SP ENERGY NETWORKS

The Kendoon to Tongland 132kV Reinforcement Project

Underground cable study summary report

Appendix 2

July 2020

Appendix 2: Technical Study of the Preferred Underground Cable Routes for Kendoon – Tongland 132kV Reinforcement Project

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Engineering Report ER1033
9th July 2020

TITLE:	**Technical Study of the Preferred Underground Cable Routes for Kendoon – Tongland 132kV Reinforcement Project**
REPORT No:	**ER 1033 Rev A**

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1 Executive Summary

This report provides technical considerations for the preferred underground cable route options on each of six underground cable (UGC) study areas forming part of the SPEN Kendoon – Tongland 132kV Reinforcement Project (KTR Project).

- UGC1: Polquhanity to Kendoon (Towers N230 to PK10)
- UGC2: Kendoon Substation to Glenlee Substation (Towers PK10 to PK33)
- UGC3: Queen's Way Crossing (Towers GT08-GT21)
- UGC4: Bennan, Slogarie and Laurieston Forests (Towers GT25-GT78)
- UGC5: A75 crossing (Towers GT97-GT104)
- UGC6: Undergrounding the proposed Glenlee Sub-Station to Tongland Sub-Station route in its entirety

The underground cable routes in this report include 16 minor route adjustments made for practical purposes, from those detailed in Kendoon – Tongland 132kV Preliminary Investigative Cable Route Study ER1003 Rev C[11]. These modifications were as a result of site visits subsequent to the issue of ER1003 rev B in July 2019, with the exception of one change to UGC5 which was due to a landowner request requiring a termination tower to be relocated. The environmental consideration for each undergrounding route section has been provided by Land Use Consultants Limited (LUC) updated to reflect the route modifications described above, refer to appendix 3.

Distribution: SPEN, File

It was found that each of the underground cable routes were assessed as constructible but that the routes:

- Contain a number of engineering difficulties some of which will require detailed investigation or the use of available alternatives.
- Will require agreements from stakeholders on the access and use of land (forestry, pastoral and arable) as well as existing track and road infrastructure (bridges, road, traffic controls, stone tracks, footpath and recreational areas).
- Will require (with the exception of UGC6) the installation of cable termination compounds or OHL terminal towers capable of supporting cable terminations.

The cost of undergrounding each cable route has been provided by SPEN, refer to Table 1.

Table 1 Summary of cost of undergrounding for each cable route from SPEN

Route	Total Route Length (km)	Projected Cost (‘000)	Cost per km (‘000)
UGC1	2.40	£17,649[1]	£7,354
UGC2	7.20	£47,725[2]	£6,628
UGC3	4.33	£15,221	£3,515
UGC4	16.00	£53,367	£3,335
UGC5	2.20	£10,789	£4,904
UGC6	37.59	£126,973	£3,378

Document Revision Record

Document Revision	Date of Issue	Revision Description
1st Draft	06.09.2019	First draft issued for LUC and SPEN comment
Rev A	09.07.2020	Addition of a confidential appendix in accordance with EPS requirements and UGC5 Tower 97 positional change.

[1] Projected cost also includes a section of OHL to facilitate the UGC route.
[2] Projected cost also includes a section of OHL to facilitate the UGC route.

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2 Introduction

2.1 Background Provided By SPEN

SPEN advised that it proposes to replace and upgrade much of the existing 132kV transmission network in the South West of Scotland. Specifically, this includes the overhead lines (OHL's) running from Kendoon to Glenlee and from Glenlee to Tongland. In addition, SPEN will also be removing the existing 132kV route between Tongland and Dumfries known as N route and R route. Together these works are known as the Kendoon to Tongland 132kV Reinforcement Project (KTR Project).

SPEN engaged CCI to undertake a study to identify technically feasible cable routes for the 'pinch points' identified through the three rounds of pre-application consultation.

The sections of the overhead line route considered for undergrounding included within this cable study were prescribed by SPEN in the KTR Cable Study briefing document dated 8th November 2108 and include:

- UGC1: Polquhanity to Kendoon (N230 to PK10)
- UGC2: Kendoon Substation to Glenlee Substation (PK10 to PK33)
- UGC3: Queen's Way Crossing (GT08-GT21)
- UGC4: Bennan, Slogarie and Laurieston Forests (GT25-GT78)
- UGC5: A75 crossing (GT97-GT104)
- UGC6: Undergrounding the proposed Glenlee to Tongland route in its entirety

Refer to Appendix 1 for a copy of the KTR Cable Study briefing document.

Potential cable route options were identified for each of the cable study areas listed above, using a combination of desktop and site survey analyses, refer to CCI study Kendoon – Tongland 132kV Preliminary Investigative Cable Route Study ER1003 Rev C[11]. With CCI's preferred cable route options identified for each of the six cable study areas taken forward into this technical engineering report.

2.2 Report Purpose

This report provides technical considerations for the preferred cable route options for each of the six agreed underground cable (UGC) study areas that form part of the Kendoon – Tongland 132kV reinforcement project.

Following completion, SPEN will consider the study conclusions as part of the EIAR process and produce a conclusions report which would be included as a technical appendix to the final EIAR.

2.3 Report Approach

The approach adopted in undertaking this study included:

- A review of technical considerations regarding the use of UGC in SPEN operational areas;
- Detailed consideration of the use of UGC for the six case study locations along the OHL routes for the new connections forming part of the KTR Project;
- Detailed development of the selected cable routes through literature review, desktop analysis and site visits; and
- Technical review meetings with other members of the multi-disciplinary project team comprising SPEN environmental planning, SPEN engineering design, Land Use Consultants (LUC) and CCI (Cable Consulting International)

2.4 Report Structure

Chapter 3 Considerations for Underground Cable Systems: provides information on the type of cable system to be employed and its method of installation.

Chapter 4 Cable System Installation Methodology: This chapter discusses the methods used to install an underground cable.

Chapter 5 Special Installation Design: This chapter discusses special installation conditions and the methods used to mitigate any associated risks to the underground cable system.

Chapter 6 Underground Cable Routes: This chapter discusses the six individual underground cable routes in six cable study areas along the Kendoon – Tongland overhead line route.

Chapter 7 Costs of Underground Cable Routes: This chapter discusses the financial implications of the design alternatives for the six UGC studies.

Chapter 8 Conclusions: This chapter summarises the findings regarding the use of UGC.

Chapter 9 Abbreviations: This chapter lists the abbreviations used within the study.

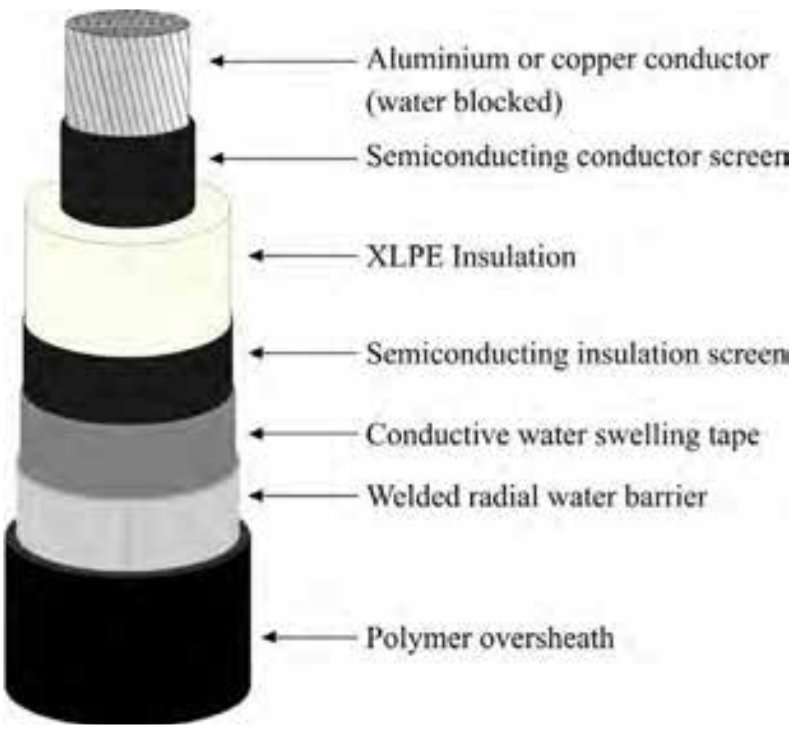
3 Considerations for Underground Cable Systems

3.1 High Voltage (HV) Cable Systems

For the KTR Project, it would be recommended that if UGC were to be installed, that cross linked polyethylene (XLPE) insulated cables should be employed. This cable technology is well established in the UK and overseas at 132kV with circuits having been installed and operated successfully for at least the last 30 years.

Figure 1 shows a typical 132kV XLPE insulated cable design with an aluminium conductor and smooth welded aluminium sheath (SWAS).

Figure 1 Components of a 132kV XLPE insulated cable



3.1.1 Conductors

Directly buried cable circuits do not receive the benefit of air cooling and in order to meet the current rating requirement for the KTR Project a cable circuit needs larger conductors than the overhead line.

Being mostly underground, there would be little chance of the conductors being struck by lightning.

There would be a requirement for one or more earth conductors to ensure an adequate return path for fault currents. These conductors may be integrated into the cable design or where necessary, such as for end point bonded cable systems, supplied as a separate earth continuity conductor.

HV transmission conductors are made from either copper or aluminium. Stranded or Milliken conductors are available but for the KTR Project, Milliken aluminium and copper conductors have been selected.

Milliken conductors consist of a number of individual wires stranded together into conductor segments (six segments is typical) which are twisted together to form a circular conductor. This geometric arrangement of conductor wires is designed to further reduce the conductor's resistance when carrying AC current.

As AC conductors become larger there is a diminishing return on their current carrying capacity. Large conductors are also difficult to manufacture and handle due to the large number of wires to be stranded together, the conductor's weight and its minimum bending radius. For transmission cables the conductor size range is generally between 800mm² to 2000mm² and manufactured from copper or aluminium.

SPEN specification INS 56.46.06 Issue 3 dated November 2017[1] gives specific conductor designs and sizes, which have been considered for use in the KTR Project. These sizes are standard for SPEN and selected by them to limit the variation and quantity of materials held for maintenance purposes.

For buried cables it is usual to install a water blocked conductor design. Conductor water blocking will limit the extent of water ingress into the cable should severe damage occur (for example due to a fault or excavator damage). During manufacture the conductor wires are compacted together with a water blocking tape or powder. The water blocking agent is designed to swell when in contact with moisture and prevent water penetrating for more than a few metres (rather than hundreds of metres) along the cable. If water blocking is not used the water penetration can be rapid, particularly in an area where the cable is installed below the water table. The entry of water into an 132kV XLPE cable insulation will result in significantly reduced cable service life.

When cable conductors are connected together it is necessary to remove the water blocking agents at the jointing position prior to assembling the joint or termination. This is necessary to ensure a good electrical connection between one conductor and the next and to the conductor connector at the joint position. If a good electrical contact with a low resistance is not achieved the connection is liable to overheat and damage the joint.

3.1.2 Conductor Screen

The conductor screen consists of a semi-conducting compound which is designed to electrically smooth the surface of the conductor to present an unblemished surface to the insulation. The conductor screen is extruded onto the cable conductor along with the insulation and the insulation screen in a single process. This is achieved using a triple headed extrusion die where the screen and insulation compounds are injected into a die simultaneously.

3.1.3 Insulation

XLPE insulation consists of thermoplastic polythene molecules which have been cross-linked to produce a thermosetting material. The non-cross-linked polythene and the cross-linking agents which are to form the insulation are extruded at high temperatures and pressures. This process must be completed under clean and controlled conditions to prevent gas cavities, material contamination, screen blemishes and conductor eccentricity which may adversely affect cable performance.

Following extrusion, the cable must undergo a period of degassing. During this process the cable is heated in an oven for several weeks to remove a substantial percentage of the by-products of the insulation cross linking process. These by-products must be removed from the insulation if the desired service life of the cable is to be achieved.

At room temperature, XLPE is a white translucent polymer, capable of operating at temperatures up to 90ºC. It is current practice to limit the temperature of XLPE insulated EHV cables to 90°C under normal operating conditions.

It is essential that XLPE insulation is kept free of water and other contaminants when used on high voltage (HV) cables. If water is allowed to come into contact with the insulation the high electric stress in the cable causes the formation of water trees which gradually destroy the properties of the XLPE insulation resulting in electrical failure.

3.1.4 Insulation Screen

The insulation screen consists of a semi-conducting compound which is designed to electrically smooth the surface of the outer earthed sheath to present an unblemished surface to the insulation.

3.1.5 Metallic Barrier

Buried high voltage cables require a moisture impermeable metallic barrier around the insulation screen. A number of alternative designs for the metallic barrier are available. These may be broken down into two categories a) seamless and b) seamed.

Prior to the application of a metallic barrier semi-conducting protective cushioning and water blocking tapes are applied.

Seamless metallic barriers (sheaths) are extruded from either lead alloy or aluminium. The manufacturing equipment required to apply these sheaths is large and expensive for cable manufacturers to install, maintain and operate. Lead sheaths are the most common type of seamless metallic barrier being used for both underground and sub-sea applications. Extruded sheaths also have excellent water tightness and are generally considered to be more mechanically robust than seamed constructions.

Seamed metallic barriers consist of a flat metal strip or foil applied longitudinally with the longitudinal seam being welded or glued. The manufacturing equipment required to apply this type of metallic barrier is less expensive to install maintain and operate than a seamless design. Manufacturers offer a number of alternative materials for the seamed sheath including aluminium, copper and stainless steel. Cables with seamed barriers are lighter and less expensive to manufacture than seamless metallic sheathed cables. Some manufacturers offer seamed barriers that use a thin metal foil with an overlapping seam being secured by means of an adhesive.

For the Kendoon – Tongland circuit, the design of any cable would require it to be capable of installation in a wet and harsh environment.

SPEN specification INS 56.46.06[1] Issue 3 dated November 2017, requires a welded aluminium radial metallic moisture barrier to be adopted.

3.1.6 Oversheath

A polymeric oversheath is applied over the metallic barrier. The oversheath material is a thermoplastic and is slightly permeable to moisture. Materials such as medium or high density polythene offer good mechanical penetration resistance at high installation temperatures and thus reduces the incidence of damage during cable laying.

The fire performance of polyethylene is poor however and for ‘in air’ installations a fire-retardant coating, an alternative material (PVC), or a co-extruded fire retardant compound may be used. The choice of material will depend on application but has not been considered necessary for this Technical Study.

It is usual to apply a conductive layer on the outside of the cable either as a co-extrusion or as a graphite paint layer to allow DC voltage withstand testing of the oversheath to confirm integrity both following manufacture and cable laying.

3.1.7 Bending Performance

The principle advantage of cables is that they are flexible. However this flexibility is limited and must be considered during installation to avoid cable distortion.

Typically the installation bending radius of a cable may be as low as twelve times its diameter (12D). But such a small bending radius should only be used at positions where restraining formers are used to constrain the cables from further bending.

For installation in ducts a minimum bending radius of 35D is specified by SPEN[6]. This is greater than the minimum bending radius recommended by manufacturers. Refer to section 4.1.5 of this report for further discussion.

3.2 Cable System Accessories

There are three main types of 132kV cable system accessories:

- joints
- terminations
- earthing and bonding equipment

Joints and terminations are the weakest components of a cable system. This is due to the electrical stress control required from accessory designs (particularly on large conductor cables) and the need for accessory component assembly on site.

In operation, thermomechanical forces act upon an accessory as the cable conductor expands and contracts with temperature. The high reliability required of a joint or termination will depend upon a fully tested manufacturing design, a specialised manufacturing process, a fully considered installation design and a high standard of accessory assembly.

The design of an accessory will usually have been the subject of long-term development and reliability testing. The accessory designs and materials employed vary between manufacturers, each having their own limitations, capabilities and performance test record. In production the accessory will also have passed through manufacturing tests and inspections determined as necessary by each manufacturer and as specified by the purchaser.

Accessories are assembled onto the cable on site without the controlled environment of a factory. Reliable performance on HV accessories therefore requires skilled trained jointers, specialist tooling, quality assured assembly instructions and a suitably prepared jointing environment.

Cable system testing requirements are set out in SPEN specification INS56.46.06[1], which is based on and references internationally recognised standards.

3.2.1 Joints

To increase the reliability of the system and to reduce costs, it can be advantageous to increase the cable section lengths and reduce the number of joints as part of the overall cable system design solution.

Cable joints connect together separate drum lengths of cable to make a continuous electrical connection. The main components of a joint are:

- The conductor connector
- The insulation and electrical stress control
- The radial water barrier
- The outer protective covering

The conductor connector is required to allow the flow of current between one cable conductor and the next. This connection is overlaid with factory prepared insulation in the form of either one or three piece joint insulation mouldings which are applied by the jointer on-site.

A metal shell is used to maintain continuity of the cable's outer sheath (or metallic barrier) and screening wires to allow the connection of any bonding leads. The metallic shell also provides a water barrier to prevent water entering the joint. Figure 2 is a photograph of six joints in a joint bay. This particular joint bay does not have any earthing or bonding leads installed.

Figure 2 Typical double circuit joint bay

The joint is enclosed in an outer protective covering which has sufficient electrical insulation to allow routine cable oversheath and joint protection testing to be performed (10kV DC at commissioning, 5kV DC thereafter). The joint protective covering is also designed to withstand ground surface loadings (typically 5 tonnes/m^2).

If required by the purchaser, although not usually applied at 132kV, partial discharge detecting devices can be installed with the joint as a condition assessment aid. The method of detecting partial discharge within a joint varies from one manufacturer to the next. Sensors may be used to detect incipient failure within the joint in order that a fault in service may be avoided. Partial discharge is a phenomenon which has been found to be a precursor to electrical failure. Detection of partial discharge at an early stage (particularly during commissioning testing) can prevent catastrophic failure and allow preventative maintenance.

If joint bays are situated within commercial forest or woodland where the ground is soft, a precaution could be taken to install the joints within reinforced concrete troughs or chambers to protect the joints and link equipment from disturbance from heavy forestry vehicles, the wheels of which can penetrate into soft soil during operations. Figure 3 provides an example of a joint bay housed in a concrete chamber with the link boxes housed in separate reinforced concrete link pits to the side.

Figure 3 Concrete chamber with cables installed ready for jointing

The design of the cable system is inherently safe for the normal activities of the general public. The depth of the cable installation, which is normally about 1 metre, is sufficient not to require any additional precautions beyond the provision of protective cable tiles, warning tape and above ground markers. At joint bay positions it would be necessary to bring earthing and bonding cables to surface-mounted link pillars or link boxes. At these locations the link equipment exposed to potential damage may be protected from the various hazards of livestock, machinery and vehicles by the use of stock-proof fencing or bollards, as appropriate. Where the power cables themselves rise to the surface, they would be within cable sealing-end compounds or substations that are protected by high security fencing. Where cables are installed onto raised sealing end platforms the cables may be afforded protection by metal boxing and anti-climb devices.

3.2.2 Terminations

Outdoor air insulated terminations, indoor gas immersed and oil immersed terminations (installed on transformers) are all available for XLPE insulated cable designs. However, for the KTR Project it is most likely that only air insulated cable terminations would be required. These terminations may be used within overhead line cable sealing end compounds, installed on tower termination platforms and used for connection on to the air insulated equipment within substations. This report therefore only considers this type of termination. Figure 4 provides an example of a 132kV air insulated cable sealing end.

Figure 4 Typical air insulated 132kV cable sealing end

A cable's XLPE insulation separates the cable conductor from earth using a few millimetres (usually in the order of 15mm at 132kV) of insulation. Air insulation requires up to a metre of insulation to provide a similar design performance. It is therefore inevitable that the cable terminations must be large enough in order to raise a live in-air cable conductor above any objects at earth potential to avoid a potential flashover.

To ensure the safety of personnel and plant this electrical clearance distance must also make allowance for such effects as those produced by transient electrical impulses (e.g. lightning) and rain, ice and snow which will all come to rest on the outer surface of the cable termination during its lifetime. Clearances to other equipment must also be maintained to allow cable insulation testing at increased voltage levels.

In general, HV cable terminations consist of:

- A conductor connector
- An electrical stress control cone
- A weatherproof hollow air insulator that may contain insulating oil, or SF6 gas. The air insulator is provided externally with sheds to maintain the air insulation performance in rain, snow and icy conditions.

The conductor connector (or stalk) connects between the cable conductor and the overhead line or busbar off-going connector. This stalk carries the electrical current from the conductor to the overhead line or busbar.

Unlike a power cable or a joint, the electrostatic field of a cable termination extends beyond the outer surface of the termination. Thus the insulation screen of the power cable is stripped from the underside of the conductor connector down to a point that reduces the electrical stress in the air. The electrical stress is further reduced by a prefabricated geometric stress control cone which is used to limit the electric field both in the termination and in the surrounding air to acceptable levels.

The insulator surrounding the XLPE cable is hollow and filled with either liquid silicone or polybutene oil or gaseous SF6. Dry type terminations that do not contain any dielectric fluid are also available, they can be rigid (self-supporting) or flexible, that require a fastening system to suspend them.

If required by the purchaser, methods of detecting partial discharge within a termination may be used. These vary from one manufacturer to the next. Such methods include the placing of sensors within the termination or around the earth bonding leads. The use of these devices becomes problematic when in remote locations due to the need for power supplies and communication is information is to be reviewed in real time.

The earthing or bonding connection is attached to the termination close to the connection with the cable screening wires or metal sheath. This connection is electrically separated from the termination support structure such that a cable DC oversheath test may be performed.

3.2.3 Earthing and Bonding Equipment

To achieve the required cable circuit ratings the preferred method for earthing and bonding of the cable system are the special bonding arrangements described in Cigré

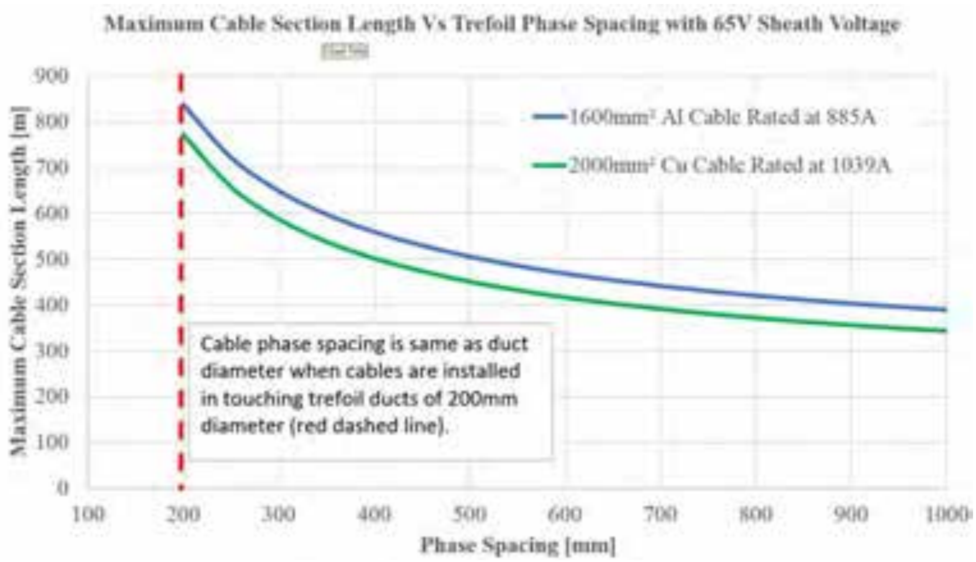
Technical Brochure 283[2] and more practically in the UK's ENA Engineering Recommendation C55/5[3].

The application of special bonding can reduce cable heat generation considerably and allow a cable circuit's conductor current carrying capacity to be increased. However, all special bonding methods available result in a voltage being induced into the cable sheath and screening wires. The magnitude of this voltage increases with, a) the magnitude of the current flowing in each of the circuit phase conductors, b) the separation between the cable sheath/screen and each conductor, c) the geometric arrangement of the cables within the cable trench (or trenches), d) the length of cable between specially bonded joints or terminations. It is a requirement of Engineering Recommendation C55/5 to limit the voltage on cable sheaths under normal continuous operating conditions to 65V for 132kV systems. This voltage limit is principally set for reasons of safety to third parties although a higher voltage of 150V has been used in the UK on some installations, Engineering Recommendation C55/5 permitting this at transmission voltage levels (275kV and above). Where cable systems are not at risk of exposure to the public (for example within purpose built deep cable tunnels) higher voltages have been employed.

A restriction on the maximum sheath standing voltage will limit the maximum length of a cable section between joint bays/terminations and the number of cable joints installed. This standing voltage may be reduced, and therefore the cable section length increased, by installing the cables in close proximity to each other; due to increased magnetic field cancellation.

Figure 5 is a typical plot of the effect of cable phase spacing on the maximum cable section lengths during the autumn post-fault loading required by SPEN for two selected 132kV cable designs: a 1600mm² aluminium conductor XLPE cable and a 2000mm² copper conductor XLPE cable.

Figure 5 Impact of phase spacing on maximum section length



The minimum cable phase spacing for cables laid in ducts to SPEN specification CAB-15-004[6] is 200mm. For the two cables designs considered gives maximum section lengths, this being distance between points of special bonding on joints and terminations, as follows:

- 1600mm² Al XLPE cable design = 837m
- 2000mm² Cu XLPE cable design = 771m

C55/5 increases the allowable standing sheath voltage limit on the cable sheath to 150V for cable systems above 132kV e.g. 275kV and 400kV. If this increase was considered for the KTR Project, it could potentially reduce the number of joint bays required along the buried cable routes. The maximum cable section lengths could increase as follows:

- 1600mm² Al XLPE cable design = 1932m
- 2000mm² Cu XLPE cable design = 1780m

However, allowing an increase in standing sheath voltage would require a robust risk assessment process to be completed for each UGC route to ensure safety from the system is maintained to the requisite standard. In addition, cable sections of the lengths provided above are unlikely to be achievable in reality, with limitations associated with installation processes including cable pulling, cable drum handling and cable drum transportation, due to practical size and weight restrictions, becoming limiting factors. Refer to Section 4 for detailed discussion of cable installation considerations and requirements.

Special bonding arrangements require the use of earth link pillars (above ground) or link boxes (underground) to be positioned at joint bays and terminations.

Link pillars, Figure 6, or link boxes would be required at every specially bonded joint bay or termination position. Existing designs of link equipment require that one pillar or box is required for each group of three power cables. At a position where twelve joints are located a total of four pillars or link boxes would be required. This link equipment is connected to the joint metallic covering by means of concentric bonding cables. In order to achieve the highest current rating on the cables the connections within the link equipment cross connect one cable sheath to the next or earth down all cable sheaths, as is appropriate, as required by the special bonding design.

Where the links in a pillar or box cross connect cable sheaths, a sheath voltage limiter is installed. This device prevents over voltages appearing on the cable sheath (or metallic barrier) during abnormal system events.

Figure 6 Link pillars in arable land enclosed in stock proof fencing

The bonding cables and equipment within these pillars are capable of delivering both electric shocks and burns. They should be locked when the circuit the service is energised and provided with labelling and danger warning signage. The pillars must be capable of withstanding an internal flash-over in case of an abnormal system event. The pillars must also be protected from farm equipment and large animals by appropriate bollards and/or stock proof fencing (Figure 6). Each pillar will have a separate earth mat for the bonding system and the link pillar carcass. This mat consists of bare copper tape and earth rods installed below ground. Each cable circuit joint bay would be required to have its own, and separate, earth mat.

3.3 Consideration of Electric and Magnetic Fields

Electric fields exist near cable air insulated terminations. However, both the underground cable and its joints are electrically screened and thus do not produce an electric field external to the cable or joint designs.

Magnetic fields are produced by UGC and will extend into the environment when the cables are carrying current. The magnitudes of both the electric and the magnetic fields in the proximity of the buried underground cables are less than those above which the International Commission on Non-Ionizing Radiation Protection (ICNIRP) recommends further consideration should be given to exposure levels[4]. No additional measures which may be applied to further lower the magnetic field near the underground cables have been considered in this report.

4 Cable System Installation Methodology

In addition to the section length criteria discussed in Section 3.2.3, other factors that are taken into account when selecting section lengths include the following:

- Balanced cable bonding;
- Sheath voltage limiter requirements;
- Manufacturing weight and height restrictions;
- HVAC testing capability and test set access positions;
- Transportation limits e.g. vehicle width, axle weight and bridge heights;
- Access through country villages and lanes;
- Cable pulling-in force limitations;
- Access to cable drum pulling-in and winch positions;
- Steep gradients; and
- Permissible joint bay locations and maintenance access to link equipment.

The cable trench arrangement is specified within SPEN specification CAB-15-004[6].

Where special constructions are required for the cables to pass under or over obstructions, these singular points require consideration within the overall design in order to establish that a route is both practical and economic. A full assessment of the numerous crossing and constructions required for the six UGC routes considered in this report has not been performed but rather a routing based on likely possibilities.

Consideration of the cable installation arrangement must include the practicalities of the civil works and ensure that sufficient space and swathe is allowed to permit economic and safe working practices to prevail along the cable trench and at jointing locations.

4.1 Construction

The method, location and routing of a cable circuit are each determined during a site survey which considers the practicalities of employing a cable system.

Examples include installation, a) in air on cable supports, b) in surface trough, c) in the ground directly buried with or without thermally stabilised or replacement backfill, d) ducts either filled or unfilled, e) in tunnel with or without forced cooling.

The location of the cable route would be limited by such issues as, a) the total length of cable required, b) the availability and cost of land, c) access limitations, d) ground conditions and ground stability for excavation and cable installation, e) obstructions e.g. unstable ground, difficult terrain, tree roots and immovable structures, f) disturbance to the environment and stakeholders, g) maintenance access.

Access to the entire route must be agreed before works can commence. Ideally this would be performed prior to the commencement of construction works or a risk assessment will have been taken on each area of doubt. The following paragraphs in this construction section detail the main tasks to be undertaken.

4.1.1 Site Accommodation and Storage

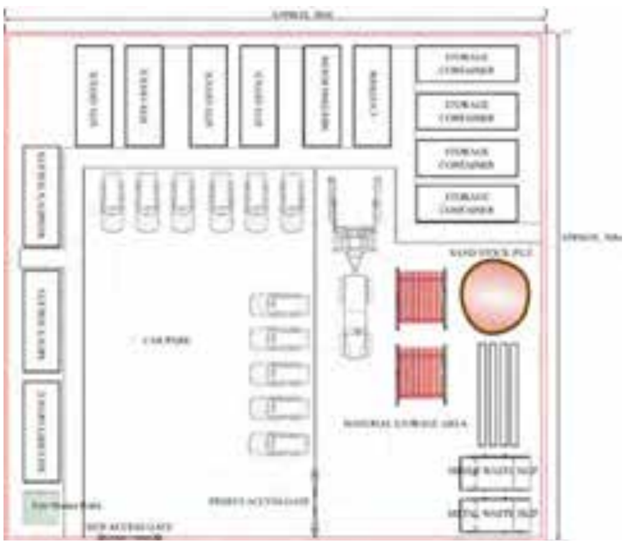
It would be necessary to locate a local site storage facility along the cable route where site offices may be located, and materials stored. This storage location would vary between UGC routes and depend on the availability of local land for hire, availability of utilities, security considerations, environmental suitability and the proximity of the site to main roads.

If the site accommodation is to be located on arable land, then the site set-up area should have the topsoil removed and stored separately for final reinstatement. A suitable surface is installed for the placing of site and security offices, welfare facilities, cable drums, aggregates, tiles, timber and vehicles etc. The area should then be made secure with suitable fencing and gates.

Dependent upon the location, generators, fresh and wastewater storage tanks, waste material and flammable gas storage would be required to support the operational and welfare facilities. Floodlighting may also be required.

Access to the site may require traffic management to be installed to allow safe entry and egress from the site accommodation. Refer to Figure 7 for examples of a typical site compound layout.

Figure 7 Typical site compound



4.1.2 Enabling Works

Enabling works are those construction works that should be performed before the main works begin. The works may, for example, enable access to the site, confirm the route is free of impassable obstructions and/or perform advance construction work at specific locations (such as drilling locations) to enable the free flow of the main work programme.

Prior to commencing the main excavations, it would be necessary for the contractor to identify any route obstructions and make sure that an economic solution exists to cross or divert each obstruction or to reposition the cable route accordingly.

Details of recorded services would be obtained from utilities and discussions held with landowners regarding any services on their property. This will include unrecorded services installed by the landowner such as land drains.

Underground services are located by trial hole excavation with the assistance of location equipment (such as ground penetrating radar).

Where roads are to be crossed a decision must be made on the method to be used. The installation of polythene or uPVC ducts is commonplace, and this may include a concrete encasement (forming a duct block). This will require traffic management with the timing of road works being agreed with the community council and other interested stakeholders. For busy carriageways the use of trenchless methods such as directional drilling may be necessary to prevent unacceptable traffic disruption.

4.1.3 Cable and Circuit Spacing

The need to keep the cable conductors from becoming too hot, may require that they be separated from each other underground. For UGC1 and UGC2 cable routes, twelve conductors are required for each route. For UGC3 to UGC6 cable routes, six conductors are required. The cables would be installed in groups with three cables to a group.

For the KTR Project, the cable routes pass along three main land types including:

- Arable/pastoral land
- forests and/or woodland
- carriageways, either with or without an accessible verge

Modifications to the working swathe are required to accommodate these different environments to ensure the cable installation is practical, economic, and to minimise the socio-environmental impact.

4.1.3.1 Arable/Pastoral Land Cable Swathe

The space requirements for four groups of three cables, a haul road and space for temporary storage of topsoil and arisings from the trenches, amounts to a working swathe some 35m wide for arable/pastoral land, this is when 2 cables per phase are considered (routes UGC1 and UGC2). This is reduced to 32m when a single cable per phase is achievable (routes UGC3 to UGC6 inclusive).

Figure 8 Typical double circuit arable/pastoral swathes for one and two cables per phase scenarios

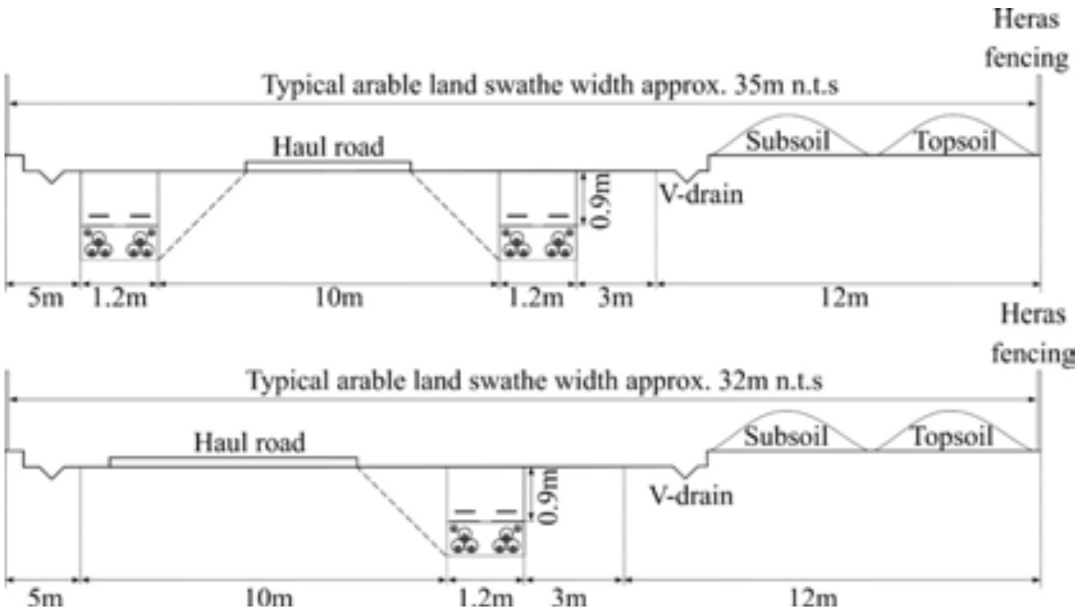


Figure 8 illustrates an arable/pastoral land swathe arrangement. The cable trench containing three cables would be approximately 1.2m. A 3m access way would be allowed between the outer trench and the fence to permit access from both sides of the trench during such activities as cable pulling and the installation of any drainage. Thermal separation between groups of cables for the same circuit would be approximately 650mm. The trench width and circuit separations are approximations based on information available and assumption made at the time of writing. Refer to Appendix 2.

During the site survey, dry stone walls were observed marking many of the field and land boundaries along the UGC routes. Where the cable route dissects a dry stone wall careful demolition and reconstruction by specially trained operatives would be required.

A reserved width of 10m is allowed to install a haul road. This road will allow construction traffic to move up and down the swathe collecting and delivering materials with minimal disruption to local roads. Within the swathe, a storage area of 12m has been allowed to retain topsoil and subsoil which has been stripped for the duration of the works. The swathe is secured by fencing or an equivalent to ensure members of the public, livestock and wildlife cannot access the site.

In order to reduce the amount of material removed from the site the trench, farthest from the soil storage area, would be excavated first. Mechanical excavation would be performed and the material to be removed from site would be placed into tipper trucks. A significant portion of this initially excavated material would be removed from site. The actual quantity of material removed would depend on the dimensions of the trench for each particular cable section, depth of the topsoil and the quantity of imported thermally stable cement bound sand (CBS) or selected sand required. A portion of the excavated material may be retained and stored within the swathe separate from the topsoil.

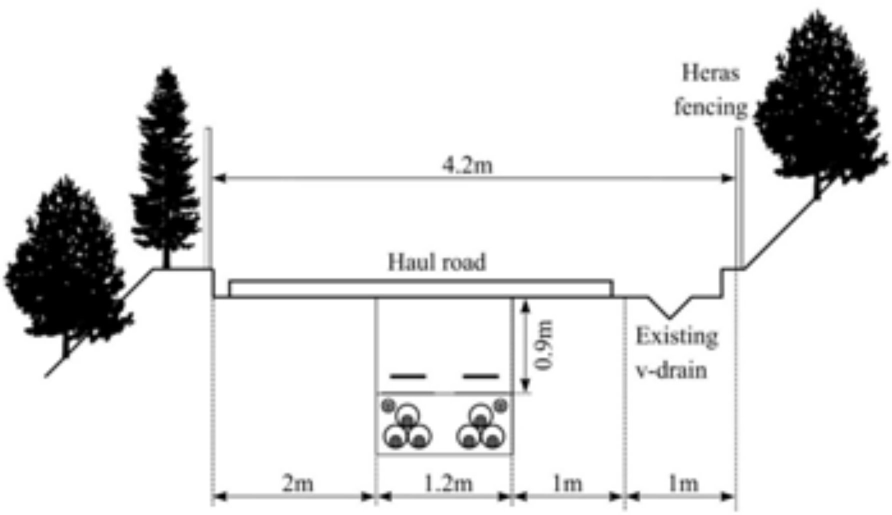
4.1.3.2 Forest and Woodland Cable Swathe

Two types of forest cable swathe have been considered; constrained and unconstrained.

In several sections of the forest, the topographic features result in only the established forest track being available for cable installation, without extensive cutting (into rock) and filling work being required which would be regarded as uneconomic. These parts of the forest cable route have been classified as constrained cable swathe sections and are approximately 4.3m wide.

Figure 9 provides a schematic of a constrained forest cable swathe, where the existing forest track would be used to install the cable circuits, with installation teams working systematically from one direction. Passing points for vehicles and plant would be established where possible.

Figure 9 Constrained double circuit forest cable swathe



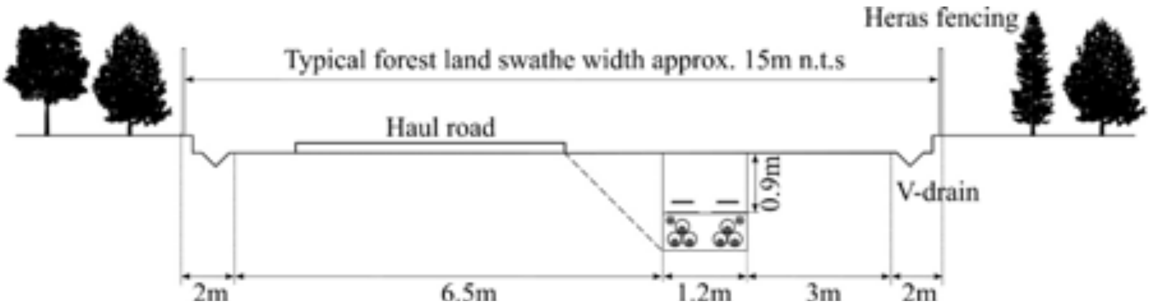
Constrained forest land swathe width approx. 4.2m n.t.s

The unconstrained forest swathe has been kept relatively narrow, typically 15m wide, to try to limit the amount of forest clearance required during installation, for example space for storage of topsoil and subsoil has been negated. Consideration has also been given to try to limit the amount of sterilised forest land in the long term, as tree growth on top of the cable circuits will not be permitted.

Within the forest and woodland sections of the cable routes, where there is a perceived risk of heavy duty commercial forestry vehicles operating on top of the cables, the cables would be enclosed within concrete rather than CBS.

Figure 10 provides typical cable swathes for unconstrained forest installation scenarios.

Figure 10 Unconstrained double circuit forest cable swathe

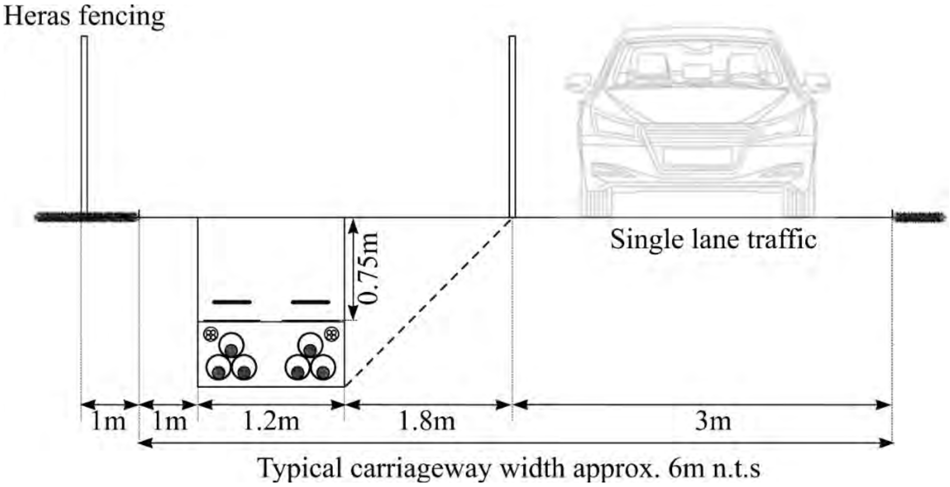


4.1.3.3 Carriageway Cable Swathe

Figure 11 shows a typical double circuit carriageway installation. Where two cables per phase are required, as in the case of UGC1 and UGC2, the layout shown in Figure 11 would be repeated in the right hand carriageway lane. Whereby first the left hand lane would be closed and a circuit comprising 6 cables would be installed. Once complete, the right hand lane would be closed and a second circuit comprising 6 cable would be installed. Resulting in a circuit comprising 6 cables each installed within each side of the carriageway.

For carriageway installations, due to the space restrictions within the swathe, stock piling of materials adjacent to the cable trench will not be possible. Instead soil and other excavation arising’s would be loaded directly into tipper trucks for removal from the working area. Installation teams will work systematically from one end, excavating and installing ducts as they go supported and protected by a rolling traffic management system.

Figure 11 Typical double circuit carriageway cable swathe



4.1.4 Swathe Preparation

Prior to any excavation the area within the swathe must be worked during the right time of year. This would depend on the expected ground conditions. Generally, the best time for working on the land is between April and October when adverse weather conditions (heavy rain, hail, ice, sleet and snow) are less frequent. There may also be an issue regarding disturbance of breeding birds that would require to be addressed.

If required, following a land drainage study, a drainage system would be installed to collect water running across or off the swathe. Where necessary this drainage system would include interceptors, drains, filters and settlement ponds to avoid silt entering water courses.

Within the arable/pastoral land swathe, the topsoil would be stripped and stored to one side. A temporary haul road would then be installed along the route between access points onto local roads. These access points would require to be agreed with the community council and interested parties. Refer to Figure 12.

Figure 12 Typical temporary haul road

For cable routes installed within forest sections of the scheme, haul roads are required to enable a looped access system to be established, with haul roads used to connect the remote ends of a cable route directly back to A-road infrastructure where possible. This would be particularly important for constrained sections of the cable routes where the working width could be as narrow as 4.2m, which would not allow space for vehicles passing the installation working parties.

In principle the haul road would carry as much as possible of the construction traffic. However, some vehicle journeys on local roads would be inevitable to reach the site access points and make use of such facilities as road bridges where rivers or railways cut across the route. Figure 13 shows a typical construction detail for a haul road, comprising a geotextile layer approximately 50mm thick, a foundation layer of compacted crushed rock and stone approximately 300mm thick, and a running surface made from compacted MOT type 1 or equivalent approximately 150mm thick. Collectively these layers act to create a haul road construction thickness of approximately 500mm.

Figure 13 Typical haul road construction detail

Wheel washing facilities would require to be maintained at all haul road egress points. Road signage would have to be provided to direct construction traffic towards and away from site access points over predetermined routes. Refer to Figure 14 for an example of a wheel washing facility.

The working swathe would be protected by fencing with limited and controlled access and egress to the site.

Figure 14 Vehicle wheel washing facility

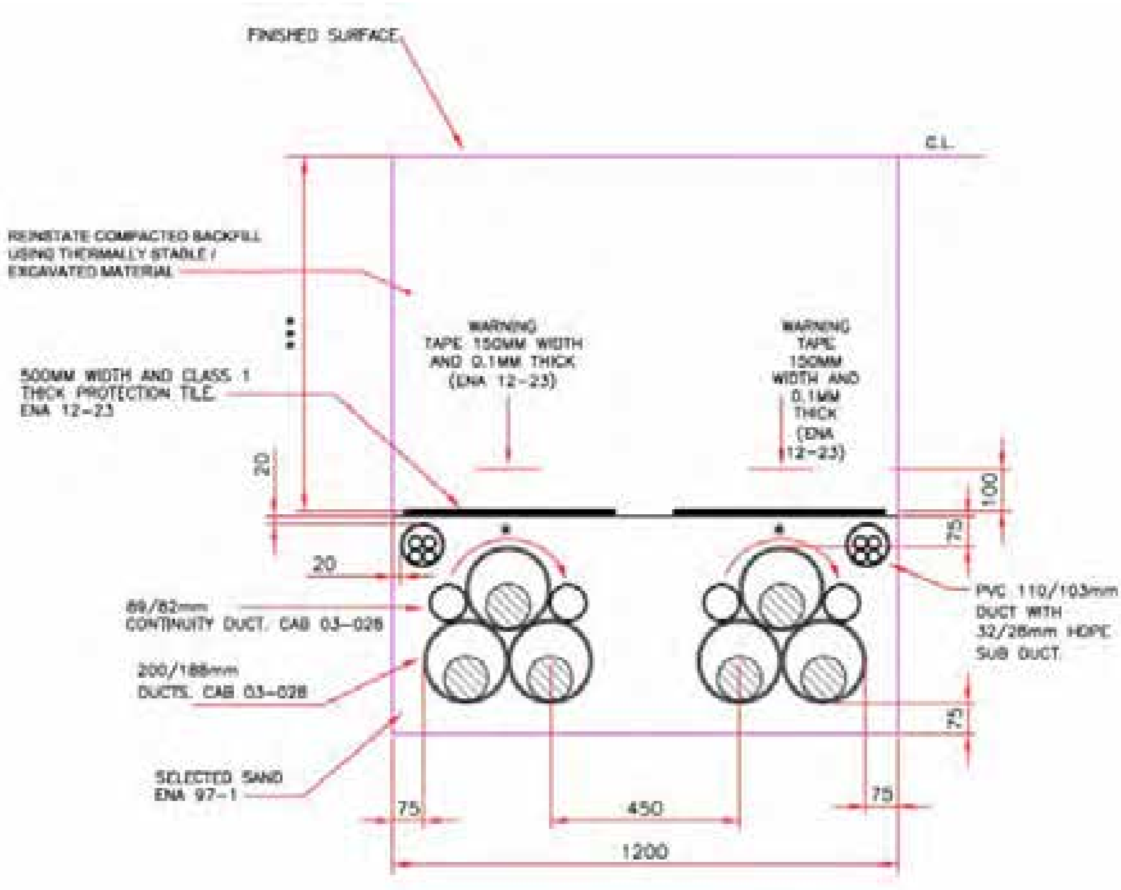
4.1.5 Excavation of and Backfilling of Ducted Trenches

Based on the UGC routes being considered for the KTR Project, up to two trenches would have to be excavated to accommodate the power cables. Additional excavations would be required at the joint bay positions to accommodate the power cable joints. If the ground is waterlogged dewatering may also be necessary.

Typical ducts used in the power industry are smooth bore uPVC, classified as a Class 1 duct type within ENATS TS-12-24[5] and are usually provided with conductive end collars to aid testing for oversheath faults and their location.

The ducts would be installed in a continuous operation with excavation at the front, followed by laying of the ducts, backfilling with CBS or selected sand which is tamped to surround the ducts to a depth of approximately 75mm. Cover tiles containing a warning are then installed above the cables. These are fabricated from reclaimed plastic materials retailed as Stokboard® tiles. The backfill is compacted and includes warning tapes installed 100mm above the cover tiles. Refer to Figure 15 for a schematic of a standard double circuit ducted cable trench cross section as detailed within SPEN's specification CAB-15-004[6].

Figure 15 Standard trench cross section



SPEN's specification CAB-15-004[6] also provides different minimum depth requirements from the top of the protective cover tile to the ground surface for different land uses. Refer to Table 2.

The depth of burial of the cables and the cable trench contents must be sufficient to comply with Section 14 of the Electricity Safety, Quality and Continuity Regulations 2002 (ESQCR 2002).

It would be usual to strap the ducts together at regular intervals to maintain the correct trefoil formation, including for any service ducts for fibre optic cables (FOC's). The duct system must be installed with care to avoid sharp discontinuities at duct joints, duct or joint breakage, duct wall crushing or the ingress of foreign objects into the duct. For the UGC routes in this report a fully ducted cable system would be considered, whereby ducts would be installed from joint bay to joint bay and termination to joint bay.

Table 2 SPEN depth of cover requirement for different land uses

Surface Type	Voltage 132kV Minimum Depth of Cover (mm)
In roads (including those within substation boundaries)	750
Across good agricultural land	900
Across open countryside	900
Footpaths or grass verges	750
Within substation boundaries (unless surface trough)	600
Under Railways	1400
Alongside and within 2 metres of a railway or tramway	1250
Special Construction	To be agreed with The Engineer

Care must be taken during duct installation to ensure minimum bend requirements of the cables are complied with. These may vary depending on the cable manufacturer and cable design selected, and guidance from the manufacturer should be sought. However, SPEN specification CAB-15-004[6] provides indicative values, refer to Table 3.

