GEOTECHNICAL – WANSFORD CROSSING

THE NATIONAL GRID ELECTRICITY TRANSMISSION PLC (SCOTLAND TO ENGLAND GREEN LINK 2) COMPULSORY PURCHASE ORDER 2023

STATEMENT OF EVIDENCE

Martin Perkins
Principal Geotechnical Engineer
Murphy Technical Services Ltd on behalf of National Grid Electricity Transmission plc

1. QUALIFICATIONS AND EXPERIENCE

1.1 My name is Martin Perkins, I am a Principal Geotechnical Engineer within Murphy Technical Services working on behalf of National Grid Electricity Transmission Plc (NGET). I hold a BSc (Hons) Degree in Applied Geology (1996) and I am a Fellow of the Geological Society (2002).

1.2 In my role on this project, I am responsible for the review of all project specific and publicly available geotechnical information for the purposes of identifying feasible trenchless crossing techniques at Wansford Lock.

1.3 I have 27 years' experience in geotechnical engineering and the design and construction of trenchless crossings. Initial experience was gained in construction of Horizontal Directional Drilling before expanding my experience into all trenchless crossing techniques. Since 2010 I have been predominantly engaged in the development of feasibility studies assessing suitable trenchless crossing techniques and making recommendations on the most suitable technique for a wide range of crossings and landfalls.

1.4 Murphy was initially engaged in January 2023 to complete a review of the Wansford Lock crossing and develop potential trenchless crossing solutions to cross the B1249, Driffield Canal, River Hull and Main Drain making a technical recommendation on the most suitable crossing technique based on a scored matrix.

2. INTRODUCTION AND SCOPE OF EVIDENCE

2.1 The purpose of my evidence is to explain the engineering design and construction methodology of the Eastern Green Link 2 (the **Project**), specifically the trenchless crossing at Wansford. My evidence is to address this point only and does not address the wider need for the Project or the engineering design and construction methodology for the converter station, or the Cable route in general.

2.2 My statement of evidence is structured as follows:

2.2.1 Section 3 provides an overview of the crossing at Wansford.

2.2.2 Section 4 describes geotechnical conditions at Wansford

2.2.3 Section 5 details trenchless solutions and considerations,

2.2.4 Section 6 comments on objections made to the Order.

2.2.5 Section 7 contains my conclusions.

3. OVERVIEW OF THE CROSSING AT WANSFORD

3.1 The crossing at Wansford includes the crossing of the B1249, Driffield Canal, River Hull and Main Drain. To the North of the crossing the land is laid to agriculture, the B1249 and Driffield Canal are directly adjacent to each other. The Driffield Canal and the River Hull are separated by an area of agricultural land and grassland adjacent to the River Hull. At the proposed location of the crossing the course of the River Hull is meandering. The River Hull is within the River Hull Headwaters SSSI. Further grassland adjacent to the River Hull separates the river from Main Drain, an engineered water course. To the South of Main Drain, the land is again laid to agriculture.

4. THE PHYSICAL AND GEOTECHNICAL CONDITIONS AT WANSFORD

4.1 This section of my statement of evidence provides specific detail on the geotechnical conditions at Wansford, including:

4.1.1 Published Information and Historical Ground Investigations;

4.1.2 Environmental Data; and

4.1.3 Ground Investigation carried out.

4.2 Section 5 of Appendix A (EGL2 Wansford Lock Trenchless Crossing Feasibility Study) provides detail about the findings at this location, including the historic and published information, indicating varying ground conditions likely along the route of the crossing. The start and end of the crossing is indicated to have been deposited in mixed glacial environments and soils are indicated to comprise firm and stiff clay and /or sand and gravel whilst the middle section is indicated to have been deposited in alluvial conditions, comprising of clay, silt, sand and gravel. Bedrock is indicated to comprise the Flamborough Chalk Formation.

4.3 Limited historic GI data is available, however, where data is available this generally confirms the published geology. Artesian water (upward force) is indicated and pumping has been required historically.

4.4 The Environment Agency classifies the River Hull and the Driffield Canal as ‘Main Rivers’ (EA managed & maintained). The channel of the River Hull is categorised as a SSSI (Site of Special Scientific Interest) by Natural England. The central portion of the crossing is within a Flood Zone 3. The bedrock is indicated to be a highly productive principal aquifer with good quality water. The crossing also interacts with a Nitrate Vulnerable designated zone.

4.5 Preliminary boreholes have been carried out to assess the feasibility of the development for this project. The location of the three boreholes, further detail, including a BH cross section, can be found in Section 6 Appendix A, figure 5.

4.6 Generally, the findings from these boreholes confirm the published data indicating varying thicknesses of soft, firm and stiff clay, loose to medium dense sand, sandy gravel, gravelly sand along with sand and gravel. Chalk bedrock was encountered in all locations between 6.15m and 9.0m below existing ground level. Upon encountering bedrock groundwater under artesian pressure was encountered in all locations.

5. TRENCHLESS SOLUTIONS FOR THE CABLE CROSSING AT WANSFORD

5.1 This section of my statement of evidence provides specific detail on the trenchless solutions that could be employed at Wansford, including:

5.1.1 General Trenchless Crossing Techniques;

5.1.2 Wansford Crossing Options and Evaluation; and

5.1.3 High level recommendations.

5.2 Murphy Feasibility Study, (Appendix A) details the types of crossing techniques available for consideration at the Wansford Crossing.

5.3 The Murphy report also provides a description of all potential trenchless crossing techniques that the Principal Contractor may consider during detailed design subject to the results of further ground investigation:

5.3.1 Horizontal Directional Drilling (HDD);

5.3.2 Auger Boring;

5.3.3 Pipe Ramming;

5.3.4 Horizontal Down the Hole Hammer;

5.3.5 Microtunneling (Pipe Jacking);

5.3.6 Direct Pipe; and

5.3.7 E-Power Pipe.

5.4 Based on the historic and preliminary scheme specific ground investigation information available, along with the known environmental constraints a review and discussion of the limitations of the potential trenchless options was undertaken by Murphy, the results of the review are presented within Appendix A

5.5 Three Horizontal Directional Drilling (HDD) solutions were considered:

5.5.1 a single long HDD crossing encompassing all features;

5.5.2 two shallower HDDs crossings with open cut tie in works; and

5.5.3 a stich drilled solution where shallow shorter crossings are completed back-to back with tie in works.

5.6 For the long HDD two parallel crossings would be required. To manage the risks posed by the shallow ground conditions the profile would likely need to be within the chalk bedrock which would introduce interaction with the artesian groundwater. The interaction with the artesian groundwater poses some significant risks which in the temporary condition would require some significant enabling works to manage. In the permanent condition the solution is reliant on an engineered seal to prevent escape of groundwater to the surface. On the basis that the design challenges present significant risks to the adoption and suitability of this solution it is not recommended that a long HDD is considered further unless the results from additional ground investigation indicate the risks can be adequately managed.

5.7 The second HDD option comprised two shorter crossings (B1249 & Driffield Canal and River Hull & Main Drain) at each location two parallel crossings would be required. Subject to further ground investigation these crossings could be undertaken at depths where interaction with the artesian groundwater could be avoided. The risks posed by shallower crossings include a greater interaction with the gravelly material indicated in the preliminary ground investigation and the increased risk of frac-out of drilling fluid to the surface may occur. In addition to the drilling risks, open cut tie in works would be required within the flood plain and in close proximity to the SSSI in the central portion of the crossing. The risks of adopting this solution with the current level of ground investigation information are high. Further ground investigation information is required to fully understand the risks to the crossing and to establish if the risks can be adequately managed and mitigated.

5.8 The third and final HDD option adopts stitch drilling where relatively short crossings are undertaken back-to-back at around 2m depth and the installed cable ducts tied in and buried at the launch and reception pits. Crossing lengths are recommended to be limited to 75-100m which result in up to four crossings being required to complete the whole section. At each location two parallel crossing would be required. Due to the shallow depths this method has the greatest interaction with the gravelly granular deposits which cause significant risks of bore failure, drilling fluid frac-out due to the limited overburden is also a significant risk. Based on the ground investigation information currently available the risks from the gravelly strata and minimal overburden are too high, for this option to be considered further additional ground investigation data should be obtained.

5.9 Auger Boring would require three separate crossings at the B1249 & Driffield Canal, River Hull and Main Drain. Work would be required within the flood zone for the construction of crossings and open cut tie in works between the crossings. From the ground investigation information available the presence of groundwater within the granular superficial deposits cannot be fully understood therefore the ground conditions are currently considered marginal for the adoption of auger boring as a feasible technique and further ground investigation would be required to confirm suitability. Launch and reception pit construction would need to be designed to ensure the risks of basal heave and groundwater ingress are adequately managed. Based on the information currently available this technique should not be progressed although it is recommended that additional ground investigations and surveys are undertaken to fully understand all risks before the technique is discounted.

5.10 Pipe Ramming would also require three separate crossing in the same configuration auger boring with work required in the flood zone for the construction of crossings and open cut tie in works. Ground conditions appear suitable for the adoption of pipe ramming although the same concerns as auger boring over the temporary works at the launch and reception pits remain. Pipe ramming is an unguided technique which installs steel casing pipe so no guarantees on line and level can be made and the interaction with a steel pipeline and the cable system design will need to be investigated further. Without further information it is not recommended that pipe ramming is adopted as the preferred technique due to the unguided nature and the concerns over the launch and receptions pit temporary works. Further surveys are recommended to fully understand the risks before the technique is discounted.

5.11 Horizontal Down the Hole Hammer, like auger boring and pipe ramming, would require three separate crossings, crossing construction and open cut works within the flood zone with the same concerns over the temporary works at the launch and reception pits. It is currently unknown if DTHH has been used on any UK based crossings, the interaction between groundwater and the technique is not fully understood nor is the availability of the equipment outside of Scandinavia. As for pipe ramming it is an unguided technique and installs steel casings therefore the same risks on alignment and interaction with the cable system design are not yet fully understood. Based the technique being unproven in UK soils, the unknowns on the interaction with groundwater and the potential issues with launch and reception pit designs it is not recommended at the current stage of the project that DTHH is progressed as a risk managed solution. However further investigations into the technique and the underlying ground conditions are recommended to fully confirm the suitability of the technique.

5.12 Microtunneling (Pipe Jacking) would complete the crossing in a single drive between launch and reception shafts located at the northern and southern extremities of the crossing. This technique is the most versatile with tunnel machines available to accommodate variations in ground and groundwater conditions. It is recommended that any tunnel drive is wholly within the chalk bedrock, the final diameter of the tunnel will need to be confirmed during detailed design, it is anticipated for a tunnel of this length a tunnel with a minimum internal diameter of 1.5m would be required. Various shaft construction techniques are also available to accommodate the anticipated ground and groundwater conditions. Control of groundwater during shaft sinking will be key to the success and multiple methods are available to construct the shafts whist controlling the groundwater, it is likely that a shaft construction method can be developed to minimise the need for long term dewatering during and post construction. Development of the cable system design will be required to confirm that all required cable can be installed within the same tunnel. Based on the information currently available it is recommended that microtunnelling is adopted as the preferred technique for the completion of the crossing. It is recommended that further ground investigation is undertaken support the detailed design process and to better establish the ground and groundwater conditions to ensure all the risks can be mitigated as far as reasonably practicable.

5.13 Direct Pipe would also complete the crossing in a single drive from a relatively shallow inclined launch pit. Direct pipe combines tunnelling techniques with the guidance of HDD and as such steel casing pipes can be installed to a predetermined profile. For this crossing the design would need to confirm that sufficient cover can be maintained under the Driffield Canal and Main Drain whilst maintaining a suitable steering radius of curvature. The most significant risk for direct pipe is the interaction with the artesian water and how the water pressures at the tunnel head are managed and controlled and how the flow of groundwater to the surface through the tunnel annulus is controlled in the temporary and permanent condition. Additional information and studies are required to confirm if the anticipated flows and pressures can be managed. Further information is required to confirm if Direct Pipe can be adopted as a risk managed solution.

