psammite. Overburden is described generally as glacial till and alluvium near the two rivers.
- Seismic refraction, 2D-Resistivity and MASW surveying was carried out at all locations. Due to varying ground conditions, surface waves do not exist everywhere and the MASW method does not work in all locations leading to some ‘gaps’ in data in some areas and no MASW results at all for area C.
- Seismic refraction data was modelled with four layers ranging from soft and loose topsoil to good to very good rock. The good to very good rock layer was found in 5 of the 8 sites.
- Seismic refraction layers 2 – 4 were subdivided using the 2D-Resistivity data to provide information on the subsurface composition.
- Layer 2 is subdivided into firm to stiff clay and silt, medium dense to dense gravelly clay and clean sand and gravel. Layer 3 is interpreted as very stiff to hard clay or silt, very dense gravelly clay or poor to fair weathered metamorphic rock. Layer 4 is described as either slightly weathered or fresh goof to very good metamorphic rock.
- The shallowest good to very good rock is found at Area C and the structure at CH1900 – 2150 where the good to very good rock layer is as shallow as 1.5 – 2 m below ground level in some parts.
- Area B, Area D and Area E have seismic layer 3 as their deepest layer which is interpreted as primarily very stiff to hard or very dense overburden rather than weathered rock.
- The lowest resistivities are found at Area E which is interpreted as clay rich overburden to depths of up to 15 m.
- The interpretation presented here should be reviewed after direct ground investigation data becomes available.

6. REFERENCES

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Table 1: Geophysical Survey Locations and Acquisition Parameters

2D-Resistivity Survey

Area	Line	Profile	Electrode Spacing (m)	Length (m)
Area B	B2	R1	3	69
Area B	B1	R2	3	72
River Swilly Crossing North	A	R3	3	105
River Swilly Crossing North	B	R4	3	102
River Swilly Crossing North	C	R5	3	99
River Swilly Crossing North	D	R6	3	93
River Swilly Crossing North	E	R7	3	93
Area A	A1	R8	3	99
Area A	A2	R9	3	102
Structure at CH 1900 - 2150	B	R10	3	189
Structure at CH 1900 - 2150	A	R11	3	177
Area E	E2	R12	3	156
Area E	E1	R13	3	108
River Finn Crossing North	A	R14	3	57
River Finn Crossing North	B	R15	3	51
River Finn Crossing North	C	R16	3	48
River Finn Crossing North	E	R17	3	72
River Finn Crossing North	D	R18	3	72
Area C	C1	R19	3	105
Area C	C2	R20	3	99
Area D	D2	R21	3	63
Area D	D1	R22	3	81
			SUM	**2112**

Seismic Refraction Survey

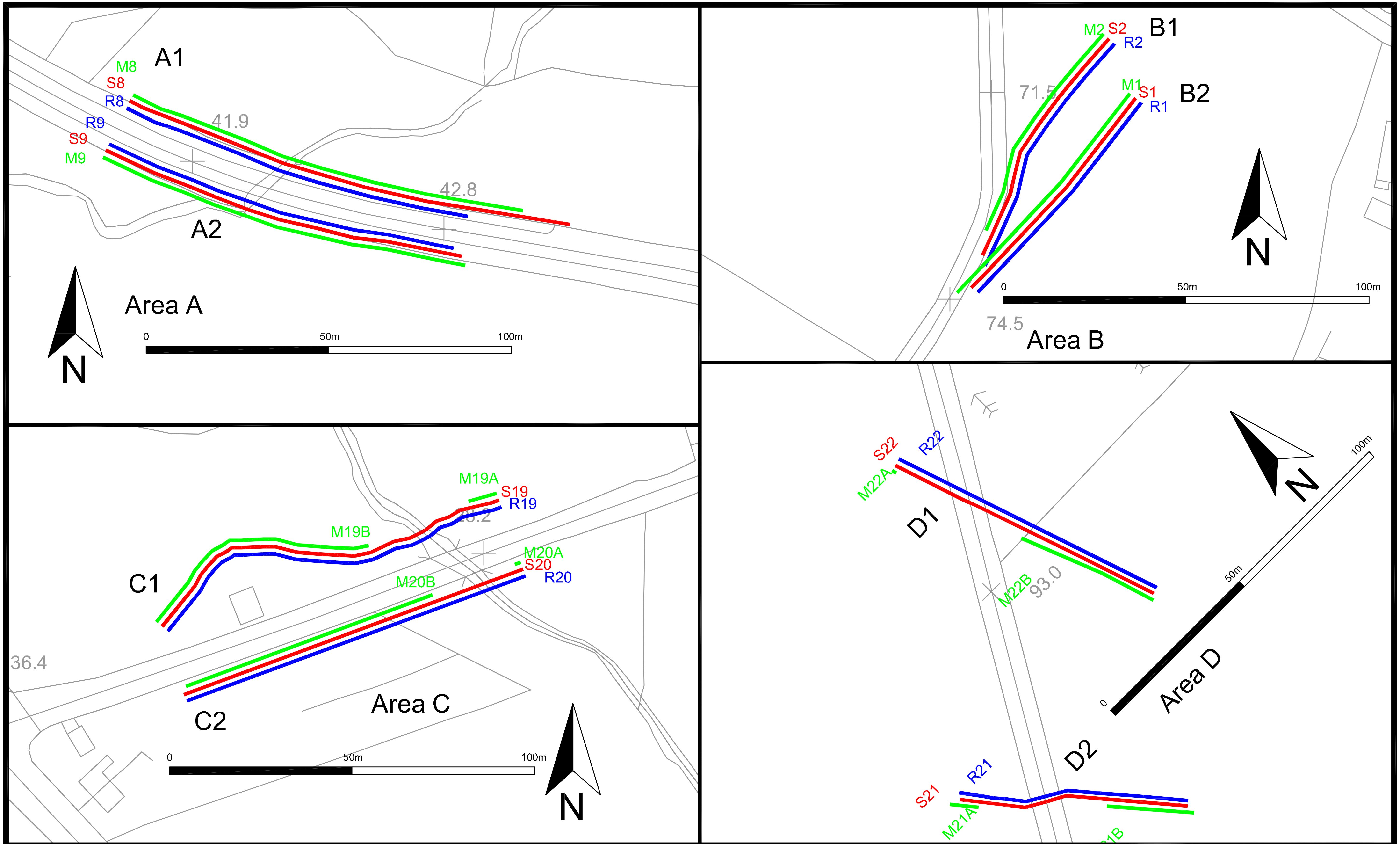
Area	Line	Profile	Geophone Spacing (m)	Length (m)
Area B	B2	S1	3	69
Area B	B1	S2	3	69
River Swilly Crossing North	A	S3	3	105
River Swilly Crossing North	B	S4	3	102
River Swilly Crossing North	C	S5	3	99
River Swilly Crossing North	D	S6	3	69
River Swilly Crossing North	E	S7	3	69
Area A	A1	S8	3	99
Area A	A2	S9	3	102
Structure at CH 1900 - 2150	B	S10	3	189
Structure at CH 1900 - 2150	A	S11	3	174
Area E	E2	S12	3	141
Area E	E1	S13	3	108
River Finn Crossing North	A	S14	3	57
River Finn Crossing North	B	S15	3	51
River Finn Crossing North	C	S16	3	48
River Finn Crossing North	E	S17	3	69

Table 1: Geophysical Survey Locations and Acquisition Parameters

River Finn Crossing North	D	S18	3	69
Area C	C1	S19	3	105
Area C	C2	S20	3	99
Area D	D2	S21	3	63
Area D	D1	S22	3	81
			SUM	**2037**
MASW Survey				
Area	**Line**	**Profile**	**Electrode Spacing (m)**	**Set out Length (m)**
Area B	B2	M1	1	95
Area B	B1	M2	1	95
River Swilly Crossing North	A	M3	1	119
River Swilly Crossing North	B	M4	1	119
River Swilly Crossing North	C	M5	1	111
River Swilly Crossing North	D	M6	1	55
River Swilly Crossing North	E	M7	1	55
Area A	A1	M8	1	127
Area A	A2	M9	1	127
Structure at CH 1900 - 2150	B	M10	1	204
Structure at CH 1900 - 2150	A	M11	1	199
Area E	E2	M12	1	175
Area E	E1	M13	1	135
River Finn Crossing North	A	M14	1	79
River Finn Crossing North	B	M15	1	79
River Finn Crossing North	C	M16	1	71
River Finn Crossing North	E	M17	1	95
River Finn Crossing North	D	M18	1	95
Area C	C1	M19A	1	31
Area C	C1	M19B	1	95
Area C	C2	M20A	1	23
Area C	C2	M20B	1	95
Area D	D2	M21A	1	31
Area D	D2	M21B	1	47
Area D	D1	M22A	1	23
Area D	D1	M22B	1	63
				2443

Table 2: Structure Locations and Geological Background

Location Name	Subsoils	Bedrock	Outcrop (Rock < 2m bgl)	Faults
A	Till derived from metamorphic Rocks	Aghyaran & Killygordon Limestone Formation - Marble, quartzite, psammite; graphitic	Yes - East side of profiles	No
B	Till derived from metamorphic Rocks	Aghyaran & Killygordon Limestone Formation - Marble, quartzite, psammite; graphitic	No	No
C	Till derived from metamorphic Rocks and Alluvium close to stream	Aghyaran & Killygordon Limestone Formation - Marble, quartzite, psammite; graphitic	Yes	No
D	Till derived from metamorphic Rocks	Aghyaran & Killygordon Limestone Formation - Marble, quartzite, psammite; graphitic	No	No
E	East:Till derived from metamorphic Rocks West: Alluvium	Aghyaran & Killygordon Limestone Formation - Marble, quartzite, psammite; graphitic	230 m to East	No
River Swilly Crossing North	Urban, Alluvium near river	Termon Formation - Banded semi-pelitic & psammitic Schist	Yes	No
Structure at CH 1900 - 2150	Till derived from metamorphic Rocks	North: Killeter Quartzite Formation - Slightly Impure Quartzite South: Termon Formation - Banded semi-pelitic & psammitic Schist	200 m to North	No
River Finn Crossing North	Alluvium	Lough Eske Psammite Formation - Feldspathic psammite; quartzite, marble	No	No
All Information is from the Geological Survey of Ireland Database and Maps (GSI 2020)				



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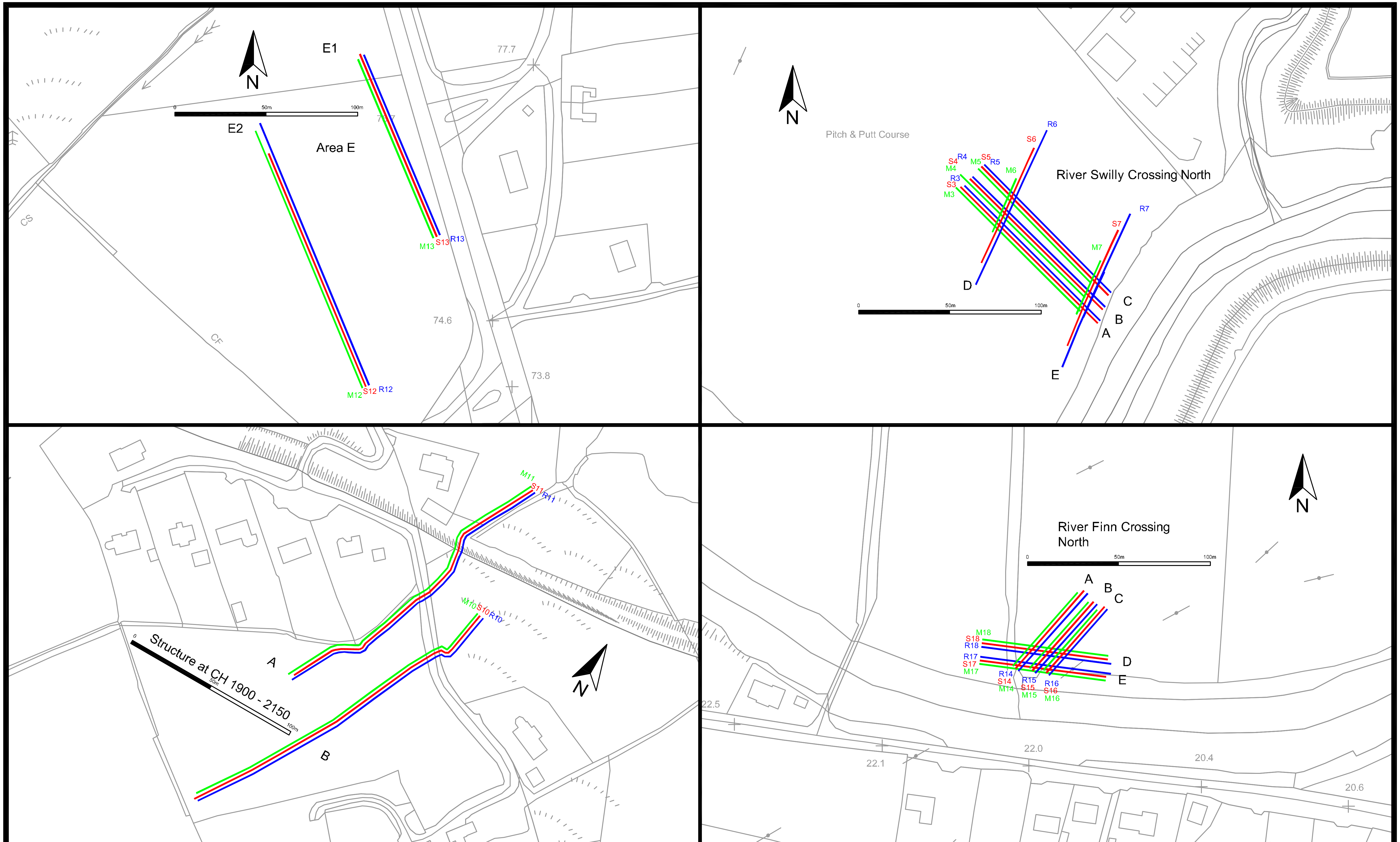
CLIENT	Irish Drilling Ltd.
PROJECT	Ten-T Co. Donegal Geophysical Survey
TITLE	Map 1a: Geophysical Surevy Location Map

SCALE:	1:1000 @ A3
PROJECT:	6526
DRAWN:	HK
DATE:	18/09/2020
MGX FILE:	6526d_MapsFigs.dwg
STATUS:	Draft

LEGEND: Geophysical Survey Locations:

R2	2D-Resistivity Profile
S1	Seismic Refraction Profile
M3	MASW Profile



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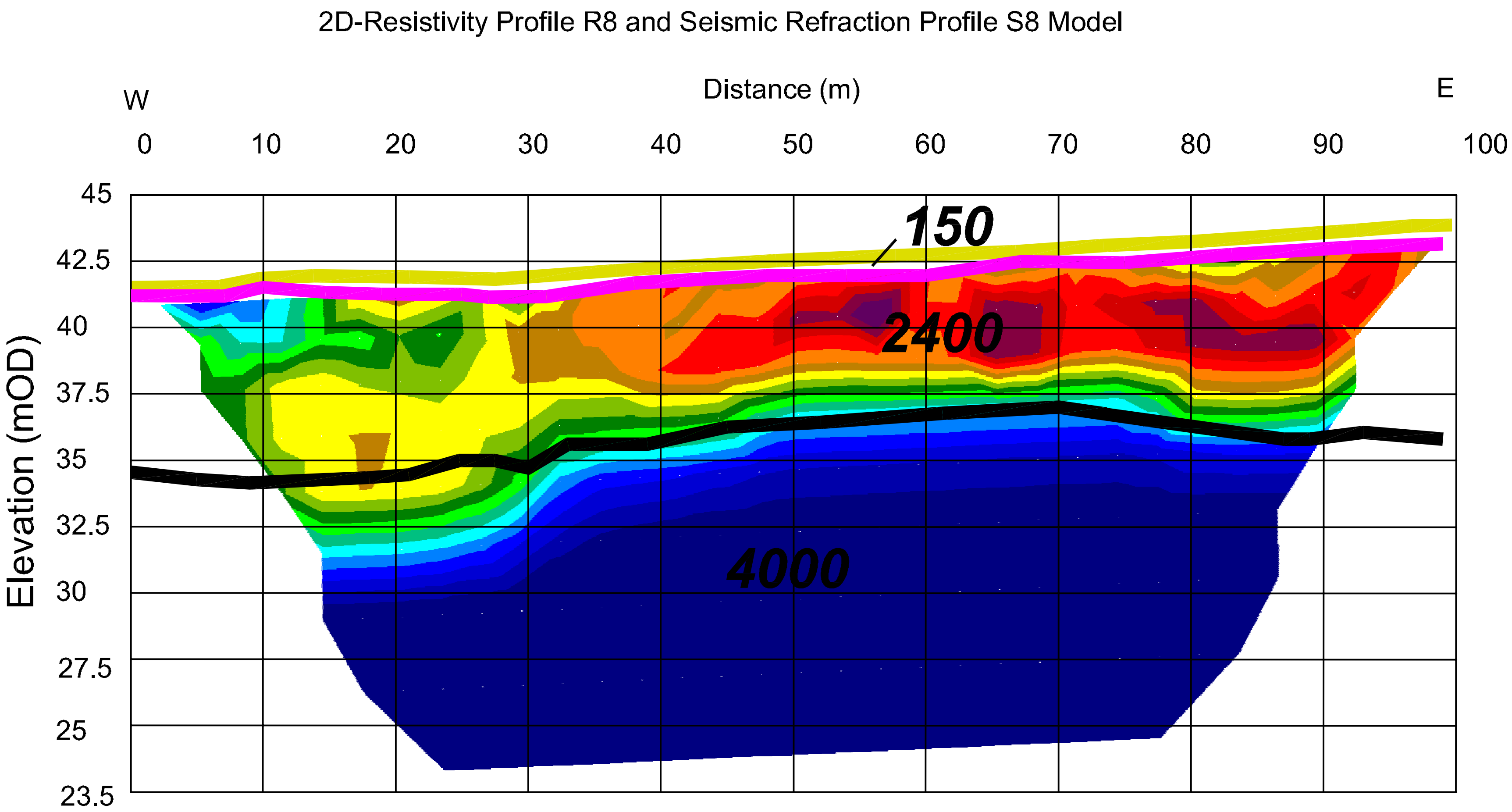
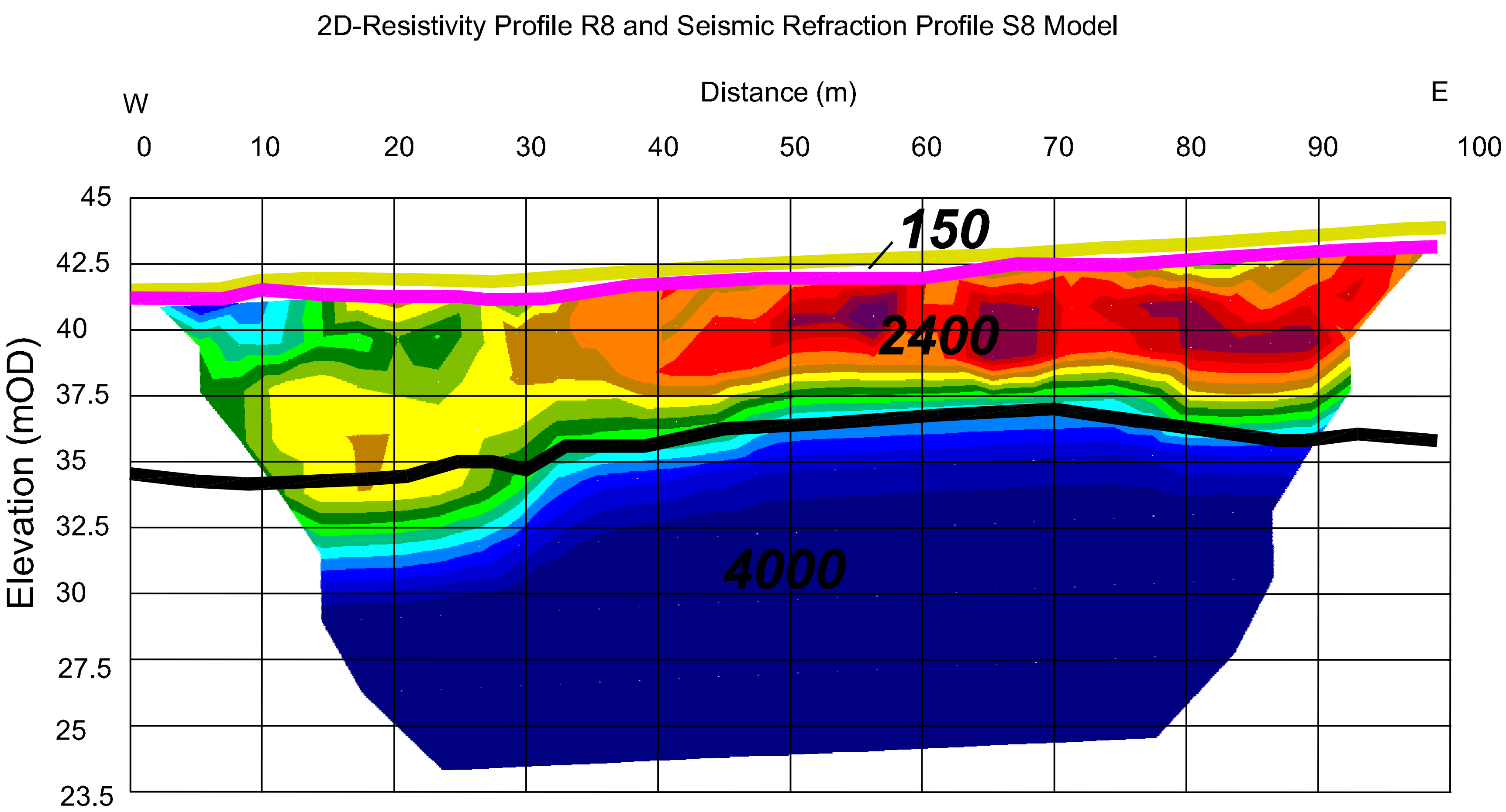
CLIENT	Irish Drilling Ltd.
PROJECT	Ten-T Co. Donegal Geophysical Survey
TITLE	Map 1b: Geophysical Surevy Location Map

SCALE:	1:2000 @ A3
PROJECT:	6526
DRAWN:	HK
DATE:	18/09/2020
MGX FILE:	6526d_MapsFigs.dwg
STATUS:	Draft

LEGEND: **Geophysical Survey Locations:**

R2	2D-Resistivity Profile
S1	Seismic Refraction Profile
M3	MASW Profile





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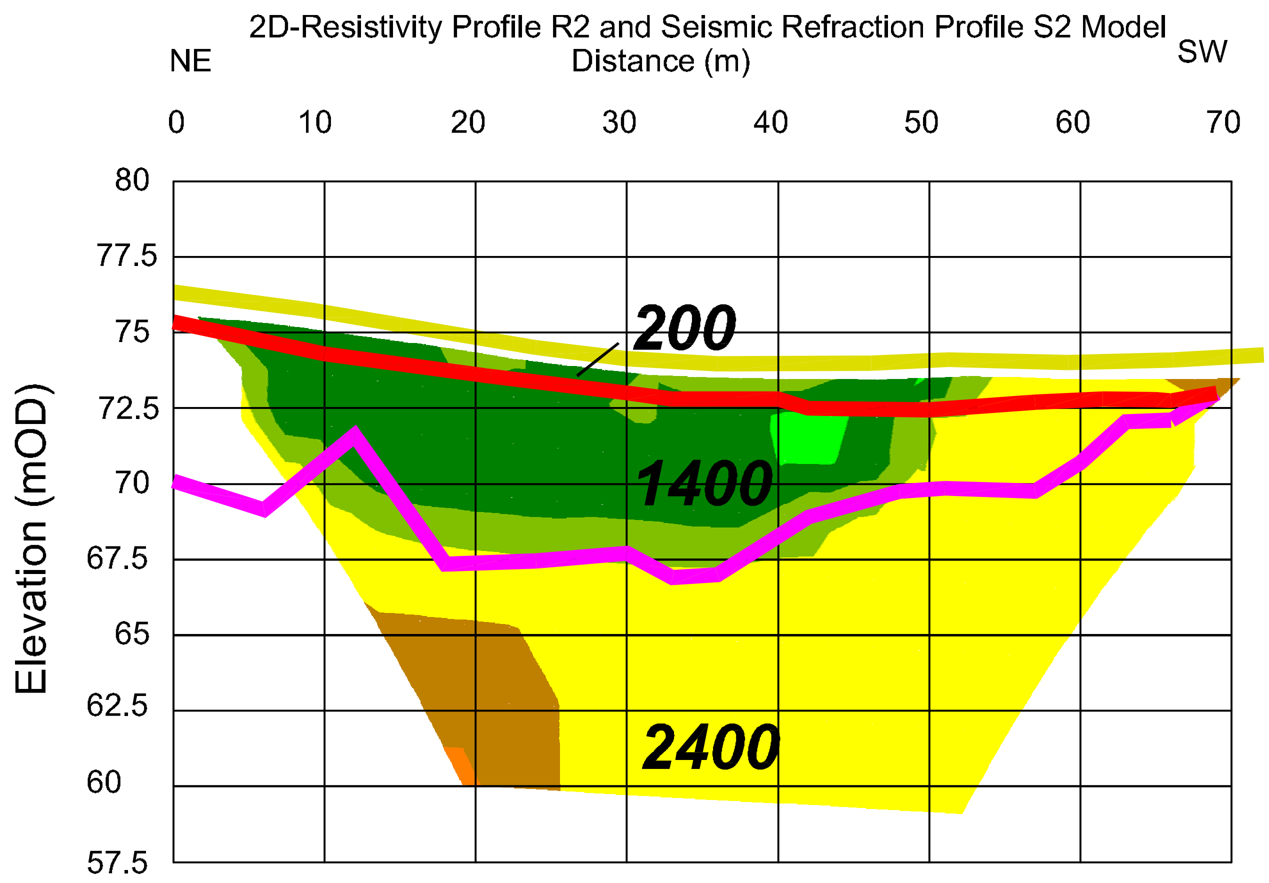
CLIENT	Irish Drilling Ltd.
PROJECT	TEN-T, County Donegal Geophysical Survey
TITLE	Figure 1a: Models of Geophysical Survey for Area A

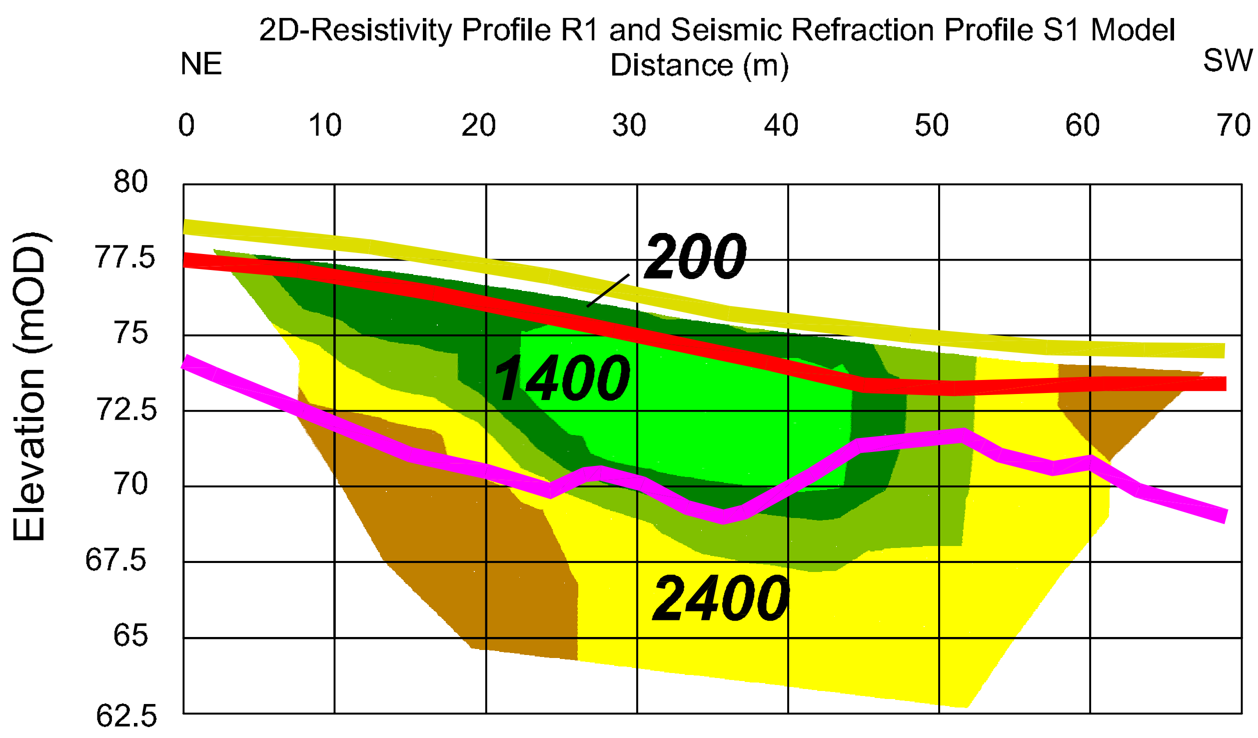
SCALE:	1:500 @ A3, VE x 2
PROJECT:	6526
DRAWN:	JC
DATE:	27/10/2020
MGX FILE:	6526d_MapsFigs.dwg
STATUS:	Draft

LEGEND: Layers from Seismic Refraction Model:
- Ground Surface/Top of Layer 1 (100 - 300 m/s)
- Top of Layer 2 (800 - 1600 m/s)
- Top of Layer 3 (1800 - 2600 m/s)
- Top of Layer 4 (3000 - 4500 m/s)

2D-Resistivity Model Values:
Resistivities (Ohmm) for 2D-Resistivity Model

31.3 62.5 125 250 500 1000 2000 4000





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CLIENT	Irish Drilling Ltd.
PROJECT	TEN-T, County Donegal Geophysical Survey
TITLE	Figure 1b: Models of Geophysical Survey for Area B

SCALE:	1:500 @ A3, VE x 2
PROJECT:	6526
DRAWN:	JC
DATE:	27/10/2020
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STATUS:	Draft

LEGEND: Layers from Seismic Refraction Model:
- Ground Surface/Top of Layer 1 (100 - 300 m/s)
- Top of Layer 2 (800 - 1600 m/s)
- Top of Layer 3 (1800 - 2600 m/s)
- Top of Layer 4 (3000 - 4500 m/s)

2D-Resistivity Model Values:
Resistivities (Ohmm) for 2D-Resistivity Model
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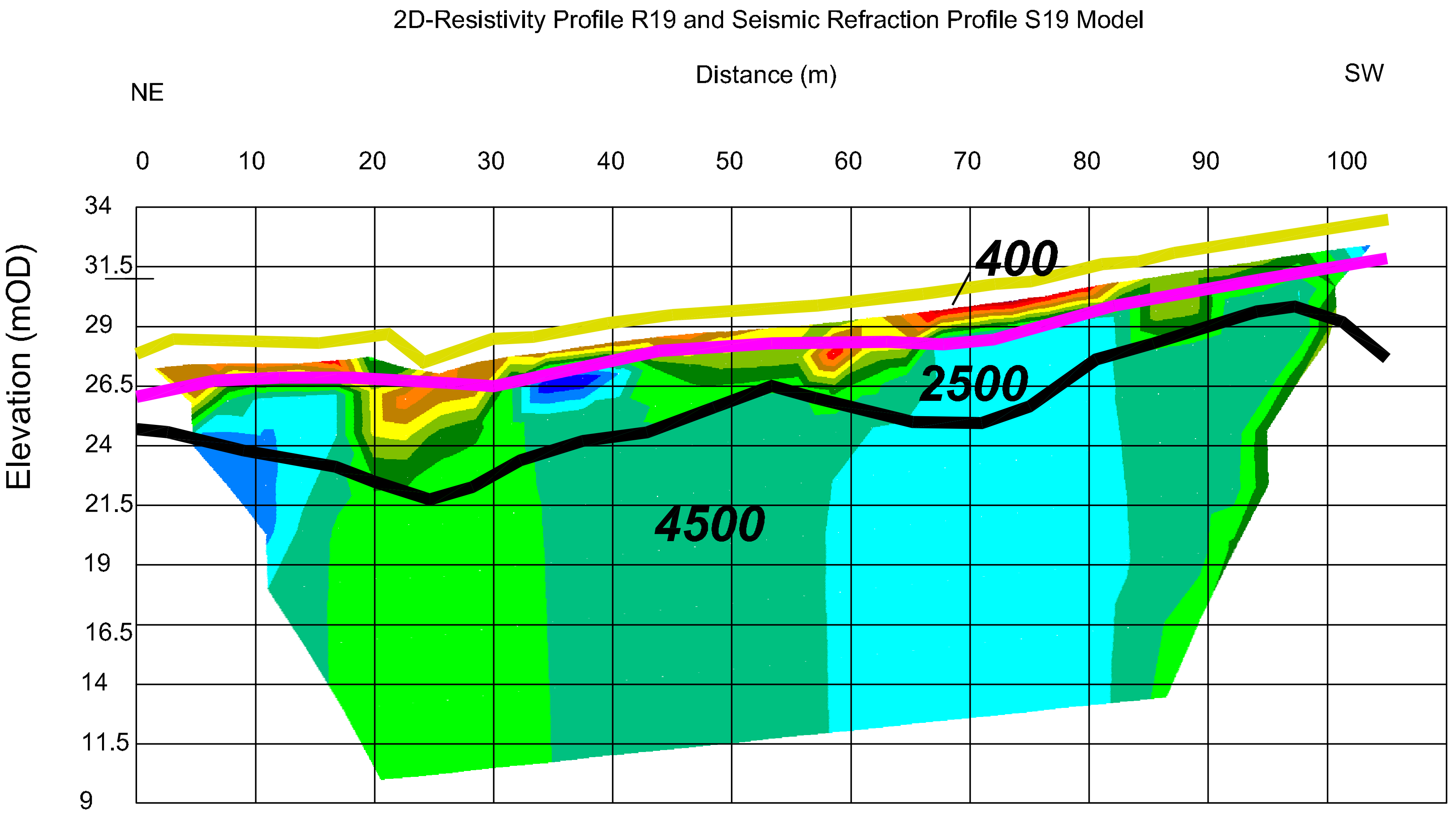