Table 3 SPEN minimum bend radii for 132kV single core XLPE cables

Cable Type		Minimum Bending Radii (m)		
		Conductor size (mm^2)		
		800 (D: 89mm)	1200 (D: 100mm)	2000 (D: 112mm)
132 kV 1-core xlpe	Dynamic	3.1	3.5	3.9
	Static	2.2	2.5	2.8

In order to keep the cable duct trench clean and safe it may be necessary to shore the trench to prevent trench wall collapse. Shoring may be provided in a number of ways. For example, traditional double sided close timbering shoring, hydraulic shoring or box shoring.

Where a vertical trench wall is not necessary an option to "batter back" the sides of the excavation to a safe angle may exist. However if the ground consists of wet sand or silt, the safe angle of batter could be less than 10° above horizontal with insufficient room within the swathe for such a wide excavation. "Battering back" would also require the use of a method to prevent foreign material such as stones from falling into the trench and being mixed in with the duct surround where it could damage the ducts; such as the use of permeable membrane sheeting.

Figure 16 provides an example of a battered trench with ducts laid in trefoil formation. Here the ducts are shown pre-assembled next to the trench, strapped in formation and laid into the trench in an on-going process.

Figure 16 Battered back trench duct installation

Excavation of the trenches would include joint bay excavation. A joint bay for six joints would be in the order of 8m long and 4m wide and approximately 2m deep. The base of the joint bay must be level and a concrete pad installed (some 150mm thick with light reinforcement) as a working surface. The sides of the excavation are shored to prevent collapse. Refer to Figure 17. For the KTR Project, several different joint bay layouts are considered, refer to section 4.3 of this report for additional detail.

Figure 17 Trench leading to a joint bay excavation

The duration of the excavation, duct installation and backfilling works for up to twelve cables in a cable section will depend on the nature of the ground e.g. rock content, dewatering etc. In general, it would be expected that twelve cable ducts would be installed and backfilled over a 500m section in approximately a month.

4.2 Cable Installation of Ducted Sections

Cable installation into a ducted system relies on a low coefficient of friction between the cable duct and the cable. This would be achieved by installing the ducts with very gradual bends using as few discontinuities as possible, good duct cleaning and the use of biodegradable water based lubricants during cable pulling.

Cable pulling calculations are required to determine the expected maximum cable pulling force required and the side wall forces expected between the cable and the duct wall. These values should not be exceeded during cable pulling.

Once the ducts are installed and the trench backfilled, the drums containing the power cables would arrive at one of the joint bay positions. The area around the joint bay would have been prepared to accept the drums onto an area of hard standing. The drums would be delivered to site by low loader or cable trailer. A typical low load trailer is 18m long, 2.5m wide and has a ground clearance of 450mm. It has an unladen weight of 28 tonnes and this gives a loaded weight of around 46.5 tonnes for a 740m cable length of 2000mm^2 copper conductor XLPE insulated cable, the heaviest of the cable designs selected for the KTR Project, refer to section 6.4 of this report. Figure 18 is an example of a cable drum on a drum trailer towed by a tractor.

Figure 18 Cable drum trailer

Transporting the drum over motorways and major roads should not present any problems and the low loader width with a drum on board could be such that escort vehicles should not be necessary.

If cable lengths longer than approximately 850m are used, drum widths may have to increase, and under such circumstances the drums may be loaded transversely onto the vehicle with the drum spindle aligned along the length of the vehicle trailer. This transverse mounting of cable drums on to low load trailers allows much wider drums to be transported. However, they would still be limited by height restrictions; for example 16’ 3” (4.95m) bridge clearance on motorways.

Specialist hauliers would also be required to transport large drums. Such hauliers can provide low load trailers with rear wheel steering and tandem tractor units for steep inclines. Figure 19 shows a low bed trailer height of around 450mm. The trailer is also fitted with rear wheel steering.

Different manufacturers use different drum sizes to suit their cable manufacturing facility and it would be important that drum weights and dimensions are fully investigated at the contract tender stage. Transporting the drum through country villages and along country lanes may present problems and the temporary removal of street furniture, overhanging tree pruning, bridge strengthening, possible road closures and other road safety and access measures may be necessary.

Figure 19 Cable drum on a low loader trailer

In order to limit the overland portion of the route it would be suggested that cable drums arrive at suitable ports in Scotland capable of handling large drums, such as Grangemouth or Cairnryan Port. It would be recommended that a detailed transportation and access survey be undertaken for all sites if cable undergrounding were to take place.

Figure 20 Offloading cable drums

The cable drum would either be unloaded at a temporary storage site or taken directly to the cable pulling-in position. Refer to Figure 20. It can be seen from Figure 19 that the ground clearance of low load vehicles is limited and that the uneven surfaces of haul roads are likely to require an alternative means of delivery from a storage location to site.

A cable pulling system would then be installed into a ducted section, from one joint bay to the next. Traditionally this is a steel bond and winching system, the cable is winched into place by pulling on the leading end of the cable (known as nose pulling). Refer to Figure 21. In recent years, synthetic winch bonds, made from Kevlar, have been developed which provide equivalent strength characteristics to their steel counterparts, but are safer due to their failure mechanism and pose less of a risk to inadvertently damaging the smooth internal bore of the ducts during use.

Winching equipment is normally diesel powered. Electrically driven winches are available however generators would usually be required to power these. The winches are usually fitted with a dynamometer or some other means to monitor and record the pulling force being applied to the cable by the winch.

Communication during the cable pulling operation is by radio hand-set to supervisors strategically positioned along the cable route, principally at the winch, the cable drum, the launching and receiving joint bays and any open trench positions containing driven rollers or caterpillars.

Figure 21 Cable pulling winch

The cable drum is threaded with a spindle and raised from the ground using hydraulic jacks mounted on lifting frames (jack stands) or rotated by under rollers. The cable may then be pulled from the drum and attached to the pulling bond by either a cable pulling head or stocking attached to a swivel. The cable is then pulled through the ducts, additional cable pushers (driven rollers or caterpillars) can be installed next to the drum to provide additional pushing force if deemed necessary by the cable pulling force calculations. Enough cable would be pulled from the drum until sufficient were available in the receiving joint bay at the far end for jointing onto the next cable length. The cable would then be disconnected from the winch bond, the bond passed through the next duct back to the cable drum and the process is repeated for all cables.

Distributed temperature sensing (DTS) fibres or communication fibres would be installed in the FOC ducts at this stage. These fibres are used as part of a temperature monitoring system to calculate the cable conductor temperature along the cable route to estimate the load current capacity of the cables and detect any locations where soil or cable surface temperatures are abnormally high. Due to the complexity of providing reliable power source to DTS units at remote locations. For the KTR Project, DTS units have only been considered for UGC routes terminating in a substation. However, a fibre can be installed along the route should a future decision be taken to thermally monitor the cable system.

4.3 Jointing

Once the cables have been installed into a joint bay a temporary weatherproof structure would be erected over the bay. The joint bay would be cleaned internally, and the cables prepared on a clean joint bay floor. The jointing operation would require dry, clean conditions and good lighting. The means of providing these conditions, by the use of concrete floors and temporary structures or mobile workshops varies between installers.

Most joint failures are as a result of assembly errors and thus jointing should only be performed by experienced and trained personnel. It is also necessary to ensure that these personnel are trained in safe methods of work, particularly when working close to other transmission lines that may induce dangerous voltages onto the cables being jointed. Circumstances vary with regard to the employment of the jointing team. They could be employees of the company supplying the cable system or alternatively employees of a contractor having received training from the cable accessory supplier to a standard suitable to assemble the joints and maintain the cable system warranty.

Depending on the number of cable installed for each circuit, either three or six power cable joints would be made off in a joint bay. There are six main stages in the power cable jointing process which are as follows:

- Preparation of the joint bay and checking of materials, drawings, assembly and safety instructions (this action is required to ensure that all components, equipment, drawings and instructions are available before jointing commences),
- Preparation of the cables including positioning and straightening,

- Assembly of the accessory primary insulation (within the radial water barrier),
- Assembly of the accessory secondary insulation (the radial water barrier and its coverings),
- Assembly of the link equipment and auxiliary cable equipment onto foundations or pits previously installed, and
- Following joint bay backfilling, initial secondary insulation checks by application of DC voltage.

The duration required between the end of cable pulling and the completion of a three or six joint bay will depend on a number of factors including, the number of joint bays open for jointing (backlog), the number of jointers assigned to the work programme for the project, the joint complexity, the location of the joint bay, access or working restrictions, any induced voltage working requirements and the speed at which each jointer feels competent and safe to assemble each type of accessory. Once a jointing team is available to assemble a joint bay the process should take in the order of two to three weeks. This period includes the assembly and removal of the jointing shelter and the final positioning of the joints.

A power supply would be required in the joint bay to operate equipment and lighting and, in the winter, to provide heating. Silenced generators would be positioned at joint bays where noise pollution may cause a disturbance. The general objective would be to reduce noise levels to 40-45 dB(A) at night, and 50-55 dB(A) during the day, at the nearest residence or at the boundary of the premises.

The jointers’ transport is normally a covered van. Self-loading vehicles would deliver and collect the jointing structures and fencing. Security patrols would be active with regular night time visits to any excavated joint bays. Stock proof fencing and/or bollards would be erected to prevent damage to any equipment which is not protected by burial.

Three main joint bay layouts considered for the KTR Project are:

- Joint bays within arable/pastoral land
- Joint bays within a carriageway, either with or without an accessible verge
- Joint bays within forests and/or woodland

4.3.1 Joint Bays in Arable/Pastoral Land

Figure 22 shows a schematic of a double circuit joint bay in arable/pastoral land. The components of the joint bay are labelled for reference, these components do not vary for the other scenarios considered within this report, with the exception of joint bays installed within forests or woodlands, where the joint bay may be encased within a reinforced concrete chamber. The joints are staggered to allow working access during assembly, and are then supported, along with the cables on CBS filled sandbags for support.

The joints are reinstated with specially selected stabilised backfill material and protected by recycled polymer cover tiles with warning tape above them. Above the cover tiles suitable native soil can be reinstated to ground level. The timber supports shown are for excavation purposes and can be removed or cut off and left in situ, once the jointing work is complete.

Adjacent to the joint bay, pits are constructed to house the link boxes and FOC joints as required. These are commonly constructed of brick, seated on a concrete base, with a suitably rated frame and cover installed for access. Typically the link box pits would be approximately 1.3m x 1.2m with a depth approximately 0.8m - 1.0m, these dimensions would be dependent on the precise design of link box installed and the access space required to assemble and maintain the box within.

Figure 22 Double circuit joint bay in arable land

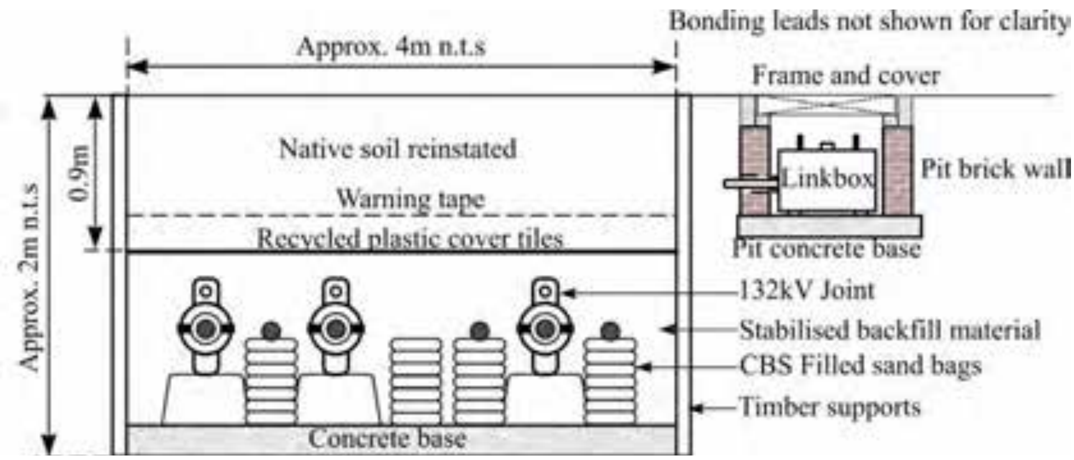
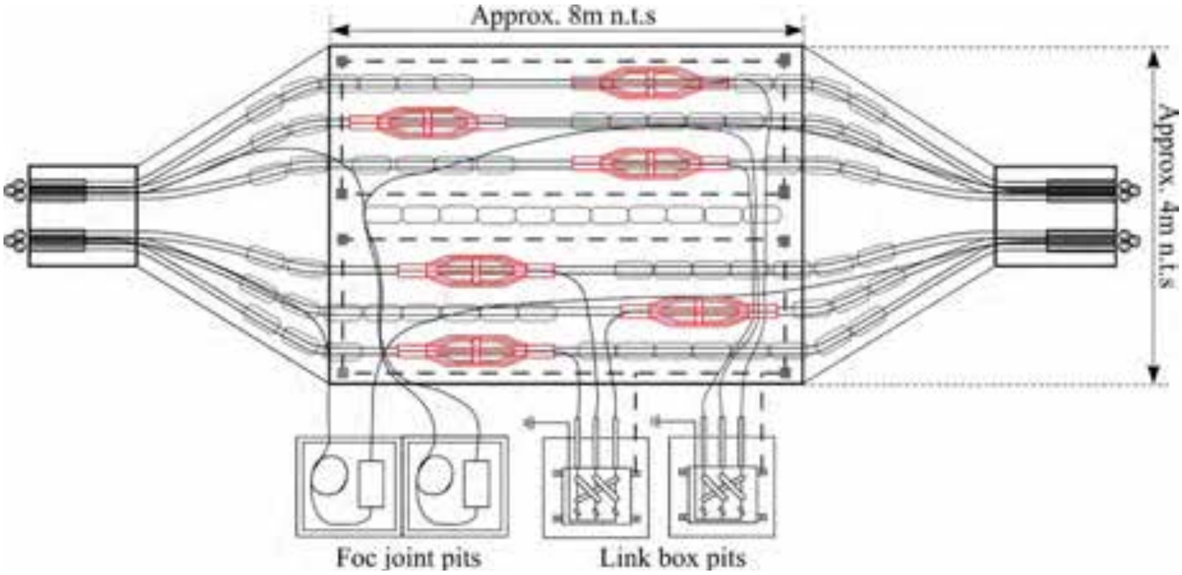


Figure 23 shows a plan view of a double circuit arable/pastoral joint bay. Without strict limitations on width, the circuit joints within this joint bay are shown side by side, with the resulting double circuit joint bay being wider but shorter when compared to the other joint bay scenarios considered. The link boxes and FOC joints are shown to the side of the joint bay in pits, however these pits could be replaced with above ground link pillar if acceptable to SPEN and the landowner.

Figure 23 Plan view of arable/pastoral joint bay



4.3.2 Joint Bays in Carriageways

Figure 24 shows a double circuit joint bay within the carriageway when no verge is available. The link boxes are shown positioned over the top of the joint bay to reduce the overall footprint and with the aim of keeping the link box lids in the centre line of the carriageway, thereby reducing exposure to direct loads from vehicles using the highway. This type of joint bay arrangement would require a carriageway lane closure to enable access to the link boxes for routine maintenance work and testing to be undertaken annually.

Figure 24 Double circuit joint bay within carriageway with no verge

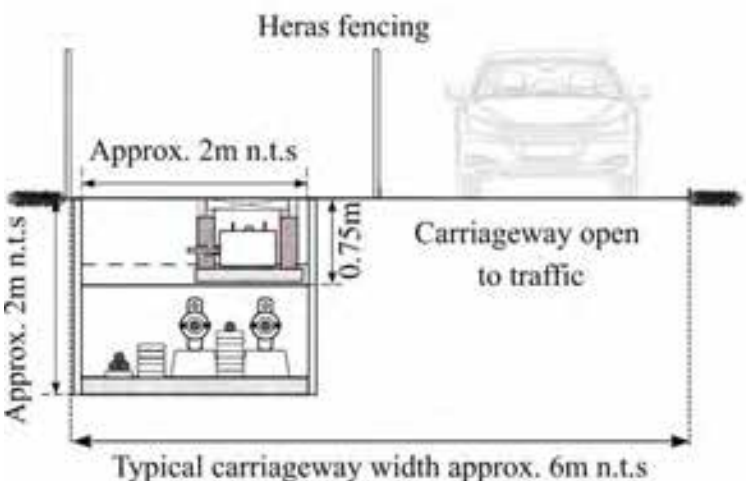
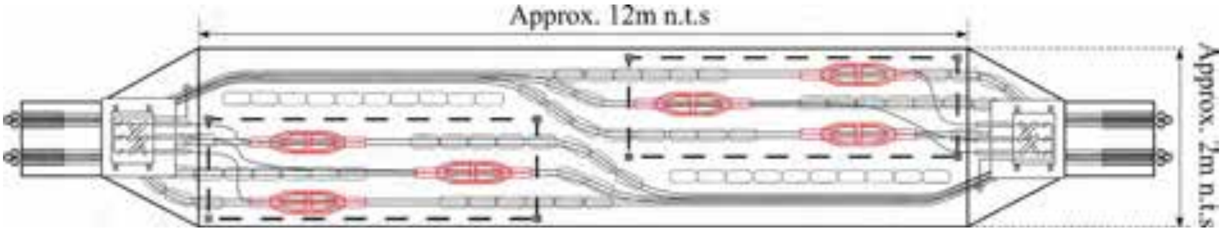


Figure 25 shows the plan view of the double circuit carriageway joint bay with the joints arranged in a compact, staggered arrow formation to minimise the joint bay width. This narrow formation results in a longer joint bay than is otherwise achievable.

Figure 25 Plan view of carriageway joint bay with no verge



Where a verge is accessible, Figure 26 shows an alternative joint bay arrangement, where the links boxes are housed in pillars within the verge, these are more accessed by maintenance crews and avoid road lane closures. However, it does create above ground infrastructure and may require planning permission.

Links could be installed in underground link boxes within the verge. However, link box pits located in the verge can become overgrown and difficult to locate. Link boxes are designed to withstand a degree of water immersion and whilst it would not be desirable to locate link equipment in areas liable to significant flooding a submersible link box would be preferable to a link pillar in a known flood risk area where water may be more than a few inches deep. If link pillars are essential that these may be installed in raised foundations (as has been used alongside rivers).

Figure 26 Double circuit joint bay within carriageway with a verge

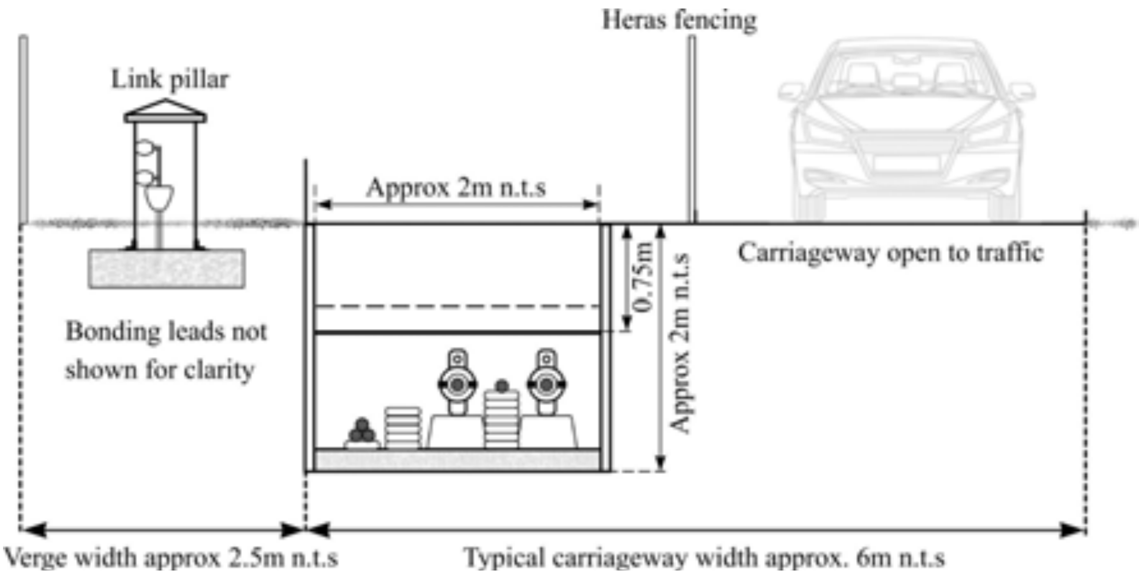
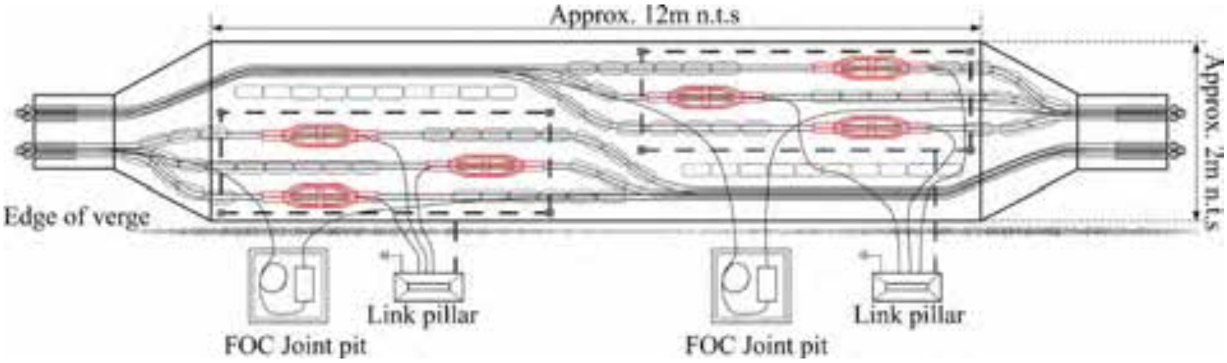


Figure 27 shows the plan view of the double circuit carriageway joint bay with the joints arranged in a thermally efficient delta formation. The link pillars and FOC splice joint positions are shown to the side, in the verge.

Figure 27 Plan view of carriageway joint bay with a verge



4.3.3 Joint Bays in Forests and Woodlands

It would be possible to utilise the carriageway and arable installations through the forestry where there is sufficient space and the ground conditions are such that penetration of the ground by forest machinery is not foreseeable. However, the use of heavy forestry vehicles over the cables with deeply rutting wheels would require that in areas of, or potentially of, soft ground that the cables and joints are mechanically protected.

For the cables themselves this may be achieved by placing the cables within a mechanically robust ducted concrete encasement. In order to protect the cable joint locations mechanical hardening may be achieved by installing the joints into reinforced lidded trough or air filled chambers with manhole access. This report considers that joints would be adequately protected when enclosed within a filled, lidded, buried trough.

Maintenance of the link equipment requires access from the surface. Where link pillars or link pits are installed it would be necessary to ensure that they have adequate surface to ensure that they are not damaged by forest machinery. Whilst coloured bollards provide both a visual and physical mitigation to accidental damage, the visual benefit would be decreased by vegetation/algae growth camouflaging the presence of warning bollards. It is therefore considered that any bollards or walls protecting link equipment should be so constructed as to be capable of substantially resisting the impact of forestry equipment.

Joint bays should be installed within unconstrained sections wherever possible to ensure adequate installation space and avoid the need for extensive ground cutting and filling operations. Figure 28 shows a cross section of a typical joint bay layout within a forest. The joints are shown enclosed within a reinforced concrete chamber that is backfilled with CBS. A typical swathe for a joint bay within a forest is also shown.

Figure 28 Double circuit joint bay within forestry

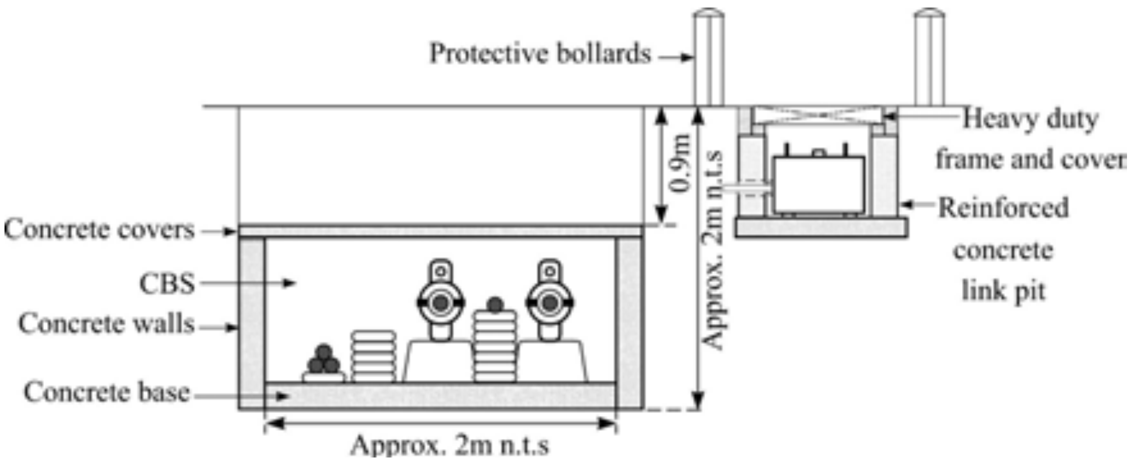
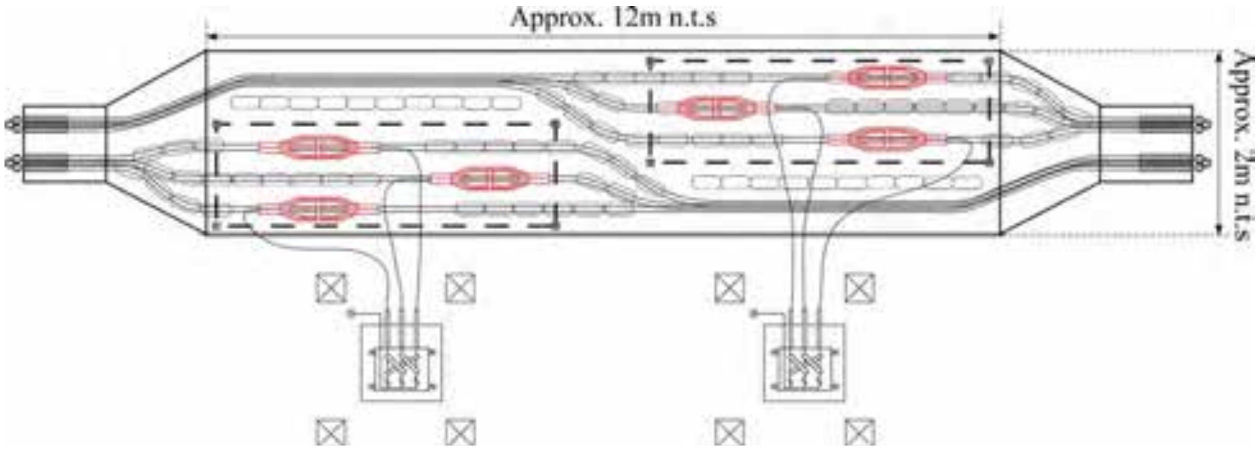


Figure 29 provides a plan view of a typical forest joint bay. The link boxes are shown positioned to the side of the joint bay with protective bollards around the link pits. The joint bays by preference should not be placed beneath the forestry track. This may require earthworks to prepare level ground for joint bays to the side of forestry tracks where this is not currently available.

Figure 29 Cross section of a typical forestry joint bay



4.4 Jointing Terminations

Depending on the UGC route considered, the cables will terminate at either a sealing end compound, or terminal tower. It is anticipated that UGC1 and UGC2 studies will terminate at a sealing end compound where there would be 6 cables to terminate per circuit. For UGC3 to UGC6 require only three cables per circuit and it is anticipated that these circuits will terminate on to terminal tower designs having an integrated cable sealing end platform.

The method of installation of the cable terminations depends on the cable termination manufacturer and installer. Methods include make the termination off in the horizontal position and then to raise it to the vertical position in its completed form onto a support structure; another would be to assemble the termination in its final vertical position at height.

The advantage of the first method is that the termination can be assembled at ground level in much smaller weatherproof enclosures. Some manufacturers do not consider such a technique as suitable for their design of cable termination and have concerns that the internal parts of the termination may move during the lifting process and result in the termination failing in service. Assembling the termination in the vertical position requires that a larger weatherproof scaffolding structure is assembled at the termination position.

All sheeted scaffold structures must be carefully designed to withstand a high wind load and are usually secured with a combination of guy ropes and ground anchor weights. The size of the structure will depend on the spacing of the cable terminations for electrical clearance and whether or not the installer uses a crane or an internal beam and hoist arrangement to install the termination insulator over the prepared cable end.

For sealing ends jointed on a sealing end platform located on a terminal tower, the scaffold structure is integrated onto the tower platform to allow weatherproof coverage of the cable sealing ends at their final termination position. Consideration for other circuits terminating at the tower would be required, to ensure safe working distances are maintained throughout the duration of the works.

The large scaffolds may take one or two weeks to construct, test (if a lifting beam is installed) and certify after which the cables are pulled into position up the structure. The jointers then prepare and terminate the cables. Following assembly of the termination the scaffolding structure must be carefully dismantled to avoid damaging the terminations.

Link equipment would then be installed inside the substation or secured to the termination support structure which provides a removable earth connection to the cable termination.

For the KTR Project, due to the complexity of providing reliable power source to DTS units at remote locations, DTS units only been considered for UGC routes terminating in a substation.

4.4.1 Jointing Cables within a Sealing End Compound

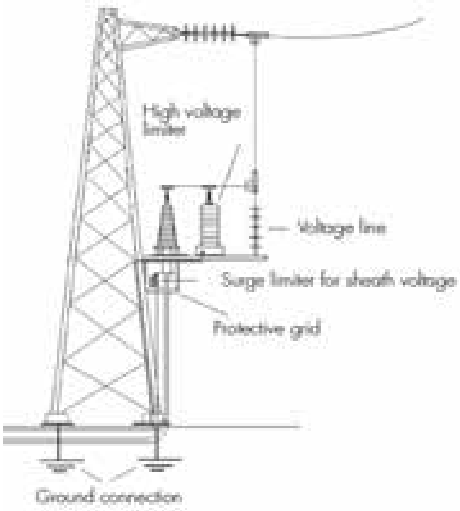
The cables would be brought out of the ground into a sealing-end compound that is fenced for safety reasons. The fence also surrounds the first Overhead Line (OHL) tower, the cable compensation reactors, and a blockhouse to accommodate the electrical protection and control systems relating to the cable. For UGC1 and UGC2 studies, it is envisaged that a sealing-end compound would be required at each end of a cable section (unless the cable terminates within a substation). Up to 12 cables may be terminated within each sealing end compound with each compound measuring approximately 24.3m x 15m. Figure 30 shows a typical cable sealing end compound with the associated cable swathe and temporary haul road.

Figure 30 Example of a cable sealing end compound (400kV)

4.4.2 Jointing Cables at a Terminal Tower

The cables would be brought out of the ground adjacent to the terminal tower and protected from solar radiation and external damage with mechanical shields. For the UGC3 to UGC6 studies, it would be envisaged that a terminal tower would be required at each end of a cable section (unless the cable terminates within a substation). Existing designs allow up to 6 cables to be terminated at each double circuit terminal tower (3 power cables per circuit). Figure 31 shows a typical terminal tower arrangement including stone guarding.

Figure 31 Terminal Tower with integrated sealing end platform (132kV)



4.5 Swathe Reinstatement

Following the installation of all cable and joints in a section the swathe would be cleared, with the exception of any sections of the haul road that are needed for future maintenance access to the buried cable route. This will include the removal of any remaining security fencing, uplifting and removal of the haul road and temporary hard standing areas reinstatement of surfaces and top soils.

Where necessary this reinstatement may include replanting of hedges, replacement of fences, removal of temporary land drains and settlement ponds, reinstatement of permanent land drains and the like.

If trees are removed, these would only be replaced if their roots did not interfere with the power cable installation. The allowable distance of any tree from a cable would depend on the type of tree and its expected future growth.

Where beneficial, and prior to topsoil replacement, the ground would be subject to sub-soil ripping to break up the compaction due to construction activities.

4.6 Operation

Once the installation had been completed, the ground apart from small sections of the route accommodating link equipment, could be returned to low growing vegetation or agricultural land. The building of permanent structures is not normally permitted over directly buried cables primarily for reasons of maintenance access or replacement.

Trees with root systems which could damage the cable system would need to be removed from the cable route during the operational life of the underground cable system.

4.7 Access Requirements for Maintenance and Future Works

Future access would be required to joint bay and termination link equipment positions along each of the 6 UGC routes, with frequency of access a factor of service performance and reliability of the cable circuits.

As recommended in Engineering Recommendation C55/5[3] the integrity of the sheath to earth insulation should be tested at yearly intervals using a test voltage of 5kV D.C. for one minute. At the same time, any SVL's installed on the circuit should be checked, by disconnecting the SVL leads from the bonding links and applying a suitable voltage (D.C.) supply connected in turn between each of the three disc leads and the earth lead. The detailed test procedure and requirements for each resistor type are provided with the Engineering Recommendation C55/5[3]. However, these tests are not obligatory some utilities retest only after periods of 5 years or more on 132kV systems.

Other checks on the link boxes and/or link pillars which may also be carried out at the same time include:

- Checking the electrical contact resistance across all link contacts in each link box or pillar using a digital micro-ohmmeter.
- Checking the connection resistance between SVL leads and the appropriate terminal pillar should be similarly measured.

If an internal fault or an external heavy through fault occurs on a specially bonded cable system, the tests outlined above should be carried out and the integrity of the sheath to earth metallic path checked before the cable would be returned to service. Resistance measurement data should be retained and made available for future reference during any future maintenance or testing of the bonding and earthing system to gauge any deterioration.

5 Special Installation Design

This section discusses particular conditions on the UGC routes that require special installation design consideration, without which medium to long term circuit performance and reliability could be curtailed.

5.1 Peat

Power cables require that heat generated by the cable whilst in service be dissipated into the environment to avoid overheating effecting the cable's insulation. The presence of peat can inhibit heat transmission through the soil due to it's thermal properties.

Peat soils are generally defined as those with an organic matter content exceeding 60% to a depth of 0.4m or greater. They are generally saturated, with a water table at or near the ground surface and have accumulated over thousands of years under cool, wet and nutrient poor conditions.

The structure of peat comprises a thin surface layer of living vegetation overlying a thicker layer of well decayed and humidified peat comprising the consolidated remains of former surface vegetation. Peat forms in wet poorly drained areas. The surface peat layer may vary between a few centimetres deep over broken rock to a depth of several metres over impermeable rock.

Specifications[7] have been developed that identify the correlation between the moisture content and the thermal resistivity of peat. This correlation may be used to establish whether a soil contains little or no peat or has a substantial peat content which required a high native soil thermal resistivity to be employed during the thermal design of a cable trench.

There are a number of methods available for installing buried cables within peat. For the KTR Project, based on the environmental information[8] available for the cable routes, it is probable that sections of the cable routes will pass through peat habitats.

Where practically unavoidable the installation of buried cable systems in peat, though feasible, can prove expensive, technically challenging and result in programme delays, if not properly planned for. Prior to starting any installation work, a detailed intrusive ground investigation should be undertaken along the cable routes which should include peat probing and thermal analysis, to understand the extent and impacts of any peat habitats. This would enable the most suitable peat crossing solution to be identified, more accurately costed and implemented.

5.1.1 Installing Power Cables in Peat

Generally, the published recommendations are that buried cable installation directly in peat should be avoided and alternative methods of installation or routing should be considered. This could mean finding another route that avoids the peat habitat or installing the cables at greater depth in the sub-strata underlying the peat habitat which may be rock, or installing the cable trench on a reinforced concrete piled strip foundation.

A number of installation methods are discussed further for sections of cable route crossing peat habitats that include:

- Drilling through the firm strata beneath the peat layer
- Supporting the cable trench on a piled reinforced concrete strip footing base
- Supporting the cable trench on a Vibro-piled reinfroced concrete strip footing base
- Excavation down to firm sub-grade

5.1.1.1 Drilling Through Firm Strata

An HDD drill would need to penetrate the underlying rock layer to ensure stability, this would be likely to be both technically challenging and a costly operation. An adequate drilling depth would be required to ensure that drilling fluid pressure would be less than hydrostatic pressure generated by the groundwater throughout the duration of the drilling process. A larger cable size may be required due to the thermal design constraints associated with cable installation at a greater depth. This method would limit the impact on the peat habitats when compared to other options considered within this report.

5.1.1.2 Trench Supported On Piled Reinforced Concrete Strip Base

This option would be to install the cable trench on a piled reinforced concrete strip footing base, this would provide a reliable method of stabilising the cable trench. The suitability of this method relies on the strata underlying the peat habitats, where unstable material would require extension of footing piles. Where deeper piling solutions are required the cost effectiveness of this solution would diminish. This method would be invasive compared with other options discussed within this report, construction of piling mats and temporary access roads would be needed, with a swathe of the peat habitat likely to be permanently displaced.

5.1.1.3 Excavation

This option involves complete excavation of the peat within the cable route corridor and backfill with compacted graded stone backfill up to the base of the cable trench. The key advantage of this installation method would be the assurance that the cable system would be founded on a stable backfill surface, removing any risk to the cable circuits associated with movement within the deep peat section. Where the peat is very deep a key disadvantage would be the cost and environmental implications associated with what would be likely to be a complex civil operation. Extensive temporary works are likely to be required to allow excavation of a deep trench. The pre-existing peat habitat would be desrtroyed by this method and a fundamental change made to the natural soil environment within the cable corridor.

5.1.1.4 Floating

This option involves excavating a trench through the peat and installing membrane and battons onto the trench floor to provide a weight bearing surface onto which the ducts or cables may be laid. This is generally a less expensive option but has some risk element in terms of long term circuit performance, such as:

a) The weight of the cable and the trench backfill employed may result in the cables and the trench contents sinking into the peat over time giving rise to general derating along with mechanical tension to any joint conductor connectors, particularly those installed within the peat.
b) The thermal resistivity of peat is significanlty affected by low moisture content. Should the peat be caused to dry out significantly due to its proximity to heavily loaded cables then a cable derating may be required to avoid a cable failure due to thermal run away.

5.2 Rock

There are a number of methods available for installing buried cables within rock. These include trenching, breaking, excavating and drilling. For the KTR Project, based on the geotechnical information[9] available for the cable routes, it is likely that sections of the cable routes will pass through rock. Trenching, breaking and excavating methods are discussed here. For the installation of ducts by drilling refer to Section 5.3 Watercourse Crossings.

Installation of buried cable systems in rock, though feasible, can prove expensive, technically challenging and result in programme delays, if not properly planned for. The type and quantity of rock encountered will vary along any given cable route, so a detailed and targeted geotechnical investigation would be recommended to enable an accurate assessment of rock depth and location to be made.

5.2.1 Rock Breaking and Excavating

Depending on the rock encountered, the installation solution will change. Where occasional boulders or rocky outcrops are found within the trench line, the use of an excavator with a hydraulic breaking attachment may offer the most cost effective solution. Refer to Figure 32. Although this method would not involve significant additional specialist machinery, it can be slow in comparison to excavating in softer native soils, with the fitting and removal of the hydraulic breaking head taking time to achieve.

Figure 32 Excavator fitted with a hydraulic breaking attachment

5.2.2 Rock Trenching

Where rock is identified within a cable trench that runs for many tens of metres, then the use of a rock trencher may be economic. Rock trenchers are tracked machines which have either a rock trenching wheel or chain trencher mounted on at one end that cuts through the rock to depths up to approximately 2m and widths up to 800mm. Refer to Figure 33. Rock trenchers use tungsten carbide tipped digging teeth to cut and remove the rocky ground as the trenching machine moves along. The resulting rock fines are collected and can potentially be reused during the reinstatement process or removed from site and recycled at a later date.

Figure 33 Rock trencher

Rock trenchers require good access to both side of cable trench and rely on firm ground either side of a trench to support the trencher. The speed at which these machines can cut a trench will vary depending on the cutting depth required, hardness of the rock and access conditions, but typically they can operate at up to 1 metre per minute once in position.

If used then extensive buried service investigations should precede the use of these machines to reduce the risk of damaging underground services, the repair of which can be expensive and create significant inconvenience for third parties.

5.3 Watercourse Crossings

There are a number of proven cable installation methods for crossing a river, burn, drainage ditch or other type of watercourse. These include bridging, horizontal directional drilling (HDD) or tunnelling beneath the riverbed, damming and pumping over to enable dredging a trench in the riverbed and laying the cables direct on the riverbed or in ducts. These methods may also be applicable to standing water such as ponds or lochs.

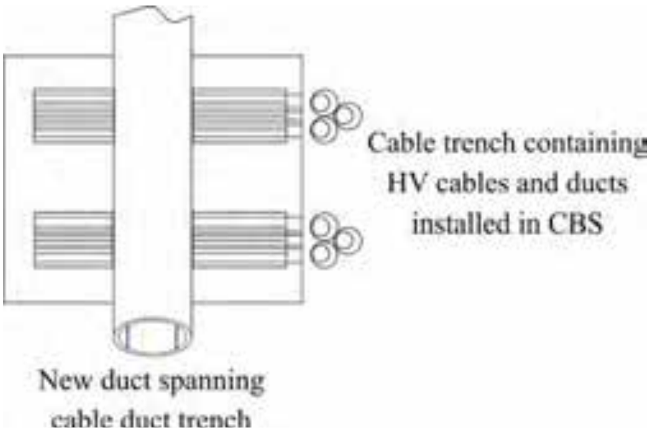
For the KTR Project, in the case of minor watercourses such as seasonal flowing burns or shallow drainage ditches, the method of ducting and cabling under would be preferred. Where flowing water is present, upstream damming and pumping over would be considered. For more major watercourses where the flow of water may not be accommodated by pumps, the preferred method would be the use of suitable existing structures such as road bridges, if available, or by HDD. Depending on the water course width, access and planning requirements a bespoke cable bridge may be installed.

Some of the older duct crossings, installed prior to regulations concerning the handling or asbestos, employed asbestos cement ducts. Specialist contractors would be required to remove, decontaminate and dispose of such material.

5.3.1 Ducting and Cabling Under

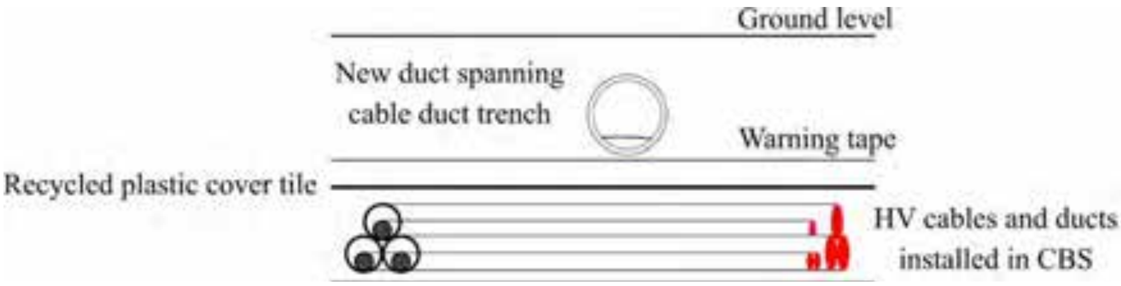
Ducting and cabling under involves excavation of the existing water crossing, likely to be a land drain or drainage ditch, breaking out of any existing pipe and replacement with a new section of suitable duct. The power cable ducts are then installed under the new drain duct at a suitable depth and the whole excavation would be reinstated to the SPEN specification[6] including the use of suitable duct surround material, cover tiles and warning tapes. Refer to Figure 34 and Figure 35 below.

Figure 34 Plan view of a ducted water crossing



Exploratory trial pits would be required at each crossing location to establish the precise depth and dimensions of any existing infrastructure, to ensure that a suitably sized replacement duct is installed. Trial pitting would also verify whether the cables would need to be installed under the existing feature or if the cables could be installed over the top whilst meeting the installation characteristics required within the SPEN specification[6].

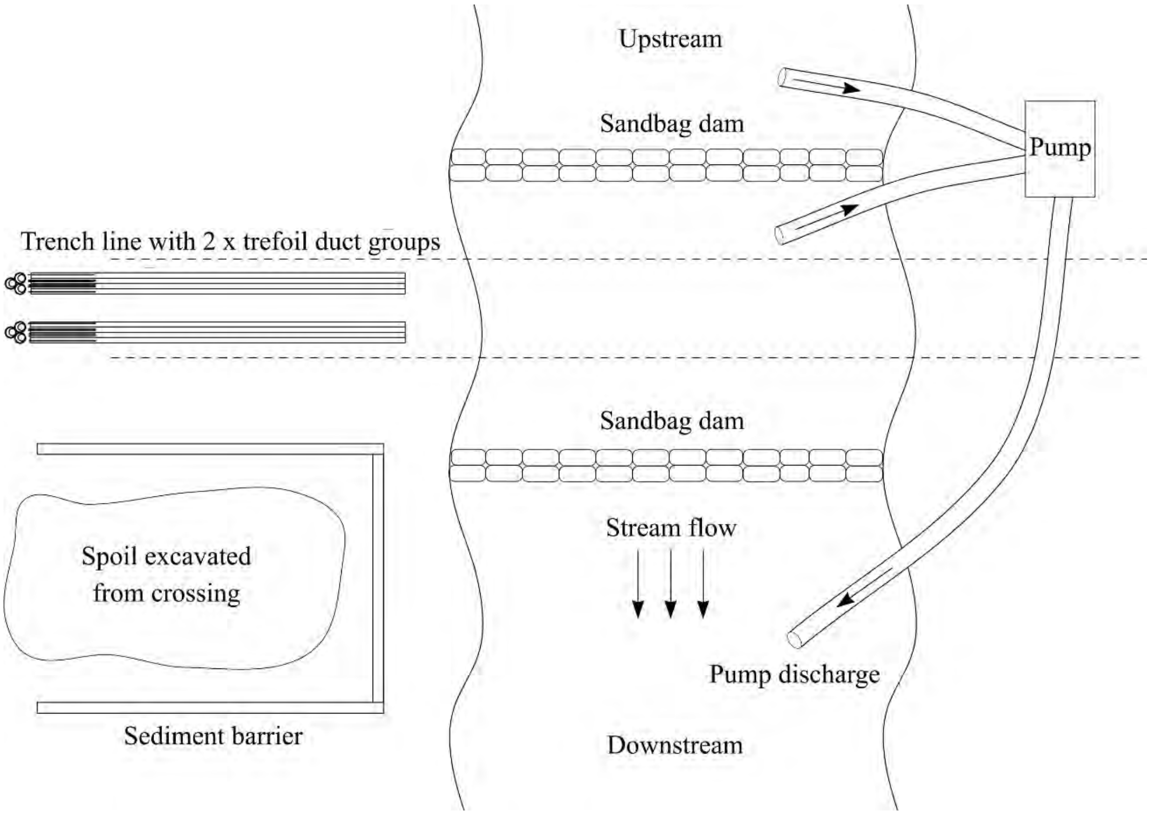
Figure 35 Cross section of a ducted water crossing



5.3.2 Dam and Pump Over Crossings

Dam and pump over crossings involves the watercourse being temporarily dammed, with the water diverted past the work site, and the watercourse bed dredged, excavated and ducted in the normal way. Once the ducts are installed the dam is removed and watercourse returned to its normal state. Refer to Figure 36 for a schematic illustration of this method.

Figure 36 Schematic of a dam and pump over crossing



5.3.3 Cable Bridges

Cable bridges have the potential to offer a relatively low risk method for a buried cable system to cross an obstacle, such as a river or burn. In general cable bridge designs fall into two categories: a standalone self-supporting cable bridge or a cable bridge supported by or installed within an existing bridge.

Figure 37 provides an example of a standalone cable bridge spanning a water course. The cables are enclosed within ducts and the bridge has anti-personnel devices which act to deter unauthorised crossings, theft and vandalism. If required, additional ventilated mechanical protection can also be applied to mitigate against the heating and UV effects of solar radiation. The bridge construct usually comprises an assembly of steel beams bolted to concrete abutments on either riverbank.

The cable bridge must not obstruct water flow or any traffic. Where the cable enters and exits the cable bridge, transition arrangements are used to secure and protect the cables as they relocate back to a buried installation arrangement. Proper design consideration of these transition sections can easily be neglected but is essential to safeguard cable performance in the long term and to meet the regulatory requirements regarding cable and public safety as a minimum. Consideration must also be given to prevent the cable bridge being accessed by the public, a method by which the cable bridge can be secured for example fencing or barriers, is usually employed.

Figure 37 Standalone cable bridge crossing a water course

Detailed geotechnical investigation and civil design is required to ensure bridge stability and performance are maintained for the service life of the cable system. The cable system designer is required to carry out detailed modelling of the cables performance within the bridge structure, to ensure current ratings for the system are met and that any electromechanical and thermomechanical forces anticipated are properly considered. Loads imposed on the cable bridge during cable installation must also be calculated and included in the overall bridge design.

The second category of cable bridges supported by an existing bridge structure. This can involve installation of the cables within the deck of an existing bridge, but the more likely configuration for the KTR Project would be the installation of a cable support bridge joined to the side of an existing road bridge.

Figure 38 shows power cables installed on an existing road bridge. Here the cables are installed in a flat spaced, close cleated, waved formation aimed at controlling any movement associated with the mechanical performance of the cable circuit and any expansion or movement of the road bridge sections.

Figure 38 Cables Installed on an Existing Structure (Road Bridge)

5.3.4 Horizontal Directional Drilling (HDD)

Horizontal directional drilling (HDD) is a method of bypassing an obstacle by directionally drilling under it from a launch position to a reception position on the other side. Typical stages involved in the HDD process include:

- Establishment of temporary compounds at the launch and reception ends of the drill
- Excavation of launch and reception pits within the compounds.

- Setup and anchoring of drilling rig, drilling fluids and drill pipe at launch site.
- Laying out of duct string, including fusion welding and duct inspection at reception compound.
- Drilling of a pilot bore along the planned drill alignment from launch pit to reception pit.
- On arrival of the pilot drill head at the reception pit, the drill head is removed and replaced with a larger back reaming head.
- The back reaming process is then undertaken whereby the reamer head is pulled back towards the launch pit, widening the pilot hole bore diameter as it passes. With the number of reaming passes varying depending on the soils encountered and the diameter of the bore required.
- Once the required bore diameter has been achieved, the reamer head is returned to the reception pit, connected to the duct string by a pulling head and pulled back to the launch pit, pulling the duct string into the pre-reamed hole as it goes.
- At either end of the completed drill, the ducts are cut to length at the correct installation depth and connected via adaptive collars to the standard cable ducts used along the rest of the cable route.

The temporary compounds required at each end of an HDD profile, are to provide space for temporary storage of plant and materials required for use during the drilling works, along with welfare facilities for the drill operators. In addition, establishment of these compounds ensures the drilling works area can be kept secure from members of the public. The footprint of these compounds would vary depending on the length, depth, complexity of the specific HDD and location along the cable route, but typically a drill launch site compound would measure approximately 30m x 30m, and a drill reception site compound 20m x 20m.