5.14 E-Power Pipe would complete the crossing in a single drive with the duct grouted in place as it is installed. E-Power pipe is suitable in a wide range of ground conditions but only has limited potential for steering requiring the drive to be horizontal under all features. Significant supported excavations are required for the launch and reception pits and the temporary works design would need to give confidence that the interaction with the artesian groundwater can be managed. There is limited history of the use of E-Power pipe in the UK and further investigations into the suitability in UK ground conditions would be required to fully assess the feasibility of the technique, further ground investigations are also required to assess if the interaction with the artesian groundwater can be managed.

5.15 Further ground investigation will be required before an optimised solution can be finalised. Based on the geotechnical information currently available a microtunnelled solution scores most favourable, completed as a single end-to-end drive, and I am confident that this solution (subject to further investigation and design) can be built within the planning boundary and within the programme timetable. However, after further investigation the Principal Contractor will be able to provide greater certainty on all of the trenchless crossing solutions, they consider viable.

5.16 The selected Principal Contractor will be responsible for selecting the crossing technique and further developing the detailed design to complete the crossing, including matters such as route alignment, micro siting and identifying drive and reception pits locations.

5.17 The final alignment and width of the corridor within which the HVDC cables will be installed is not yet known. This will be influenced by a number of factors including: the varying ground conditions; topography and constraints which are anticipated to be encountered along the route; and the different construction/installation techniques which may need to be used. It is anticipated that a solution can be developed to remain wholly within the current proposed red line boundary.

6. OBJECTIONS MADE TO THE ORDER

6.1 Section 8 of the evidence of (Camilla Horsfall) outlines the objections remaining at the time of writing, NGET's response to them and the status of negotiations.

Wansford Objections

6.2 Objection 8(2) as detailed in Core Document 16 – Objection 8(2)

6.3 The Objection relates to a bridge over which the project is seeking access rights. The objection relates to the use of the bridge, no clear indication on the level of access has been provided. Once the construction technique is determined the level of access required across the bridge will be determined and communicated; to date NGET has requested copies of the as-build drawings which have not been provided, once these are provided a full assessment of the bridge capacity can be undertaken to assess access suitability.

6.4 Objection 10, as detailed in Core Document 25 – Objection 10

6.5 The objection notes concern as the methodology for the completion of the crossing and the location of pits potentially within the water meadow. This statement of Evidence details that a trenchless solution is possible at this location subject to further investigation and detailed design. The crossing methodology, alignment and pit locations will be finalised during the detailed design process.

6.6 The objection notes concern around dewatering. As stated, the project has currently undertaken preliminary surveys. It has been stated that the Principal Contractor will be required to carry out further investigation to determine the exact crossing technique. Once the technique is determined a dewatering and groundwater management plan can be formulated to mitigate these concerns. NGET have held discussions with Natural England, in light of these discussions NGET is confident that no adverse impact will occur in relation to the SSSI.

6.7 The objection notes that RWE have discounted this option as part of its Dogger Bank South project. Further to the response within the Statement of Case, Appendix A, this Statement of Evidence details that a trenchless solution is possible at this location – subject to further investigation and detailed design.

6.8 Objection 14, as detailed Core Document 29 – Objection 14

6.9 The objection notes that RWE have discounted this option as part of its Dogger Bank South project. Further to the response within the Statement of Case, Appendix A, this Statement of Evidence details that a trenchless solution is possible at this location – subject to further investigation and detailed design. NGET have held discussions with Natural England, in light of these discussions NGET is confident that no adverse impact will occur in relation to the SSSI.

7. SUMMARY AND CONCLUSION

7.1 In my statement of evidence, I have described the physical characteristics of the ground conditions based on the publicly available and scheme specific ground investigation information. Groundwater under artesian pressure encountered at chalk bedrock is the greatest risk to the completion of the crossing using trenchless crossing techniques. Ground conditions are generally considered suitable for the adoption of trenchless crossing techniques although within the superficial deposits the presence of gravel in significant quantities and perched groundwater present risks and requires further investigation. Further information is also needed on the composition of the chalk bedrock to allow a fully risk managed solution to be developed.

7.2 Potential trenchless crossing techniques that have been considered in the early stages of the project are discussed and the main risks associated with each technique are presented based on the limited preliminary ground investigation carried out to date.

7.3 I would at this stage not recommend a single HDD drive. However, no options should be discounted prior to further ground investigation and surveys being carried out.

7.4 Based on all the information currently available I am confident that the crossing can be completed as a single drive with the adoption of microtunnelling (pipe jacking) as the preferred crossing technique. Further investigations are required to allow the Principal Contractor and their specialist advisors to further develop and optimise the crossing solution which may include other construction options including HDD.

8. DECLARATION

8.1 I confirm that the opinions expressed in this proof of evidence are my true and professional opinions.

Martin Perkins

16th February 2024

APPENDIX A

Client	**National Grid**
Contract Title	**EGL2 Wansford Lock Trenchless Crossing Feasibility Study**
Contract Number	**X20-016**
Operating Unit	**Murphy Applied Engineering**

REPORT

EGL2 WANSFORD LOCK TRENCHLESS CROSSING FEASIBILITY STUDY

MAIN AUTHOR	REVIEWER	APPROVER
Martin Perkins Principal Geotechnical Engineer 14th February 2024	**James Curran** Senior Engineering Manager 15th February 2024	**James Curran** Senior Engineering Manager 15th February 2024

ISSUE CONTROL

DOCUMENT No.	**X20-16-JMS-XX-SC-RP-Z-1001**

CURRENT REVISION	CURRENT STATUS CODE	SECURITY CLASSIFICATION
C01	**S5**	**Confidential**

REVISION HISTORY

REVISION	STATUS CODE	DATE	REVISION DESCRIPTION
P01	S3	1st March 2023	Client Review
P02	S3	29th March 2023	Final
C01	S5	15th Feb 2024	Final Incl. Amendments

Contents

1 Introduction

National Grid contracted Murphy Technical Services to provide support to review the available trenchless crossing techniques and provide recommendations for the technically challenging crossing at Wansford Lock as part of the wider EGL2 project. The crossing includes the B1249, Driffield Canal, River Hull and Main Drain.

Ground investigation undertaken as part of the wider scheme have indicated that artesian groundwater is present at relatively shallow depths at the crossing location and a solution that is technically feasible with no long-term impact to the groundwater is required.

2 Scope

This report aims to complete a technical review of the available trenchless crossing techniques to complete the Wansford Lock crossing, provide a recommendation on the most suitable crossing technique from a technical perspective and provide a high-level crossing design.

2.1 Project Location

The crossing is located approximately 3.5km southeast of the Market town of Driffield, East Riding of Yorkshire the centre of the crossing located at approximate NGR 505532mE, 456430mN as depicted on Figure 1 and Figure 2

Figure 1 - General Crossing Location

Figure 2 - Detailed Crossing Location

3 References

Document Number	Document Title
F194492 IR4 Issue 03	Eastern Link 2 (E4D3) On-Shore HVDC Cable Link – Phase 4 Batches 2 to 4, Factual Report on Ground Investigation – Fugro Geoservices Limited

4 Definitions & Abbreviations

Acronym	Description
AGL	Above Ground Level
BH	Borehole
DCA	Drilling Contractors Association
DTH	Down the Hole
EA	Environment Agency
GRP	Glass Reinforced Plastic
HDD	Horizontal Directional Drilling
HDPE	High Density Polyethylene
mbgl	meters below ground level
Murphy	Murphy Technical Services
NG	National Grid
NGR	National Grid Reference

Acronym	Description
SSSI	Site of Special Scientific Interest
TBM	Tunnel Boring Machine

5 Published Information

5.1 Published Geology

Published geological data has been obtained from www.bgs.ac.uk/geoindex

Superficial deposits are indicated to vary along the line of the crossing and are depicted on Figure 3. To the northern and southern extremities of the crossing Devensian Glacial till is indicated.

Alluvium, comprising clay, silt, sand and gravel is indicated associated with the meandering channel of the river Hull. Either side of the alluvial channel Sand and Gravel of unknown origin is indicated, it is possible the sand and gravel was deposited by a former river channel possibly of glacial origin.

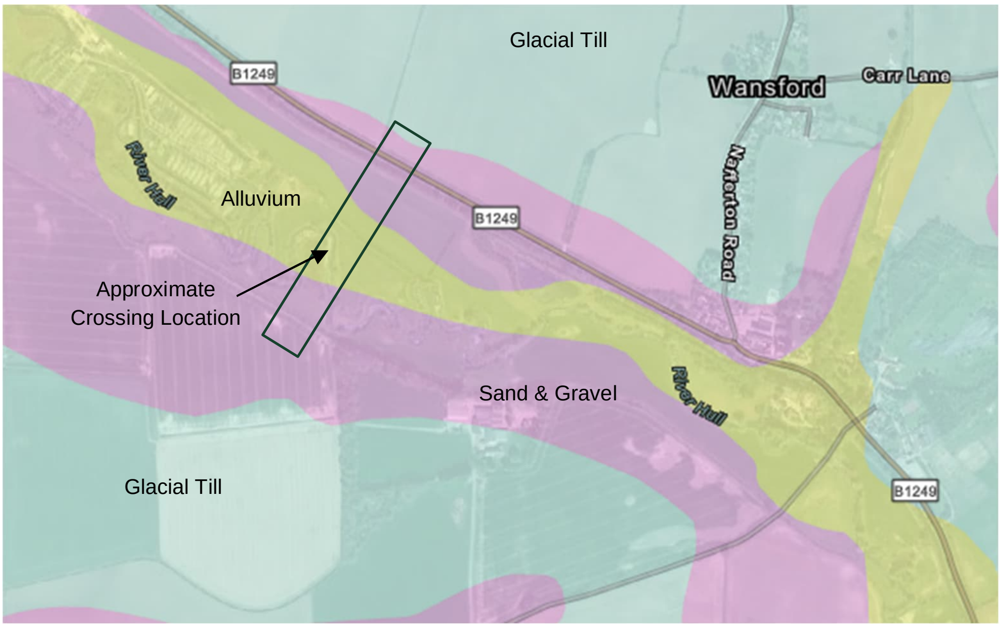


Figure 3 - Published Superficial Deposits

No mass movement deposits, artificial ground or linear features are recorded in proximity to the location of the proposed crossing.

Solid deposits are indicated to comprise the Flamborough chalk formation which typically comprises white, well-bedded, flint free chalk with common marl seams and common stylolitic surfaces and pyrite nodules.

5.2 Historical Ground Investigations

Limited historical ground investigation data is available for the proposed location of the crossing comprising three boreholes within a 1500m radius of the crossing. All boreholes are in use as water wells.

Where strata have been recorded this generally confirms the details indicated by the published geology. In all boreholes the groundwater is recorded as artesian and if pumping is not undertaken the boreholes overtop the casing. In one of the boreholes groundwater is noted to be standing at 1.42m above ground level without pumping.

5.3 Environmental Data

The Environment Agency main river map has been reviewed and indicates the River Hull and Driffield Canal as main rivers. Main Drain is not classified as a main river. The central portion of the crossing from the canal to Main Drain are indicated to be within a flood zone 3.

Natural England's Magic Website (www.magic.gov.uk) has been interrogated to establish if there are any significant environmental considerations in close proximity to the crossing.