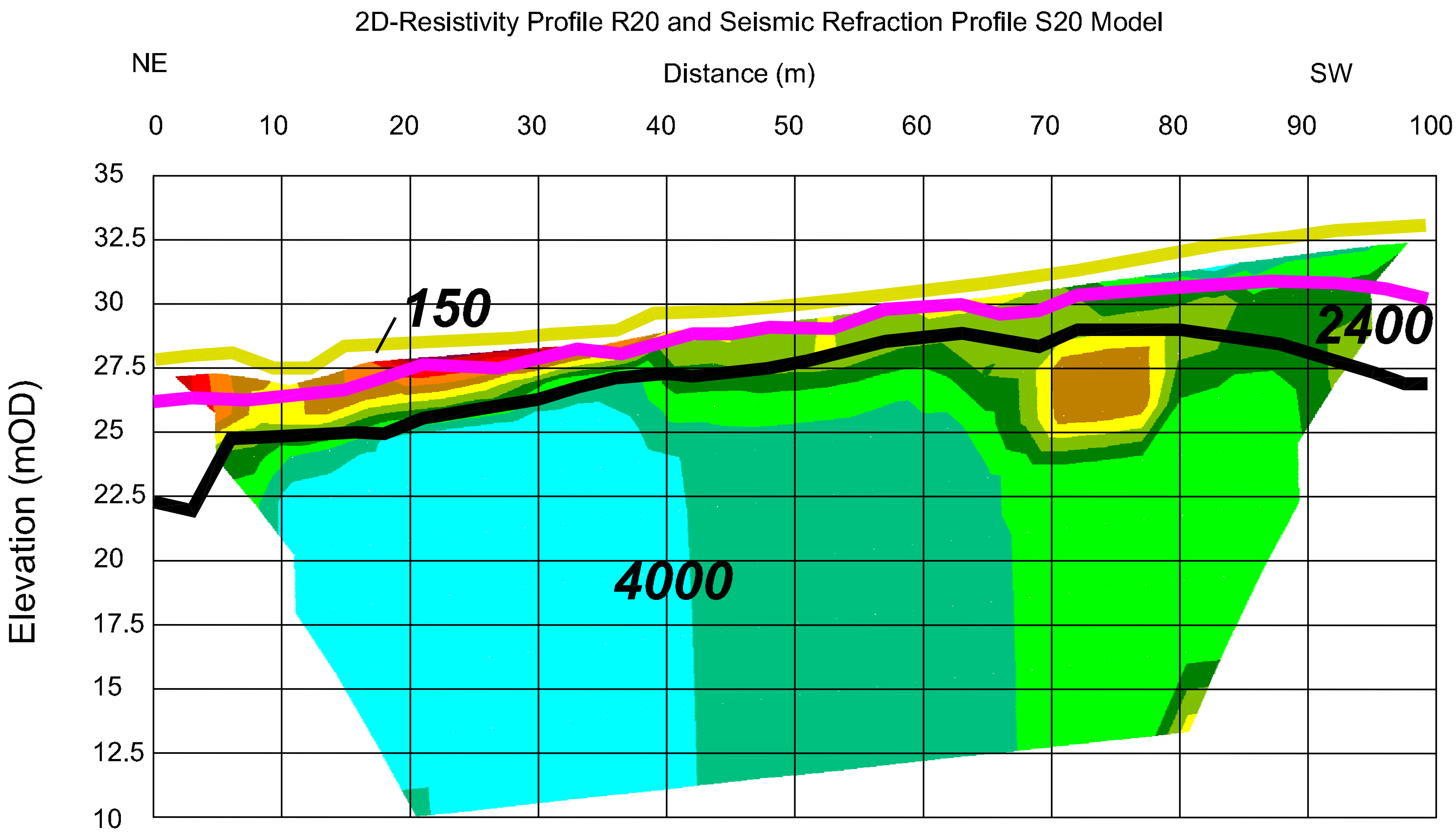

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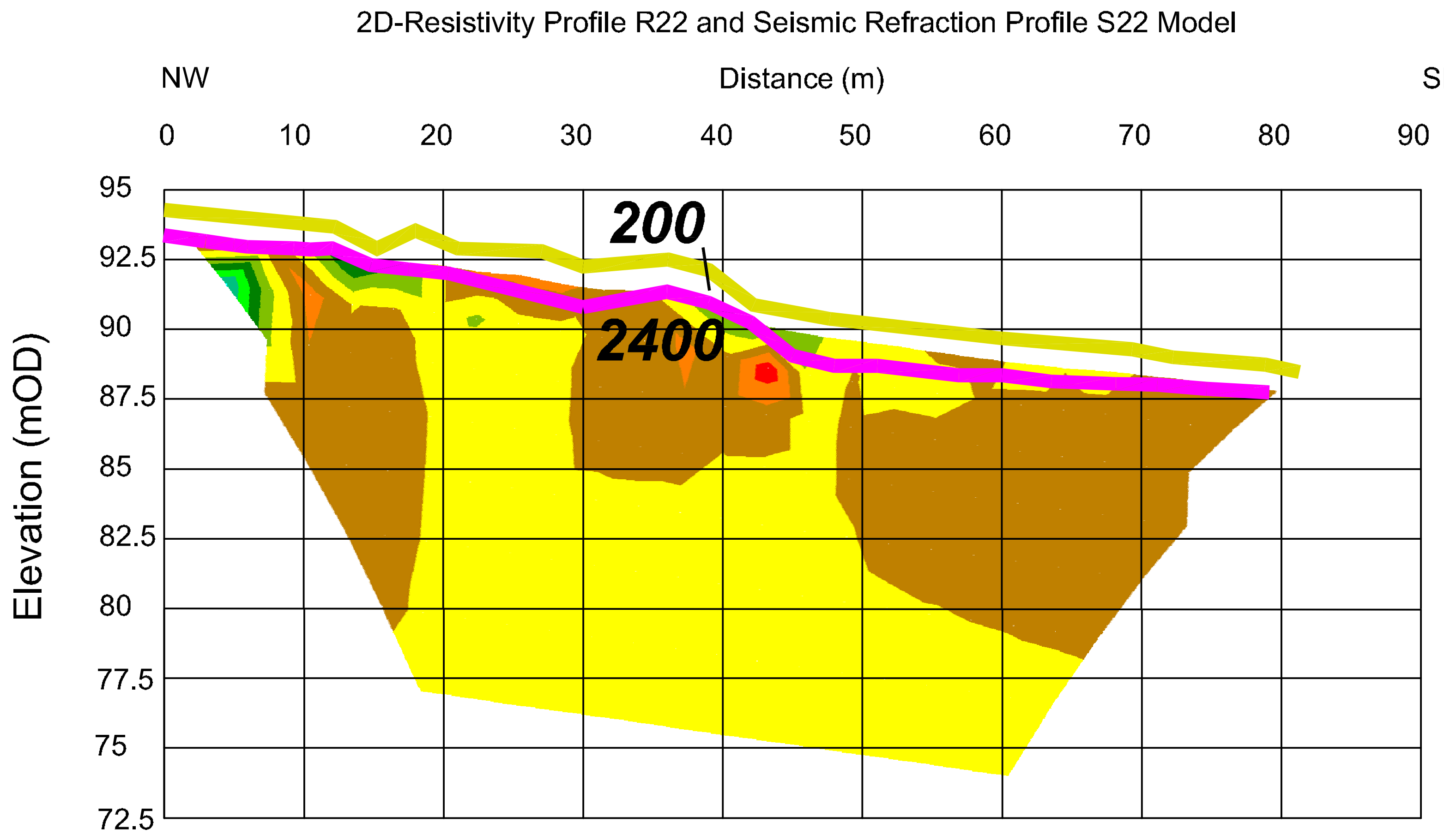
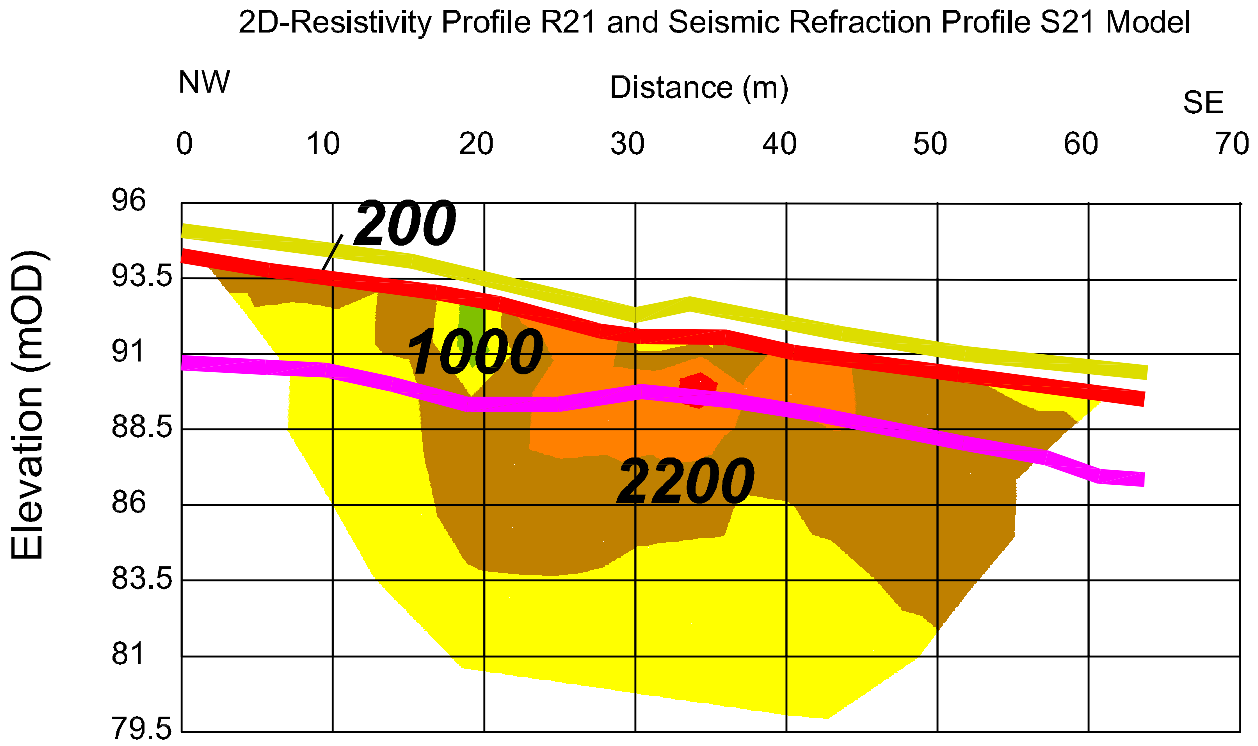
CLIENT	Irish Drilling Ltd.	SCALE:	1:500 @ A3, VE x 2
PROJECT	TEN-T, County Donegal Geophysical Survey	PROJECT:	6526
		DRAWN:	JC
		DATE:	27/10/2020
TITLE	Figure 1c: Models of Geophysical Survey for Area C	MGX FILE:	6526d_MapsFigs.dwg
		STATUS:	Draft

LEGEND: Layers from Seismic Refraction Model:
- Ground Surface/Top of Layer 1 (100 - 300 m/s)
- Top of Layer 2 (800 - 1600 m/s)
- Top of Layer 3 (1800 - 2600 m/s)
- Top of Layer 4 (3000 - 4500 m/s)

2D-Resistivity Model Values:
Resistivities (Ohmm) for 2D-Resistivity Model
31.3 62.5 125 250 500 1000 2000 4000





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CLIENT	Irish Drilling Ltd.
PROJECT	TEN-T, County Donegal Geophysical Survey
TITLE	Figure 1d: Models of Geophysical Survey for Area D

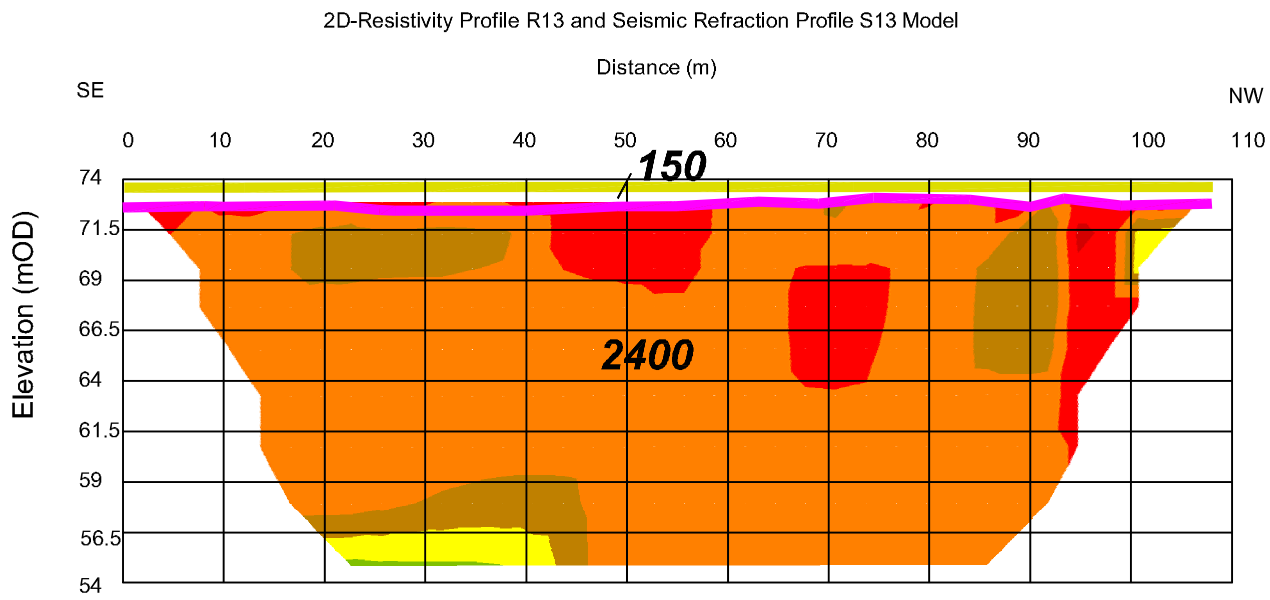
SCALE:	1:500 @ A3, VE x 2
PROJECT:	6526
DRAWN:	JC
DATE:	27/10/2020
MGX FILE:	6526d_MapsFigs.dwg
STATUS:	Draft

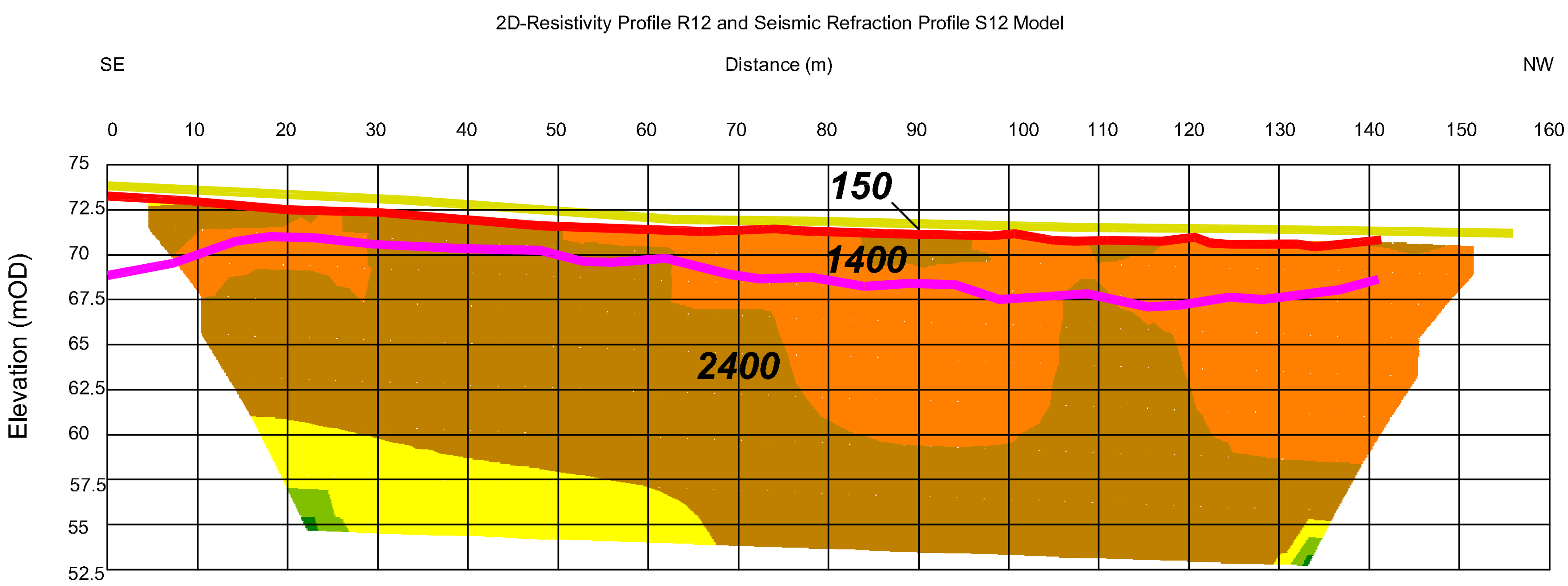
LEGEND: Layers from Seismic Refraction Model:

- Ground Surface/Top of Layer 1 (100 - 300 m/s)
- Top of Layer 2 (800 - 1600 m/s)
- Top of Layer 3 (1800 - 2600 m/s)
- Top of Layer 4 (3000 - 4500 m/s)

2D-Resistivity Model Values:
Resistivities (Ohmm) for 2D-Resistivity Model

31.3 62.5 125 250 500 1000 2000 4000





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CLIENT Irish Drilling Ltd.

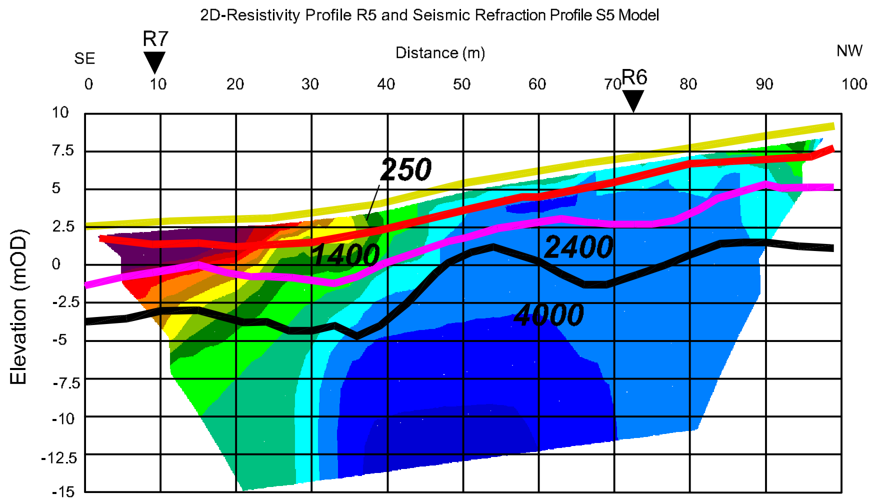
PROJECT TEN-T, County Donegal Geophysical Survey

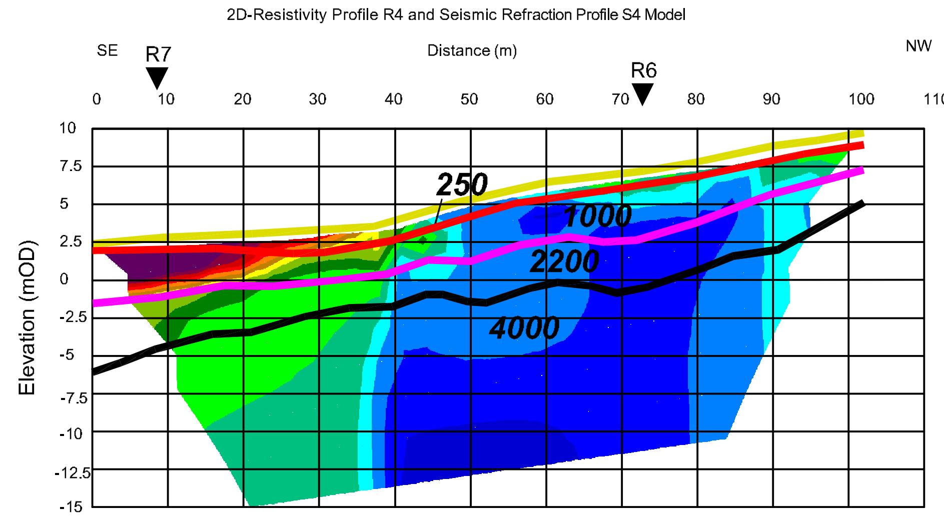
TITLE Figure 1e: Models of Geophysical Survey for Area E

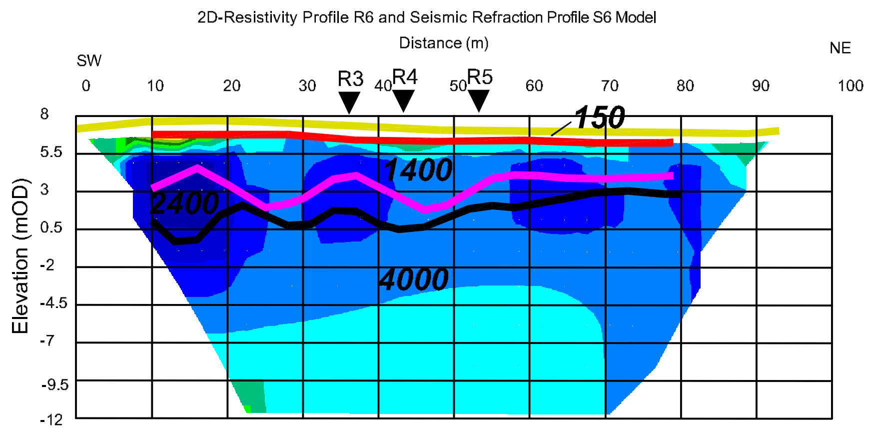
SCALE:	1:750 @ A3, VE x 2
PROJECT:	6526
DRAWN:	JC
DATE:	27/10/2020
MGX FILE:	6526d_MapsFigs.dwg
STATUS:	Draft

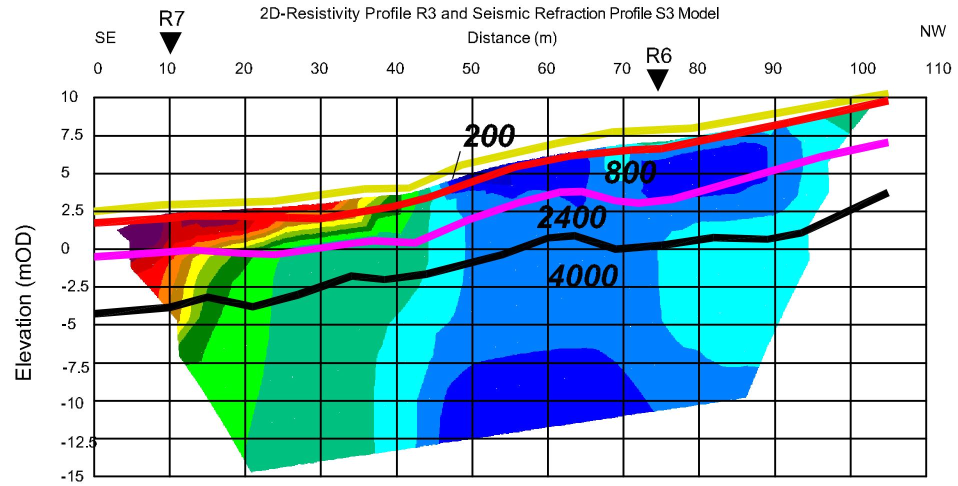
LEGEND: Layers from Seismic Refraction Model:
Ground Surface/Top of Layer 1 (100 - 300 m/s)
Top of Layer 2 (800 - 1600 m/s)
Top of Layer 3 (1800 - 2600 m/s)
Top of Layer 4 (3000 - 4500 m/s)

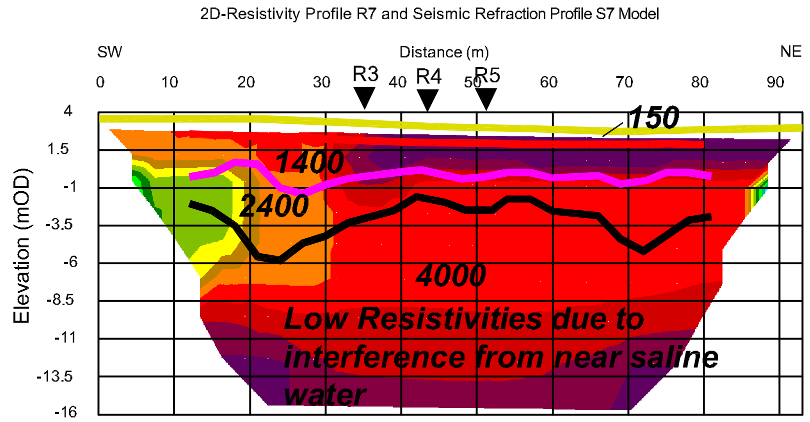
2D-Resistivity Model Values:
Resistivities (Ohmm) for 2D-Resistivity Model
31.3 62.5 125 250 500 1000 2000 4000











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CLIENT	Irish Drilling Ltd.
PROJECT	TEN-T, County Donegal Geophysical Survey
TITLE	Figure 1f: Models of Geophysical Survey for River Swilly Crossing N

SCALE:	1:1000 @ A3, VE x 2
PROJECT:	6526
DRAWN:	JC
DATE:	27/10/2020
MGX FILE:	6526d_MapsFigs.dwg
STATUS:	Draft

LEGEND:

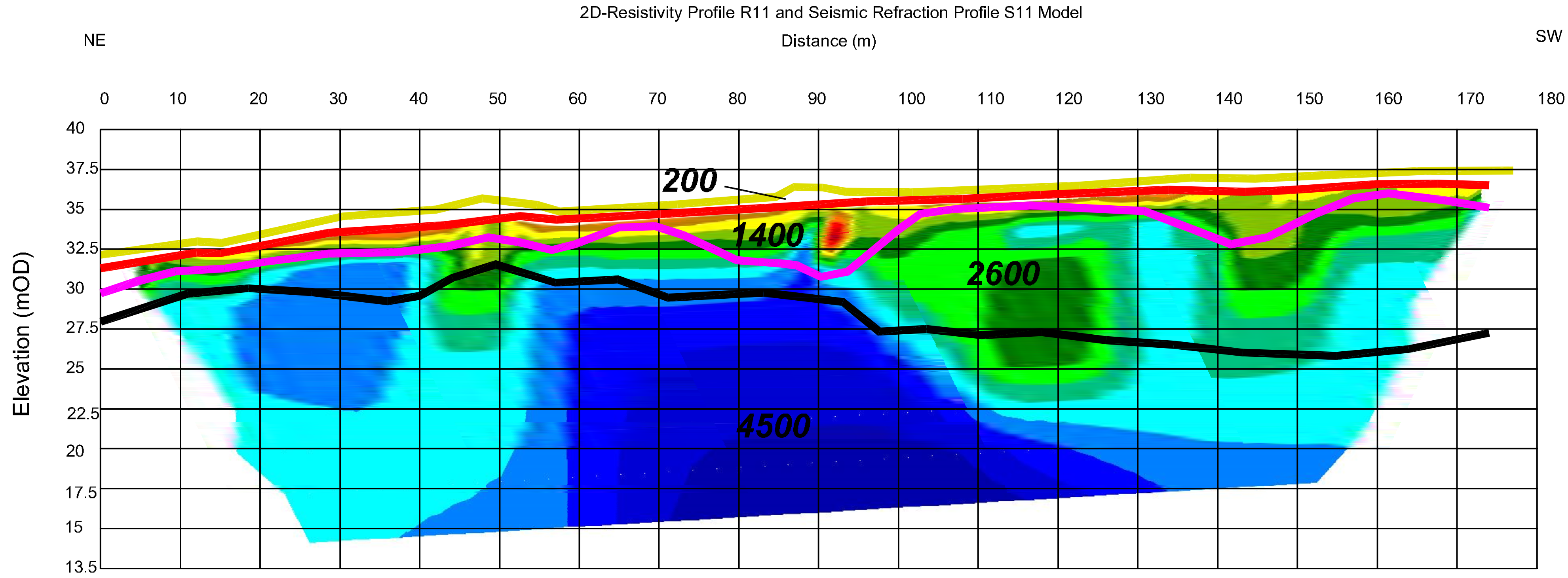
Layers from Seismic Refraction Model:

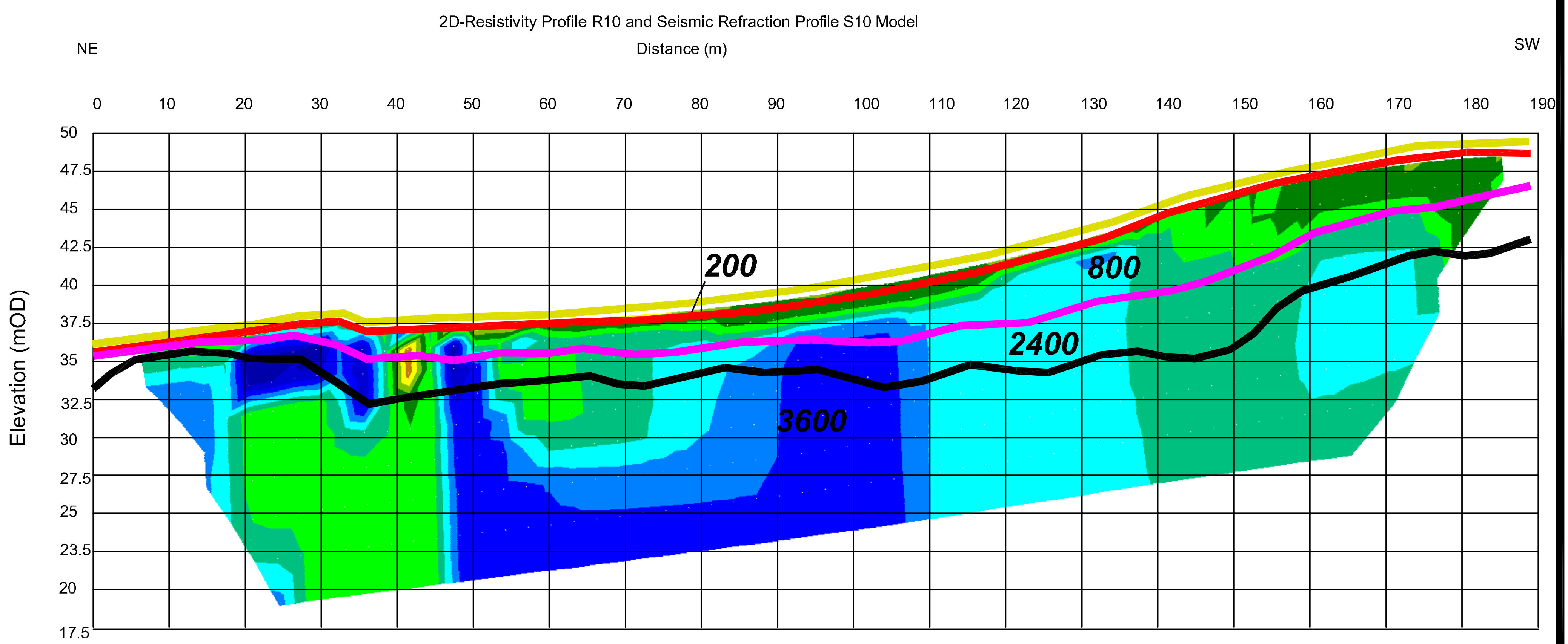
- Ground Surface/Top of Layer 1 (100 - 300 m/s)
- Top of Layer 2 (800 - 1600 m/s)
- Top of Layer 3 (1800 - 2600 m/s)
- Top of Layer 4 (3000 - 4500 m/s)

2D-Resistivity Model Values:

Resistivities (Ohmm) for 2D-Resistivity Model

31.3 62.5 125 250 500 1000 2000 4000





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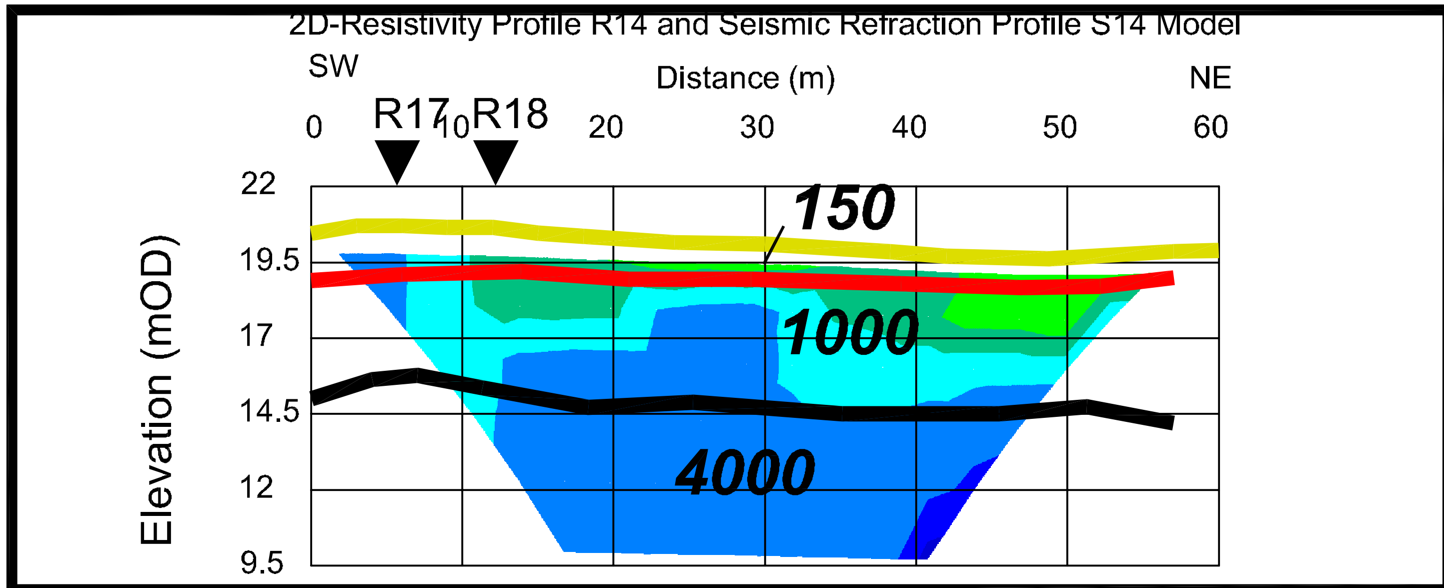
CLIENT	Irish Drilling Ltd.
PROJECT	TEN-T, County Donegal Geophysical Survey
TITLE	Figure 1g: Models of Geolphysical Survey for CH 1+900 - 2+150

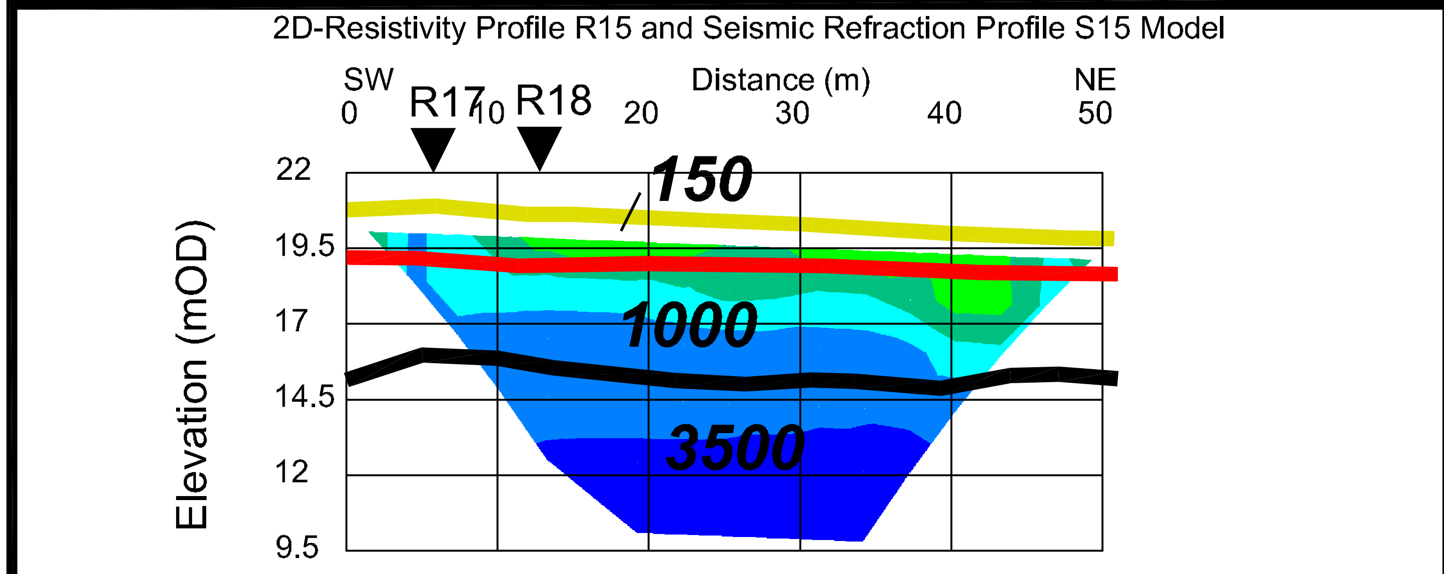
SCALE:	1:750 @ A3, VE x 2
PROJECT:	6526
DRAWN:	JC
DATE:	27/10/2020
MGX FILE:	6526d_MapsFigs.dwg
STATUS:	Draft