The cables can be installed within the HDD's in either a flat spaced or close trefoil formation, depending on the anticipated depth, thermal characteristics and circuit rating requirements for a particular cable route. Each formation has different requirements, for example the flat spaced configuration requires additional bores than the trefoil formation, and so requires a wider swathe. Conversely the bore sizes are smaller so quicker and less technically challenging than the larger bore dimensions required for a close trefoil formation. Figure 39 shows a typical cross section of an HDD with 2 circuits, with the cables laid in a flat spaced formation. No dimensions are given as these will vary depending on the specific drill requirements and the position along the drill profile at which the cross section is taken.

Figure 39 Typical HDD cross section for flat spaced cable formation

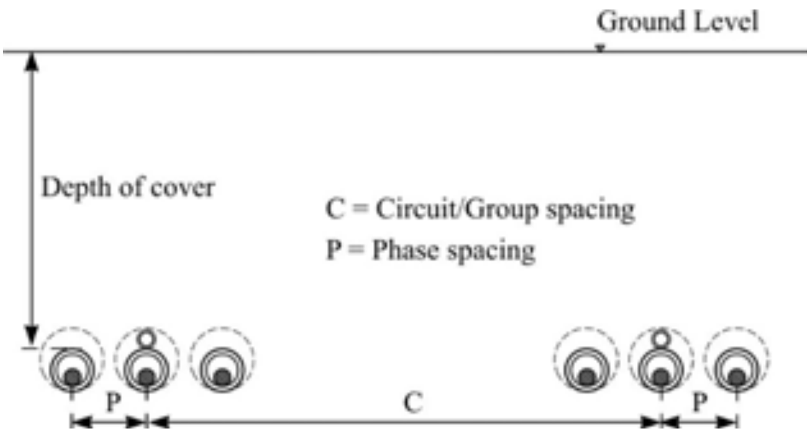
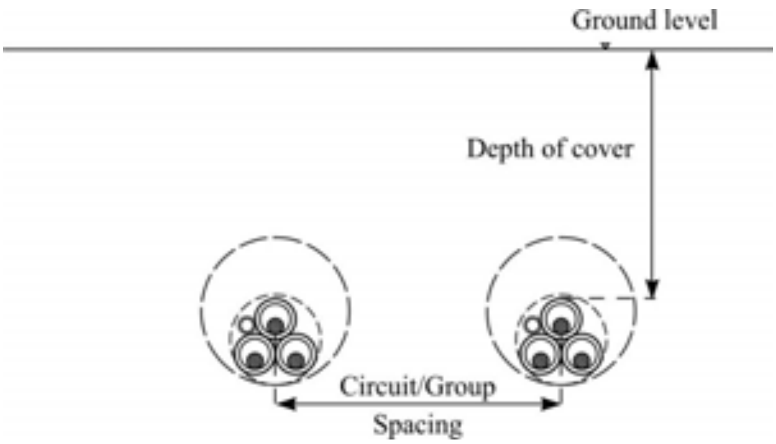


Figure 40 shows a typical cross section of an HDD with 2 circuits, with the cable laid in a close trefoil formation. No dimensions are given as these will vary depending on the specific drill requirements and the position along the drill profile at which the cross section is taken.

Figure 40 Typical HDD cross section for close trefoil cable formation



Most watercourses and other underground obstacles will have minimum clearance values associated with them, for a watercourse, this usually defines a minimum clearance from the riverbed. Guidance should be sought during the planning and consents stage of the works to ascertain the clearance requirements for each planned crossing location.

For an HDD section of a cable route, the cables are installed within a polyethylene (PE) ducts with an outside diameter of approximately 250mm. Typically the bore diameter would be 1.5 times that of the outside diameter of the duct, though this dimension can change depending on the depth of the HDD and ground conditions encountered[10].

The cable/duct spacing requirement between the circuits and the cable phases will vary depending on the depth required and the thermal resistivity of the native soil at any given location along the cable route. Figure 41 shows circuit spacing against burial depth for cables in a close trefoil formation for three different XLPE cable conductor sizes and types; 800mm² copper, 1600mm² aluminium and 1600mm² copper. This is representative of the cable designs required to deliver the 815A rating for UGC3 to UGC6. Refer to section 6.4 of this report.

Figure 41 HDD circuit spacing vs burial depth for close trefoil cable formation

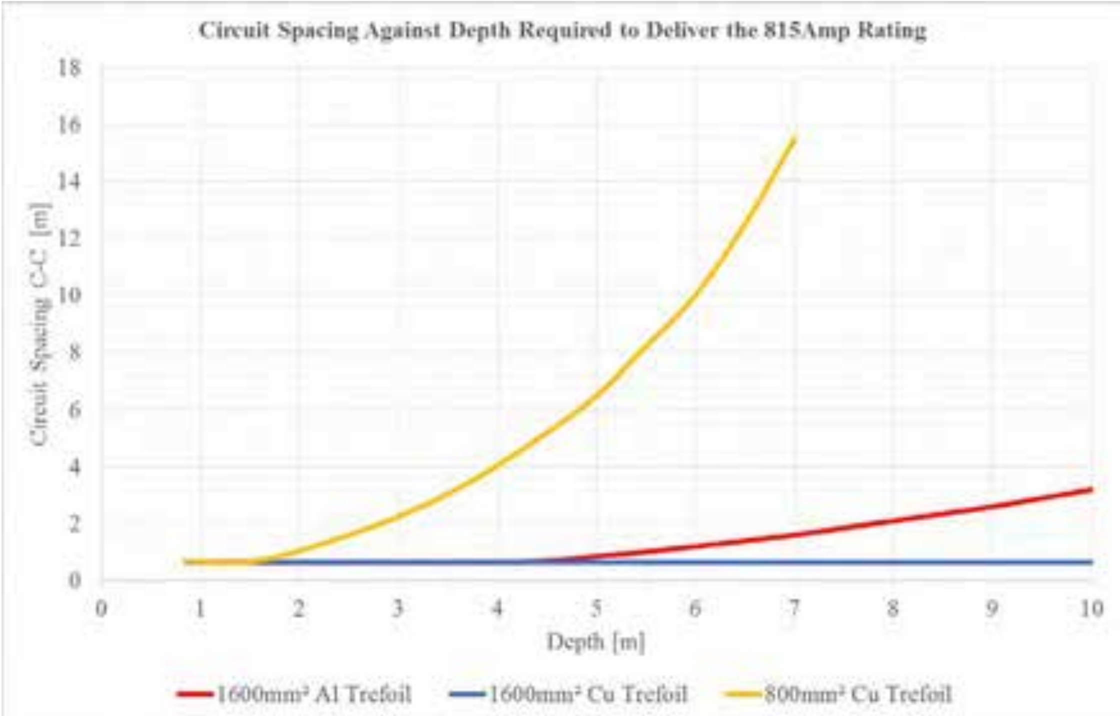


Figure 41 shows that 1600mm² copper XLPE cable can meet the 815A requirement at a depth up to 10m whilst installed at the SPEN minimum circuit spacing of 450mm between circuits. Both the other cable designs shown require additional circuit spacing to maintain the 815A requirement, with the 800mm² copper cable requiring unrealistic spacing from a burial depth of approximately 6m or more.

In practice, in addition to meeting the current rating requirements as detailed above, bore spacing may also be governed by any practical limitations at a proposed drill site, these generally include geotechnical features like soil makeup and consistency, and topographical constraints such as embankments, rocky outcrops and other features of the landscape which could hamper drilling activities.

5.4 Thermomechanical Force (TMF) Design

A cable with a 1600mm² aluminium conductor, can generate an axial force of several tonnes when it is heated to its maximum operating temperature.

Various sections of the cable routes identified have steep profiles. Where gradients are significant cable installers must perform a detailed TMF design analysis. Cable snaking (waving) may be necessary in order to ensure that movement at the highly stressed cable/accessory interfaces does not occur. In addition, filling ducts installed on an incline with bentonite may be desirable to prevent cable movement/slippage within the ducts themselves.

Consideration must also be given to mechanically restraining the ducts with steps taken to ensure that the ducts do not migrate down a steep incline. This can be achieved by installing the ducts within a concrete duct block which would be either pinned to the underlying rock or keyed footings (shear keys) are used to prevent movement. Figure 42 shows the excavations for a keyed footing (left photograph) and the ducts and reinforcement installed prior to concrete pouring.

Figure 42 Example of a ducted cable installation on a steep incline

After the cables are installed the ducts may be filled with a grout and/or be secured by anchor point at the top and bottom of the slope where the cables are cleated to a substantial buried concrete foundation.

6 Underground Cable Routes

6.1 Introduction

This section considers undergrounding in six locations in proximity to the routes of the overhead line connections forming part of the KTR Project. The six UGC studies are as follows:

- UGC1: Polquhanity to Kendoon (Tower N230 to Tower PK10)
- UGC2: Kendoon Substation to Glenlee Substation (Tower PK10 to Tower PK33)
- UGC3: Queen's Way Crossing (Tower GT08- Tower GT21)
- UGC4: Bennan, Slogarie and Laurieston Forests (Tower GT25- Tower GT78)
- UGC5: A75 crossing (Tower GT97-Tower GT104)
- UGC6: Undergrounding the proposed Glenlee to Tongland route in its entirety

The areas considered for undergrounding and the underground cabling routes selected for inclusion in this report are discussed in CCI engineering report Kendoon – Tongland 132kV Preliminary Investigative Cable Route StudyER1003 Rev C[11] subject to the 16 minor route adjustments detailed within this report.

6.2 Cable System Design Considerations

The main engineering aspects considered for each of the six UGC route system designs are:

- Cable system performance requirements of safety, voltage and rating,
- Cable designs and circuit configuration,
- Cable routing through the terrain, environmentally sensitive areas (advised by LUC) including swathes and trench layout,
- Crossing schedules and termination compounds,
- Cable section lengths, joint bay swathes and critical joint bay locations.

In addition to these considerations are broader system requirements that are associated with SPEN's transmission and distribution network. SPEN has undertaken a study of the electrical network to determine what, if any, reactive compensation may be required should any of the underground studies considered in this report be adopted.

6.3 Reactive Compensation

A cable circuit's electrical capacitance can cause significant changes to the transmission system voltage and a loss of useful power transfer capacity. These voltage changes may need to be corrected to avoid equipment damage and poor quality of supply at consumer premises. The normal way of controlling such voltages is to install "reactive compensation" in the form of shunt reactors. Electrically, these reactors perform in exactly the opposite way to cables (they are electrically inductive rather than capacitive) and consequently, by siting reactors on the transmission system at strategic locations the capacitive effect of the installed cables on the transmission system may be reduced or neutralised. The size and positioning of shunt reactors on the system must be performed as part of a wider electrical network design.

Therefore as a result some UGC routes may not require reactive compensation as there is sufficient already on the system to provide adequate compensation, where others may require reactors to be installed either at the terminal substations or elsewhere on the system as the system requirements dictate. Refer to Figure 43 for an overview of SPEN's existing transmission network in Dumfries and Galloway. The locations where reactive compensation is proposed have been marked with a red ring for clarity.

Figure 43 SPEN's Electricity Transmission network in southern Scotland 2015

SPEN undertook such an electrical network design study which examined each of the underground cable options considered as part of the KTR scheme and identified reactive compensation requirements, where needed, for the six underground cable routes. These are summarised in section 6.3.1 to 6.3.6 below.

6.3.1 UGC1 Polquhanity to Kendoon Substation Reactive Compensation

From the network study conducted by SPEN, no reactive compensatation was found to be required for UGC1 between Polquhanity and Kendoon substation.

6.3.2 UGC2 Kendoon Substation to Glenlee Substation Reactive Compensation

From the network study conducted by SPEN, the reactive gain generated by underground cabling UGC2 was calculated to be approximately 54 MVAr. To provide the reactive compensation required to offset this SPEN's study recommended to install 1No. 132kV

75MVAr oil-filled shunt reactor at Glenlee substation in an extension to the existing substation layout. This substation compound extension is anticipated to measure approximately 17m x 13m.

6.3.3 UGC3 Queen's Way Crossing Reactive Compensation

From the network study conducted by SPEN, no reactive compensatation was found to be required for UGC3 the Queen's Way crossing.

6.3.4 UGC4 Bennan, Slogarie and Laurieston Forest Reactive Compensation

From the network study conducted by SPEN, the reactive gain generated by underground cabling UGC4 was calculated to be approximately 70MVAr. To provide the reactive compensation required to offset this SPEN's study recommended to install the following:

- 1No. 132kV 75MVAr shunt reactor at Glenlee substation;
- 1No. 33kV 30MVAr shunt reactor at Glenluce substation;
- 1No. 33kV 30MVAr shunt reactor at Newton Stewart substation.

The SPEN study identified that each shunt reactor compound would be housed in extensions to the existing substation layouts. With the 132kV oil filled shunt reactor housed in compounds measuring approximately 17m x 13m and the 33kV air cored shunt reactors housed in compounds measuring approximately 30m x 40m. SPEN informed CCI that air cored shunt reactors require a larger compound area in comparison to oil filled alternatives, as an additional fenced buffer zone is required to manage magnetic field exposure limits. Refer to Figure 44 for a schematic of a typical 33kV air cored shunt reactor layout as provided by SPEN.

6.3.5 UGC5 A75 Crossing Reactive Compensation

From the network study conducted by SPEN, no reactive compensatation was found to be required for UGC5 the A75 crossing.

6.3.6 UGC6 Glenlee Substation to Tongland Substation Reactive Compensation

From the network study conducted by SPEN, the reactive gain generated by underground cabling UGC6 was calculated to be approximately 165MVAr. To provide the reactive compensation required to offset this SPEN's study recommended to install the following:

- 1No. 132kV 75MVAr shunt reactor at Glenlee substation;
- 1No. 132kV 75MVAr shunt reactor at Kendoon substation;
- 1No. 33kV 30MVAr shunt reactor at Glenluce substation;
- 1No. 33kV 30MVAr shunt reactor at Newton Stewarts substation;
- 1No. 33kV 30MVAr shunt reactor at Tongland substation.

The SPEN study identified that each shunt reactor compound would be housed in extensions to the existing substation layouts. With the 132kV oil filled shunt reactors housed at Glenlee in a compound measuring approximately 17m x 13m and at Kendoon housed in a compound measuring 35m x 20m. SPEN informed CCI that the layout at Kendoon substation is larger than that required at Glenlee substation as it also incorporates the circuit breaker associated with the 132kV oil filled shunt reactor.

The 33kV air cored shunt reactors are proposed to be housed in compounds measuring approximately 30m x 40m. SPEN informed CCI that air cored shunt reactors require a larger compound area in comparison to oil filled alternatives, as an additional fenced buffer zone is required to manage magnetic field exposure limits. Refer to Figure 44 and Figure 45Figure 45 for a plan and cross section schematic of a typical 33kV air cored shunt reactor layout as provided by SPEN.

Figure 44 Typical shunt reactor layout provided by SPEN.

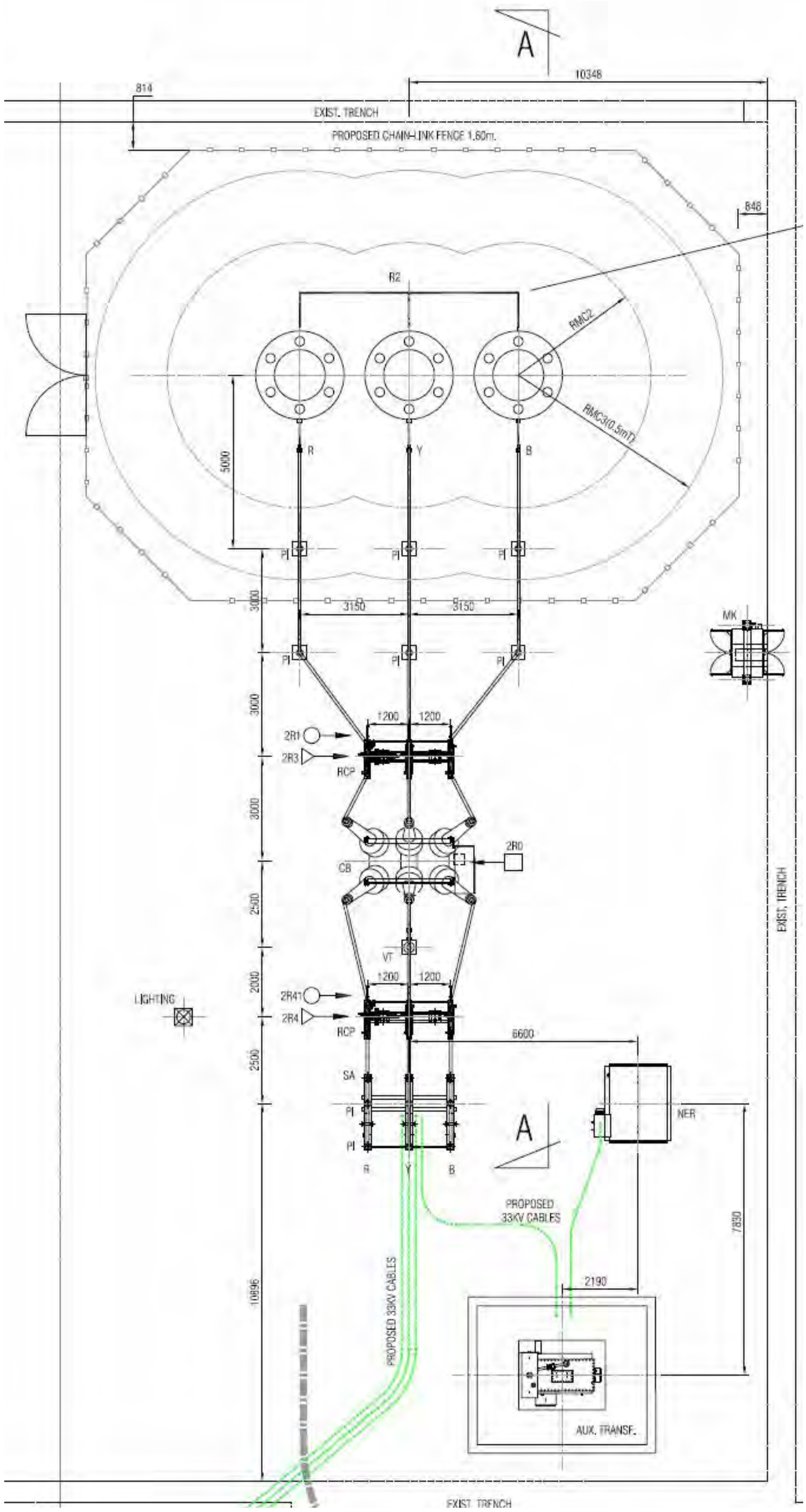
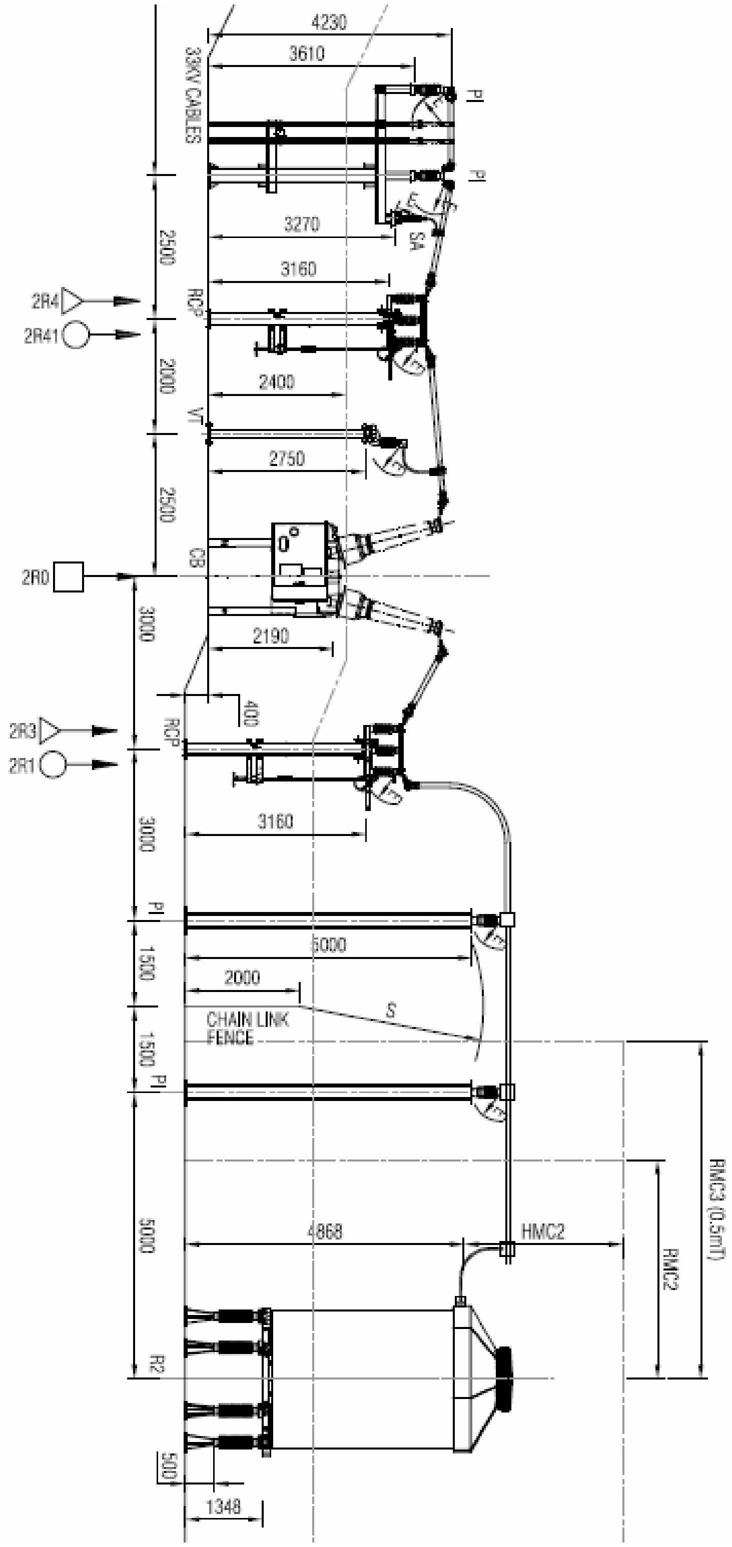


Figure 45 Cross section of typical shunt reactor layout provided by SPEN



6.4 Cable System Performance Requirements, Voltage and Rating

The cable system operating line voltage and current rating are determined by the overall power transmission design requirements determined and advised by SPEN.

Power cable systems generate heat when transmitting power between source and load. This heat would be generated by cable joule heat losses, principally conductor resistive (I^2R) losses. A 90ºC limit is set for XLPE insulated cables under continuous operation, this limit is stated within the SPEN specifications[1] and also by cable manufacturers and suppliers. This temperature limit is determined by the temperature limits of the XLPE insulation. As the conductor is in contact with the XLPE insulation system, and is the hottest component in normal service, the conductor temperature is also limited to 90ºC under continuous operation.

Secondary heat loss generation also occurs in the cable's metallic sheath and within the XLPE insulation; the latter being a resistive dielectric loss. These heat losses, together with the conductor heat loss, comprise the total heat loss that must be transferred from the cable into the environment during operation.

The materials surrounding the conductor thermally insulate the conductor from the environment and restrict the heat transfer. The heat flow is also further restricted by the materials used to bury the cables in the ground. A minimum depth of burial of 900mm to the top of the cable protection tiles has been applied in accordance with SPEN's specification CAB-015-004[6].

The allowable continuous current carrying capacity of the cables is therefore restricted by the amount of heat generated and the rate at which this heat energy is capable of being dissipated with a conductor temperature limitation of 90ºC. When calculating continuous ratings (using the international standard IEC 60287[13]), all cable heat loss is considered to eventually dissipate into the atmosphere. This calculation includes, amongst other thing, the cable material properties and dimensions, the effects of any mutual heating between cables, the depth of burial and the thermal properties of the soil surrounding the cables and the temperature of the atmosphere into which the heat will eventually be lost.

Heat transfer from a cable circuit may be improved by, a) minimising cable losses, b) increasing the cable spacing, c) minimising cable burial depth, d) maintaining the cable surround's overall thermal resistance to a low value.

Table 4 gives the pre and post fault ratings for the KTR Project cable circuits provided by SPEN. These requirements meet the same performance of the overhead line and thus the 132kV cables must be designed to carry the same current. The most challenging rating requirement is highlighted in red, in the spring / autumn season, as the current rating is higher than the summer equivalent and the maximum ground temperature is the same as the summer value. Refer to Appendix 2 of this report for details of source SPEN documentation and cable rating parameters.

Table 4 Seasonal circuit ratings and maximum ambient temperatures

Cable Route Study	All Ratings Are Per Circuit	Winter		Spring / Autumn		Summer	
		Amps	MVA	Amps	MVA	Amps	MVA
UGC1 & 2 Polquhanity – Glenlee S/S	Pre-fault Continuous	1770	405	1690	385	1540	350
	Post-fault Continuous	2110	480	2010	460	1830	420
UGC3, 4, 5 & 6 Glenlee S/S – Tongland S/S	Pre-fault Continuous	725	166	685	157	615	141
	Post-fault Continuous	865	198	815	186	735	168
Max. Ground Temperature Direct buried (°C)		10°C		15°C		15°C	

The power cable conductor size and design would be affected by the cable current rating requirement. For the power transmission requirement between Polquhanity and Glenlee substation (UGC1 and UGC2) it would be necessary to install two underground cables per phase to meet the overhead line rating. For Glenlee substation to Tongland substation (UGC3 to UGC6 inclusive) a single cable per phase would be sufficient.

The heat delivered into the ground by the cables will tend to dry out the soil by driving moisture away from the cable. Under these circumstances the soil thermal resistance is likely to increase allowing less heat to escape from the cable resulting in the cable overheating when at significant load. In order to prevent overheating of the cable as a result of soils drying out, a backfill with known thermal properties when dry is used around the cables. The UK a 50ºC isotherm is considered the boundary within which drying out may occur. In the UK the most common material used where drying out may occur is cement bound sand (CBS). This material is selected quarry sand mixed with cement in the ratio of 14:1 by volume. The requirement for the sand and CBS mixture is specified in ENA TS97-1[12].

For the purposes of current ratings, the soil outside of this isotherm is assumed to have a thermal resistivity of 1.05K.m/W in the winter and spring months and 1.2K.m/W in the summer and autumn months in line with general UK practice.

A field survey of the indigenous soil thermal resistivity may be performed to confirm the installation design and cable selection for cable rating figures required. If areas of soil are found that do not meet with these requirements, then the cables must be more widely spaced, or the indigenous materials exchanged for more thermally acceptable material. This procedure is not a common occurrence in the UK and usually occurs on industrial sites where high thermal resistivity materials such as coke, fly ash or steel slag may be found. Such testing requires the excavation of test pits to the depth of the cable burial and the insertion of a test probe into the ground. This probe contains a heating element and thermocouple assembly. Temperature readings are taken at regular intervals and the thermal resistivity of the soil calculated.

6.5 Cable Design Selection

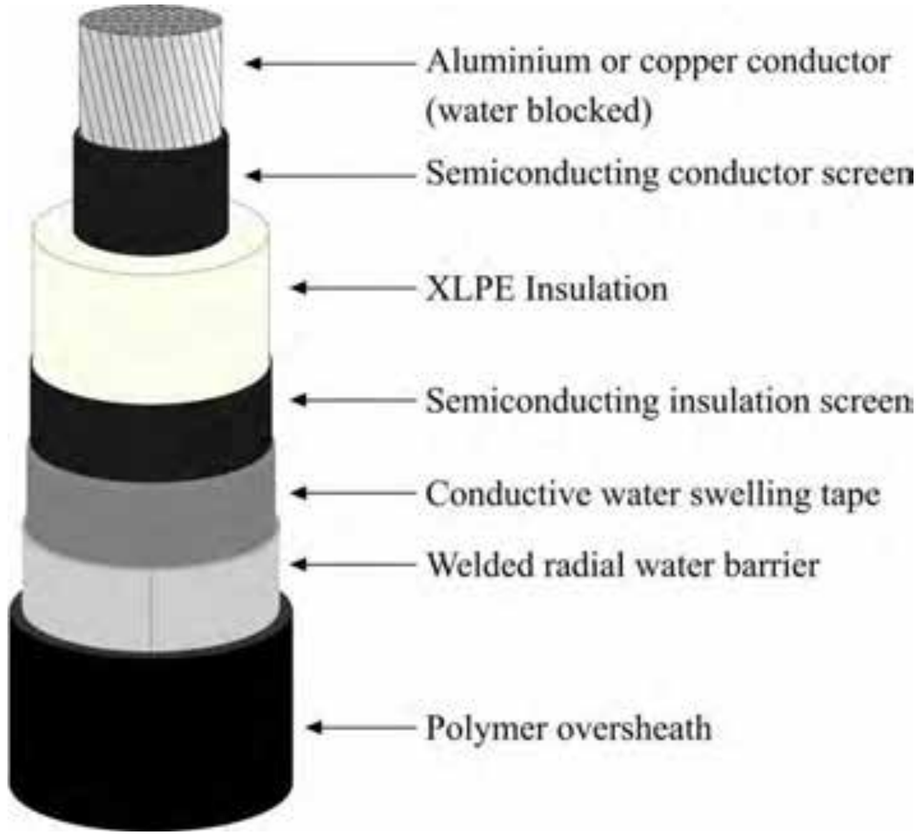
To achieve the rating requirements specified in Table 4 applying the cable parameters and information provided within SPEN specifications as detailed in Appendix 2, the following cable sizes and designs were selected for each UGC study, refer to Table 5. The dried out rating calculations were completed in line with IEC 60287 specification[13].

Table 5 Cable sizes and designs for each UGC study

Cable Route Study	Rating Requirement per Circuit (A)	Cable Design	Cable Weight (kg per m)	Cable Outside Diameter (mm)	Dried Out Rating (A)	Total No. of cables Required
UGC1 and UGC2	2010	2000mm² Milliken copper XLPE, welded aluminium sheath and PE oversheath	25	110	1039 (2 cables per phase required)	12 (6 per circuit)
UGC3 to UGC6	815	1600mm² Milliken aluminium XLPE cable, welded aluminium sheath and PE oversheath	10	99	885	6 (3 per circuit)

For cable studies UGC1 and UGC2 a 2000mm² copper conductor XLPE cable with a welded aluminium sheath has been selected, with 2 cables per phase required to deliver the required rating of 2010A.

Figure 46 132kV XLPE cable



For cable studies UGC3 to UGC6 inclusive, a 1600mm² aluminium conductor XLPE cable with a welded aluminium sheath has been selected, with a single cable per phase required to deliver the required 815A rating. A typical example of this cable design is given in Figure 46.

6.6 Electrical Configuration of UGC1 and UGC2

The electrical configuration of the circuits between Polquhanity and Glenlee substation requires that dual consideration of UGC1 and UGC2 cable studies is necessary, as UGC1 and UGC2 contain the following three 132kV circuits:

- UGC1 – A single 132kV circuit from Polquhanity (Tower N230) to Kendoon substation (Tower PK10). Refer to section 6.7 of this report.
- UGC2 – A single 132kV circuit from Kendoon substation (Tower PK10) to Glenlee substation (Tower PK33). Refer to section 6.8 of this report.
- UGC1 and UGC2 – A single 132kV circuit from Polquhanity (Tower N230) to Glenlee substation (Tower PK33). Refer to section 6.9 of this report.

Figure 47 Electrical schematic for tower N230 at Polquhanity, Kendoon S/S and Glenlee S/S

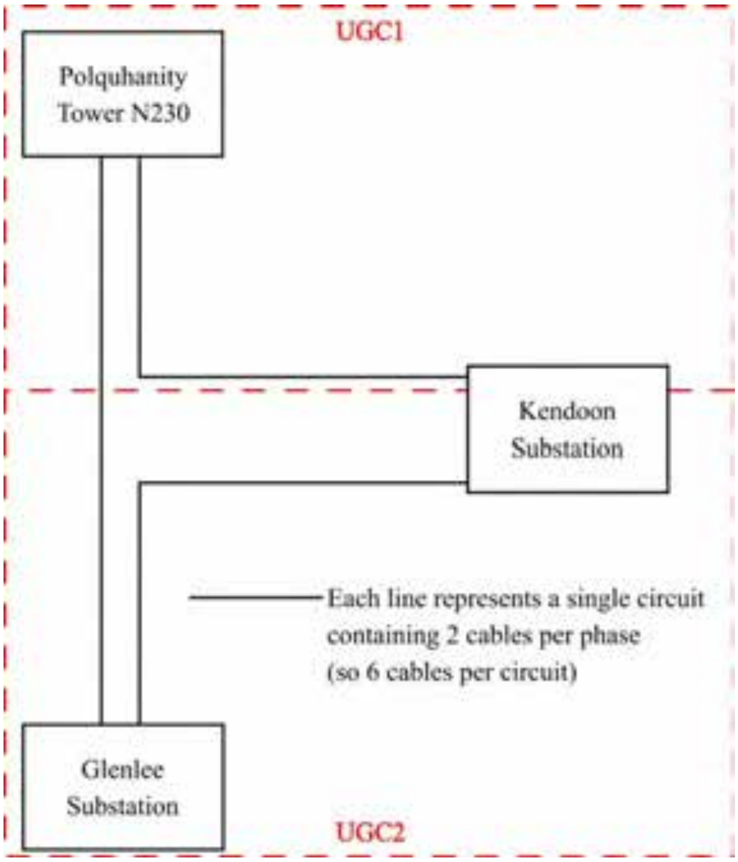


Figure 47 provides an electrical schematic of the Polquhanity, Kendoon and Glenlee substation circuit arrangement with red dotted lines showing how the electrical arrangement is covered within cable studies UGC1 and UGC2.

6.7 UGC1 Polquhanity to Kendoon Substation

The UGC1 cable route discussed here was developed and selected through an optioneering process detailed within the Kendoon – Tongland 132kV Preliminary Investigative Cable Route Study ER1003 Rev C[11]. Since the completion of cable study ER1003, one change to the UGC1 route has been identified. This modification was as a result of site visits subsequent to the issue of ER 1003 Rev B in July 2019. This change relates to the diversion of the cable route from the A713 at Polmaddy into the adjacent fields, for the HDD crossing of the river at Polmaddy. The impact of this change would be to lengthen the cable route by approximately 30m.

The UGC1 cable route starts at the cable sealing end compound at Tower N230 in Polquhanity, heads southeast across arable/pastoral land before following the A713 south, through Polmaddy and Dundeugh. Once south of Dundeugh the UGC route leaves the A713 and would head southwest to a cable sealing end compound at Tower PK10. The closing end of the route into Kendoon substation would be OHL from PK10.

Table 6 contains points of engineering difficulty and environmental sensitivity identified along the route, with each item number marked in red circles on Figure 48.

Table 6 UGC1 key points of engineering difficulty and environmental sensitivity

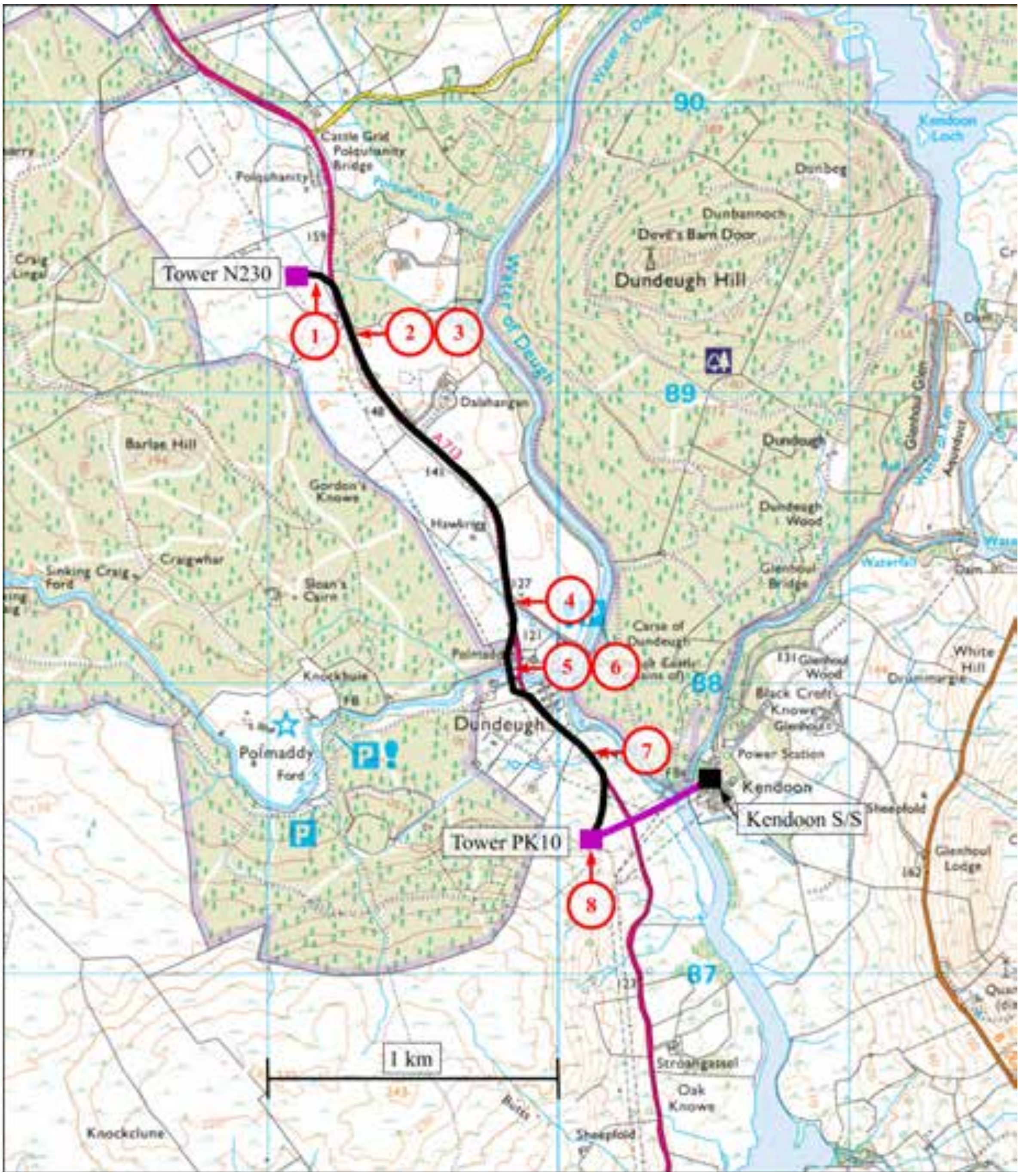
Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
1	Peat	Adjacent to termination tower N230 the ground is believed likely to contain peat. Peat ground preparation work may be required. This could also impact on cable conductor material and size.  The photograph shows the land section between the compound (in the centre) and the A713 (on the right hand side).
2	Cabling within A713	Cable would be installed within A713. An appropriate traffic management plan would need to be developed and adopted. Joints and link equipment would be located in the verge where practicable.
3	HV cable crossing	The UGC1 cable circuit would be required to cross an existing HV cable circuit located within the A713.

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
4	Burn crossing	 Unnamed burn crossing north of Polmaddy bridge. A shallow ducted crossing would be proposed requiring trial holes to establish the exact depth of the existing pipe. The new cable circuit would then be installed beneath it and the burn duct replaced.
5	Buried services in road	Scarring was noted on the road close to Polmaddy bridge, with BT manhole covers and kiosks noted in the verge adjacent to the A713. Manhole covers relating to other services, likely to be water supply and sewers, were also noted close to Polmaddy bridge. 

6	Polmaddy burn crossing	Burn crossing at Polmaddy, with an HDD required to span the burn and the adjacent track. The HDD launch and reception pits would be located in fields adjacent to the A713 carriageway. Directly adjacent to the Polmaddy bridge is a medium flood risk zone (1 in 200 years). 
7	Burn crossing	 Unnamed burn crossing south of Polmaddy Bridge. A deep ducted crossing that will require trial holes to establish the exact depth of the existing duct. The new cable circuit would then be installed over it, depth allowing.

8	Termination tower	Civil engineering difficulties associated with the construction of a cable termination sealing end compound at PK10 (mid-distance in photo). Micro-routing would be required between the A713 and tower PK10 to ensure the most suitable cabling route were selected. 

Figure 48 Black line showing cable route UGC1



6.7.1 UGC1 Typical Installation Swathes

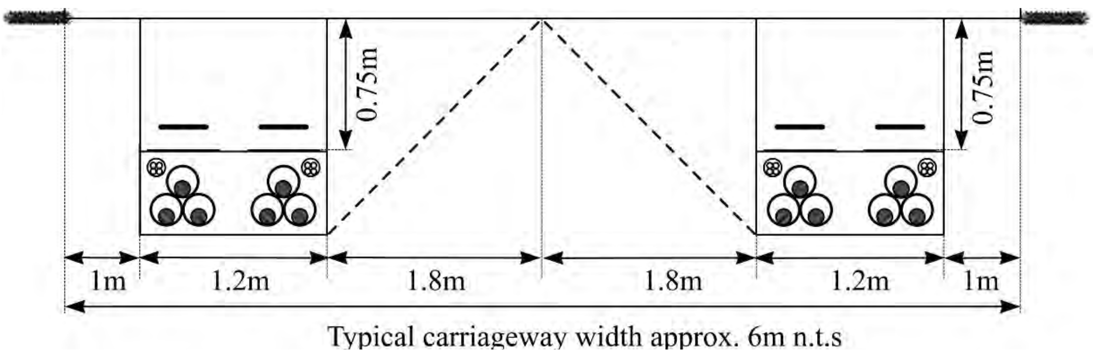
UGC1 cable route would be approximately 2.93km long, of which 2.40km would be buried cable comprising two main types of installation swathe:

- Installation within arable/pastoral land (0.83km)
- Installation within the carriageway (1.57km)

The typical double circuit arable/pastoral land swathe shown in Figure 8 on page 26 would apply to this route.

Figure 49 below shows a typical double circuit carriageway installation, whereby first the left hand lane would be closed and a circuit comprising 6 cables would be installed. Once complete, the right hand lane would be closed and a second circuit comprising 6 cables would be installed. This approach would require extensive traffic management and a two pass installation process. There are very few scars in the road surface (for example when compared to urban cable routes). However, a full utility search would be required to confirm the practicability of this route.

Figure 49 Typical double circuit carriageway cable swathe



6.7.2 UGC1 Haul Road Requirements

Haul roads would be required at various locations along the UGC1 cable route to enable both labour, plant and material access during the construction phase of the project, and to allow future maintenance and fault repair work to be carried out. Refer to section 4.1.4 of this report for additional information on typical haul road layouts.

Table 7 provides anticipated location and length of the haul road requirements for UGC1.

Table 7 UGC1 haul road requirements

Haul Road Location and Type Temporary (T) or Permanent (P)	Approximate Haul Road Length (m)
From N230 to the A762 for cabling access and access to the termination position (T)	300
From PK10 to the A762 for cabling access and access to the termination position (T)	300
Total Haul Road Requirement for UGC1	600

Although an access road already exists at tower N230 at Polquhanity, it is unclear of its condition, so an additional allowance has been included here.

6.7.3 UGC1 Crossing Schedule

Table 8 gives the crossing schedule for UGC1. From this schedule, key crossings have been highlighted in red and are discussed in detail.

Table 8 UGC1 crossing schedule

Crossing No.	GPS Crossing Location	Crossing Description	Proposed Crossing Solution
1	55° 10' 36.75 "N 4° 12' 39.42" W	132kV windfarm circuit	Excavate and cable under
2	55° 10'8.07" N 4° 12' 8.17" W	Unnamed burn north of Polmaddy Bridge	Replace existing duct and cable under
3	55° 10' 0.52" N 4° 12' 5.46" W	River at Polmaddy	HDD approximately 250m
4	55° 09' 51.17" N 4° 11' 51.61" W	Unnamed burn south of Polmaddy Bridge at Dundeugh	Replace existing duct and cable over

UGC1 has one significant watercourse crossing, at Polmaddy for which an HDD solution would be proposed.

In addition to this significant crossing, there are three more minor underground features that will also require crossing. The proposed solution for the two burns and the windfarm circuit would be to duct and cable under or over where depth allows. Refer to section 5.3 of this report for additional information of these proposed crossing methodologies.

6.7.3.1 UGC1 HDD Launch and Reception Compound Positions

The footprint of the HDD compounds would vary depending on the length, depth, complexity of the specific HDD and location along the cable route, but typically a drill launch site compound would measure approximately 30m x 30m, and a drill reception site compound 20m x 20m. Additional information is provided in section 5.3.4 of this report.

The launch and reception compound positions for the HDD on the UGC1 cable route has been identified and photographs showing their locations along with a brief description are provided in Table 9.

Table 9 UGC1 HDD launch and reception positions

HDD Description	Photograph
River at Polmaddy Bridge, HDD length approximately 250m. This would include crossing under an adjacent lane which provides access to residential properties and a public car park. Launch and reception positions were identified on the western side of the bridge in arable/pastoral land with reasonable access back onto the A762.	

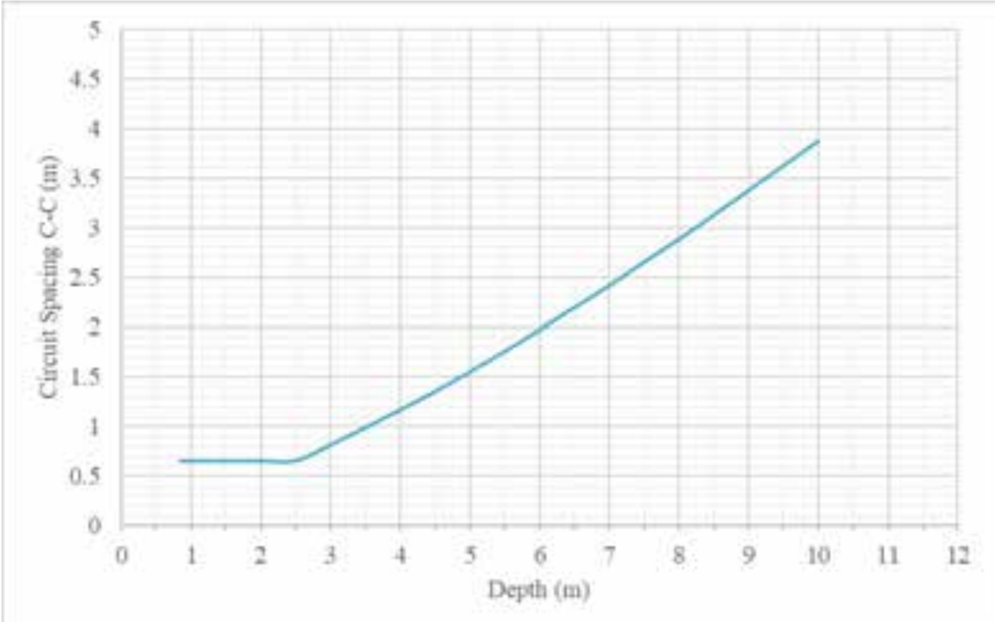
6.7.3.2 UGC1 HDD at Polmaddy Burn Crossing

UGC1 would require the connection of 12 cables to deliver the 2010A required. It may not be practicable to install all 12 cables within the deck of the bridge at Polmaddy, therefore an alternative solution of using an HDD has been considered.

An HDD solution would be proposed spanning from field to field on the west side of the existing Polmaddy road bridge. With 6 cables per circuit, the HDD formation would comprise 4 trefoil groups. The spacing between each trefoil group would be dictated by the depth the HDD profile needs to achieve to clear the riverbed.

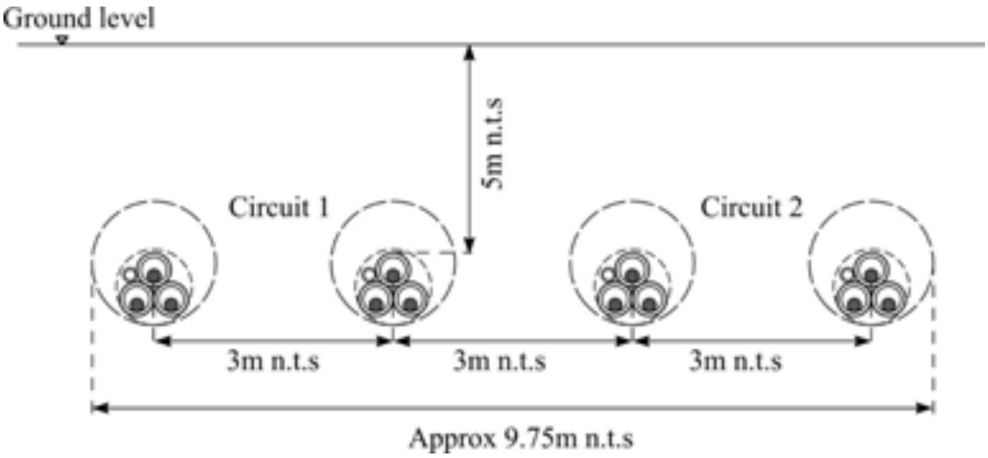
Figure 50 shows the relationship between burial depth and circuit spacing when the 2000mm² copper XLPE cable would be considered delivering a current rating of 2010A per circuit.

Figure 50 HDD circuit spacing vs burial depth for 2000mm² Copper XLPE cable



At a nominal burial depth of 5m, Figure 50 gives the centre to centre spacing between each circuit as approximately 1.55m, based on a PE duct OD of 250mm. Each trefoil duct group would be strapped together in formation and installed within a bore diameter of approximately 750mm. However, to ensure the structural integrity of all four bores, a greater centre to centre bore separation of 3m has been considered here. Figure 51 provides a cross section of this HDD arrangement and provides an indicative swathe width for the HDD section of approximately 9.75m for a drill depth of 5m. Guidance should be sought during the planning and consents stage of the works to ascertain the clearance requirements for each planned crossing location.