The channel of the River Hull is indicated to be a Site of Special Scientific Interest.

The crossing is indicated to be within a 2017 designation Nitrate Vulnerable zone, Zone ID 254, River Hull from Arram Beck to Humber and Zone ID 106 Yorkshire Chalk.

The Flamborough chalk bedrock is classified as a Highly Productive Principal Aquifer with good quality water.

The crossing is not indicated to be within a groundwater source protection zone.

6 Ground Investigation

Three boreholes (BH07, BH08 & BH09) have been undertaken along the line of the crossing as part of a wider investigation for the project. Crossing specific boreholes are located as indicated on Figure 4.

Figure 4 - Crossing Specific Borehole Locations

The results of the scheme specific investigation generally confirmed the sequence identified on published mapping.

North of the canal and road, alluvium described as soft to firm and firm to stiff gravelly Clay and extends to 3.2m depth. From 3.2m depth to the top of the chalk bedrock at 9.00m a mixed glacial sequence is indicated, predominantly described as firm and stiff slightly gravelly sandy silty Clay interbedded with slightly gravelly to gravelly silty Sand in layers up to 1.3m in thickness.

In the central section between the Driffield Canal and River Hull alluvium was only recorded as being 150mm in thickness directly below the topsoil and was described as soft slight sandy Clay. Beneath the alluvium glaciofluvial deposits comprising very gravelly, very clayey fine to coarse Sand and medium dense very sandy slightly silty Gravel is recorded 2.1m in thickness to 2.8mbgl. Glacial till is present from 2.80m to 6.15m depth and is described as firm and stiff slightly gravelly sandy Clay. Chalk bedrock was encountered at 6.15m depth and was proven for 1.15m, the chalk was recovered as sandy slightly silty gravel.

In the southern section between the River Hull and Main Drain alluvium is noted to be absent with glacio-fluvial deposits described as loose sandy gravel and very gravelly sand encountered directly below the topsoil to a depth of 1.60m depth. From 1.60m depth to 6.50m depth glacial till described as firm, occasionally thinly laminated slightly gravelly sandy clay. From 6.50m depth to the base of the borehole at 10.00m the material encountered is described as medium dense off-white very sandy gravel. Sand is medium and coarse. Gravel is subangular fine and medium of flint and chalk.

In the southern section (BH09), the preliminary draft borehole logs classified the material deeper than 6.50m as Chalk, recovered as dense off white very sandy subangular fine and medium gravel of flint and chalk of the Flamborough Chalk Formation. However, in the final factual report the same strata from 6.50m is described as medium dense off white very sandy Gravel which is classified as Glaciofluvial deposits. No laboratory testing is available to substantiate the change in deposition. In the opinion of Murphy this material should be classified as Chalk of the Flamborough Chalk formation.

Artesian groundwater was encountered in all exploratory holes across the site. In BH07 artesian groundwater was encountered at 7.20m bgl which rose to 0.97m AGL after 20 minutes. A groundwater monitoring installation was installed within the borehole with a response zone monitoring within the upper chalk, on each of the three monitoring visits the water level was recorded as 0.57m AGL which is anticipated to be at the top of the upright monitoring cover. Anecdotal evidence suggests groundwater was overtopping the monitoring cover and as such the installation has been sealed to prevent any further flooding. In BH08 artesian groundwater was encountered at 6.15mbgl rising to 2.50m AGL and in BH09 artesian groundwater was encountered at 6.10mbgl rising to 1.85m AGL. In all cases the artesian groundwater was encountered upon reaching the chalk bedrock.

A cross section though the boreholes is presented as Figure 5.

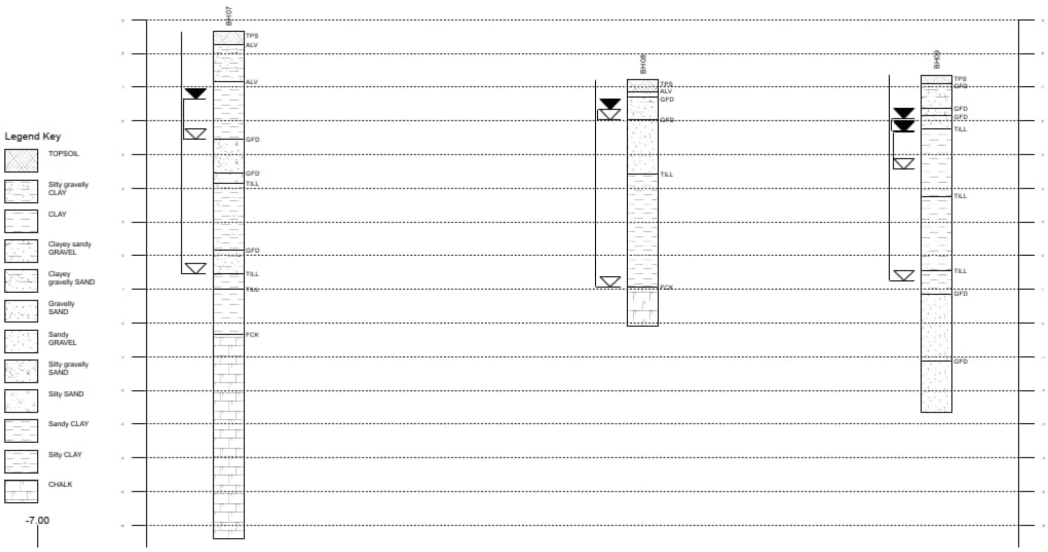


Figure 5 - Geotechnical Cross Section along Crossing Alignment

7 Site Visit

A site walkover was undertaken by Murphy personnel accompanied by National Grid personnel on 20th February 2023. Land access was agreed by National Grid ahead of the visit to enable access to all areas of the proposed crossing.

The land to the north of the B1249 was observed to be relatively flat farmland currently laid to agriculture with a winter crop laid in the field. The groundwater monitoring installation from BH07 was noted in the field the area around the borehole was indicated to be dry, anecdotally the borehole has been sealed to prevent over topping of groundwater.

Ditches were observed on the northern field boundary with the B1249 and the western field boundary. A culvert with a brick headwall was noted on the western field boundary carrying the water under the B1249 and discharging into the Driffield Canal.

The B1249 was noted to be on a slight embankment with the carriageway being approximately 1.5m higher than the field to the north of the road.

Photos 1 to 4 refer.

Photo 1 – Land to the North of the B1249

Photo 2 – BH07 Groundwater Monitoring Installation

Photo 3 – Ditch and Brick Headwall to Culvert

Photo 4 – B1249 from field

The Driffield Canal is directly adjacent to the B1249 with the embankment from the road forming the cutting slope for the canal. The water level in the canal was observed to be approximately 2m lower than carriageway level. A brick headwall was noted in the canal cutting carrying the water from the field drains to the north of the road. Photo 5 refers.

Photo 5 – Canal and Culvert Brick headwall

South of the canal the land remains relatively flat, currently laid to grass. Midway between the canal and the River Hull along the field boundary a water filled ditch was observed, the direction of flow and discharge location from the ditch was not able to be identified but it is anticipated that the ditch discharges directly to the River Hull. The whole area between the canal and the north side of River Hull appears to be the flood plain for the river. Photos 6 & 7 refer.

Photo 6 – View looking south from canal towards river

Photo 7 – Waterfilled ditch on field boundary

The River Hull meanders within the proposed order limits and was observed to be fast flowing with good clear water quality. The weather in the week preceding the site visit has been cold and wet and the river level was at the top of the riverbanks. The river was observed to be in the region of 10m wide. Photos 8 & 9 refer.

Photo 8 – River Hull

Photo 9 – River Hull

South of the River Hull, hydrophilic grass was noted indicating high potential for soft, wet, waterlogged ground. The area of land between the river and Main Drain was narrow and was accessed through a farm and over a bridge. Should construction access be required into this area an alternative access route and temporary bridge over Main Drain may be required.

Main Drain was observed to be a managed drain up to 1.5m in depth, at the crossing location the drain is approximately 7m crest to crest. The water was observed to be flowing east.

The area to the south of Main Drain was not visited on foot but viewed across Main Drain, the land was observed to be slightly higher than the north side of Main Drain, relatively flat currently laid to pasture for sheep. Photos 10 – 13 refer.

Photo 10 – Hydrophilic Vegetation South of River Hull

Photo 11 – View looking North along centreline of order limits

Photo 12 – View across Main Drain

Photo 13 – Main Drain

8 Trenchless Crossing Techniques

8.1 Horizontal Directional Drilling

Horizontal Directional Drilling (HDD) is a commonly used technique for the installation of pipelines beneath obstacles such as roads, rivers, runways, landfalls, existing services, SSSI's etc. It has also been used to install pipelines in areas where the use of conventional open-cut burial is problematic due to the presence of existing services.

The HDD technique involves guiding a pilot hole along a pre-determined profile beneath the obstacle. The depth of the drilled profile can be set to minimise damage to the obstacle being crossed, deeper crossings can be undertaken when 'fragile' or sensitive obstacles need to be crossed.

Once the pilot hole is complete the bore is enlarged in stages using reamers in soft ground or hole openers in hard ground to a diameter approximately 40% greater than the diameter of the pipeline to be installed.

When the bore has been enlarged to the required diameter the product pipeline is pulled through using the drilling rig. A stringing site equivalent to the length of the HDD crossing is required to fabricate the product pipeline in a single length allowing the installation operation to be completed without interruption.

A typical HDD sequence is indicated in Figure 6, Figure 7 and Figure 8.

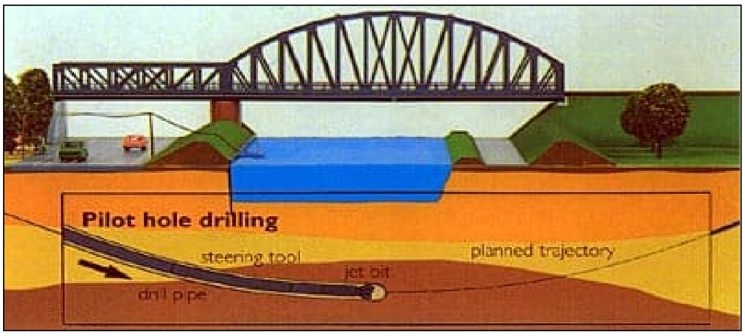


Figure 6 - Pilot Hole Drilling

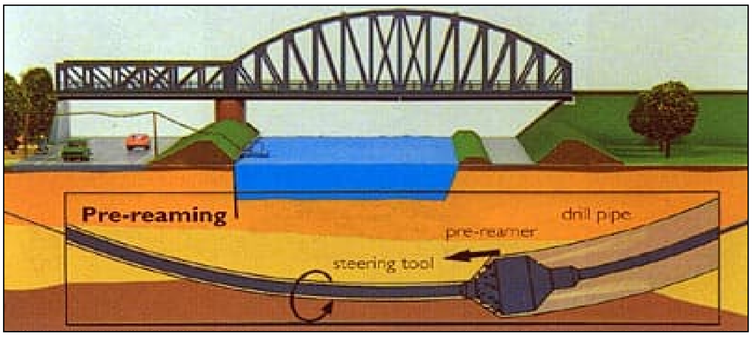


Figure 7 - Pre-Reaming

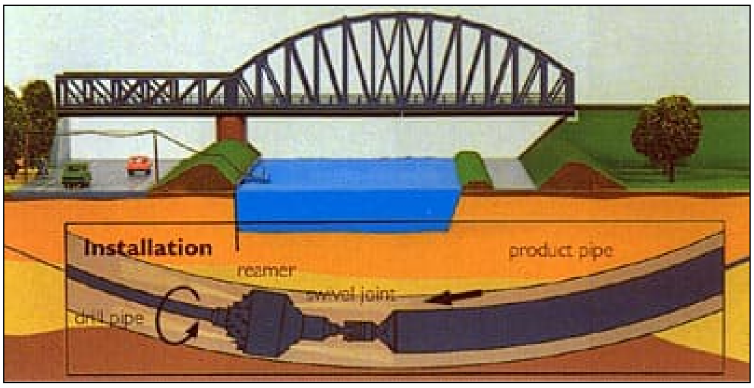


Figure 8 - Pipeline / Duct Installation

During drilling operations, the bore is supported by drilling fluid which also performs functions such as drill bit cooling, lubrication and removal of drill cuttings.