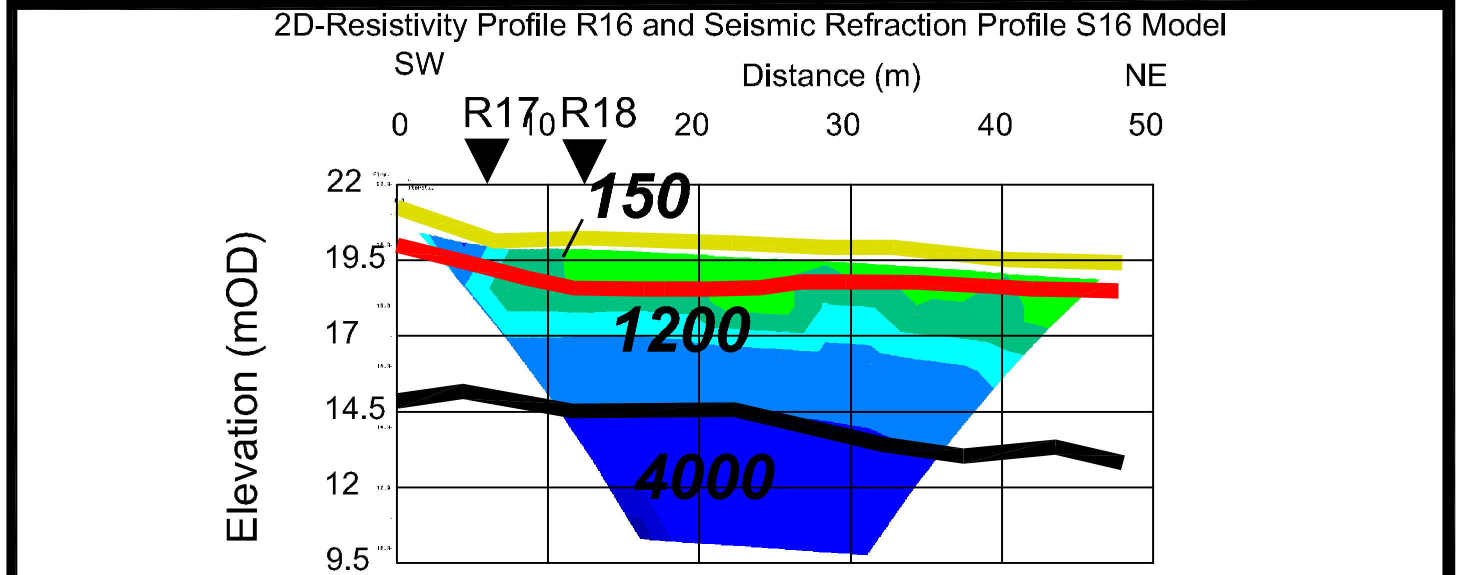
LEGEND: Layers from Seismic Refraction Model:
- Ground Surface/Top of Layer 1 (100 - 300 m/s)
- Top of Layer 2 (800 - 1600 m/s)
- Top of Layer 3 (1800 - 2600 m/s)
- Top of Layer 4 (3000 - 4500 m/s)

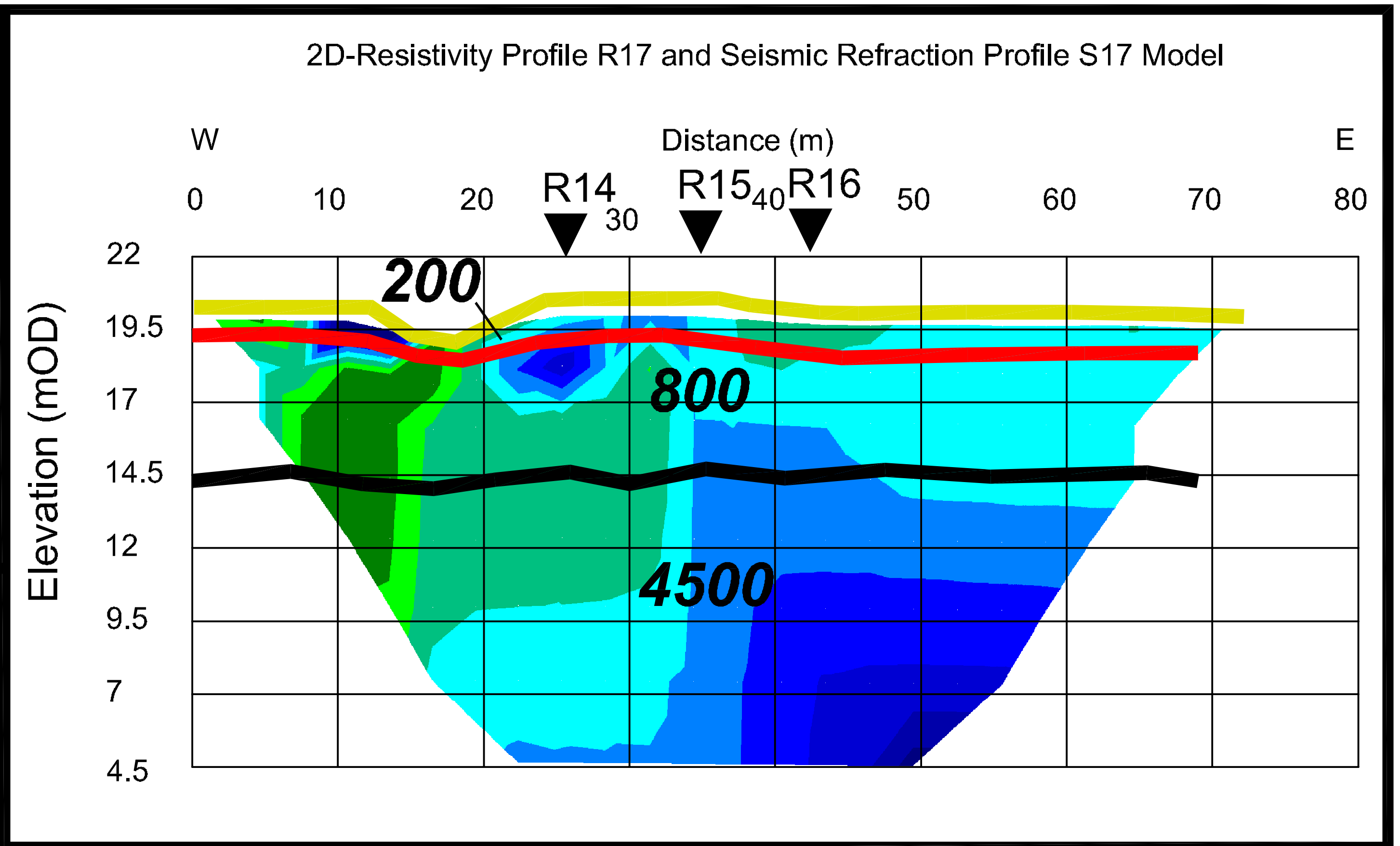
2D-Resistivity Model Values:
Resistivities (Ohmm) for 2D-Resistivity Model

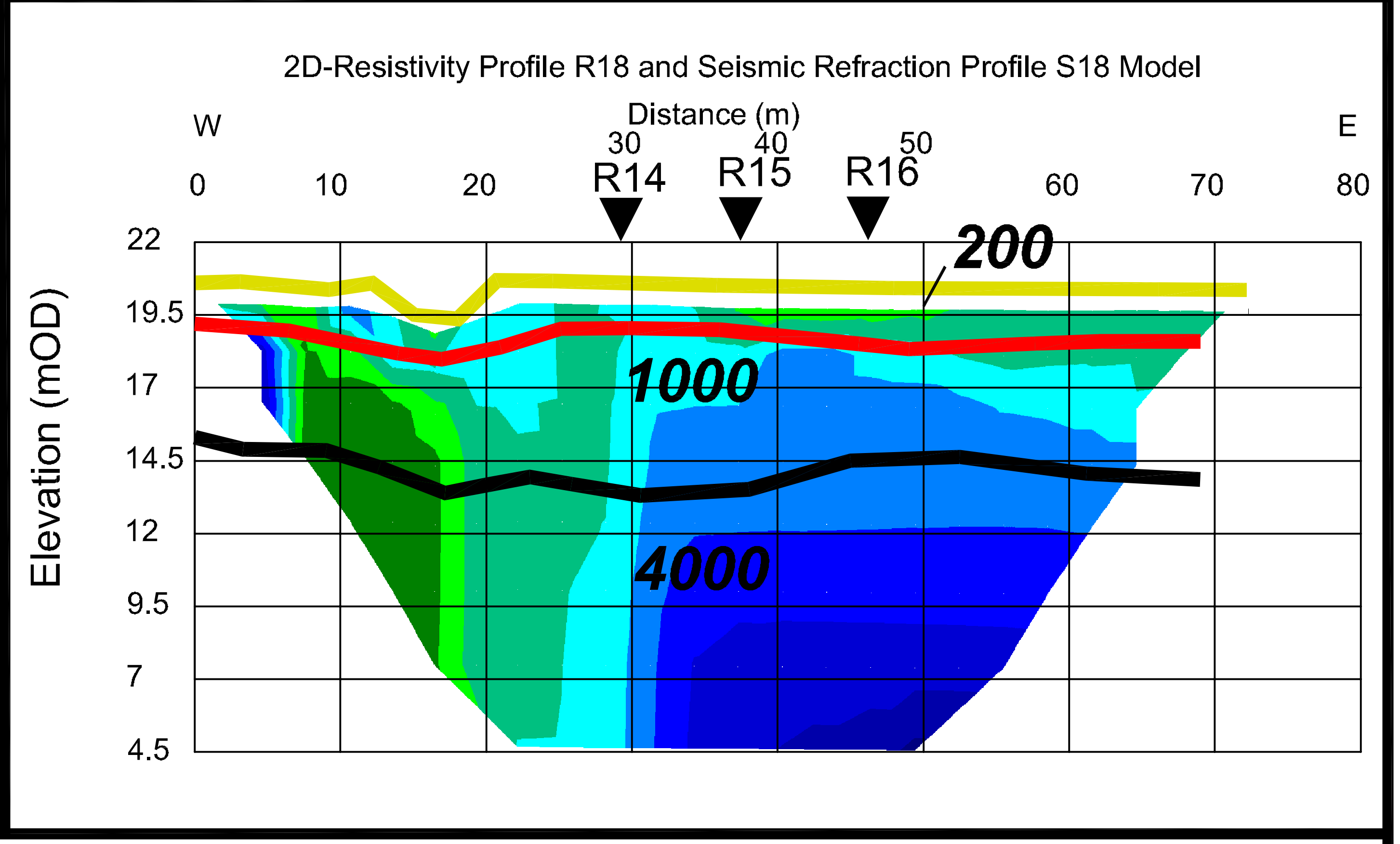
31.3 62.5 125 250 500 1000 2000 4000











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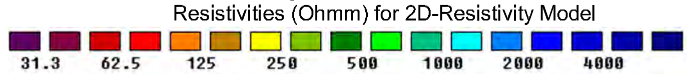
CLIENT	Irish Drilling Ltd.
PROJECT	TEN-T, County Donegal Geophysical Survey
TITLE	Figure 1h: Models of Geophysical Survey for River Finn Crossing N

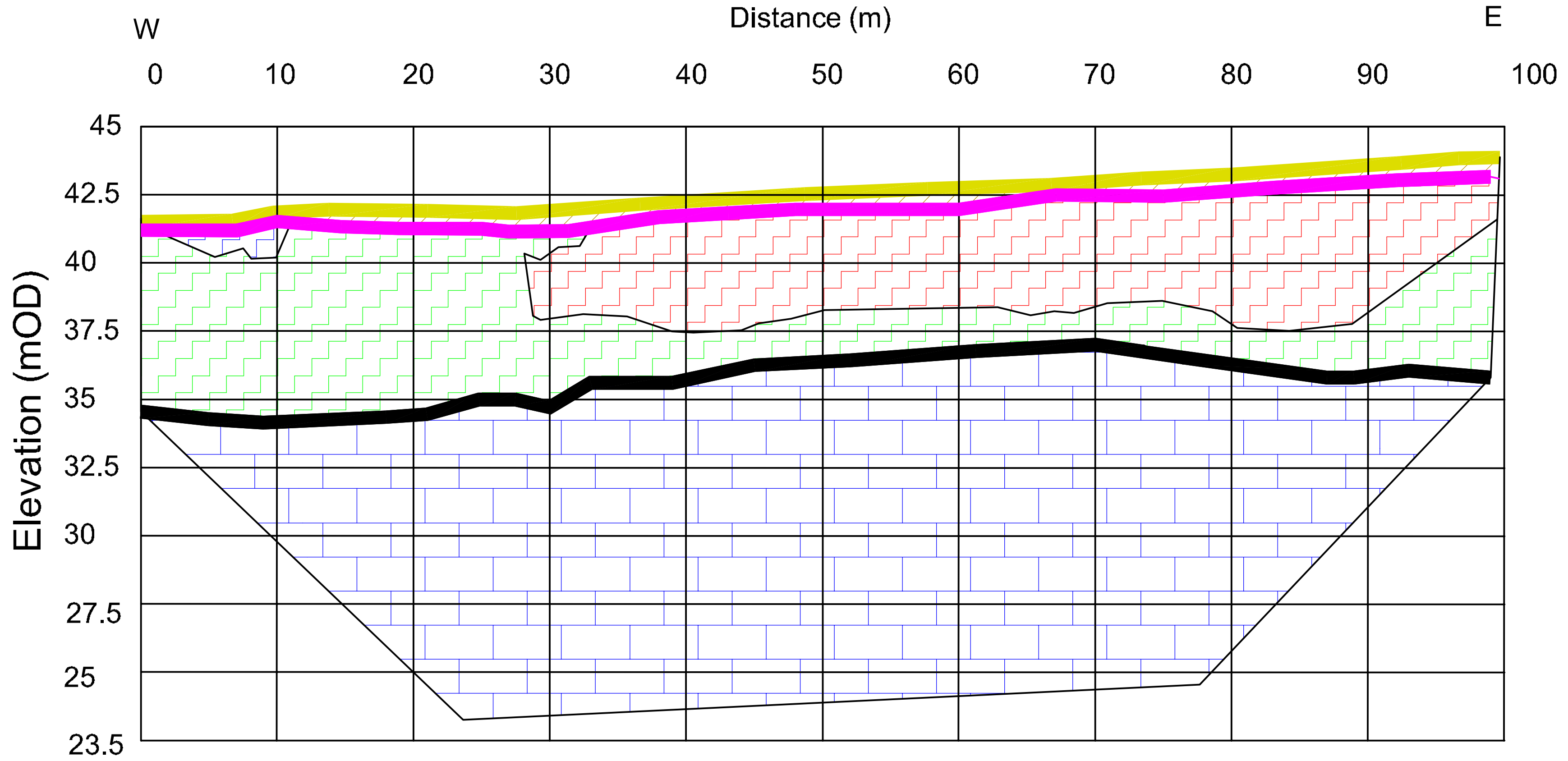
SCALE:	1:500 @ A3, VE x 2
PROJECT:	6526
DRAWN:	JC
DATE:	27/10/2020
MGX FILE:	6526d_MapsFigs.dwg
STATUS:	Draft

LEGEND: Layers from Seismic Refraction Model:
- Ground Surface/Top of Layer 1 (100 - 300 m/s)
- Top of Layer 2 (800 - 1600 m/s)
- Top of Layer 3 (1800 - 2600 m/s)
- Top of Layer 4 (3000 - 4500 m/s)

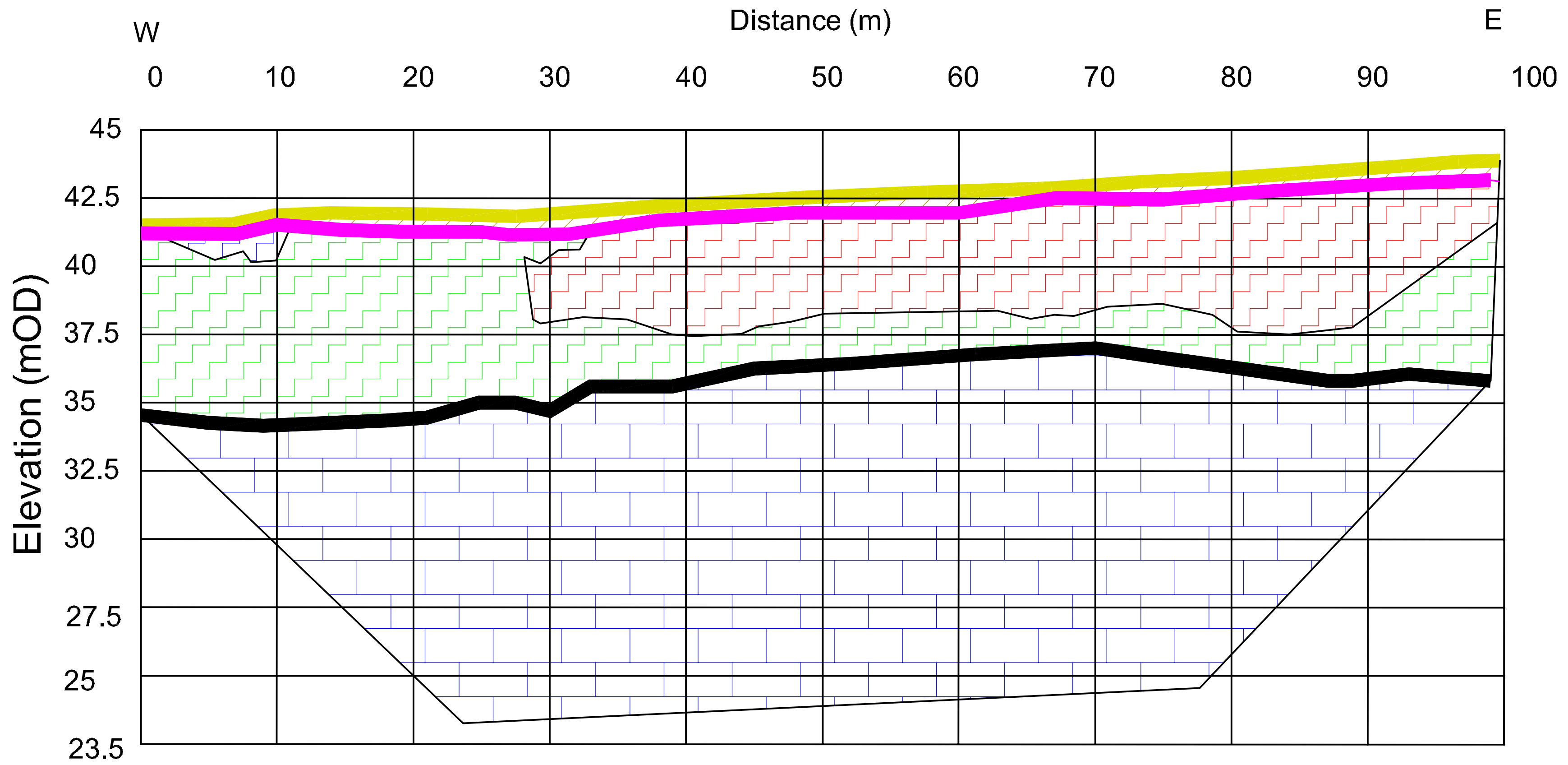
2D-Resistivity Model Values:
Resistivities (Ohmm) for 2D-Resistivity Model



2D-Resistivity Profile R8 and Seismic Refraction Profile S8 Interpretation



2D-Resistivity Profile R8 and Seismic Refraction Profile S8 Interpretation



Interpretation: Resistivity and Seismic Area

- 1 Soft or loose Topsoil, Soil or Made Ground
- 2a Firm to Stiff Clay or Silt Overburden
- 2b Firm to Stiff Gravelly Clay Overburden
- 2c Medium Dense to Dense Sand or Gravel Overburden
- 3a Very Stiff to Hard Clay or Silt Overburden
- 3b Poor to Fair Weathered Metamorphic Rock or Very Stiff to Hard Gravelly Clay Overburden
- 3c Poor to Fair Weathered Metamorphic Rock
- 4b Good to Very Good Slightly Weathered Metamorphic Rock
- 4c Good to Very Good Fresh Metamorphic Rock

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		PROJECT:	6526
PROJECT	TEN-T, County Donegal Geophysical Survey	DRAWN:	JC
		DATE:	27/10/2020
TITLE	Figure 2a: Interpretation of Geophysical Survey for Area A	MGX FILE:	6526d_MapsFigs.dwg
		STATUS:	Draft

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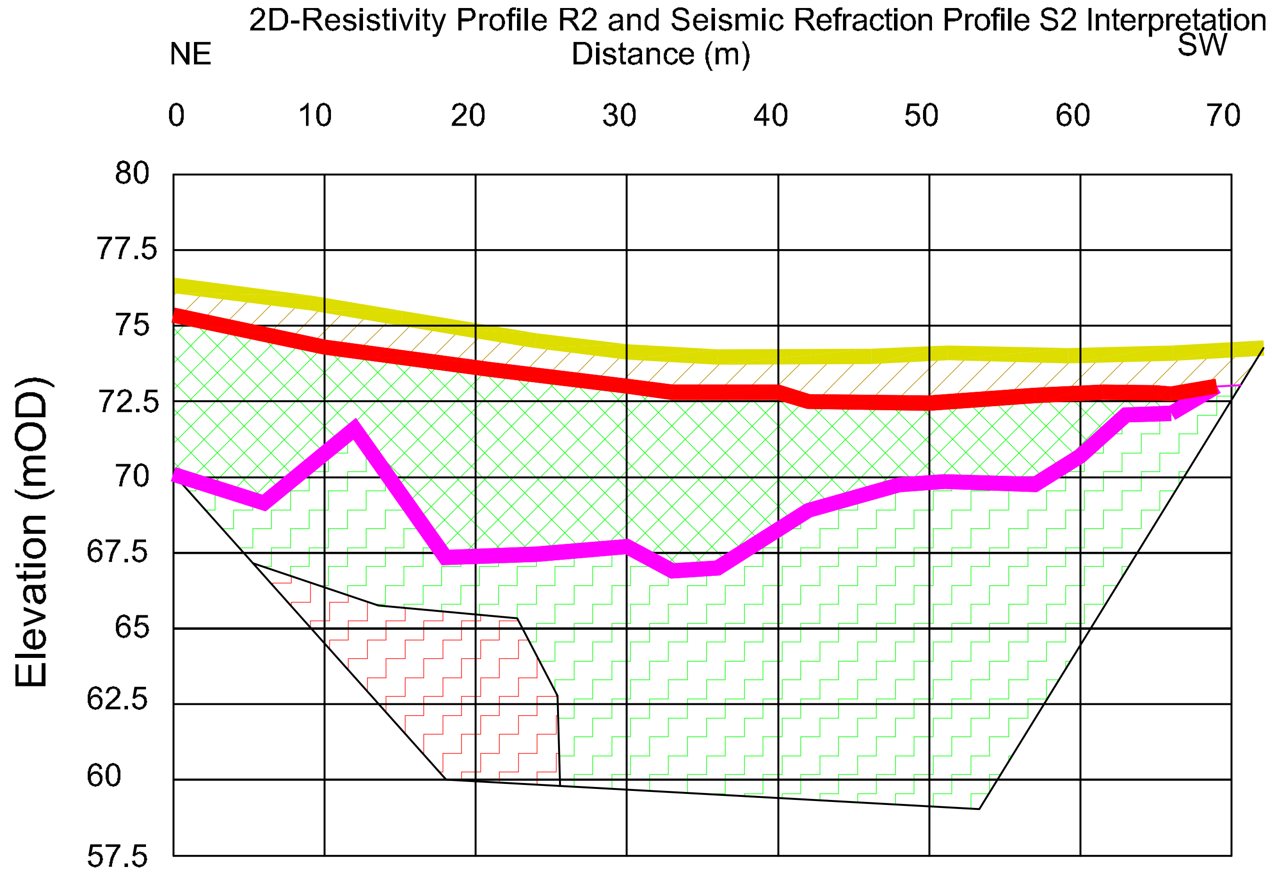

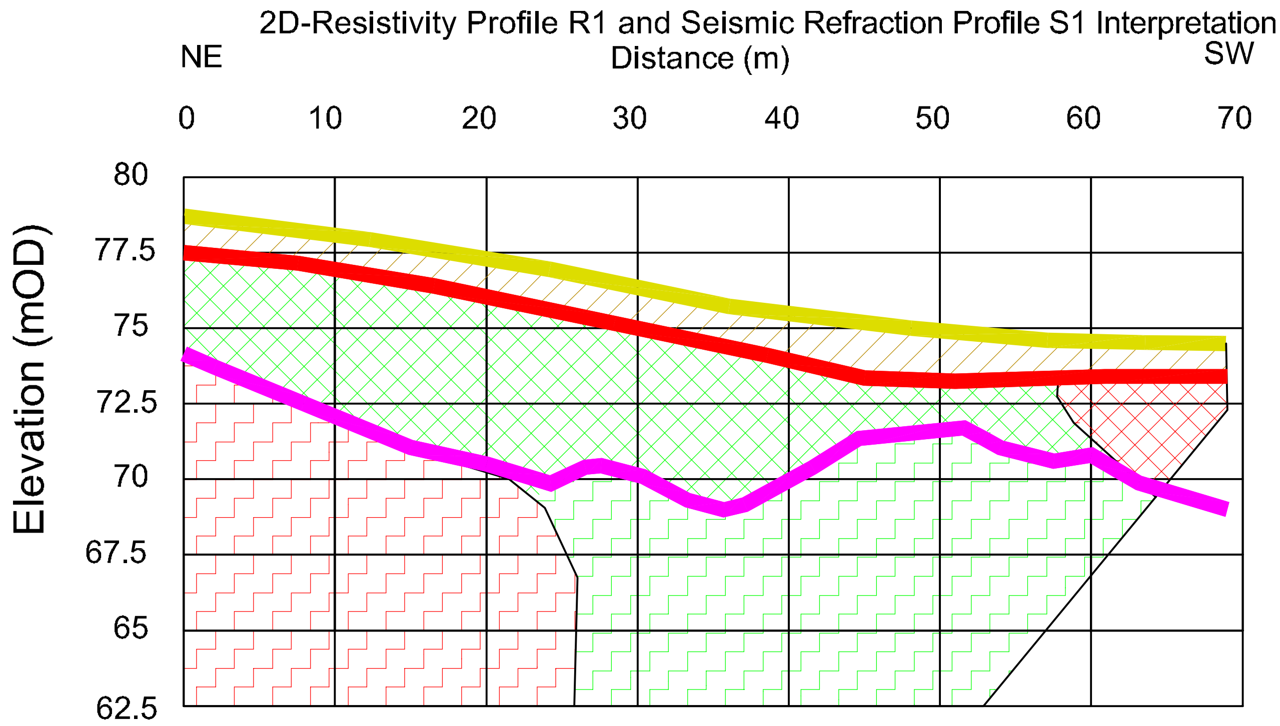

Interpretation: Resistivity and Seismic Area

- 1 Soft or loose Topsoil, Soil or Made Ground
- 2a Firm to Stiff Clay or Silt Overburden
- 2b Firm to Stiff Gravelly Clay Overburden
- 2c Medium Dense to Dense Sand or Gravel Overburden
- 3a Very Stiff to Hard Clay or Silt Overburden
- 3b Poor to Fair Weathered Metamorphic Rock or Very Stiff to Hard Gravelly Clay Overburden
- 3c Poor to Fair Weathered Metamorphic Rock
- 4b Good to Very Good Slightly Weathered Metamorphic Rock
- 4c Good to Very Good Fresh Metamorphic Rock

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PROJECT	TEN-T, County Donegal Geophysical Survey	DRAWN:	JC
		DATE:	27/10/2020
TITLE	Figure 2b: Interpretation of Geophysical Survey for Area B	MGX FILE:	6526d_MapsFigs.dwg
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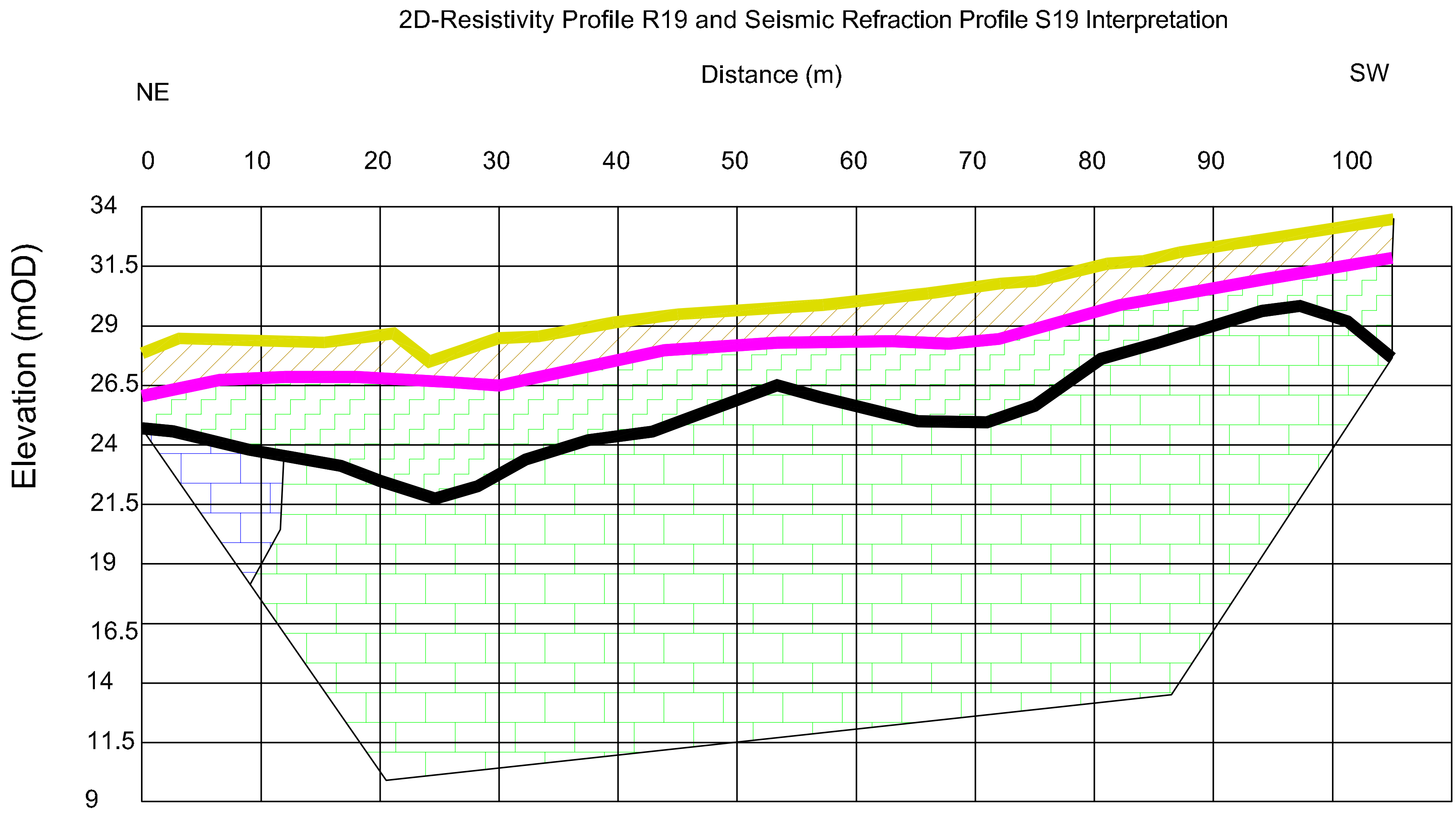

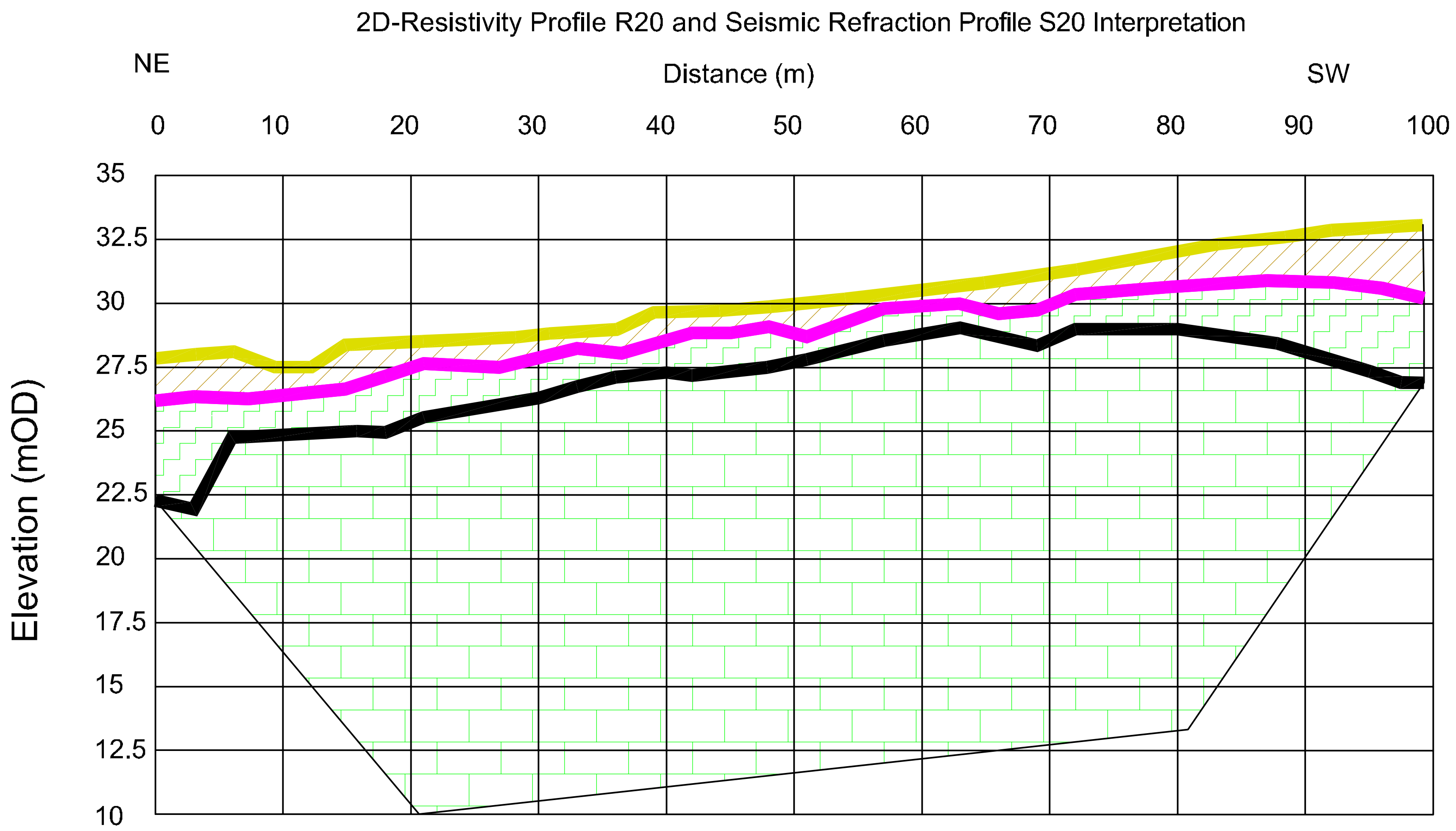

Interpretation: Resistivity and Seismic Area

- 1 Soft or loose Topsoil, Soil or Made Ground
- 2a Firm to Stiff Clay or Silt Overburden
- 2b Firm to Stiff Gravelly Clay Overburden
- 2c Medium Dense to Dense Sand or Gravel Overburden
- 3a Very Stiff to Hard Clay or Silt Overburden
- 3b Poor to Fair Weathered Metamorphic Rock or Very Stiff to Hard Gravelly Clay Overburden
- 3c Poor to Fair Weathered Metamorphic Rock
- 4b Good to Very Good Slightly Weathered Metamorphic Rock
- 4c Good to Very Good Fresh Metamorphic Rock

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		PROJECT:	6526
PROJECT	TEN-T, County Donegal Geophysical Survey	DRAWN:	JC
		DATE:	27/10/2020
TITLE	Figure 2c: Interpretation of Geophysical Survey for Area C	MGX FILE:	6526d_MapsFigs.dwg
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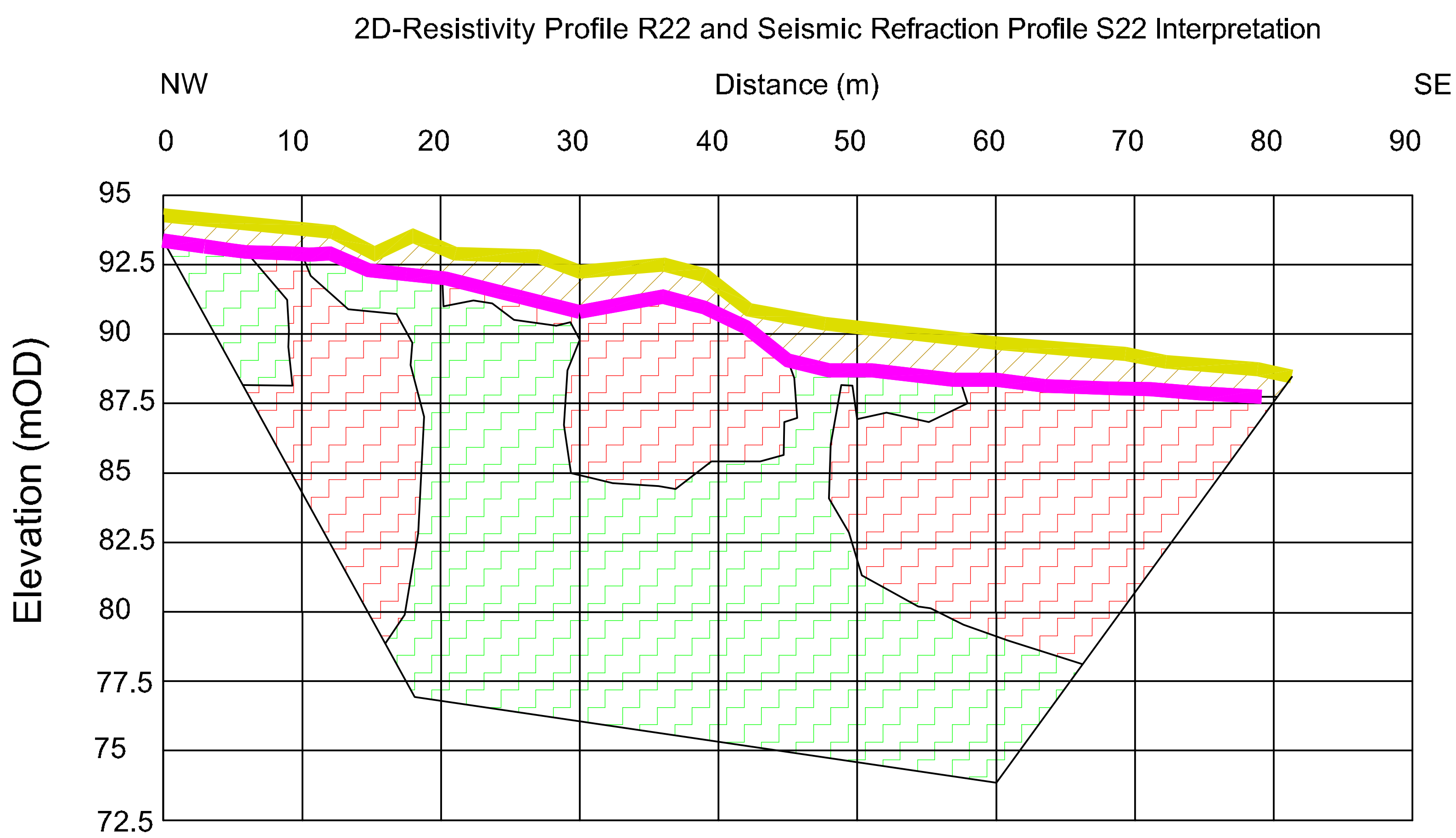