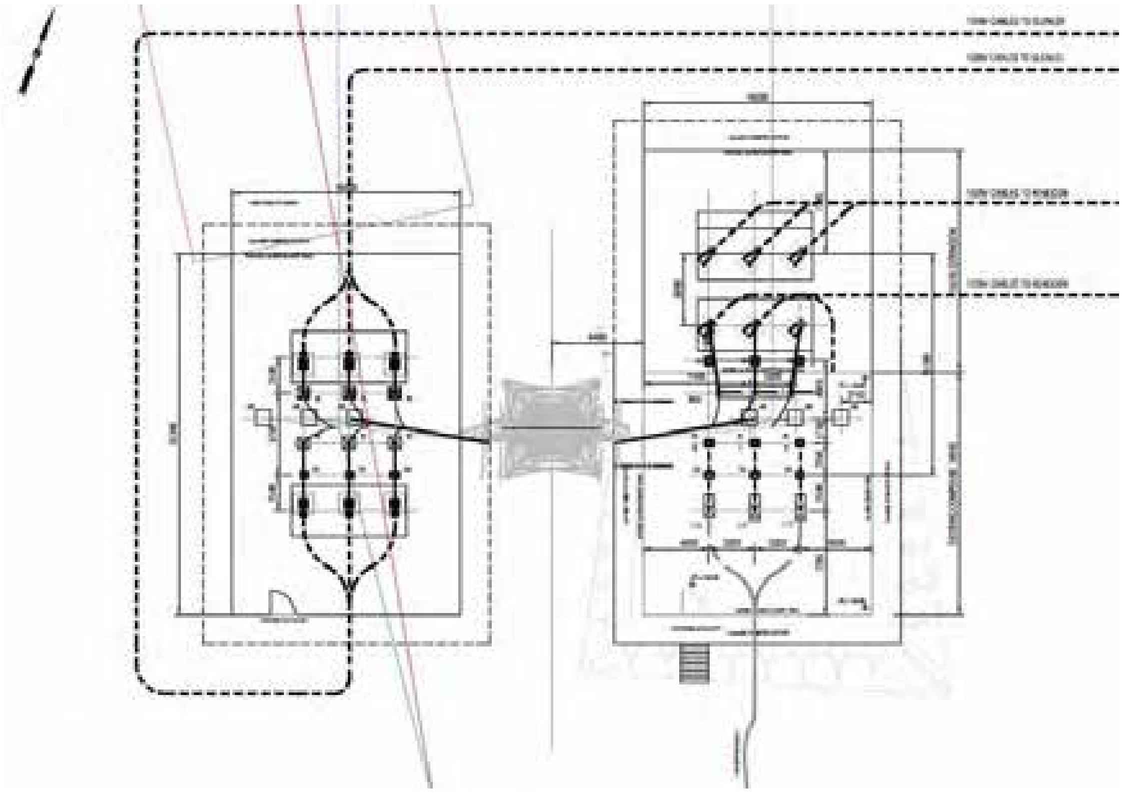
Figure 51 HDD cross section at Polmaddy Burn crossing



6.7.4 UGC1 Cable Sealing End Compounds

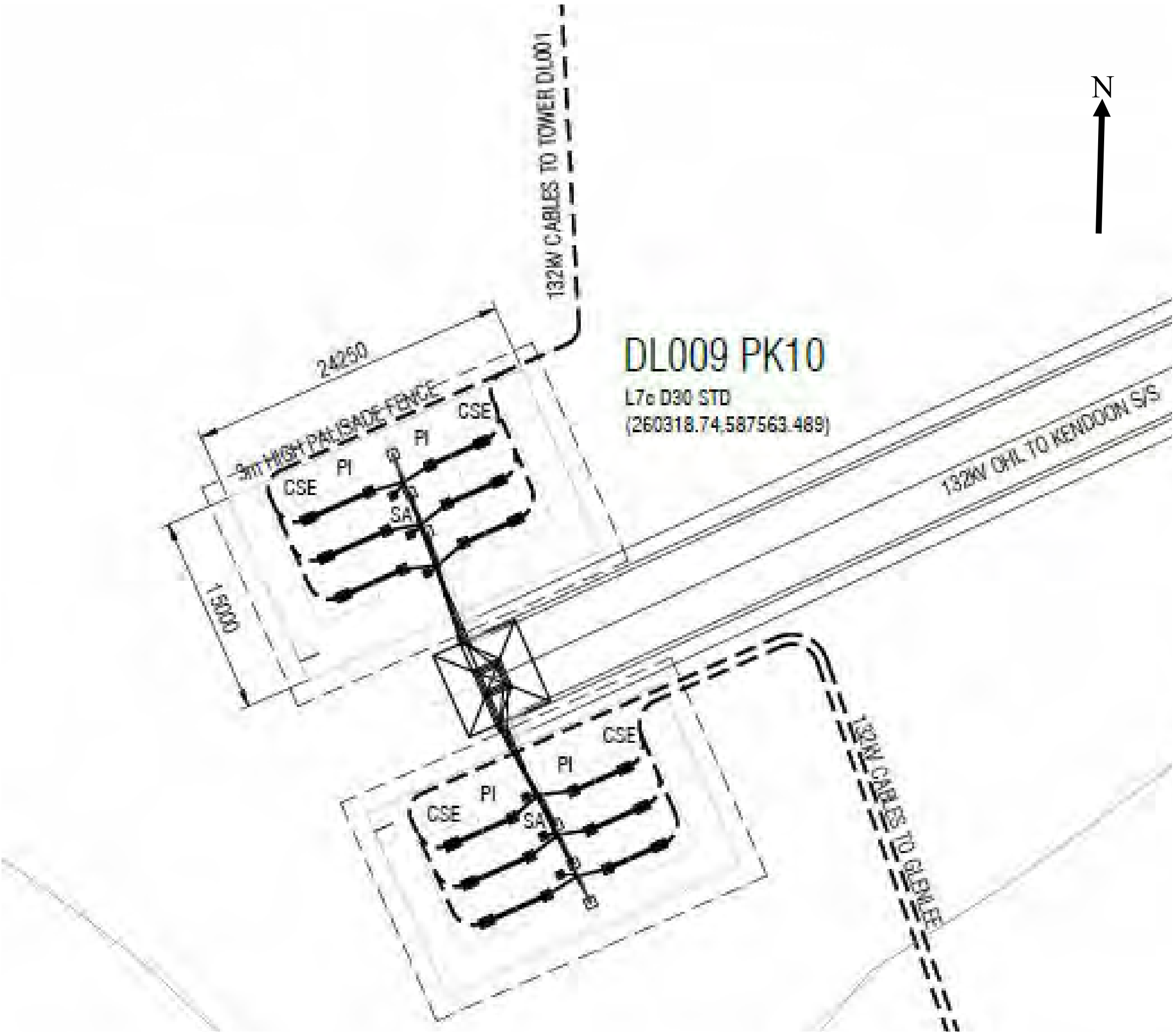
One of the key installation features of the UGC1 route are the sealing end compounds located at either end of the cable route. At the northern end of the cable route, the existing sealing end compound at Polquhanity would be extended to terminate the two new 132kV circuits running to Kendoon substation. Refer to Figure 52 which shows a draft layout for the sealing end compound extension. The extension area dimensions are approximately 16m x 16m.

Figure 52 Cable sealing end compound layout at Polquhanity



At the Kendoon substation end of the cable route, UGC1 terminates at terminal tower PK10, where a new cable sealing end compound would be required, refer to Figure 53. The proposed sealing end compound dimensions are given as 24.3m x 15m for each double circuit.

Figure 53 Cable sealing end compound at PK10



6.7.5 UGC1 Cable Section Lengths and Critical Joint Bay Locations

Based on the selected cable designs and the selected cable route for UGC1, Table 10 provides suggested cable section lengths based on the principles of a cross bonded cable system design and the cable section length constraints associated with the 65V standing voltage limit on the cable sheath detailed within section 3.2.3 of this report.

Where the standing sheath voltage limit is increased to 150V, as is the case for 275kV and 400kV cable systems then the section lengths could be essentially doubled to approximately 800m, which would halve the number of joint bays required for UGC1. However, allowing an increase in standing sheath voltage would require a robust risk assessment process to be completed to ensure safety from the cable system is maintained.

Table 10 UGC1 cable section lengths

Section No.	Joint Bay No.	Chainage (km)	Section Length (m)	Bonding		Installation Description
N/A	Tower N230	0.00	N/A	N/A		N230 sealing end compound
1	½	0.40	400	Major section	Minor section	Carriageway adjacent to layby
2	2/3	0.80	400		Minor section	Carriageway adjacent to layby
3	¾	1.20	400		Minor section	Carriageway adjacent to layby
4	4/5	1.60	400	Major section	Minor section	Carriageway
5	5/6	2.0	400		Minor section	Carriageway – potential land available in the verge
6	Tower PK10	2.40	400		Minor section	PK10 sealing end compound
OHL	Kendoon S/S	2.93	530	OHL		Kendoon S/S

The joint bay positions where possible have been aligned with sections of the carriageway that contain either a layby or are wider due to the inclusion of a verge, with joint bay 4/5 being the only exception to this. Figure 54 provides a typical cross section for a joint bay installed within a carriageway with a verge.

Figure 54 Typical cross section for a joint bay installed within a carriageway with a verge

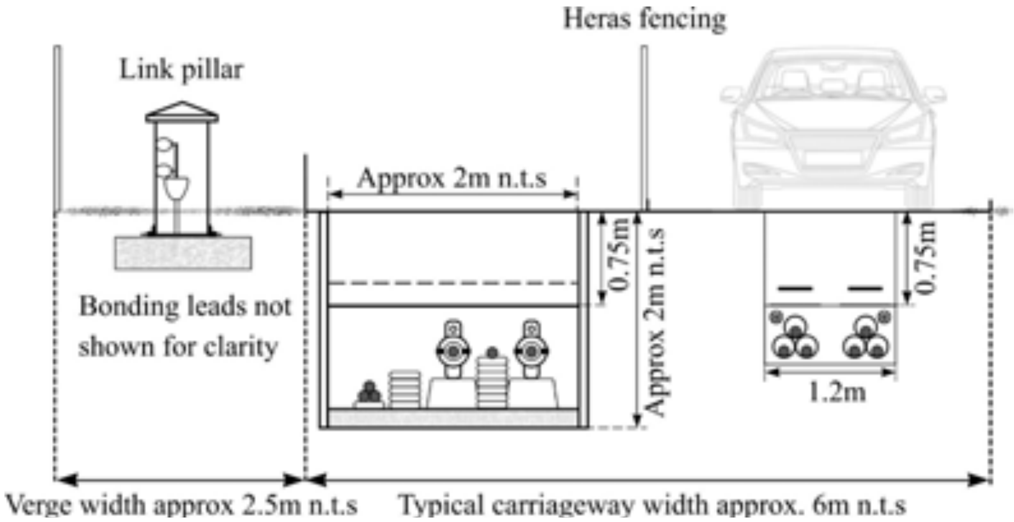
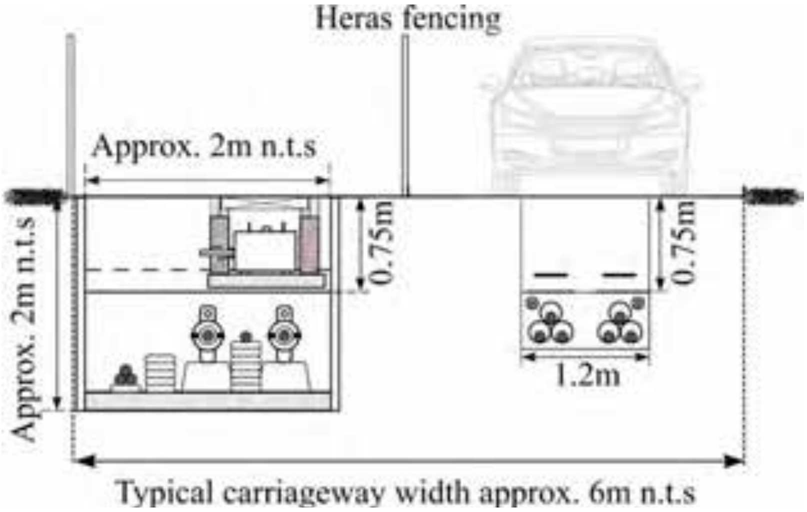


Figure 55 provides a typical cross section for a joint bay installed within a carriageway with no verge.

Figure 55 Typical cross section for a joint bay installed within a carriageway with no verge



All activities on the highways will require traffic management in accordance with National requirements and with the agreement of stake holding authorities.

6.7.6 UGC1 Outline Construction Programme

Based on the cable system design information discussed within this study, CCI have developed an outline construction programme for the UGC1 cable route. Refer to Table 11. This programme states the critical path construction and installation activities and provides duration estimates for each. From this, an approximate duration to complete the UGC1 works has been derived given in weeks.

Table 11 UGC1 critical path programme

Critical Path Activity	Critical Path Duration (weeks)
Mobilisation	1.4
Enabling, civil and reinstatement works	13
Cable installation and jointing works	6.5
HV testing and commissioning	1.4
Demobilisation and site clearance	1.4
Total Duration	**23.7**

The durations are a critical path estimate based on up to 2 installation teams and 2 reinstatment teams working simulaneously along different sections of the route. These civil teams would be supported jointing teams working to make off the cable joints and terminations.

6.8 UGC2 Kendoon Substation to Glenlee Substation

The UGC2 cable route discussed here was developed and selected through an optioneering process detailed within the Kendoon – Tongland 132kV Preliminary Investigative Cable Route Study ER1003 Rev C[11]. Since the completion of cable study ER1003, two changes to the UGC2 route have been identified. These modifications were as a result of site visits subsequent to the issue of ER1003 rev B in July 2019. These changes include:

- Diversion of the cable route from the A713 onto the old road bridge at Polharrow burn
- The cable route remaining in the A713/A762 at Earlstoun power station, due to the technical difficulties associated with the planned diversion to the eastern side the Water of Ken at Allangibbon Bridge.

The impact of these changes would be to shorten the cable route by approximately 100m.

The UGC2 cable route starts at the cable sealing end compound at Tower PK10, adjacent to Kendoon substation, heads southeast across arable/pastoral land before following the A713 south, past Carsfad Loch and Earlstoun Loch. South of Earlstoun Loch the cable route continues down the A762, passing Earlstoun power station before leaving the carriageway south of Craigubble wood and heading southwest across arable/pastoral land and terminating in a proposed cable sealing end compound at Tower PK33.

Table 12 contains points of engineering difficulty and environmental sensitivity identified along the route, with each item number marked in red circles in Figure 56 and Figure 57.

Table 12 UGC2 key points of engineering difficulty and environmental sensitivity

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
1	Termination tower at PK10	Civil engineering difficulties associated with the construction of a cable termination compound at PK10. Micro-routing would be required between the A713 and tower PK10 to ensure the most suitable cabling route were selected. 
2	Peat	Peat habitats between PK10 and the A713. Peat ground preparation work may be required. This may also impact on cable conductor material and size.
3	Cabling within A713	Cables to be installed within A713. An appropriate traffic management plan would need to be developed and adopted with joints and link equipment located in the road verge where practicable.
4	Burn crossings adjacent to tower PK11	A deep burn crossing adjacent to tower PK11 that will require trial holes to establish the exact depth of the existing crossing. The new cable circuit would then be installed over it, depth allowing.
5	Peat	Peat habitats next to the A713, alongside the cable route, adjacent to tower PK12. Peat ground preparation work may be required. This may also impact on cable conductor material and size.
6	Residential property and Peat at Stroangassel	Residential property and peat habitats adjacent to the A713 and the cable route at Stroangassel. Peat ground preparation work may be required. This may also impact on cable conductor material and size.

<table>
<tr><th>Item No.</th><th>Points of Engineering Difficulty and Environmental Sensitivity</th><th colspan="2">Comment</th></tr>
<tr><td>7</td><td>Burn crossing at north of Owlet Knowe</td><td></td><td>A deep burn crossing north of Owlet Knowe, comprising a retaining wall to the eastern side of the A713 and culvert. The crossing will require trial holes to establish its exact depth. The new cable circuit would then be installed over it, depth allowing.</td></tr>
<tr><td>8</td><td>Burn crossing at Owelet Knowe</td><td></td><td>An unnamed burn crossing at Owelet Knowe comprising a shallow duct crossing that will require trial holes to establish the exact depth of the existing pipe. The new cable circuit would then be installed under it and the duct replaced.</td></tr>
<tr><td>9</td><td>Archaeological sensitive area</td><td colspan="2">West of the A713 and alongside the cable route, an archaeological sensitive area is located at Owlet Knowe, adjacent to Carsfad Loch.</td></tr>
<tr><td>10</td><td>Native woodlands at Carsfad Loch</td><td colspan="2">A native woodland is situated between the A713 and Carsfad Loch to the east, alongside the cable route.</td></tr>
</table>

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
11	Flood zone	The A713 and the cable route pass through a medium likelihood (1 in 200 years) flood zone at the southern end of Carsfad Loch.
12	Carsfad dam and Power Station	Carsfad dam and hydroelectric Power Station are located either side of the A713, alongside the cable route. Infrastructure relating to this could be located within the carriageway. Residential properties are also noted at this location.
13	Peat, non-inventory designed landscapes ancient and native woodlands	Peat habitats west of the A713 south of Carsfad Loch, alongside the cable route. Peat ground preparation work may be required. This may also impact on cable conductor material and size. Non-inventory designed landscapes are located west of the A713 along with ancient woodlands at Knocknalling Wood. Native woodlands were also noted to the east of the A713. These features are all located alongside the cable route.
14	Flood zone	The A713 passes through a medium likelihood (1 in 200 years) flood zone at the south of Carsfad Loch, associated with the Water of Ken.
15	Polharrow burn crossing	Polharrow burn crossing; options to use the old road bridge as a cable bridge, with the cables installed on the old bridge within surface mounted troughs. Old road bridge is a category B listed structure. Alternatively a self-supporting cable bridge or cable bridge mounted to the side of the current carriageway bridge could be considered. Scarring on the carriageway surface was noted at Polharrow burn suggestive of buried services. 

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
16	Peat, native woodlands at Polharrow Bridge	Peat habitats west of the A713 at Polharrow Bridge. Peat ground preparation work may be required. This may also impact on cable conductor material and size. Native woodlands were noted to the west of the A713.
17	Listed Building south of Polharrow Bridge	The cable route passes close to a category B listed building located east of the A713, south of Polharrow Bridge.
18	Unnamed burn crossing	 2 x unnamed burn crossings at the northern end of Earlstoun Loch, within a section of elevated carriageway. Each burn will require trial holes to establish the exact depth of the existing crossings. The new cable circuit would then be installed over it, depth allowing.
19	Ancient and native woodlands at White Hill	The A713 and the cable route dissects an area of ancient woodlands to the west and ancient and native woodlands to the east at White Hill. The area of ancient and native woodlands continue south to Fairy Knowe and the Earlstoun dam.

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment	
20	Services in verge adjacent to Earlstoun Loch		BT services were observed running in the verge of the A713 on the eastern side of the carriageway. In places the ducts containing these services were exposed.
21	Unnamed burn crossing		5 x unnamed burn crossings spanning the central to southern end of Earlstoun Loch, within a section of elevated carriageway. Each burn will require trial holes to establish the exact depth of the existing crossing. The new cable circuit would then be installed over them, depth allowing.

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
22	Earlstoun dam crossing	 Earlstoun dam is crossed by the A713. A self-supporting cable bridge, or bridge supported by the existing road bridge would be required. The bridge deck was noted to be too shallow to install cables within it. Additional infrastructure relating to the dam may be located within the carriageway.
23	Native woodlands	The cable route crosses areas of native woodland south of Earlstoun Dam that extend south to Allangibbon Bridge.
24	Crossing of the A713 and A762	Disruption associated with cabling across an A-road intersection. Appropriate traffic management plan would need to be developed and adopted. Two category B listed buildings which are located on the A762 adjacent to the Power Station and several residential properties lay close to Earlstoun Dam.
25	Cabling within a flood zone	The cable route passes through a medium (1 in 200 year) flood risk zone on the western bank of the Water of Ken.
26	Native woodlands	Native woodland is located on the western bank of the Water of Ken. Peat habitats are located west of the A762. Crossing peat ground, if required, could impact on cable conductor material and size.

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
27	Earlstoun Power Station Bridge crossing	 Earlstoun Power Station Bridge is crossed by the A762. A standalone cable bridge, or bridge supported by the existing road bridge would be required, as the bridge deck was noted to be too shallow to install cables within it. Additional infrastructure relating to the power station could be located within the carriageway.
28	Flood risk zones	The A762 and cable routes pass close to a medium (1 in 200 year) and low (1 in 1000 year) flood risk zone at Covenanters' Grave.
29	Private water supply zone of interest	The cable route passes through a private water supply 'zone of interest' at tower PK33.
30	Burn crossing	 Unnamed burn crossing at Craiggubble wood. The crossing will require trial holes to establish the exact depth of the existing crossing. The new cable circuit would then be installed over it, depth allowing.

31	Overhead services	The cable route passes under several existing OHL routes feeding into Glenlee substation. 
32	Peat	Peat habitats adjacent to PK33. Peat ground preparation work may be required. This may also impact on cable conductor material and size.
33	Termination tower at PK33	Civil engineering difficulties associated with the construction of a cable termination position at PK33.

Figure 56 Black line showing cable route UGC2 (map 1 of 2)

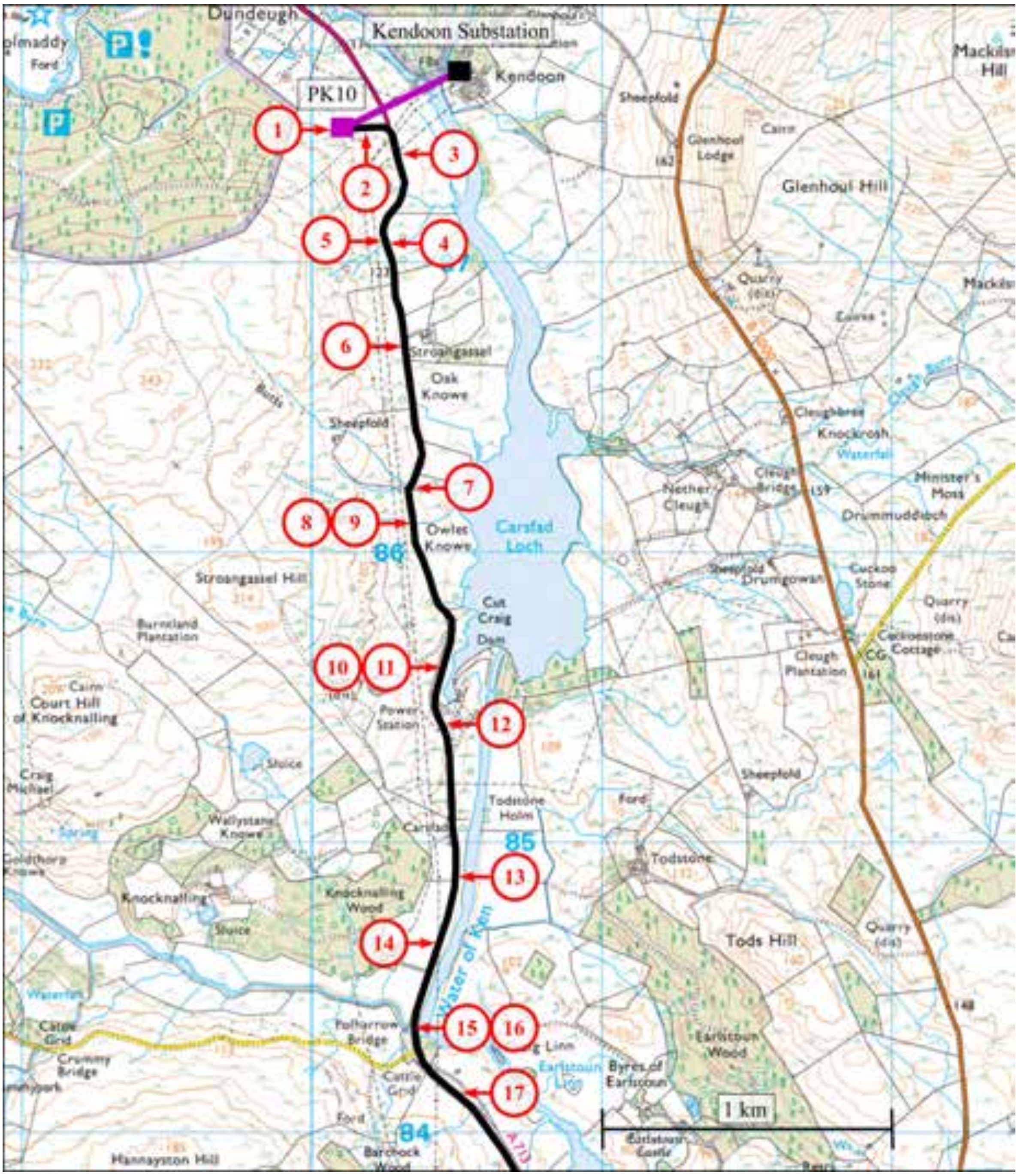
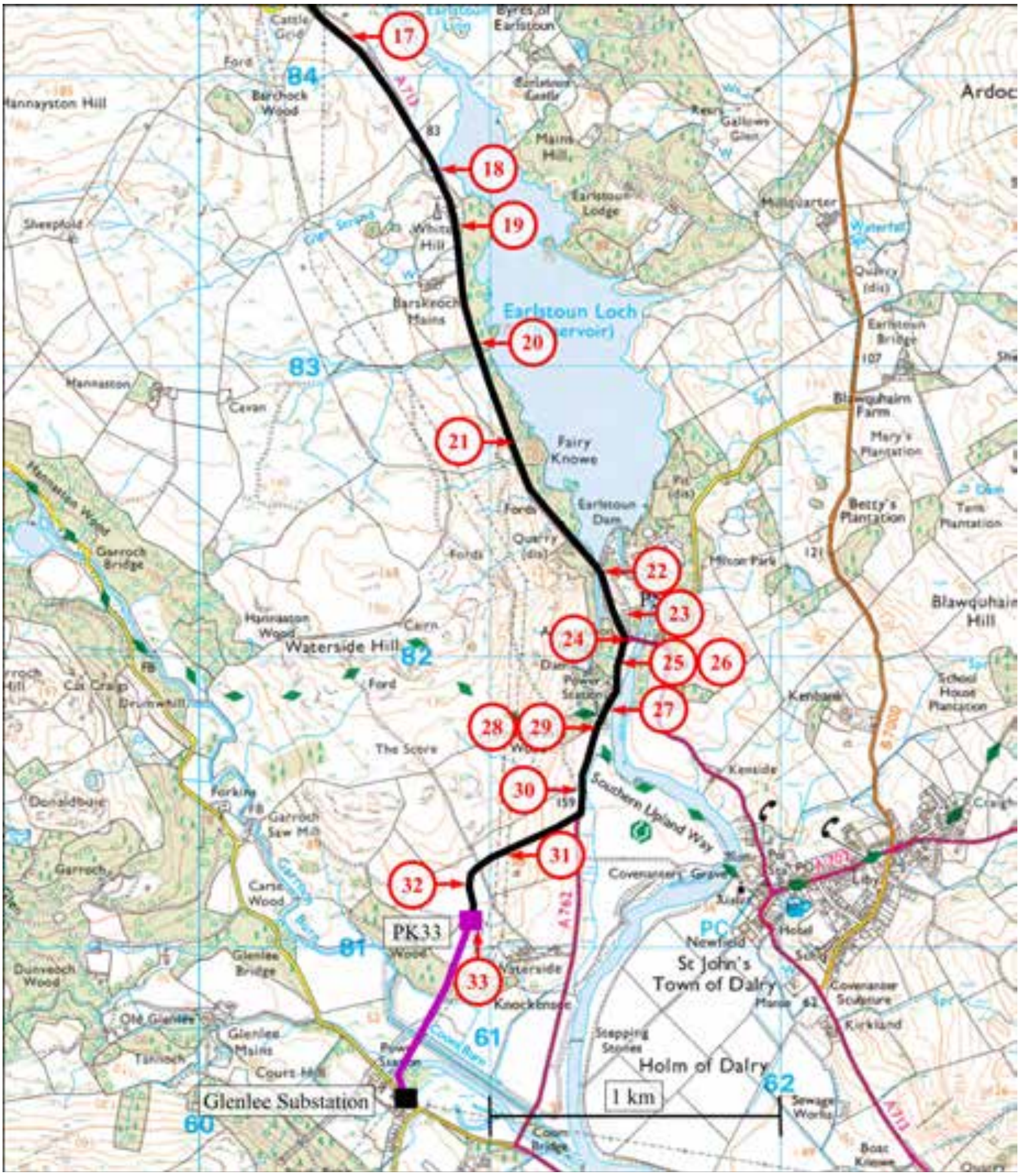


Figure 57 Black line showing cable route UGC2 (map 2 of 2)



6.8.1 UGC2 Typical Installation Swathes

UGC2 cable route would be approximately 8.33km long, of which 7.20km would be buried cable comprising two main types of installation swathe:

- Installation within arable/pastoral land (0.9km)
- Installation within the carriageway (6.3km)

Figure 8 on page 26 shows a typical double circuit arable/pastoral land swathe.

Figure 49 on page 79 shows a typical double circuit carriageway installation. Whereby first the left hand lane would be closed and a circuit comprising 6 cables would be installed. Once complete, the right hand lane would be closed and a second circuit comprising 6 cables would be installed. This approach would be likely to require extensive traffic management and a two pass installation process.

6.8.2 UGC2 Haul Road Requirements

Haul roads would be required at various locations along the UGC2 cable route to enable both labour, plant and material access during the construction phase of the project, and to allow future maintenance and fault repair work to be carried out. Refer to section 4.1.4 of this report for additional information on typical haul road layouts.

Table 13 provides anticipated location and length of the haul road requirements for UGC2.

Table 13 UGC2 haul road requirements

Haul Road Location and Type Temporary (T) or Permanent (P)	Approximate Haul Road Length (m)
From PK10 to the A762 for cabling access and access to the termination position (T)	300
From PK33 to the A762 for cabling access and access to the termination position (T)	600
Total Haul Road Requirement for UGC2	900

6.8.3 UGC2 Crossing Schedule

Table 14 gives the crossing schedule for UGC2. From this schedule, key crossings have been highlighted in red and discussed further.

Table 14 UGC2 crossing schedule

Crossing No.	GPS Crossing Location	Crossing Description	Proposed Crossing Solution
1	55° 09' 32.5" N 4° 11' 41.2" W	Burn adjacent to tower PK11	Replace existing duct and cable over
2	55° 09' 2.329" N 4° 11' 34.98" W	Burn north of Owlet Knowe	Replace existing duct and cable over
3	55° 8' 57.92" N 4° 11' 34.47" W	Burn at Owlet Knowe	Replace existing duct and cable under
4	55° 8' 17.60" N 4° 11' 32.64" W	Polharrow Burn	Cable bridge within old road bridge, standalone cable bridge or supported by current road bridge.
5	55° 7' 40.41" N 4° 11' 4.559" W 55° 7' 21.02" N 4° 10' 55.55" W	2 x Burns at northern end of Earlstoun Loch	Cable over
6	From 55° 6' 56.73" N 4° 10' 30.86" W to 55° 7' 20.68" N 4° 10' 55.65" W	5 x Burns spanning the central and southern end of Earlstoun Loch	Cable over
7	55° 6' 56.15" N 4° 10' 31.39" W	Earlstoun Dam	Cable bridge supported by road bridge or standalone cable bridge
8	55° 6' 42.75" N 4° 10' 26.34" W	Earlstoun Power Station Bridge	Cable bridge supported by road bridge or standalone cable bridge
9	55° 6' 32.93" N 4° 10' 31.89" W	Burn at Craigubble wood	Replace existing duct and cable over

UGC2 has three significant watercourses to cross, Polharrow Burn, Earlstoun Dam and at Earlstoun Power Station. An option to try to avoid Earlstoun Power Station Bridge was considered which included crossing to the eastern side of the River Ken. However, the challenges of crossing or bridging the river on or alongside the Allangibbon Bridge over the river did not offer an easier cable route solution.

In addition to these significant watercourse crossings, there are eleven minor burns that will require crossing. The proposed solution for minor watercourses would be to duct and cable over or cable under depending on the depth of cover available. Refer to section 5.3 of this report for additional information of these proposed crossing methodologies.

6.8.3.1 UGC2 Water Crossings at Polharrow Burn, Earlstoun Dam and Earlstoun Power Station

12 cables could not be installed within the deck of the bridges at Polharrow Burn, Earlstoun Dam or Earlstoun Power Station owing to their shallow design, therefore alternative crossing solutions will need to be considered. Due to restrictions in accessible, open land either side of the bridges at each of these locations, HDD's are not considered feasible at this stage.

The remaining option for crossing each of these water features would be by cable bridge. However, due to the complexity of these crossings and the number, and size of cables required, these are likely to prove challenging both technically and financially to achieve.

For Polharrow Burn, several options are viable. Either a standalone cable bridge or cable bridge supported by the current road bridge could be considered. In addition, a disused former road bridge was also identified adjacent to the A713. Refer to Figure 58 below. The former road bridge has the potential to provide an ideal cable bridge solution if assessed as structurally sound and permitted to be used by the bridge and access-land owners. The cables could be installed on the bridge deck in a filled trough arrangement that transitions either side back to its correct burial depth. However, this disused road bridge is noted to be a category B listed structure, and therefore an acceptable design for use as cable bridge may not be straightforward. In addition, the use of a surface trough installation would require special consideration to ensure regulatory compliance with the ESQC 2002 to ensure that the cables are adequately protected.

Figure 58 Polharrow Bridge

At Earlstoun Dam it is proposed that a self-supporting cable bridge be installed or one supported by the existing road bridge (Figure 59 below). Refer to section 5.3.3 of this report for examples and further discussion of cable bridges. Consideration of how the cables transition from a buried position in the ground to the cable bridge would be required, with existing structures associated with the dam potentially requiring alteration to accommodate the 12 new HV cables. Agreement from the bridge owners and relevant highway and planning authority would need to be sought. This crossing would require further consultation with stakeholders and development of a variety of cable support design options.

Figure 59 Road bridge at Earlstoun Dam

At Earlstoun Power Station, the road narrows to approximately 4.8m in the centre of the road bridge (Figure 60 below), with the outflow of the hydroelectric power station passing under the bridge. It would be proposed that a self-supporting cable bridge were installed, or one supported by the existing road bridge. Refer to section 5.3.3 of this report for examples and further discussion of cable bridges.

Consideration of how the cables transition from a buried position in the ground to the cable bridge would be required, with existing structures associated with the bridge potentially requiring alteration to accommodate the 12 new HV cables. Agreement from the bridge owners, power station operators, relevant highway and planning authority must be sought. This crossing would require further consultation with stakeholders and development of a variety of cable support design options.

Figure 60 Earlstoun Power Station Bridge

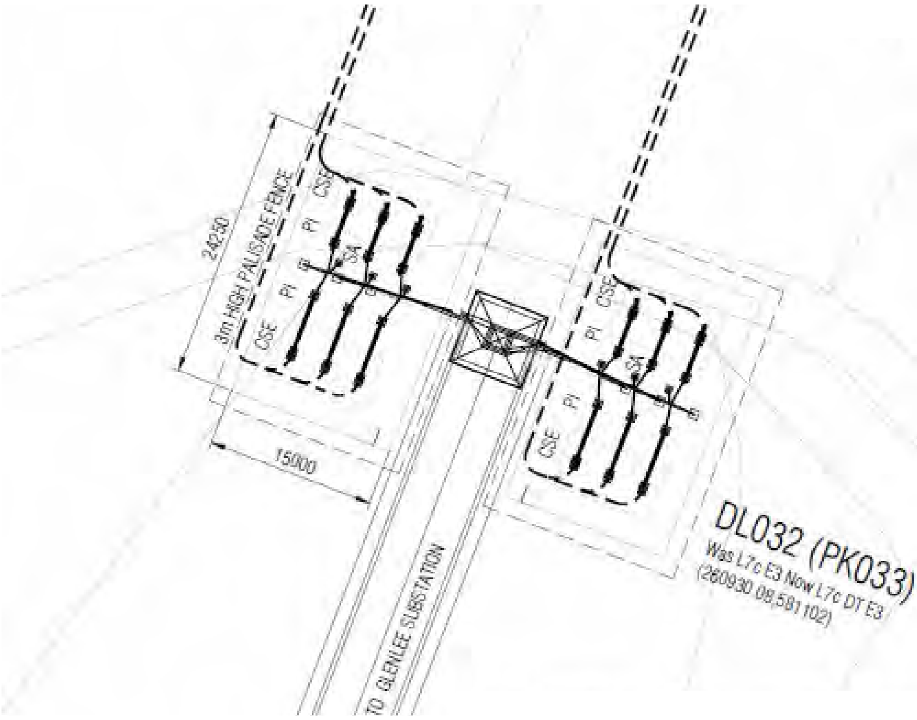
If one or more bridge crossings become impassable then consideration of a cable route to the West of the power stations following the overhead line may need to be considered. This alternative is not discussed or costed in this report.

6.8.4 UGC2 Cable Sealing End Compounds

UGC2 requires sealing end compounds located at either end of the cable route. At the Kendoon substation end of the cable route, UGC2 terminates at terminal tower PK10, where a new cable sealing end compound would be required. Refer to Figure 53 on page 84. The proposed sealing end compound dimensions are provisionally given as 24.3m x 15m for each double circuit.

At the Glenlee substation end of the cable route, a similar double circuit cable sealing end compound would be required at tower PK33, with the proposed compound dimensions provisionally given as 24.3m x 15m. Refer to Figure 61.

Figure 61 Cable sealing end compound layout at Glenlee substation.



6.8.5 UGC2 Cable Section Lengths and Critical Joint Bay Locations

Based on the cable designs selected and the preferred cable route for UGC2, Table 15 provides suggested cable section lengths based on the principles of a cross bonded cable system design which essentially requires balanced minor sections within a 3 cable major section. Joint bays that are considered to be critical have been highlighted in red.

Table 15 UGC2 cable section lengths

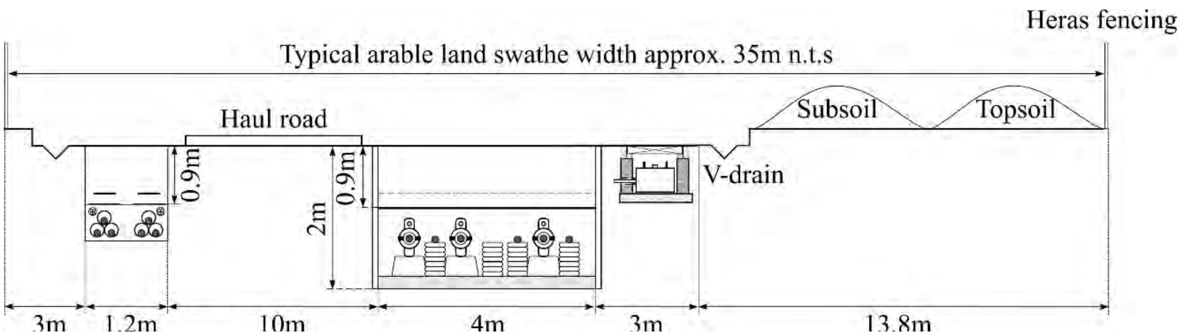
Section No.	Joint Bay No.	Chainage (km)	Section Length (m)	Bonding		Installation Description
N/A	Kendoon S/S	0	N/A	N/A		Kendoon S/S
OHL	Tower PK10	0.53	530	OHL		PK10 sealing end compound
1	1/2	1.13	600	Major section	Minor section	Carriageway
2	2/3	1.73	600		Minor section	Carriageway
3	3/4	2.33	600		Minor section	Carriageway
4	4/5	2.93	600	Major section	Minor section	Carriageway – close to Carsfad Power Station access
5	5/6	3.53	600		Minor section	Carriageway
6	6/7	4.13	600		Minor section	Polharrow Burn crossing – Carriageway
7	7/8	4.73	600	Major section	Minor section	Carriageway
8	8/9	5.33	600		Minor section	Carriageway
9	9/10	5.93	600		Minor section	Carriageway
10	10/11	653	600	Major section	Minor section	Earlstoun Dam crossing – Carriageway – Flood Plain
11	11/12	7.13	600		Minor section	Earlstoun Power Station crossing – Sloping arable/pastoral land
12	Tower PK33	7.73	600		Minor section	PK33 Sealing end compound
OHL	Glenlee S/S	8.33	600	OHL		Glenlee S/S

Joint bays within UGC2 fall within two installation types, installation within the carriageway or installation within arable/pastoral land. Figure 54 on page 85 provides a typical cross section for a joint bay installed within a carriageway with a verge.

Figure 55 on page 86 provides a typical cross section for a joint bay installed within a carriageway with no verge.

Figure 62 below provides a typical cross section for a joint bay installed within arable/pastoral land.

Figure 62 Typical cross section for a joint bay installed within arable/pastoral land



For the UGC 2 cable study, two critical joint bays have been identified, joint bay 10/11 and joint bay 11/12.

Joint bay 10/11 would be positioned within a medium (1 in 200 year) flood zone. It would be essential that for the duration of the jointing works the joint bay is kept dry and a clean working environment maintained. Water pump drainage sump positions within the joint bay concrete base slab would be used to remove ground water from joint bays, with pumps potentially required to run 24 hours a day, 7 days a week. Standby pumps may also be required in the event of a pump breakdown.

Joint bay 11/12 would be positioned on sloping arable/pastoral land adjacent to the A762. Efforts would be made to identify the most suitable position for a joint bay at this location, minimising the impact of the slope. However, consideration must be given for the inclusion of additional measures required to mitigate risk associated from cable migration down the slope. Refer to section 5.4 which discusses cable TMF and the design of cable installations on sloping ground.

6.8.6 UGC2 Outline Construction Programme

Based on the cable system design information discussed within this study, CCI have developed an outline construction programme for the UGC2 cable route. Refer to Table 16. This programme states the critical path construction and installation activities and provides duration estimates for each. From this, an approximate duration to complete the UGC2 works has been derived given in weeks.

Table 16 UGC2 critical path programme

Critical Path Activity	Critical Path Duration (weeks)
Mobilisation	1.4
Enabling, civil and reinstatement works	36.3
Cable installation and jointing works	16.2
HV testing and commissioning	1.4

Critical Path Activity	Critical Path Duration (weeks)
Demobilisation and site clearance	1.4
Total Duration	**56.7**

The durations are a critical path estimate based on up to 2 installation teams and 2 reinstatment teams working simulaneously along different sections of the route. These civil teams would be supported by jointing teams working to make off the cable joints and terminations.

6.9 UGC1 and UGC2 Polquhanity to Glenlee Substation

As described within section 6.6 of this report, this subcategory of UGC1 and UGC2 defines the proposed joint bay positions and cable section length for the single 132kV cable circuit running from Tower N230 at Polquhanity to Glenlee substation.

As this cable circuit follows the same route as UGC1 and UGC2 cable studies all the details relevant to this cable route are covered within the following sections of this report:

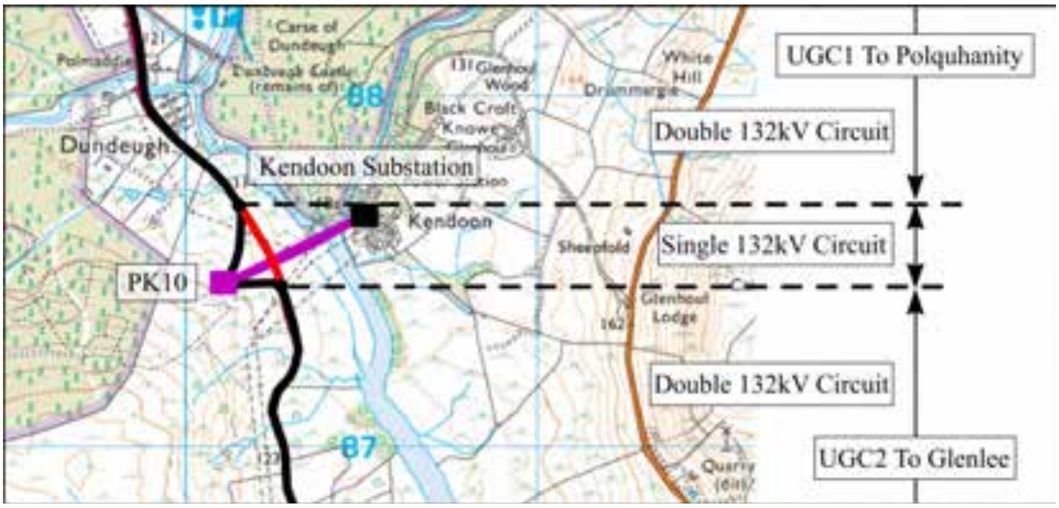
- Section 6.7 for UGC1
- Section 6.8 for UGC2

The cable route between Tower N230 at Polquhanity and Glenlee substation would be approximately 10.09km long, of which 9.49km would be buried cable.

The route starts at the cable sealing end compound at Tower N230 in Polquhanity, heads southeast across arable/pastoral land before following the A713 south. It passes through Polmaddy and continues along the A713 past Kendoon substation, past Carsfad Loch and Earlstoun Loch. South of Earlstoun Loch the cable route continues down the A762, passing Earlstoun Power Station before leaving the carriageway south of Craigubble wood and heading southwest across arable/pastoral land and terminating in a proposed cable sealing end compound at Tower PK33.

Figure 63 shows the short section of the cable route, marked as a line in red, where the circuit would be installed as single circuit, with the other related circuits terminating at tower PK10. The purple line is OHL into Kendoon substation.

Figure 63 Section of single circuit connecting Polquhanity to Glenlee substation



6.9.1 UGC1 and UGC2 Cable Section Lengths and Critical Joint Bay Locations

Based on the selected cable designs and the selected cable route between Tower N230 at Polquhanity and Glenlee substation, Table 17 provides suggested cable section lengths based on the principles of a cross bonded cable system design which essentially requires balanced minor sections within a 3 cable major section. Joint bays that are considered to be critical have been highlighted in red.

Table 17 UGC1 and UGC2 cable section lengths

Section No.	Joint Bay No.	Chainage (km)	Section Length (m)	Bonding		Installation Description
N/A	Tower N230	0	N/A	N/A		N230 sealing end compound
1	1/2	0.63	630	Major section	Minor section	Carriageway – Potential land available in the verge
2	2/3	1.26	630		Minor section	Carriageway
3	3/4	1.89	630		Minor section	Carriageway
4	4/5	2.52	630	Major section	Minor section	Carriageway
5	5/6	3.15	630		Minor section	Carriageway
6	6/7	3.78	630		Minor section	Carriageway – Potentially close to a road section with several corners

Section No.	Joint Bay No.	Chainage (km)	Section Length (m)	Bonding	Installation Description	Section No.
7	7/8	4.41	630	Major section	Minor section	Carriageway
8	8/9	5.04	630		Minor section	Carriageway
9	9/10	5.67	630		Minor section	Polharrow Burn crossing – Carriageway
10	10/11	6.30	633	Major section	Minor section	Carriageway
11	11/12	6.94	633		Minor section	Carriageway
12	12/13	7.57	633		Minor section	Carriageway
13	13/14	8.21	640	Major section	Minor section	Earlstoun Dam crossing – Carriageway – Flood Plain
14	14/15	8.85	640		Minor section	Earlstoun Power Station crossing – Sloping arable/pastoral land
15	Tower PK33	9.49	640		Minor section	PK33 Sealing end compound
OHL	Glenlee S/S	10.09	600	OHL		Glenlee S/S

Joint bays between tower N230 at Polquhanity and Glenlee substation fall within two installation types, installation within the carriageway or installation within arable/pastoral land. Figure 54 on page 85 provides a typical cross section for a joint bay installed within a carriageway with a verge.

Figure 55 on page 86 provides a typical cross section for a joint bay installed within a carriageway with no verge. Figure 62 on page 105 provides a typical cross section for a joint bay installed within arable/pastoral land.

For the cable route between Tower N230 at Polquhanity and Glenlee substation, two critical joint bays have been identified, joint bay 13/14 and joint bay 14/15.

Joint bay 13/14 would be positioned within a medium (1 in 200 year) flood zone. It would be essential that for the duration of the jointing works the joint bay is kept dry and a clean working environment maintained. Sump positions within the joint bay concrete base slab are used to dewater joint bays, with pumps potentially required to run 24 hours a day, 7 days a week. Standby pumps may also be required in the event of pump breakdown. However, in the case of a serious flood, pumping is unlikely to be adequate and seasonal (Summer) installation is more likely to prove more effective.

Joint bay 14/15 would be positioned on sloping arable/pastoral land adjacent to the A762. Efforts would be made to identify the most suitable position for a joint bay at this location, minimising the impact of the slope. However, consideration must be given for the inclusion of additional measures required to mitigate risk associated from cable migration down the slope. Refer to section 5.4 which discusses TMF and slope design.

6.10 UGC3 Queen's Way Crossing

The UGC3 cable route discussed here was developed and selected through an optioneering process detailed within the Kendoon – Tongland 132kV Preliminary Investigative Cable Route Study ER1003 Rev C[11]. Since the completion of cable study ER1003, one change to the UGC3 route has been identified. This modification was as a result of site visits subsequent to the issue of ER1003 revision B in July 2019. This change relates to the cable route following the existing forest track on the southern side of the Queen's Way, rather than running parallel to the tracks as previously planned. It is considered that following the tracks will be easier to construct with fewer unknowns regarding ground conditions. The impact of this change would be to lengthen the cable route by approximately 130m.

The UGC3 cable route starts at tower GT08 and heads southeast, around the eastern flanks of Achie Hill to the Queen's Way crossing, avoiding areas containing peat habitats and outcropping rock. The approximate Queen's Way crossing location was selected as a position with minimal surface elevational change across the proposed HDD position for the Queen's Way crossing. The cable route would continue south around the east side of Peal Hill, following existing forest tracks where possible, before turning to the southwest and terminating at GT21.

Table 18 contains the points of engineering difficulty and environmental sensitivity identified along the route, with each item number marked in red circles on Figure 64.

Due to restricted access to land either side of the Queen's Way crossing, it has only been possible to assess this section of the cable route by desktop study. Access to the south side of the Queen's Way would be from the A712 with a haul road crossing Knocknairling Burn which runs parallel to the A road. This would also provide a northerly exit for all traffic working on the cable route between the A712 and the cable termination position at GT21.