HDD is feasible in a wide range of ground conditions; however, the presence of gravel in high quantities will normally preclude the use of the technique due to the increased risk of failure. The presence of groundwater under artesian and sub-artesian pressure also limits the suitability of the technique.

Detailed information on the ground and groundwater conditions along the proposed route is required to fully assess the suitability of the technique.

8.2 Auger Boring

Auger boring is a technique to install pipelines by simultaneously removing the soil whilst jacking pipe into the ground. The installation can be guided or unguided as detailed below. The achievable length and accuracy is dependent on the method employed, the diameter of the pipeline to be installed and the anticipated ground conditions.

8.2.1 Un-guided Auger Boring

Unguided auger boring involves driving a casing pipe into the ground with an auger screw installed inside; a cutting head suitable for the ground being bored is located at the front of the first auger.

The auger is rotated creating a void in ground which allows the casing pipe to be advanced into the void created. Where a large diameter casing pipe is required the size of the auger is increased in increments. The pipeline can either be installed within the casing pipe or the casing pipe can be replaced with the product pipeline. As indicated in the figures below, for clarity auger boring can also be undertaken from suitably battered or supported excavations:

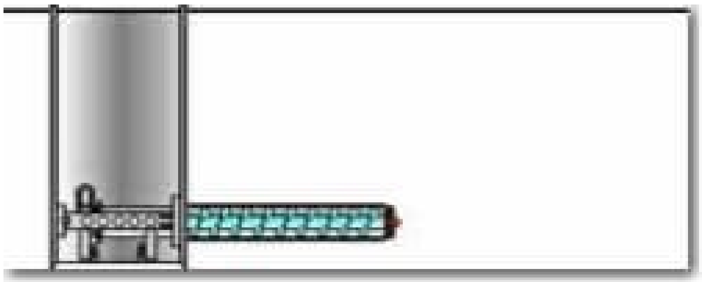


Figure 9 – Un-guided Auger Boring Stage 1 Driving Casing

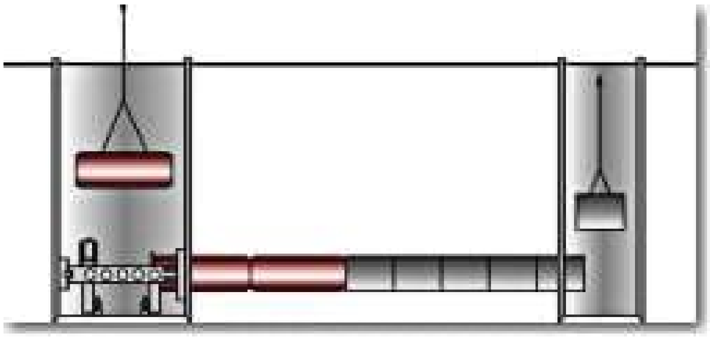


Figure 10 - Un-Guided Auger Boring Stage 2 Replacing Casing with Product Line

Unguided auger boring is suitable for lengths up to a maximum of 90m where line and level are not critical, although crossing lengths are dependent on pipe diameter and ground conditions. The initial set up of the machine is critical to permit the line and level to be as accurate as possible.

The presence of boulders larger than the auger flights and significant quantities of groundwater especially in granular ground can preclude the use of the technique.

8.2.2 Guided Auger Boring

Guided auger boring involves 'steering' a small diameter pilot bore along the pre-designed profile between two excavations before enlarging the bore to the required diameter in stages using auger screws located inside the casing pipe. Once the required diameter is achieved the casing pipe is pushed out and replaced with the product pipeline as indicated in the figures below, for clarity guided auger boring can also be undertaken from suitably battered or supported excavations:

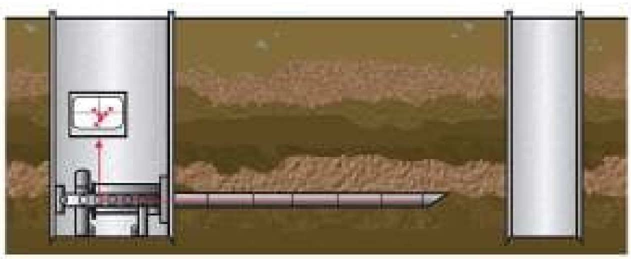


Figure 11 - Guided Auger Boring Stage 1: Guiding a pilot bore between shafts

Figure 12 - Guided Auger Boring Stage 2: Enlarging bore

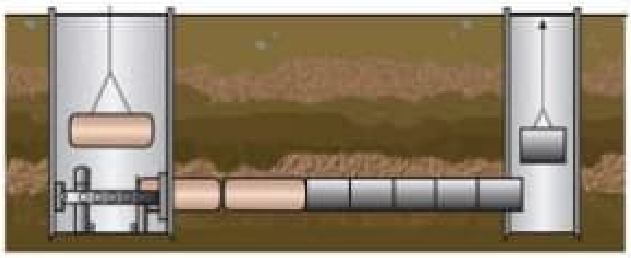


Figure 13 - Guided Auger Boring Stage 3: Installing Product pipe

Where line and level is considered critical, guided auger boring should be adopted.

Guided auger boring is suitable for crossing lengths up to a maximum of 100m due to the ability to sight the guidance laser through the pilot pipe onto the target in the steering head. Crossing lengths are dependent on ground conditions, the presence of significant quantities of cobbles and boulders and groundwater, especially in granular horizons can preclude the use of guided auger boring.

The auger boring process generally installs a steel pipeline, it is common for the steel casing to be replaced with clay, HDPE, concrete or GRP, the choice of pipeline can be selected based on the most suitable thermal dissipation properties.

8.3 Pipe Ramming

Pipe ramming is a method for the installation of pipelines between two previously excavated pits. The method is most useful for shallow installation under railway lines and roads where other trenchless methods could cause surface settlement or heave. The majority of installations are horizontal, although inclined drives can be achieved if required. Pipe ramming is not recommended where rock is anticipated along the length of the crossing.

The pipeline is installed using a pneumatic hammer to drive the pipe between two pits before the spoil is removed from inside the pipeline as indicated in Figure 14:

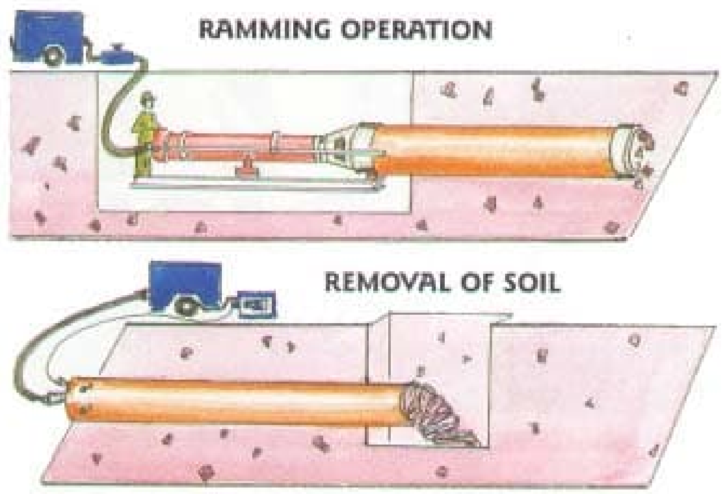


Figure 14 - Pipe Ramming Schematic

In all but the smallest diameters the pipeline is installed open ended and allowed to fill with soil as the pipe is advanced into the ground. Once the installation of the pipeline is completed between the two pits the soil is removed from the installed pipe by one or a combination of methods including, pressurisation and blow-out, pressure jetting, augering or for larger casing diameters by mini excavator.

Distances up to 70m are achievable with diameters up to 2000mm depending on the prevailing ground conditions and the suitability of the pipeline to withstand the anticipated ramming forces. Line and level cannot be guaranteed with the use of pipe ramming.

8.4 Horizontal Down the Hole Hammer

Typical application for DTH-Hammer drilling is installing casings for cables and pipelines under roads, railway, canals etc. DTH-Hammer drilling works most efficiently in mixed and rocky soil conditions.

Control of line and level is a function of the machine set up, once the crossing commences no steering corrections can be made. Diameters between 140mm – 1220mm are possible.

A typical DTH-Hammer drill set up is depicted on Figure 15

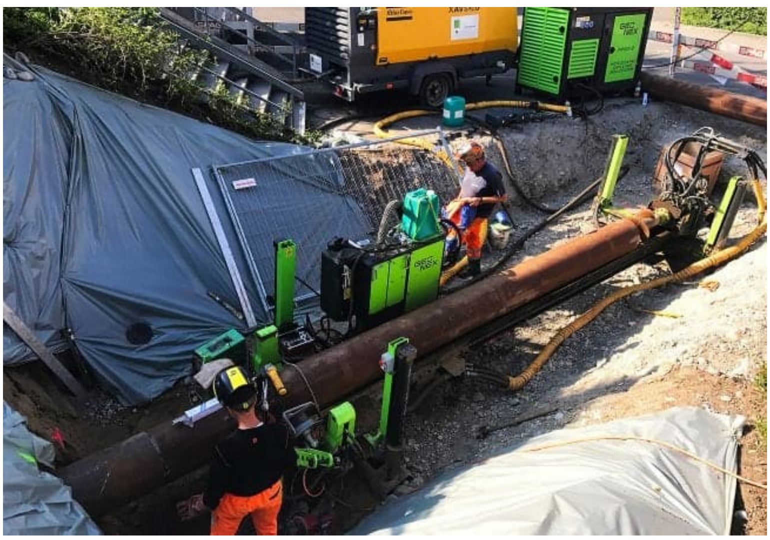


Figure 15 - Typical DTH-Hammer Drill Set Up (Image courtesy of https://geonex.fi/)

Steel casing provides the necessary support to the ground during and post installation. The DTH-Hammer and drill bit combination pulls the casing pipe behind as the crossing is advanced, auger rods, installed inside the casing convey the cut material through the casing back to the launch pit. This installation method does not displace or expand any soil around the casing pipe minimising any overcut to ensuring surface settlement is managed.

The permanent steel casing pipes are added and welded as the crossing progresses. Crossing lengths up to 150m in length have been achieved. Whilst the DTH-Hammer can operate in material where groundwater is present groundwater entering the launch and reception pits needs to be controlled.

It is currently unknown if the technique has been used in the UK, it is understood to be used in Europe, predominantly Scandinavia.

8.5 Microtunnelling

Pipe jacking, which in the smaller diameters is referred to as microtunnelling, involves the formation of drive and reception pits / shafts either side of the crossing followed by remote driving of a tunnelling machine between the two excavations along a pre-determined path. As the machine is advanced, concrete conduit is jacked into the ground behind it preventing the ground from collapsing. Once the tunnel is complete the tunnel would be fitted out for cable installation.

The jacking force applied to the concrete conduit is transferred along the tunnel and assists the advance of the tunnelling machine. The jacking loads are resisted by a thrust block cast into the drive pit. The pipe jacking technique is indicated on Figure 16.