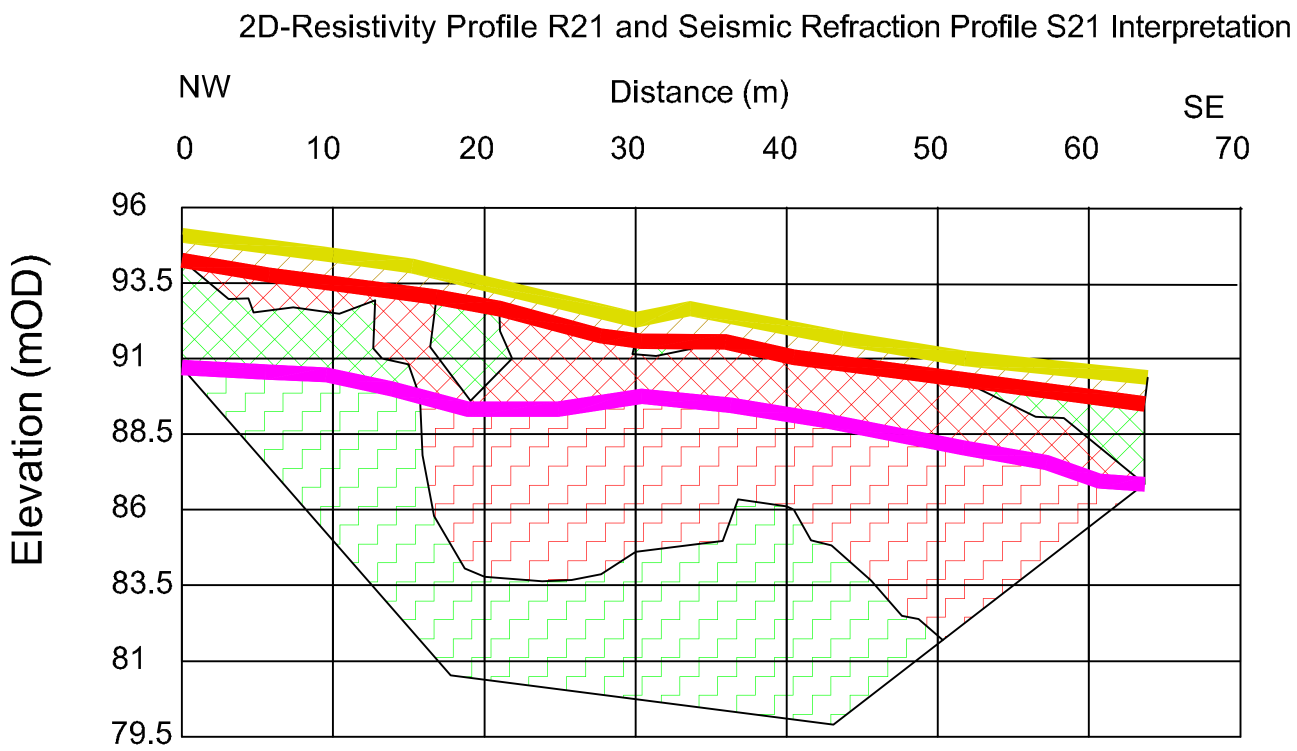

Interpretation: Resistivity and Seismic Area

1 Soft or loose Topsoil, Soil or Made Ground
2a Firm to Stiff Clay or Silt Overburden
2b Firm to Stiff Gravelly Clay Overburden
2c Medium Dense to Dense Sand or Gravel Overburden
3a Very Stiff to Hard Clay or Silt Overburden
3b Poor to Fair Weathered Metamorphic Rock or Very Stiff to Hard Gravelly Clay Overburden
3c Poor to Fair Weathered Metamorphic Rock
4b Good to Very Good Slightly Weathered Metamorphic Rock
4c Good to Very Good Fresh Metamorphic Rock

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		PROJECT:	6526
PROJECT	TEN-T, County Donegal Geophysical Survey	DRAWN:	JC
		DATE:	27/10/2020
TITLE	Figure 2d: Interpretation of Geophysical Survey for Area D	MGX FILE:	6526d_MapsFigs.dwg
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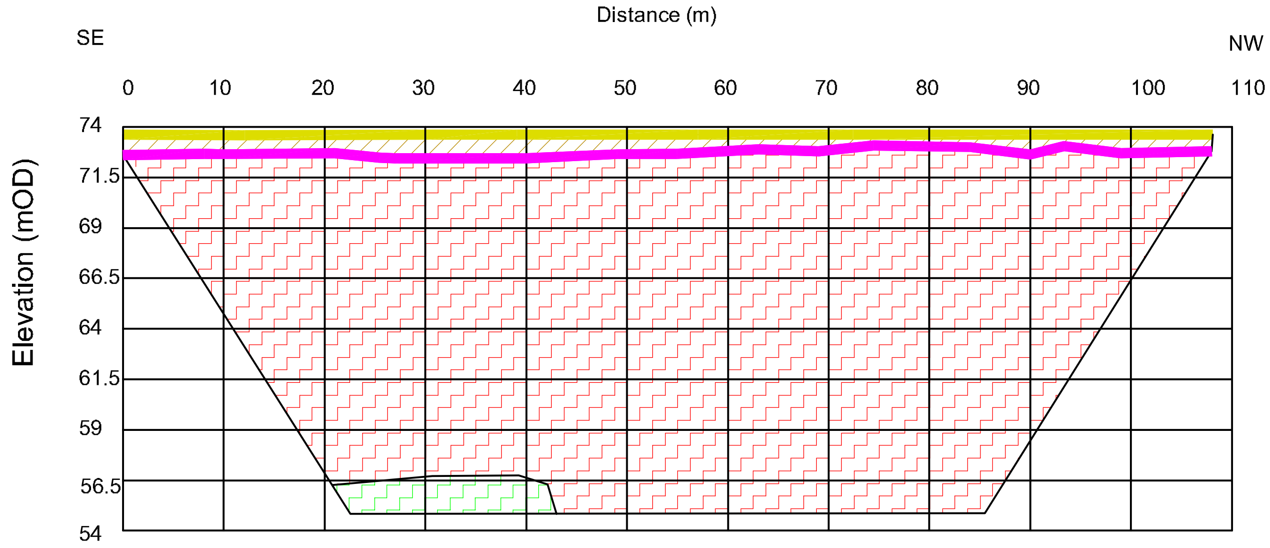
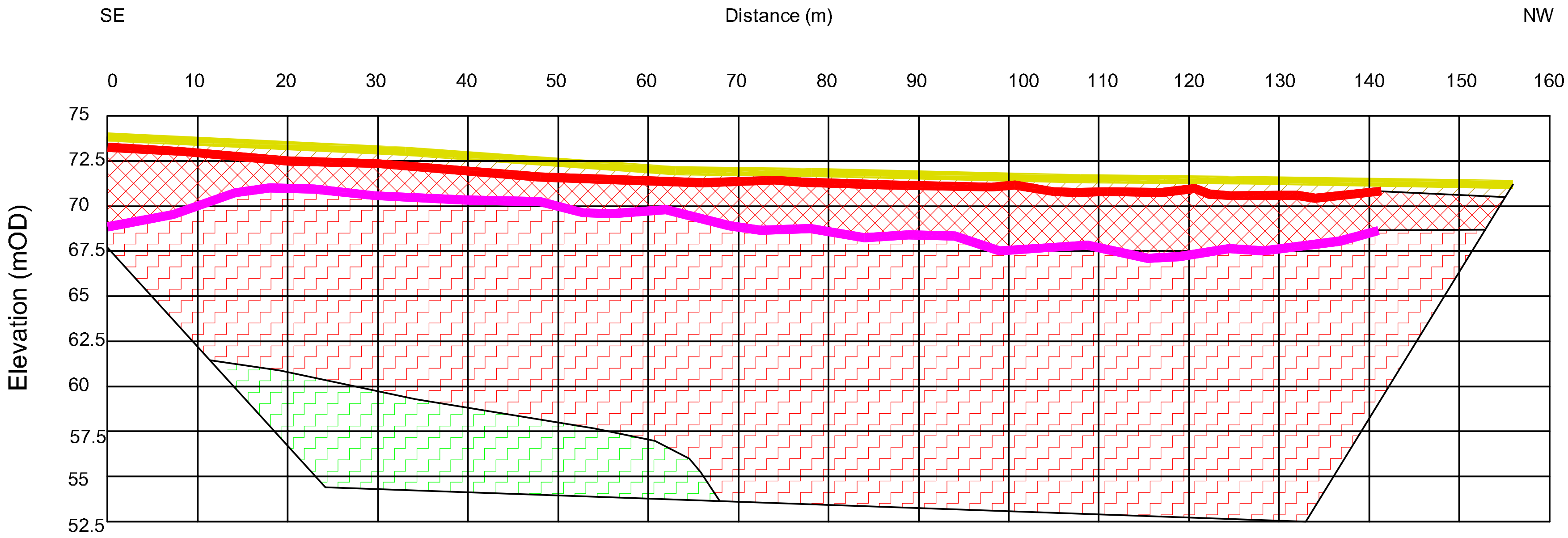
LEGEND:

2D-Resistivity Profile R13 and Seismic Refraction Profile S13 Interpretation



2D-Resistivity Profile R12 and Seismic Refraction Profile S12 Interpretation



Interpretation: Resistivity and Seismic Area

- 1 Soft or loose Topsoil, Soil or Made Ground
- 2a Firm to Stiff Clay or Silt Overburden
- 2b Firm to Stiff Gravelly Clay Overburden
- 2c Medium Dense to Dense Sand or Gravel Overburden
- 3a Very Stiff to Hard Clay or Silt Overburden
- 3b Poor to Fair Weathered Metamorphic Rock or Very Stiff to Hard Gravelly Clay Overburden
- 3c Poor to Fair Weathered Metamorphic Rock
- 4b Good to Very Good Slightly Weathered Metamorphic Rock
- 4c Good to Very Good Fresh Metamorphic Rock

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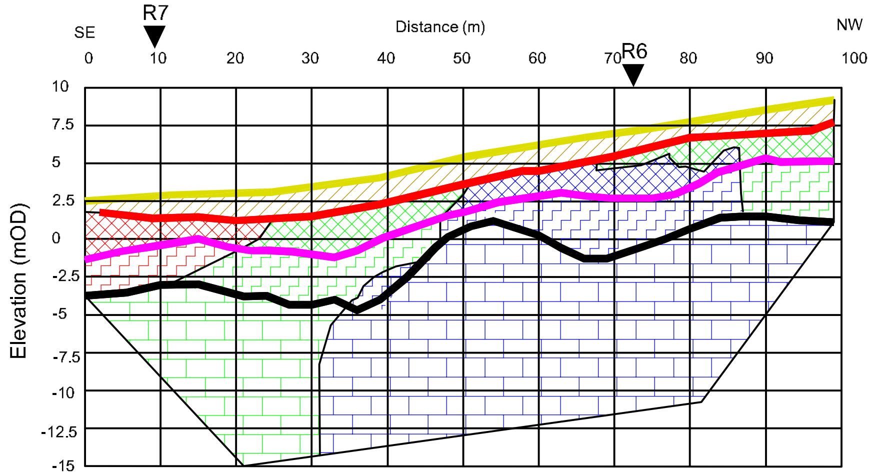
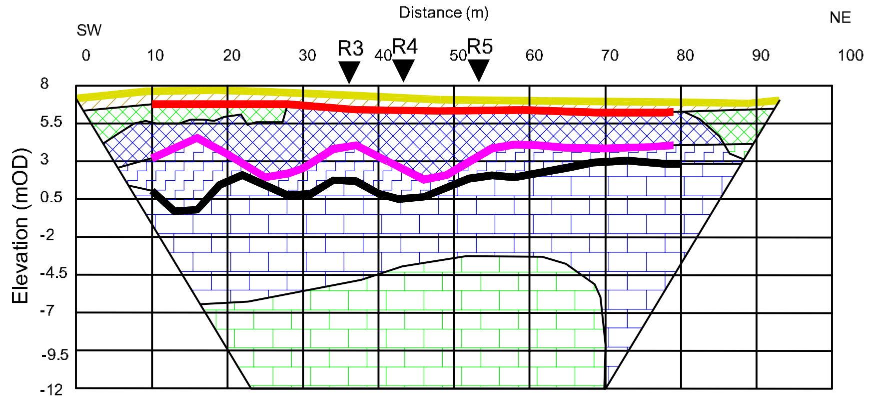
PROJECT	TEN-T, County Donegal Geophysical Survey	PROJECT:	6526
		DRAWN:	JC
		DATE:	27/10/2020
TITLE	Figure 2e: Interpretation of Geophysical Survey for Area E	MGX FILE:	6526d_MapsFigs.dwg
		STATUS:	Draft

LEGEND:

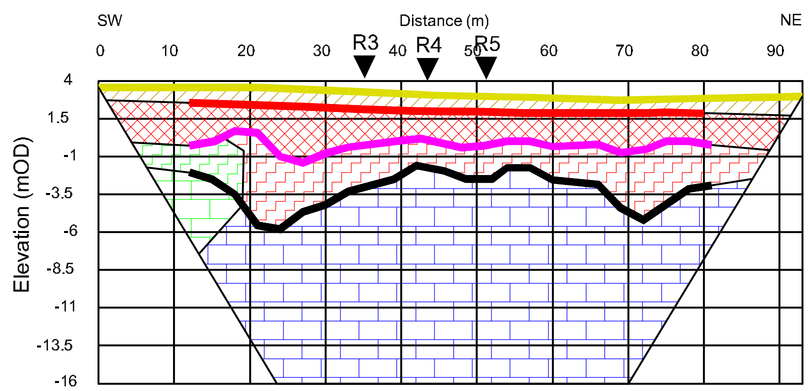
2D-Resistivity Profile R5 and Seismic Refraction Profile S5 Interpretation



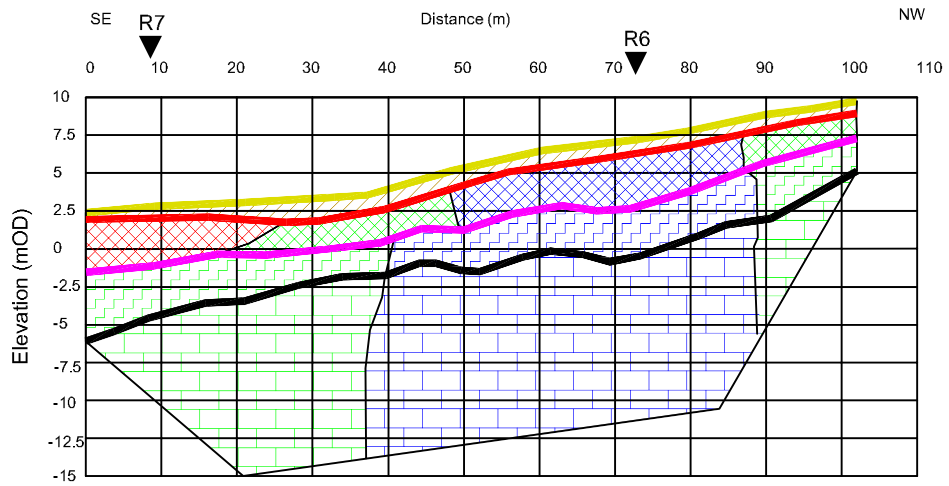
2D-Resistivity Profile R6 and Seismic Refraction Profile S6 Interpretation



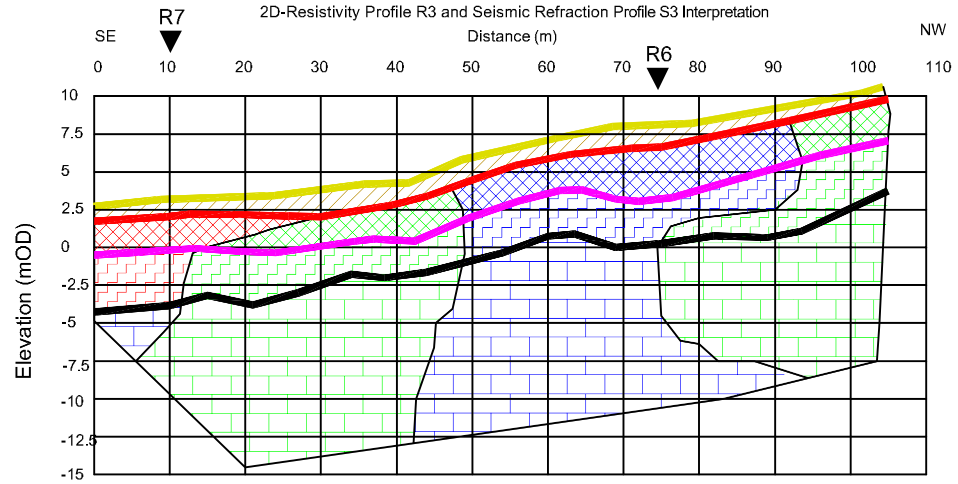
2D-Resistivity Profile R7 and Seismic Refraction Profile S7 Interpretation



2D-Resistivity Profile R4 and Seismic Refraction Profile S4 Interpretation



2D-Resistivity Profile R3 and Seismic Refraction Profile S3 Interpretation



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CLIENT: Irish Drilling Ltd.

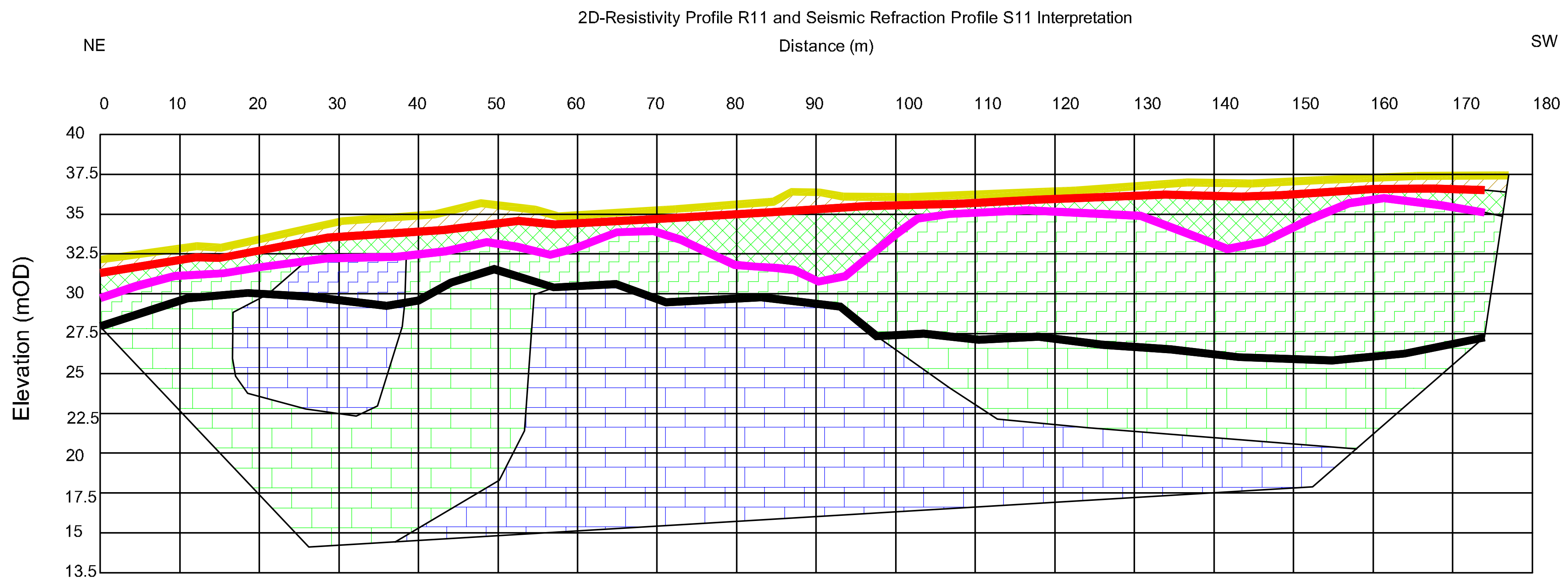
PROJECT: TEN-T, County Donegal Geophysical Survey

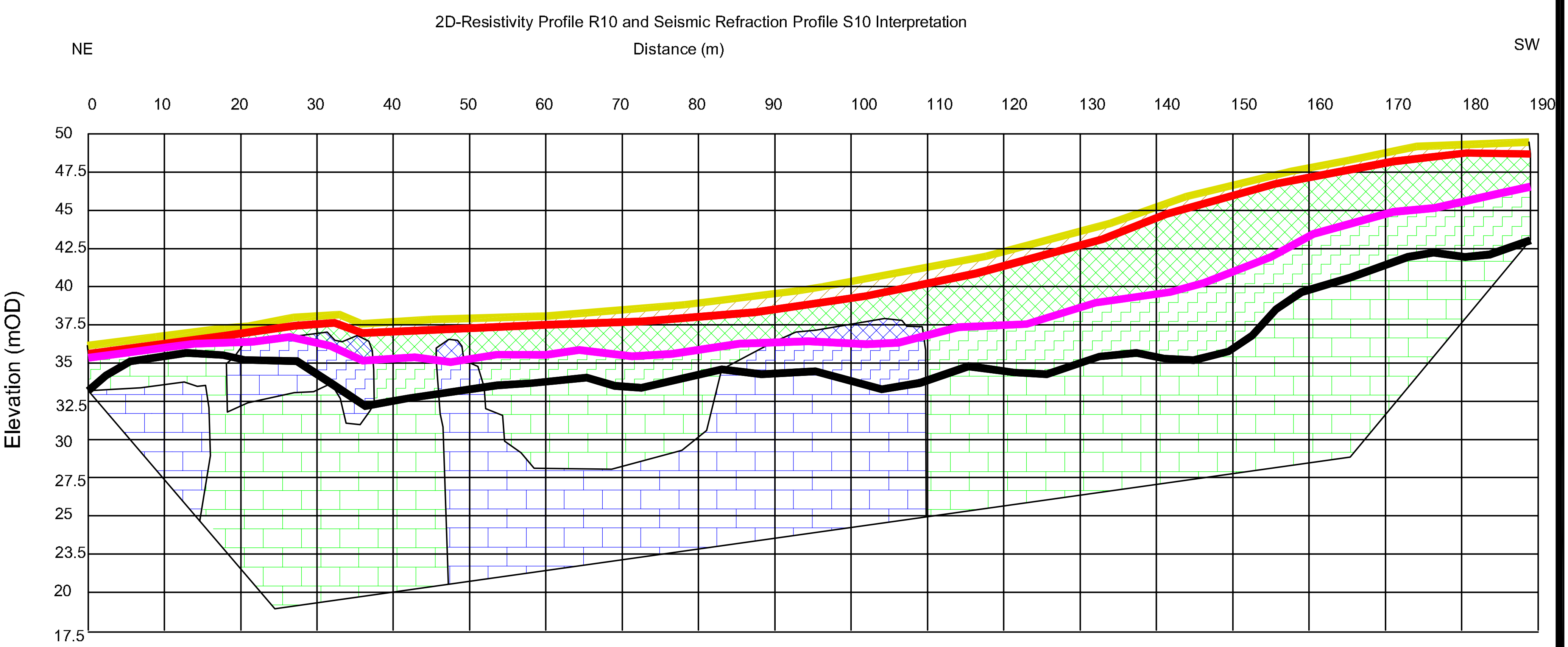
TITLE: Figure 2f: Interpretation of Geophys Survey for River Swilly Crossing N

SCALE:	1:1000 @ A3, VE x 2
PROJECT:	6526
DRAWN:	JC
DATE:	27/10/2020
MGX FILE:	6526d_MapsFigs.dwg
STATUS:	Draft

LEGEND: Interpretation: Resistivity and Seismic Area

- 1 Soft or loose Topsoil, Soil or Made Ground
- 2a Firm to Stiff Clay or Silt Overburden
- 2b Firm to Stiff Gravelly Clay Overburden
- 2c Medium Dense to Dense Sand or Gravel Overburden
- 3a Very Stiff to Hard Clay or Silt Overburden
- 3b Poor to Fair Weathered Metamorphic Rock or Very Stiff to Hard Gravelly Clay Overburden
- 3c Poor to Fair Weathered Metamorphic Rock
- 4b Good to Very Good Slightly Weathered Metamorphic Rock
- 4c Good to Very Good Fresh Metamorphic Rock





Interpretation: Resistivity and Seismic Area

- 1 Soft or loose Topsoil, Soil or Made Ground
- 2a Firm to Stiff Clay or Silt Overburden
- 2b Firm to Stiff Gravelly Clay Overburden
- 2c Medium Dense to Dense Sand or Gravel Overburden
- 3a Very Stiff to Hard Clay or Silt Overburden
- 3b Poor to Fair Weathered Metamorphic Rock or Very Stiff to Hard Gravelly Clay Overburden
- 3c Poor to Fair Weathered Metamorphic Rock
- 4b Good to Very Good Slightly Weathered Metamorphic Rock
- 4c Good to Very Good Fresh Metamorphic Rock

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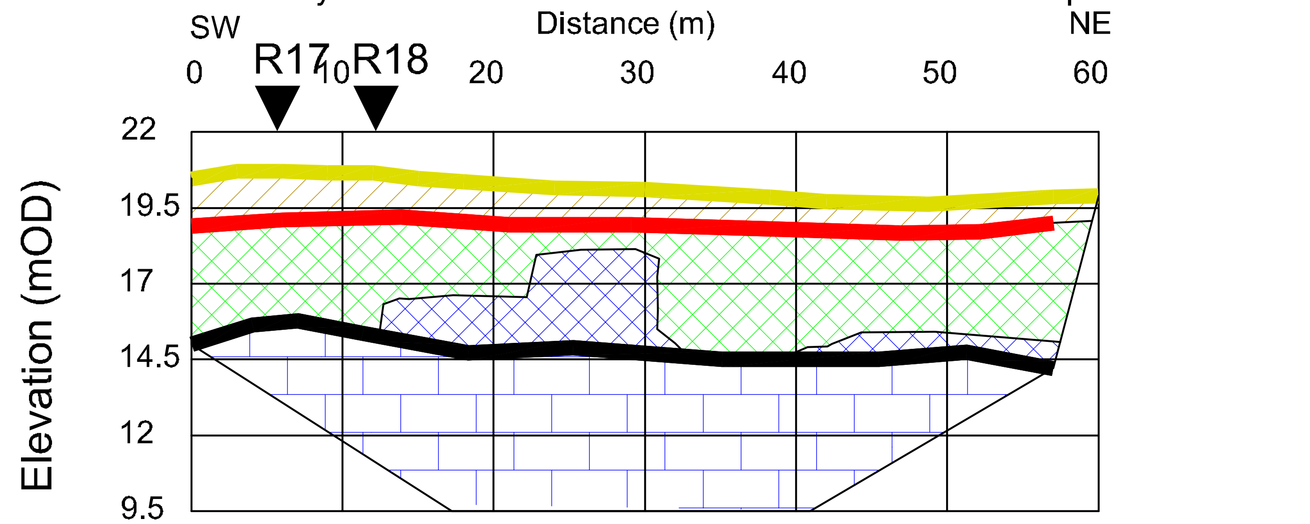
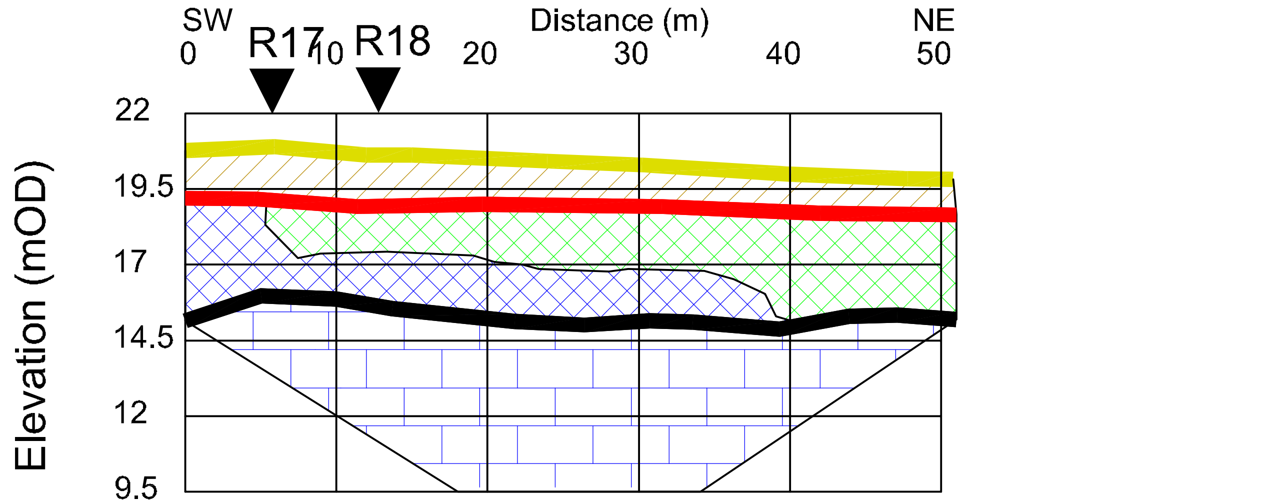
CLIENT	Irish Drilling Ltd.
PROJECT	TEN-T, County Donegal Geophysical Survey
TITLE	Figure 2g: Interpretation of Geolphys Survey for CH 1+900 - 2+150
SCALE:	1:750 @ A3, VE x 2
PROJECT:	6526
DRAWN:	JC
DATE:	27/10/2020
MGX FILE:	6526d_MapsFigs.dwg
STATUS:	Draft
LEGEND:	

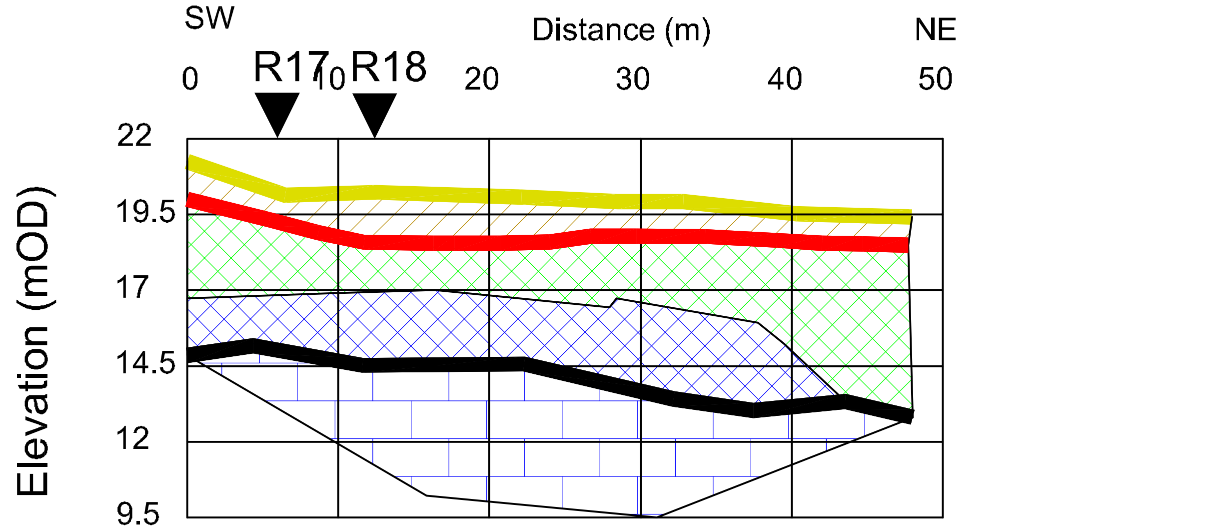
2D-Resistivity Profile R14 and Seismic Refraction Profile S14 Interpretation



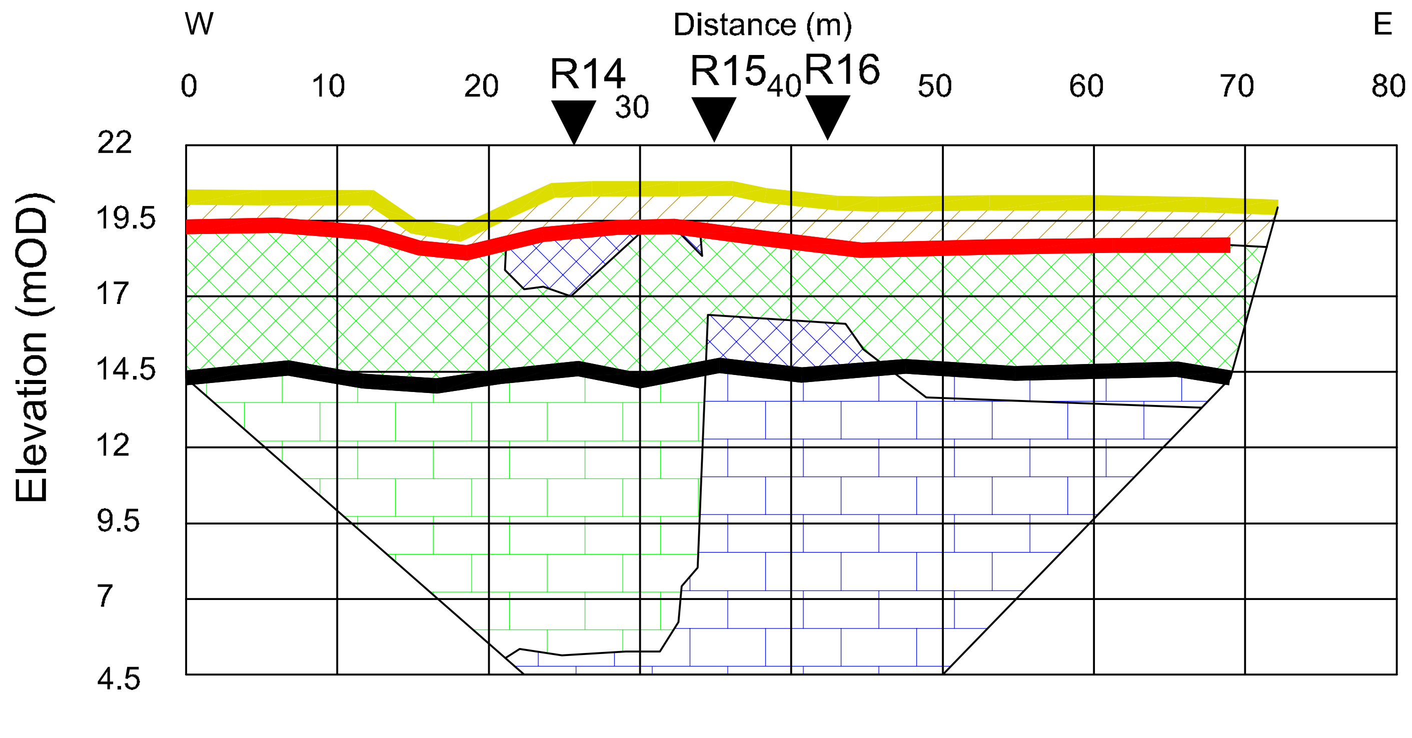
2D-Resistivity Profile R15 and Seismic Refraction Profile S15 Interpretation