Table 18 UGC3 key points of engineering difficulty and environmental sensitivity

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
1	Peat	Adjacent to tower GT08 the ground was noted to contain significant peat. Peat ground preparation work may be

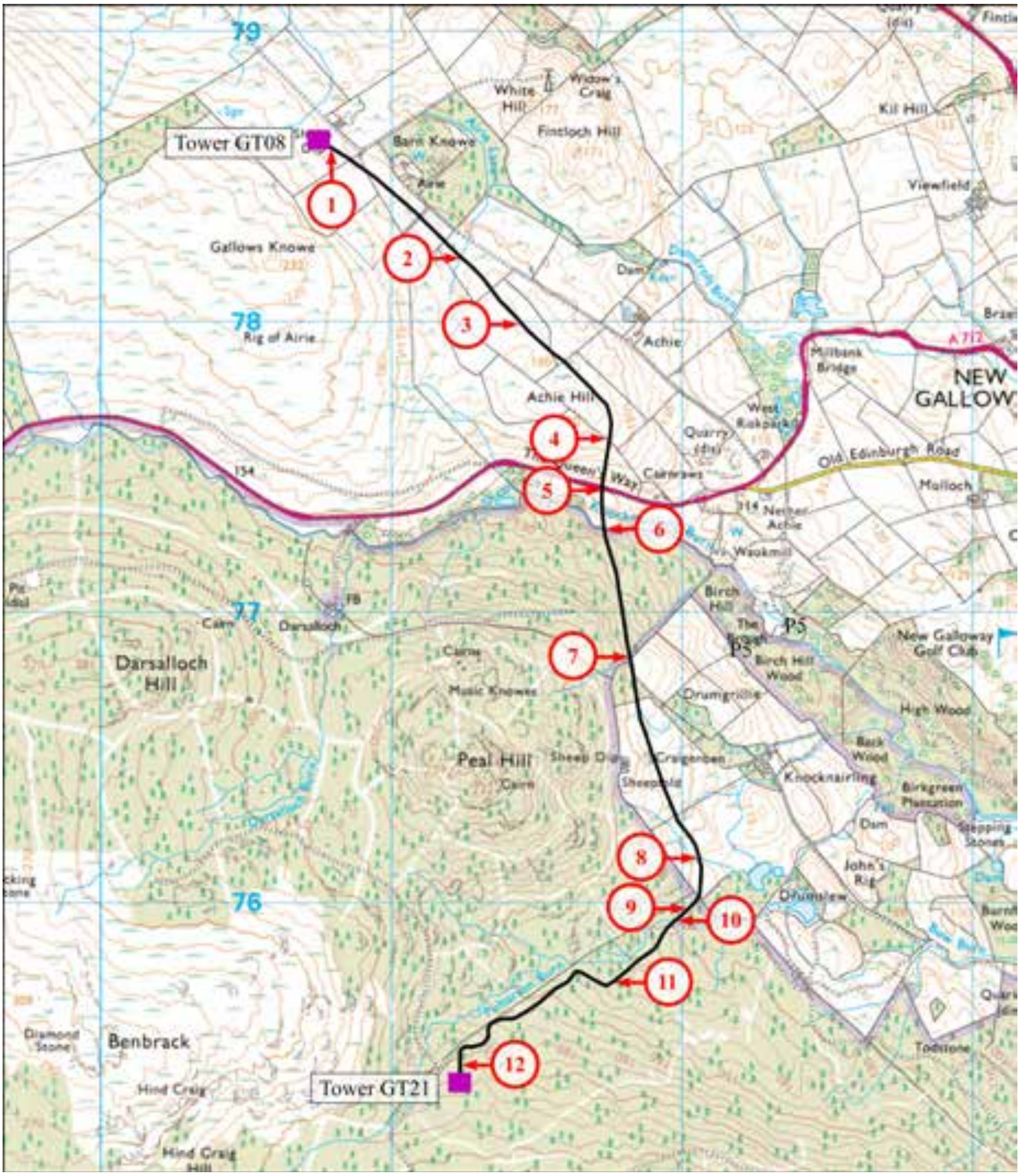
Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
		required. This may also impact on cable conductor material and size. Tower GT08 is within a private water supplies zone of interest.
2	Burn crossing	Unnamed burn will require crossing south of Barn Knowe and Airie farmhouse. The crossing will require trial holes to establish the exact depth of the existing crossing. The new cable circuit would then be installed over it, depth allowing. 
3	Shallow rock	The cable route bypasses rocky outcrops on the hill side north of the A712.
4	Significant changes in elevation	Steep undulations within the topography from the hill locations either side of the valley containing the A712, that may require cable anchoring systems to be designed and installed to minimise migration of the cable down a slope over the long term. 

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
5	Crossing of A712	HDD crossing under Queen's Way (A712) would be required with launch and reception pit identification to be developed. This HDD would pass through native woodland areas and medium (1 in 200 year) flood risk zones. 
6	Knocknairling Burn crossing	HDD or dam and pump over crossing of burns and any associated tributaries adjacent to Peal hill would be required. Medium flood risk zone (1 in 200 years) is located adjacent to the burn. 
7	Burn crossing	Burn crossing east of Music Knowes. The burn will require trial holes to establish the exact depth of the existing crossing. The new cable circuit would then be installed over it, depth allowing.

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
8	Burn crossing	Burn crossing west of Drumslew. The burn will require trial holes to establish the exact depth of the existing crossing. The new cable circuit would then be installed over it, depth allowing.
9	Dense forest	Tree and stump clearing works would be required when cabling through forestry, temporary access roads would need to be constructed during the installation and for future maintenance. There is a potential to HDD this section along with the adjacent burn. 
10	Pultarson Burn crossing	Burn crossing by either dam and pump over or by HDD, with the option to extend the HDD to cross the dense forest section adjacent to the burn.

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
		
11	Heavy forestry machinery	Risk to the cable being traversed and damaged by heavy forestry machinery for all forestry shown on the map. The cable route passes through a section of native woodland southwest of Peal Hill.
12	GT21 located in dense forest	Tower GT21 is located in dense forest that includes areas of peat habitats which will require clearing to enable access with temporary access roads constructed during the installation and for future maintenance. 

Figure 64 Black line showing cable route UGC3



6.10.1 UGC3 Typical Installation Swathes

UGC3 cable route would be approximately 4.33km long all of which would be buried cable comprising two main types of installation swathe:

- Installation within arable/pastoral land (2.16km)
- Installation within forests (2.17km)

Figure 8 on page 26 shows a typical double circuit arable/pastoral land swathe, approximately 32m wide.

Two types of forest cable swathe have been considered; width constrained and width unconstrained by topographic features.

Figure 9 on page 27 provides a schematic of a constrained width forest cable swathe, where the existing forest track would be used to install the cable circuits, with installation teams working systematically from one direction. Passing points for vehicles and plant would be established where possible.

Figure 10 on page 28 provides typical cable swathes for an unconstrained width forest installation swathe.

Within the forest and woodland sections of the cable routes, where there would be a perceived risk of heavy duty commercial logging vehicles operating on top of the cables, the cables would be enclosed within concrete rather than CBS.

6.10.2 UGC3 Haul Road Requirements

Haul roads would be required at various locations along the UGC3 cable route to enable both labour, plant and material access during the construction phase of the project, and to allow future maintenance and fault repair work to be carried out. Refer to section 4.1.4 of this report for additional information on typical haul road layouts.

Table 19 provides anticipated location and length of the haul road requirements for UGC3.

Table 19 UGC3 haul road requirements

Haul Road Location and Type Temporary (T) or Permanent (P)	Approximate Haul Road Length (m)
From GT08 to Queen's Way for cabling access, access to the termination position and access for the HDD crossing of the Queen's Way (T)	2,160
From GT21 to Queen's Way for cabling access, access to the termination position and access for the HDD crossing of the Queen's Way (T)	2,170
Total Haul Road Requirement for UGC3	4,330

It is anticipated that temporary haul roads would be required for the entire UGC3 route, specifically to the south of the Queen's Way crossing where the cable route passes into forestry land. Existing access routes in this area are limited, so it is envisaged that a temporary haul road including a temporary bridge crossing at the Knocknairling Burn and at the Pultarson Burn would be required to provide access from the Queen's Way to the existing forest tracks and GT21.

6.10.3 UGC3 Crossing Schedule

Table 20 gives the crossing schedule for UGC3. From this schedule, key crossings have been highlighted in red and discussed further.

Table 20 UGC3 crossing schedule

Crossing No.	GPS Crossing Location	Crossing Description	Proposed Crossing Solution
1	55° 04' 33.99" N 4° 10' 9.04" W	Burn north of Queen's Way	Duct and cable over
2	55° 04' 19.57" N 4° 10' 4.46" W	Queen's Way Crossing	200m HDD
3	55° 04' 13.59" N 4° 10' 50.85" W	Knocknairling Burn	50m HDD
4	55° 04' 00.7" N 4° 09' 55.7" W	Burn east of Music Knowes	Duct and cable over
5	55° 03' 38.6" N 4° 09' 41.4" W	Burn west of Drumslew	Duct and cable over
6	55° 03' 31.4" N 4° 09' 44.3" W	Pultarson Burn	50m HDD

UGC3 has one significant road crossing, at the Queen's Way for which an HDD solution would be proposed.

In addition to this major crossing, there are five more minor burns that will require crossing. The proposed solution for minor watercourses would be a combination of HDD and to duct and cable-under, refer to section 5.3 of this report for additional information of these proposed crossing methodologies.

6.10.3.1 UGC3 HDD Launch and Reception Compound Positions

The footprint of the HDD compounds would vary depending on the length, depth, complexity of the specific HDD and location along the cable route, but typically a drill launch site compound would measure approximately 30m x 30m, and a drill reception site compound 20m x 20m. Additional information is provided in section 5.3.4 of this report.

The launch and reception positions for each HDD along the UGC3 cable route have been identified and photographs showing their locations along with a brief description are provided in Table 21.

Table 21 UGC3 HDD launch and reception positions

HDD Description	Photograph
Queen's Way, HDD length is approximately 200m. Launch and reception positions were identified on the northern and southern sides of the carriageway in arable/pastoral land. Access onto the Queen's Way would require temporary haul road construction.	

HDD Description	Photograph
Knocknairling Burn, HDD length is approximately 50m. Launch and reception positions were identified in arable/pastoral land to the north and forestry land to the south. Substantial temporary haul roads would be required, bridging the burn, to allow access to the forest section of the route including GT21 to the south of the Queen's Way.	
Pultarson Burn, HDD length is approximately 50m. Launch and reception positions were identified in forestry land to the north, with the southern position falling within an existing forestry track. Substantial temporary haul roads would be required, bridging the burn, to allow access to the forest section of the route including GT21.	

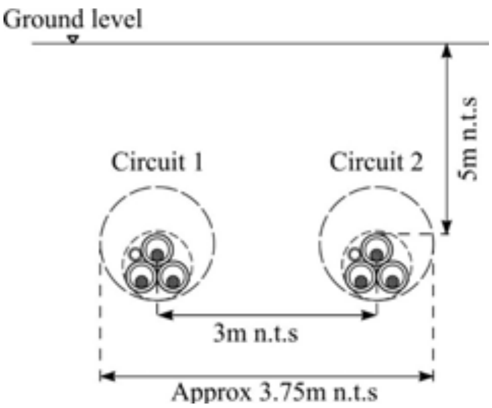
6.10.3.2 UGC3 Queen's Way Road Crossing

With 3 cables per circuit, an HDD formation would comprise 2 trefoil groups. The spacing between each trefoil group would be dictated by the depth the HDD profile needs to achieve to clear the carriageway foundations. Figure 41 on page 61 shows the relationship between burial depth and circuit spacing for two cable types: 1600mm² aluminium and 1600mm² copper.

At a nominal burial depth of 5m for 1600mm² aluminium XLPE cable, Figure 41 on page 61 gives a minimum centre to centre spacing between each circuit as approximately

0.85m, based on a PE duct OD of 250mm, each trefoil duct group would be strapped together in formation and installed within a bore diameter of approximately 750mm. However to ensure the structural integrity of both bores, a greater centre to centre bore separation of 3m has been considered here. Figure 65 provides a cross section of this HDD arrangement and provides an indicative swathe width of approximately 3.75m for a drill depth of 5m. Guidance should be sought during the planning and consents stage of the works to ascertain the clearance requirements for each planned crossing location.

Figure 65 HDD cross section at Queen's Way Crossing



6.10.4 UGC3 Termination Towers

Towers with an elevated sealing end platform (sealing end platform attached to the tower body) would be required at both ends of this route at tower position GT08 and GT21. Tower position GT08 is noted to be situated in a peat habitat and within a private water supplies zone of influence. These would likely necessitate civil works to make the ground suitable for construction. In addition, both tower positions would likely require some levelling work and temporary haul road access to be constructed. Figure 31 on page 48 is an example of a typical double circuit terminal tower with an integrated sealing end platform.

6.10.5 UGC3 Cable Section Lengths and Critical Joint Bay Locations

Based on the selected cable designs and the selected cable route for UGC3, Table 22 provides suggested cable section lengths based on the principles of a cross bonded cable system design which essentially requires balanced minor sections within a 3 cable major section. Joint bays that are considered to be critical have been highlighted in red.

Table 22 UGC3 cable section lengths

Section No.	Joint Bay No.	Chainage (km)	Section Length (m)	Bonding		Installation Description
N/A	Tower GT08	0.00	N/A	N/A		Terminal tower GT08
1	½	0.72	720	Major section	Minor section	Arable/pastoral
2	2/3	1.44	720		Minor section	Peat/arable/pastoral
3	¾	2.16	720		Minor section	HDD under the Queen's Way – sloping land
4	4/5	2.88	723	Major section	Minor section	Arable/pastoral
5	5/6	3.61	723		Minor section	Forest track – protection from forestry vehicles required
6	Tower GT21	4.33	723		Minor section	Terminal tower GT21

Joint bays within UGC3 fall within two installation types, installation within arable/pastoral land and installation within forest track.

Figure 66 shows a typical cross section for a joint bay installed within in an arable/pastoral swathe.

Figure 66 Typical cross section for joint bay installed within arable/pastoral land

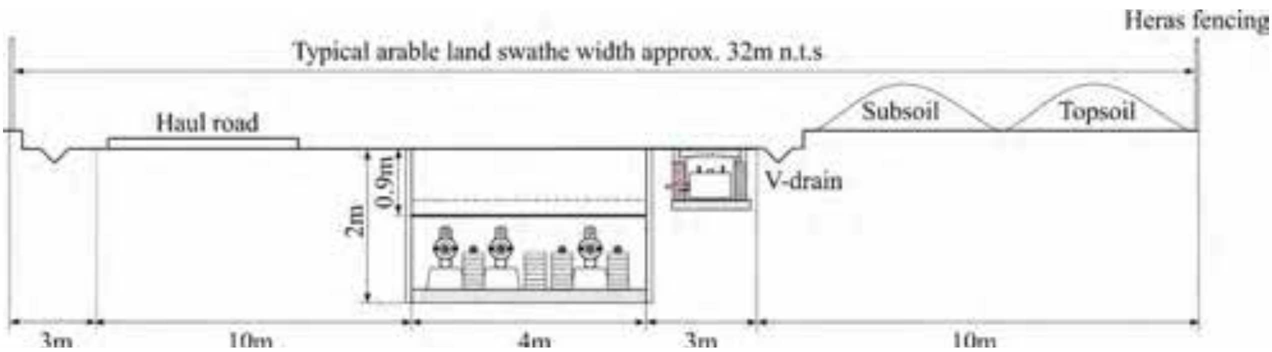
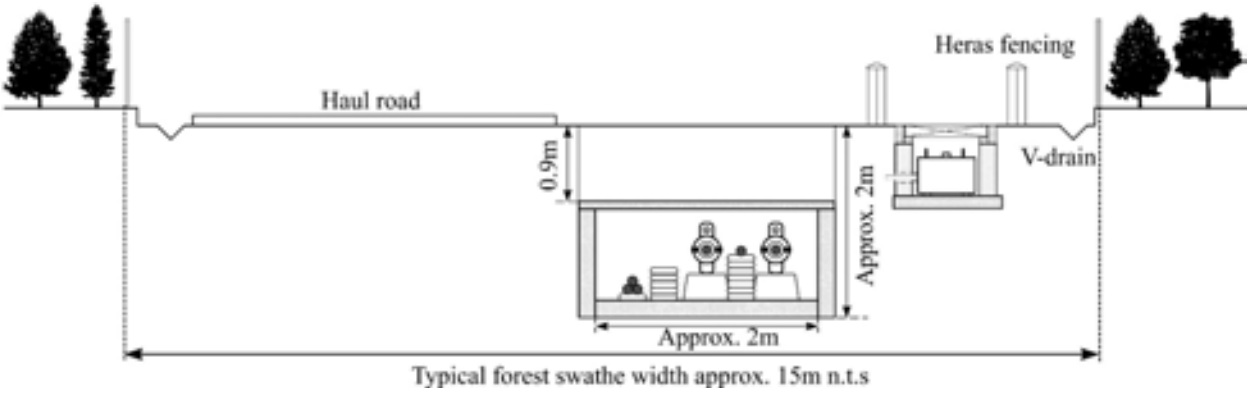


Figure 67 shows a typical cross section for a joint bay installed within a forest swathe.

Figure 67 Typical cross section for joint bay swathe installed within forestry



For the UGC 3 cable study, two critical joint bays have been identified, joint bay ¾ and joint bay 5/6. Both joint bays may require additional measures to be taken to ensure protection from forestry vehicles that operate in the forestry commission areas. It is proposed that consideration be given to the joints being installed within reinforced concrete troughs for protection, with concrete duct blocks utilised where cables cross forest access tracks or are at risk of heavy forestry machinery operating overhead.

Figure 28 on page 45 shows a typical reinforced joint bay proposed for use within commercially managed forests. The cables and joints are supported on sandbags and would be backfilled within the reinforced concrete chamber with a reinforced concrete lids placed over the top to provide additional mechanical protection. Above the chamber suitable excavation arising's, subsoils and topsoils would be used to complete the reinstatement process. The forest swathe would be relatively narrow to try to limit the amount of forest clearance required during installation, and also to limit the amount of sterilised forest land in the long term, as penetrating tree growth on top of the cable circuit should not be permitted.

Figure 29 on page 45 provides a more detailed plan view of a typical forest joint bay. The link boxes are shown positioned to the side of the bay, with protective bollards installed to protect the heavy duty frames and covers from forestry vehicles.

In addition to the protective measures outline above, joint bay ¾ would potentially be positioned on sloping land. Efforts would be made to identify the most suitable position for a joint bay at this location, minimising the impact of the slope. However, consideration must be given for the inclusion of additional measures required to mitigate risk associated from cable migration down the slope. Refer to section 5.4 which discusses TMF and slope design.

6.10.6 UGC3 Outline Construction Programme

Based on the cable system design information discussed within this study, CCI have developed an outline construction programme for the UGC3 cable route. Refer to Table

23. This programme states the critical path construction and installation activities and provides duration estimates for each. From this, an approximate duration to complete the UGC3 works has been derived given in weeks.

Table 23 UGC3 critical path programme

Critical Path Activity	Critical Path Duration (weeks)
Mobilisation	1.4
Enabling, civil and reinstatement works	11.2
Cable installation and jointing works	2.9
HV testing and commissioning	1.4
Demobilisation and site clearance	1.4
Total Duration	**18.3**

The durations are a critical path estimate based on up to 2 installation teams and 2 reinstatment teams working simulaneously along different sections of the route. These civil teams would be supported by jointing teams working to make off the cable joints and terminations.

6.11 UGC4 Bennan, Slogarie and Laurieston Forest

The UGC4 cable route discussed here was developed and selected through an optioneering process detailed within Kendoon – Tongland 132kV Preliminary Investigative Cable Route Study ER1003 Rev C[11]. Since the completion of cable study ER1003, two changes to the UGC4 route have been identified and included in this report. These modifications were as a result of site visits subsequent to the issue of ER 1003 rev B in July 2019. These changes are:

- The cable route re-joining the A713 at Mossdale on the western side of the carriageway, rather than looping around and joining the carriageway from the eastern side as previously planned; and
- Diversion of the cable route from the A713 at Hensol Bridge to enable launch and reception positions to HDD under the River Dee

The impact of these changes would be to shorten the cable route by approximately 100m.

UGC4 cable route starts at tower GT25 and heads south through Galloway forest park following the Raiders Road, circumnavigating Stroan Loch until it reaches the Stroan viaduct. Here the cable route turns east out of the forest area, via the dismantled railway line between the Stroan viaduct and Mossdale, where it heads south on the A762. The cable route remains in the carriageway heading south through Laurieston until it leaves the carriageway close to Camelon Bridge and turns southwest where it dissects the proposed OHL route and terminates at tower GT78.

Table 24 contains points of engineering difficulty and environmental sensitivity identified along the route, with each item number marked in red circles on Figure 68, Figure 69, Figure 70 and Figure 71.

Table 24 UGC4 key points of engineering difficulty and environmental sensitivity

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
1	Peat	Potential for significant peat located in dense woodland within the forests adjacent to tower GT25. Peat ground preparation work may be required. This may also impact on cable conductor material and size. 
2	Significant changes in elevation	Steep undulations within the forest topography associated with Cairn Edward Hill that may require cable anchoring systems to be designed and installed to minimise migration of the cable down a slope over the long term.
3	Drainage crossing	Unnamed drainage crossing comprising a shallow concrete or cement asbestos duct that will require trial holes to establish the exact depth. The duct would be removed and replaced with a suitably sized polymeric duct and the new cable circuit would then be installed over it, depth allowing.

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
		
4	Mid Burn crossing	Mid burn crossing comprising a concrete bridged culvert approximately 700mm deep from road surface to burn. An HDD or dam and pump over crossing method would be required to the side of the track. 
5	Dense woodland	Tree and stump clearing works would be required when cabling through dense woodland adjacent to Forest Drive. The

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
		forest areas at this location are noted to be a mix of native and ancient woodlands. 
6	Drainage crossing	Unnamed drainage crossing comprising a shallow cement or cement asbestos duct that will require trial holes to establish the exact depth. The duct would be removed and replaced with a suitably sized polymer duct and the new cable circuit would then be installed over it, depth allowing. 
7	Heavy forestry machinery	Risk to the cable being traversed by heavy forestry machinery for all forestry shown on the map.

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
8	Acre Burn crossing	Acre Burn crossing comprising a 1.5m diameter duct. HDD would be required. Low (1 in 1000 year) and medium (1 in 200 year) flood risk zones are located just south of the cable route. 
9		Unnamed drainage crossing comprising a shallow 600mm diameter polymer duct that will require trial holes to establish the exact depth. The duct would be inspected, and the new cable circuit would then be installed over it, depth allowing. 
10	Clachrum Burn crossing	Clachrum burn crossing comprising a concrete bridge with 2 No. 8 " – 12 " cement or cement asbestos ducts embedded within the bridge structure. An HDD or dam and pump over crossing would be required. Low (1 in 1000 year) and medium

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
		(1 in 200 year) flood risk zones are located just south of the cable route. A pine marten den is noted north east of the cable route, which the cable route avoids. 
11	Dismantled railway cutting	Native woodland and pine marten dens are located adjacent to the cable route where it merges with the dismantled railway line adjacent to the Stroan viaduct. The native woodland extends along the railway line east where the railway line is cut into the rock. Due consideration would be required of the elevational change as the cable route aligns with the disused railway line.

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
		
12	Dismantled railway cutting and embankment	Cabling within both an elevated embankment and narrow cutting section (Approx. 2.8m wide) with dense forest and peat habitats located on either side. Public access to be restricted temporarily during cable installation works. Access to residential properties reliant on the dismantled railway line will require alternative access routes to be arranged. 

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
13	Cabling within A762 at Mossdale	Potential disruption associated with cabling through the village of Mossdale. A traffic management plan would need to be developed and adopted. Cabling in close proximity to residential properties within Mossdale.
14	River Dee Crossing at Hensol Bridge and Weir	River Dee crossing adjacent to Hensol Bridge requiring HDD, with the cable route diverting from the carriageway into adjacent fields. Low (1 in 1000 year) and medium (1 in 200 year) flood risk zones are located either side of Hensol Bridge. 
15	Listed Buildings and Native Woodlands	A762 and the cable route pass two grade 2 category B listed buildings and through a section of native woodland south of Hensol Bridge. The native woodland extends south to a third category C listed building at Little Duchrae.
16	Cabling within A762	Potential for several tributary crossings within A762 adjacent to Woodhall Loch. Low (1 in 1000 year) and medium (1 in 200 year) flood risk zones are located east of Woodhall Loch. The A762 passes through sections of native woodland adjacent to Woodhall Loch.
17	Burn crossing	Unnamed burn crossing south of Urioch Cottages that will require trial hole excavations to establish the exact depth. Any duct found would be removed and replaced with a suitably sized polymer duct and the new cable circuit would then be installed over it, depth allowing.

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
		
18	Laurieston Hall	Cabling in A762 adjacent to Laurieston Hall a non-inventory designed landscape and category B listed building.
19	Burn crossing	Unnamed burn crossing at Willowbank Bridge comprising a culvert approximately 0.9m deep. Trial holes to establish the exact depth would be required. Any duct found would be removed and replaced with a suitably sized polymer duct and the new cable circuit would then be installed over it, depth allowing. 
20	Burn crossing	Shallow unnamed burn crossing south of Willowbank Bridge. Scarring thought to be associated with the crossing was noted in the carriageway. Trial holes to establish the exact depth

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
		would be required. Any duct found would be removed and replaced with a suitably sized polymer duct and the new cable circuit would then be installed under it. 
21	Burn Crossing	Shallow unnamed burn crossing at Greystone. Trial holes to establish the exact depth would be required. Any duct found would be removed and replaced with a suitably sized polymer duct and the new cable circuit would then be installed under it.
22	Services within A762	Both OHL and buried services were noted on A762 north of Laurieston.
23	Cabling within Laurieston	Difficulties associated with cabling within a narrow road in the village. An appropriate traffic management plan would need to be developed and adopted. Temporary bus stop position and diversions may be required. The cable route passes within close proximity to residential properties. Buried utilities within the carriageway would need to be located by utility search prior to excavation.

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
		
24	Burn crossing at Mill Lade	Burn crossing adjacent to Mill Lade in the centre of Laurieston. The bridge deck was approximately 1.75m thick, likely possible to install the cables within the bridge deck. 
25	Services within A762	OHL services were noted along the A762 running the extent of Laurieston village.
26	Cabling at junction with B795	Evidence of services buried in the carriageway and overhead services noted at the junction of the A762 and B795. Potential traffic disruption associated with cabling across the road junction. Traffic management plan would need to be developed and adopted.

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
		
27	Cabling within A762	Potential for several tributary crossings and shallow bridge sections within A762 south of Laurieston.
28	Burn crossing at Gatehouse Bridge	Burn crossing at Gatehouse Bridge comprising a shallow culvert with approximately 600mm of cover. Trial holes to establish the exact depth would be required. Any structure found would be removed and replaced with a suitably sized polymer duct and the new cable circuit would then be installed under it. 

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
29	Otter resting point and PWS zone of influence	The A762 passes close to an otter resting point and private water supply zone of influence south of Gatehouse Bridge. By cabling within the A762 these are avoided.
30	Otter resting point and native woodland	The cable route dissects a native woodland north east of Camelon Bridge. Three otter resting points are marked close by which are bypassed by the cable route.
31	Peat habitat and otter resting points	Potential for unquantifiable peat located adjacent to tower GT78. Peat ground preparation work may be required. This may also impact on cable conductor material and size. Tower position is close to two otter resting points. 

Figure 68 Black line showing cable route UGC4 (map 1 of 4)

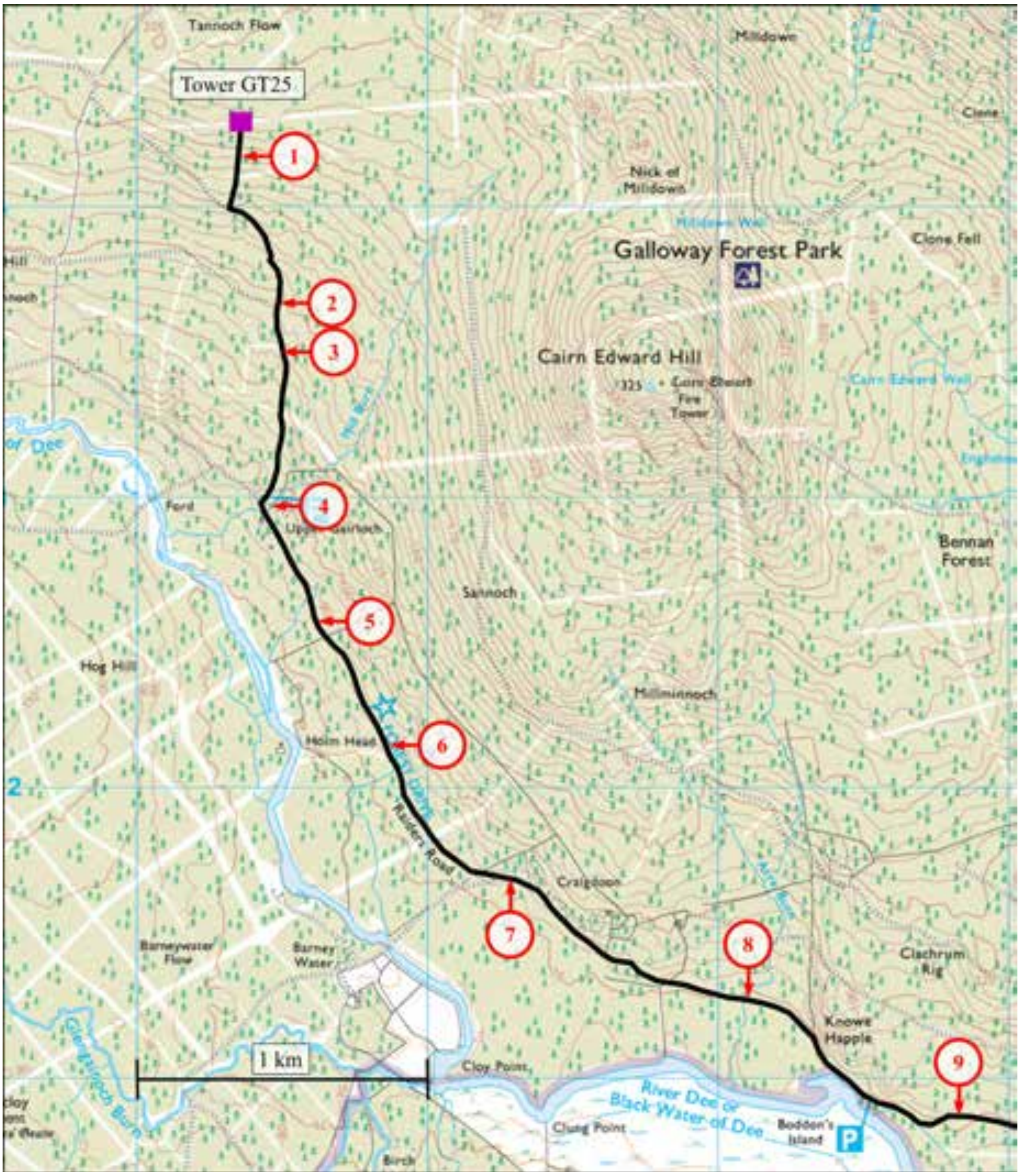


Figure 69 Black line showing cable route UGC4 (map 2 of 4)

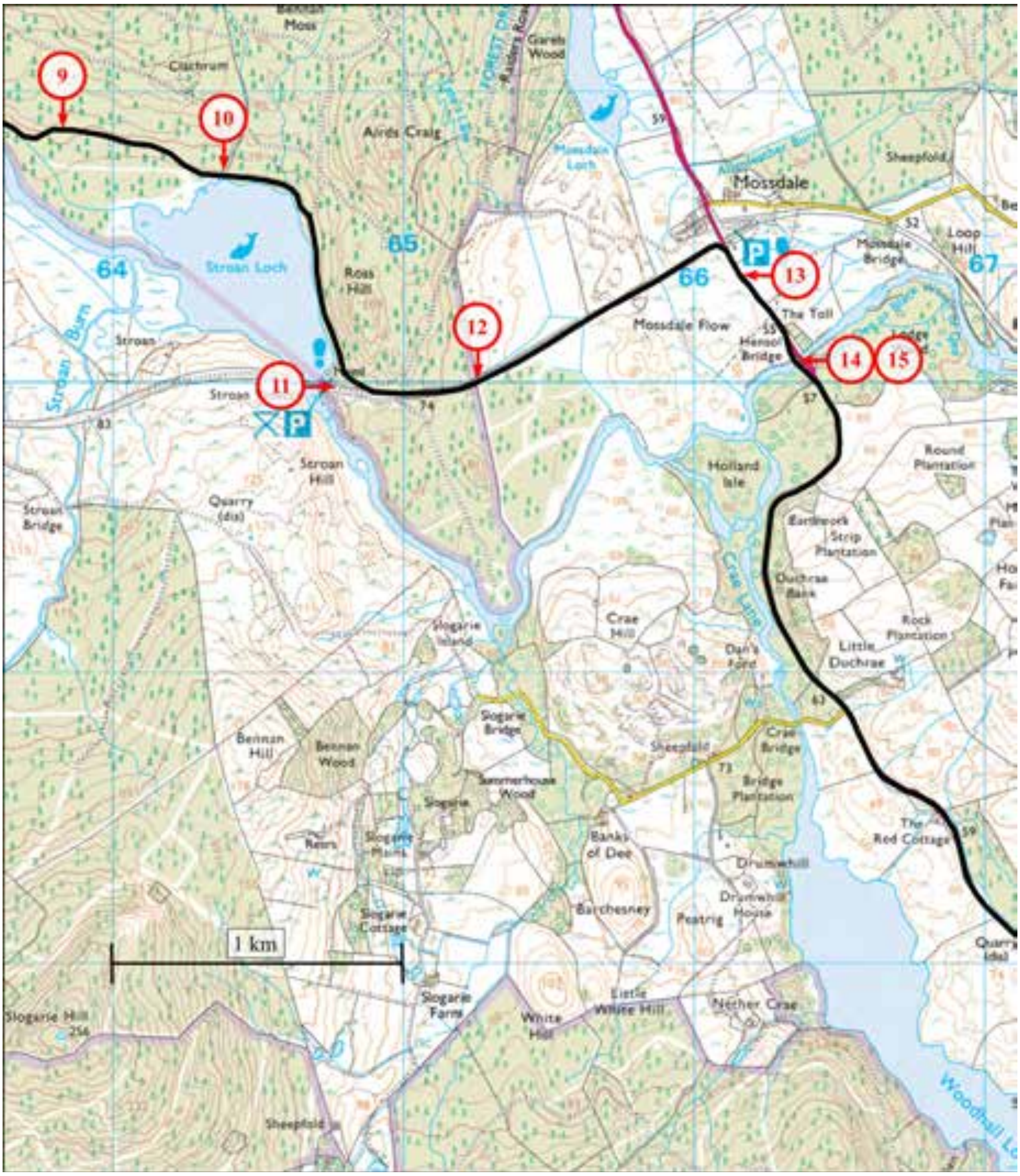
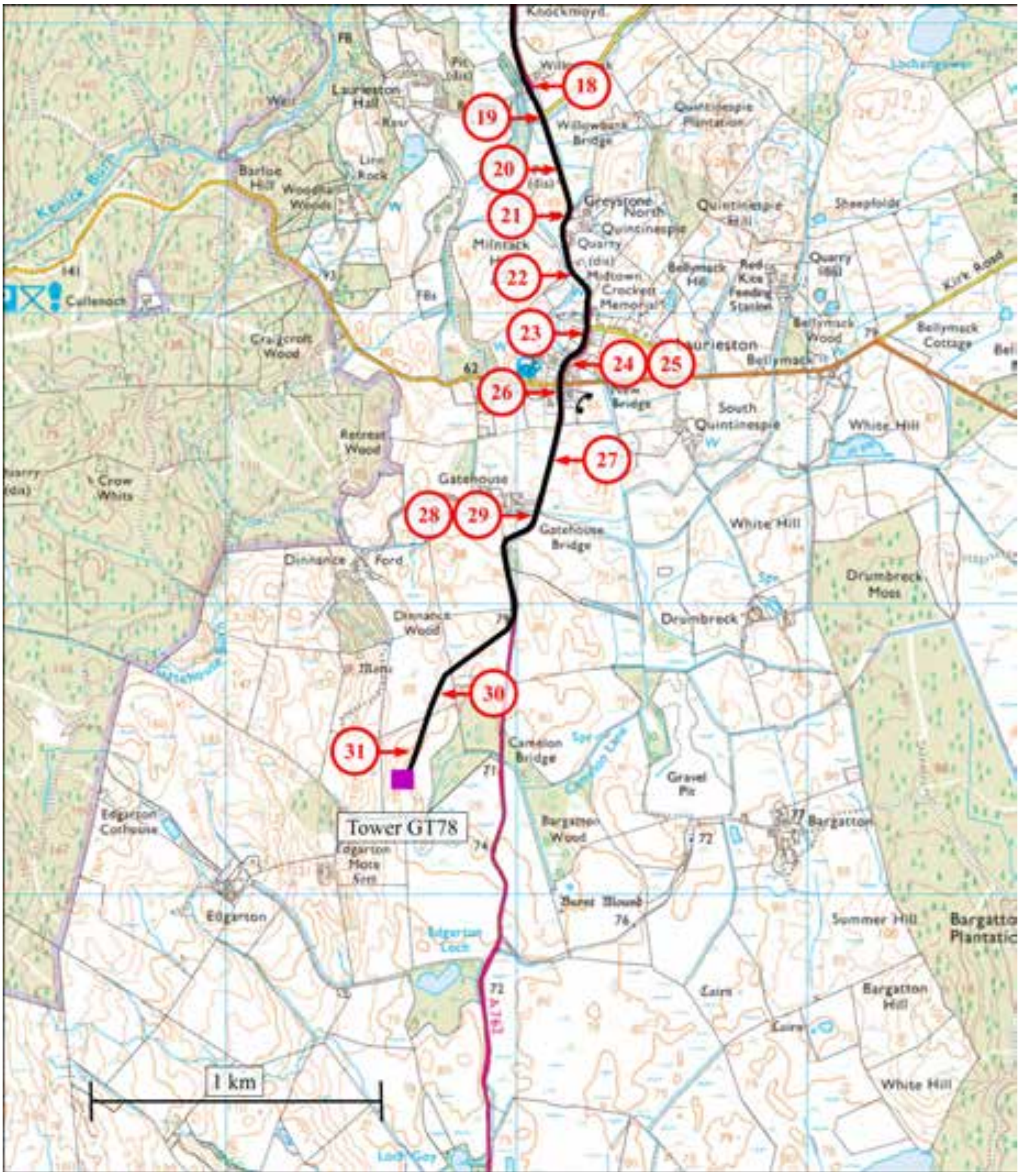


Figure 70 Black line showing cable route UGC4 (map 3 of 4)

Figure 71 Black line showing cable route UGC4 (map 4 of 4)



6.11.1 UGC4 Typical Installation Swathes

UGC4 cable route would be approximately 16.0km long all of which would be buried cable comprising three main type of installation swathe:

- Installation within forest including the dismantled railway line (7.80km)
- Installation within carriageway (7.44km)
- Installation within arable/pastoral land (0.76km)

Two types of forest cable swathe have been considered; constrained and unconstrained by topographic features.

Figure 9 on page 27 provides a schematic of a constrained forest cable swathe, where the existing forest track would be used to install the cable circuits, with installation teams working systematically from one direction. Passing points for vehicles and plant would be established where possible. This constrained case will also apply to the dismantled railway section of the cable route, where the railway line is either on an embankment or within a cutting.

Within the forest and woodland sections of the cable routes, where there is a perceived risk of heavy duty commercial logging vehicles operating on top of the cables in soft ground, the cable ducts would be enclosed within concrete.

Drawings of the various joint bay installation arrangements may be located within this report as follows:

- Figure 8 on page 26 shows a typical double circuit arable/pastoral land swathe, approximately 32m wide.
- Figure 10 on page 28 provides typical cable swathes for an unconstrained forest installation swathe.
- Figure 11 on page 29 shows a typical carriageway installation, with both circuits installed within one lane of the carriageway.

6.11.2 UGC4 Haul Road Requirements

Haul roads would be required at various locations along the UGC4 cable route to enable both labour, plant and material access during the construction phase of the project, and to allow future maintenance and fault repair work to be carried out. Refer to section 4.1.4 of this report for additional information on typical haul road layouts.

Table 25 provides anticipated location and length of the haul road requirements for UGC4.

Table 25 UGC4 haul road requirements

Haul Road Location and Type Temporary (T) or Permanent (P)	Approximate Haul Road Length (m)
From GT25 to Stroan Valley viaduct for cabling access, access to the termination position and access for the 3 x HDD crossings of small burns within the forest (T)	6,200
At Hensol Bridge on the A762 for cabling access and access for the HDD crossing of the River Dee and Weir (T)	400
From A762 to GT78 for cabling access and access to the termination position (T)	800
Total Haul Road Requirement for UGC4	7,400

It would be envisaged that future access to the forest section of UGC4 would be via Raiders Road, in which case the need for a separate permanent haul road would not be necessary but some general road condition improvement and repair would be required.

6.11.3 UGC4 Crossing Schedule

Table 26 gives the crossing schedule for UGC4. From this schedule, key crossings are highlighted in red and discussed further.

Table 26 UGC4 Crossing Schedule

Crossing No.	GPS Crossing Location	Crossing Description	Proposed Crossing Solution
1	55° 02' 12.79" N 4° 10' 7.51" W	Drainage duct on Raider Road	Replace existing duct and cable over
2	55° 01' 54.09" N 4° 10' 9.91" W	Mid burn on Raider Road	HDD approximately 50m or dam and pump over
3	55° 01' 41.31" N 4° 09' 57.95" W	Drainage duct on Raider Road	Replace existing duct and cable over
4	55° 0' 49.60" N 4° 07' 51.39" W	Drainage duct on Raider Road	Replace existing duct and cable over
5	55° 01' 1.70" N 4° 08' 33.67" W	Acre Burn on Raider Road	HDD approximately 50m
6	55° 0' 43.42" N 4° 07' 7.62" W	Clachrum Burn on Raider Road	HDD approximately 50m or dam and pump over
7	55° 0' 26.04" N 4° 05' 27.96" W	River Dee at Hensol Bridge on A762	HDD approximately 200m
8	54° 58' 19.38" N 4° 03' 49.66" W	Burn at Urioch Cottages on A762	Replace existing duct and cable over
9	54° 58' 4.96" N 4° 03' 42.92" W	Burn at Willowbank Bridge on A762	Replace existing duct and cable over
10	54° 58' 2.20" N 4° 03' 41.47" W	Shallow burn south of Willowbank Bridge on A762	Replace existing duct and cable under
11	54° 57' 55.40" N 4° 03' 37.70" W	Shallow burn at Greystone on A762	Replace existing duct and cable under
12	54° 57' 38.59" N 4° 03' 36.92" W	Mill Lade crossing on A762	Install within bridge deck
13	54° 57' 36.19" N 4° 03' 37.94" W	Crossing junction with	Duct block

Crossing No.	GPS Crossing Location	Crossing Description	Proposed Crossing Solution
		B795 and A762	
14	54° 57' 21.00" N 4° 03' 43.14" W	Burn at Gatehouse Bridge on A762	Replace existing duct and cable under

UGC4 has one significant watercourse crossing, the River Dee at Hensol Bridge on the A762 for which an HDD solution would be proposed on the western side of the carriageway within adjacent arable/pastoral land and native woodland.

In addition to the major river crossing at Hensol Bridge, there are 12 more minor burn and drainage crossings and one road crossing. With the proposed crossing solutions being a mix of short HDD, dam and pump over and duct and cable under. Refer to section 5.3 of this report for additional information on these proposed crossing methods.

6.11.3.1 UGC4 HDD Launch and Reception Compound Positions

The footprint of the HDD compounds would vary depending on the length, depth, complexity of the specific HDD and location along the cable route, but typically a drill launch site compound would measure approximately 30m x 30m, and a drill reception site compound 20m x 20m. Additional information is provided in section 5.3.4 of this report.

The launch and reception positions for each HDD along the UGC4 cable route have been identified and photographs showing their locations along with a brief description are provided in Table 27.

Table 27 UGC4 HDD launch and reception positions

HDD Description	Photograph
Mid Burn within Raiders Road, HDD length is approximately 50m. Launch and reception positions were identified within the existing Raiders Road.	
Acre Burn within Raiders Road, HDD length is approximately 50m. Launch and reception positions were identified within the existing Raiders Road.	

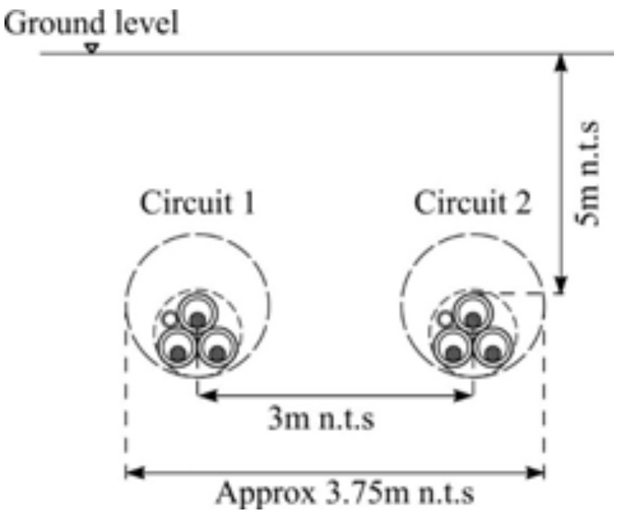
HDD Description	Photograph
Clachrum Burn within Raiders Road, HDD length is approximately 50m. Launch and reception positions were identified within the existing Raiders Road.	
River Dee at Hensol Bridge, HDD length is approximately 200m. Launch and reception positions were identified on the south-western side of the A762 in arable/pastoral land and woods. Access onto the A762 would require temporary haul road construction.	

6.11.3.2 UGC4 River Dee Crossing at Hensol Bridge

With 3 cables per circuit, an HDD formation would comprise 2 trefoil groups. The spacing between each trefoil group would be dictated by the depth the HDD profile needs to achieve to clear the carriageway foundations. Figure 41 on page 61 shows the relationship between burial depth and circuit spacing for three cable types: 800mm² copper, 1600mm² aluminium and 1600mm² copper.

At a nominal burial depth of 5m for 1600mm² aluminium XLPE cable, Figure 41 on page 61 gives the centre to centre spacing between each circuit as approximately 0.85m. This is based on a PE duct OD of 250mm. Each trefoil duct group would be strapped together in formation and installed within a bore diameter of approximately 750mm. However, to ensure the structural integrity of both bores, a greater centre to centre bore separation of 3m has been considered here. Figure 72 provides a cross section of this HDD arrangement and provides a minimum width of approximately 3.75m for a drill depth of 5m. Guidance should be sought during the planning and consents stage of the works to ascertain the clearance requirements for each planned crossing location.

Figure 72 HDD cross section at River Dee crossing at Hensol Bridge



6.11.4 UGC4 Termination Towers

Towers with an elevated sealing end platform (sealing end platform attached to the tower body) would be required at both ends of this route at tower position GT25 and GT78. Both tower positions GT25 and GT78 are situated in or close to peat habitats which would likely necessitate civil works to make the ground suitable for construction. In addition, both tower positions would likely require some levelling work. A temporary haul road access would need to be constructed at GT25 and GT78. Figure 31 on page 48 shows an example of a typical terminal tower with an integrated sealing end platform.

6.11.5 UGC4 Cable Section Lengths and Critical Joint Bay Locations

Based on the selected cable designs and the selected cable route for UGC4, Table 28 provides suggested cable section lengths based on the principles of a cross bonded cable system design which essentially requires balanced minor sections within a 3 cable major section. Joint bays that are considered to be critical have been highlighted in red.

Table 28 UGC4 cable section lengths

Section No.	Joint Bay No.	Chainage (km)	Section Length (m)	Bonding		Installation Description
N/A	Tower GT25	0.00	N/A	N/A		Terminal tower GT25
1	1/2	0.76	760	Major section	Minor section	Forest track – Protection from Forestry vehicles required
2	2/3	1.52	760		Minor section	Forest track – Protection from Forestry vehicles required

Section No.	Joint Bay No.	Chainage (km)	Section Length (m)	Bonding		Installation Description
3	3/4	2.28	760		Minor section	Forest track – Protection from Forestry vehicles required
4	4/5	3.04	760	Major section	Minor section	Forest track – Protection from Forestry vehicles required
5	5/6	3.80	760		Minor section	Forest track – Protection from Forestry vehicles required
6	6/7	4.56	760		Minor section	Forest track – Protection from Forestry vehicles required
7	7/8	5.32	760	Major section	Minor section	Forest track – Protection from Forestry vehicles required
8	8/9	6.08	760		Minor section	Forest track – Protection from Forestry vehicles required
9	9/10	6.84	760		Minor section	Disused railway line
10	10/11	7.60	760	Major section	Minor section	Disused railway line
11	11/12	8.36	760		Minor section	Carriageway adjacent to property access
12	12/13	9.12	760		Minor section	Carriageway adjacent to layby
13	13/14	9.88	764	Major section	Minor section	Carriageway
14	14/15	10.65	764		Minor section	Carriageway adjacent to peat habitat
15	15/16	11.41	764		Minor section	Carriageway adjacent to layby
16	16/17	12.18	765	Major section	Minor section	Carriageway
17	17/18	12.94	765		Minor section	Carriageway
18	18/19	13.71	765		Minor section	Carriageway
19	19/20	14.47	765	Major section	Minor section	Carriageway adjacent to layby and park
20	20/21	15.24	765		Minor section	Carriageway with wide verge
21	Tower GT78	16.00	765		Minor section	Terminal tower GT78

Joint bays on the UGC4 cable route fall within three installation categories; installation within carriageway, installation within forest track and installation within arable/pastoral land.

Joint bays 1/2 through to 8/9 are inclusively located within areas managed by the Forestry Commission and will require additional measures to ensure protection from forestry vehicles that operate in the area. It would be proposed that the joints are installed within reinforced concrete troughs for protection, with concrete duct blocks utilised where cables cross forest access tracks or are at risk of heavy forestry machinery operating overhead in soft soil.

Due to the space constraints within the forestry section of the route and on the dismantled railway line, joint bay excavations will likely prevent vehicle access beyond them, making the establishment of haul road access to the northern end of the route (beyond GT25) essential. The jointing work will also require careful planning to ensure no sections of the route are inadvertently sterilised. Localised levelling at joint bay positions to place the joints to the side of the road may be possible.

Drawings of the various joint bay installation arrangements may be located within this report as follows:

- Figure 24 on page 42 shows a typical cross section for a joint bay installed within a carriageway without a verge.
- Figure 26 on page 43 shows a typical cross section for a joint bay installed within a carriageway with a verge.
- Figure 66 on page 120 shows a typical joint bay installed within arable/pastoral land.
- Figure 67 on page 121 shows a typical joint bay installed within a forest track.

6.11.6 UGC4 Outline Construction Programme

Based on the cable system design information discussed within this study, CCI have developed an outline construction programme for the UGC4 cable route. Refer to Table 29. This programme states the critical path construction and installation activities and provides duration estimates for each. From this, an approximate duration to complete the UGC4 works has been derived given in weeks.

Table 29 UGC4 critical path programme

Critical Path Activity	Critical Path Duration (weeks)
Mobilisation	1.4
Enabling, civil and reinstatement works	39.5
Cable installation and jointing works	14.3

Critical Path Activity	Critical Path Duration (weeks)
HV testing and commissioning	1.4
Demobilisation and site clearance	1.4
Total Duration	**58**

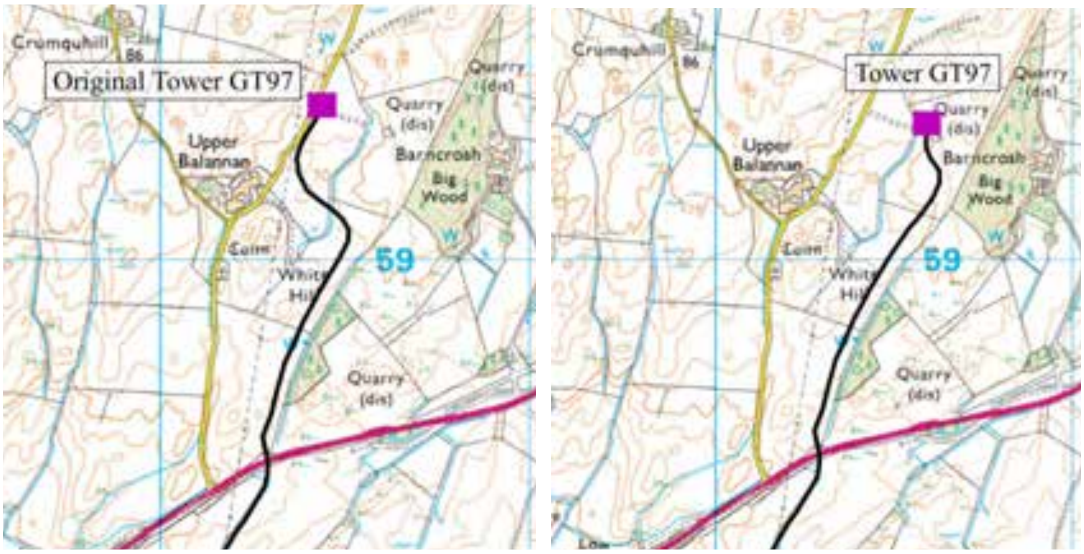
The durations are a critical path estimate based on up to 2 installation teams and 2 reinstatment teams working simulaneously along different sections of the route. These civil teams would be supported by jointing teams working to make off the cable joints and terminations.