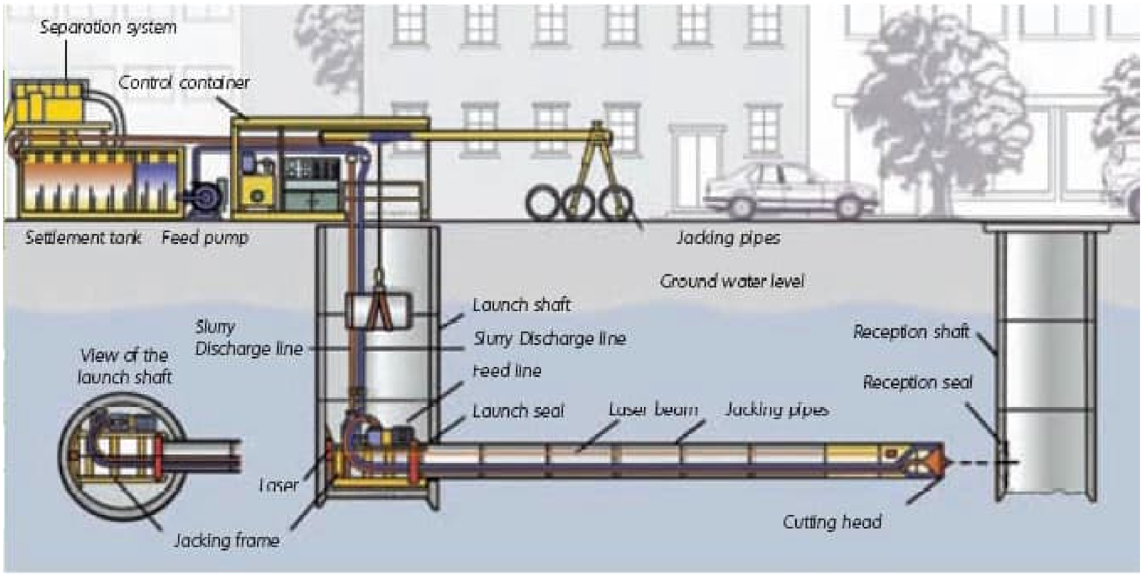


Figure 16 - Pipe Jacking Schematic

Pipe jacking is normally undertaken from a specially constructed shaft but dependent on depth, can also be undertaken from suitably battered or supported excavations. Where high groundwater levels and groundwater under artesian pressure are present at the crossing locations the use of shafts is normally required. The provision of a thrust wall is required in all types of launch structures.

Numerous types of tunnel boring machine are available; machines can be configured to work in almost any ground conditions. Tunnel machines can be configured to work in areas of high groundwater and artesian groundwater pressure.

The achievable length of a tunnel drive is not dependent on the size of the pipeline to be installed but by a combination of the diameter of the TBM, the capacity of the jacking system and the ground conditions. For reference purposes for tunnel diameters of 1.5m, drive lengths in the region of 400m are readily achievable with a wide variety of machines.

8.6 Direct Pipe

Direct pipe® combines the advantages of microtunnelling and HDD technology. In one set up, a prefabricated steel pipe can be installed simultaneously as the required bore is being excavated allowing for speedy and highly economic installation of pipelines.

From the launch pit, the ground is excavated using a slurry supported Herrenknecht Microtunnelling Machine, excavated material is pumped though the slurry circuit installed within the prefabricated steel product pipeline.

The pipeline, laid out on the surface on rollers and welded to the end of the microtunnelling machine, is pushed into the borehole at the same time as excavation takes place. The thrust force to advance the microtunnelling machine is provided by a Pipe Thruster which pushes the microtunnelling machine forward together with the pipeline.

During excavation, the tunnel face is controlled using slurry-supported tunnelling technology even in heterogeneous, water permeable soils. Uphill and downhill gradients as well as precise curve drives along the alignment can be managed with the gyro-based navigation system.

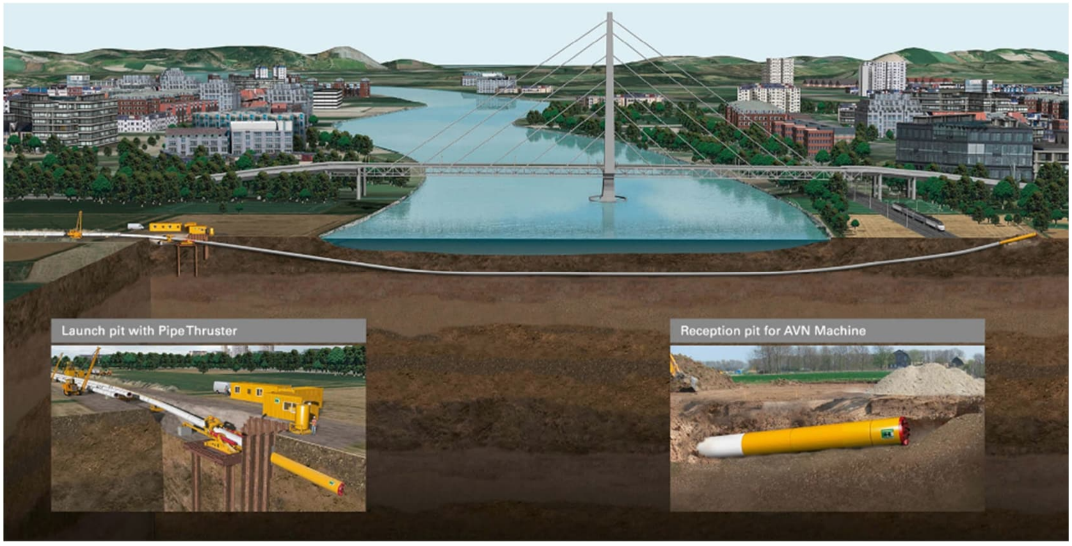


Figure 17 - Direct Pipe Overview (image courtesy of https://www.herrenknecht.com/)

Direct Pipe® is currently only available in diameters between 800mm and 1500mm. Lengths in excess of 1500m are achievable.

8.7 E Power Pipe

The Herrenknecht E-Power Pipe method is a relatively new technology used for the trenchless installation of small diameter product pipes at shallow depths. The technique is a two-stage process which integrates aspects of HDD and pipejacking.

Initially a jacking frame is installed in the launch excavation. The specialist tunnel boring machine and reusable steel jacking pipes specifically developed for the E-Power Pipe method are pushed through behind the tunnel machine along the required alignment. Following breakthrough at the target exit point, the TBM is separated from the steel jacking pipes.

In the exit pit a pullhead is attached to the jacking pipe string and connected to the prefabricated product pipe. The steel jacking pipes are pulled back by the jacking frame at the launch site progressively installing the product pipeline(s) into the bore. The bore remains mechanically supported during the whole process. During pipeline installation the annular gap between the borehole and the pipeline is backfilled. A typical site set up is shown on Figure 18

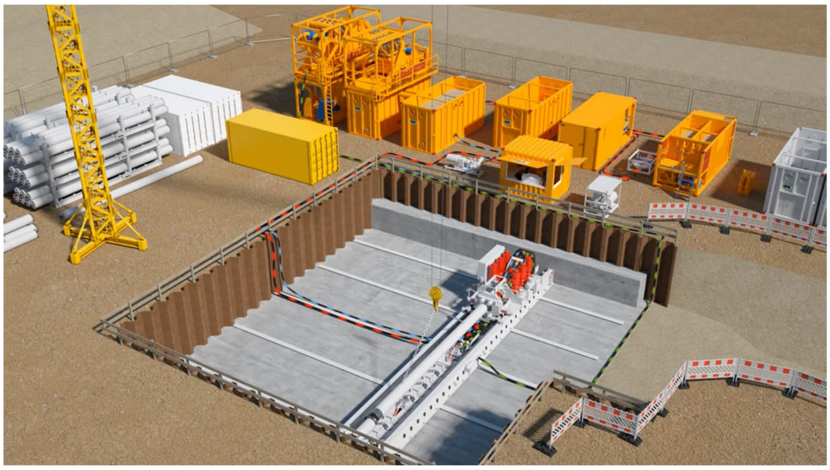


Figure 18 - Typical E-Power Pipe Launch Site Set Up (image courtesy of https://www.herrenknecht.com/)

The specialist tunnelling machine can be configured to work in a wide range of ground conditions. E-Power pipe is currently available in diameter between 500mm and 980mm. Crossing lengths in excess of 1500m can be readily achieved.

9 Crossing Options

A crossing assessment matrix for all the crossing techniques considered for use on this crossing has been prepared. Relevant information is contained in the sections below. A copy of the crossing assessment matrix is presented as appendix A. The crossing matrix should not be used in isolation and should be read in conjunction with the report text.

In addition to the information within the crossing assessment matrix the following sections provide narrative on each of the techniques.

9.1 HDD

9.1.1 Long HDD

A long HDD crossing would cross all the features in a single crossing and whilst the ground conditions are suitable for a long HDD the presence of groundwater under artesian pressure would cause significant issues. Two parallel crossings would be required, one for each of the proposed HVDC cables.

To achieve a crossing design that would minimise the risk of frac-out into the Driffield Canal and River Hull and manage carriageway settlements to the B1249 the crossing would need to be in the region of 7m below each of these features, at this depth the majority of the crossing would be within the Chalk and would encounter the artesian groundwater. The artesian groundwater would pose a significant risk of flooding at the entry and exit locations and measures would need to be implemented to control the flow of water to the surface in the temporary conditions during the HDD works and in the permanent condition following the installation of the cable ducts.

In the temporary condition the ground level at the entry and exit locations would need to be raised to create a working platform above the anticipated water level, which is currently understood to be up to 2.50m above ground level. The working platform would need to be construction from imported fill material, as a minimum the platform would need to be large enough to accommodate the drilling rig and the casing pipe, the ancillary drilling equipment could be positioned on natural ground. The number of vehicle movements would be significant for the construction of an elevated working platform and would need to be considered in the planning application as would identifying a source to import material from. Visual impact assessments would also need to be undertaken and included in the planning application.

Along with raising the ground level a casing pipe would need to be installed and sealed in the natural ground to contain and prevent the groundwater flowing out of the bore at the entry and exit locations. Installation and sealing of the casing pipe would need to be completed from the working platform level, the seal around the outside of the casing pipe would need to be suitable in the temporary and permanent condition to resist groundwater pressures and to seal any potential pathway to the surface for the groundwater.

The casing pipe would need to be cut back to ground level and would need to remain the permanent condition with the annulus between the cable duct and the casing pipe sealed to close the pathway for groundwater back to ground level.

The success of this technique relies upon being able to form a seal between the casing pipe and the natural ground and the cable ducts and the casing pipe to close off any pathway for groundwater back to the surface. Even if escape of groundwater to the surface can be prevented this crossing technique has an impact to the hydrological regime across the site as the aquiclude is breached allowing groundwater to enter the upper superficial deposits and as such liaison with the Environment Agency would be required prior to adopting as a suitable crossing technique.

Should the issues with groundwater be overcome the ground conditions are considered suitable for the application of HDD for the crossing although additional ground investigation is recommended prior to finalising any design. To manage the geotechnical risks posed by the gravel contents within the superficial deposits the profile is best positioned within the underlying chalk for a long crossing. Installing the crossing within the chalk also minimises the risks of drilling fluid frac-out to the Driffield Canal, River Hull, SSSI and to the EA flood zone.

A long HDD would encounter groundwater under artesian pressure and the mitigation measures to manage the impact with the groundwater would result in hydrological changes to the groundwater in the area requiring discussion with the Environment Agency. Significant enabling works are also required to achieve the crossing and the long-term success of the crossing relies on a permanent seal between the natural ground and casing pipe and the casing pipe and the cable duct.