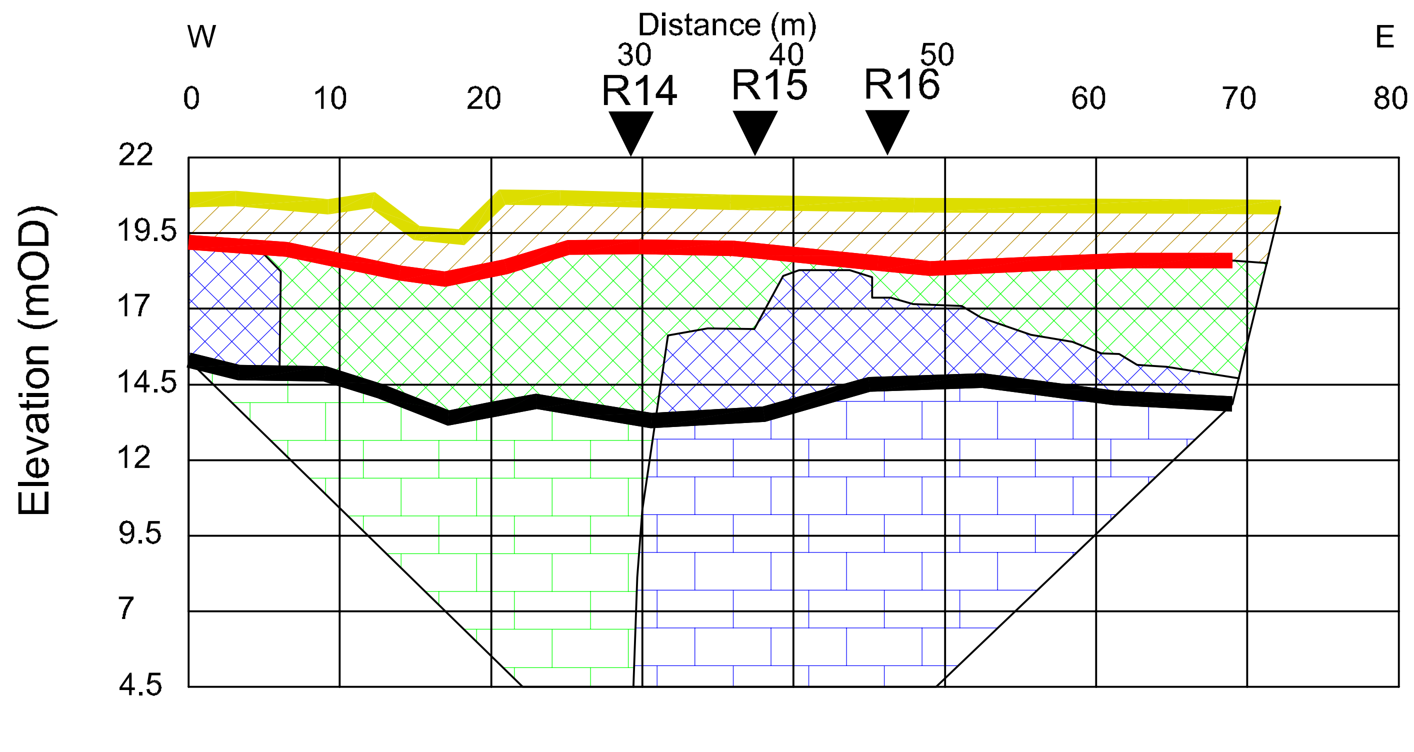
2D-Resistivity Profile R16 and Seismic Refraction Profile S16 Interpretation



2D-Resistivity Profile R17 and Seismic Refraction Profile S17 Interpretation



2D-Resistivity Profile R18 and Seismic Refraction Profile S18 Interpretation



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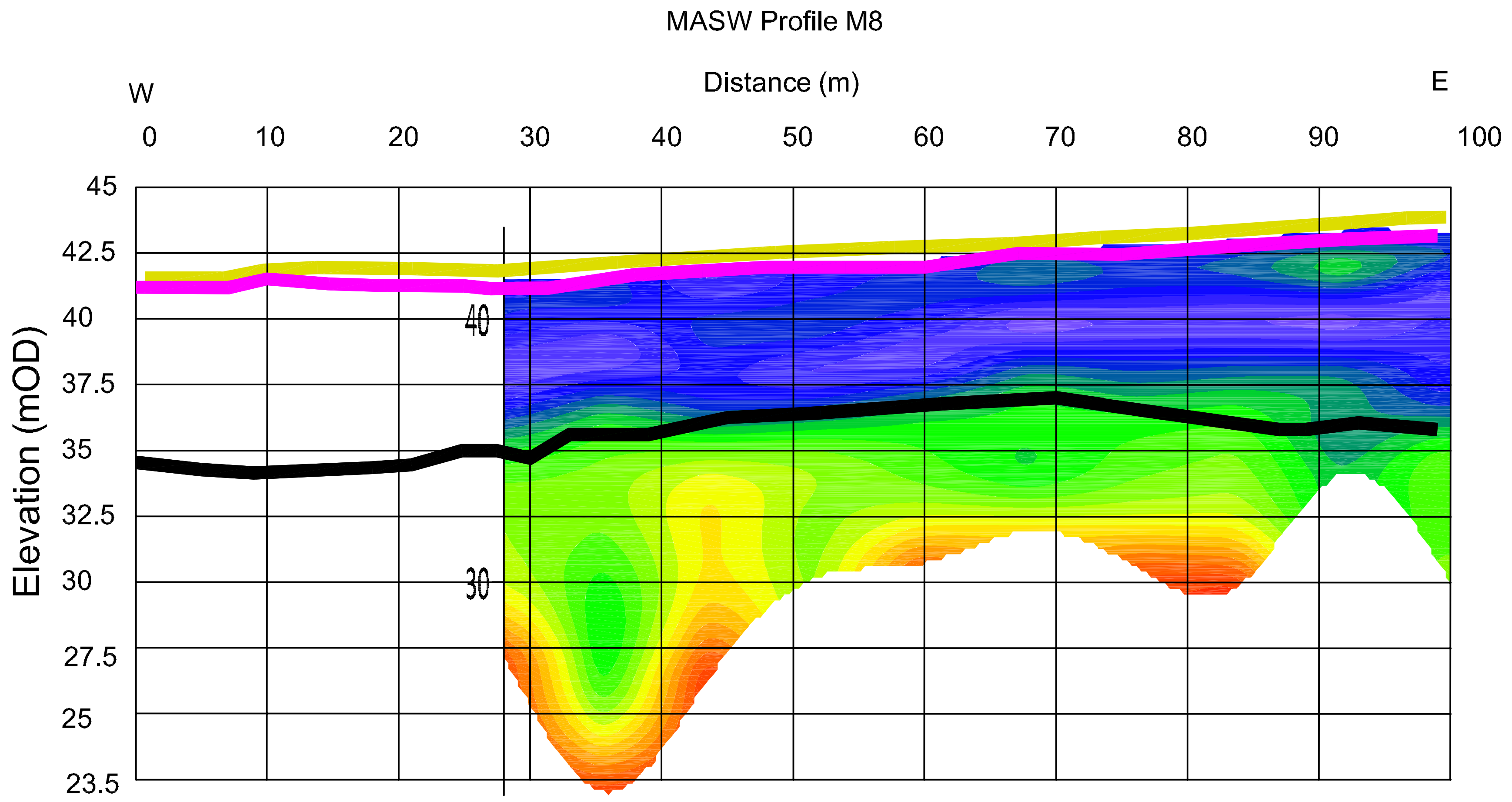
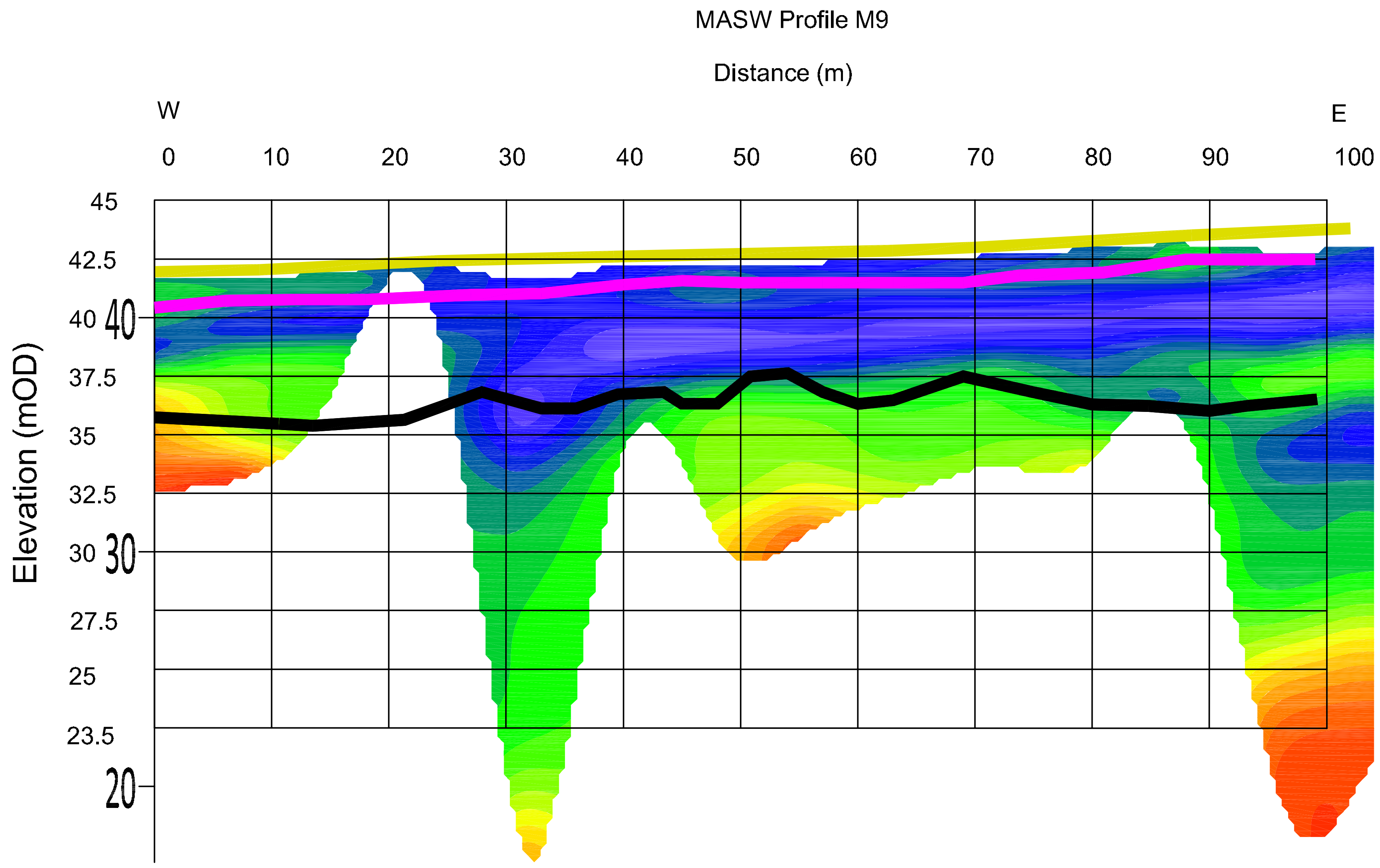
		PROJECT:	6526
PROJECT	TEN-T, County Donegal Geophysical Survey	DRAWN:	JC
		DATE:	27/10/2020
TITLE	Figure 2h: Interpretation of Geophys Survey for River Finn Crossing N	MGX FILE:	6526d_MapsFigs.dwg
		STATUS:	Draft

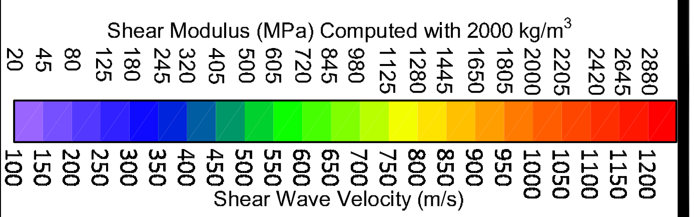
LEGEND: Interpretation: Resistivity and Seismic Area

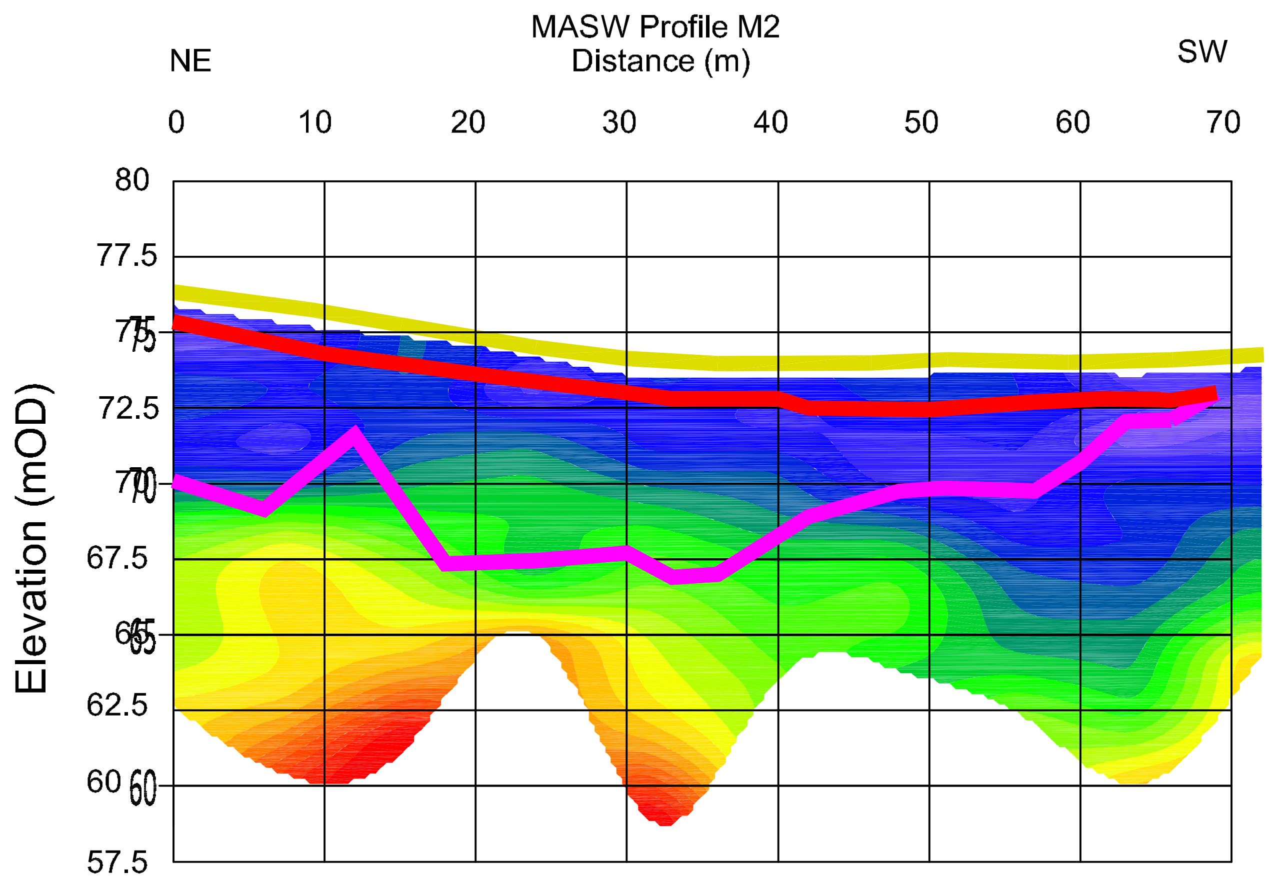
- 1 Soft or loose Topsoil, Soil or Made Ground
- 2a Firm to Stiff Clay or Silt Overburden
- 2b Firm to Stiff Gravelly Clay Overburden
- 2c Medium Dense to Dense Sand or Gravel Overburden
- 3a Very Stiff to Hard Clay or Silt Overburden
- 3b Poor to Fair Weathered Metamorphic Rock or Very Stiff to Hard Gravelly Clay Overburden
- 3c Poor to Fair Weathered Metamorphic Rock
- 4b Good to Very Good Slightly Weathered Metamorphic Rock
- 4c Good to Very Good Fresh Metamorphic Rock

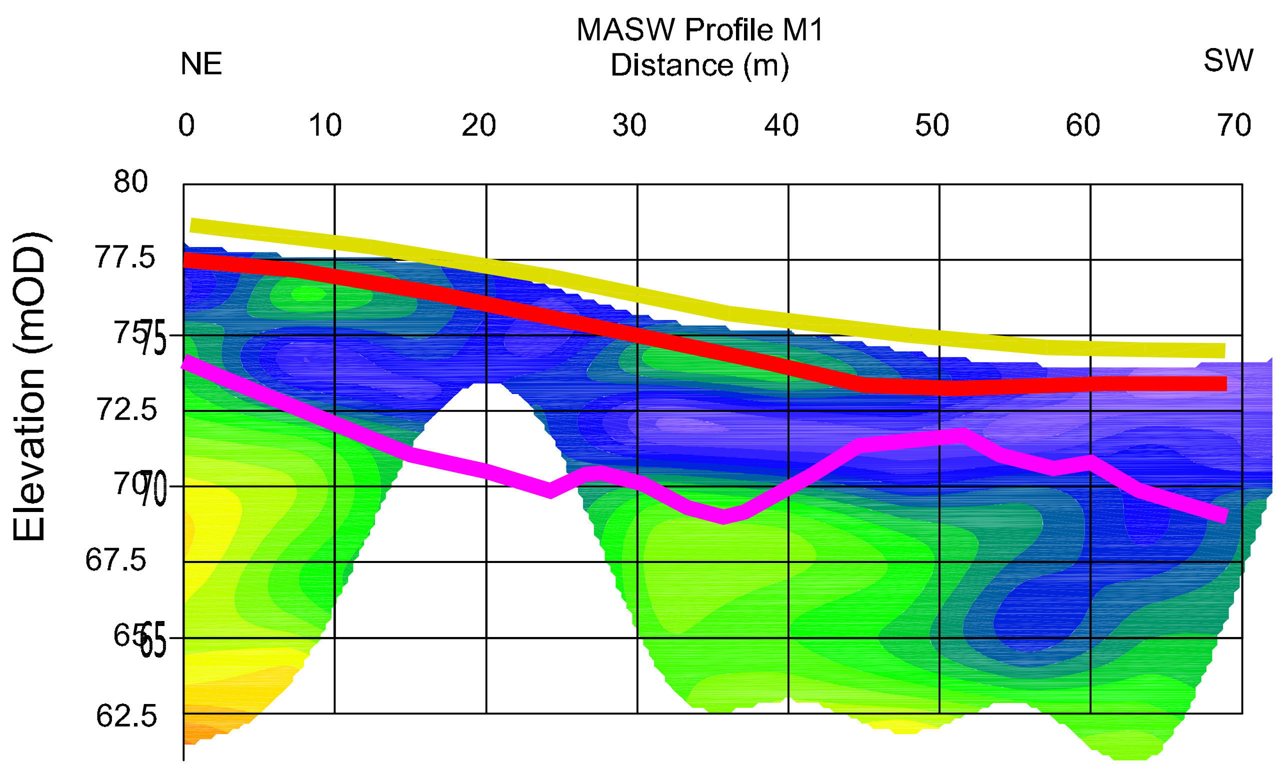




Minerex Geophysics Limited Unit F4, Maynooth Business Campus Maynooth, Co. Kildare Tel. (01) 6510030 Email: info@mgx.ie Web: www.mgx.ie	CLIENT: Irish Drilling Ltd. PROJECT: TEN-T, County Donegal Geophysical Survey TITLE: Figure 3a: Models of MASW Survey for Area A	SCALE: 1:500 @ A3, VE x 2 PROJECT: 6526 DRAWN: JC DATE: 27/10/2020 MGX FILE: 6526d_MapsFigs.dwg STATUS: Draft	LEGEND: MASW Models & Results:







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Tel. (01) 6510030
Email: info@mgx.ie
Web: www.mgx.ie

CLIENT	Irish Drilling Ltd.	SCALE:	1:500 @ A3, VE x 2
		PROJECT:	6526
PROJECT	TEN-T, County Donegal Geophysical Survey	DRAWN:	JC
		DATE:	27/10/2020
TITLE	Figure 3b: Models of MASW Survey for Area B	MGX FILE:	6526d_MapsFigs.dwg
		STATUS:	Draft

LEGEND: MASW Models & Results:

Shear Modulus (MPa) Computed with 2000 kg/m³

20 45 80 125 180 245 320 405 500 605 720 845 980 1125 1280 1445 1650 1805 2000 2205 2420 2645 2880

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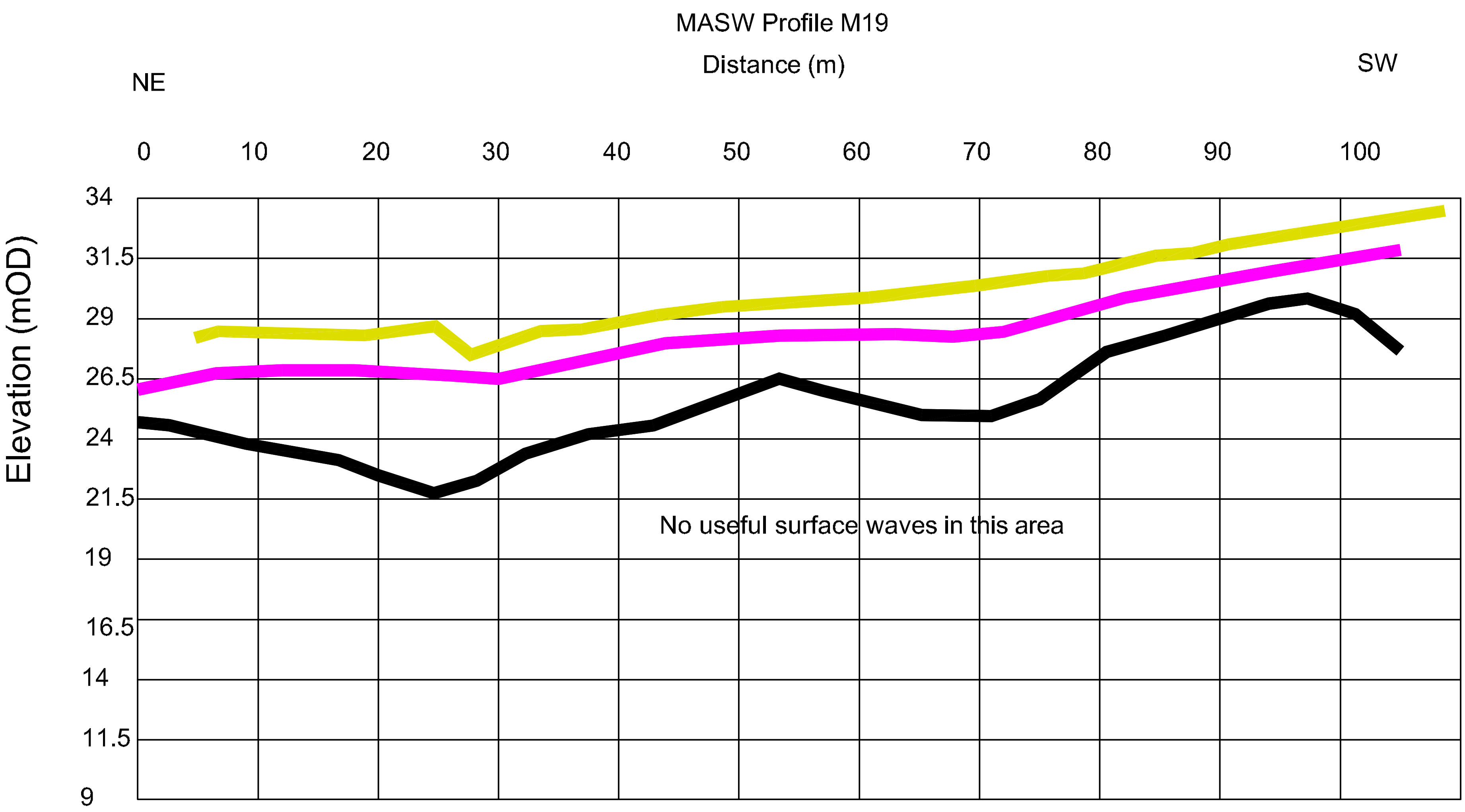
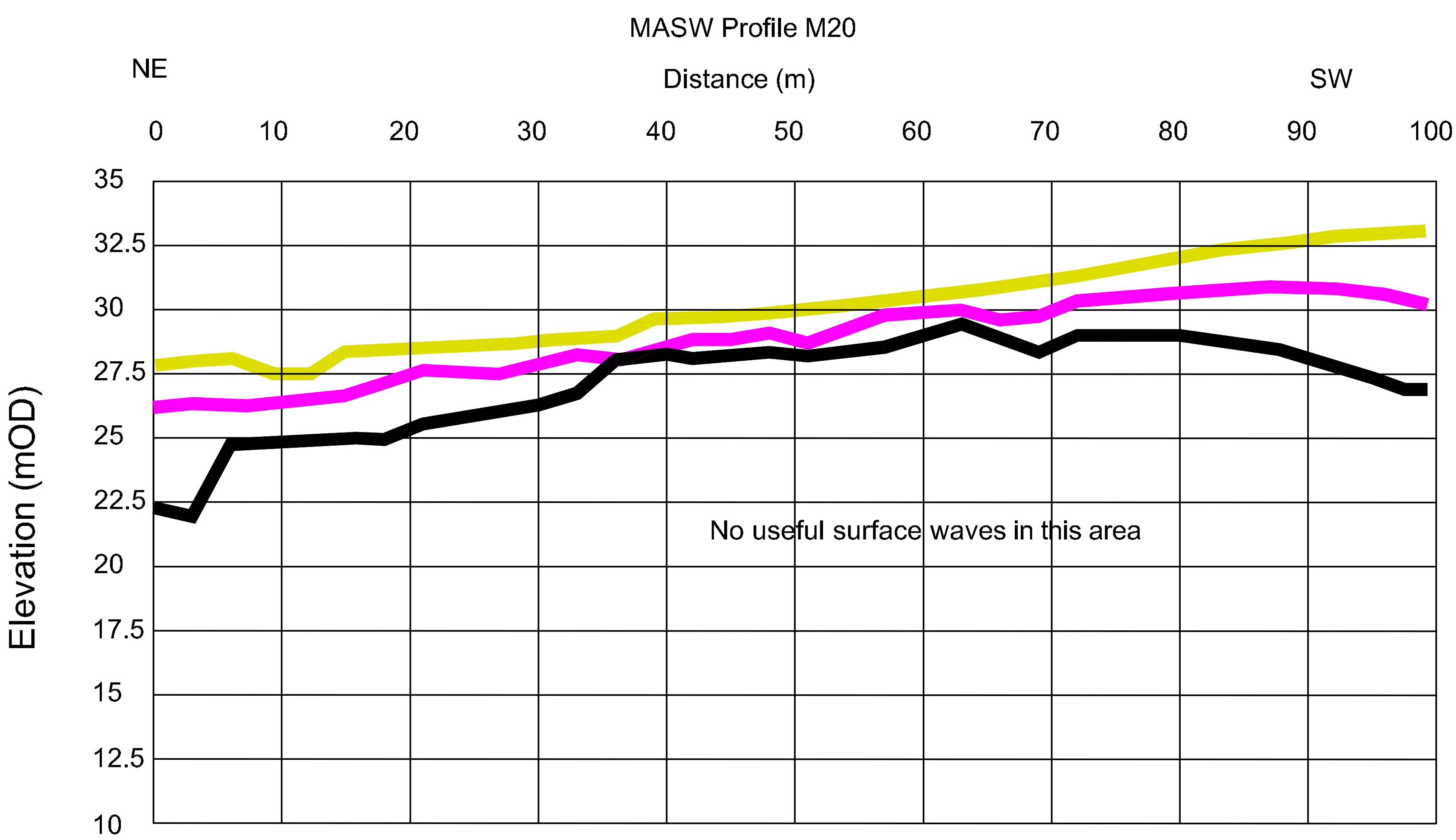
Shear Wave Velocity (m/s)





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Web: www.mgx.ie

CLIENT Irish Drilling Ltd.

PROJECT TEN-T, County Donegal Geophysical Survey

TITLE Figure 3c: Models of MASW Survey for Area C

SCALE:	1:500 @ A3, VE x 2
PROJECT:	6526
DRAWN:	JC
DATE:	27/10/2020
MGX FILE:	6526d_MapsFigs.dwg
STATUS:	Draft

LEGEND: MASW Models & Results:

Shear Modulus (MPa) Computed with 2000 kg/m^3

20 45 80 125 180 245 320 405 500 605 720 845 980 1125 1280 1445 1650 1805 2000 2205 2420 2645 2880

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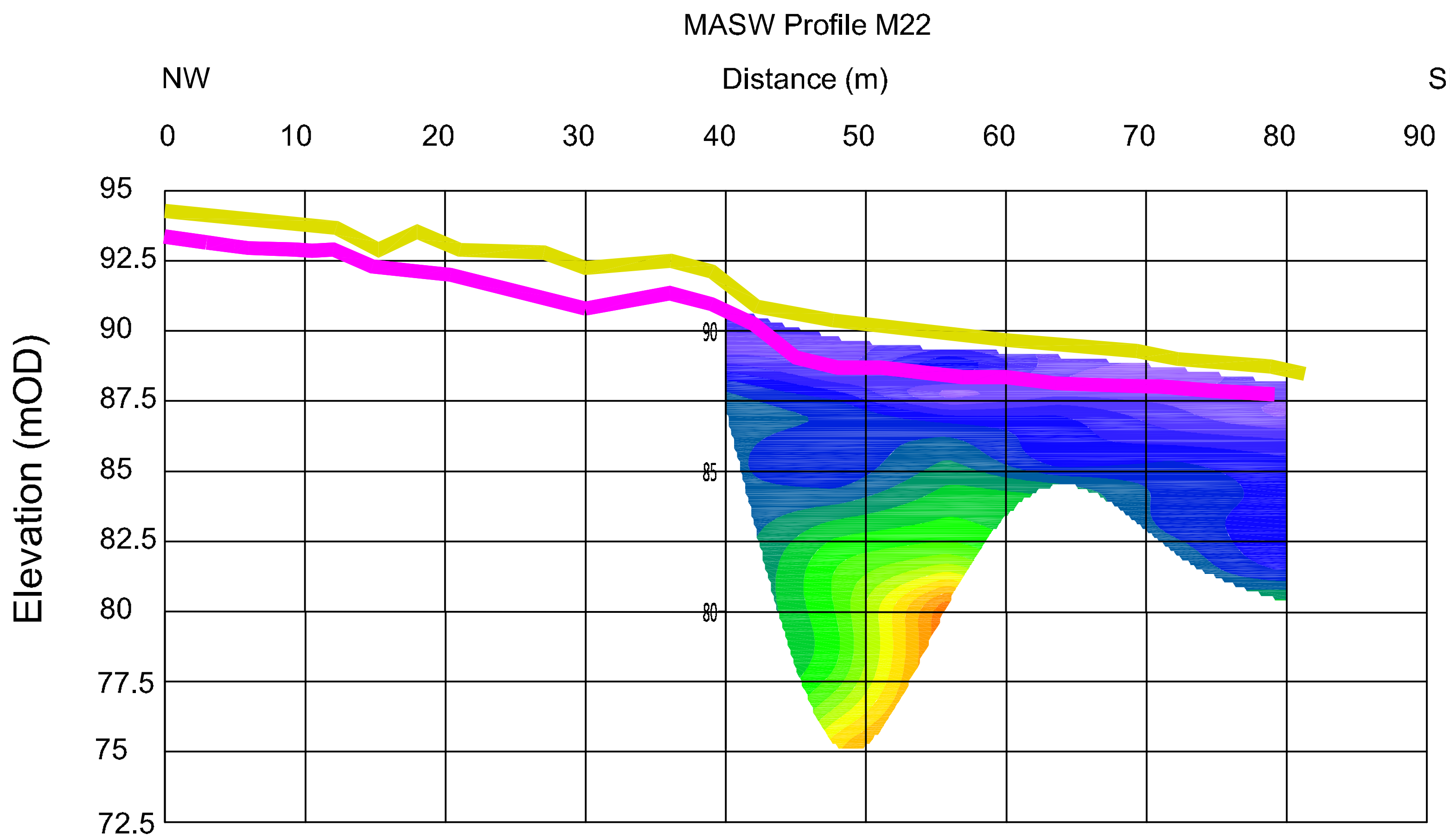
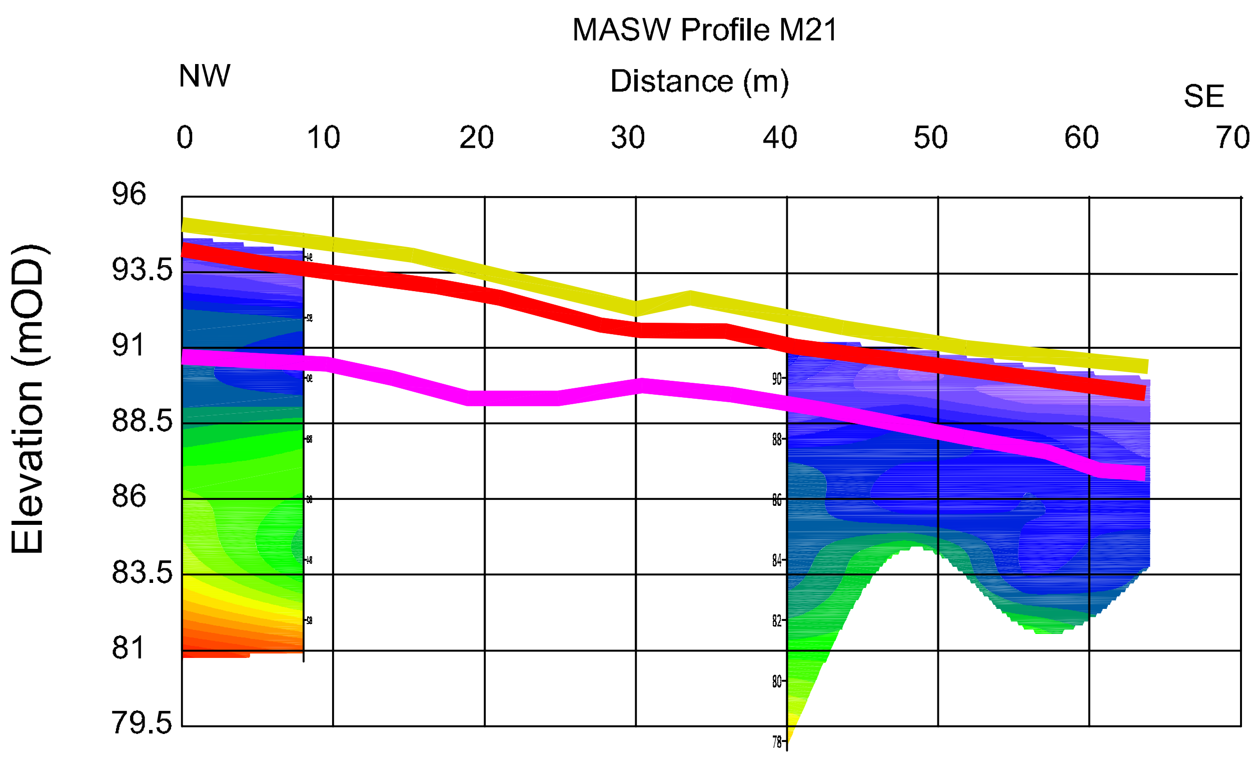
Shear Wave Velocity (m/s)





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Email: info@mgx.ie
Web: www.mgx.ie

CLIENT	Irish Drilling Ltd.
PROJECT	TEN-T, County Donegal Geophysical Survey
TITLE	Figure 3d: Models of MASW Survey for Area D

SCALE:	1:500 @ A3, VE x 2
PROJECT:	6526
DRAWN:	JC
DATE:	27/10/2020
MGX FILE:	6526d_MapsFigs.dwg
STATUS:	Draft

LEGEND: MASW Models & Results:

Shear Modulus (MPa) Computed with 2000 kg/m^3

20 45 80 125 180 245 320 405 500 605 720 845 980 1125 1280 1445 1650 1805 2000 2205 2420 2645 2880

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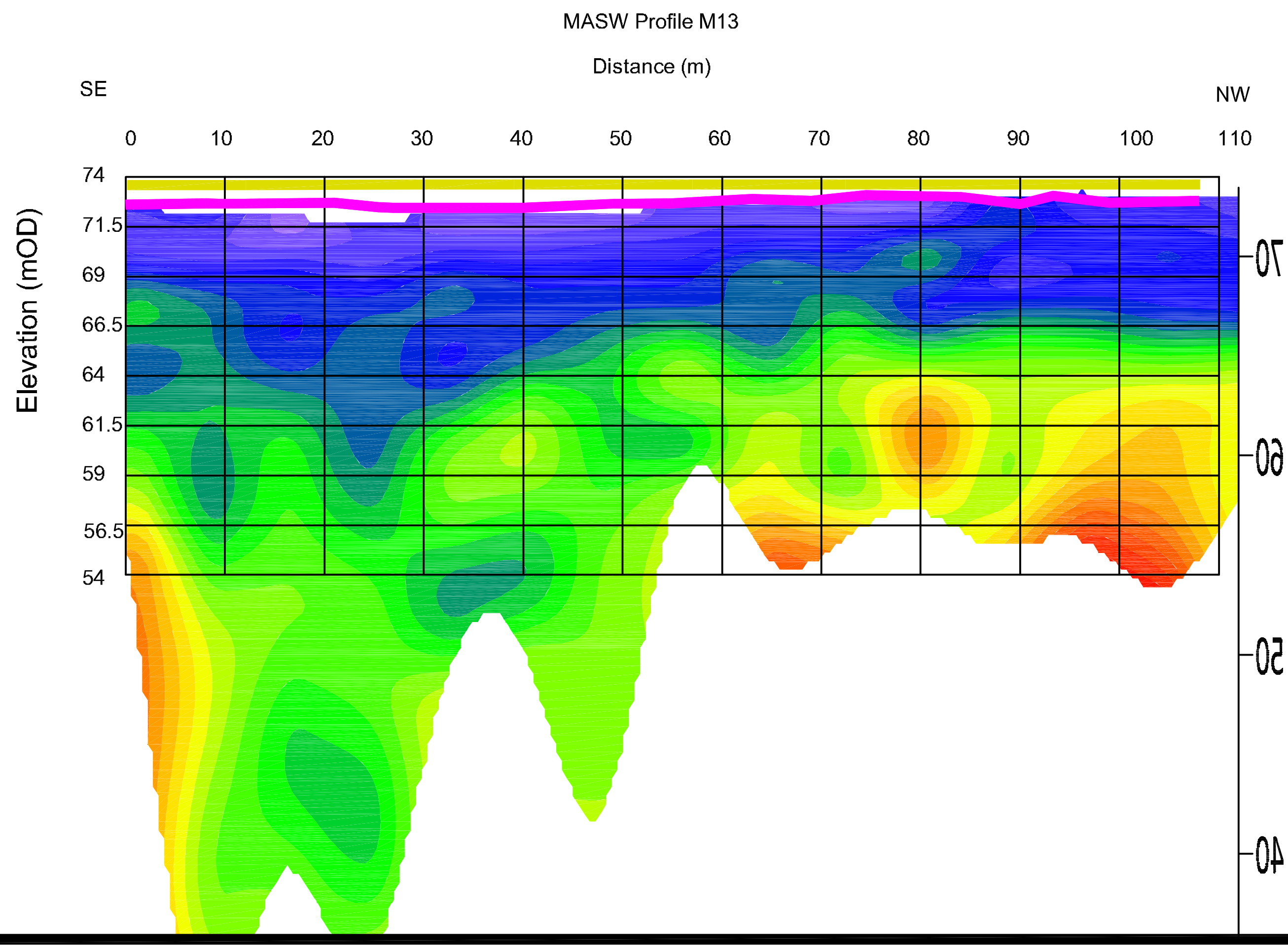
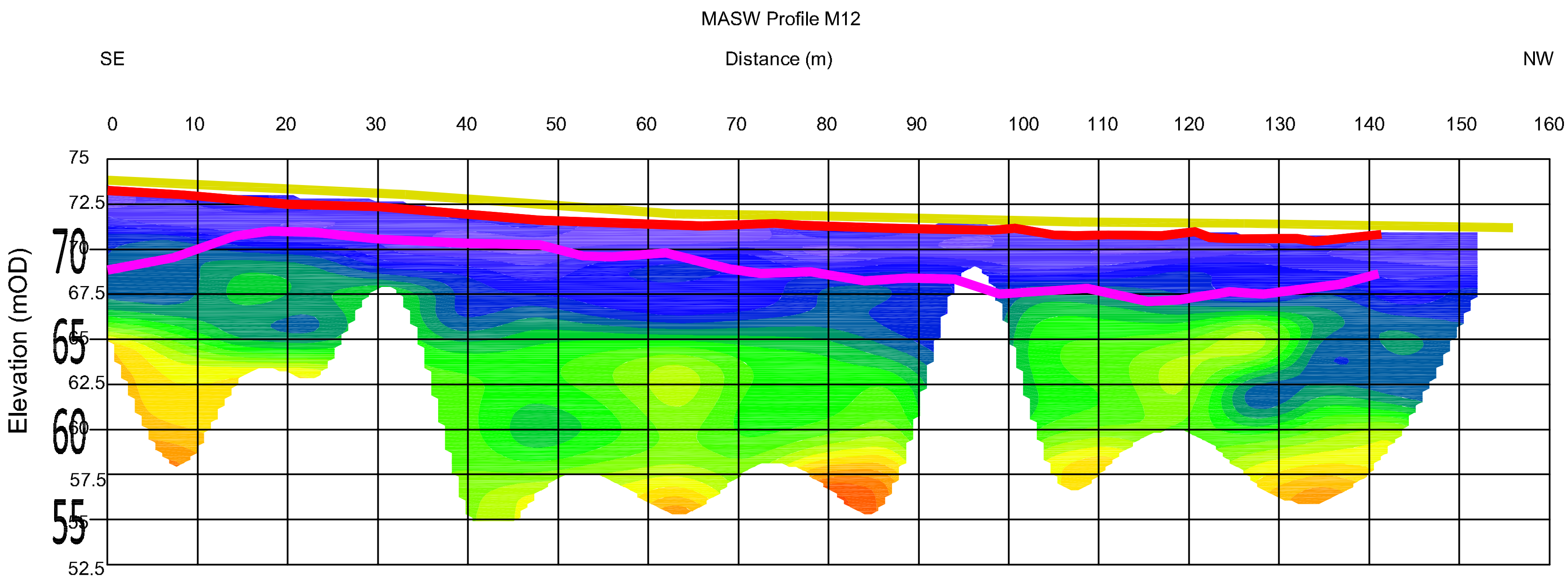
Shear Wave Velocity (m/s)





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Maynooth, Co. Kildare
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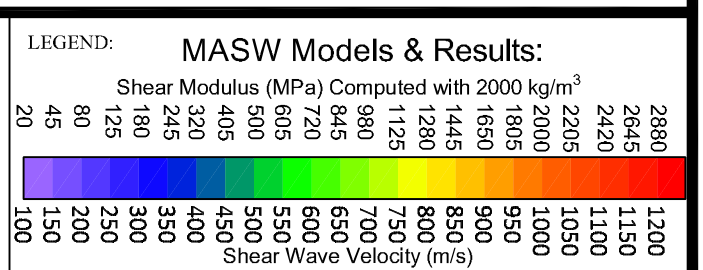
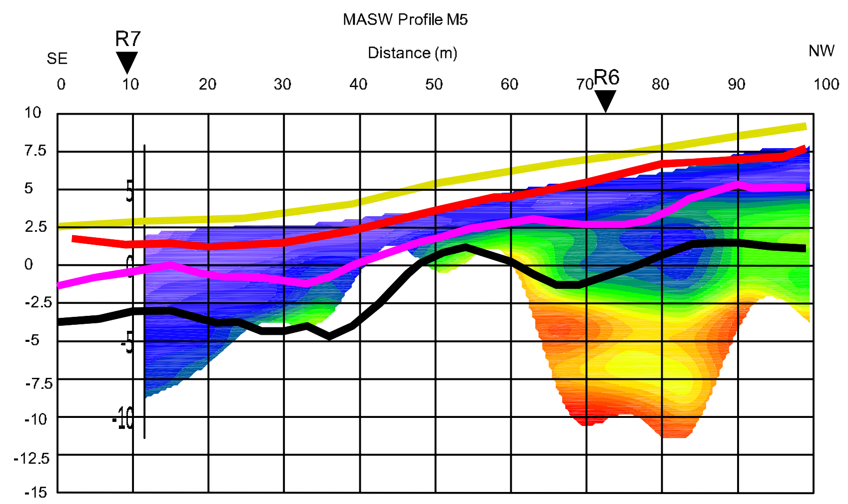
Email: info@mgx.ie
Web: www.mgx.ie

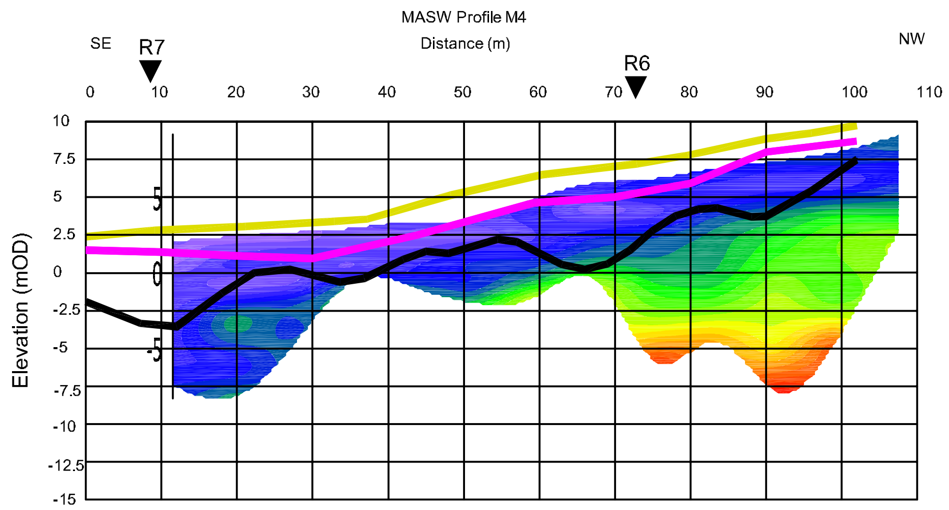
CLIENT	Irish Drilling Ltd.
PROJECT	TEN-T, County Donegal Geophysical Survey
TITLE	Figure 3e: Models of MASW Survey for Area E

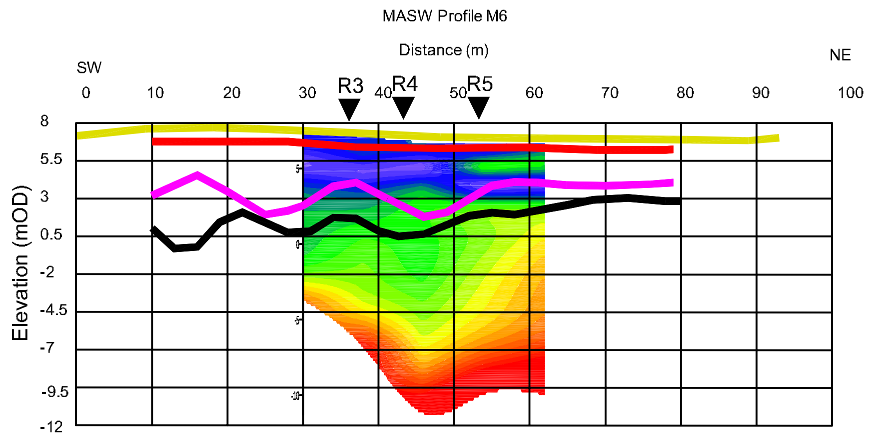
SCALE:	1:750 @ A3, VE x 2
PROJECT:	6526
DRAWN:	JC
DATE:	27/10/2020
MGX FILE:	6526d_MapsFigs.dwg
STATUS:	Draft

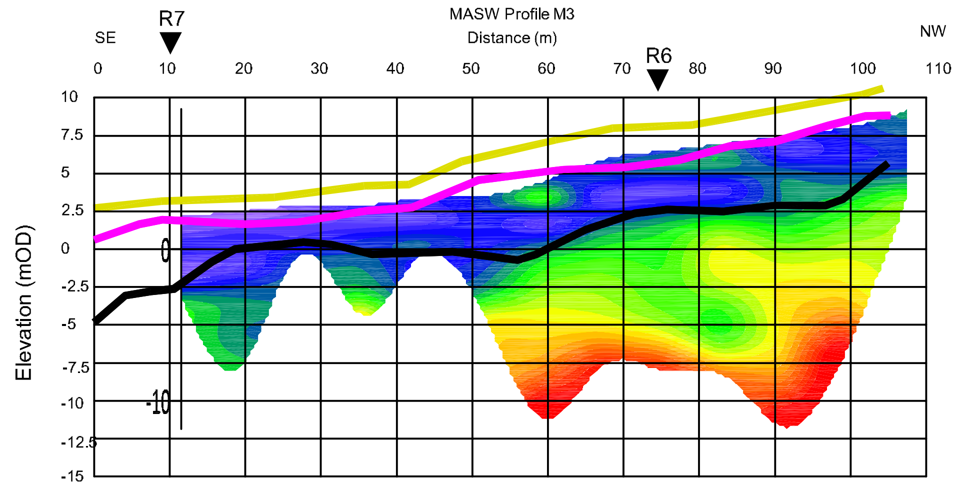
LEGEND:

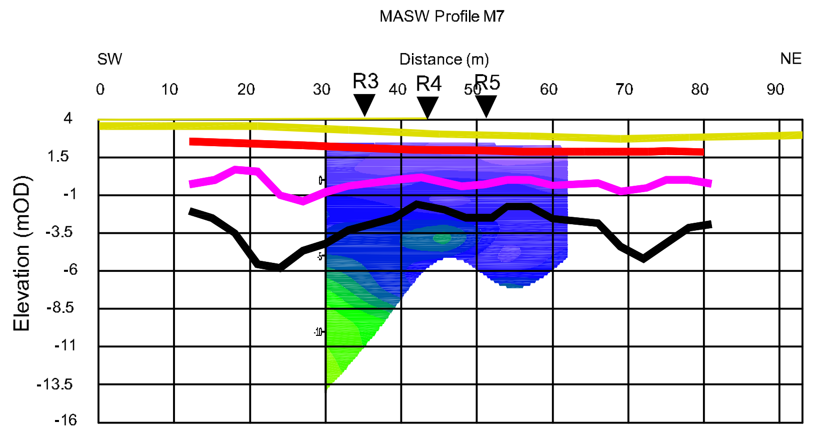












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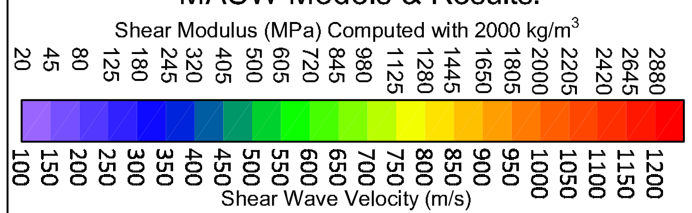
Email: info@mgx.ie
Web: www.mgx.ie

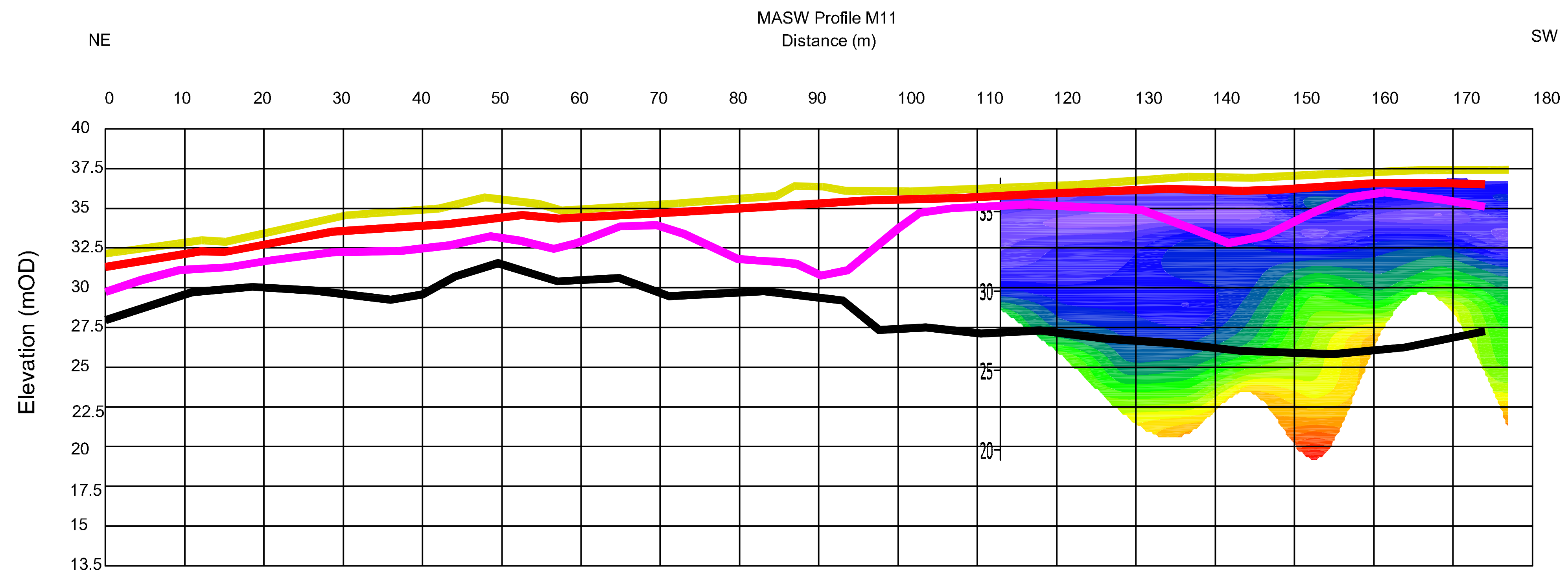
CLIENT	Irish Drilling Ltd.
PROJECT	TEN-T, County Donegal Geophysical Survey
TITLE	Figure 3f: Models of MASW Survey for River Swilly Crossing N

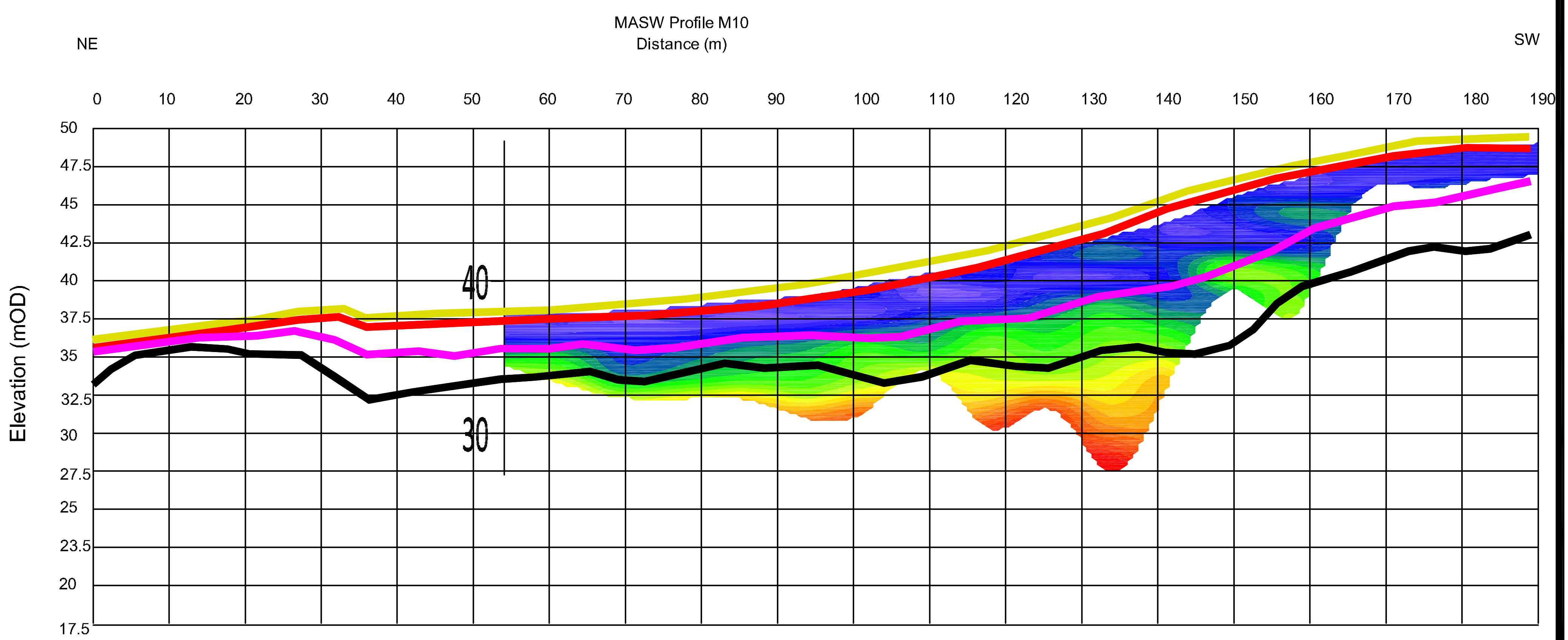
SCALE:	1:1000 @ A3, VE x 2
PROJECT:	6526
DRAWN:	JC
DATE:	27/10/2020
MGX FILE:	6526d_MapsFigs.dwg
STATUS:	Draft

LEGEND:

MASW Models & Results:







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CLIENT	Irish Drilling Ltd.
PROJECT	TEN-T, County Donegal Geophysical Survey
TITLE	Figure 3g: Models of MASW Survey for CH 1+900 - 2+150

SCALE:	1:750 @ A3, VE x 2
PROJECT:	6526
DRAWN:	JC
DATE:	27/10/2020
MGX FILE:	6526d_MapsFigs.dwg
STATUS:	Draft

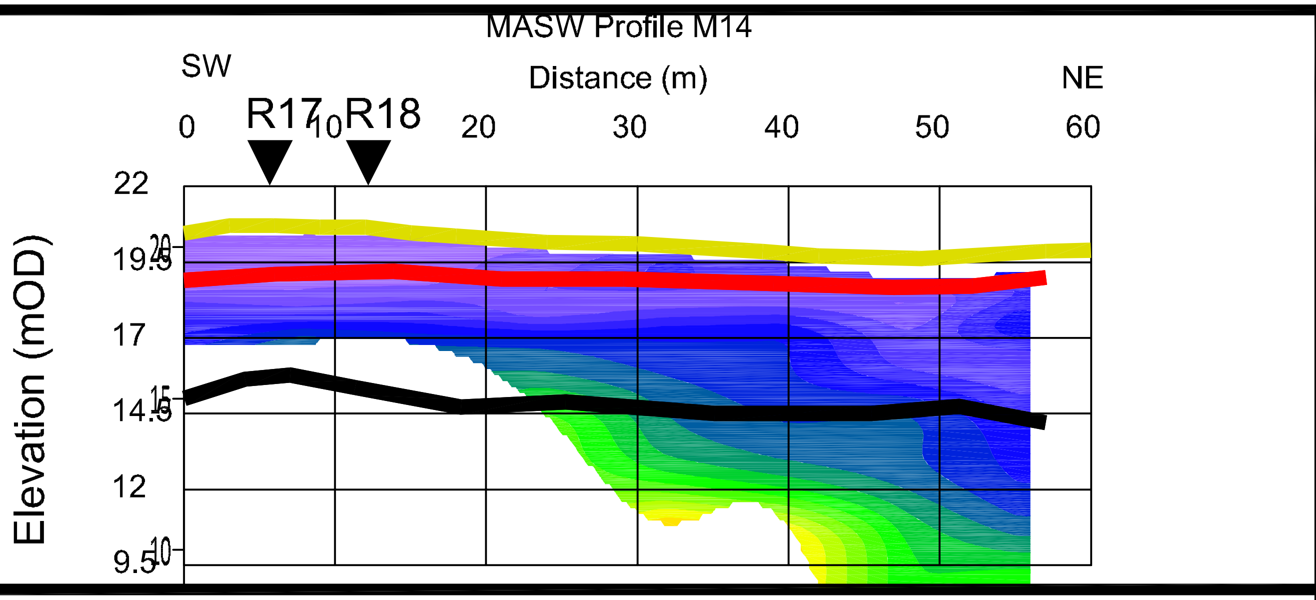
LEGEND: **MASW Models & Results:**

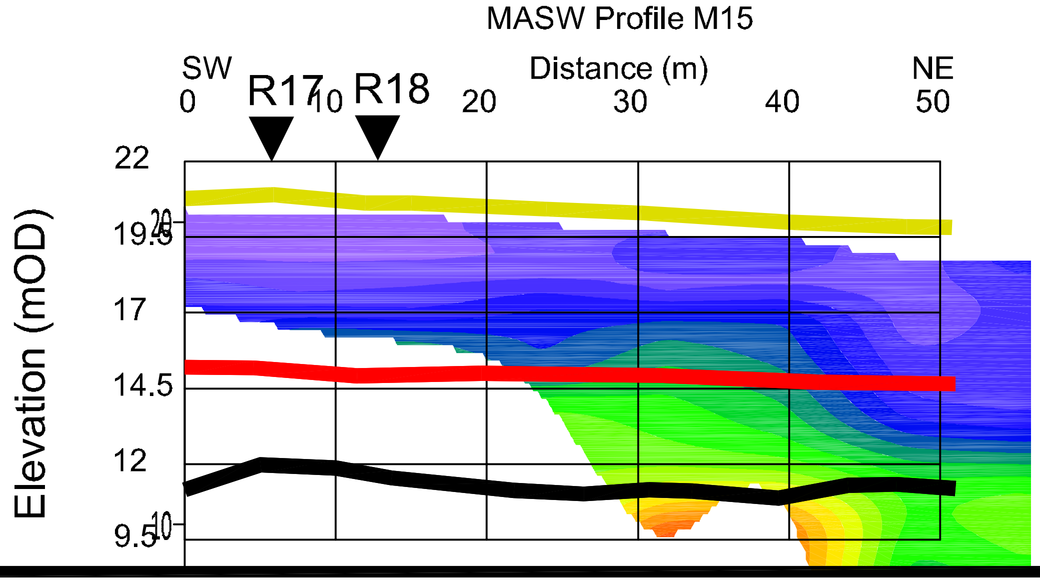
Shear Modulus (MPa) Computed with 2000 kg/m^3

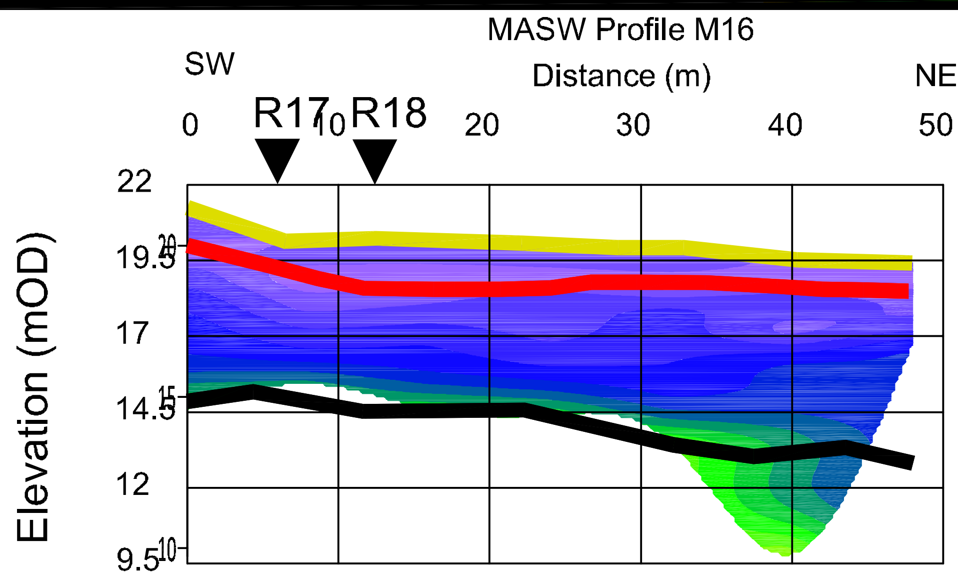
20 45 80 125 180 245 320 405 500 605 720 845 980 1125 1280 1445 1650 1805 2000 2205 2420 2645 2880

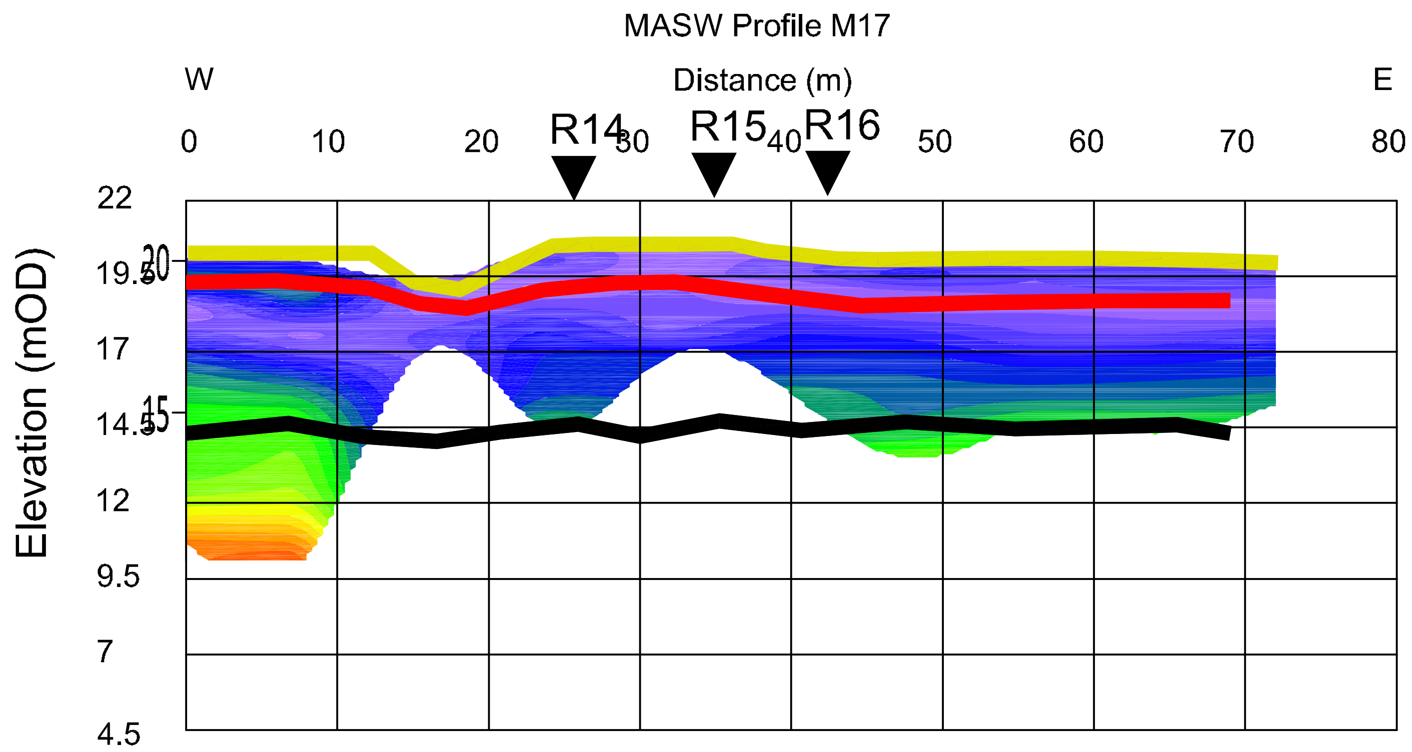
100 150 200 250 300 350 400 450 500 550 600 650 700 750 800 850 900 950 1000 1050 1100 1150 1200

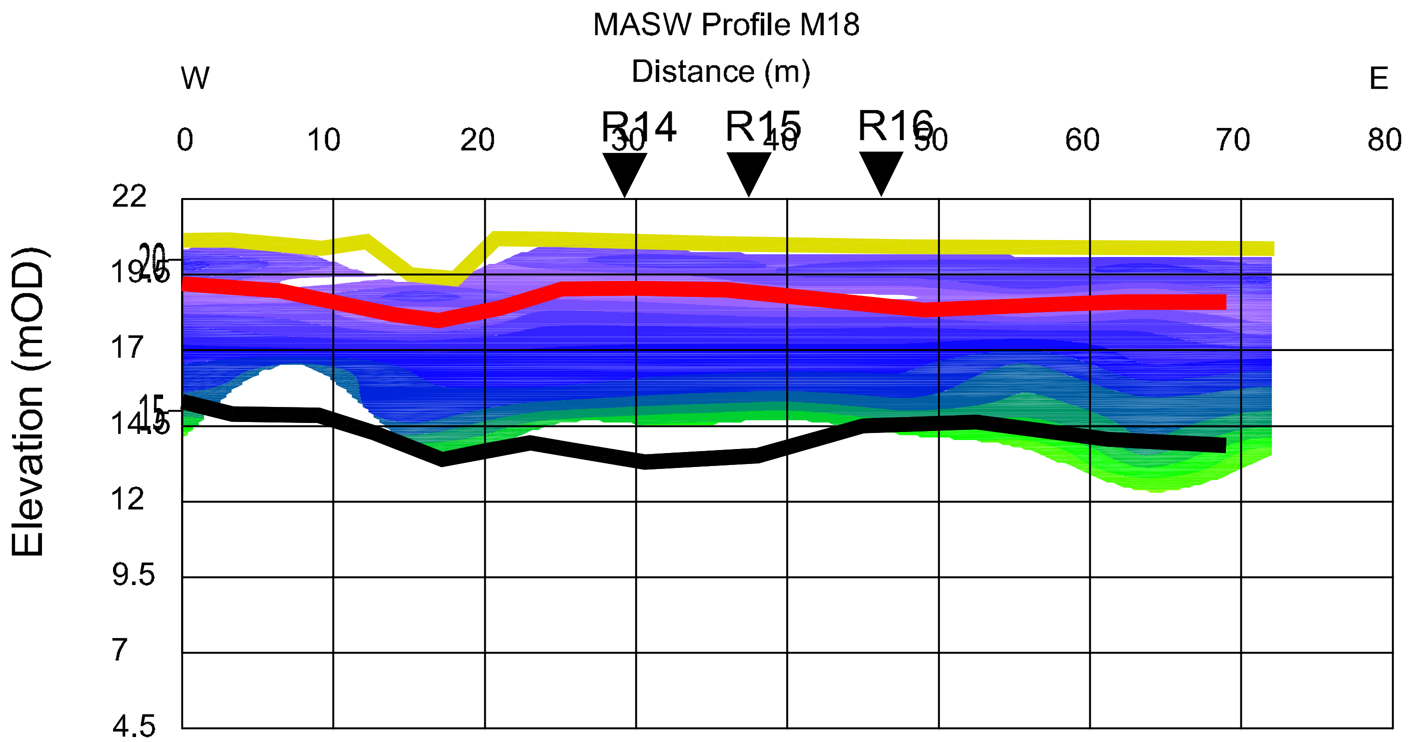
Shear Wave Velocity (m/s)











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Email: info@mgx.ie
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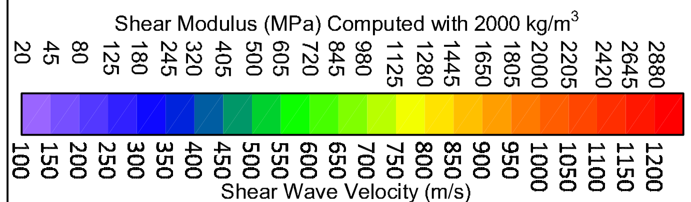
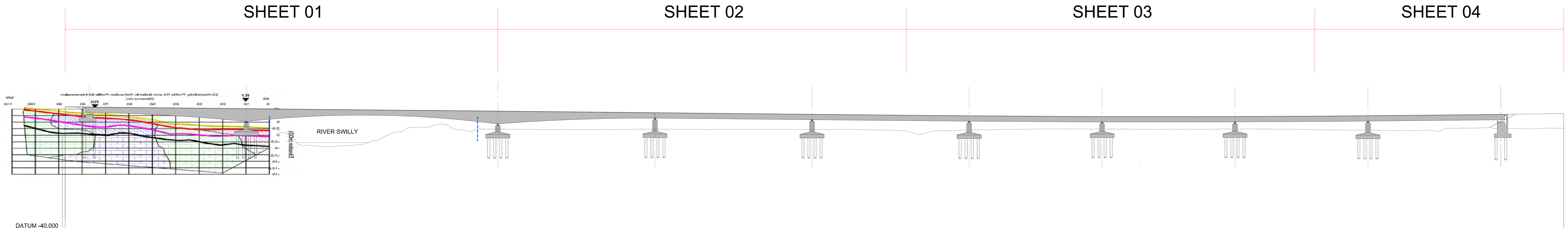
CLIENT	Irish Drilling Ltd.	SCALE:	1:500 @ A3, VE x 2
PROJECT	TEN-T, County Donegal Geophysical Survey	PROJECT:	6526
		DRAWN:	JC
		DATE:	27/10/2020
TITLE	Figure 3h: Models of MASW Survey for River Finn Crossing N	MGX FILE:	6526d_MapsFigs.dwg
		STATUS:	Draft

LEGEND: MASW Models & Results:



PLAN
Scale: 1/1000 @ A1, 1/2000 @ A3



CHAINAGE	PROPOSED LEVEL	EXISTING LEVEL
380.00	12.460	8.696
400.00	11.263	7.492
450.00	10.763	3.339
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550.00	9.763	2.136
600.00	9.263	2.034
650.00	8.763	2.036
700.00	8.263	2.115
750.00	7.769	1.744
800.00	7.758	2.291
850.00	7.406	2.150
900.00	7.611	1.901
950.00	8.069	2.044
1000.00	8.603	2.621

LONG SECTION
Scale: 1/1000 @ A1, 1/2000 @ A3

LEGEND

PLAN
- TRIAL PIT
- BOREHOLE/ SCT
- SAC BOUNDARY
- GEOPHYSICS PROFILE LINE

PROFILE
- TOPSOIL
- NO RECOVERY
- CLAY
- SILT
- SILT
- SAND
- GRAVEL/ COBBLES & BOULDERS
- ROCK
- N= N-VALUE
- WATER STRIKE
- WATER STRIKE 20 MINUTES AFTER STRIKE
- EXISTING GROUND LEVEL

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NOTES

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Rev.	Date	Drawn	Description	Chk'd	Appr.
P01	25.03.21	JOC	ISSUE FOR INFORMATION	KC	CMcG

Project Title: TEN-T Priority Route Improvement Project, Donegal
Section 2 - N56/N13 Letterkenny to Manorcunningham

Drawing Title: RIVER SWILLY CROSSING

Status: S2

Designed: JM
Drawn: JOC
Approved: KC
Checked: CMcG

Date: MAR 2021
Scale @ A1: As Shown
@ A3: As Shown
Sheet: 01 of 05

Model File Identifier: N/A
File Identifier: TT_MGT0337-RPS-P3-S2-DR-C-GI0002

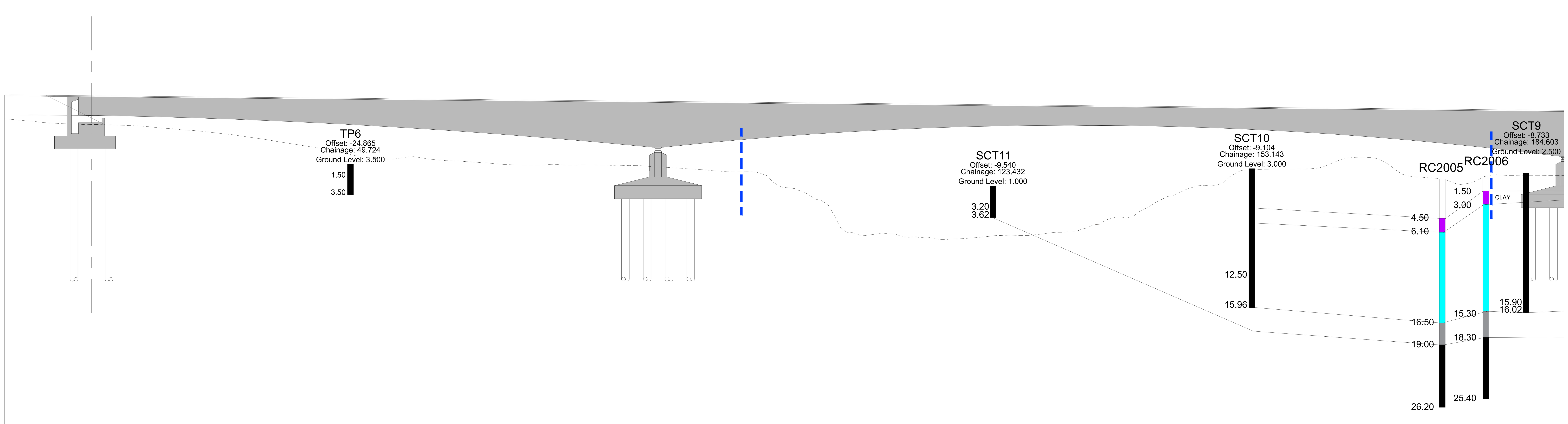
Rev: P01

T:\MGT0337 - Ten-T Priority Route Imp - Donegal\6.x Project Directories\14.0 Geotech\9. Structures\Swilly Bridge\TT_MGT0337-RPS-P3-S2-DR-C-BR0135_BR0136_River Swilly Bridge.dwg

LEGEND

PLAN: TRIAL PIT; BOREHOLE/ SCT; SAC BOUNDARY; GEOPHYSICS PROFILE LINE

PROFILE: TOPSOIL; NO RECOVERY; CLAY; SILT; SILT; SAND; GRAVEL/ COBBLES & BOULDERS; ROCK; N= N-VALUE; WATER STRIKE; WATER STRIKE 20 MINUTES AFTER STRIKE; EXISTING GROUND LEVEL



DATUM = -30.000m

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PROPOSED LEVEL	12.460	11.263	10.763	10.263	9.763	
EXISTING LEVEL	8.696	7.492	3.339	4.379	2.136	

LONG SECTION
Scale: 1/250 @ A1, 1/500 @ A3

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Rev.	Date	Drawn	Description	Chk'd	Appr.
P01	25.03.21	JOC	ISSUE FOR INFORMATION	KC	CMcG

Project Title: TEN-T Priority Route Improvement Project, Donegal
Section 2 - N56/N13 Letterkenny to Manorcunningham

Drawing Title: RIVER SWILLY CROSSING

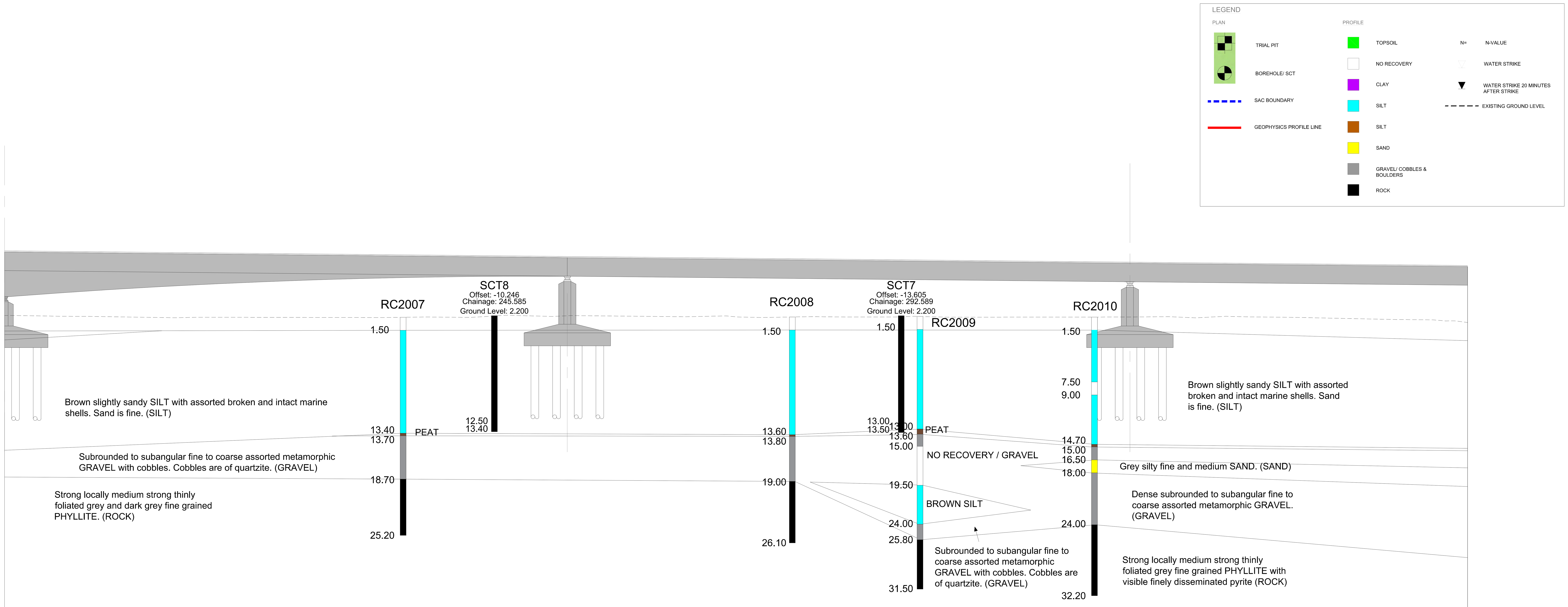
Status: S2

Designed: JM
Drawn: JOC
Approved: KC
Checked: CMcG

Date: MAR 2021
Scale @ A1: As Shown
@ A3: As Shown
Sheet: 02 of 05

Model File Identifier: N/A
File Identifier: TT_MGT0337-RPS-P3-S2-DR-C-GI0002

Rev: P01



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PROPOSED LEVEL		9.263	8.763	8.263	
EXISTING LEVEL		2.034	2.036	2.115	

LONG SECTION

Scale: 1/250 @ A1, 1/500 @ A3

T:\MGT0337 - Ten-T Priority Route Imp - Donegal\6.x Project Directories\14.0 Geotech\9. Structures\Swilly Bridge\TT_MGT0337-RPS-P3-S2-DR-C-BR0135_BR0136_River Swilly Bridge.dwg

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Rev.	Date	Drawn	Description	Chk'd	Appr.
P01	25.03.21	JOC	ISSUE FOR INFORMATION	KC	CMcG

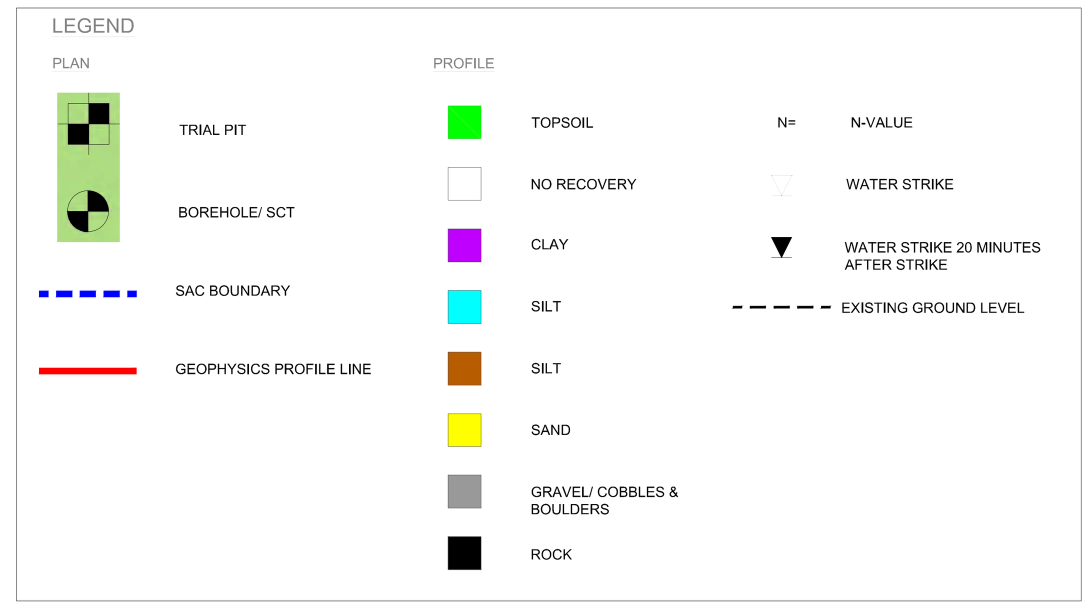
Project Title: TEN-T Priority Route Improvement Project, Donegal
Section 2 - N56/N13 Letterkenny to Manorcunningham

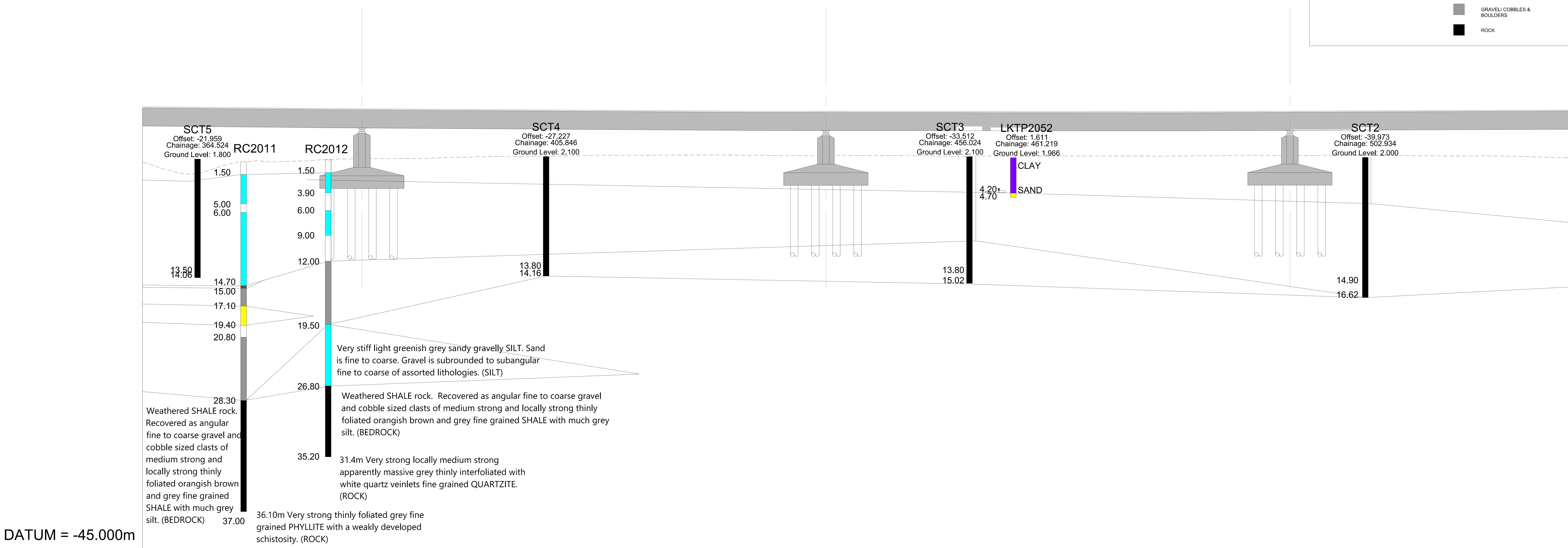
Drawing Title: RIVER SWILLY CROSSING

Status: S2

Designed: JM	Date: MAR 2021	Model File Identifier: N/A	Rev: P01
Drawn: JOC	Scale @ A1: As Shown		
Approved: KC	@ A3: As Shown	File Identifier: TT_MGT0337-RPS-P3-S2-DR-C-GI0002	
Checked: CMcG	Sheet: 03 of 05		

LEGEND





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EXISTING LEVEL		1.744	2.291	2.150	

LONG SECTION
Scale: 1/250 @ A1, 1/500 @ A3

T:\MGT0337 - Ten-T Priority Route Imp - Donegal\6.x Project Directories\14.0 Geotech\9. Structures\Swilly Bridge\TT_MGT0337-RPS-P3-S2-DR-C-BR0135_River Swilly Bridge.dwg

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Donegal County Council

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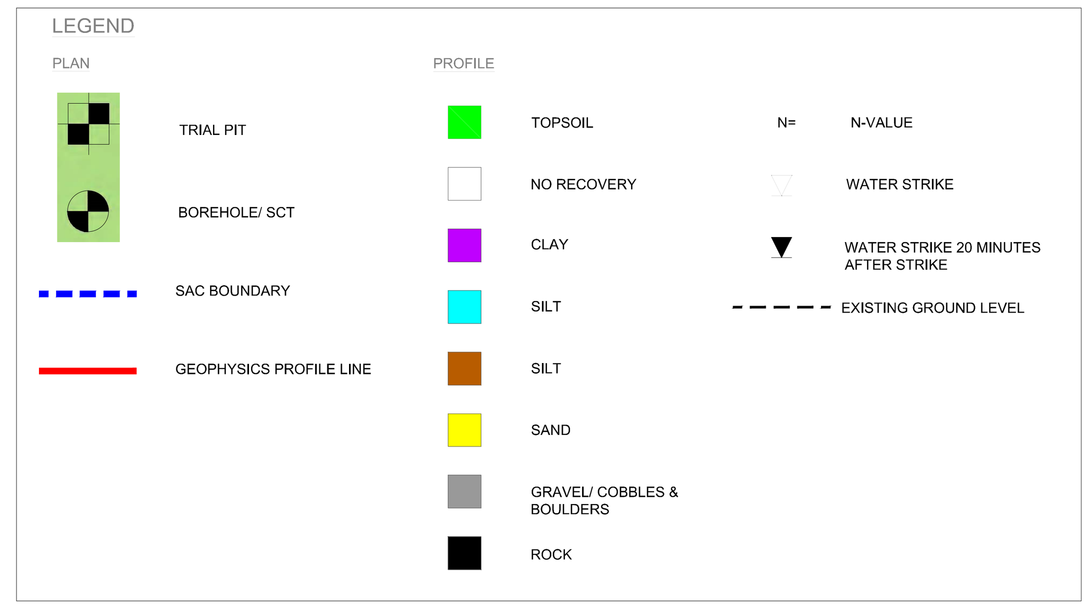
Rev.	Date	Drawn	Description	Chk'd	Appr.
P01	25.03.21	JOC	ISSUE FOR INFORMATION	KC	CMcG

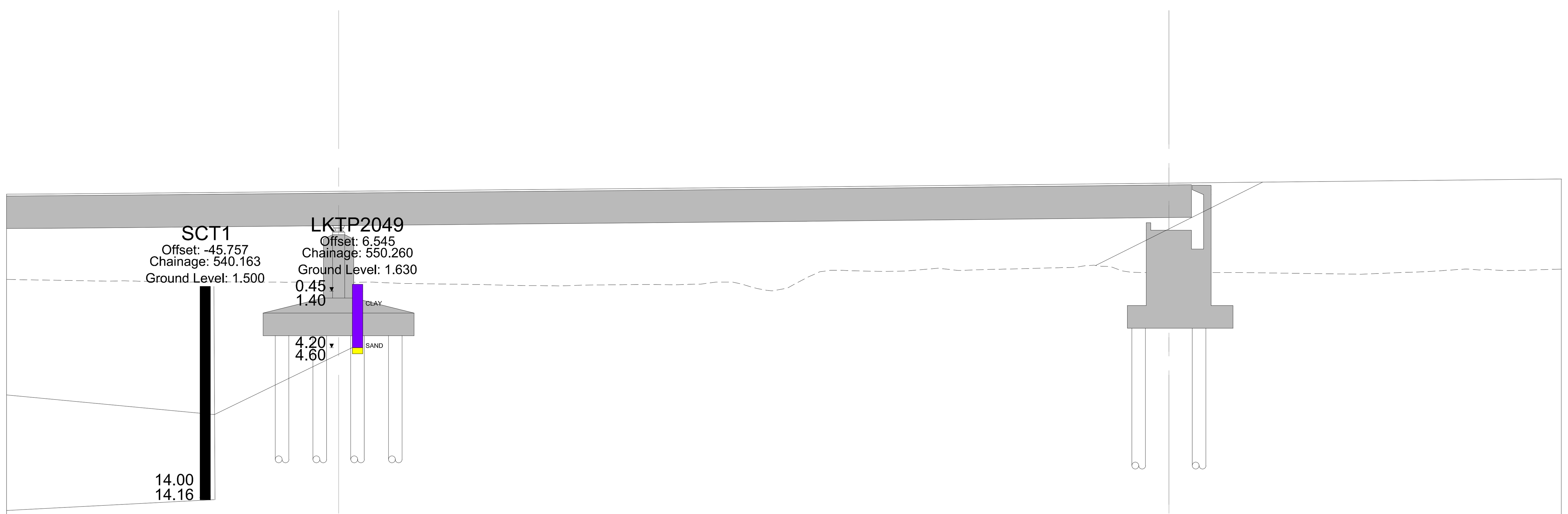
Project Title: TEN-T Priority Route Improvement Project, Donegal
Section 2 - N56/N13 Letterkenny to Manorcunningham

Drawing Title: RIVER SWILLY CROSSING

Status: S2

Designed: JM	Date: MAR 2021	Model File Identifier: N/A	Rev: P01
Drawn: JOC	Scale @ A1: As Shown		
Approved: KC	@ A3: As Shown	File Identifier: TT_MGT0337-RPS-P3-S2-DR-C-GI0002	
Checked: CMcG	Sheet: 04 of 05		





DATUM = -20.000m

CHAINAGE	897.00	900.00	950.00	1000.00
PROPOSED LEVEL		7.611	8.069	8.603
EXISTING LEVEL		1.901	2.044	2.621

LONG SECTION
Scale: 1/250 @ A1, 1/500 @ A3

T:\MGT0337 - Ten-T Priority Route Imp - Donegal\6.x Project Directories\14.0 Geotech\9. Structures\Swilly Bridge\TT_MGT0337-RPS-P3-S2-DR-C-BR0135_BR0136_River Swilly Bridge.dwg

Bonneagar Iompair Éireann
Transport Infrastructure Ireland
Co-financed by the Connecting Europe Facility of the European Union
Rialtas na hÉireann Government of Ireland
Tionscadal Éireann Project Ireland 2040
Donegal NRO
Oifig Bóithre Náisiúnta Dhún na nGall
Comhairle Contae Dhún na nGall
Donegal County Council
RPS
BARRY TRANSPORTATION

NOTES

DO NOT SCALE, use figured dimensions only.

All levels are referred to Ordnance Survey Datum, Malin Head.

Rev.	Date	Drawn	Description	Chk'd	Appr.
P01	25.03.21	JOC	ISSUE FOR INFORMATION	KC	CMcG

Project Title: TEN-T Priority Route Improvement Project, Donegal
Section 2 - N56/N13 Letterkenny to Manorcunningham

Drawing Title: RIVER SWILLY CROSSING

Status: S2

Designed: JM	Date: MAR 2021	Model File Identifier: N/A	Rev:
Drawn: JOC	Scale @ A1: As Shown		
Approved: KC	@ A3: As Shown	File Identifier: TT_MGT0337-RPS-P3-S2-DR-C-GI0002	P01
Checked: CMcG	Sheet: 05 of 05		

irish drilling

BOREHOLE LOG

Project	TEN-T Preliminary GI, Section 2	Location	Letterkenny, Co Donegal	BOREHOLE No	LKCP2215
Job No: 2020DL101A	Date: 29-05-20 29-05-20	Ground Level (m OD): 2.39	Co-Ordinates (): E 619,414.2 N 911,274.3		
Engineer: RPS Consulting Engineers		GROUNDWATER STRIKES	Water strikes: 1st: dry 2nd: 3rd: Rose to (@ 20 min.): Sealed at:	Sheet 1 of 1	Rev. DRAFT

SAMPLES & TESTS / STRATA

Depth	Type No	Test Result	Water	Reduced Level	Legend	Depth (Thickness)	DESCRIPTION
0.00-1.00	B1			1.79		(0.60) 0.60	MADE GROUND: Clause 804 type material.
1.00	CPT	N = 14 (8, 10, 6, 3, 3, 2)					MADE GROUND: Gravel fill with cobbles.
1.00	D2					(1.20)	
1.00-1.50	B4						
1.50	D5			0.59		1.80	
2.00	SPT	N = 11 (2, 3, 2, 2, 3, 4)					Soft to firm grey silty CLAY.
2.00-2.50	B7						
2.50	D8						
3.00	SPT	15 for 267 mm (3, 3, 4, 4, 3, 4)					
3.00-3.50	B10						
3.50	D11						
4.00	SPT	N = 16 (4, 5, 3, 5, 4, 4)				(4.70)	
4.00-4.50	B13						
4.50	D14						
5.00	SPT	N = 14 (3, 2, 2, 3, 3, 6)					
5.00-5.50	B16						
5.50	D17			-4.11		6.50	
6.50	SPT	N = 60 (8, 7, 10, 10, 11, 29)					Grey very sandy SILT with small shells.
6.50-7.00	B19			-4.61		7.00	
7.00	D20			-4.71		7.10	Obstruction.
							BH terminated at 7.10m bgl - obstruction.

Boring Progress and Water Observations

Date	Time	Depth	Casing Depth	Casing Dia. mm	Water (bgl) Depth, m
29-05-20	15.00	7.10	7.00	203	basal seepage

Chiselling

From	To	Hours
7	7.1	1

Water Added

From	To

GENERAL REMARKS

BH backfilled.

All dimensions in metres Scale 1:68.75	Client: Donegal County Council	Method/ Plant Used: Dando 2000	Bit Design	Driller BT	Logged By BT

irish drilling

BOREHOLE LOG

Project	Location	BOREHOLE No
TEN-T Preliminary GI, Section 2	Letterkenny, Co Donegal	**LKCP2216**

Job No	Date	Ground Level (m OD)	Co-Ordinates ()
2020DL101A	02-06-20 02-06-20	2.37	E 619,380.5 N 911,301.8

Engineer	GROUNDWATER STRIKES	Water strikes:	Rose to (@ 20 min.):	Sealed at:	Sheet 1 of 1
RPS Consulting Engineers		1st: dry 2nd: 3rd:			Rev. DRAFT

SAMPLES & TESTS / STRATA

Depth	Type No	Test Result	Water	Reduced Level	Depth (Thickness)	DESCRIPTION
0.00-1.00	B1				(0.80)	MADE GROUND: Gravel fill.
				1.57	0.80	
1.00	SPT	N = 11 (6, 2, 2, 3, 3, 3)				Firm grey sandy SILT.
1.00	D2					
1.00-1.50	B4					
1.50	D5					
2.00	SPT	9 for 235 mm (3, 3, 1, 3, 2, 3)				
2.00-2.50	B7					
2.50	D8				(4.20)	
3.00	SPT	N = 15 (3, 4, 4, 4, 5, 2)				
3.00-3.50	B10					
3.50	D11					
4.00	SPT	N = 10 (1, 2, 2, 3, 2, 3)				
4.00-4.50	B13					
4.50	D14			-2.63	5.00	
5.00	SPT	N = 7 (2, 1, 2, 2, 1, 2)				Firm grey very sandy SILT.
5.00-5.50	B16					
5.50	D17				(2.00)	
6.50	SPT	N = 12 (2, 3, 2, 3, 3, 4)				
6.50-7.00	B19			-4.63	7.00	
7.00	D20					Soft very sandy SILT with small shells.
8.00	CPT	N = 13 (3, 2, 5, 2, 2, 4)			(2.00)	
8.00-8.50	B22					
8.50	D23			-6.63	9.00	
				-6.93	9.30	Obstruction.
						BH terminated at 9.30m bgl - obstruction.

Boring Progress and Water Observations

Date	Time	Depth	Casing Depth	Casing Dia. mm	Water (bgl) Depth, m
02-06-20	16.00	9.30	9.00	203	

Chiselling

From	To	Hours
9	9.3	1

Water Added

From	To

GENERAL REMARKS

50mm standpipe installed. Response zone 2.70m to 8.70m bgl.

All dimensions in metres Scale 1:68.75	Client: Donegal County Council	Method/ Plant Used: Dando 2000	Bit Design	Driller BT	Logged By BT

irish drilling

BOREHOLE LOG

Project: TEN-T Preliminary GI, Section 2		Location: Letterkenny, Co Donegal		BOREHOLE No **LKCP2217**
Job No: 2020DL101A	Date: 05-06-20 08-06-20	Ground Level (m OD): 2.34	Co-Ordinates (): E 619,407.8 N 911,342.4	
Engineer: RPS Consulting Engineers		GROUNDWATER STRIKES	Water strikes: 1st: dry 2nd: 3rd: Rose to (@ 20 min.): Sealed at:	Sheet 1 of 2 Rev. DRAFT

SAMPLES & TESTS / STRATA

Depth	Type No	Test Result	Water	Reduced Level	Legend	Depth (Thickness)	DESCRIPTION
0.00-1.00	B1					(1.20)	MADE GROUND: Gravel fill.
1.00	CPT	N = 12 (4, 6, 3, 4, 2, 3)		1.14		1.20	
1.00	D2						Firm grey sandy silty CLAY.
1.00-1.50	B4						
1.50	D5						
2.00	SPT	N = 10 (2, 2, 2, 3, 2, 3)					
2.00-2.50	B7					(2.80)	
2.50	D8						
3.00	SPT	N = 8 (2, 4, 3, 2, 1, 2)					
3.00-3.50	B10						
3.50	D11			-1.66		4.00	
4.00	SPT	N = 7 (1, 1, 2, 1, 3, 1)					Very sandy silty CLAY.
4.00-4.50	B13						
4.50	D14						
5.00	SPT	N = 7 (1, 2, 2, 2, 1, 2)					
5.00-5.50	B16						
5.50	D17					(5.00)	
6.50	SPT	N = 14 (2, 4, 4, 3, 4, 3)					
6.50-7.00	B19						
7.00	D20						
8.00	SPT	N = 12 (3, 3, 3, 2, 4, 3)					
8.00-8.50	B22						
8.50	D23			-6.66		9.00	
							Soft to firm greenish grey SILT with small shells.
9.50	SPT	N = 12 (2, 2, 4, 3, 2, 3)				(1.50)	
9.50-10.00	B25						
10.00	D26			-8.16		10.50	
				-8.66		11.00	Medium dense grey fine SAND.

Boring Progress and Water Observations

Date	Time	Depth	Casing Depth	Casing Dia. mm	Water (bgl) Depth, m
05-06-20	16.00	11.00	11.00	203	
08-06-20	08.00	11.00	11.00	203	6.60

Chiselling

From	To	Hours

Water Added

From	To

GENERAL REMARKS

BH backfilled.

All dimensions in metres Scale 1:68.75	Client: Donegal County Council	Method/ Plant Used: Dando 2000	Bit Design	Driller BT	Logged By BT

irish drilling

BOREHOLE LOG

Project	TEN-T Preliminary GI, Section 2	Location	Letterkenny, Co Donegal	BOREHOLE No
Job No 2020DL101A	Date 05-06-20 08-06-20	Ground Level (m OD) 2.34	Co-Ordinates () E 619,407.8 N 911,342.4	**LKCP2217**
Engineer	RPS Consulting Engineers	GROUNDWATER STRIKES	Water strikes: 1st: dry 2nd: 3rd: Rose to (@ 20 min.): Sealed at:	Sheet 2 of 2 Rev. DRAFT

SAMPLES & TESTS			Water	STRATA				Geology	Instrument/ Backfill
Depth	Type No	Test Result		Reduced Level	Legend	Depth (Thickness)	DESCRIPTION		
11.00	CPT	N = 17 (3, 4, 5, 4, 4, 4)					Grey sandy SILT.		
11.00-11.50	B28								
11.50	D29								
12.50	CPT	N = 11 (2, 2, 3, 2, 2, 4)							
12.50-13.00	B31					(4.00)			
13.00	D32								
14.00	CPT	N = 4 (1, 0, 1, 1, 1, 1)							
14.00-14.50	B34								
14.50	D35			-12.66		15.00			
							Dense GRAVEL with cobbles.		
15.50	CPT	N = 31 (4, 5, 8, 7, 7, 9)							
15.50-16.00	B37								
16.00	D38					(2.50)			
17.00	CPT	N = 48 (8, 9, 10, 10, 11, 17)							
17.00-17.50	B40			-15.16		17.50			
17.50	D41			-15.26		17.60	Obstruction as possible rock.		
17.60	CPT	50 for 0 mm (25, -, 50)					BH terminated at 17.60m bgl - obstruction as possible rock.		

Boring Progress and Water Observations

Date	Time	Depth	Casing Depth	Casing Dia. mm	Water (bgl) Depth, m
08-06-20	16.00	17.60	17.50	203	13.00

Chiselling

From	To	Hours
17.6	17.6	1

Water Added

From	To

GENERAL REMARKS

BH backfilled.

All dimensions in metres Scale 1:68.75	Client: Donegal County Council	Method/ Plant Used Dando 2000	Bit Design	Driller BT	Logged By BT

irish drilling

BOREHOLE LOG

Project: TEN-T Preliminary GI, Section 2		Location: Letterkenny, Co Donegal		BOREHOLE No **LKCP2218**
Job No: 2020DL101A	Date: 03-06-20 04-06-20	Ground Level (m OD): 2.30	Co-Ordinates (): E 619,376.2 N 911,361.9	
Engineer: RPS Consulting Engineers		GROUNDWATER STRIKES	Water strikes: 1st: dry 2nd: 3rd: Rose to (@ 20 min.): Sealed at:	Sheet 1 of 2 Rev. DRAFT

SAMPLES & TESTS / STRATA

Depth	Type No	Test Result	Water	Reduced Level	Legend	Depth (Thickness)	DESCRIPTION	Geology	Instrument/ Backfill
0.00-1.00	B1						MADE GROUND: Stone fill and concrete and broken tarmac.		
						(1.20)			
1.00	SPT	N = 16 (8, 4, 5, 4, 4, 3)		1.10		1.20			
1.00	D2						Grey sandy silty CLAY with bands of fine sand.		
1.00-1.50	B4								
1.50	D5								
2.00	SPT	N = 11 (2, 2, 3, 2, 3, 3)							
2.00-2.50	B7								
2.50	D8								
3.00	SPT	N = 13 (2, 3, 3, 3, 4, 3)							
3.00-3.50	B10								
3.50	D11					(5.10)			
4.00	SPT	N = 7 (2, 1, 1, 2, 2, 2)							
4.00-4.50	B13								
4.50	D14								
5.00	SPT	N = 5 (1, 0, 1, 1, 2, 1)							
5.00-5.50	B16								
5.50	D17								
				-4.00		6.30			
							Soft grey very sandy SILT.		
6.50	SPT	N = 17 (3, 3, 4, 5, 4, 4)							
6.50-7.00	B19								
7.00	D20								
8.00	SPT	N = 11 (3, 2, 3, 3, 2, 3)							
8.00-8.50	B22					(4.30)			
8.50	D23								
9.50	SPT	N = 9 (2, 3, 1, 2, 3, 3)							
9.50-10.00	B25								
10.00	D26								
				-8.30		10.60			
							Medium dense grey fine SAND.		

Boring Progress and Water Observations

Date	Time	Depth	Casing Depth	Casing Dia. mm	Water (bgl) Depth, m
03-06-20	17.00	10.60	10.50	203	
04-06-20	08.00	10.60	10.50	203	6.00

Chiselling

From	To	Hours

Water Added

From	To

GENERAL REMARKS

BH backfilled.

All dimensions in metres Scale 1:68.75	Client: Donegal County Council	Method/ Plant Used: Dando 2000	Bit Design	Driller BT	Logged By BT

PROJECT: TEN-T Preliminary GI, Section 2		TRIALPIT: LKTP2048
LOCATION: Letterkenny, Co Donegal		Sheet 1 of 1
CLIENT: Donegal County Council	Co-ordinates:	Rig: Zaxis 120
ENGINEER: RPS Consulting Engineers	E 619,464.1 N 911,183.6	Rev: DRAFT
Ground level: 1.99m O.D.		DATE: 2.6.20

GROUNDWATER

Water strikes:		Rose to after:	
1st:	4.50m	5min	4.30m
2nd:			
3rd:			

PIT DIRECTION:
PIT DIMENSION: 1.50 * 4.00m
LOGGED BY: PC

Pit plan: A 4.00, B 1.50, C, D

Shoring/Support: N/A
Stability: Pit stable.

Depth (m)	Date	Water	Samples	Depth (m)	In-situ Vane Tests	LEGEND	Elevation m O.D.	Depth (m)	DESCRIPTION
0							0.89	1.10	MADE GROUND: Greyish brown silty angular to subangular fine to coarse phyllite GRAVEL with high cobble content and medium boulder content. Cobbles are angular to subangular of phyllite. Boulders are subangular to subrounded of phyllite. Boulders are up to 900mm in length.
1			B 1	1.01-1.40					
			VANE	1.20	19mm vane used 14 kN/m²		0.29	1.70	Firm bluish orangish grey silty CLAY with some bivalve shell fragments.
2									Soft bluish grey sandy SILT with some bivalve shell fragments. Sand is fine.
3			B 2	3.00-3.50					
4		1 (rose to 4.30)							
		1 (strike 4.50)					-2.51	4.50	
						END			TP terminated at 4.50m bgl on REs instruction.
5									

Remarks: Ingress of water at 4.50m bgl. TP backfilled with arisings.

Scale: 1:27.5

irish drilling

Ph.
Fax

PROJECT: TEN-T Preliminary GI, Section 2	**TRIALPIT:** LKTP2049
LOCATION: Letterkenny, Co Donegal	Sheet 1 of 1
CLIENT: Donegal County Council **ENGINEER:** RPS Consulting Engineers	**Co-ordinates:** E 619,306.8 N 911,341.8
Rig: Zaxis 120	**Rev:** DRAFT
Ground level: 1.63m O.D.	**DATE:** 4.6.20

GROUNDWATER

Water strikes:		Rose to after:
1st:	0.45m	
2nd:	4.20m	
3rd:		

PIT DIRECTION: 340-160
PIT DIMENSION: 1.50 * 4.00m
LOGGED BY: PC

Pit plan: A 4.00, B 1.50, C, D

Shoring/Support: N/A
Stability: Pit stable.

Depth (m)	Date	Water	Samples	Depth (m)	In-situ Vane Tests	LEGEND	Elevation m O.D.	Depth (m)	DESCRIPTION
0									Grass over orangish greyish brown silty CLAY with rootlets.
		1 (0.45m)					1.18	0.45	
			B 1	0.50-0.80					Firm damp orangish grey silty CLAY with rare bivalve shell fragments and rootlets.
			VANE	0.70	19mm vane used 8 kN/m^2				
1									
							0.23	1.40	Soft damp dark bluish grey silty CLAY.
2									
			B 2	2.50-2.80					
3									
4			VANE	4.00	33mm vane used 20 kN/m^2				
		2 (4.20m)					-2.57	4.20	Moist brownish grey silty fine to coarse SAND with many bivalve shell fragments.
			B 3	4.20-4.50					
						END	-2.97	4.60	TP terminated at 4.60m bgl on REs instruction.
5									

Remarks: Damp from 0.45m to 4.20m bgl. Moist from 4.20m to 4.60m bgl. TP backfilled with arisings.

Scale: 1:27.5

PROJECT: TEN-T Preliminary GI, Section 2 LOCATION: Letterkenny, Co Donegal		TRIALPIT: **LKTP2050** Sheet 1 of 1
CLIENT: Donegal County Council ENGINEER: RPS Consulting Engineers	Co-ordinates: E 618,818.4 N 911,913.3	Rig: Zaxis 120 Rev: DRAFT
Ground level: 11.90m O.D.		DATE: 10.6.20

GROUNDWATER

Water strikes: Rose to after:
1st: 0.20m
2nd:
3rd:

PIT DIRECTION: 010-190
PIT DIMENSION: 1.50 * 4.00m
LOGGED BY: PC

Plan: A 4.00, B 1.50, C, D

Shoring/Support: N/A
Stability: Pit stable.

Water	Samples	Depth (m)	In-situ Vane Tests	Elevation m O.D.	Depth (m)	DESCRIPTION
1 (0.20)				11.50	0.40	Grass over firm brown clayey gravelly SILT. Gravel is subangular to subrounded fine to coarse of schist and quartzite.
	B 1	0.40-0.70		11.20	0.70	Firm orangish brown gravelly silty CLAY. Gravel is subangular to subrounded fine to coarse of schist phyllite and quartzite.
	B 2	0.70-1.00		10.70	1.20	Firm damp orangish grey gravelly silty CLAY. Gravel is subangular to subrounded fine to medium of quartz psammite quartzite and schist.
	B 3	1.30-1.60		10.30	1.60	Soft reddish brown gravelly SILT with low cobble content and low boulder content. Gravel is subangular to subrounded fine to coarse of schist. Cobbles are subangular to subrounded of schist. Boulders are subangular to subrounded of schist. Boulders are up to 300mm in length.
				9.90	2.00	Blackish brown sandy silty angular to subangular fine to coarse schist GRAVEL with low cobble content and low boulder content. Cobbles are angular to subangular of schist. Boulders are angular to subangular of schist.
				END		TP terminated at 2.00m bgl. Obstruction as probable rock.

Remarks: Damp from 0.20m to 1.20m bgl. TP backfilled with arisings.

Scale: 1:27.5

PROJECT: TEN-T Preliminary GI, Section 2 **LOCATION: Letterkenny, Co Donegal**		**TRIALPIT: LKTP2051** **Sheet 1 of 1**
CLIENT: Donegal County Council **ENGINEER: RPS Consulting Engineers**	**Co-ordinates:** **E 618,917.9 N 911,839.1**	**Rig: Zaxis 120** **Rev: DRAFT**
Ground level: 14.81m O.D.		**DATE: 10.6.20**

GROUNDWATER

Water strikes: Rose to after:
1st: 0.60m
2nd:
3rd:

PIT DIRECTION: 040-220
PIT DIMENSION: 1.50 * 3.50m
LOGGED BY: PC

Pit plan: A 3.50, B 1.50, C, D

Shoring/Support: N/A
Stability: Pit stable.

Depth (m)	Date	Water	Samples	Depth (m)	In-situ Vane Tests	LEGEND	Elevation m O.D.	Depth (m)	DESCRIPTION
0			B 1	0.30-0.60			14.21	0.60	Grass over firm brown gravelly SILT with low cobble content and low boulder content and rootlets. Gravel is subangular to subrounded fine to coarse of psammite and quartzite. Cobbles are subangular to subrounded of psammite and quartzite. Boulders are subangular to subrounded of psammite and quartzite. Boulders are up to 500mm in length.
1		1 (0.60)	B 2	0.60-0.90			13.51	1.30	Damp orangish brown clayey silty angular to subangular fine to coarse quartzite and gneiss GRAVEL with low cobble content and high boulder content. Cobbles are angular to subangular of quartzite and gneiss. Boulders are angular to subangular of quartzite and gneiss. Boulders are up to 1100mm in length.
						END			TP terminated at 1.30m bgl. Obstruction as probable rock.
2									
3									
4									
5									

Remarks: Damp from 0.60m to 1.30m bgl. TP backfilled with arisings.

Scale: 1:27.5

PROJECT: TEN-T Preliminary GI, Section 2		**TRIALPIT: LKTP2052**
LOCATION: Letterkenny, Co Donegal		**Sheet 1 of 1**
CLIENT: Donegal County Council	**Co-ordinates:**	**Rig: Zaxis 120**
ENGINEER: RPS Consulting Engineers	**E 619,262.8 N 911,419.6**	**Rev: DRAFT**
Ground level: 1.97m O.D.		**DATE: 4.6.20**

GROUNDWATER

Water strikes:		Rose to after:	
1st:	4.10m	5min	3.90m
2nd:			
3rd:			

PIT DIRECTION: 260-080
PIT DIMENSION: 1.50 * 4.00m
LOGGED BY: PC

4.00 A, B 1.50, C, D

Shoring/Support: N/A
Stability: Pit stable.

Date	Water	Samples	Depth (m)	In-situ Vane Tests	Elevation m O.D.	Depth (m)	DESCRIPTION
					1.57	0.40	Grass over firm orangish greyish brown silty CLAY with rootlets.
		B 1	0.40-0.70		0.67	1.30	Soft light orangish grey silty CLAY.
		B 2	1.80-2.10		-2.23	4.20	Firm damp dark bluish grey thinly laminated sandy clayey SILT. Laminae are 50mm thick. Sand is fine.
	1	B 3	4.20-4.50		-2.73	4.70	Moist dark bluish black clayey silty fine to coarse SAND. sand comprises shell fragments.
							END — TP terminated at 4.70m bgl on REs instruction.

Remarks: Ingress of water at 4.10m bgl. TP backfilled with arisings.

Scale: 1:27.5

irish drilling

Ph.
Fax

TRIAL PIT VANE & WL RISES TENT LETTERKENNY TPS ALL FILE JULY 17 2020.GPJ IRISHDRL.GDT 17/7/20

APPENDIX 3: COST ESTIMATE

Cost Estimate for Ten-T Priority Route Improvement Project, Donegal: Swilly Crossing Bridge Options

Option	Width	Length	Deck Area	Rate ex VAT	Sub-Total	10% Contingency for high level cost estimate	Total Cost
	m	m	m2	€/m2	€	€	€
1	28.25	234	6610.5	€ 3,864	€ 25,540,568	€ 2,554,057	€ 28,094,625
2	28.25	234	6610.5	€ 4,000	€ 26,442,000	€ 2,644,200	€ 29,086,200
3	28.25	364	10283	€ 3,864	€ 39,733,512	€ 3,973,351	€ 43,706,863
4	28.25	584	16498	€ 3,864	€ 63,748,272	€ 6,374,827	€ 70,123,099
5	28.25	228.5	6455.125	€ 6,000	€ 38,730,750	€ 3,873,075	€ 42,603,825
6	28.25	174	4915.5	€ 4,645	€ 22,832,498	€ 2,283,250	€ 25,115,747

Rate ex VAT (incl contingency)
€/m2
€ 4,250
€ 4,400
€ 4,250
€ 4,250
€ 6,600
€ 5,110

APPENDIX 4: CLIMATE ASSESSMENT

MAKING COMPLEX EASY

MGT0337 TEN-T - RIVER SWILLY BRIDGE CLIMATE ASSESSMENT

MGT0337
D02
26th January 2022

Contents

Tables

Figures

1 SUMMARY

This report details the climate assessment of three proposed options for the River Swilly bridge crossing. The project is currently at Phase 3 Design & Environmental Evaluation. As part of this phase, a number of design options for the River Swilly crossing have been shortlisted for further evaluation. Specifically, this climate assessment is focussed on three of the shortlisted bridge options:

- BR0122 Option 2 – 3-span concrete box
- BR0123 Option 6 – 3-span steel boxes with steel deck
- BR0137 Option 6 – multicell single span concrete box

This climate assessment has been carried out using the Transport Infrastructure Ireland (TII) Carbon Tool, which is TII's proprietary software for carrying out carbon assessments on road and rail infrastructure projects. The Tool uses a combination of default assumptions and user-defined inputs to generate an estimated, carbon footprint for the project.

The results of this options comparison assessment are set out in **Table 1-1** below.

Table 1-1: Total Carbon Emissions by Life Cycle Stage (kgCO$_2$e)

Name	Before Use (kgCO2e)			Use (kgCO2e)	Total (kgCO2e)
	Pre-Construction	Embodied Carbon	Construction Activities	Use	
Option 1 - 3-span Concrete Box BR0131	162.56	4,932,249.28	363,480.00	270,891.11	5,566,782.95
Option 2 - 3-span Steel boxes with steel deck BR0136	162.56	5,350,896.91	363,480.00	270,891.11	5,985,430.59
Option 6 - Multicell Single Span Concrete Box BR0137	87.65	3,991,942.40	335,520.00	201,402.24	4,528,952.29

Overall, Option 6 – multicell single-span concrete box BR0137 is the preferred option from a climate perspective.

This is mainly due to the lower embodied carbon of the materials. Option 2 – steel box BR0136 uses steel extensively in its design. Steel, as a material, has a high carbon footprint due to the energy required in extracting raw materials, processing and manufacturing the final product. Additionally, the type of structural steel used in bridge building is usually imported from other countries due to lack of manufacturing in Ireland. This adds higher transport emissions to the embodied carbon footprint, compared to sourcing materials closer to the site.

Option 1 uses similar design principles and materials to Option 6. Both of these options utilise reinforced concrete as the main, structural material. However, Option 6 has a smaller bridge deck and span (one span versus there spans), therefore it requires less materials in its construction compared to Option 1. This lesser demand for materials also results in lower maintenance ('Use') emissions, as evident in **Table 1-1**.

2 RESULTS

TII's Carbon Tool has been used to estimate and compare the carbon footprint of three crossing options over the River Swilly. The tool has been specifically developed to model carbon emissions associated with large-scale infrastructure projects for TII. Reporting units are presented in equivalent kilogrammes of carbon dioxide (hereafter $kgCO_2e$). The results of the analysis are set out below.

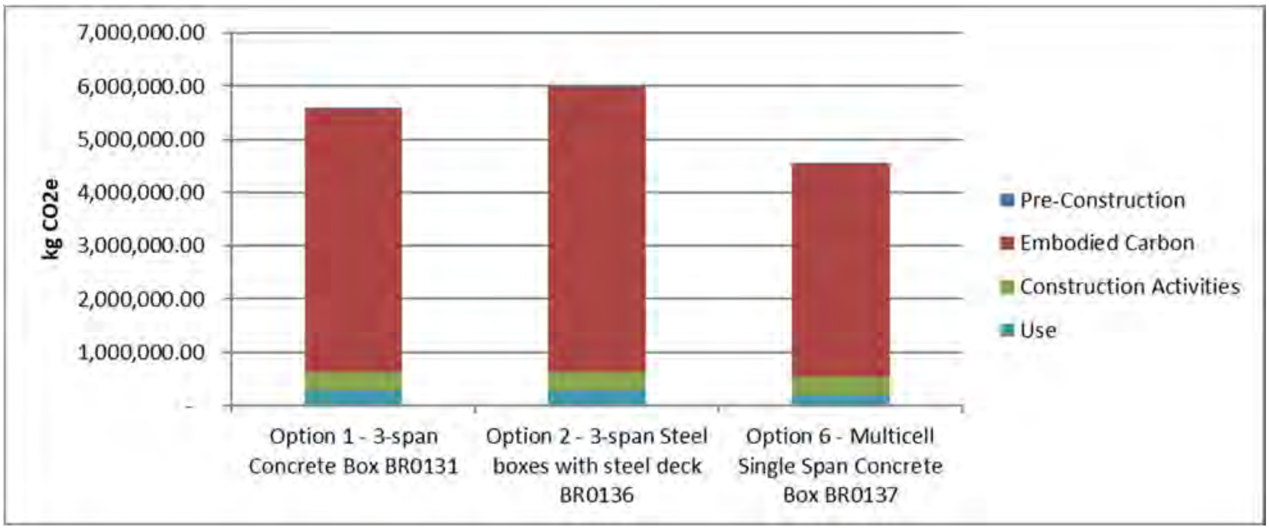


Figure 2-1: Total Carbon Emissions by Life Cycle Stage ($kgCO_2e$)

Table 1-1 and **Figure 2-1** above show the total carbon emissions for Options 1, 2 and 3 by life cycle stage. The results are presented by life cycle stage to emphasise where carbon is being generated for each option.

Overall, Option 2 (steel box structure) is shown to have a greater carbon footprint than Option 1 (3-span concrete box structure) and Option 6 (single-span concrete box structure). Option 2 will generate a total of 5,985,430.59 kgCO2e over its life cycle. Option 1 will generate a total of 5,566,782.95 kgCO2e over the same period. In the overall context of the project, this is virtually the same carbon footprint, so there is no significant preference between Option 1 and Option 2.

Option 6 has a significantly lower carbon footprint than the other options. This is mainly due to the lower carbon footprint of materials needed to construct this option. This is reflected in the 'Embodied Carbon' emissions in the graph above. 'Pre-Construction' emissions show a similar trend. Also, the 'Construction Activities' emissions for Option 6 are slightly lower than the other options, which is due to less energy and resource consumption during the construction programme. These differences are further detailed in the following Section 3.

3 DISCUSSION

The results of the carbon assessments are split by life cycle stage in the following sections.

3.1 Before Use – Pre-Construction

The pre-construction impacts for Options 1 and 2 are identical at 162.56 kgCO_2e. This is due to the same assumptions being applied to both options for site clearance activities (further detail in **Section 4** below). The pre-construction emissions capture the impact of site clearance activities, such as fuel use of heavy plant and other associated energy required to clear the site for construction. These assumptions may be refined as the project develops and more data becomes available e.g. water usage for site clearance and significant land use change.

The pre-construction impacts for Option 6 are slightly lower, at 87.65 kgCO_2e. This is due to a smaller area requiring site clearance compared to the other two options. All other assumptions remain the same otherwise.

3.2 Before Use – Embodied Carbon

The embodied carbon emissions represent the impact of construction materials and the transport of these materials to site. Typically, this life cycle stage has the largest carbon footprint of all stages in an infrastructure project. This is also the case for this assessment; Option 1 has an embodied carbon footprint of 4,932,249.28 kgCO2e. Option 2 has an embodied carbon footprint of 5,350,896.91 kgCO2e. Option 6 has an embodied carbon footprint of 3,991,942.40 kgCO2e. It should be noted that these estimates for embodied carbon include the associated transport impacts for bringing the materials to site. The difference between the lowest Option (Option 6) and the highest option (Option 2) is 1,358,954.51 kgCO2e, which represents a 34% increase in embodied carbon emissions.

3.2.1 Option 1

Option 1 is a 3-span concrete box structure. The design is similar to that of Option 6 in terms of materials used, except this option specifies 3 spans as opposed to the single-span design of Option 6. Consequently, more structural concrete is needed for this design versus Option 6, particularly with regard to increased quantities of reinforced concrete for piers and piles.

The carbon footprint of concrete used in Option 1 is 2,538,220.40 kgCO_2e compared to 2,289,602.20 kgCO_2e for Option 6. This is a difference of 248,618.2 kgCO_2e (or 10% reduction). Furthermore, rebar for the structural concrete has a global warming potential (hereafter GWP) of 1,941,199.40 kgCO_2e for Option 1, versus 1,367,604.97 kgCO_2e for Option 6. This is an increase of 42%. The greater quantities of reinforced concrete in Option 1 are the main contributors to its GWP.

3.2.2 Option 2

Option 2 is designed as a 3-span steel structure. Steel has a high carbon footprint due to the energy required to extract, process and manufacture the raw materials into a final product. Steel has the highest embodied carbon emissions of all materials used for this option, at 4,194,015.99 kgCO_2e. As a proportion, steel alone is responsible for 78% of embodied carbon emissions for Option 2. This carbon footprint also contains emissions as a result of reinforcement for concrete elements (i.e. rebar). However, it is the structural steel beams, columns and bridge deck which result in the highest carbon emissions.

The material with the second highest carbon footprint is structural concrete. Structural concrete is used for elements such as piling, piers, abutments and wingwall. The carbon footprint of structural concrete for Option 2 is 770,519.60 kgCO_2e, or 14% of embodied carbon emissions.

Option 2 has the highest carbon footprint of all options, but only marginally. Option 2 has a very similar carbon footprint to Option 1, so any differences are immaterial to overall impacts. Therefore, Option 1 and Option 2 will be treated equally in terms of preference.

3.2.3 Option 6

Option 6 is designed as a single-span concrete box structure. This option's design is similar to Option 1. As a result, structural concrete has the largest carbon footprint of all materials used. However, the quantity of concrete required for Option 6 is lower than Option 1. The carbon footprint of concrete used in Option 6 amounts to 2,289.602.20 kgCO_2e. This is 248,618.2 kgCO_2e lower than structural concrete emissions in Option 1 (a reduction of 10%). In addition, the carbon footprint of rebar used for the structural concrete is lower in Option 6 versus Option 1. Rebar in Option 1 is responsible for 1,941,199.40 kgCO_2e, whereas this is reduced to 1,367,604.97 kgCO_2e in Option 6 (a reduction of 573,594.43 kgCO_2e or 30%). Despite the use of rock anchors for Option 6, the overall carbon footprint is the lowest of the three options due to a shorter bridge span section, therefore a reduced quantity of materials.

3.2.4 All Options

A series of assumptions are made to estimate the carbon footprint of the remaining materials needed for each structure.

Pavement layers and surfacing are assumed to be the same for Options 1 and 2, given that both options are the same length and width. For Option 6, lower quantities of pavement construction materials are assumed due to a smaller bridge deck (single-span). Bridge deck waterproofing, buried concrete waterproofing, parapets and rubbing strips are also assumed to be the same for Options 1 and 2. Again, Option 6 will require less of these materials due to a smaller design concept. These materials are not discussed in further detail in this section, as their associated emissions are not crucial to the option comparison process. For further detail on assumptions made for these materials, see **Section 4**.

3.3 Before Use – Construction Activities

The construction activities section of the tool captures carbon emissions associated with the construction phase of the project. These emissions are typically comprised of fuel, electricity and water usage on site during the construction phase, as well as more granular impacts such as employee travel to site. Given the preliminary design stage of this project, these data are not available nor have any estimates been made around these impacts. Therefore, the default calculation in the Tool is used to estimate the carbon footprint of the construction stage.

The Tool estimates construction emissions based on the size of the project and also its expected duration. All options are assumed to be 'Very Large (construction cost > €10m, more than 25 people permanently on site)' as per TII definition in the Tool. As per Chapter 11 Construction and Buildability of the main report, the construction period for Option 1 is estimated at 104 weeks, Option 2 at 104 weeks and for Option 6, 96 weeks. Using the TII calculation parameters, this estimates that Option 1 and Option 2 have a construction impact of 270,891.11 kgCO_2e each. Meanwhile, Option 6 has a construction impact of 201,402.24 kgCO_2e. This calculation does not take into account any nuanced differences in construction methodologies, rather it approximates the impact based on size of the construction site and time to complete the works.

3.4 Use – Maintenance

Emissions in the use phase account for maintenance of the structure over its design life i.e. 120 years. The maintenance frequency of different materials are default values within the TII tool. The user does have the option to change these values manually, but in the absence of specific information, the default TII values have been retained. These default values have been selected by TII based on project experience and industry averages. They provide an estimate of the maintenance emissions that will be accrued over the structure's lifespan.

Only three materials are deemed to require significant maintenance for all options; asphalt, surface dressing and steel parapets (more detail in **Table 3-1** below). The same quantities of these materials have been assumed for both Option 1 and Option 2, hence both options have the same total maintenance emissions of 229,637.02 kgCO_2e. Option 6 has a lower quantity of these materials, and this is reflected in the lower GWP of maintenance activities throughout the structure's life cycle.

Table 3-1: Material maintenance frequency and associated emissions (kgCO_2e)

Option	Material	Default maintenance percentage	Maintenance emissions (kgCO_2e)
Option 1 & 2	Road pavement – hot rolled asphalt	408%	234,001.87
Option 1 & 2	Road pavement – surface dressing	850%	32,500.24
Option 1 & 2	Galvanised steel parapets	6%	4,389
Option 6	Road pavement – hot rolled asphalt	408%	174,001.39
Option 6	Road pavement – surface dressing	850%	24,166.85
Option 6	Galvanised steel parapets	6%	3,234

4 ASSUMPTIONS AND LIMITATIONS

- The project value is estimated at €29,978,000, which is an estimated average cost of either option based on information in the structures options report TT_MGT0337-RPS-P3-ZZ-RP-S-BR0004;
- The design life of the structures is estimated to be 120 years (excluding any road surfacing material, which will require more frequent maintenance and replacement in line with the rest of the scheme);
- AADT modelling has been excluded, as this will be addressed in the overall carbon assessment;
- General site clearance is assumed to occur on land principally occupied by agriculture.

  Site clearance activities for Options 1 and 2 are expected to be the same. A total of 0.37 ha of land is estimated to be cleared, based on the drawings for the 2 proposed options (TT_MGT0337-RPS-P3-S2-DR-C-BR0131, TT_MGT0337-RPS-P3-S2-DR-C-BR0136). The area to be cleared has been estimated based on an assumed bridge width of 28.5 m and 130 m combined length (65 m either side of the river channel).

  For Option 6, site clearance is expected to be slightly less, at 0.2 ha. This is based on an assumed bridge width of 28.5 m and 70 m combined length (35 m either side of the river channel – refer to drawing TT_MGT0337-RPS-P3-S2-DR-C-BR0137);
- No modelling of land use change/vegetation loss has been undertaken, as the River Swilly crossing structure will be built on primarily agricultural land. This change of land use does not have a negative climate impact in the TII carbon tool, so the exclusion of land use change, in this instance, does not have any effect on overall calculations;
- Earthworks have not been included in the calculations, as quantities will be broadly similar for all bridge options;
- Bridge deck surfacing assumes the following pavement construction and transport parameters:
  - Cement bound granular material to a depth of 100-150 mm
  - Asphalt concrete (14 mm aggregates to a depth of 40 mm)
  - Surface chippings (coated, 14 mm, assumed depth of 5 mm)
  - Road pavement materials are assumed to be sourced within 50 km of the site. Road pavement materials will be delivered via rigid HGV. It is assumed that each HGV load will carry 20 tonnes of material. An average material density for road pavement materials is estimated at 2.1 tonnes per m^3. These assumptions are necessary in estimating total kilometres required for the transportation of road materials

  Option 1 and Option 2 each have bridge deck areas of 6,669 m^2 for surfacing (assumed deck dimensions of 234 m length by 28.5 m width for both options). Option 6 has a bridge deck area of 4,959 m^2 for surfacing (174 m length by 28.5 m width).
- A specific carbon factor for structural concrete has been added to the Carbon Tool. The design team has specified that the in situ concrete for structural elements uses 50% ground granulated blast furnace slag (GGBS) in its composition. The emissions factor used for this material has been taken from the Bath Inventory of Carbon and Energy (ICE) v3. This material assumes a strength class of C40/50 and 50% mix of GGBS in the concrete binders. This material is deemed to be the best match to the structural concrete specified for this scheme. The original emissions factor is expressed in $kgCO_2e/kg$ (0.102). This is multiplied by the material density of the structural concrete (assumed 2,400 kg/m^3. This gives an emissions factor of 244.8 $kgCO_2e/m^3$. The same factor is used for both options across all structural concrete elements (piles, piers, abutments, wingwalls, deck, etc.).

  It is assumed that the concrete will be transported via HGV to site. The TII tool does not have a factor for a concrete mixer truck, so HGV is chosen as the closest proxy. It is assumed that each load of concrete will be 8 m^3 (taken from One Click LCA Ecoinvent datapoint for structural concrete). It is estimated that the concrete will be sourced 100 km from the site. The density of the structural concrete is estimated to be 2.4 tonnes per m^3. This is used to calculate the number of trips (i.e. total distance in kilometres) required to transport all of the structural concrete to site.
- The TII tool does not contain an emissions factor for rebar (reinforcement steel). Rebar represents a significant proportion of the materials for the bridge designs. An external datapoint has been manually

added to the tool based on information from this document https://www.igbc.ie/wp-content/uploads/2021/05/LIFE-Levels-CAR-Report_revA_29April-2021_clean.pdf. Section 5.4 (page 50) estimates the average GWP of rebar used in Ireland at 737 kgCO_2e/tonne. This estimate is used as a datapoint for the TII tool.

In calculating the associated transport emissions, it is assumed that the rebar will be transported from Dublin via HGV (due to the imported steel arriving in Dublin Port) to the site area. This is a distance of roughly 240 km. The truck is assumed to have a fill capacity of 40 tonnes. The density of the rebar is 7,850 kg/m^3. According to the IGBC report, all rebar in Ireland is imported, with the majority from Portugal (37%). These transport emissions are included in the embodied carbon emissions factor, and so do not need to be counted in this transport to site phase.

- Structural steel (mainly for Option 2 Steel Box BR0136) uses the emissions factor for structural steel columns in the TII tool. For Option 2, the bridge deck and box girders use this emissions factor.

  Post-tensioning materials for Option 1 and Option 6 are allocated the TII emissions factor for anchorages and holding down bolt assemblies.

  In terms of transport emissions for structural steel, these have been calculated using the same assumptions as those set out above for rebar.

- Waterproofing is needed for both the bridge deck and buried concrete elements of the bridges. All waterproofing quantities are assumed to be the same for all options, as per guidance from the design team.

  The waterproofing system uses a liquid resin which will be applied to the elements noted above. There is no carbon factor for waterproofing membranes in the TII carbon tool, so the material has been added manually as an external datapoint. A representative material has been selected from the Ecoinvent[1] database to estimate the carbon footprint of waterproofing the structural elements. The product selected is Resfoam 1K-M, a waterproofing, polyurethane resin manufactured by Mapei in Norway.

  The design team have calculated that 17.9 tonnes of waterproofing resin will be needed for Option 1 and Option 2. Option 6 will require 13.27 tonnes of waterproofing resin. This quantity is used for all options in the carbon tool calculations. The GWP (global warming potential) for this material is stated at 3.7 kgCO_2e/kg. This conversion factor is used to estimate the associated carbon emissions.

  The transport emissions are calculated on the assumption that the material will be transported 240 km from Dublin (assumes that the material will be imported from outside of Ireland). In addition, it is assumed that the material will be delivered via a 9 tonne delivery truck (Ecoinvent datapoint parameter). These assumptions allow for the calculation of total kilometres travelled, therefore the transport impact for stage A4.

- Steel parapets will also be included as part of the final bridge design. In order to estimate the impact of parapets, galvanised steel handrails from the TII carbon tool are used as an equivalent material. This default material provides the best proxy for steel/aluminium parapets within the tool.

  The design team has calculated that **47.5 tonnes** of steel will be needed for parapets for Option 1 and Option 2. This is a combination of both pedestrian and vehicle parapets.

  For Option 6, a total of **35 tonnes** of steel (vehicular and pedestrian) will be needed for parapets.

  The calculations are based on the following assumptions:

  – Vehicle parapets (VSGH 2001 – galvanised steel or aluminium) – 84.7kg/m

  – Pedestrian parapets – 30.8kg/m

  For the transport impact, it is assumed that the steel will be sourced from Dublin (due to steel likely coming from abroad). Therefore, it is assumed that the steel will be transported via HGV with a capacity of 40 tonnes.

- Rubbing strip design - The design team has specified that the strips will be made of concrete and reinforced with rebar.

[1] https://ecoinvent.org/the-ecoinvent-database/

Quantities of concrete with rebar for rubbing strips are estimated to be the same for both Option 1 and Option 2 (assumption from design team). The total concrete needed will be 758.4 tonnes with 13 tonnes of rebar for Option1 and the same quantity for Option 2.

Option 6 will require slightly less concrete and rebar. Option 6 will require 564 tonnes of concrete, reinforced with 9.7 tonnes of rebar.

The quantities have been worked out as per the formulae below:

– Concrete –2,400 kg/m^3

– Rebar –6.16kg/m^2

An external datapoint for precast concrete has been added to the tool to estimate the impact of the material. The external datapoint (taken from Ecoinvent database) estimates the GWP of precast concrete manufacturing at 0.13 kgCO_2e/kg.

The carbon factor for rebar (previously added to the tool – see earlier bullet points) will again be used to model the reinforcement required for the rubbing strips (737 kgCO_2e/tonne).

In terms of transport impact, it is assumed the materials will be sourced from a supplier within 100 km of the site. The materials will be delivered via HGV at a fill capacity of 40 tonnes. These assumptions are used to estimate total kilometres.

- Rock anchors – The design for Option 6 specifies that rock anchors will be required. A total of 30 no. rock anchors will be used. Each will be 25 m long with a breaking load of 3,094 kN (see Table 3.2 of https://www.structuraltechnologies.com/wp-content/uploads/2018/02/VSL_soil_rock_anchors.pdf). This table states the weight per steel strand, for this strength, is 13.3 kg/m. There are 17 steel strands per metre for this specification, giving a total weight of 226.2 kg/m (13.3 x 7). This allows the total weight of the anchor strands to be estimated at 169.65 tonnes (30 no. anchors at 25 m = 750 m x 226.2 kg/m = 169,650 kg / 1,000 = 169.65 tonnes).

  The GWP of rock anchors for Option 6 is estimated using the emissions factor for structural steel columns in the TII tool.

  In terms of modelling the transport impacts, it is assumed that the anchoring system will be transported from Dublin via HGV (due to the imported steel arriving in Dublin Port) to the site area. This is a distance of roughly 240 km. The truck is assumed to have a fill capacity of 40 tonnes.

- Excavation activities have not been included, due to lack of data. Regardless, excavation for both options is likely to be very similar, so the effect of this exclusion will not impact comparison of the options.
- While energy usage (fuel, lighting, heating, etc.) is unknown for the duration of the construction periods, this is estimated using default assumptions in the TII tool. The tool calculates an estimated energy usage based on length of construction period (in weeks) for each option. Estimated construction programmes have been provided for both options in TT_MGT0337-RPS-P3-ZZ-RP-S-BR0004. Option 1 (Concrete Box BR0131) will require 24 months to construct. Option 2 (Steel Box BR0136) will take 24 months to construct. Option 6 (Single-span Concrete Box BR0137) will take 22 months to construct. This methodology does not take into account different construction techniques/equipment required for each option, rather it calculates an estimate of energy usage based on time alone.
- Other variables during the construction period, such as worker travel to site, water use and landscaping, are also excluded due to lack of detailed information at this time.
- Construction waste is excluded from the calculations.
- Energy use during the operations phase (use phase for the bridge) has also been excluded. This includes activities such as maintenance, lighting, signs, vehicular use, etc.). These activities would be very similar for all options, so exclusion of these activities will not impact the comparison of both options.
- End of life (decommissioning) emission shave been excluded from the calculations due to lack of data.
- **Table 4-1** below outlines the methodology used for calculating transport distances of materials.

Table 4-1: Transport distance calculations

Option	Material Category	Material Name	Area (m2)	Depth (m)	Volume of material (m3)	Weight of material (t)	Transport distance (km)	Transport vehicle capacity (tonnes)	Density of material (tonnes per m3)	Transport vehicle capacity (m3)	Number of loads (no.)	Total distance (km)
Option 1 & 2	Series 800 - Road Pavements	Cement bound granular material	6669	0.15	1000	-	50	20	2.1	9.5	105	5252
Option 1 & 2	Series 900 - Road Pavements	Dense asphalt concrete	6669	0.04	267	-	50	20	2.1	9.5	28	1400
Option 1 & 2	Series 900 - Road Pavements	Surface chippings, coated	6669	0.005	33	-	50	20	2.1	9.5	4	175
Option 6	Series 800 - Road Pavements	Cement bound granular material	4959	0.15	744	-	50	20	2.1	9.5	78	3905
Option 6	Series 900 - Road Pavements	Dense asphalt concrete	4959	0.04	198	-	50	20	2.1	9.5	21	1041
Option 6	Series 900 - Road Pavements	Surface chippings, coated	4959	0.005	25	-	50	20	2.1	9.5	3	130
Option 1	Series 1700 - Structural Concrete	Concrete-Average	-	-	14352	-	100	19	2.4	8.0	1794	126225
Option 2	Series 1700 - Structural Concrete	Concrete-Average	-	-	6643	-	100	19	2.4	8.0	830	35963
Option 6	Series 1700 - Structural Concrete	Concrete-Average	-	-	9569	-	100	19	2.4	8.0	1196	92300
Option 1	Series 1800 - Structural Steelwork	Rebar	-	-	-	2442	240	40	7.85	5.1	61	9828
Option 2	Series 1800 - Structural Steelwork	Rebar	-	-	-	1244	240	40	7.85	5.1	31	3144

Option 6	Series 1800 - Structural Steelwork	Rebar	-	-	-	1536	240	40	7.85	5.1	38	6660
Option 1	Series 1800 - Structural Steelwork	Anchorages and holding down bolt assemblies	-	-	-	404	240	40	7.85	5.1	10	2424
Option 2	Series 1800 - Structural Steelwork	Column	-	-	-	2715	240	40	7.85	5.1	68	16290
Option 6	Series 1800 - Structural Steelwork	Anchorages and holding down bolt assemblies	-	-	-	170	240	40	7.85	5.1	4	1018
Option 1 & 2	Series 1700 - Structural Concrete	Waterproofing (resin) for steel and concrete elements	-	-	-	18	240	9	-	-	2	477
Option 6	Series 1700 - Structural Concrete	Waterproofing (resin) for steel and concrete elements	-	-	-	13	240	9	-	-	1	354
Option 1 & 2	Other-Street Furniture and Electrical Equipment	Galvanised steel handrail	-	-	-	48	240	40	-	-	1	285
Option 6	Other-Street Furniture and Electrical Equipment	Galvanised steel handrail	-	-	-	35	240	40	-	-	1	240
Option 1 & 2	Series 1100 - Kerbs, Footways and Paved Areas	Precast rubbing strips (no rebar)	-	-	-	758	100	40	-	-	19	1896
Option 6	Series 1100 - Kerbs, Footways and Paved Areas	Precast rubbing strips (no rebar)	-	-	-	564	100	40	-	-	14	1410

Option 1 & 2	Series 1800 - Structural Steelwork	Rebar	-	-	-	13	100	40	-	-	0	100
Option 6	Series 1800 - Structural Steelwork	Rebar	-	-	-	10	100	40	-	-	0	100
Option 6	Series 1800 - Structural Steelwork	Column	-	-	-	170	240	40	-	-	4	1018