6.12 UGC5 A75 Crossing

The UGC5 cable route discussed here was developed and selected through an optioneering process detailed within Kendoon – Tongland 132kV Preliminary Investigative Cable Route Study ER1003 Rev C[11]. There has been one change to the route since the completion of cable study ER1003 in July 2019. This change is the movement of tower 97 approximately 140m to the east due to a new development promoted by the landowner being approved which encroaches on the towers original proposed position. Refer to Figure 73, where the black line represents the UGC5 cable route, with the left image showing the original tower 97 position and UGC5 route, and the right image showing the new tower 97 and altered UGC5 route.

A study of aerial photography and OS map data provided sufficient information for this minor route change and thus it was not necessary for CCI to conduct an additional site visit for this location.

Figure 73 Magnified view of northern end of UGC5 route and new tower 97 position



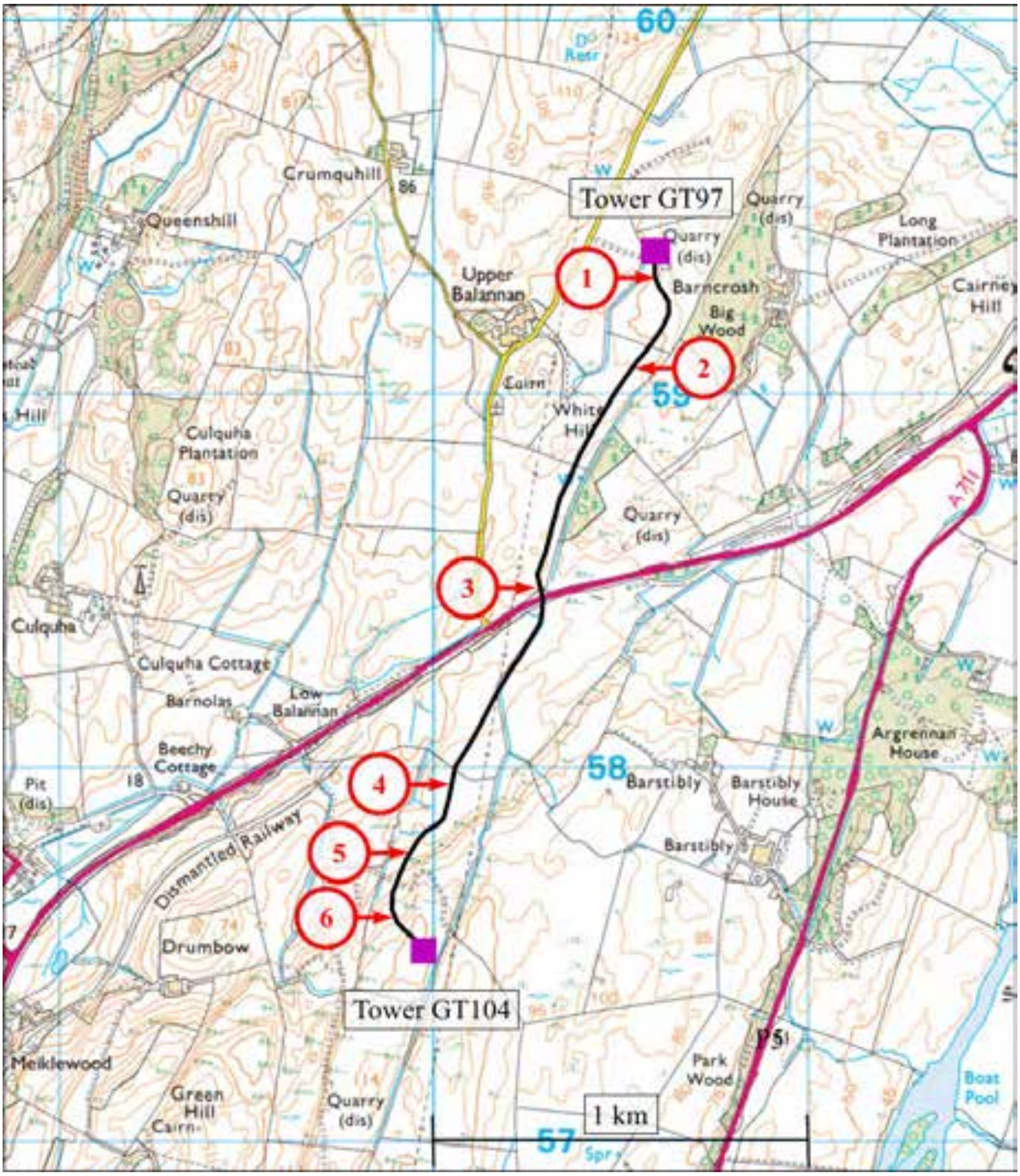
The UGC5 cable route starts from tower GT97 and heads south across arable/pastoral land towards the A75. Having crossed the A75 the cable route continues south across arable/pastoral land terminating at tower GT104. Table 30 contains points of engineering difficulty and environmental sensitivity identified along the route, with each item number marked in red circle on Figure 74. Confidential data on the locations of European protected species is provided in confidential appendix ER1033-1 which has been provided to SNH, DGC and the Scottish Government ECU.

Table 30 UGC5 key points of engineering difficulty and environmental sensitivity

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
1	Shallow rock and significant changes in elevation	Adjacent to tower GT97 the ground was noted to contain several rocky outcrops. Micro-routing at these locations may be required to mitigate the rocks impact on the cable route. Steep undulations within the topography heading south from proposed tower GT97 were also noted that may require cable anchoring systems to be designed and installed to minimise migration of the cable down a slope over the long term.
2	Residential Properties	Several residential properties are located on the lane west of the cable route at White Hill.
3	A75 crossing	HDD under A75 would be required, launch and reception pit identification and access for drilling rigs would be likely to be good. 
4	Native woodlands, burn crossing and Peat	Native woodland would be located east of the cable route at Barstibly, with intermittent peat habitats present and a burn that would need to be crossed. Trial holes to establish the exact depth would be required. Any structure found would be removed and replaced with a suitably sized

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
		polymer duct and the new cable circuit would then be installed over under it. Several residential properties are also situated east of the cable route at Barstibly. 
5	Significant changes in elevation	Steep undulations within the topography heading south from the A75 towards proposed tower GT103 that may require cable anchoring systems to be designed and installed to minimise migration of the cable down a slope over the long term. 
6	Shallow rock	Rocky outcrops are bypassed by the cable route on the hill side south of the A75 close to proposed tower location GT103 and GT104.

Figure 74 Black line showing cable route UGC5



6.12.1 UGC5 Typical Installation Swathes

UGC5 cable route would be approximately 2.20km long all of which would be buried cable comprising one main type of installation swathe:

- Installation within arable/pastoral land (2.20km)

Figure 8 on page 26 shows a typical double circuit arable/pastoral land swathe, approximately 32m wide.

6.12.2 UGC5 Haul Road Requirements

Haul roads would be required at various locations along the UGC5 cable route to enable both labour, plant and material access during the construction phase of the project, and to allow future maintenance and fault repair work to be carried out. Refer to section 4.1.4 of this report for additional information on typical haul road layouts.

Table 31 provides anticipated location and length of the haul road requirements for UGC5.

Table 31 UGC5 haul road requirements

Haul Road Location and Type Temporary (T) or Permanent (P)	Approximate Haul Road Length (m)
From GT97 to A75 for cabling access and access for the HDD crossing of the A75 (T)	1,100
From A75 to GT104 for cabling access and access for the HDD crossing of the A75 (T)	1,100
Total Haul Road Requirement for UGC5	2,200

6.12.3 UGC5 Crossing Schedule

Table 32 gives the crossing schedule for UGC5. From this schedule, key crossings are highlighted in red and discussed further.

Table 32 UGC5 crossing schedule

Crossing No.	GPS Crossing Location	Crossing Description	Proposed Crossing Solution
1	54° 54' 14.88" N 4° 01' 28.14" W	A75 Road crossing	HDD approximately 400m
2	54° 54' 04.80" N 4° 01' 34.50" W	Burn west of Barstibly	Duct and cable under

UGC5 has one significant carriageway crossing, the A75 for which an HDD solution would be proposed.

In addition to the major crossing at the A75, there is one more minor watercourses that will require crossing, with the proposed solution for the minor watercourse to use the duct and dig under method, refer to section 5.3 of this report for additional information.

6.12.3.1 UGC5 HDD Launch and Reception Compound Positions

The footprint of the HDD compounds would vary depending on the length, depth, complexity of the specific HDD and location along the cable route, but typically a drill launch site compound would measure approximately 30m x 30m, and a drill reception site compound 20m x 20m. Additional information is provided in section 5.3.4 of this report.

The launch and reception positions for each HDD along the UGC5 cable route have been identified and photographs showing their locations along with a brief description are provided in Table 33.

Table 33 UGC5 HDD launch and reception positions

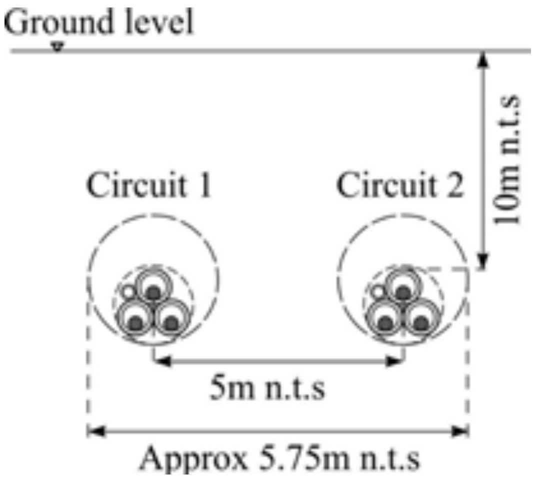
HDD Description	Photograph
A75, HDD length is approximately 400m. Launch and reception positions were identified on the northern and southern side of the A75 in arable/pastoral land with good access back onto the A75.	

6.12.3.2 UGC5 A75 Crossing

With 3 cables per circuit, an HDD formation would comprise 2 trefoil groups. The spacing between each trefoil group will be dictated by the depth to which the HDD profile needs to achieve to clear the carriageway foundations. Figure 41 on page 61 shows the relationship between burial depth and circuit spacing for three cable types: 800mm² copper, 1600mm² aluminium and 1600mm² copper.

At a nominal burial depth of 10m for 1600mm² aluminium XLPE cable, Figure 41 on page 61 gives the centre to centre spacing between each circuit as approximately 3.2m, based on a PE duct OD of 250mm, each trefoil duct group would be strapped together in formation and installed within a bore diameter of approximately 750mm. However, to ensure the structural integrity of both bores, a greater centre to centre bore separation of 5m has been considered here. Figure 75 provides a cross section of this HDD arrangement and provides an indicative swathe width of approximately 5.75m for a drill depth of 10m. Guidance should be sought during the planning and consents stage of the works to ascertain the clearance requirements for each planned crossing location.

Figure 75 HDD cross section at A75 crossing



6.12.4 UGC5 Termination Towers

Towers with an elevated sealing end platform (sealing end platform attached to the tower body) would be required at both ends of this route at tower position GT97 and GT104. GT97 has good access available from a lane which joins the A75. At GT104, access is more restricted with temporary haul roads being required to link the tower position to lanes that lead onto the A711. Construction may also be hampered by an adjacent area of native woodland. Figure 31 on page 48 is an example of a typical terminal tower with an integrated sealing end platform.

6.12.5 UGC5 Cable Section Lengths and Critical Joint Bay Locations

Based on the selected cable designs and the selected cable route for UGC5, Table 34 provides suggested cable section lengths based on the principles of a cross bonded cable system design which essentially requires balanced minor sections within a 3 cable major section. Joint bays that are considered to be critical have been highlighted in red.

Table 34 UGC5 Cable section lengths

Section No.	Joint Bay No.	Chainage (km)	Section Length (m)	Bonding		Installation Description
N/A	Tower GT97	0.00	N/A	N/A		Terminal tower GT97
1	½	0.73	734	Major section	Minor section	Arable/pastoral
2	2/3	1.47	734		Minor section	HDD – A75 – Arable/pastoral
3	Tower GT104	2.20	734		Minor section	Terminal tower GT104

Joint bays within UGC5 fall within one installation type, installation within arable/pastoral land.

The joint bay positions where possible have been positioned at locations with reasonable access, specifically for cable section 2 which incorporates the HDD under the A75. Figure 66 on page 120 shows a typical double circuit arable/pastoral land swathe, approximately 32m wide.

6.12.6 UGC5 Outline Construction Programme

Based on the cable system design information discussed within this study, CCI have developed an outline construction programme for the UGC5 cable route. Refer to Table 35. This programme states the critical path construction and installation activities and provides duration estimates for each. From this, an approximate duration to complete the UGC5 works has been derived given in weeks.

Table 35 UGC5 critical path programme

Critical Path Activity	Critical Path Duration (weeks)
Mobilisation	1.4
Enabling, civil and reinstatement works	6.9
Cable installation and jointing works	3.5
HV testing and commissioning	1.4
Demobilisation and site clearance	1.4
Total Duration	**14.6**

The durations are a critical path estimate based on up to 2 installation teams and 2 reinstatment teams working simulaneously along different sections of the route. These civil teams would be supported by jointing teams working to make off the cable joints and terminations.

6.13 UGC6 Glenlee Substation to Tongland Substation

The UGC6 cable route discussed here was developed and selected through an optioneering process detailed within the Kendoon – Tongland 132kV Preliminary Investigative Cable Route Study ER1003 Rev C[11]. Since the completion of the cable study ER1003, approximately 9 changes to the UGC6 route have been identified. These modifications were as a result of site visits subsequent to the issue of ER 1003 rev B in July 2019. These include:

- Diversion of the cable route from the A713 adjacent to Coom Bridge to enable launch and reception positions to HDD under the burn
- Amendment to the HDD crossing position at the Water of Ken to try to minimise the drill length
- Diversion of the cable route from the A713 at Garple Bridge to enable launch and reception positions to HDD under the burn
- Diversion of the cable route from the A713 at Shirmers Bridge onto the old road bridge to cross the burn
- Diversion of the cable route from the A713 at Burnfoot Bridge to enable launch and reception positions to HDD under Arvie burn
- Diversion of the cable route from the A713 at Boreland of Parton to enable launch and reception positions to HDD under the burn
- Diversion of the cable route from the A713 at Parton Mill Bridge to enable launch and reception positions to HDD under 2 burns and a lane
- Removal of the diversion at Crossmichael with the cable route remaining on the A713 through the town
- Diversion of the cable route into an unmarked country lane, south of Glenlochar at Barnboard wood to avoid the woodland

The impact of these changes would be to shorten the cable route by approximately 700m.

The UGC6 cable route starts at Glenlee substation heading south along the A762, before turning east and crossing the Water of Ken at Meikle Isle, then continues south following the A713 down the east side of Loch Ken. The cable route follows the A713 south to Crossmichael and once through the town it turns west, passing around the Mains of Greenlaw, to cross the River Dee at Barony Isle. The cable route continues heading southwest following several country lanes south of Glenlochar, before following the existing overhead line route over the A75. Once south of the A75 the cable route continues along the line of the existing OHL route before sweeping west towards Castle Hill to take a more gradual incline into Tongland substation from the south west, thus avoiding the steeper incline into the substation from the north.

It was intended that the route would divert around Crossmichael to minimise disruption to the local residences and businesses, but on completion of a detailed site walkover cabling options were limited by the steep undulating topography associated with Rhone Hill to the north and the environmental restrictions associated with non-inventory designed landscapes at Culgruff House to the south. Therefore the A713 carriageway was deemed the next best alternative. It also has the advantage of being the shortest route through the village.

Table 36 contains points of engineering difficulty and environmental sensitivity identified along the route, with each item number marked in red circles on Figure 76, Figure 77, Figure 78, Figure 79, Figure 80, Figure 81, Figure 82, Figure 83 and Figure 84. Confidential data on the locations of European protected species is provided in confidential ER1033-1 which has been provided to SNH, DGC and the Scottish Government ECU.

Table 36 UGC6 key points of engineering difficulty and environmental sensitivity

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
1	Glenlee Substation	Approaching the substation in the road, requiring appropriate traffic management plan to be developed and adopted. The road and cable route dissects native woodlands to the north and a non-inventory design landscape and five category B listed buildings. The road is located within a medium likelihood (1-200 year) flood zone associated with the adjacent Water of Ken.
2	Burn crossing at Coom Bridge	Burn crossing adjacent to Coom Bridge requiring either HDD or installation in a cable bridge. Several residential dwellings are located to the south. The road is located within a medium likelihood (1-200 year) flood zone associated with the adjacent Water of Ken. 
3	Water of Ken crossing	HDD under water of Ken would be required, with launch and reception pit identification and access for drilling rigs to be developed. The cable route is located within a medium

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
		likelihood (1-200 year) flood zone associated with the adjacent Water of Ken. 
4	Cabling within A713	 Cabling in A713 carriageway requiring appropriate traffic management plan to be developed and adopted. With joints and link equipment located in the verge where practicable. BT services were noted to be running in the verge on the western side of the carriageway. The road is located within a medium likelihood (1-200 year) flood zone associated with the adjacent Water of Ken. Several residential properties are situated along the A713 which the cable route passes.

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
5	Burn crossing south of Craig House	 Unnamed burn crossing south of Craig House on the A713. Trial holes to establish the exact depth would be required. Any duct found would be removed and replaced with a suitably sized polymer duct and the new cable circuit would then be installed over it, depth allowing.
6	Unidentified burn crossings south of Grennam	Two further burns marked on the OS maps south of Grennam were not located during a visit to their expected location, this may be due to them only flowing seasonally. Provision should be allowed for crossing them when planning the works.
7	Burn crossing at Garple Bridge	Burn crossing at Garple Bridge requiring an HDD on the western side of the carriageway. The bridge deck was found not to be deep enough measuring only approximately 1.1m deep and comprising what appears to be a single section reinforced concrete slab. The road is located within a medium likelihood (1-200 year) flood zone associated with the adjacent Water of Ken. Several residential properties are situated along the A713 which the cable route passes including a category A listed building to the west.

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
		
8	Burn crossing south of Ken Bridge Hotel	 Unnamed burn crossing in a suspected culvert, south of Ken Bridge Hotel on the A713. Trial holes to establish the exact depth would be required. Any structure found would be removed and replaced with a suitably sized polymer duct and the new cable circuit would then be installed over it, depth allowing.
9	Unidentified burn crossing north of Cubbox	A burn marked on the OS maps north of Cubbox was not located when visited. This may be due to it only flowing seasonally. Provision should be allowed for crossing it when planning the works.

<table>
<tr><th>Item No.</th><th>Points of Engineering Difficulty and Environmental Sensitivity</th><th colspan="2">Comment</th></tr>
<tr><td>10</td><td>Shallow burn crossing at Killochy Cottage</td><td></td><td>Shallow burn crossing at Killochy Cottage. Trial holes to establish the exact depth would be required. Any structure found would be removed and replaced with a suitably sized polymer duct and the new cable circuit would then be installed under it.</td></tr>
<tr><td>11</td><td>High Park burn crossing</td><td colspan="2">High Park burn marked on the OS maps was not located, this may be as it has been culverted or due to it only flowing seasonally. Provision should be allowed for crossing it when planning the works.
</td></tr>
<tr><td>12</td><td>Maukinhowe burn crossing</td><td colspan="2">Deep crossing of Maukinhowe burn at Fauld-O’-Wheat Bridge, potential to install cable within the bridge deck as approximately 1.6m deep.</td></tr>
</table>

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
		
13	Deep burn crossing south of Shirmers Moss	 Unnamed burn crossing south of Shirmers Moss on the A713. Trial holes to establish the exact depth would be required. Any structure found would be removed and replaced with a suitably sized polymer duct and the new cable circuit would then be installed over it, depth allowing.
14	Dry burn crossing north of White Hill	Dry burn crossing north of White Hill, in a section where the A713 is raised. Trial holes to establish the exact depth would be required. Any structure found would be removed and replaced with a suitably sized polymer duct and the new cable circuit would then be installed over it, depth allowing.

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
		
15	Burn crossing at Shirmers Bridge	Burn crossing at Shirmers Bridge potentially requiring HDD, with options to install on either side of the carriageway. Alternatively an old road bridge was identified that may be used as a cable bridge, with the cables installed on the old bridge within surface mounted troughs. Several sections of native woodland are located west of the A713. The road is located within a medium likelihood (1-200 year) flood zone associated with the adjacent Water of Ken. Several residential properties are situated along the A713 alongside the cable route. 
16	Unidentified burn crossings at Mid Tors.	Two further burns crossing the A713 marked on the OS maps at Mid Tors were not located, this may be due to them only flowing seasonally. Provision should be allowed for crossing them when planning the works.
17	Burn crossing at Kiln Hill	Dry burn crossing at Kiln Hill within a built up section of the A713. Trial holes to establish the exact depth would be

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
		required. Any structure found would be removed and replaced with a suitably sized polymer duct and the new cable circuit would then be installed over it, depth allowing. 
18	Burn crossing at Arvie Wood	 Burn crossing at Arvie Wood within a built up section of the A713. Trial holes to establish the exact depth would be required. Any structure found would be removed and replaced with a suitably sized polymer duct and the new cable circuit would then be installed over it, depth allowing.
19	Arvie Burn crossing at Burnfoot Bridge	Crossing of Arvie Burn at Burnfoot Bridge, requiring an HDD potentially located to the south of the carriageway. The bridge deck was measure to be approximately 0.5m deep, so not

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
		suitable for cable installation. Services were noted crossing the bridge on the eastern side of the carriageway. 
20	Unidentified burn crossing at Drumrash.	 Burn marked south of Little Drumrash on the OS maps was not located, this may be as it has been culverted or due to it only flowing seasonally. Provision should be allowed for crossing it when planning the works.
21	Burn crossing at Glenlaggan Wood	Burn crossing at Glenlaggan Wood within a built up section of the A713. Burn and banks noted to be overgrown with no visible sign of flow. Trial holes to establish the exact depth would be required. Any structure found would be removed and

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
		replaced with a suitably sized polymer duct and the new cable circuit would then be installed over it, depth allowing. 
22	Burn crossing at Airds House Bridge	 Burn crossing at Airds House Bridge comprising an approximately 600mm diameter pipe, 600mm deep. Trial holes to establish the exact depth would be required. Any structure found would be removed and replaced with a suitably sized polymer duct and the new cable circuit would then be installed over it, depth allowing.

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
23	Unidentified burn crossing at Lochside Wood	 Burn marked at Lochside Wood on the OS maps was not located, this may be as it has been culverted or due to it only flowing seasonally. Provision should be allowed for crossing it when planning the works.
24	Listed buildings at Loch Ken Viaduct	The road is located within a medium likelihood (1-200 year) flood zone associated with the adjacent Water of Ken. Several residential properties are situated along the A713 which the cable route passes, including several category b listed buildings to the east with associated non-inventory designed landscapes.
25	Burn crossing at Boreland of Parton	Burn crossing at Boreland of Parton, an HDD would be required as the bridge deck is shallow, approximately 200mm. Potential to site the HDD on the north side of the A713. 
26	Listed buildings at Parton	Several residential properties are situated along the A713 alongside the cable route, including several category B listed buildings close to the road at Parton. A scheduled monument is also noted south of the A713 at Parton. The road is located within a medium likelihood (1-200 year) flood zone associated with the adjacent Water of Ken.

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
27	Burn crossing at Cranearie	Burn crossing at Cranearie comprising a small diameter pipe approximately 80mm. Trial holes to establish the exact depth would be required. Any structure found would be removed and replaced with a suitably sized polymer duct and the new cable circuit would then be installed over it, depth allowing. 
28	Burn crossing at Glengunnoch Wood	 Burn crossing at Glengunnoch Wood. Trial holes to establish the exact depth would be required. Any structure found would be removed and replaced with a suitably sized polymer duct and the new cable circuit would then be installed over it, depth allowing.
29	Unidentified burn crossing at Chapelbrae Wood	Burn marked at Chapelbrae Wood on the OS maps was not located, this may be as it has been culverted or due to it only flowing seasonally. Provision should be allowed for crossing it when planning the works.
30	Non-inventory designed	The A713 and cable route pass south of Parton passing non-inventory designed landscapes. The road is located within a

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
	landscape south of Parton	medium likelihood (1-200 year) flood zone associated with the adjacent Water of Ken.
31	Burn and lane crossing at Parton Mill Bridge	Burn and lane crossing at Parton Mill Bridge requiring HDD on eastern side of the carriageway, as bridge deck is shallow, approximately 600mm deep. Services were noted adjacent to the bridge on the north-eastern side of the carriageway. 
32	Burn crossing south of Parton Mill Bridge	Burn crossing south of Parton Mill Bridge comprising a deep culvert. Trial holes to establish the exact depth would be required. Any structure found would be removed and replaced with a suitably sized polymer duct and the new cable circuit would then be installed over it, depth allowing.

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
		
33	Burn crossing at Spearford Culvert	Burn crossing at Spearford culvert. Trial holes to establish the exact depth would be required. Any structure found would be  removed and replaced with a suitably sized polymer duct and the new cable circuit would then be installed over it, depth allowing. The road is located within a medium likelihood (1-200 year) flood zone associated with the adjacent Water of Ken.
34	Burnfoot Culvert crossing	Culvert crossing at Burnfoot culvert north of Crossmichael. Trial holes to establish the exact depth would be required. Any structure found would be removed and replaced with a suitably sized polymer duct and the new cable circuit would then be installed over it, depth allowing.

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
		
35	Cabling through Crossmichael	Difficulties associated with cabling within a narrow road (6.6m at the narrowest point adjacent to the bus stop in the centre of town) in a populated area. An appropriate traffic management plan would need to be developed and adopted. Temporary bus stop position and diversions may be required. The cable route passes within close proximity to residential properties. Buried utilities within the carriageway would need to be located by utility search prior to excavation. Directly north of the cable route are non-inventory designed landscapes and a category A listed building. 

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
36	Upper Burnside culvert crossing	 Culvert crossing at Upper Burnside south of Crossmichael. Trial holes to establish the exact depth would be required. Any structure found would be removed and replaced with a suitably sized polymer duct and the new cable circuit would then be installed over it, depth allowing.
37	Danevale Park culvert crossing	 Culvert crossing at Danevale Park south of Crossmichael. Trial holes to establish the exact depth would be required. Any structure found would be removed and replaced with a suitably sized polymer duct and the new cable circuit would then be installed over it, depth allowing.
38	Drainage ditch crossing at Little Mains	Drainage ditch crossing at Little Mains south of Crossmichael. Trial holes to establish the exact depth would be required. Any structure found would be removed and replaced with a suitably sized polymer duct and the new cable circuit would then be installed over it, depth allowing.

<table>
<tr><th>Item No.</th><th>Points of Engineering Difficulty and Environmental Sensitivity</th><th>Comment</th></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>39</td><td>Mains of Greenlaw</td><td>The cable route passes adjacent to the Mains of Greenlaw, a site of cultural heritage. The cable routing at this location would need to consider any specific requirements to avoid/mitigate any loss cultural loss. The cable route is located within a medium likelihood (1-200 year) flood zone associated with the adjacent Water of Ken.
</td></tr>
<tr><td>40</td><td>Peat</td><td>Potential for peat within land adjacent to River Dee. Peat ground preparation work may be required. This may also impact on cable conductor material and size. The cable route is located within a medium likelihood (1-200 year) flood zone associated with the adjacent Water of Ken.</td></tr>
</table>

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
41	Burn crossing at Barony Isle	Burn crossing at Barony Isle requiring HDD. The cable route is located within a medium likelihood (1-200 year) flood zone associated with the adjacent Water of Ken. Scheduled monuments are sited directly north and south of the cable route. 
42	River Dee crossing	HDD under river Dee would be required, with launch and reception pit identification and access for drilling rigs to be developed. The cable route is located within a medium likelihood (1-200 year) flood zone associated with the adjacent Water of Ken. 
43	Peat	Potential for peat within land adjacent to River Dee. Peat ground preparation work may be required. This may also impact on cable conductor material and size. The cable route is located within a medium likelihood (1-200 year) flood zone associated with the adjacent Water of Ken.

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
44	Lane crossing	Lane crossing south of Glenlochar comprising a duct block spanning the carriageway width. The cable route is located within a medium likelihood (1-200 year) flood zone associated with the adjacent Water of Ken and passes through a low likelihood (1-1000 years) flood zone south of Braefoot. The cable route passes through an area of non-inventory designed landscape extending to the north. Several residential properties are located in close proximity north of the cable route. 
45	Cabling within arable/pastoral farmland	The cable crosses pastoral farmland as it heads south towards the A75 from Glenlochar. 
46	Cabling in lane at Barnboard Wood	The cable route diverts from pastoral land into an unmarked lane to avoid a section of native and ancient woodland at Barnboard Wood, before returning to the arable/pastoral farmland again. Within the lane is a drainage crossing at

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
		 Balmaghie Bridge. Trial holes to establish the exact depth of the crossing would be required. Any conflicting structure found would be removed and replaced with a suitably sized polymer duct and the new cable circuit would then be installed under or over it, dependant on depth.
47	Lane and drainage ditch crossing at Barnboard Cottage	 The cable, having returned to the pastoral farmland, crosses a lane and drainage ditch at Barnboard Cottage. An HDD would be required to cross, spanning the Lane and ditch together.
48	Lane and drainage ditch crossing at Longwood	The cable crosses a lane and drainage ditch at Longwood Cottage. An HDD would be required to cross, spanning the Lane and ditch together.

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
		
49	Lane crossing at Dunjop	Lane crossing at Dunjop comprising a duct block spanning the carriageway width. 
50	Significant changes in elevation south of Long Wood	Steep undulations within the topography in land south of Long Wood that may require cable anchoring systems to be designed and installed to minimise migration of the cable down a slope over the long term.

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
		
51	Lane crossing at Upper Balannan	Lane crossing at Upper Balannan comprising a duct block spanning the carriageway width. 
52	Lane crossing at south of White Hill	Lane crossing at south of White Hill comprising a duct block spanning the carriageway width. Several residential properties

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
		are located on the lane west of the cable route at White Hill. 
53	Shallow rock	The cable route bypasses rocky outcrops on the hill sides in land north of the A75. 
54	A75 crossing	HDD under A75 would be required, with launch and reception pit identification and access for drilling rigs to be developed.

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
		
55	Native woodlands and Peat	Native woodland is located east of the cable route at Barstibly, with intermittent peat habitats. Several residential properties are also situated east of the cable route at Barstibly. 
56	Significant changes in elevation	Steep undulations within the topography in land south of A75 and Tongland substation that may require cable anchoring systems to be designed and installed to minimise migration of the cable down a slope over the long term. The cable route passes adjacent to several residential dwellings.

Item No.	Points of Engineering Difficulty and Environmental Sensitivity	Comment
		
57	High pressure gas pipeline crossing	Cable circuits cross a high-pressure gas pipeline at Chapel. Early correspondence with the pipeline operators would be advised to understand constraints including spacing requirements, protection, supervised digging arrangements etc.
58	Significant changes in elevation	Steep undulations within the topography in land south of A75 at Castle Hill that may require cable anchoring systems to be designed and installed to minimise migration of the cable down a slope over the long term.
59	Shallow rock	The cable route bypasses rocky outcrops on the hill side south of Bar Hill.
60	Watercourse and residential properties	Several residential properties are located to the east of the cable route as it heads towards Tongland substation. A watercourse is marked directly north of the cable route.

Figure 76 Black line showing cable route UGC6 (map 1 of 9)

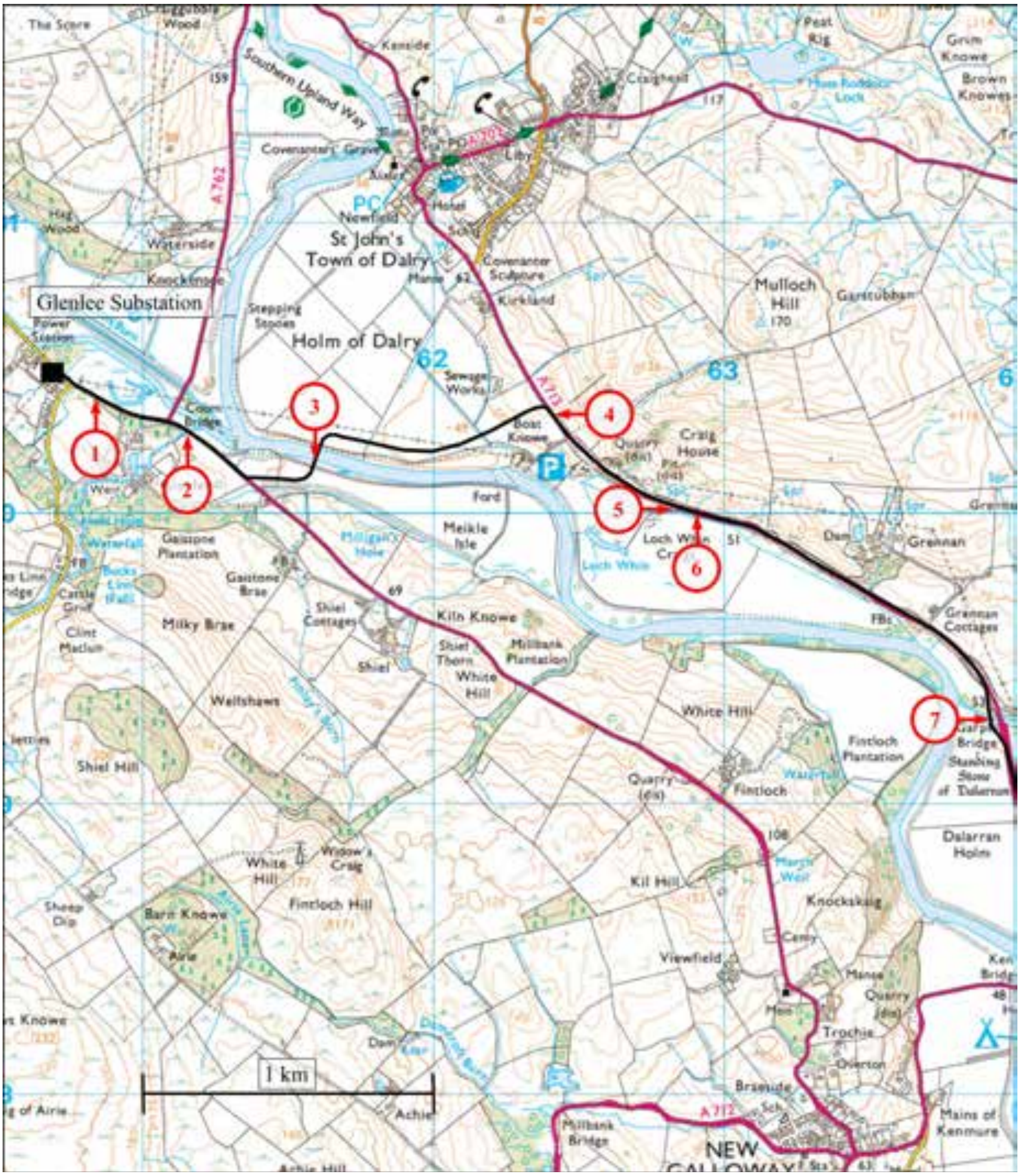


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Figure 77 Black line showing cable route UGC6 (map 2 of 9)

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Figure 78 Black line showing cable route UGC6 (map 3 of 9)

Figure 79 Black line showing cable route UGC6 (map 4 of 9)

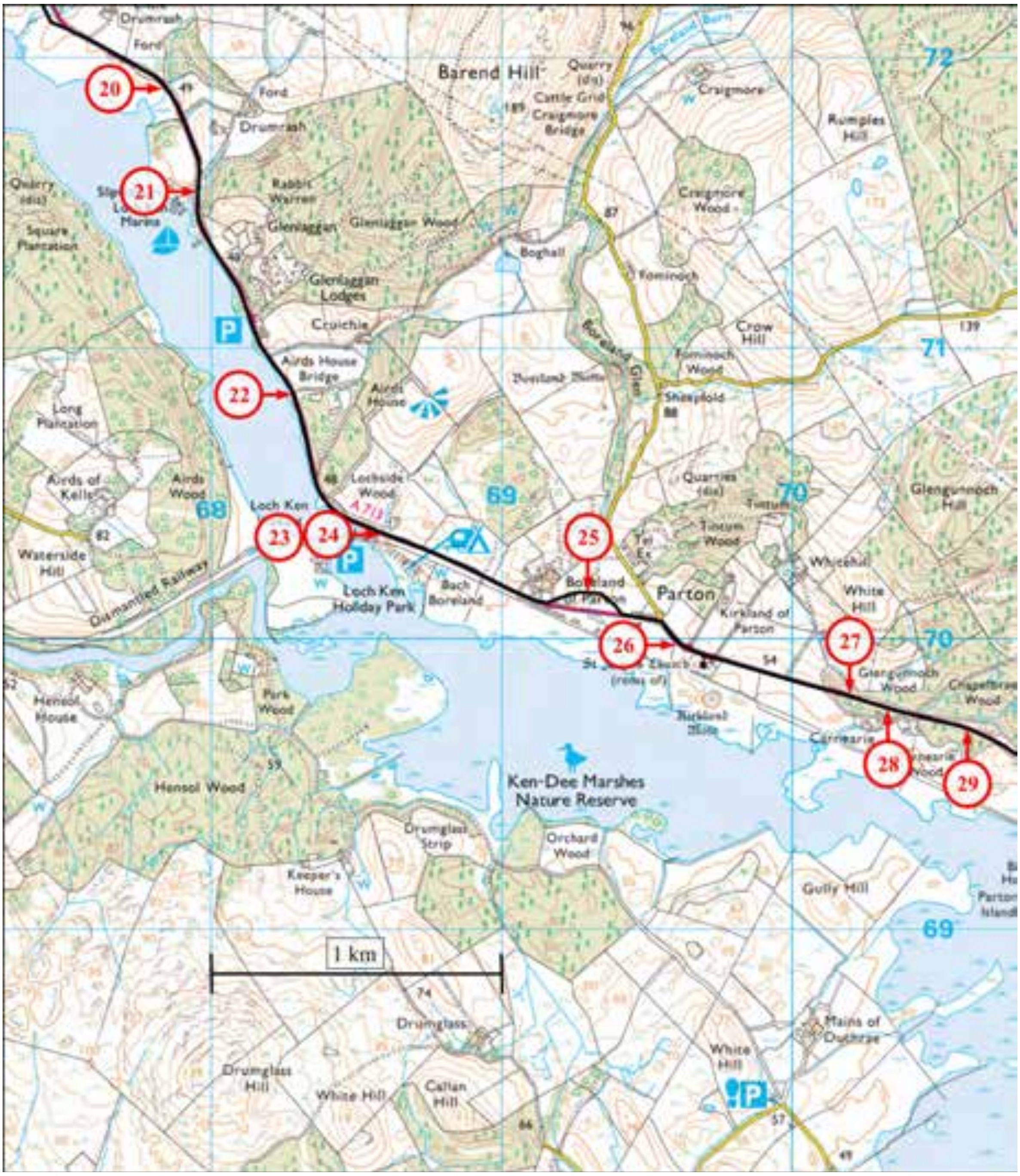

Figure 80 Black line showing cable route UGC6 (map 5 of 9)

Figure 81 Black line showing cable route UGC6 (map 6 of 9)

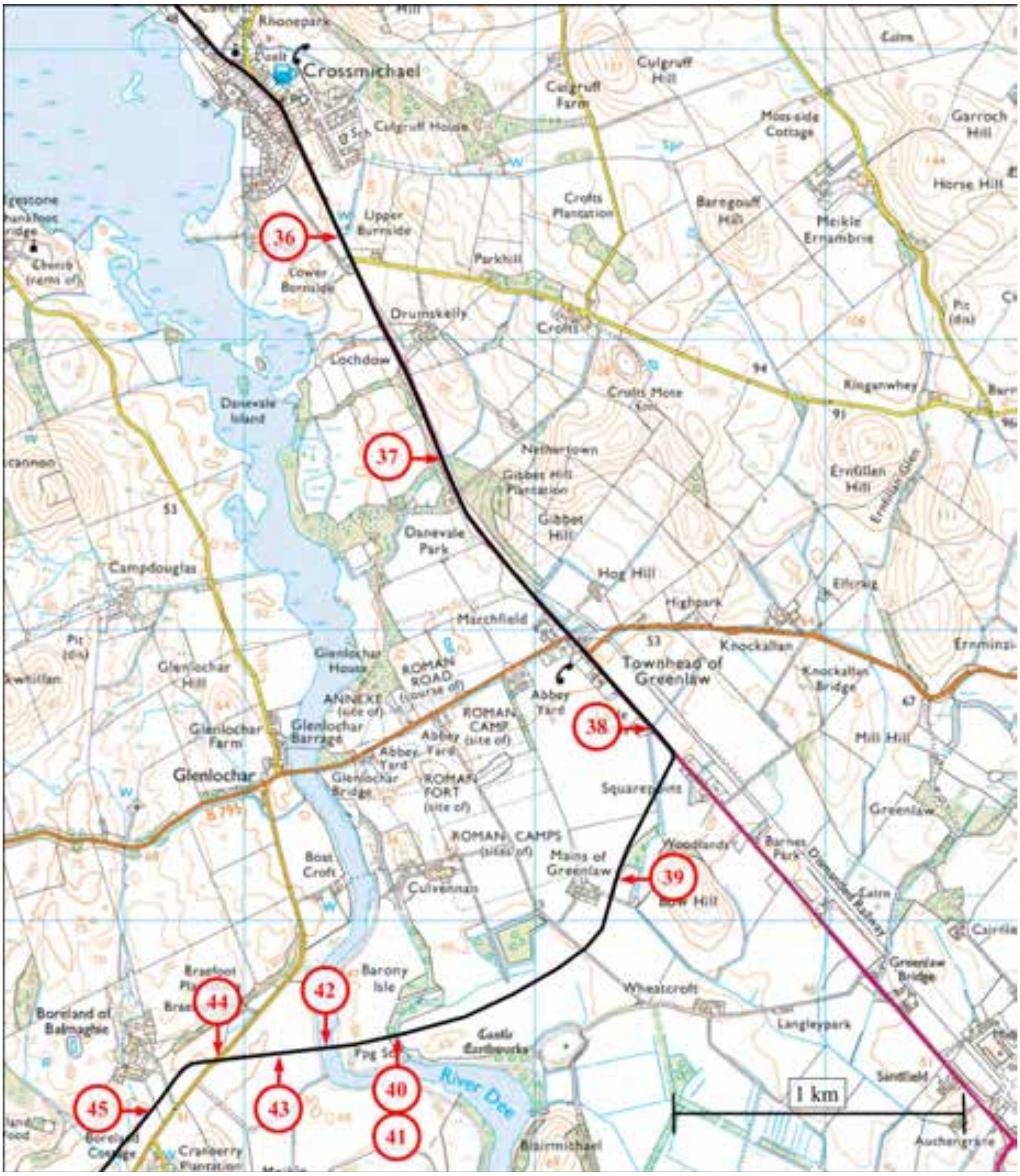

Figure 82 Black line showing cable route UGC6 (map 7 of 9)

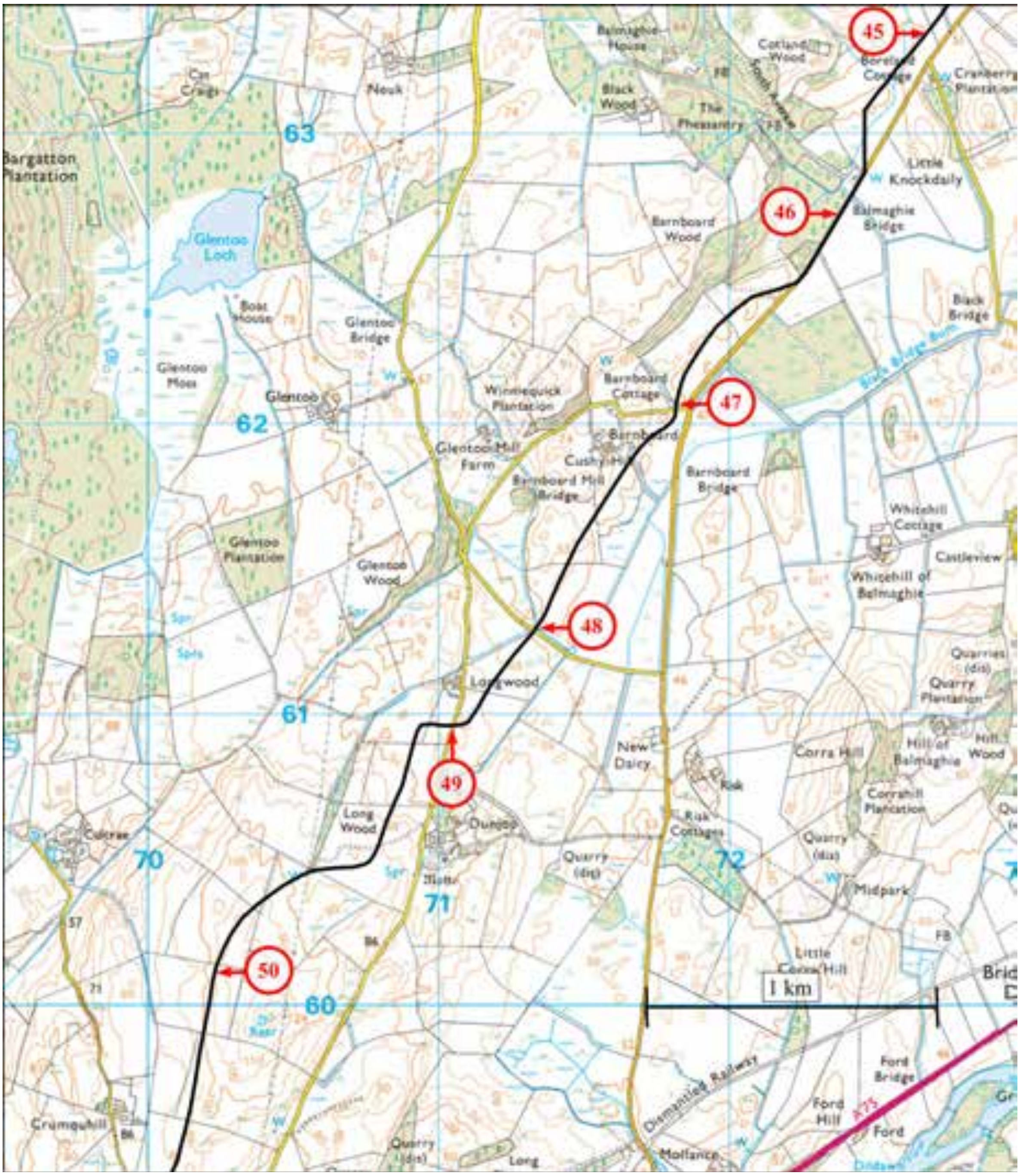

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Figure 83 Black line showing cable route UGC6 (map 8 of 9)

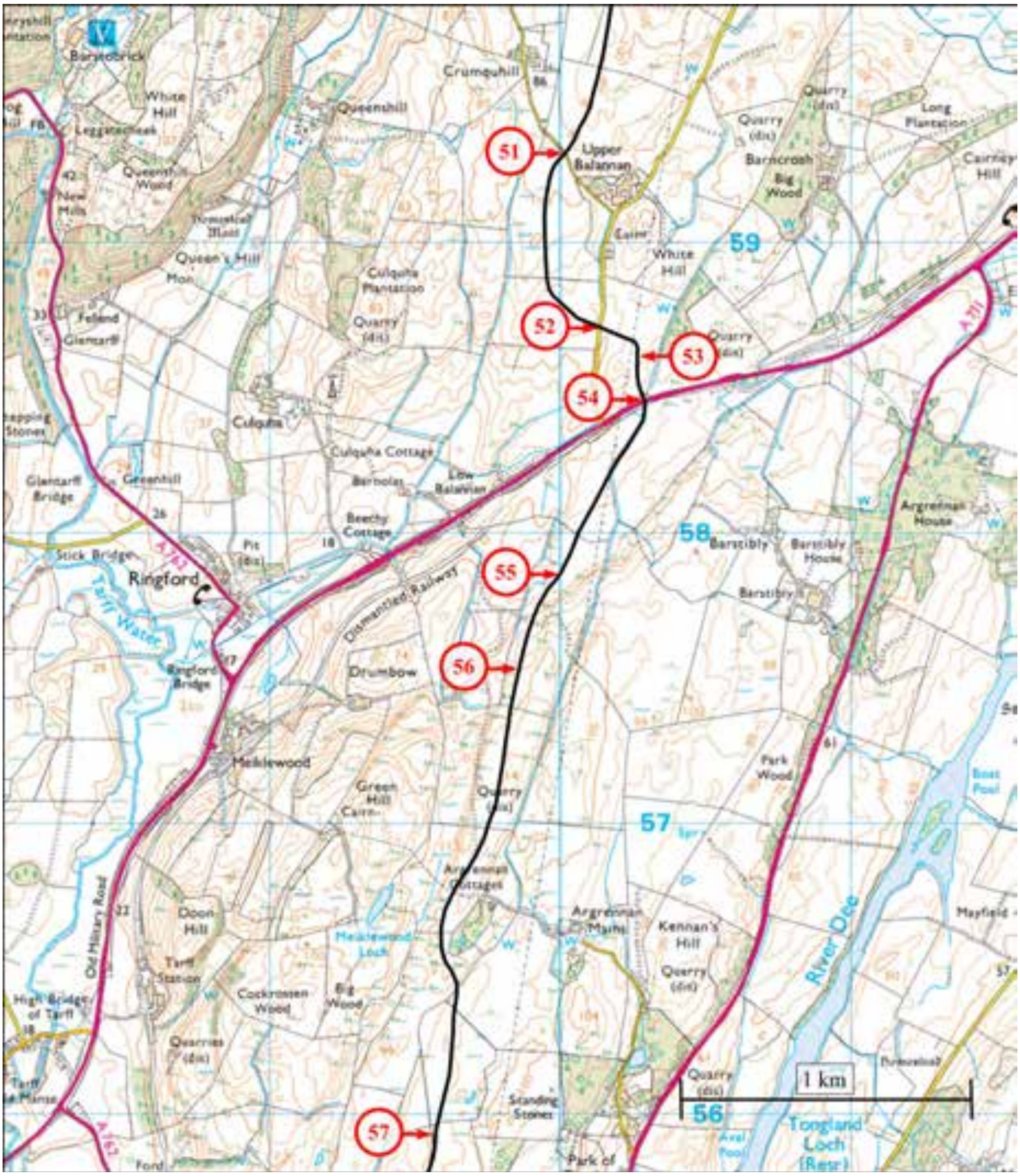
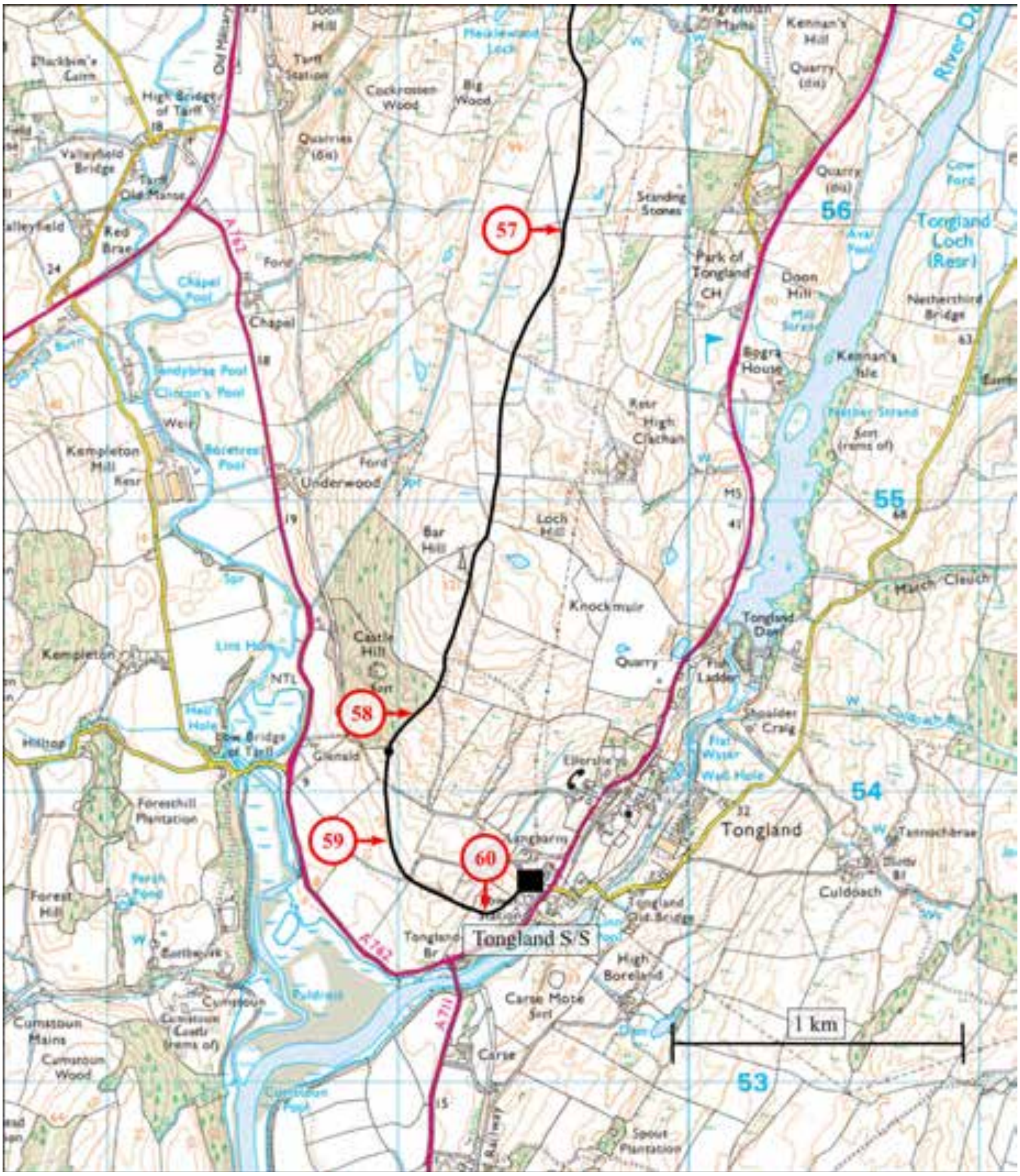


Figure 84 Black line showing cable route UGC6 (map 9 of 9)



6.13.1 UGC6 Typical Installation Swathes

UGC6 cable route would be approximately 37.59km long, all of which would be buried cable comprising two main type of installation swathe:

- Installation within arable/pastoral land (16.40km)
- Installation within carriageway (21.19km)

Figure 8 on page 26 shows a typical double circuit arable/pastoral land swathe, approximately 32m wide.