Should the design challenges from a long HDD be overcome, it is anticipated that the construction could be completed within the currently proposed 100m wide order limits.

The crossing assessment matrix, included in appendix A indicates that adopting this crossing technique ranks 6 out of 9 with a score of 62/99.

On the basis that the design challenges present significant risks to the adoption and suitability of this technique, it is not recommended that a long HDD technique is considered further.

9.1.2 Short HDDs

As an alternative to a long HDD to complete the crossing in a single length the crossing could be split into shorter drills, which if agreement to drill outside of the limits recommended by the DCA (Drilling Contractors Association) could be agreed, (in terms of depth of cover), and the associated increased risks managed, the drills could be undertaken at shallower depth.

It is anticipated that to complete the crossing two HDDs would be required as follows:

HDD 01 – B1249 & Driffield Canal

HDD 02 – River Hull and Main Drain

The section between the two drills would need to be installed using conventional open cut duct laying techniques which would involve linear excavations. At each HDD location, two parallel drills would be required, one for each of the proposed HVDC cables.

Completing the crossings at cover depths less than what is recommended in the DCA guidelines significantly increases the risk of drilling fluid frac-out along the line of the crossing and also increases the potential for surface settlement to occur at the carriageway level of the B1249.

Frac-out is most likely to occur where the level of cover is the lowest which is likely to be at the Driffield Canal, River Hull and Main Drain locations which are the most sensitive locations where breakout of drilling fluid would cause the greatest impact. Breakout of fluid into the canal could cause significant damage to the canal especially if the canal liner is damaged. Breakout into the River Hull could have a negative impact on the SSSI.

The drills could be designed to be above the level where interaction with artesian groundwater is likely however, uncontrollable changes in the pressure head of the groundwater may result in the cable ducts becoming a pathway for groundwater. A shallower profile also increases the risks posed by the shallow gravel bands as a greater proportion of the crossing will be undertaken within the upper deposits.

Each of the required crossings and the open cut excavations would require construction to be undertaken with the EA flood zone. A permit would need to be applied for from the EA for all construction taking place within the flood zone and all measures required by the EA permit for working within the flood zone would need to be adhered to. Without making contact with the local EA officers, it is not possible to understand what local restrictions would be required. In other areas measures to prevent the storage of excavated soil and the impact of the works should a flood event occur are common restrictions.

It is anticipated that the construction could be completed within the proposed 100m wide order limits.

The crossing assessment matrix, included in appendix A indicates that adopting this crossing technique ranks 9 out of 9 with a score of 46/99.

On the basis that the risks of adopting this technique as highlighted by the low score on the crossing assessment matrix are too high, it is not recommended that short HDDs with open cut tie-ins are considered further unless additional ground investigation is undertaken which indicates the ground related risks can be adequately managed and mitigated.

9.1.3 Stitch drilling

The third crossing option using HDD involves using a stich drilling technique where short crossings are undertaken at around 2m depth back-to-back from excavated pits with the cable duct joined with electrofusion couplings in the excavated pits.

Should this option be preferred, several options exist for the development of the route alignment and the number of crossings all within the proposed 100m wide order limits. To minimise the risks from shallow crossings, it is recommended that crossing lengths are restricted to 75m to 100m in length. It is estimated that up to four crossings would be required for each cable. At each crossing location two separate parallel HDDs would be required, one for each of the proposed HVDC cables.

Although crossings at circa 2m depth would manage the risks posed by the artesian groundwater the risks of drilling fluid frac-out and bore failure are significantly higher due to the limited overburden. The risk of failure from the shallow gravel deposits is highest for this option.

Each of the required crossings would require construction to be undertaken with the EA flood zone. A permit would need to be applied for from the EA for all construction taking place within the flood zone and all measures required by the EA permit for working within the flood zone would need to be adhered to. Without making contact with the local EA officers, it is not possible to understand what the local restrictions would be. Common restrictions include storing any excavated soil outside of a flood zone to minimise any impacts to the flood plain.

The crossing assessment matrix, included in appendix A indicates that adopting this crossing technique ranks 4 out of 9 with a score of 64/99.

On the basis that the risks of adopting this technique are too high it is not recommended that stich drilling is considered further, unless additional ground investigation is undertaken which indicates the ground related risks can be adequately managed and mitigated.

9.2 Auger Boring

To complete the scheme using auger boring, it is anticipated that three separate crossings would be required as follows:

Crossing 1 – B1249 and Driffield Canal

Crossing 2 – River Hull

Crossing 3 – Main Drain

There is potential for the number of crossings to be reduced to two should a suitable location for a combined crossing of the River Hull and Main Drain be achievable. Detailed design would be required to establish if both HVDC cables could be installed in the same casing pipe or whether individual crossings are required for each HVDC cable.

Between the auger bored crossings, the remainder of the section would need to be installed using open cut duct laying techniques which would involve linear excavations.

Each of the required crossings and the open cut excavations would require construction to be undertaken with the EA flood zone. A permit would need to be applied for from the EA for all construction taking place within the flood zone and all measures required by the EA permit for working within the flood zone would need to be adhered to. Without making contact with the local EA officers, it is not possible to understand what the local restrictions would be. Restrictions may include storing any excavated soil outside of a flood zone to minimise any impacts to the flood plain.

Ground conditions for the adoption of auger boring are considered to be marginal as the presence of groundwater within granular horizons cannot be fully understood from the current ground investigations. Current ground investigation indicates that the upper granular horizons contain groundwater. Further ground investigation would be required to establish the lateral extents and continuity of the granular horizons along each of the crossing drives and whether measures can be implemented to mitigate the risks posed by installing within these horizons.

Launch and reception pit design and construction would need to give confidence that the risks posed by removing overburden would not result in basal heave of the excavation due to the underlying groundwater under pressure. The excavation support method would also need to give confidence that a pathway for long term groundwater migration from the chalk into the superficial deposits is avoided.

It is anticipated that all construction would be possible within the current order limits and no extension to the order limits would be required. Consideration will need to be given to presence of the ditch / drain within the current order limits and the associated brick culvert carrying water under the B1249 prior to discharging into the Driffield Canal.

The crossing assessment matrix, included in appendix A indicates that adopting this crossing technique ranks 7 out of 9 with a score of 61/99.

Based on the information available, the probability that granular horizons containing groundwater at the crossing locations and the perceived risks to the temporary works posed by the underlying groundwater cannot be adequately assessed, it is therefore recommended that Auger Boring is not progressed as a risk managed crossing technique unless further ground investigation is undertaken and the results indicate that the risks can be managed and mitigated.

9.3 Pipe Ramming

To complete the scheme using pipe ramming, it is anticipated that three separate crossings would be required as follows:

Crossing 1 – B1249 and Driffield Canal

Crossing 2 – River Hull

Crossing 3 – Main Drain

There is potential for the number of crossings to be reduced to two should a suitable location for a combined crossing of the River Hull and Main Drain be achievable. Detailed design would be required to establish if both HVDC cables could be installed in the same casing pipe or whether individual crossing are required for each HVDC cable.

Between the crossings, the remainder of the section would need to be installed using open cut duct laying techniques which would involve linear excavations.

Each of the required crossings and the open cut excavations would require construction to be undertaken with the EA flood zone. A permit would need to be applied for from the EA for all construction taking place within the flood zone and all measures required by the EA permit for working within the flood zone would need to be adhered to. Without making contact with the local EA officers, it is not possible to understand what the local restrictions would be. Restrictions may include storing any excavated soil outside of a flood zone to minimise any impacts to the flood plain.

Ground conditions for the adoption of pipe ramming are considered to be suitable providing the temporary works solutions to support the launch and receptions pits are suitable to control the ingress of water from the upper granular horizons.

Launch and reception pit design and construction would need to give confidence that the risks posed by removing overburden would not result in basal heave of the excavation due to the underlying groundwater under pressure. The excavation support method would also need to give confidence that a pathway for long term groundwater migration from the chalk into the superficial deposits is avoided.

Pipe ramming installs a steel casing and confirmation on the interaction between the steel casing and the cable system design would need to be confirmed.

Pipe ramming is an unguided technique, the line and level of the crossing are set as a function of the initial equipment set up and as such no guarantees on the line and level of the crossing can be made.

It is anticipated that all construction would be possible within the current order limits and no extension to the order limits would be required. Consideration will need to be given to presence of the ditch / drain within the current order limits and the associated brick culvert carrying water under the B1249 prior to discharging into the Driffield Canal. Special consideration will need to be given to the effects of vibration on the existing culvert.

The crossing assessment matrix, included in appendix A indicates that adopting this crossing technique ranks 5 out of 9 with a score of 63/99.

Based on the available information the perceived risks to the temporary works posed by the underlying groundwater cannot be adequately assessed and further ground investigation is recommended to better understand and assess if those risks can be managed. The technique is unguided and the requirements for open cut working within the EA flood plain need to be fully understood, it is therefore not recommended that pipe ramming is adopted as a risk managed technique for the completion of the crossing until further information is available.

9.4 Horizontal Down the Hole Hammer

To complete the scheme using horizontal down the hole hammer, it is anticipated that three separate crossings would be required as follows:

Crossing 1 – B1249 and Driffield Canal

Crossing 2 – River Hull

Crossing 3 – Main Drain

There is potential for the number of crossings to be reduced to two should a suitable location for a combined crossing of the River Hull and Main Drain be achievable. Detailed design would be required to establish if both HVDC cables could be installed in the same casing pipe or whether individual crossing are required for each HVDC cable.

Between the crossings, the remainder of the section would need to be installed using open cut duct laying techniques which would involve linear excavations.

Each of the required crossings and the open cut excavations would require construction to be undertaken with the EA flood zone. A permit would need to be applied for from the EA for all construction taking place within the flood zone and all measures required by the EA permit for working within the flood zone would need to be adhered to. Without making contact with the local EA officers, it is not possible to understand what the local restrictions would be. Restrictions may include storing any excavated soil outside of a flood zone to minimise any impacts to the flood plain.

Ground conditions for the adoption of DTHH are considered to be suitable although the interaction with shallow groundwater is not known for this technique and further discussions with suppliers is required to gain further understanding. The temporary works solutions to support the launch and receptions pits would also need to be suitable to control the ingress of water from the upper granular horizons.

Launch and reception pit design and construction would need to give confidence that the risks posed by removing overburden would not result in basal heave of the excavation due to the underlying groundwater under pressure. The excavation support method would also need to give confidence that a pathway for long term groundwater migration from the chalk into the superficial deposits is avoided.

Horizontal DTHH installs a steel casing and confirmation on the interaction between the steel casing and the cable system design would need to be confirmed.

Horizontal DTHH is an unguided technique, the line and level of the crossing are set as a function of the initial equipment set up and as such no guarantees on the line and level of the crossing can be made.

It is anticipated that all construction would be possible within the current order limits and no extension to the order limits would be required. Consideration will need to be given to presence of the ditch / drain within the current order limits and the associated culvert carrying water under the B1249 to discharging into the Driffield Canal.

At the time of writing the report authors are unaware of this technique being used in the UK and the availability of equipment to adopt this technique outside of Scandinavia.

The crossing assessment matrix, included in appendix A indicates that adopting this crossing technique ranks 8 out of 9 with a score of 51/99.

Based on the available information, the perceived risks to the temporary works posed by the underlying groundwater cannot be adequately assessed and further ground investigation is recommended to better understand and assess if those risks can be managed. The technique is unguided and the requirements for open cut working within the EA flood plain need to be fully understood, it is therefore not recommended that Horizontal DTHH is adopted as a risk managed technique for the completion of the crossing until further information is available.

The unknown history of the technique in UK ground conditions along with equipment availability should also be given consideration in the assessment of the suitability of this technique.

9.5 Microtunnelling

Microtunnelling (Pipe jacking) would complete the crossing in a single drive between shafts constructed to launch and receive the tunnel machine. This technique is the most versatile technique with tunnel machines available to accommodate variations in ground and groundwater conditions and would complete the crossing within the proposed order limits. No work would be required within the EA floodplain within this method.

It is recommended that the tunnel drive is wholly within the chalk bedrock with a minimum of 2 to 3 tunnel diameters cover below the interface with the overlying superficial deposits.

To achieve the anticipated drive length a 1.5m ID, 1.8m OD tunnel machine is recommended and is in line with the Tunnelling and Pipejacking guidance for designers published by the HSE in conjunction with the British Tunnelling association and Pipe Jacking association. It is anticipated that than earth pressure balanced slurry machine will be required for with the anticipated ground and groundwater conditions. Specialist advice should be obtained from tunnelling specialists to confirm the tunnel machine most suited to this project. Once installed tunnel segments are grouted in place permanently fixing the tunnel in place and sealing the external annulus cutting off any pathways for groundwater movement.

To achieve a tunnel drive launch and reception shafts are required. Various techniques are available to construct shafts in the anticipated ground conditions and a method can be configured to accommodate the anticipated ground and groundwater conditions. Methods such as a wet caisson with additional rings placed above ground level to prevent groundwater flooding or secant piles with base grouting prior to excavation could be explored at detailed design to prevent the need for long term dewatering. Depending on the shaft construction method back grouting of the shaft to seal the shaft from water ingress can be undertaken. Shaft construction methods can be developed so there is no long-term hydrological changes to the area.

Whilst not essential to assist in the construction of the shafts consideration should be given to temporarily locally raising the ground level at the shaft locations to minimise risks to construction and construction workers.

To prevent groundwater flows from the tunnel drive entering the shafts it is anticipated that a launch eye with adequate seals will be required. At the reception shaft a method will need to be developed at detailed design, it is anticipated that a soft eye behind tunnel segments or similar will be required.

It is anticipated that no signification dewatering will be required during shaft and tunnel construction and there is adequate space within the current order limits to facilitate construction using this method.

Cable system studies will need to be undertaken to confirm that both cables can be installed into a single tunnel of this diameter and the interaction between the cables. The method of cable installation into the tunnel and the permanent cable design will also need to be developed. If required HDPE ducts could be installed into the tunnel for the later installation of the cables. The method of cable installation within the vertical shafts will also need careful consideration and the cable system manufacturers and designers need to be aware of this requirement.

Once the cables are installed and tested if required the tunnel could be filled with a thermally efficient material to assist with the dissipation of heat from the cables. It is recommended that the shafts are broken out to below ground level and backfilled in the permanent condition.

Consideration will also need to be given to the transition of the cables from the tunnel into the shafts and back to nominal cover for the ongoing open cut cable laying.

The crossing assessment matrix, included in appendix A indicates that adopting this crossing technique ranks 1 out of 9 with a score of 83/99.

On this basis it is recommended that microtunnelling is progressed as the preferred crossing technique and as such an outline tunnel profile has been developed for consideration and included in appendix B. It is recommended that further ground investigation is undertaken to better establish the ground and groundwater conditions including chalk classification, strength and permeability to allow all risks to be mitigated as far as reasonably practicable.

9.6 Direct Pipe

Direct pipe would complete the crossing in a single drive within the proposed order limits and would install a single steel pipeline, therefore confirmation on the interaction between the steel casing and the cable system design would need to be confirmed along with the minimum permissible cable separation to allow the steel pipeline to be sized. Currently Direct Pipe is available in diameter ranging from 800mm to 1500mm.

Direct pipe is surface launched from a graded excavation. For this crossing the excavation would need to be sufficient to ensure adequate cover to the base of the canal was achievable. Whilst direct pipe is a steerable technique the radius that can be steered is a function of the tunnel machine, pipeline diameter and wall thickness.

The temporary launch excavation would need to be supported and the support method would need to give confidence that that the artesian water would not be breached resulting in significant quantities of groundwater entering the excavation. For machine reception a smaller excavation is required, again confidence that the artesian groundwater will not be breached by any support methods will be required.

The most significant risk with adopting Direct Pipe is the interaction with the artesian groundwater. The crossing profile will encounter the groundwater, which is not considered to be a concern for the tunnel machine at the head of the pipeline, the concern is from the flow of groundwater through the annulus back to the ground surface. During the drive in the temporary condition a tunnel eye could be adopted to prevent flooding at the launch site. In the reception pit a method to control groundwater will need to be developed. In the permanent condition the annulus will need to be sealed to prevent groundwater escape, methods would need to be developed to seal the annulus as no method is currently known.

Even if escape of groundwater to the surface can be prevented in the long term this crossing technique has an impact to the hydrological regime across the site as the aquiclude is breached allowing groundwater to enter the upper superficial deposits and as such liaison with the Environment Agency would be required prior to adopting as a suitable crossing technique.

Direct pipe installs a steel casing, studies will need to be completed to establish if both cables can be installed in the same pipeline along with confirmation on the interaction between the steel casing and the cables to confirm a single drive is sufficient for the scheme.

No works would be required within the EA flood plain for this installation method.

The crossing assessment matrix, included in appendix A indicates that adopting this crossing technique ranks 3 out of 9 with a score of 73/99.

On the basis that at the time of writing it is unknown whether a seal can be formed to prevent groundwater flows to the surface in the permanent condition it is not recommended that Direct Pipe is adopted as a risk managed technique for the completion of the crossing. Further ground investigation and analysis of the ground conditions and ground water regime is recommended and discussions with suppliers undertaken should development of a direct pipe solution be considered.

9.7 E Power Pipe

E Power pipe would complete the crossing in a single drive with the duct grouted in place as it is installed into the bore. There would be no requirement for any work within the EA flood plain. Detailed design would need to be undertaken to establish if both cables could be installed in a single drive or if two parallel drives, once for each HVDC cable is required.

The superficial deposits are expected to be suitable for the application of E Power pipe and there are no concerns from the present of perched groundwater within the upper granular deposits. E-Power pipe works in a range of ground conditions. There is limited potential for steering of the technique so each drive would need to be flat.

Significant supported excavations would be required for the launch and reception pits and the design of the excavations would need to give confidence that there would be no interaction with the artesian groundwater, which poses a significant risk to the success of the temporary works solution.

It is anticipated that all construction would be possible within the current order limits and no extension to the order limits would be required.

E Power pipe is understood to have only been used on one project in the UK to date. Therefore, discussions with the developers of the technique are recommended should the technique be considered further.

The crossing assessment matrix, included in appendix A indicates that adopting this crossing technique ranks 2 out of 9 with a score of 73/99.

Further ground investigation is required to determine if the ground and groundwater risks can be managed to overcome the construction challenges related to the potential interaction from the temporary works elements of the project with the artesian groundwater and the application of the technique in the identified ground conditions. The limited history of the technique in UK ground conditions along with equipment availability is also a cause for concern and it is recommended discussions are held with the developers to further understand the suitability of the technique at the site location to understand what risks can be managed prior to a decision on the suitability being made.

10 Cost and Programme Comparison

Whilst this is a technical report it is understood that cost and programme have an impact to each of the crossing techniques and as such the following table has been developed as a comparison to the likely construction durations and anticipated costs.

Please note a full assessment of programmes and durations has not been undertaken and the following is provided for high level guidance only.

Technique	Programme	Cost
Long HDD	6	6
Short HDD & Open Cut	2	2
Stitch Drilling	1	1
Auger Boring & Open Cut	3	4
Pipe Ramming & Open Cut	3	3

Technique	Programme	Cost
Horizontal DTHH	3	5
Microtunnelling	9	9
Direct Pipe	7	7
E Power Pipe	8	8

Key:

Programme 1 to 9 where 1 is shortest programme and 9 is longest programme.

Cost 1 to 9 where 1 is the lowest cost and 9 is the highest cost.

11 Conclusions and recommendations

The proposed crossing at Wansford Lock is a complicated and technically challenging crossing comprising the B1249, Driffield Canal, River Hull and Main Drain. The channel and banks of the river Hull are classified as a SSSI and the area between the Driffield Canal and Main Drain are classified as an EA Flood Zone 3.

Ground conditions are indicated to comprise mixed superficial deposits comprising gravel, sand, silt and clay in varying proportions overlying chalk bedrock. Groundwater under artesian pressure is present within the chalk bedrock. When encountered during ground investigations groundwater levels reached 1.5m above ground level.

Nine potential construction solutions have been developed, technically assessed and scored against criteria in a scoring matrix.

Technically, microtunnelling scored as the most favourable crossing technique as it can be developed to work in all types of ground and groundwater conditions. A microtunnel solution completes the crossing in a single drive and avoids the need to work within the EA flood zone.

To ensure that a microtunnel solution is acceptable for the cable system design, checks need to be undertaken to confirm that both cables can be installed in the same tunnel, the transition from the tunnel through the shaft and back to nominal cover is possible and if there is a need for a thermally efficient backfill to the tunnel and shafts to assist with heat dissipation.

To progress with a microtunnel solution it is recommended that further ground investigation is undertaken to gain a better appreciation of the chalk bedrock and complete classification of the chalk in accordance with CIRIA guidance for the selection of the tunnel machine and the construction and excavation method for the shafts. The ground investigation should include rotary coring of the chalk to permit logging and classification. Permeability testing in the chalk is also recommended during the ground investigation. It is recommended that early discussions with the EA are conducted before moving to detailed design to ensure all requirements and responsibilities are understood.

The main risks that need to be designed out / reduced involve those associated with the presence of artesian groundwater. The shaft construction method needs to prevent flow of groundwater to the surface and changes to the hydrological regime in the area where methods such as back grouting shaft rings or adopting a Secant piled solution with base grouting ahead of excavation are available. Should investigations confirm these methods are not suitable temporary ground freezing could also be given consideration. Confirmation is also required that the seal between the tunnel and shaft can be made watertight in both the temporary condition during tunnel driving and reception and in the permanent condition.

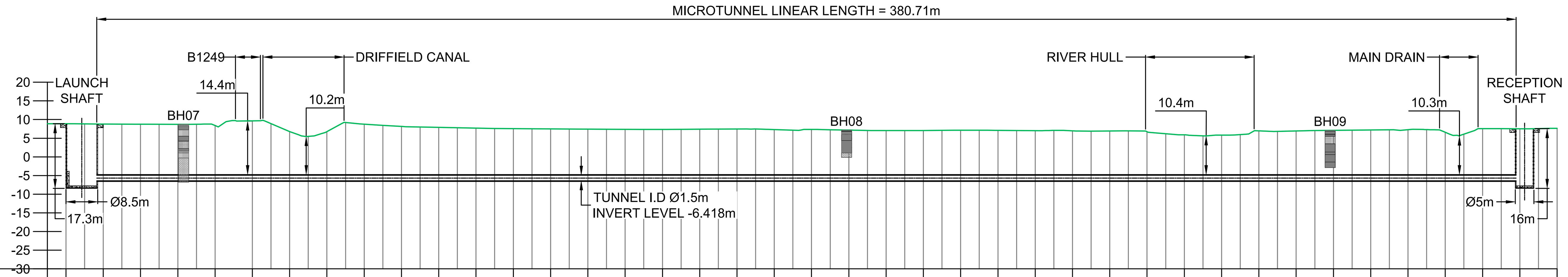
Whist microtunnelling is the preferred solution, with further ground investigation, discussions with the EA, equipment manufacturers and suppliers the risks associated with the other crossing techniques discussed could be mitigated and an alternative crossing technique could be adopted for completion of the crossing.