Figure 11 on page 29 shows a typical carriageway installation, with both circuits installed within one lane of the carriageway.

6.13.2 UGC6 Haul Road Requirements

Haul roads would be required at various locations along the UGC6 cable route to enable both labour, plant and material access during the construction phase of the project, and to allow future maintenance and fault repair work to be carried out. Refer to section 4.1.4 of this report for additional information on typical haul road layouts.

Table 37 provides anticipated location and length of the haul road requirements for UGC6.

Table 37 UGC6 haul road requirements

Haul Road Location and Type Temporary (T) or Permanent (P)	Approximate Haul Road Length (m)
From A762 to Meikle Isle for cabling access and access for the HDD crossing of the Water of Ken (T)	500
From A713 to Water of Ken crossing position adjacent to Boat Knowe (T)	300
From A713 to Barony Isle for cabling access and access for the HDD crossing of the River Dee (T)	1,600
From the lane south of Glenlochar to the HDD crossing position on the River Dee (T)	500
Parallel to the lane at Boreland Cottage for cabling access (T)	800
Parallel to the lane at Barnboard Wood for cabling access (T)	800
From Barnboard Cottage to A75 for cabling access and access to HDD positions at Longwood, Upper Balannan and the A75 (T)	4,800
From A75 HDD position to Tongland substation south of Langbarns, for cabling access (T)	6,400

Haul Road Location and Type Temporary (T) or Permanent (P)	Approximate Haul Road Length (m)
Total Haul Road Requirement for UGC6	15,700

6.13.3 UGC6 Crossing Schedule

Table 38 gives the crossing schedule for UGC6. From this schedule, key crossings are highlighted in red and discussed further.

Table 38 UGC6 crossing schedule

Crossing No.	GPS Crossing Location	Crossing Description	Proposed Crossing Solution
1	55° 05' 51.29" N 4° 10' 39.12" W	Burn at Coom Bridge	HDD approximately 100m or cable bridge
2	55° 05' 48.23" N 4° 10' 21.12" W	Water of Ken Crossing	HDD approximately 350m
3	55° 05' 57.71" N 4° 09' 36.19" W	Burn south of Craig House on A713	Duct and cable over
4	55° 05' 35.90" N 4° 08' 26.00" W	Unidentified burn at Grennam on A713	Duct and cable over
5	55° 05' 21.70" N 4° 08' 00.20" W	Burn at Garple Bridge	HDD approximately 100m
6	55° 04' 36.70" N 4° 07' 45.90" W	Burn south of Ken Bridge Hotel	Duct and cable over
7	55° 04' 35.40" N 4° 07' 45.80" W	Unidentified burn north of Cubbox on A713	Duct and cable over
8	55° 04' 17.30" N 4° 07' 33.90" W	Burn at Killochy Cottage on A713	Duct and cable under
9	55° 03' 52.70" N 4° 07' 29.30" W	Burn at High Park on A713	Duct and cable over
10	55° 03' 14.30" N 4° 06' 45.60" W	Burn at Maukinhowe on A713	Install cable in bridge deck
11	55° 03' 08.10" N 4° 06' 37.30" W	Burn south of Shirmers Moss on A713	Duct and cable over

Crossing No.	GPS Crossing Location	Crossing Description	Proposed Crossing Solution
12	55° 03' 06.00" N 4° 06' 34.70" W	Burn (dry) north of White Hill on A713	Duct and cable over
13	55° 02' 22.20" N 4° 05' 51.40" W	Burn at Shirmers Bridge	Install in old road bridge
14	55° 02' 03.80" N 4° 05' 36.30" W	2 x unidentified burns at Mid Tors on the A713	Duct and cable over
15	55° 01' 44.80" N 4° 04' 53.60" W	Burn at Kiln Hill on the A713	Duct and cable over
16	55° 01' 43.10" N 4° 04' 47.20" W	Burn at Arvie Wood on the A713	Duct and cable over
17	55° 01' 34.50" N 4° 04' 30.00" W	Arvie burn at Burnfoot Bridge on the A713	HDD approximately 100m
18	55° 01' 23.00" N 4° 04' 04.60" W	Unidentified burn at Drumrash on the A713	Duct and cable over
19	55° 01' 15.20" N 4° 04' 01.10" W	Burn at Glenlaggan Wood on the A713	Duct and cable over
20	55° 00' 52.60" N 4° 03' 41.60" W	Burn at Airds House Bridge on the A713	Duct and cable over
21	55° 00' 37.60" N 4° 03' 22.60" W	Unidentified burn crossing at Lochside Wood on the A713	Duct and cable over
22	55° 00' 29.20" N 4° 02' 42.60" W	Burn at Boreland of Parton on the A713	HDD approximately 100m

Crossing No.	GPS Crossing Location	Crossing Description	Proposed Crossing Solution
23	55° 00' 20.60" N 4° 01' 52.40" W	Burn at Cranearie on the A713	Duct and cable over
24	55° 00' 19.40" N 4° 01' 45.40" W	Burn at Glengunnoch Wood on the A713	Duct and cable over
25	55° 00' 18.60" N 4° 01' 38.70" W	Unidentified burn at Chapelbrae Wood on the A713	Duct and cable over
26	54° 59' 53.60" N 4° 00' 22.40" W	Burn and lane at Parton Mill Bridge on the A713	HDD approximately 50m
27	54° 59' 52.60" N 4° 00' 21.00" W	Burn south of Parton Mill Bridge on the A713	HDD approximately 50m
28	54° 59' 27.20" N 3° 59' 51.40" W	Burn at Spearford culvert on the A713	Duct and cable over
29	54° 58' 57.60" N 3° 59' 23.50" W	Burnfoot culvert on the A713	Duct and cable over
30	54° 58' 32.40" N 3° 58' 50.10" W	Upper Burnside culvert on the A713	Duct and cable over
31	54° 58' 07.30" N 3° 58' 28.10" W	Danevale Park culvert on the A713	Duct and cable over
32	54° 57' 40.60" N 3° 57' 51.00" W	Drainage ditch at Little Mains	Duct and cable over
33	54° 57' 04.60" N 3° 58' 34.50" W	Burn at Barony Isle	HDD approximately 100m
34	54° 57' 02.70" N 3° 58' 48.80" W	River Dee	HDD approximately 350m

Crossing No.	GPS Crossing Location	Crossing Description	Proposed Crossing Solution
35	54° 56' 58.60" N 3° 59' 11.70" W	Lane crossing south of Glenlochar	Duct block
36	54° 56' 11.80" N 4° 00' 07.40" W	Lane and drainage ditch at Barnboard Cottage	HDD approximately 50m
37	54° 55' 46.70" N 4° 00' 34.80" W	Lane and drainage ditch at Longwood	HDD approximately 50m
38	54° 55' 41.80" N 4° 00' 47.80" W	Lane at Dunjop	Duct block
39	54° 54' 38.70" N 4° 01' 43.10" W	Lane at Upper Balannan	Duct block
40	54° 54' 21.70" N 4° 01' 37.40" W	Lane south of White Hill	Duct block
41	54° 54' 13.40" N 4° 01' 30.30" W	A75 road	HDD approximately 400m
42	54° 52' 50.60" N 4° 02' 12.60" W	Gas pipeline	Cable under

UGC6 has two significant watercourse crossings at the Water of Ken at Meikle Isle and the River Dee at Barony Isle and one significant A-road crossing at A75, for which HDD solutions would be proposed for each.

In addition to the major crossings considered for this cable route, there are 9 minor watercourses including burns, culverts, drainage ditches and minor country lanes that would require crossing. With the proposed crossing solutions being a mix of short HDD, cable bridge and duct and cable under. Refer to section 5.3 of this report for additional information on these proposed crossing methods.

For minor roads the proposed solution would be to install a duct block across the width of the road. A duct block comprises concrete encasing the ducts within a mass concrete block spanning the roads width. This allows the road to be reinstated and reopened prior to the cable being pulled into position.

In addition to the crossings provided in Table 38 a second gas pipeline (IC1 operated by GNI (UK) Ltd) was identified during the site survey which appeared to run in close proximity to the UGC6 cable route between Glenlochar and the A75. At the time of writing no route map for this gas pipeline had been obtained to clarify its precise location in relation to the proposed UGC6 cable route. Once the exact position of the pipeline has been identified, changes to the cable route may be required to avoid multiple crossing and re-crossing of the pipeline by the cables thereby decreasing the risk of damage to the pipeline during cable route construction.

6.13.3.1 UGC6 HDD Launch and Reception Compound Positions

The footprint of the HDD compounds would vary depending on the length, depth, complexity of the specific HDD and location along the cable route, but typically a drill launch site compound would measure approximately 30m x 30m, and a drill reception site compound 20m x 20m. Additional information is provided in section 5.3.4 of this report.

The launch and reception compound positions for each HDD along the UGC6 cable route have been identified and photographs showing their locations along with a brief description are provided in Table 39.

Table 39 UGC6 HDD launch and reception positions

HDD Description	Photograph
Burn at Coom Bridge, HDD length approximately 100m. Launch and reception positions were identified on the southern side of the bridge in scrub land with access back onto the A762.	

HDD Description	Photograph
Water of Ken Crossing, HDD length is approximately 350m. Launch and reception positions were identified on either side of the river in arable/pastoral land. Flood defence embankments were noted on both riverbanks. Consideration of this additional burial depth would be required when carrying out the cable rating assessment. Access to the launch and reception positions would be by temporary haul roads.	
Burn at Garple Bridge, HDD length is approximately 100m. Launch and reception positions were identified on the western side of the A713 in adjacent arable/pastoral land with access back onto the A713. Flood defence embankments were noted in the fields adjacent to Garple Bridge.	
Arvie burn at Burnfoot Bridge on the A713, HDD length is approximately 100m. Launch and reception positions were identified on western side of the A713 in arable/pastoral land with good access onto the A713.	

HDD Description	Photograph
Burn at Boreland of Parton on the A713, HDD length is approximately 100m. Launch and reception positions were identified on northern side of the A713 in arable/pastoral land, with good access onto the A713.	
Burn at Parton Mill Bridge on the A713 and burn south of Parton Mill Bridge including a lane. HDD length approximately 100m (50m each). Launch and reception positions were identified on the eastern side of the A713 in arable/pastoral land, with good access onto the A713.	
Burn at Barony Isle and the River Dee, HDD length is approximately 450m (100m + 350m). Launch and reception positions were identified to the east and west of the River Dee in arable/pastoral land, with access to the launch and reception positions provided by temporary haul roads.	

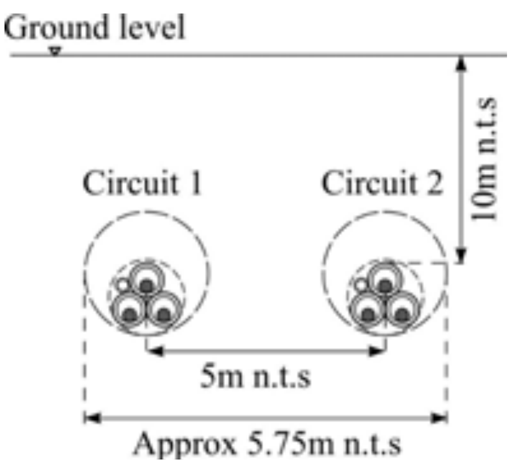
HDD Description	Photograph
Lane and drainage ditch at Barnboard Cottage, HDD length is approximately 50m. Launch and reception positions were identified to the north and south of the lane in arable/pastoral land, with good access back onto the lane as required.	
Lane and drainage ditch at Longwood, HDD length is approximately 50m. Launch and reception positions were identified to the north and south of the lane in arable/pastoral land, with good access back onto the lane as required.	
A75 road, HDD length is approximately 400m. Launch and reception positions were identified north and south of the A75 in arable/pastoral land, with good access onto the A75.	

6.13.3.2 UGC6 Water of Ken, the River Dee and the A75 Crossing

With 3 cables per circuit, an HDD formation would comprise 2 trefoil groups. The spacing between each trefoil group would be dictated by the depth the HDD profile needs to achieve to clear the carriageway foundations. Figure 41 on page 61 shows the relationship between burial depth and circuit spacing for three cable types: 800mm² copper, 1600mm² aluminium and 1600mm² copper.

For all three crossings: at a nominal burial depth of 10m for 1600mm² aluminium XLPE cable, Figure 41 on page 61 gives the centre to centre spacing between each circuit as approximately 3.2m, based on a PE duct OD of 250mm, each trefoil duct group would be strapped together in formation and installed within a bore diameter of approximately 750mm. However, to ensure the structural integrity of both bores at each crossing position, a greater centre to centre bore separation of 5m has been considered here. Figure 85 provides a cross section of this HDD arrangement and provides an indicative swathe width of approximately 5.75m for a drill depth of 10m. Guidance should be sought during the planning and consents stage of the works to ascertain the clearance requirements for each planned crossing location.

Figure 85 HDD cross section at Water of Ken, River Dee and A75 crossing



6.13.4 UGC6 Termination Positions

The UGC6 cable route runs from substation to substation with terminations likely to be ODSE type installed within substation compounds. Figure 4 on page 18 provides an example of a typical air insulated 132kV cable termination.

Within the confines of the substation the cables can be installed in surface flush concrete troughs filled with CBS. These can make future access to the cables more convenient but entail additional cost and could require sporadic maintenance to the lids etc.

6.13.5 UGC6 Cable Section Lengths and Critical Joint Bay Locations

Based on the selected cable designs and the selected cable route for UGC6, Table 40 provides suggested cable section lengths based on the principles of a cross bonded cable system design which essentially requires balanced minor sections within a 3 cable major section. Joint bays that are considered to be critical have been highlighted in red.

Table 40 UGC6 cable section lengths

Section No.	Joint Bay No.	Chainage (km)	Section Length (m)	Bonding		Installation Description
N/A	Glenlee S/S	0.00	N/A	N/A		Glenlee S/S
1	1/2	0.78	783	Major section	Minor section	Carriageway – within a flood zone
2	2/3	1.57	783		Minor section	HDD under River Ken – arable/pastoral - within flood zone
3	3/4	2.35	783		Minor section	Carriageway with verge – within a flood zone
4	4/5	3.13	783	Major section	Minor section	Carriageway with verge – within a flood zone
5	5/6	3.92	783		Minor section	Carriageway with verge – within a flood zone
6	6/7	4.70	783		Minor section	Carriageway with verge – within a flood zone
7	7/8	5.48	783	Major section	Minor section	Carriageway with verge – within a flood zone
8	8/9	6.26	783		Minor section	Carriageway with verge
9	9/10	7.05	783		Minor section	Carriageway
10	10/11	7.83	783	Major section	Minor section	Carriageway
11	11/12	8.61	783		Minor section	Carriageway
12	12/13	9.40	783		Minor section	Carriageway
13	13/14	10.18	783	Major section	Minor section	Carriageway
14	14/15	10.96	783		Minor section	Carriageway – within a flood zone
15	15/16	11.75	783		Minor section	Carriageway with verge – within a flood zone
16	16/17	12.53	783	Major section	Minor section	Carriageway – within a flood zone
17	17/18	13.31	783		Minor section	Carriageway with verge – within a flood zone

Section No.	Joint Bay No.	Chainage (km)	Section Length (m)	Bonding		Installation Description
18	18/19	14.09	783		Minor section	Carriageway adjacent to layby – within a flood zone
19	19/20	14.88	783	Major section	Minor section	Carriageway with pavement
20	20/21	15.66	783		Minor section	Carriageway
21	21/22	16.44	783		Minor section	Carriageway – within a flood zone
22	22/23	17.23	783	Major section	Minor section	Carriageway - adjacent to layby – within a flood zone
23	23/24	18.01	783		Minor section	Carriageway – within a flood zone
24	24/25	18.79	783		Minor section	Carriageway – within a flood zone
25	25/26	19.58	783	Major section	Minor section	Carriageway
26	26/27	20.36	783		Minor section	Carriageway
27	27/28	21.14	783		Minor section	Carriageway
28	28/29	21.92	783	Major section	Minor section	Carriageway
29	29/30	22.71	783		Minor section	Carriageway
30	30/31	23.49	783		Minor section	Arable/pastoral - adjacent to road joining position
31	31/32	24.27	783	Major section	Minor section	Arable/pastoral - Mains of Greenlaw – within a flood zone
32	32/33	25.06	783		Minor section	HDD - Loch Ken – Arable/pastoral land – within a flood zone
33	33/34	25.84	783		Minor section	Arable/pastoral – within a flood zone
34	34/35	26.62	783	Major section	Minor section	Carriageway
35	35/36	27.41	783		Minor section	Arable/pastoral
36	36/37	28.19	783		Minor section	Arable/pastoral
37	37/38	28.97	783	Major section	Minor section	Arable/pastoral
38	38/39	29.75	783		Minor section	Arable/pastoral
39	39/40	30.54	783		Minor section	Arable/pastoral

Section No.	Joint Bay No.	Chainage (km)	Section Length (m)	Bonding		Installation Description
40	40/41	31.32	783	Major section	Minor section	HDD A75 – Arable/pastoral
41	41/42	32.10	783		Minor section	Arable/pastoral
42	42/43	32.89	783		Minor section	Arable/pastoral
43	43/44	33.67	783	Major section	Minor section	Arable/pastoral
44	44/45	34.45	783		Minor section	Arable/pastoral – Close to high pressure gas pipeline
45	45/46	35.24	783		Minor section	Arable/pastoral
46	46/47	36.02	785	Major section	Minor section	Arable/pastoral
47	47/48	36.81	785		Minor section	Arable/pastoral
48	Tongland Substation	37.59	785		Minor section	Tongland Substation

Joint bays within UGC6 fall within two installation types, installation within carriageway and installation within arable/pastoral land.

Drawings of the various joint bay installation arrangements may be located within this report as follows:

- Figure 24 on page 42 shows a typical cross section for a joint bay installed within a carriageway with no verge.
- Figure 26 on page 43 shows a typical cross section for a joint bay installed within a carriageway with a verge.
- Figure 66 on page 120 shows a typical joint bay installed within arable/pastoral land.

For UGC6 joint bays 1/2 to 7/8, 14/15 to 18/19, 21/22 to 24/25, and 31/32 to 34/35 inclisive are located within either low (1 in 1000 year) or medium (1 in 200 year) risk flood risk zones. It would be essential that for the duration of the jointing works the joint bay is kept dry and a clean working environment maintained. Sump positions within the joint bay concrete base slab are used as dewatering points, with pumps potentially required to run 24 hours a day, 7 days a week. Standby pumps may also be required in the event of pump breakdown.

Joint bay 44/45 would be located close to where the cable route crosses a high pressure gas pipeline. Supervision may be required during the excavation of this joint bay by the owner/operator of the gas pipeline, along with excavation guidance and minimum clearnace requirements. Dialogue at an early stage with the gas line owner/operator would be recommended to ensure minimal delays during the installation programme. If the pipeline has a cathodic protection (CP) system fitted then a study would be required to show that any adverse impact the cable system might have on the gas pipelines CP system has been assessed and mitigated appropriately.

6.13.6 UGC6 Outline Construction Programme

Based on the cable system design information discussed within this study, CCI have developed an outline construction programme for the UGC6 cable route. Refer to Table 41. This programme states the critical path construction and installation activities and provides duration estimates for each. From this, an approximate duration to complete the UGC6 works has been derived given in weeks.

Table 41 UGC6 critical path programme

Critical Path Activity	Critical Path Duration (weeks)
Mobilisation	1.4
Enabling, civil and reinstatement works	65.5
Cable installation and jointing works	35.9
HV testing and commissioning	1.4
Demobilisation and site clearance	1.4
Total Duration	**105.6**

The durations are a critical path estimate based on up to 3 installation teams and 2 reinstatment teams working simulaneously along different sections of the route. These civil teams would be supported by jointing teams working to make off the cable joints and terminations.

7 Costs of Underground Cable Routes

SPEN has provided a bill of quantities (BoQ) which gives cost breakdowns for each of the 6 UGC routes. Refer to Table 42 below.

Table 42 UGC route costs

Route	UGC1	UGC2	UGC3	UGC4	UGC5	UGC6
Route Length [km]	2.40	7.20	4.33	16.00	2.20	37.59
	£(000's)	£(000's)	£(000's)	£(000's)	£(000's)	£(000's)
Materials	6,579	18,699	3,013	10,304	1,670	23,881
Construction	5,164	11,896	7,563	20,785	5,835	54,299
Project management, accommodation & site welfare	2,936	7,648	2,644	7,772	1,876	19,545
Tree cutting	28	104	16	558	1	296
Wider system requirements (e.g. OHL sections, reactive compensation)	737	3,626	0	8,035	0	14,249
Sub Total	**15,444**	**41,973**	**13,236**	**47,545**	**9,382**	**112,270**
Contingency (15%)	2,205	5,752	1,985	5,913	1,407	14,703
Total	**17,649**	**47,725**	**15,221**	**53,367**	**10,789**	**126,973**

Based on the UGC route assessment provided by CCI, costs for each of the 6 UGC routes have been compiled and provided by SPEN using their own in house data. These costs are summarised in Table 42 along with a calculated cost per km, in Table 43.

Table 43 Summary of cost of undergrounding for each cable route from SPEN

Route	Total Route Length (km)	Projected Cost (‘000)	Cost per km (‘000)
UGC1	2.40	£17,649	£7,354
UGC2	7.20	£47,725	£6,628
UGC3	4.33	£15,221	£3,515
UGC4	16.00	£53,367	£3,335
UGC5	2.20	£10,789	£4,904
UGC6	37.59	£126,973	£3,378

8 Conclusions

This report provides technical considerations for the preferred cable route options on each of six underground cable (UGC) study areas forming part of the SPEN Kendoon – Tongland 132kV reinforcement project.

- UGC1: Polquhanity to Kendoon (Towers N230 to PK10)
- UGC2: Kendoon Substation to Glenlee Substation (Towers PK10 to PK33)
- UGC3: Queen's Way Crossing (Towers GT08-GT21)
- UGC4: Bennan, Slogarie and Laurieston Forests (Towers GT25-GT78)
- UGC5: A75 crossing (Towers GT97-GT104)
- UGC6: Undergrounding the proposed Glenlee Sub-Station to Tongland Sub-Station route in its entirety

The underground cable routes in this report include 16 minor route adjustments made for practical purposes, from those detailed in the Kendoon – Tongland 132kV Preliminary Investigative Cable Route Study ER1003 Rev C[11]. 15 of these modifications were as a result of site visits subsequent to the issue of cable study ER1003 rev B and one change was due to a landowner request requiring a termination tower to be relocated.

The environmental consideration for each undergrounding route section has been provided by Land Use Consultants Limited (LUC) refer to Appendix 3, and the estimated costs of any undergrounding provided by SPEN.

Table 44 provides a summary of the key cable route installation characteristics for each of the six UGC routes.

Table 44 Summary of key UGC installation characteristics

Cable Route	Installation Type						Total Route Length (km)
	Carriageway		Arable/Pastoral Land		Forest Track		
	km	% of route	km	% of route	km	% of route	
UGC1	1.57	65.42%	0.83	34.58%	0.00	0.00%	2.40
UGC2	6.30	87.50%	0.90	12.50%	0.00	0.00%	7.20
UGC3	0.00	0.00%	2.16	49.98%	2.17	50.02%	4.33
UGC4	7.44	46.47%	0.76	4.78%	7.80	48.75%	16.0
UGC5	0.00	0.00%	2.20	100.00%	0.00	0.00%	2.20
UGC6	21.19	56.37%	16.40	43.63%	0.00	0.00%	37.59

It was found that each of the underground cable routes were assessed as constructible but that the routes:

- Contains a number of engineering difficulties some of which will require furthermore detailed investigation or the use of available alternatives.

- Will require agreements from stakeholders on the access and use of land (forestry, pastoral and arable) as well as existing track and road infrastructure (bridges, road, traffic controls, stone tracks, footpath and recreational areas).
- Will require (with the exception of UGC6) the installation of cable termination compounds or OHL terminal towers capable of supporting cable terminations.
- Require a utilities search to determine the presence of any underground services that may obstruct each cable route (including high pressure gas lines).

Based on the UGC route assessment, costs for each of the 6 UGC routes have been compiled and provided based on SPEN's in house data collated from previous installation experience and summarised in Table 45 along with a calculated cost per km.

Table 45 Summary of cost of undergrounding for each cable route from SPEN

Route	Total Route Length (km)	Projected Cost ('000)	Cost per km ('000)
UGC1	2.40	£17,649	£7,354
UGC2	7.20	£47,725	£6,628
UGC3	4.33	£15,221	£3,515
UGC4	16.00	£53,367	£3,335
UGC5	2.20	£10,789	£4,904
UGC6	37.59	£126,973	£3,378

9 Abbreviations

AC	Alternating Current
BoQ	Bill of Quantities
CBS	Cement Bound Sand
CCI	Cable Consulting International
CP	Cathodic Protection
DC	Direct Current
DTS	Distributed Temperature Sensing
EIAR	Environmental Impact Assessment Report
ESQCR 2002	Electricity Safety, Quality and Continuity Regulations 2002
FOC	Fibre Optic Cable
HDD	Horizontal Directional Drilling
HV	High Voltage
KTR	Kendoon to Tongland Reinforcement
LUC	Land Use Consultants Limited
NTS	Not To Scale
NWSS	Native Woodland Survey of Scotland
OHL	Overhead Line
PE	Polyethylene
RF	Reinforced
SPEN	Scottish Power Energy Networks
SVL	Sheath Voltage Limiter
TMF	Thermomechanical Force
UGC	Underground Cable
XLPE	Cross Linked Polyethylene

Appendix 1 SPEN Document : Kendoon to Tongland Reinforcement (KTR) Project

Kendoon to Tongland Reinforcement (KTR) Project

The following intends to set out a brief update on the Kendoon to Tongland Reinforcement (KTR) Project, specifically SP Energy Network's (SPEN) intention to undertake an appraisal of underground cable options as part of the Environmental Impact Assessment (EIA) process.

SPEN's Approach

SPEN's approach to routeing is set out in its published document "*Major Infrastructure Projects: Approach to Routeing and Environmental Impact Assessment*" which can be viewed under the Project Documents tab of the KTR website at www.spendgsr.co.uk. This document underpins the work undertaken to date to develop a proposal for the required reinforcement of the transmission network between Kendoon and Tongland.

On the basis of the detailed routeing work undertaken to date, informed by the previous three rounds of stakeholder consultation, SPEN remains of the view that the use of an overhead line on the selected routes meets the Statutory and Transmission License holder obligations under the Electricity Act 1989. However, in line with the overall approach, SPEN recognises that routeing the overhead line is an iterative process and will continue to review both the routes and the apparatus used throughout the consultation and Environmental Impact Assessment (EIA) stages of the KTR Project.

Background to the Cable Study

A fundamental part of the EIA process is the consideration of alternatives. For overhead line projects, this is taken to mean consideration of alternative overhead line routes. Notwithstanding SPEN's published approach to routeing major electrical infrastructure projects, the Scottish Ministers, in their scoping opinion (October 2017) stated that SPEN's Environmental Impact Assessment Report (EIA-R) for KTR should "*include information on alternative measures, including undergrounding, which have been considered to avoid, prevent or reduce and if possible offset the likely significant adverse landscape and visual effects where these have been identified through consultation feedback from affected communities or the routeing process e.g. 'pinch points' or cumulative effects on sensitive receptors.*"

In response to the Scottish Ministers' scoping opinion, taken with consultation feedback received from stakeholders and communities affected by the KTR Project, SPEN propose to undertake a study of underground options for the areas identified through the three rounds of pre-application consultation. The areas identified for inclusion in this study are as follows:

- Polquhanity to Kendoon
- Queen's Way Crossing
- Bennan, Slogarie and Laurieston Forests
- A75 crossing
- Consideration of undergrounding the proposed Glenlee to Tongland route in its entirety

Study Aims and Outputs

The main aim of the study is to undertake a comparative appraisal of underground cable and overhead lines for the identified areas. The findings of the resulting appraisals will be presented as alternatives in the KTR EIA Report (EIA-R) which will accompany the applications for consent to the Scottish Minsters. This appraisal will focus on a range of factors under the following broad headings:

- technical
- economic
- environmental

Identification of Cable Routes

For a variety of reasons an underground cable will not necessarily follow the route of the proposed overhead line, therefore, it is proposed that potential cable route options will be identified and appraised for each of the areas, culminating in the selection of a cable route for each area.

In a similar method to developing an overhead line route, a cable routeing objective has been developed to *"identify a technically feasible and economically viable cable route, between the specified points, which causes on balance the least disturbance to people and the environment."* Cable routes will therefore have to establish a balance between engineering requirements, economic viability, land use and the environment. This approach is consistent with SPEN's transmission license duties and environmental obligations under Schedule 9 of the Electricity Act 1989.

The criteria for the identification of cable routes may include the following:

- safety and reliability;
- constructability
- Suitable locations for transition between OHL and cable;
- ease of access for construction and maintenance along route of cable;
- likely impact on the local environment during construction and ability to mitigate this;
- disruption to third parties during construction and ability to mitigate this;
- ground conditions, including risk of contamination and also ground stability;
- the need to cross wet areas and/or habitats that are difficult to reinstate successfully;
- flood risk, proximity to water supplies and ability to cross watercourses at their narrowest point;
- long term visibility of the cable route post construction, including the length that will be seen and the distance at which it will be visible;
- likely long term loss of landscape features such as hedges or individual trees;
- likely long term impact on known and unknown archaeology.

Appraisal of Cable and Overhead Line

The final cable routes for each area will be used as the basis for a comparative appraisal against the proposed overhead line routes developed to date. SPEN will consider the outcome of this study as part of the EIA process and will publish its overall conclusions as part of the EIA Report.

Roles and Responsibilities

SPEN have brought together a multi-disciplinary team consisting of both in-house and external expertise to undertake this appraisal. The broad roles and responsibilities for each discipline are set out in the table below.

Project Team Member	Responsibilities
Cable Consulting International Limited (CCI)	Identify technically feasible cable routes Technical commentary on cable options
SPEN	Economic assessment of cable options provided by CCI Economic assessment of overhead line options by CCI Technical assessment of overhead line sections
Land Use Consultants (LUC)	Provide landscape and environmental information/site input to inform CCI work on identification of cable options. Provide landscape and environmental commentary on cable options provided by CCI. Provide landscape and environmental commentary on overhead line sections provided by SPEN.
Copper Consultants	Community relations, consultation and managing public and stakeholder enquiries for the KTR Project. **Note: Any queries regarding the cable study should be made to the existing KTR contact centre** **Freephone 0800 157 7353** **Email** dgsr@communityrelations.co.uk

Cable Consulting International Limited (CCI) CV

Cable Consulting International Ltd (CCI) is a wholly independent specialist engineering consultancy providing power cable engineering support to underground and subsea power cable system owners, operators, developers and insurers.

CCI's experience and expertise in all aspects of land and subsea power cable systems from 10kV to above 500kV mean they are well placed to lead on the identification of potential cable options for the KTR cable study.

CCI has a range of experience on large infrastructure projects, including:

- An underground cable route survey for a 275kV underground cable connection between Kirkby and Liverpool.
- Cable route studies in England for a 600kV HVDC cable connection between Scotland and England.
- Providing expert witness evidence on 400kV and 275kV power cable route options and costs to the Beauly-Denny Inquiry.

Land Use Consultants CV

LUC provides award winning planning, impact assessment, landscape design and ecology services to a wide range of public and private sector clients.

LUC's extensive experience in grid connection development encompasses projects throughout Scotland, including leading on the routeing and assessment work for the KTR Project to date. Their sound knowledge of the landscape, environmental and community issues on the KTR Project will enable them to identify key issues, constraints to be fed into the design of cable options and help to ensure the successful delivery of high quality outputs.

LUC has also secured the Institute of Environmental Management and Assessment (IEMA)'s Quality Mark, demonstrating their commitment to ensuring the high quality of their EIA Reports, as well as contributing to and developing good practice.

Copper Consultants CV

Copper Consultancy is a leading expert in communications, community relations, public consultation and stakeholder engagement during the planning and construction of major infrastructure projects, with particular expertise in electricity transmission and distribution.

Copper has provided the interface between SPEN and the community on the KTR Project since work commenced in 2015 and will continue to assist in fielding external enquiries from stakeholders and communities as the cable study progresses.

Appendix 2 SPEN Specification Review and Current Rating Parameters

CCI identified the following SPEN specifications as relevant to the KTR project:

- ASSET-02-005 Major Projects Technical Requirements
- CAB-03-038 Issue 3 Specification for Warning Tapes, Protection Tapes and Protection Tiles for the Marking and Protection of Underground Power Cables
- CAB-03-039 Issue 4 Technical Specification for Tapes and Mastics
- CAB-03-041 Issue 1 Specification for DCR Systems Associated with Underground Power Cables
- CAB-06-001 Issue 11 Approved Equipment Register Cables and Cable Accessories
- CAB-15-004 Issue 1 Handling and installation Guidance for 132kV Power Cables
- INS_56-46-06 Issue 3 Single Core Power Cables with Extruded Insulation and Associated Accessories for 115kV up to 132kV
- TEL-03-012 Issue 4 General Specification for Underground Fibre Optic Cables

From these specifications CCI identified the parameters used to develop the cable system design for the six cable routes. Essentially Annex A1 of SPEN specification INS_56-46-06 states that current rating calculations shall be carried out in accordance with IEC 60287.

Other key design parameters and their source specifications are given in Table 46.

Table 46 Cable system design parameters

Design Parameter		Source
Continuous Summer* Rating Conditions	Ambient Temp 15°C	INS_56-46-06
	Ground / CBS T.R 1.2 K.m/W	INS_56-46-06
	Dried out ground / soft sand T.R 2.7 K.m/W	INS_56-46-06
Continuous Winter Rating Conditions	Ambient Temp 10°C	INS_56-46-06
	Ground / soft sand T.R 1.2 K.m/W	INS_56-46-06
Metal Sheath Design	Smooth Welded Aluminium	INS_56-46-06
Max. Short Circuit Currents in Cable Screens**	20kA for 3 Seconds	INS_56-46-06
Max. Temperature of Metallic Sheath	250°C for 3 Seconds	INS_56-46-06
Minimum Circuit Burial Depth – Roads and Verge	750mm from ground surface to the top of the cover tile	CAB-15-004
Minimum Circuit Burial Depth – Agricultural Land & Open Countryside	900mm from ground surface to the top of the cover tile	CAB-15-004
Min. Circuit Spacing	450mm centreline of closet trefoil groups	CAB-15-004
Min. Cover Around Ducts	75mm in every plain	CAB-15-004
Duct Dimensions	Power Cables: uPVC: OD 200mm; ID 188mm	CAB-15-004
	Telecommunications: OD:110mm; ID:103mm	CAB-15-004
Trench Dimensions	Min. Single Circuit Trench Width 550mm	CAB-15-004
	Min. Double Circuit Trench Width 1200mm	CAB-15-004
Min. Joint Bay Dimensions	8m x 2m	CAB-15-004

*Summer ratings shall be calculated and quoted assuming drying to be within the 50°C isotherm.
** For XLPE insulated cables, the earth fault capacity would be provided entirely by the longitudinally welded sheath

SPEN specification INS_56-46-06 also provides a list of approved cable designs for use within 132kV systems. From this list CCI have identified the following cable types as suitable for the Tongland scheme:

- 1600mm² Aluminium conductor XLPE insulated cable with smooth welded Aluminium sheath and MDPE oversheath
- 2000mm² Copper conductor XLPR insulated cable with smooth welded Aluminium sheath and MDPE oversheath

Appendix 3 Cable Route Appraisal Document By LUC

Preliminary Investigative Cable Route Study: Environmental Appraisal of Revised Underground Cable Route Options

1.1 This appraisal comprises a desk-based review of the environmental constraints and sensitivities of the cable route options identified within the *Report on Technical Study of the Preferred Underground Cable Routes for Kendoon – Tongland 132kV Reinforcement Project (ER1033)* prepared by Cable Consulting International (CCI) Ltd. ER1033 included 15 minor route adjustments made subsequent to a site visit and issue of *Kendoon – Tongland 132kV Preliminary Investigative Cable Route Study - ER1003* and which are considered in the appraisal below.

1.2 The investigation of cable routes is based on cable routeing principles as set out in SPEN's published summary document outlining the approach taken to routeing transmission infrastructure (*Major Infrastructure Projects: Approach to Routeing and Environmental Impact Assessment*, SPEN 2015). This document is available at www.spendgsr.co.uk.

1.3 As set out within the *Approach to Routeing and Environmental Impact Assessment* document, there is very little established environmental guidance on the routeing of underground electricity transmission cables. Therefore, for each of the six UGC sections, the relative performance of the CCI identified UGC route options are appraised against a number of environmental criteria.

1.4 The appraisal criteria are presented in **Table 1** below. Where an environmental factor was not located within the study area, or did not influence the appraisal, it is not included within the relevant appraisal tables below. In addition to the environmental criterion, length of the UGC section is also considered in the appraisals below.

Table 1: Appraisal Criteria

Criterion	Sub-criteria	Objectives
Biodiversity and Geological Conservation	Special Protection Areas Special Areas of Conservation* Sites of Special Scientific Interest SNH Priority Peatland Habitats (Classes 1, 2 and 3)	To seek to avoid/reduce, as far as practical, effects on designated sites of ecological or geological conservation importance. To seek to avoid/reduce, as far as practical, effects on ornithological species of high conservation value. To seek to avoid/reduce loss of peatlands in accordance with Scottish Planning Policy (SPP).
Landscape and Visual Amenity	National Scenic Areas* Regional Scenic Areas Landscape Character Visual amenity from residential properties (Residential Visual Amenity) Tourism and Recreation (e.g. SUSTRANS routes, Core Paths, long distance trails, tourist attractions and recreational areas such as golf courses)	To seek to avoid/reduce, as far as practical, effects on designated landscapes. To contribute to the understanding of likely landscape and visual sensitivities within different areas for routeing the UGC. To seek to avoid/reduce, as far as practicable, potential effects on views from residential receptors. To seek to avoid/reduce, as far as practicable, potential effects on formal/informal recreational areas and tourism features.
Cultural Heritage	Scheduled Monuments Listed Buildings Category A, B and C Inventory Gardens and Designed Landscapes*	To seek to avoid/reduce, as far as practical, direct effects on designated features of cultural heritage interest.
	Conservation Areas Archaeologically Sensitive Areas Non-Inventory Gardens and Designed Landscapes	
Forestry and Woodland	Commercial forestry, Ancient and Semi Natural Woodland and Native Woodland	To seek to avoid/reduce, as far as practical, effects of forestry, particularly areas of ancient woodland and native woodland, and on future forestry operations.
Flood Risk	Flood zones and waterbodies	To cross flood zones at their narrowest point to minimise locating UGC within flood zones.

* The extent and geographical location of these features are such that they have not informed the identification or appraisal of route options.

1.5 Following an evaluation of the relative performance of each cable route option against the environmental criteria as described, a preferred cable route option in environmental terms is identified for each of the six UGC sections.

1.6 It should be noted that at this stage in the cable routeing process a 'blank sheet' approach has been adopted, whereby the presence of the existing 132kV transmission network (overhead line infrastructure), has not solely influenced the identification of route options (a route option has been identified which broadly follows the existing network as an alternative option to one following the proposed KTR Project and alternative route options).

1.7 Assumptions made as parts of the desk-based appraisal have been included in the appraisal tables where applicable.

Table 1: UGC 1 (Kendoon – Polquhanity)[1]

Criterion	Sub-Criteria	1A	1B	1C
Section Description	N/A	CCI route alternative	CCI route alternative with OHL into Kendoon S/S	Undergrounding proposed OHL route
KTR Tower Numbers	N/A	N230 (existing tower) – Substation (S/S)	N230 – PK10	N230 – S/S
Approximate Length of Route (km)	N/A	3.2 km	2.93 km (UGC = 2.4km and OHL = 0.53km)	2.9 km
Biodiversity and Geological Conservation	Scottish Natural Heritage (SNH) Priority Peatland Habitats[2]	Class 3 peatland habitat is present at two locations adjacent to the east and west of the point at which 1A crosses the Water of Ken. Unlike Class 1/2 peatland, Class 3 peatland is not identified as a 'nationally important resource'.	Class 3 peatland habitat is present to the west of the point at which 1B crosses the Water of Ken (as an OHL). Unlike Class 1/2 peatland, Class 3 peatland is not identified as a 'nationally important resource'.	Class 3 peatland habitat is present west of the point at which 1c crosses the Water of Ken. Unlike Class 1/2 peatland, Class 3 peatland is not identified as a 'nationally important resource'.
Landscape and Visual Amenity	Regional Scenic Areas (RSA)	All options are located within the Galloway Hills RSA.		
	Landscape Character / Landscape Features	1A follows the road carriageway of the A713 between Polquhanity and Dundeugh, before crossing enclosed pasture/grazing and the Water of Ken within the Upper Dale (165) LCT. Key characteristics of the LCT unlikely to be adversely affected. Permanent loss of landscape features is unlikely, however temporary disturbance and reinstatement to stone dykes is likely to be required.	1B follows the road carriageway of the A713 between Polquhanity and Dundeugh, before crossing into enclosed pasture/grazing within the Upper Dale (165) LCT west of the A713. Key characteristics of the LCT unlikely to be adversely affected. Creation of sealing end compound and overhead line connection into Kendoon from west of the A713 will result in localised significant effects on the LCT. Permanent loss of landscape features is unlikely, however temporary disturbance and reinstatement to stone dykes is likely to be required.	1C follows the proposed OHL route corridor between Polquhanity and Dundeugh, before crossing enclosed pasture/grazing and the Water of Ken within the Upper Dale (165) LCT. Key characteristics of the LCT unlikely to be adversely affected. The cable corridor will pass through existing commercial forestry creating a permanent and perceptible linear feature within this area of the Galloway Forest Park. Permanent loss of other landscape features is unlikely, however temporary disturbance and reinstatement to stone dykes is likely to be required.
	Visual Amenity / Tourism and Recreation (e.g. SUSTRANS routes, Core Paths, long distance trails, tourist attractions and recreational areas such as golf courses)	1A follows the Galloway Tourist Route/A713 and crosses the Bardennoch Trail head (Core Path) to the west of Dundeugh and the Dundeugh Hill Trail head (Core Path) to the north at the point at which they meet the A713/The Galloway Tourist Route. The route will pass close to the licensed caravan/ campsite adjacent to the property of Hawkrigg.	1B follows the Galloway Tourist Route/A713 and crosses the Bardennoch Trail head (Core Path) to the west of Dundeugh and the Dundeugh Hill Trail head (Core Path) to the north at the point at which they meet the A713/The Galloway Tourist Route. The route will pass close to the licensed caravan/ campsite adjacent to the property of Hawkrigg.	1C crosses the Bardennoch trail west of Dundeugh within the forestry. There is a picnic site associated with Polmaddy medieval and post-medieval settlement Scheduled Monument to which there is a walking trail however this is over 200m to the west of the route. The majority of this route passes through the eastern extents of the Galloway Forest Park.
	Residential Visual Amenity	No effects on residential visual amenity will occur following completion of construction and restoration works.	No effects on residential visual amenity will occur following completion of construction and restoration works associated with the cable route between Polquhanity and the terminal tower near Dundeugh. The introduction of the sealing end compound, terminal tower and overhead line connection into Kendoon S/S is likely to result in significant visual effects from residential properties at the southern extent of Dundeugh and properties at Kendoon.	No effects on residential visual amenity will occur following completion of construction and restoration works.
Cultural Heritage	Scheduled Monuments	There is one Scheduled Monument, Dundeugh Castle (SM2476) approximately 250m east of 1A. The principal views from Dundeugh Castle are to the west towards the UGC, however it is not anticipated the scheduled monument will be affected during or post construction.	There is one Scheduled Monument, Dundeugh Castle (SM2476) approximately 250m east of 1B. The principal views from Dundeugh Castle are to the west towards the UGC, however it is not anticipated the scheduled monument will be affected during or post construction.	Dundeugh Castle (SM2476) is located approximately 950m to the east of 1C. The principal views from Dundeugh Castle are to the west towards the UGC, however it is not anticipated the scheduled monument will be affected either during or following construction. As noted above, Polmaddy Scheduled Monument is located approximately 200m to the west of 1C. but will not be directly affected by the route.
	Listed Buildings Category A, B and C	There are two Category B Listed Buildings (Kendoon Power Station and Kendoon Valve House) located approximately 60m to the north of the route at Kendoon S/S. There are two Category C Listed Building (Dalshangan, Dovecot and Dalshangan, Stables) located approximately 30m to the north-east of the route at Dalshangan House. No adverse effects are anticipated as a result of the UGC.	There are two Category B Listed Buildings (Kendoon Power Station and Kendoon Valve House) located approximately 150m to the north of the route at Kendoon S/S. There are two Category C Listed Building (Dalshangan, Dovecot and Dalshangan, Stables) located approximately 30m of the route to the north-east of the route at Dalshangan House. No adverse effects are anticipated as a result of the UGC.	There are two Category B Listed Buildings (Kendoon Power Station and Kendoon Valve House) located approximately 150m to the north of the route at Kendoon S/S. There are two Category C Listed Building (Dalshangan, Dovecot and Dalshangan, Stables) located approximately 30m of the route to the north-east of the route at Dalshangan House. No adverse effects are anticipated as a result of the UGC.

[1] Section 39C, a section of cable approximately 450m long and wholly contained within the confines of the A713 (as outlined within section 4.1.2 of the CCI Ltd report) has not been assessed as a discrete section within the appraisal tables; however consideration has been given to it as part of UGC1 and UGC2 accordingly. The lengths of the cable routes referred to in Table 1 and Table 2 do not include section 39C.
[2] Mapping of SNH Carbon Rich Soil, Deep Peat and Priority Peatlands (CPP) July 2016.

Criterion	Sub-Criteria	1A	1B	1C
Forestry and Woodland	Ancient Woodland (AWI) Native Woodland (NWSS) Forestry (NFI)	1A avoids forestry for much of its length by running alongside the existing A713 carriageway. However, the UGC passes through an area of NWSS adjacent to Kendoon S/S.	1B avoids forestry for much of its length by running alongside the existing A713 carriageway. However, the OHL section of this connection passes through an area of NWSS adjacent to Kendoon S/S.	1C is located almost entirely within forestry (NFI).
Flood Risk	Flood Zones and Waterbodies	1A crosses two areas within the 1/200yr and 1/1000yr flood risk zones; one area adjacent to Dundeugh and one to south west of Kendoon, where the Water of Deugh meets the Water of Ken. The route crosses several watercourses. Whilst most of these already crossed by the A713, it is recommended that the route in the vicinity of Kendoon is reviewed to rationalise this and minimise the number of crossings if possible.	1B crosses two areas within the 1/200yr and 1/1000yr flood risk zones; one area adjacent to Dundeugh where the route diverts from the A713 into the adjacent fields for the HDD crossing of the river, and one to the west of Kendoon where the Water of Deugh meets the Water of Ken. The route crosses several watercourses. Whilst most of these already crossed by the A713, it is recommended that the route in the vicinity of Kendoon is reviewed to rationalise this and minimise the number of crossings if possible. As this section is where the OHL section of this route is located there may the option to span flood zones.	1C crosses two areas within the 1/200yr and 1/1000yr flood risk zones; one area adjacent to Dundeugh and one to south west of Kendoon, where the Water of Deugh meets the Water of Ken. The route crosses several watercourses. It is recommended that the route in the vicinity of Kendoon is reviewed to rationalise this the route in the vicinity of Kendoon is reviewed to rationalise this and minimise the number of crossings if possible.
Environmental Summary	N/A	1A is slightly longer than 1B and 1C due primarily to the loop around the south of Kendoon S/S from south and east. Option 1A crosses through two areas of Class 3 peatland, while 1C crosses through an area of Class 3 peatland to the west of the Water of Ken, which is unavoidable. 1B also passes through this area to the west of the Water of Ken however, this can be spanned by the OHL section of the route. All options are in the Galloway Hills RSA, and although some disturbance to stone dykes is likely to be required for all options, none will result in any permanent loss of landscape features. All options cross Core Paths and recreational routes. All options are in proximity to a number of cultural heritage features, but none will be affected by any of the route options. All options cross two areas within the 1/200yr and 1/1000yr flood risk zones. Less forestry felling would be required for options 1A and 1B as they parallel the existing A713 carriageway for much of their length. **On balance option 1B is the environmental preference. Option 1A and 1B require less felling than option 1C. Additionally, in comparison to 1A, 1B can span the Water of Ken (as an OHL) minimising impacts in the riparian environment and potentially the areas of peatland habitat and flood risk zone in the vicinity of Kendoon S/S. However, very localised significant landscape and visual effects will arise from the introduction of a sealing end compound and terminal tower to facilitate the transition between OHL and UGC.**		

Table 2: UGC 2 (Kendoon – Glenlee)[3]

Criterion	Sub-Criteria	2A	2B	2C
Section Description	**N/A**	CCI route alternative	CCI route alternative with OHL into Kendoon and Glenlee S/S	Undergrounding proposed OHL route
KTR Tower Numbers	**N/A**	S/S – S/S	PK10 – PK33	S/S – S/S
Approximate Length of Route (km)	**N/A**	8.97 km	8.33 km (UGC = 7.2km and OHL = 1.13km)	7.7 km
Biodiversity and Geological Conservation	**Special Site of Scientific Interest (SSSI) Sites**	To the south of the Glenlee S/S where the route crosses Coom Bridge it runs immediately adjacent to the Water of Ken Woods SSSI (designated for upland oak woodland and lichen assemblage).	N/A	
	Scottish Natural Heritage (SNH) Priority Peatland Habitats[2]	Class 3 peatland habitat is present at two locations adjacent to the east and west of the point at which 2A crosses the Water of Ken. Unlike Class 1/2 peatland, Class 3 peatland is not identified as a 'nationally important resource'.	Class 3 peatland habitat is present to the west of the point at which 2B crosses the Water of Ken via OHL. Unlike Class 1/2 peatland, Class 3 peatland is not identified as a 'nationally important resource'.	Class 3 peatland habitat is present to the west of the point at which 2C crosses the Water of Ken. Unlike Class 1/2 peatland, Class 3 peatland is not identified as a 'nationally important resource'.
Landscape and Visual Amenity	**Regional Scenic Areas (RSA)**	All options are located within the Galloway Hills RSA.		
	Landscape Character / Landscape Features	2A follows the road carriageway of the A713 and A762 between Kendoon and Glenlee S/S, within the Upper Dale LCT. Key characteristics of the LCT unlikely to be adversely affected. Permanent loss of landscape features unlikely, however temporary disturbance and reinstatement of stone dykes and woodland may occur where the cable route passes through enclosed pasture/grazing and crosses the Water of Ken between Kendoon S/S and the A713, and crosses the flood plain east of the Water of Ken near St John's Town of Dalry.	2B follows the road carriageway of the A713 and A762 between Kendoon and Glenlee S/S, within the Upper Dale LCT. Key characteristics of the LCT unlikely to be adversely affected. Creation of sealing end compounds and overhead line connection into Kendoon S/S from west of the A713 and into Glenlee S/S from near Waterside will result in localised significant effects on the LCT. Permanent loss of landscape features unlikely, however temporary disturbance and reinstatement of stone dykes and woodland may occur where the cable route passes through areas of enclosed pasture/grazing between the sealing end compound and the A713 near Dundeugh, and between the A762 and the sealing end compound near Waterside.	2C follows the proposed OHL route corridor between Kendoon S/S and Dundeugh, before crossing enclosed pasture/grazing and the Water of Ken within the Upper Dale LCT. Key characteristics of the LCT unlikely to be adversely affected. Permanent loss of other landscape features unlikely, however temporary disturbance and reinstatement to stone dykes likely to be required. It has been assumed that the UGC corridor would be within the existing OHL wayleave south of Waterside so would therefore not result in additional loss of woodland.
	Visual Amenity / Tourism and Recreation (e.g. SUSTRANS routes, Core Paths, long distance trails, tourist attractions and recreational areas such as golf courses)	2A follows the Galloway Tourist Route/A713 for much of its length. The route crosses the Southern Upland Way to the north-west of St John's Town of Dalry and then the Glenlee Core Path to the north of Coom Bridge.	2B follows the Galloway Tourist Route/A713 for much of its length. The route crosses the Southern Upland Way to the north-west of St John's Town of Dalry and then the Glenlee Core Path where it crosses the Coom Burn to the north of Glenlee S/S.	2C crosses the Southern Upland Way to the north-west of St John's Town of Dalry and then the Glenlee Core Path where it where it crosses the Coom Burn to the north of Glenlee S/S.
	Residential Visual Amenity	No effects on residential visual amenity will occur following completion of construction and restoration works.	No effects on residential visual amenity will occur following completion of construction and restoration works associated with the cable route between the terminal tower sealing end compound near Dundeugh ad terminal tower and sealing end compound near Waterside. The introduction of the sealing end compound, terminal tower and overhead line connection into Kendoon S/S is likely to result in significant visual effects from residential properties at the southern extent of Dundeugh and properties at Kendoon. The introduction of the sealing end compound terminal tower and overhead line connection into Glenlee S/S is unlikely to result in significant visual effects from residential properties due to distance and intervening woodland and vegetation.	No effects on residential visual amenity will occur following completion of construction and restoration works.
Cultural Heritage	**Listed Buildings Category A, B and C**	There are several Category B listed buildings directly adjacent to the route in the area around Allangibbon, Glenlee S/S and Polharrow Bridge, which itself is Category B listed. There are also several Category C Listed Buildings adjacent to the A713. The route crosses Coom Bridge a Category C Listed structure. No adverse effects are anticipated as a result of 2A.	There are several Category B listed buildings directly adjacent to the route in the area around Allangibbon, Glenlee S/S and Polharrow Bridge, which itself is Category B listed. There are also a number of Category C Listed Buildings adjacent to the A713. Following the optioneering process detailed in Cable Study ER1003 RevB, the diversion of the route on to Polharrow burn crossing was identified as the preference over continuing along the A713. The options in this location are to use the old road bridge as a cable bridge, with the cables installed on the old bridge within surface	There are several Category B listed buildings directly adjacent to the route in the area around Glenlee S/S and Polharrow Bridge, which itself is Category B listed. There are also as a number of Category C Listed Buildings to the east of the route adjacent to the A713.No adverse effects are anticipated as a result of 2C.

[3] Section 39C, a section of cable approximately 450m long and wholly contained within the confines of the A713 (as outlined within section 4.1.2 of the CCI Ltd report) has not been assessed as a discrete section within the appraisal tables; however consideration has been given to it as part of UGC1 and UGC2 accordingly. The lengths of the cable routes referred to in Table 1 and Table 2 do not include section 39C.

Criterion	Sub-Criteria	2A	2B	2C
			mounted troughs. Alternatively, a self-supporting cable bridge or cable bridge mounted to the side of the current carriageway bridge could be considered. Should 2B be taken forward, further advice will be required from an archaeologist as Listed Building consent may be required depending on the extent of the works.	
	Archaeologically Sensitive Areas (ASA)	2A and 2B passes immediately to the east of Polharrow Burn ASA. No long-term significant adverse effects are anticipated as a result of the UGC.		2C passes through Polharrow Burn ASA. Careful consideration of the route through the ASA would be required to ensure no effects arise during construction.
	Garden and Designed Landscapes (GDL) and Non-Inventory Designated Landscapes (NIDL)	2A passes approximately 100m east of Knocknalling NIDL in the carriageway of the A713 and immediately adjacent to Glenlee park NIDL in the public road. No long-term significant adverse effects are anticipated as a result of the UGC.	2B passes approximately 100m east of Knocknalling NIDL. No long-term significant adverse effects are anticipated as a result of the UGC.	2C passes through the eastern edge of Knocknalling NIDL and immediately adjacent to Glenlee park NIDL. No long-term significant adverse effects are anticipated as a result of the UGC.
Forestry and Woodland	**Ancient Woodland (AWI)** **Native Woodland (NWSS)** **Forestry (NFI)**	2A avoids forestry for much of its length by running alongside the existing A713 and A762 carriageways. However, where 2A is routed to avoid Earlstoun Power Station in the vicinity of Allangibbon and adjacent to Kendoon S/S it crosses an area of NWSS.	2B avoids forestry for much of its length by running alongside the existing A713 carriageway.	2B crosses multiple areas of forestry to the west of the A713, including areas of NWSS at Knocknalling Wood to the north of Polharrow and two separate areas of NWSS to the north of Glenlee S/S.
Flood Risk	**Flood Zones and Waterbodies**	2A crosses four areas within the 1/200yr and 1/1000yr flood risk zones: one area to the south of Kendoon S/S, one to the north of Polharrow Bridge, one to the west of St John's Town of Dalry and one at Glenlee in the vicinity of Knockensee. The route crosses several watercourses. Most of these are already crossed by the A713 and A762 and would be difficult to avoid without considerable revisions.	2B crosses four areas within the 1/200yr and 1/1000yr flood risk zones: one area to the south of Kendoon S/S, one to the north of Polharrow Bridge, one south of Earlstoun Loch in the carriageway of the A762 and one at Glenlee in the vicinity of Coom Burn. The route crosses a number of watercourses. Most of these are already crossed by the A713 and A762 and would be difficult to avoid without considerable revisions.	2C crosses three areas within the 1/200yr and 1/1000yr flood risk zones: one area to the south of Kendoon S/S, one to the north of Polharrow Bridge and one at Glenlee in the vicinity of Coom Burn. The route crosses a number of watercourses which would be difficult to avoid without considerable revisions.
Environmental Summary	**N/A**	2A will be slightly longer than 2B and 2C due to the loop around the south of Kendoon S/S from south and east. Option 2A crosses through two areas of Class 3 peatland, while 2C crosses through an area of Class 3 peatland to the west of the Water of Ken, which is unavoidable. 2B also passes through this area to the west of the Water of Ken however, this can be spanned by the OHL section of the route. All options are in the Galloway Hills RSA, and although some disturbance to stone dykes and woodland is likely to be required for all options, none will result in any permanent loss of landscape features. All the options will cross tourist and recreational routes, including the Southern Upland Way. 2A and 2C would have no effects on residential visual amenity, while 2C would likely have significant visual and localised effects on the LCT as a result of the need for a sealing end compound and terminal tower to facilitate the transition between OHL and UGC. 2B will have direct effects on Polharrow Bridge Listed Building and may require Listed Building consent. 2A and 2B pass immediately adjacent to Polharrow Burn ASA while 2C passes through the eastern edge and would require careful routeing to ensure no significant effects on archaeological features. 2A requires the least felling as it parallels the existing A713 and A762 carriageway for much of its length. 2A crosses four flood risk zones and 2B/2C each cross three. **On balance option 2C is the environmental preference as it is the shortest and will result in fewer visual effects on residential receptors in comparison to 2B and avoids direct effects on Polharrow Bridge Listed Building. Care would require to be taken to ensure no effects on the ASA.**		

Table 3: UGC 3 (Queen's Way Crossing)

Criterion	Sub-Criteria	3A	3B
Section Description	**N/A**	CCI route alternative	Undergrounding proposed OHL route
KTR Tower Numbers	**N/A**	GT08 – GT21	GT08 – GT21
Approximate Length of Route (km)	**N/A**	4.33 km	3.6 km
Landscape and Visual Amenity	**Regional Scenic Areas (RSA)**	Both options are located within the Galloway Hills RSA.	
	Landscape Character / Landscape Features	3A passes through the Foothills with Forest (176) and Rugged Uplands with Forest (181) LCTs. Key characteristics of these large scale LCTs are unlikely to be adversely affected. Permanent loss of landscape features unlikely, however temporary disturbance and reinstatement of stone dykes and woodland may occur where the cable route passes through enclosed pasture/grazing north of the Queen's Way/A712. Introduction of terminal towers likely to result in very localised significant effects on the LCT. The cable corridor will pass through existing enclosed pasture/grazing, east of Peal Hill, and commercial forestry south of the A712 creating a permanent and perceptible linear feature within this area of the Galloway Forest Park.	3B passes through the Foothills with Forest (176) and Rugged Uplands with Forest (181) LCTs, along the route of the proposed OHL. Key characteristics of these large scale LCTs are unlikely to be adversely affected. Permanent loss of landscape features unlikely, however temporary disturbance and reinstatement of stone dykes and woodland may occur where the cable route passes through enclosed pasture/grazing north of the Queen's Way/A712. Introduction of terminal towers likely to result in very localised significant effects on the LCT. The cable corridor will pass through existing commercial forestry south of the A712 creating a permanent and perceptible linear feature within this area of the Galloway Forest Park.
	Visual Amenity / Tourism and Recreation (e.g. SUSTRANS routes, Core Paths, long distance trails, tourist attractions and recreational areas such as golf courses)	Option 3A crosses the Robert the Bruce Trail and a section of the Galloway Kite Trail (between New Galloway and Clatteringshaws Loch) which corresponds to the Queen's Way / the A712 between New Galloway and Newton Stewart, crossing the road perpendicular to the north of Peal Hill. South of the Queen's Way the route passes through the Galloway Forest Park. At its southern extent 3A crosses and subsequently runs broadly parallel to a section of the Raiders road to Kenmuir Link Core Path.	Option 3B crosses the Robert the Bruce Trail and a section of the Galloway Kite Trail (between New Galloway and Clatteringshaws Loch) which corresponds to the Queen's Way / the A712 between New Galloway and Newton Stewart, crossing the road perpendicular to the north of Peal Hill. South of the Queen's Way the route passes through the Galloway Forest Park. At its southern extent 3B crosses a section of the Raiders road to Kenmuir Link Core Path.
	Residential Visual Amenity	Effects on residential visual amenity predicted in relation to the terminal tower location north-west of Airie (views possible from access track and curtilage); however significant effects are considered unlikely to occur.	
Forestry and Woodland	**Ancient Woodland (AWI)** **Native Woodland (NWSS)** **Forestry (NFI)**	The most southern section of 3A runs through areas of both NFI and NWSS on the eastern flanks of the Peal Hill. To the north of Peal Hill, the route utilises a natural wayleave to avoid two areas of AWI to the east and west. The most southerly extent of 3A is located in existing forestry access tracks, thereby avoiding the need for additional felling in this location.	Approximately two thirds of route 3B is located within forestry to the west of Peal Hill and an area of AWI is crossed to the south of the Queen's Way.
Flood Risk	**Flood Zones and Waterbodies**	Both 3A and 3B cross the Knocknairling Burn which is within the 1/200yr and 1/1000yr flood risk zones to the north of Peal Hill (Knocknairling Burn).	
Environmental Summary	**N/A**	3A will be slightly longer than 3B. Both 3A and 3B are in the Galloway Hills RSA, and although some disturbance to stone dykes and woodland may be required for both options, neither will result in any permanent loss of landscape features. Both 3A and 3B will cross tourist and recreational routes which correspond to the Queen's Way. Both 3A and 3B would likely have very localised significant effects on the LCT as a result of the need for a sealing end compound and terminal tower to facilitate the transition between OHL and UGC. Effects on residential visual amenity are likely in relation to the terminal tower location north-west of Airie however these will not be significant. Both 3A and 3B will require forest felling on the eastern and western slopes of Peal Hill respectively. Comparatively however, 3A will affect less forestry through utilising existing wayleaves and forest breaks. Both 3A and 3B cross one small area within the 1/200yr and 1/1000yr flood risk zones (Knocknairling Burn). **On balance, although longer, option 3A is the environmental preference, primarily as less forestry felling would be required.**	

Table 4: UGC 4 (Bennan, Slogarie and Laurieston Forests)

Criterion	Sub-Criteria	4A	4B	4C
Section Description	**N/A**	CCI route alternative	Undergrounding proposed OHL route	CCI route alternative
KTR Tower Numbers	**N/A**	GT25 – GT74	GT25 – GT74	GT25 – GT78
Approximate Length of Route (km)	**N/A**	14.2 km	13 km	16.0 km
Biodiversity and Geological Conservation	**Special Site of Scientific Interest (SSSI) Sites**	4A runs directly adjacent to the Laughenghie and Airie Hills SSSI at Stroan Loch. The SSSI is designated for wintering hen harrier and breeding bird assemblage including osprey, goosander, goldeneye and non-feral greylag geese, golden plover and curlew and a wide range of other moorland species. As 4A is proposed within is an existing access track and it will be possible to avoid locating infrastructure within the SSSI.	4B is approximately 150m from the Laughenghie and Airie Hills SSSI at Stroan Loch.	4C runs directly adjacent to the Laughenghie and Airie Hills SSSI at Stroan Loch. Further to the south the route also runs adjacent to the east of the Woodhall Loch SSI designated for beetles, Caddisfly, Fen Meadow and Oligotrophic loch freshwater habitat. As 4C is proposed within is an existing access track to the north and A762 to the south it will be possible to avoid locating infrastructure within the SSSIs.
Landscape and Visual Amenity	**Regional Scenic Areas (RSA)**	The majority of 4A, 4B and 4C are located within the Galloway Hills RSA. The southern extent of the route in the vicinity of Laurieston Forest is located outside the RSA.		
	Landscape Character / Landscape Features	4A passes through the Rugged Uplands with Forest (181) and Foothills with Forest (176) LCTs. Key characteristics of these large scale LCTs are unlikely to be adversely affected. Cable corridor will pass through existing commercial forestry within the Bennan and Laurieston forest areas broadly following existing forestry access tracks, however some new sections of wayleave will create a permanent and perceptible linear feature within this area of the Galloway Forest Park. Introduction of terminal towers is likely to result in very localised significant effects on the LCTs, however their position within surrounding commercial forestry will limit perceptibility across the wider landscape. Permanent loss of landscape features is unlikely, however temporary disturbance and reinstatement to stone dykes is likely to be required.	4B passes through the Rugged Uplands with Forest (181) and Foothills with Forest (176) LCTs, along the route of the proposed OHL. Key characteristics of these large scale LCTs are unlikely to be adversely affected. Cable corridor will pass through existing commercial forestry within the Bennan and Laurieston forest areas creating a permanent and perceptible linear feature within this area of the Galloway Forest Park. Introduction of terminal towers likely to result in very localised significant effects on the LCTs, however their position within surrounding commercial forestry will limit perceptibility across the wider landscape. Permanent loss of landscape features is unlikely, however temporary disturbance and reinstatement to stone dykes is likely to be required.	4C passes through the Rugged Uplands with Forest (181), Foothills with Forest (176) and the Drumlin Pastures (169) LCTs, along the route of the proposed OHL. Key characteristics of these large scale LCTs are unlikely to be adversely affected. Cable corridor will pass through existing commercial forestry within the Bennan forest area broadly following existing forestry access tracks and the disused railway line to the east of Stroan Loch, however some new sections of wayleave will create a permanent and perceptible linear feature within this area of the Galloway Forest Park. The cable route then follows the road carriageway of the A762 between Mossdale and Dinnance, before passing into enclose pasture/grazing west of the A762. Introduction of terminal towers likely to result in very localised significant effects on the LCT, however their position within surrounding commercial forestry (tower GT25) and woodland shelterbelts (tower GT78) will limit perceptibility across the wider landscape. Permanent loss of landscape features is unlikely, however temporary disturbance and reinstatement to stone dykes is likely to be required.
	Visual Amenity / Tourism and Recreation (e.g. SUSTRANS routes, Core Paths, long distance trails, tourist attractions and recreational areas such as golf courses)	From north to south 4A runs along the Raiders Road Kenmuir Link Core Path, utilising the wayleave formed by the existing road. The route then turns south east following the Raiders Road to Mossdale section of the Core Path which also forms part of the Galloway Kite Trail. Both the northern and southern extents of this route pass through the eastern extent of the Galloway Forest Park. There are several recreational receptors related to the park to the east of Stroan Loch. The route continues to follow the Raiders road to Mossdale, where at the southern banks of Stroan Loch, it turns south running perpendicular to and crossing the Mossdale to Gatehouse Station Railway Walk. At its southern extremity the route then crosses the Retreat Wood Laurieston Core Path before terminating at GT74.	4B crosses a number of Core Paths at various points, including the Raiders Road to Kenmure Link west of Cairn Edward Hill, Cairn Edward Hill Core Path to the north east of Stroan Loch as well Raiders Road to Mossdale and Mossdale to Gatehouse Station Railway Walk to the east of Stroan Loch. At this point the route also crosses a section of the Galloway Kite Trail. Further south the route crosses the Stroan Bridge Link Core Path Both the northern and southern extents of this route pass through the eastern extent of the Galloway Forest Park. There are several recreational receptors related to the park to the east of Stroan Loch as well as to the east of the route within Laurieston Forest.	From north to south 4C runs along the Raiders Road Kenmuir Link Core Path as far as the Stroan Loch viaduct a section of which also forms part of the Galloway Kite Trail. The northern extent of this route passes through the eastern extent of the Galloway Forest Park. The route diverts to the east to the A762 at Mossdale utilising the existing wayleave created by the Mossdale to Gatehouse Station Railway Walk. Turning to the south the route then follows the Galloway kite trail/A762 before terminating at GT78, west of the A762.
	Residential Visual Amenity	Terminal tower at GT74 is likely to be visible from nearby property of Edgarton Cothouse, but effects on residential visual amenity unlikely to be significant due to distance and presence of intervening landform and coniferous forestry to the north of property.	Terminal tower at GT74 is likely to be visible from nearby property of Edgarton Cothouse, but effects on residential visual amenity unlikely to be significant due to distance and presence of intervening landform and coniferous forestry to the north of property.	Terminal tower at GT78 is likely to be visible from nearby property of Edgarton, but effects on residential visual amenity unlikely to be significant due to distance and presence of intervening landform and woodland to the north-east of property.
Cultural Heritage	**Scheduled Monuments**	N/A		There are two Scheduled Monuments, Edgarton Mote Fort (SM1119) and Little Duchrae Fort (SM1077) located approximately 365m south west and within 25m of 4C respectively. The principal views from Edgarton Mote are to the south; therefore at this distance visibility would be reduced by intervening topography.

Criterion	Sub-Criteria	4A	4B	4C
				Duchrae Fort is located immediately adjacent to the A762 carriageway. No adverse effects on any of the SMs are anticipated as a result of the UGC.
	Listed Buildings Category A, B and C	The closest listed building is over 100m away from both 4A and 4B at Stroan Viaduct (Category B listed). No adverse effects are anticipated as a result of the UGC.		There are several Category B and C listed buildings directly adjacent to the route adjacent to the A762 in the areas around Hensol Lodge, Little Duchrae and Laurieston. No adverse effects are anticipated as a result of the UGC.
	Archaeologically Sensitive Areas (ASA)	4A runs adjacent, immediately to the west of the Grobdale ASA. No adverse effects are anticipated as a result of the UGC.	4B runs through Grobdale ASA and a number of local features are associated with this area. Careful consideration of the route through the ASA would be required to ensure no effects arise during construction.	4C runs immediately adjacent to the west of the Grobdale ASA. No adverse effects are anticipated as a result of the UGC.
	Garden and Designed Landscapes (GDL) and Non-Inventory Designated Landscapes (NIDL)	4A runs directly to the west of Laurieston Hall and to the east of Slogarie NIDL along existing accesses at their closest points. No long-term significant adverse effects are anticipated as a result of the UGC.	N/A	4C runs immediately to the west of Hensol House NIDL and further to the south runs through Laurieston Hall NIDL. However, the route is within the public highway at these locations therefore no long-term significant adverse effects are anticipated as a result of the UGC.
Forestry and Woodland	**Ancient Woodland (AWI)** **Native Woodland (NWSS)** **Forestry (NFI)**	Both 4A and 4B pass through areas of forestry comprising the eastern extents of the Galloway Forest Park and Laurieston Forest. Both routes cross areas of predominantly commercial forestry but will also intersect areas of AWI, NWSS and NFI particularly to the west of Cairn Edward Hill and the valley between Bennan and Crae Hill. 4A will utilise the existing wayleave formed by the Raiders Road for much of northern section prior to Stroan Viaduct and where possible existing forest roads south of this point.		The northerly section of 4C passes through forestry comprising the eastern extents of the Galloway Forest Park made up of predominantly commercial forestry but will also intersect areas of AWI, NWSS and NFI particularly to the west of Cairn Edward Hill. To the south of Mossdale 4C avoids forestry by running alongside the existing A762 carriageway before terminating at GT78.
Flood Risk	**Flood Zones and Waterbodies**	4A crosses three areas within the 1/200yr and 1/1000yr flood risk zones (to the north and east of Slogarie, and once within the Laurieston Forest at the Kenick Burn).	4B crosses two areas within the 1/200yr and 1/1000yr flood risk zones (one north of Slogarie and one within Laurieston Forest at the Kenick Burn).	4C crosses two areas within the 1/200yr flood risk zone to the north of Woodhall Loch and to the north-west of Laurieston.
Environmental Summary	**N/A**	4C will be longer than 4A and 4B. 4A and 4C are adjacent to Lughenghie and Airie Hills SSSI at Stroan Loch but are within an existing forestry track. 4B is approximately 150m away from the SSSI at its closest point. The majority of 4A, 4B and 4C are located within the Galloway Hills RSA. All of the options will cross tourist and recreational routes, including the Raider's Road. For all routes, introduction of terminal towers is likely to result in very localised significant effects on the LCTs, however their position within surrounding commercial forestry will limit perceptibility across the wider landscape. Permanent loss of landscape features is unlikely, however temporary disturbance and reinstatement to stone dykes is likely to be required for all options. All of the option would likely have significant very localised effects on LCT, however their position within surrounding commercial forestry will limit perceptibility across the wider landscape. Although terminal towers for all of the options would be visible from nearby property of Edgarton Cothouse, significant effects are considered unlikely due to distance and presence of intervening landform and coniferous forestry. 4A and 4C avoid the Grobdale ASA while 4B route would pass through this area. If taken forward, 4B should be modified to avoid any features in this area if possible. All of the options will require forest felling, however the 4C will impact less forestry through utilising existing wayleaves and forest breaks, in particular those formed by the Raider's Road and the A762. Both 4A and 4B will require felling to the east and west of Kenick Hill through Laurieston Forest respectively. 4A will cross three areas within the 1/200yr and 1/1000yr flood risk zones; 4B and 4C will cross two areas within these flood risk zones. **On balance option 4C is the environmental preference over 4A and 4B, as although longer it requires the least felling and will have the least impact on the Raiders Road and other recreational routes through paralleling the A762.**		

Table 5: UGC 5 (A75 crossing)

Criterion	Sub-Criteria	5A	5B
Section Description	**N/A**	CCI route alternative	Undergrounding proposed OHL route
KTR Tower Numbers	**N/A**	GT97 – GT104	GT97 – GT104
Approximate Length of Route (km)	**N/A**	2.2 km	2.03 km
Landscape and Visual Amenity	**Landscape Character / Landscape Features**	5A passes through the Drumlin Pastures (169) LCT, although key characteristics of the LCT are unlikely to be adversely affected. The cable corridor passes through enclosed pasture/grazing to the north and south of the A75. Introduction of terminal towers likely to result in very localised significant effects on the LCT, however their position in relation to adjacent landform will limit perceptibility across the wider landscape. Permanent loss of landscape features is unlikely, however temporary disturbance and reinstatement to stone dykes is likely to be required.	5B passes through the Drumlin Pastures (169) LCT along the route of the proposed OHL, although key characteristics of the LCT are unlikely to be adversely affected. Cable corridor passes through enclosed pasture/grazing to the north and south of the A75, along the route of the proposed OHL. Introduction of terminal towers likely to result in very localised significant effects on the LCT, however their position in relation to adjacent landform will limit perceptibility across the wider landscape. Permanent loss of landscape features is unlikely, however temporary disturbance and reinstatement to stone dykes is likely to be required.
	Visual Amenity / Tourism and Recreation (e.g. SUSTRANS routes, Core Paths, long distance trails, tourist attractions and recreational areas such as golf courses)	Visibility of terminal towers (tower GT97 and GT104) will be largely imperceptible in views from the A75, whilst the cable corridor crosses this busy road route between Dumfries and Stranraer perpendicular.	
	Residential Visual Amenity	Although terminal tower at GT97 is located in relatively close proximity to Upper Balannan Farm, effects on residential visual amenity are unlikely to be significant due to the presence of intervening landform and large-scale agricultural buildings to the north, north-east of the property.	
Forestry and Woodland	**Ancient Woodland (AWI)** **Native Woodland (NWSS)** **Forestry (NFI)**	Both 5A and 5B are close to an area of AWI adjacent to Argrennan Cottages but unlikely to directly affect it.	
Environmental Summary	**N/A**	5A will be slightly longer than 5B. Neither option will result in any effects on the LCT. Permanent loss of landscape features is unlikely, however temporary disturbance and reinstatement to stone dykes is likely to be required for both options. No significant effects in relation to visual amenity are anticipated. Both options are close to an area of AWI but neither is likely to affect it directly. **There is no environmental preference between 5A and 5B due to the presence of very few environmental constraints along the route options. Both 5A and 5B closely following the alignment of the existing 132kV OHL.**	

Table 6: UGC 6 (Glenlee to Tongland)

Criterion	Sub-Criteria	6A	6B	6C	6D	6E
Section Description	N/A	CCI route alternative following the west side of Loch Ken	CCI route alternative following the proposed OHL wayleave to the Queen's Way crossing before following the west side of Loch Ken	CCI route alternative following west side of Loch Ken and crossing the A75 close to the proposed OHL wayleave	CCI route alternative following the east side of Loch Ken	CCI route alternative following the east side of Loch Ken and then diverting to follow the A762 into Tongland S/S
KTR Tower Numbers	N/A	Glenlee S/S – Tongland S/S				
Approximate Length of Route (km)	N/A	31.24 km	31.34 km	33.15 km	37.79 km	37.59 km
Biodiversity and Geological Conservation	Special Protection Areas (SPA)	6A, 6B and 6C pass immediately to the west of the Loch Ken and River Dee Marshes SPA and Ramsar site (also designated as Kenmure Holmes SSSI). Qualifying features of the SPA include populations of the Annex I listed Greenland White-fronted Goose *Anser albifrons flavirostris* as well as migratory Greylag Goose *Anser anser*. As these routes would be in the carriageway of the A762, it is assumed that infrastructure within the SPA itself can be avoided.			The route passes immediately to the east of the Loch Ken and River Dee Marshes SPA and Ramsar site. Qualifying features of the SPA include populations of the Annex I listed Greenland White-fronted Goose *Anser albifrons flavirostris* as well as migratory Greylag Goose *Anser anser*. As these routes would be in the carriageway of the A762, it is assumed that infrastructure within the SPA itself can be avoided.	
	Special Site of Scientific Interest (SSSI) Sites	To the south of the Glenlee S/S the route runs immediately adjacent to the Water of Ken Woods SSSI designated for upland oak woodland and lichen assemblage. At the northern reaches of Loch Ken, the route runs adjacent to Kenmure Holmes SSSI, part of the Loch Ken and River Dee Marshes SPA and Ramsar site. South of Mossdale the route runs adjacent to the Woodhall Loch SSSI designated for freshwater, lowland and fen habitats, and invertebrate species. Where the cable is proposed in proximity to the designations above, this is all within the public highway therefore it is assumed that works directly within the designated areas can be avoided.	At the northern reaches of Loch Ken, the route runs adjacent to Kenmure Holmes SSSI, part of the Loch Ken and River Dee Marshes SPA and Ramsar site. South of Mossdale the route runs adjacent to the Woodhall Loch SSSI designated for freshwater, lowland and fen habitats, and invertebrate species. Where the cable is proposed in proximity to the designations above, this is all within the public highway therefore it is assumed that works directly within the designated areas can be avoided.	To the south of the Glenlee S/S the route runs immediately adjacent to the Water of Ken Woods SSSI designated for upland oak woodland and lichen assemblages. At the northern reaches of Loch Ken, the route runs adjacent to Kenmure Holmes SSSI, part of the Loch Ken and River Dee Marshes SPA and Ramsar site. South of Mossdale the route runs adjacent to the Woodhall Loch SSSI designated for freshwater, lowland and fen habitats, and invertebrate species. Where the cable is proposed in proximity to the designations above, this is all within the public highway therefore it is assumed that works directly within the designated areas can be avoided.	To the south of the Glenlee S/S the route runs immediately adjacent to the Water of Ken Woods SSSI designated for upland oak woodland and lichen assemblages. At the northern reaches of Loch Ken, the route runs adjacent to Kenmure Holmes SSSI, part of the Loch Ken and River Dee Marshes SPA and Ramsar site. To the southern extents of Loch Ken the routes runs broadly adjacent to the River Dee (Parton to Crossmichael) SSSI, part of the Loch Ken and River Dee Marshes SPA and Ramsar site. Where the cable is proposed in proximity to the designations above, this is all within the public highway therefore it is assumed that works directly within the designated areas can be avoided.	
	Scottish Natural Heritage (SNH) Priority Peatland Habitats[2]	Class 1 peatland habitat (designated as a 'nationally important resource') is present at one location adjacent to the east and west of the A762 near Beech Moor. Class 3 peatland habitat is present at one location adjacent to the east and west of the A762 near Back Fell. It is assumed that 6A/6B/6C will be within the carriageway of the A762 where Class 1 peatland is shown.			Class 3 peatland habitat is present at one location to the west of the A713 adjacent to Mid Tors. It is assumed that 6D/6E will be within the carriageway of the A762 where Class 3 peatland is shown.	
Landscape and Visual Amenity	Regional Scenic Areas (RSA)	The routes are located within the Galloway Hills RSA to the north and a small section of the Solway Coast RSA to the south where the UGC terminates at Tongland S/S.				
	Landscape Character / Landscape Features	Follows the road carriageway of the A762 between Glenlee S/S and Ringford, within the Upper Dale (165), Flooded Valley (164) and Drumlin Pasture (169) LCTs. Key characteristics of the LCTs unlikely to be adversely affected. South of Ringford the cable route passes through enclosed pasture/grazing before crossing the A75 and continuing through enclosed pasture/grazing fields east of the A762, before passing through woodland on the southern flanks of Castle Hill. Permanent loss of landscape features largely avoidable, however temporary disturbance and reinstatement to stone dykes likely to be required and loss of	Route heads west, south-west from Glenlee S/S through enclosed pasture/grazing within the Upper Dale (164) and Foothills with Forest (176) LCTs, before entering commercial forestry of the Rugged Uplands with Forest (181) LCT to the south of the A712 before continuing through enclosed pasture/grazing fields west of New Galloway and joining the A762 road carriageway at Burnfoot Bridge. Key characteristics of the LCTs unlikely to be adversely affected. As for 6A south of Burnfoot Bridge on the A762.	As for 6A north of Glentarff on the A762. Route heads through enclosed pasture/grazing fields of the Drumlin Pastures (169) LCT east of the A762 north of Ringford, before crossing the A75 and heading south through further enclosed pasture fields and approaching Tongland S/S from the west. Key characteristics of the LCTs unlikely to be adversely affected. Permanent loss of landscape features largely avoidable, however temporary disturbance and reinstatement to stone dykes likely to be required.	The route follows the A762 south from Glenlee S/S before crossing the Water of Ken at Meikle Isle in the foot of the valley before reaching the A713 on the east side of the river valley. The route then follows the road carriageway of the A713 within the Upper Dale (165) and Flooded Valley (164) LCTs. between Loch Whin Craigs and Crossmichael, where it heads eastwards through enclosed pasture/grazing of the and Drumlin Pasture (169) LCT, passing over relatively high ground of Rhone Hill and Culgruff Hill before descending south-eastwards and crossing the A713 and the River Dee. The route then passes through an area of woodland at Barnboard Wood near Balmaghie Bridge, which will create a	As for 6D between Glenlee S/S and Park of Tongland, where to the west, the cable route deviates slightly south-west towards Barr Hill where it descends towards the A762 east of woodland on Castle Hill before approaching Tongland S/S from the west passing through the Drumlin Pasture (169) LCT. Key characteristics of the LCTs unlikely to be adversely affected. Permanent loss of landscape features largely avoidable, however temporary disturbance and reinstatement to stone dykes and hedgerows likely to be required.

Criterion	Sub-Criteria	6A	6B	6C	6D	6E
		woodland likely at Castle Hill.			permanent linear feature in the landscape. South of here the route passes through enclosed pasture/grazing fields before crossing the A75 near Upper Balannan Farm and heading south and approaching Tongland S/S from the north. Key characteristics of the LCTs unlikely to be adversely affected. Permanent loss of landscape features largely avoidable, however temporary disturbance and reinstatement to stone dykes and hedgerows likely to be required.	
	Visual Amenity / Tourism and Recreation (e.g. SUSTRANS routes, Core Paths, long distance trails, tourist attractions and recreational areas such as golf courses)	The route then runs along the all year-round Galloway Kite Trail adjacent to Loch Ken, crossing the A712/Queen's Way to the west of New Galloway. To the south of New Galloway the route crosses the New Galloway Golf Club. Continuing south the route crosses a section of the Cairn Edward Hill Core Path before passing close to several recreational receptors to the east of Bennan Hill. The route continues to follow the Galloway Kite Trail south crossing the Mossdale to Gatehouse Station Railway Walk at Mossdale. At its southern extent the route crosses the Lairdmannoch and Barstobrick Core Paths and Barstobrick visitor centre north of Ringford.	The route runs in parallel with the New Galloway West Core Path before turning south, crossing the Queen's Way/A712, and the route of the Robert Bruce Trail and Galloway Kite Trail to the west of New Galloway. To the south of New Galloway the route passes through a small section of the eastern extents of the Galloway Forest park. South of New Galloway the route follows the A762/ all year-round Galloway Kite Trail, crossing the Mossdale to Gatehouse Station Railway Walk to the west of Mossdale. At its southern extent the route crosses the Lairdmannoch and Barstobrick Core Paths and Barstobrick visitor centre north of Ringford.	The route then runs along the all year-round Galloway Kite Trail adjacent to Loch Ken, crossing the A712/Queen's Way to the west of New Galloway. To the south of New Galloway the route crosses the New Galloway Golf Club. Continuing south the route crosses a section of the Cairn Edward Hill Core Path before passing close to a number of recreational receptors to the east of Bennan Hill. The route continues to follow the Galloway Kite Trail south crossing the Mossdale to Gatehouse Station Railway Walk at Mossdale. At its southern extent the route crosses the Lairdmannoch and Barstobrick Core Paths and Barstobrick visitor centre north of Ringford.	The route runs parallel with the Galloway Tourist Route, running adjacent to Loch Ken. The route then crosses the Dalry to new Galloway Core Path twice, first immediately to the south of Boat Knowe and then at Garplefoot. Further south the route passes to the east of the Galloway Activity Centre situated on Loch Ken. At the southern reaches of Loch ken, the route crosses the Cruichie and Glengunnock Wood Core Paths. Further to the south the route then bypasses Crossmichael before turning south west, at this point, it crosses both the Galloway Tourist Route and Robert Bruce Trail.	
	Residential Visual Amenity	No effects on residential visual amenity will occur following completion of construction and restoration works.				
Cultural Heritage	**Scheduled Monuments**	Little Duchrae Fort Scheduled Monument (SM1077) is located directly adjacent to the route, east of the A762. On the assumption that the route will be within the carriageway of the A762, any direct effects on the Scheduled Monument will be avoided.			Crofts Mott, fort (9SM1065) and Castle earthworks, enclosure 500m SSW Mains of Greenlaw (SM6110), and Kirkland Mote, Motte (SM1124), and Glenlochar, Roman Fort, annexe, camps and barrows 50m E of Montford (SM12792) are within 100m of the route. No long-term significant adverse effects are anticipated as a result of the UGC.	
	Listed Buildings Category A, B and C	A Category B listed building is located directly adjacent to the route at Hensol Lodge, south of Mossdale. No long-term significant adverse effects are anticipated as a result of the UGC.			There are several Category B listed buildings directly adjacent to the route in the area around Parton. No long-term significant adverse effects are anticipated as a result of the UGC.	
	Garden and Designed Landscapes (GDL) and Non-Inventory Designated Landscapes (NIDL)	The route is directly adjacent to Glenlee Park NIDL, Hensol House NIDL and Laurieston Hall within the carriageway of the A762. It also passes through Kenmure Castle NIDL. It is recommended that the route is realigned to avoid passing through Kenmure Castle by continuing along the A762. No long-term significant adverse effects are anticipated as a result of the UGC.	The route is directly adjacent to Hensol House and Lauriston Hall NIDLs within the carriageway of the A762. No long-term significant adverse effects are anticipated as a result of the UGC.	The route is directly adjacent to Glenlee Park NIDL, Hensol House NIDL and Laurieston Hall NIDL within the carriageway of the A762. It also passes through Kenmure Castle NIDL. It is recommended that the route is realigned to avoid passing through Kenmure Castle by continuing along the A762. No long-term significant adverse effects are anticipated as a result of the UGC.	The routes pass through Balmaghie House NIDL and close to a number of other NIDLs, however they are within the public highway at these locations. No long-term significant adverse effects are anticipated as a result of the UGC.	
Forestry and Woodland	**Ancient Woodland (AWI)** **Native Woodland (NWSS)** **Forestry (NFI)**	The route follows the A762 from Glenlee S/S before diverging cross-country at White Hill. At this point the route crosses a small area of NFI. Further south the route crosses an area of AWI, NWSS and NFI at High Wood to the south of New Galloway Golf Club before skirting Burnfoot Cottage and re-joining the alignment	The route passes through an area of AWI, NWSS and NFI as part of the Black Bank wood before tuning south. The route then passes through an area of NWSS and NFI to the north of Peal Hill as well as a small section of Burnfoot Wood, before joining the A762 heading south along the western bank of Loch Ken. To the west this	The route follows the A762 from Glenlee S/S before diverging cross-country at White Hill. At this point the route crosses a small area of NFI. Further south the route crosses an area of AWI, NWSS and NFI at High Wood to the south of New Galloway Golf Club before skirting Burnfoot Cottage and re-joining the alignment	The route follows a small section of the A762 before following the line of the A713 south along the eastern banks for Loch Ken before diverging cross-country to the north of Crossmichael. To the south of Loch Ken the route passes through a small section of NWSS and NFI at Barony Isle. As the route turns south west, it runs along the farm access track, avoiding an area of AWI and NFI at Balmaghie Bridge. At its southern extent the route skirts an area of AWI adjacent to Argrennan Cottages.	

Criterion	Sub-Criteria	6A	6B	6C	6D	6E
		of the A762 heading south along the western bank of Loch Ken. To the west this section is heavily wooded with areas of AWI, NWSS and NFI forming the Galloway Forest Park. The route continues south following the line of the existing A762 passing intermittent areas of woodland, predominately comprised of NWSS adjacent to the carriageway on both sides. The route then diverges from A762 north of Ringford passing through an area of AWI, NWSS and NFI situated immediately to the north of Tongland at Underwood.	section is heavily wooded with areas of AWI, NWSS and NFI forming the Galloway Forest Park. The route continues south following the line of the existing A762 passing intermittent areas of woodland, predominately comprised of NWSS adjacent to the carriageway on both sides. The route then diverges from A762 to the north of Ringford passing through an area of AWI, NWSS and NFI situated immediately to the north of Tongland at Underwood.	of the A762 heading south along the western bank of Loch Ken. To the west this section is heavily wooded with areas of AWI, NWSS and NFI forming the Galloway Forest Park. The route continues south following the line of the existing A762 passing intermittent areas of woodland, predominately comprised of NWSS adjacent to the carriageway on both sides. The route then diverges from A762 north of Ringford passing through an area of AWI, NWSS and NFI situated immediately to the north of Tongland at Underwood.		
Flood Risk	**Flood Zones and Waterbodies**	This route crosses 10 areas within the 1/200yr and 1/1000yr flood risk zones (to the immediate south east of Glenlee S/S (Coom Burn); to the west of Burnfoot Bridge (Knocknairling Burn); to the east of Bennan Hill (Loch Ken); to the immediate south of Mossdale (River Dee); to the north of Laurieston (unnamed tributaries of the Kenick Burn); to the east of White Hill (Tarff Water); three to the north west of Ringford (Tarff Water); and to the south of Ringford (Tarff Water).	This route crosses 12 areas within the 1/200yr and 1/1000yr flood risk zones (to the immediate south west of Glenlee (an unnamed burn which meets Coom Burn); two to the north and east of Peal Hill (Knocknairling Burn); to the east of Bennan Hill (Loch Ken); to the immediate south of Mossdale (River Dee); to the north of Laurieston (unnamed tributaries of the Kenick Burn); to the east of White Hill (Tarff Water); three to the north west of Ringford (Tarff Water); and to the south of Ringford (Tarff Water).	This route crosses eight areas within the 1/200yr and 1/1000yr flood risk zones (to the immediate south east of Glenlee S/S (Coom Burn); to the west of Burnfoot Bridge (Knocknairling Burn); to the east of Bennan Hill (Loch Ken); to the immediate south of Mossdale (River Dee); to the north of Laurieston (unnamed tributaries of the Kenick Burn); to the east of White Hill (Tarff Water); and two to the north west of Ringford (Tarff Water).	6D and 6E cross four areas within the 1/200yr and 1/1000yr flood risk zones (two to the immediate south east of Glenlee S/S (Coom Burn and the Water of Ken); and two to the north of Longwood (Black Bridge Burn).	
Environmental Summary	**N/A**	Proposed cable route 6A is shorter than 6B and 6C. The proposed cable route 6C is slightly longer due to deviating east to the north of Ringford having followed the existing alignment of the A762 from Glenlee S/S, before crossing the A75 to the north east of Ringford. 6A/6B/6C are all located in proximity to several natural heritage designations however all options are within the public highway therefore it is assumed that works directly within the designated areas can be avoided. All three cable routes cross two area of peatland habitat; Class 1 peatland habitat adjacent to the east and west of the A762 near Beoch Moor and Class 3 peatland habitat adjacent to the east and west of the A762 near Back Fell. These areas are adjacent to the A762, along which the cables are routed in line with the key routeing principal to follow existing linear features such as roads or existing overhead line wayleaves. As such these areas are unavoidable without deviating from the A762, likely increasing the length of the route significantly. The routes are located within the Galloway Hills RSA to the north and a small section of the Solway Coast RSA to the south where the UGC terminates at Tongland S/S. The proposed cable routes will cross tourist and recreational routes, including the Robert Bruce Trail, Galloway Kite Trail and various Core Paths. For all of the cable routes key characteristics of the LCTs are unlikely to be adversely affected with the permanent loss of landscape features considered largely avoidable, however temporary disturbance and reinstatement to stone dykes likely to be required and loss of woodland is likely. None of the cable routes will result in effects on residential visual amenity. No archaeological or cultural heritage features would be directly affected by the cable routes. All of the cable routes will require forest felling, however the cable routes will impact significantly reduced forestry through utilising existing wayleaves and forest breaks, in particular those formed by the A762 to the west of Loch Ken. Route **6A** will affect marginally more forestry than the other cable routes proposed for this section as upon leaving Glenlee S/S the route heads west, before turning east of Peal Hill then converging with the A762 near Burnfoot. All of the cable routes cross multiple areas within the 1/200yr and 1/1000yr flood risk zones. Several of these are within the public highway however further consideration should be given to limiting the length of cable through flood risk zones if possible. Of the prosed cable routes **6C** crosses the least number of flood risk zones, while **6B** the most. **On balance, of the proposed cable routes to the west of Loch Ken, cable route option 6B is the environmental preference as it is the second shortest to 6A, but will result in the least loss of AWI and NWSS and has the greatest potential to minimise effects on tourism and recreation receptors. Option 6B crosses the greatest number of flood risk zones and waterbodies, however as many of the flood risk zone are crossed within the public highway; effects are unlikely to be significant.**			Cable route 6E is only 0.04km longer than 6D. Both options are located in proximity to a number of natural heritage designations however all options are within the public highway therefore it is assumed that works directly within the designated areas can be avoided. Both proposed cable routes cross Class 3 peatland habitat to the east of the A713 adjacent to Ervie Moor. This area is adjacent to the A713, along which the cables is routed in line with the key routeing principal to follow existing linear features such as roads or existing overhead line wayleaves. This area could potentially be avoided during detailed alignment depending on which carriageway is utilised for cable construction. The routes are located within the Galloway Hills RSA to the north and a small section of the Solway Coast RSA to the south where the UGC terminates at Tongland S/S. Both proposed cable routes will cross tourist and recreational routes, including the Robert Bruce Trail and Galloway Kite Trail. For all of the cable routes key characteristics of the LCTs are unlikely to be adversely affected with the permanent loss of landscape features considered largely avoidable, however temporary disturbance and reinstatement to stone dykes and hedgerows likely to be required. No archaeological or cultural heritage features would be directly affected by the cable routes. Both of the cable routes require forest felling, however this can be minimised through utilising existing wayleaves and forest breaks, in particular those formed by the A713 to the east of Loch Ken. Both of the proposed cable routes will result in similar impacts on forestry. Both cable routes cross multiple areas within the 1/200yr and 1/1000yr flood risk zones however further consideration should be given to limiting the length of cable through flood risk zones if possible. Both of the proposed cable routes cross the same flood risk zones. **There is no overall environmental preference between 6D and 6E due to the presence of very similar environmental constraints along the route options with only a marginal difference in route length.**	
		Of the five route options investigated for the route between Glenlee and Tongland S/S, the overall environmental preference would be route option 6D or 6E as although longer, these options require the least forestry felling, cross fewer flood risk zones and waterbodies as well as have the greatest potential to minimise effects on tourism and recreation receptors than route options west of Loch Ken.				

10 References

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