Appendix A- Crossing Assessment Matrix

Assessment Criteria / Method	Long HDD		Short HDD		HDD Stitch		Auger Boring		Pipe Ramming		DTHH		Micro tunnel		Direct Pipe		E Power Pipe	
Number of crossings	Single Drill	9	Crossing 1 - Road and Canal Crossing 2 - River and Ditch	1	Up to four separate drills	1	Crossing 1 - Road and Canal Crossing 2 - River Hull Crossing 3 - Main Drain	1	Crossing 1 - Road and Canal Crossing 2 - River Hull Crossing 3 - Main Drain	1	Crossing 1 - Road and Canal Crossing 2 - River Hull Crossing 3 - Main Drain	1	Single Drive	9	Single Drive	9	Single Drive	9
Suitable ground conditions	Suitable for a long crossing at depth within the chalk. Upper gravel bands need to be given consideration for bore stability. Artesian water could cause significant issues without remedial measures.	5	Marginal - shallower crossings will have a greater impact on upper gravel bands.	5	High Risk - 2-3m deep crossings within the gravel layers. High risk of bore stability issues.	3	Marginal - potential for wet granular material along drives not fully understood from ground investigation.	4	Considered suitable	6	Considered suitable	7	Micro tunnel machines can be configured for all ground conditions therefore suitable	9	Machine Head can be configured for all ground conditions.	9	Relatively new technology but understood to be suitable in anticipated ground conditions	6
Impacts Flood Zone	No -All construction undertaken outside of the flood zone	9	Yes - Construction required within the flood zone	1	Yes - Construction required within the flood zone	1	Yes - Construction required within the flood zone	1	Yes - Construction required within the flood zone	1	Yes - Construction required within the flood zone	1	No	9	No	9	No	9
Impacts to artesian groundwater	Yes - artesian groundwater flows anticipated back to the surface as the bore progresses.	1	Possibly if DCA guidelines are followed for crossing design	4	No all works anticipated above known artesian water level	9	Possible interaction from temporary works at launch and reception sites	5	Possible interaction from temporary works at launch and reception sites	5	Possible interaction from temporary works at launch and reception sites	5	Yes - Shaft construction method should be selected to minimise impact and tunnel machine specificed to deal with anticiapted pressures.	4	Yes - groundwater flows anticipated through bore annulus during bore driving	2	Possible interaction from temporary works at launch and reception sites.	5
Potential to Permently Seal Groundwater at Crossing Entry/Exit	Yes, methods available success not guarenteed	3	Possible, depending if water is encountered. If required method is available but success not guarentted.	4	No	9	Not Anticipated	7	Not Anticipated	7	Not Anticipated	7	Yes - Permanent seal required for shaft and for tunnel. Known method available	6	Yes permanent seal required outside of casing duct. No commonly used method available.	3	Yes - Seal injected as duct is installed provided full seal to bore annulus	6
Potential to Temporarily Seal Groundwater at Crossing Entry/Exit during Construction	Working platform and steel casings required to seal off groundwater flows	2	Potentially required depending on crossing depths	4	Unlikely although design not sufficiently progressed to rule out	7	Unlikely although design not sufficiently progressed to rule out	7	Unlikely although design not sufficiently progressed to rule out	7	Unlikely although design not sufficiently progressed to rule out	7	Working platform would assist for shaft construction. Tunnel eye required to launch machine through.	6	Seal to prevent groundwater leekage to the surface from the bore bore annulus required. Tunnel eye could be adopted in temporary condition.	5	Not anticipated to be required	9
Dewatering required	No	9	No	9	No	9	No	9	No	9	No	9	Potential depending on shaft construction method.	6	No	9	No	9
Additional duct laying required to Complete Crossing	No, crossing completed in a single length	9	Open cut required between short drills	1	Yes - ducts required to be electro fusion coupled at enty / exit locations	5	Open cut required between crossing locations	1	Open cut required between crossing locations	1	Open cut required between crossing locations	1	No - crossing completed as a single length	9	No - crossing completed as a single length	9	No - crossing completed as a single length	9
Potential for environmental impact to SSSI	Significant potential for drilling fluid break out into river	4	Significant potential for drilling fluid break out into river	3	Significant potential for drilling fluid break out into river	2	No impacts to SSSI anticipated	8	No impacts to SSSI anticipated	8	No impacts to SSSI anticipated	8	Low potential for impact to SSSI	7	Low potential for impact to SSSI	7	Low potential for impact to SSSI	7
Proven Construction for anticipated crossing conditions	Proven technique although limited success where artesian groundwater is present	2	Yes - Providing there is no interaction with artesian groundwater	5	Yes - Providing there is no interaction with artesian groundwater	9	Yes - Providing there is no interaction with artesian groundwater	9	Yes - Providing there is no interaction with artesian groundwater	9	No - unknown if used in the UK	2	Yes	9	Yes	5	No - understod to have only been used once	2
Equipment availability	Equipment readily available from multiple UK based suppliers	9	Equipment readily available from multiple UK based suppliers	9	Equipment readily available from multiple UK based suppliers	9	Equipment readily available from multiple UK based suppliers	9	Equipment readily available from multiple UK based suppliers	9	Equipment available in Scandanavia	3	Equipment readily available from multiple UK based suppliers	9	Limited equipment and suppliers in UK	5	Equipment available in Germany	2
Overall Score	62		46		64		61		63		51		83		72		73	

Scoring Matrix
Negative Attribute 1-3
Average Attribute 4-6
Positive Attribute 7-9

Appendix B – Outline Tunnel Profile

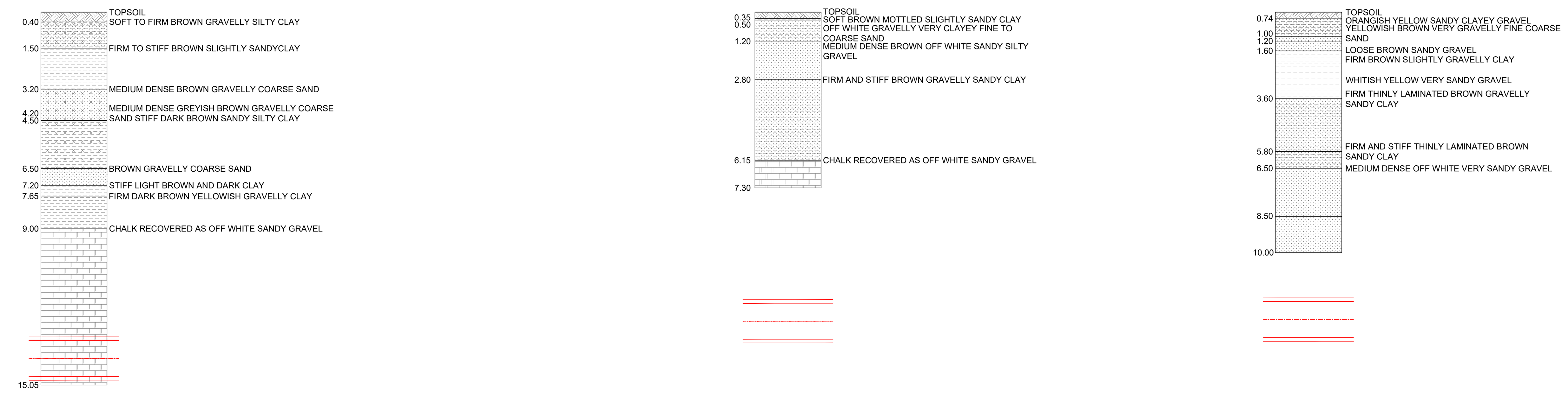


GROUND LEVEL	8.89	8.88	8.81	8.75	8.72	8.39	9.66	6.76	6.76	8.75	8.15	7.90	7.71	7.57
COVER TO CROWN			13.57	13.52	13.49	13.16	14.42	11.52	11.53	13.51	12.91	12.67	12.48	12.34
DEPTH TO INVERT			15.22	15.17	15.14	14.81	16.07	13.18	13.18	15.16	14.56	14.32	14.13	13.99
CHAINAGE	-05.00	00.00	10.00	20.00	30.00	40.00	50.00	60.00	70.00	80.00	90.00	100.00	110.00	120.00

GROUND LEVEL	7.49	7.42	7.39	7.36	7.41	7.46	7.31	7.35	7.18	7.07	7.08	7.12	7.11	7.02
COVER TO CROWN	12.25	12.19	12.15	12.13	12.17	12.23	12.07	12.11	11.94	11.83	11.84	11.89	11.87	11.79
DEPTH TO INVERT	13.91	13.84	13.80	13.78	13.82	13.88	13.72	13.76	13.59	13.48	13.49	13.54	13.52	13.44
CHAINAGE	130.00	140.00	150.00	160.00	170.00	180.00	190.00	200.00	210.00	220.00	230.00	240.00	250.00	260.00

GROUND LEVEL	6.99	6.94	6.74	5.91	5.82	6.98	6.95	7.11	7.20	7.28	6.59	7.55	7.53	7.64
COVER TO CROWN	11.76	11.70	11.51	10.68	10.59	11.75	11.72	11.88	11.96	12.05	11.36	12.32		
DEPTH TO INVERT	13.41	13.35	13.16	12.33 12.34	12.24	13.40	13.37	13.53	13.62	13.70	13.01	13.97	15.30	
CHAINAGE	270.00	280.00	290.00	300.00	310.00	320.00	330.00	340.00	350.00	360.00	370.00	380.00	390.00	400.00

SECTION VIEW SHOWN ALONG CIRCUIT CENTERLINE
(SCALE: 1:1000)



BOREHOLE LOGS
(SCALE: NTS)

PLAN VIEW
(SCALE: 1:1000)

NOTES:

1. ALL DIMENSIONS, LEVELS AND CHAINAGES ARE IN METRES UNLESS STATED OTHERWISE LEVELS ARE RELATIVE ZERO AT THE LAUNCH SHAFT. ORDNANCE DATUM NEWLYN (ODN). CENTRELINE CHAINAGES ARE RELATIVE CO-ORDINATE SYSTEM TO OSGB GRID 36.
2. TOPOGRAPHY HAS BEEN TAKEN FROM CLIENTS DRAWING DES21023 EASTERN LINK REV6_RIVER HULL HDD TOPO ONLY.
3. GROUND INVESTIGATION DATA TAKEN FROM FUGRO FACTUAL REPORT ON GROUND INVESTIGATION - EASTERN LINK 2 (E4D3) ON-SHORE HVDC CABLE LINK - PHASE 4 AND BATCHES 2 TO 4.
4. FINAL TUNNEL INVERT TO BE DETERMINED FOLLOWING ADDITIONAL GROUND INVESTIGATION TO CLASSIFY THE CHALK.
5. THE DETAILS SHOWN ON THIS DRAWING ARE FOR STUDY PURPOSES ONLY AND HAVE BEEN PREPARED FROM THE DATA AND INFORMATION AVAILABLE AT THE TIME. DETAILS MAY CHANGE DEPENDING ON THE RESULTS AND OUTCOME OF FURTHER ENGINEERING AND SURVEYS.

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-	-	-	-	-	-
P01	W.SMITH	M.PERKINS	J.CURRAN	27/02/23	FIRST ISSUE

Project:	WANSFORD LOCH CROSSING STUDY		
Revision:	P01	Dwg Title:	PROPOSED MICROTUNNEL PLAN & PROFILE
Suitability:	S3		
Scale @ A1:	1:1000	Dwg No:	X20-16-JMS-XX-SC-XX-Z-1001
Sheets:	1 OF 1	Purpose of Issue:	FEASIBILITY STUDY
Internal Proj Ref:	X20-16	Client Ref Number:	-

Plotted: 28/02/2023 3:26 PM
Attached Xrefs: