Underground Transmission Mains Design

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Endeavour Energy

POWER together

Revision History

Details of minor amendments are recorded below. The most recent changes for this minor amendment are highlighted in this document with grey colouring.

Amendment	Amendment Details
1	Full Revision.
1.1	• Cl 4.7.2 – revised Table 1 to include 32mm conduit for bonding leads • Cl 4.7.4 – additional requirements for DTS conduit installations. • Cl 4.9 – clarification of installation depths of cables • Cl 4.20 – updated Table 4.20 drawing versions

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1 Scope

This document details the minimum design requirements for Endeavour's 33 kV, 66 kV and 132 kV underground transmission mains network.

This Standard does not cover:

- The design and construction details of overhead transmission lines and UGOH construction, which are covered in MDI 0031 and MCI 0005.
- The sheath bonding arrangements of underground cables, which are covered in MDI 0045.
- The ratings of underground transmission cables, which are covered in MDI 0046.
- The commissioning and routine testing requirements of underground cables, which are covered in MMI 0025 and SDI 120.
- The design and construction details of the underground distribution network, which are covered in MDI 0028.
- The installation of circuits within a Transmission/Zone Substation, which is detailed in SDI 531.
- Easement requirements for cables and joint bays, which are covered in MDI 0044.

2 References

External Regulations
Electricity Supply Act 1995 (NSW)
ENA National Electricity Network Safety Code (Doc 001-2019)

External Standards		
Standard No.	Year	Title
AS 1141.11.1	2020	Methods for sampling aggregates, Method 11.1: Particle size distribution — Sieving method
AS 3600	2018	Concrete structures
AS 3966	2019	Access covers and grates
AS 4702	2000	Polymeric cable protection covers
AS/NZS 4130	2018	Polyethylene (PE) pipes for pressure applications
AS/NZS 2053.2	2001	Conduits and fittings for electrical installations

Company Policies and Procedures
Company Policy (Network) 9.1.6 – Approved Materials List
Company Policy (Network) 9.2.5 – Network Asset Design
Company Policy (Network) 9.7.1 – Network Asset Construction
Network Management Plan – December 2013 Review

Company Standards
ETS 0103 – 33kV, 66kV and 132kV Cable Accessories
ETS 0111 - 132kV Polymeric Insulated Underground Cables
ETS 0112 - 66kV Polymeric Insulated Underground Cables
ETS 0113 - 33kV Polymeric Insulated Underground Cables
ETS 0063 – Electrical Conduit, Conduit Fittings, Cable protection Cover and Marking Tape
ETS 0081 – Installation of Conduits using Trenchless Techniques
MDI 0045 – Cable Sheath Bonding Design
MDI 0046 – Transmission Underground Cables – Continuous Ratings

3 Definitions and Abbreviations

Term	Definition
BYDA	Before You Dig Australia, previously Dial Before You Dig (DBYD).
Backfill	Material used for filling trenches and excavations after conduits have been laid, usually placed on top of bedding material.
Bedding	A layer of material encasing conduits for the purpose of reducing thermal resistance. Typical bedding materials are sand-cement mixes and TSBs.
Bulkhead	A support or partition built within the ground to prevent the passage water and/or earth.
Cadastre	Maps displaying land parcel boundaries in relation to each other and to adjoining roads.
CAT hole	An open hole or pit used to install a Caterpillar puller to reduce cable pulling tension.
Cable protective cover	A hard polymeric cover placed directly above the cable bedding layer to provide mechanical protection of cables during future excavation.
CSA	Cross-sectional area – typically refers to conductor size in mm^2.
HDPE	High density polyethylene
Marking Tape	A soft warning tape installed within the backfill layer approximately 150mm above the cable protective cover to provide visual warning during future excavation.
Minimum cover /depth of burial	Minimum distance between ground level and the top of the uppermost conduit within the trench.
PVC	Poly-vinyl chloride
TSB	Thermally-stable bedding – an alternative to standard sand-cement mix. Used where required circuit rating cannot be achieved with standard bedding.
TR	Thermal resistivity
TfNSW	Authority for State roads, previously RMS.
UGOH	Underground to overhead connected cable, typically supported by a pole.
XLPE	Cross-linked polyethylene cable insulation

4 Actions

All underground transmission mains designs must be in accordance with this Standard and associated drawings.

4.1 Design Brief

Endeavour shall determine the need for any new or modified lines and whether the work is contestable. A Design Brief shall be prepared for each new section of a sub-transmission line, defining the scope of the project, and detailing specific information relevant to the project. The Design Brief shall include the following information where applicable:

- Project scope and description.
- Required completion date, if applicable to satisfy system loading requirements.
- Operating voltage.
- Rating requirements, including provision for other adjacent circuits, feeder route options, corridor widths and trench boundary maximum operating temperatures if required.
- Proposed route or endpoints.
- Environmental GIS report.
- Details of power cables, including any requirements for compatibility with existing cable installations
- Details of communication cables, including any requirements for interfacing with existing systems.
- Any project-specific design or construction requirements/constraints
- Where required, the number of spare conduits shall be specified, refer to the Note below.
- Segregation requirements for multiple circuits along a common route.
- Allowance for additional circuits, or conduits, if applicable.

Note: Endeavour may require spare conduits alongside new circuits to cater for known future network enhancements. In cases where access is extremely limited (Rail Crossings, Water Crossings) and trenchless technologies are adopted, the installation of ‘operational spare’ conduits can occur and will be provided in the Design Brief.

4.2 Design documentation

The Proponent shall provide a design and all details in accordance with the Design Brief, drafting standards such as SAD0006, and including, but not limited to the following:

Route plan

A route plan shall be provided showing the cable route on a cadastre plan (including dimensions from property boundaries if required for EMF calculations); the location of joint bays, pulling pits, link boxes and communications/DTS pits; and long section showing existing or proposed services, vertical separation from services, cover to proposed trench from existing/proposed ground levels, etc.

Property schedule

Where easements are to be acquired or land purchased, a property schedule shall be prepared, giving details of the Lot and DP numbers (and street addresses where known) of all properties affected, name, postal address and contact phone number of property owners, and comments on the nature of the interest to be obtained and any agreements made with the property owner, such as access conditions, disposal of vegetation removed during line construction, etc.

Schematic and single line diagram

A schematic and single line diagram shall be provided showing feeder numbers, cable sections, joint bays, section lengths, cable types, accessory types, and sheath bonding arrangements.

Design calculations

Design calculations shall include thermal ratings, short-circuit fault ratings, sheath voltage rise, currents and tension/sidewall pressure during pulling for all cables.

Cable details

Cable details shall include cross-section, dimensions, materials, thermal and electrical properties.

Cable accessory details

This shall include manufacturers' drawings.

Factory test plan

This shall include test specification references and pass criteria for all sample and routine tests carried out in the factory on all cables and accessories.

Trench construction

This shall include trench cross-sections, backfill and reinstatement details.

Joint bay general arrangement

This shall include internal and external dimensions, location of joints, support details for cables and joints, bonding lead conduits, link boxes and earthing details.

Native soil details

This shall include results of soil sampling, geotechnical, earth resistivity and thermal resistivity testing.

4.3 Survey & route selection

4.3.1 Survey

A route survey shall be carried out before commencing any design work, this should include the following information:

- Cadastre
- Combined services information from the designated underground asset information provider.
- Property ownership, e.g. DP/strata "F" plan to identify any areas that are not gazetted as road reserve.
- Conduit/cable longitudinal sections.

Borehole samples shall be taken from the preferred route for the purpose of:

- TR sampling at 200m intervals, or at changes in soil type or site-specific cut/fill locations, for rating calculations.
- Road pavement make-up, details of layer materials and thickness, for road restoration purposes.
- Characterisation of soil layers and environmental testing, for work method planning and waste classification.

Trial holes may need to be excavated at survey stage to gain details of known obstructions / pinch points that may affect route viability.

4.3.2 Route selection

Where possible, the cable route should follow public roads and reserves, while avoiding state and regional roads. The feeder must be installed in the kerb-side lane to minimise the impact during construction and future repairs. Where this is not possible, the road shoulder will be considered if there are not any other underground services installed.

Crossing of major roads must be avoided as much as possible. Where cables cross major roads, they must be installed in conduits, at right angles to the kerb. Where these roads are the responsibility of TfNSW, these must be installed using directional drilling. Where an open trench is proposed, consent must be sought from the relevant authority (TfNSW or local council).

For joint bay location requirements refer to Clause 4.16.4.

On route sections where a trenchless method is required, a pre-planning report must be completed. The report must cover, as a minimum, the following aspects:

1. The scope of the works
2. A search for existing utilities (BYDA)
3. Route review for the trenchless technology
4. Risk assessment
5. Location of entry and exit pits
6. Installation length and depth
7. Surface and sub-surface description
8. Indicative bore profile
9. Approximation of amount of drill slurry.

4.4 Cable route marking

All cable routes must be clearly labelled in accordance with the following requirements:

1. Where cables are installed in the road shoulder or footpath allocation, the kerb must be labelled by means of a printed sign on the kerb as follows:

   - have red lettering on a white background
   - at 50m intervals along the cable route
   - at road intersections
   - at either end of road crossings
   - wherever significant route deviations occur
   - label details: "*Endeavour Energy*
     Cables laid in this street
     (Voltage) Feeder XXX"

2. Where cables are installed off-road, the route must be marked l by means of 1345mm x 110mm x 90mm steel reinforced concrete posts (Endeavour *Material No.1000005583*) as shown in Figure 1. The posts must be painted yellow (if sandstone colour oxide is not incorporated into the concrete) and have the warning "*Endeavour Energy cables in the area. For locations phone 131 081*" etched into the face of the post. The posts must be located at intervals of approximately 150m along the cable route and wherever significant route deviations occur.

3. Where cables are installed under, paved areas e.g. car parks, 340mm x 340mm concrete marker blocks

must be installed. The blocks must be installed flush with the paved surface, at intervals of 50m along the cable route and wherever significant route deviations occur. The blocks must be painted yellow and have "*Endeavour Energy cables in the area. For locations phone 131 081*" moulded into the top surface.

4. Wherever cables are installed off-road and the route crosses, for example, a creek, river, or railway line, a signpost on either bank must be installed. The signpost must consist of an aluminium post 3000mm in length and an aluminium sign plate 750mm x 500mm, with the warning message detailed in scenario 2 above.

Figure 1: Typical cable route marker

4.5 Cable selection

Only approved cables shall be installed on Endeavour's network. Approved cables are the range of cables from suppliers under current period contract with Endeavour or listed on Endeavour's AML.

For Cable rating details associated with each conductor size refer to MDI 0046 – Transmission underground cables-continuous current ratings.

Endeavour Energy's underground sub-transmission network consists of polymeric insulated as well as legacy paper-insulated oil-filled cables. All new cables shall be XLPE insulated cables that comply with Endeavour's specifications ETS 0111, ETS 0112 and ETS 0113.

4.6 Cable accessories

All transmission cable joints, terminations, and ancillary equipment installed on Endeavour's network must be from suppliers under current period contract with Endeavour or listed on Endeavour's AML.

4.7 Conduits

4.7.1 Conduit types

Conduits installed in trenches must be PVC heavy duty type manufactured to AS/NZS 2053. Conduits installed in directional drilling sections must be HDPE type manufactured to AS/NZS 4130.

Conduits must be of the socket and spigot type and “Corflo” type conduits must not be used.
Where conduit bends are to be installed, these must be encased with a minimum of 75mm thick concrete of 15 MPa, with a minimum bending radius of 6m. Where TSB is required for cable rating purposes, approved wet TSB shall be utilised in lieu of 15MPa concrete at conduit bends.

HDPE conduit specifications shall consider the appropriate SDR rating subject to site specific trenchless design calculations by specialists, such as axial tension loads and buckling pressures.

For small route length bores of approximately 200m, HDPE conduits with an SDR rating of 13.6, PN 12.5 may suffice for various locations. However, this shall be verified in accordance with the trenchless design analysis for each underbore.

Unless otherwise stipulated in the Design Brief, transmission conduits for power cables in open trenching alignments shall be 200mm NB and 250 NB in trenchless excavations.

4.7.2 Conduit sizing

Conduit sizes required for Endeavour’s transmission cables are provided in Table1.

Table 1: Transmission cable conduit sizes

Cable	Nominal Conduit size (mm)	Conduit internal diameter – min (mm)	Conduit outside diameter – min (mm)
All 33kV and 66kV cables	150	141	160
All 132kV cables*	200	202	225
ECC & telecommunications cables	100	101	114
Sheath bonding leads	63	55	63
DTS fibre – currently 132kV cables only	32	26	32
Directional drilling – All 33kV and 66kV cables	180	150	180
Directional drilling – All 132kV cables	225	191	225
Directional drilling – Fibre optic and ECC cables	140	117	140
Directional drilling – DTS fibre	63	52	63

*132kV 300mm^2 cables are typically installed in 150mm conduits to supply transformers in substation trenches, which is outside the scope of this standard.

4.7.3 Feeder ratings

As part of conduit installation works, Endeavour Planners may provide feeder rating requirements for each conduit bank or circuit.

Designers shall at a minimum verify that their designed conduit profiles will achieve the stipulated feeder ratings based on MDI0046.

Where site specific design is not catered by factors or standard profiles in MDI0046, rating calculations in specialist software such as CYMCAP will need to be performed, and results provided to Endeavour.

On brownfield sites, the designer is recommended to engage specialists to perform thermal resistivity testing at site to acquire native soil TR values at 0% and 3% moisture content. TR tests shall be undertaken at least twice per kilometre of route length, and additional testing incorporated where significant change of soil profiles or fill is encountered. All tests to be carried out directly adjacent to the proposed conduit routes.

On greenfield sites, it is recommended to acquire the fully dried-out TR values of imported fill materials where the spare transmission conduit banks will be placed. This may require a combination of native soil TR testing as well to determine the worst-case bulk soil TR value at the fully dry state, subject to the depth of conduit installation and the dominant bulk soil layer.

4.7.4 Distributed temperature sensing (DTS)

An additional conduit to facilitate a dedicated DTS fibre is required for all new 132kV feeder installations.

For 132kV cables installed in standard trefoil formation within a trench, a 32mm orange HD PVD PVC conduit (AS/NZS 2053) shall be installed in the centre of the trefoil formation as per Figure 8. Where a trefoil formation transitions into flat formation, the 32mm conduit shall be secured to one of the outer power cable conduits as per Figure 12.

For 132kV cables installed in trenchless (underbored) sections, a 63mm orange HDPE conduit (AS/NZS 4130) shall be installed in the centre of the conduit formation as in Figure 23 and then jointed to the 32mm HD PVC conduit at each end of the underbore.

Where a new 132kV feeder design utilizes existing trench sections, with power cable conduits installed prior to the requirement for a DTS conduit, designers shall facilitate a continuous path for the DTS fibre for the entire route. This can be achieved by introducing a new fibre pit on either side of the interface between new and existing trenches.

At this pit, the 100mm comms conduit from the existing trench interfaces with the 100mm comms conduit and 32mm DTS conduit from the new section. This enables the separate comms and DTS fibres from the new section to transition into (share) the single 100mm conduit in the existing section.

The new fibre pit shall be a P8 type with lockable lids and is to be located preferably in the back of the kerb, in a similar alignment to Endeavour's comms and earth pits. All conduits shall enter the new pit via 900mm sweep bends transitioning over a sufficient distance to avoid sharp or 90° bends.

All conduits shall be mandrel or camera tested and roped to ensure continuity and future use.

These sections and transition points must be clearly marked on the WAE drawings for future DTS installation projects.

4.7.5 Conduit bends

All proposed conduit bends shall be designed to have a minimum radius of 6m. Typical bend angles include 11.25º, 22.5º, 45º and 90º.

The conduit bends in horizontal layout (plan view) shall be designed such that the inner-most conduit within the bend also has a min. 6m radius. This can typically be achieved by doing a filet radius of 6.5m for the centre of trench line in drafting software.

For ease of construction, all designed bends, especially long gradual bends, should be clearly labelled on the design drawing with the associated bend radius and bend angle.

All bends shall be concrete encased with min. 75mm of 15 MPa concrete with a fully dried-out TR of 1.2º C.m/W. Where bends are proposed with low local backfill TR requirements, wet TSB shall be used as per Endeavour's Approved Products List (AML).

Generally, the maximum allowable transmission conduit flexure for HD PVC conduit s is 2° - 3° and deviations greater than this must use min. 6m radius concrete/wet TSB encased bends as specified previously.

Bends in the vertical plane shall be avoided and only change inverts over reasonable grades, not violating the 2° - 3° conduit flexure.

Where these flexure values need to be challenged, the bending radius of the relevant HD PVC conduits should be verified and incorporated in the design, prior to designing bends in the vertical plane as a last resort.

4.7.6 Spare conduits

Endeavour may require the installation of spare conduits in portions of the proposed cable route in selected projects. Where applicable, Endeavour will note spare conduit details in the Design Brief, following the ASP's proposed method of supply (PMOS). Spare conduits shall be installed in accordance with requirements of Clause 4.8.

4.8 Cable trench design

4.8.1 Trench alignment

Transmission conduits are required to be installed in the nearest kerbside lane of carriageways. If space permits, the shoulder area of a carriageway can be utilised to install the transmission conduits, provided the below mentioned offsets are generally achieved.

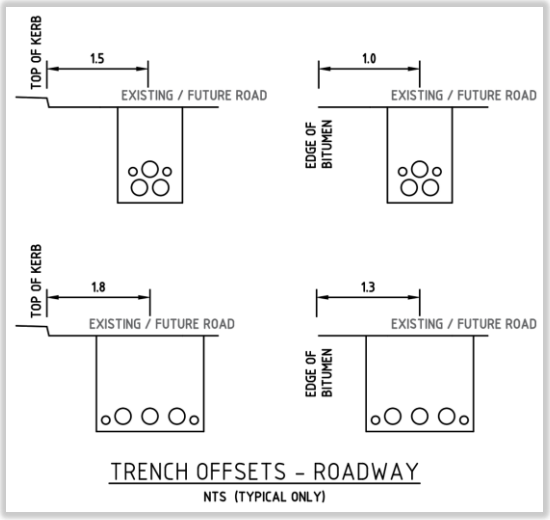
Depending on the conduit configurations and presence of kerb & gutter, the following trench offsets are recommended.

- Trefoil arrangement with kerb & gutter: 1500mm to the centre of transmission trench from top of kerb, in towards the carriageway
- Trefoil arrangement without kerb & gutter: Approx. 1000mm to the centre of transmission trench from edge of bitumen, in towards the carriageway
- Flat arrangement with kerb & gutter: 1800mm to the centre of transmission trench from top of kerb, in towards the carriageway
- Flat arrangement without kerb & gutter: Approx. 1300mm to the centre of transmission trench from edge of bitumen, in towards the carriageway

Due to the presence of existing and/or proposed stormwater pipes and kerb inlet pits, the offset may need to be increased to provide appropriate horizontal separation to pipes and pits. Recommended horizontal separation to stormwater pipes and edge of pits is 300mm from edge of trench or 225mm from edge of conduit bank concrete encasement. Pits for pipe sizes greater than 450mm may require greater trench offsets. Please liaise with road designers or acquire appropriate information from councils or TfNSW at design stage.

Recommended transmission cable trench offsets are provided in Figure 2.

Figure 2: Trench Offsets - Roadway



4.8.1.1 Notifications

In addition to standard council and residential notifications, approval of the works must be sought from road authorities (Local Councils and TfNSW) under s138 of the Roads Act.

Major utility approvals shall also be sought for under/over crossings and or interactions with their assets. Requirements for clearances between Endeavour and third-party assets are detailed in Clause 4.11.2.

4.8.1.2 Access requirements

Alignments and assets shall be designed such that 24x7 access will be available to Endeavour. In private land, other requirements will apply as per MDI0044.

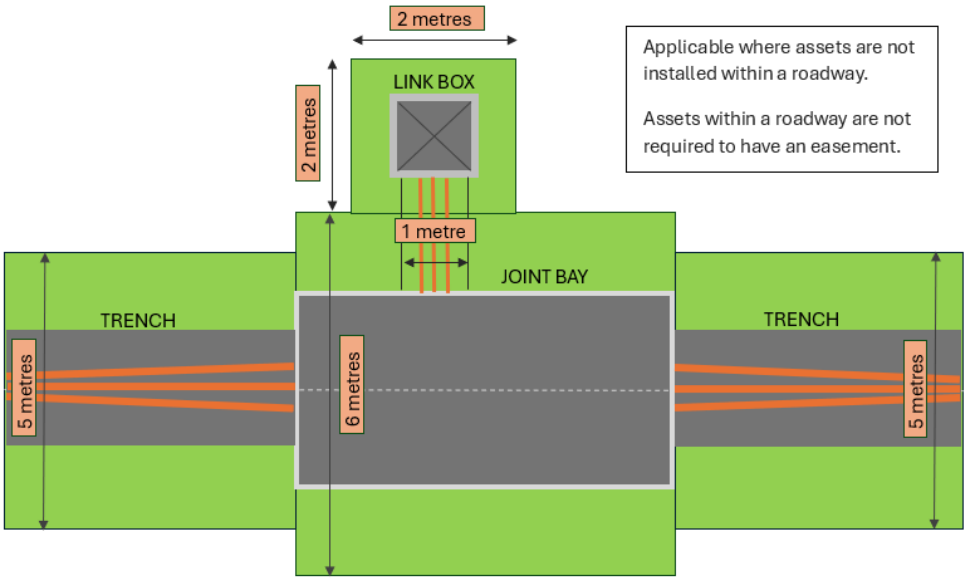
Where transmission underground alignments are not favourable or practical to be placed in the standard kerbside lanes of carriageways due to staging or construction constraints, the developer or proponent shall arrange for a dedicated utility corridor to be provided in the roadside verge or private land. Heavy vehicle access shall be provided on a 24x7 basis to these corridors, and easements and/or rights-of-ways shall be registered in favour of Endeavour as per MDI0044.

Heavy vehicle access should generally comply with Table 1 of EMS0006. At a minimum, the access track should be 4m wide and cater for vehicles up to 30T GVM and 15T weight for structures that support only one axle at a given time. Appropriate turning and U-turn bays should be provided for safe entrance and exiting of vehicles; catering for fixed truck and trailer combinations inside turning circle radius of approx. 8.3m (22.6m overall) and a vehicle width of approximately 3m.

Dedicated utility corridors should allow for appropriate horizontal separations to other utilities. Typically, for major trunk gas mains, 4m horizontal separation is recommended. Sydney Water may require min. 1m horizontal separation from their assets. The designer should guide the developer to provide appropriate separations whilst working in conjunction with other utilities and Endeavour.

The transmission underground asset allocation should cater for the worst-case joint bay, earth, and fibre pit width side-by-side. A 132kV joint bay, with earth and fibre pit combination will require a typical allocation width of 6m minimum as shown in Figure 3.

Figure 3: Typical allocation for transmission assets at joint bay



4.8.2 Type of laying

All cable systems must be installed within conduits. Direct buried transmission cable designs will only be accepted where cables approach a UGOH structure or outdoor termination.

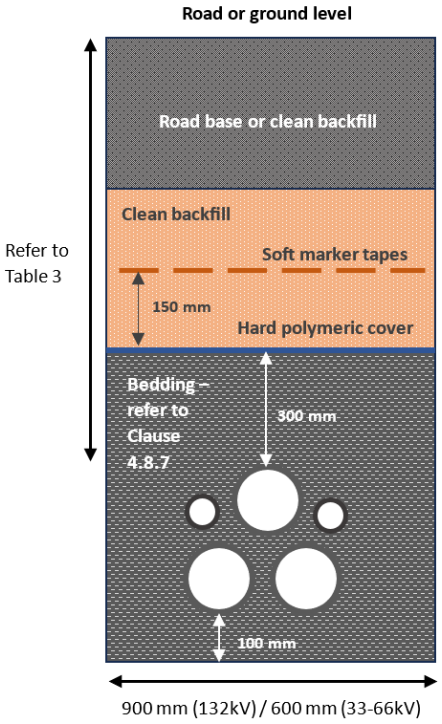
All conduits must be installed using an open trench method, except for the following instances:

- Crossing of a railway corridor
- Crossing of a TfNSW road
- Undercrossing of a waterway
- Installing circuits longitudinally along a pre-existing TfNSW road (where open -trenching will have considerable impacts on traffic -flow).
- Any other situation that requires the use of directional drilling.

4.8.3 Trench profile

The typical cable trench profile used in Endeavour is shown in Figure 4.

Figure 4: Typical cable trench profile



Trench profiles will vary depending on location, number of circuits, etc., in accordance with the depth of cover requirements in Table 3 and the trench configuration drawings provided in Sections 4.9 and 4.10.

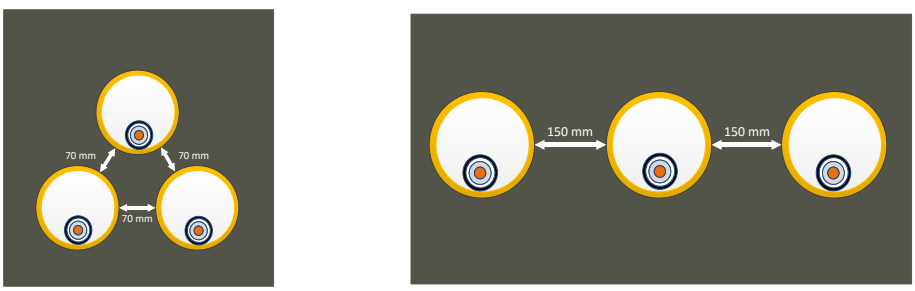
4.8.4 Cable-conduit phase separation

The standard separation between phases in a typical trench profile is given in Table 2. These distances may be increased/decreased where required, though the effect on cable ratings must be considered (refer to MDI 0046). Phase separation distances are shown in figure 5, which are measured from the outside of the conduits.

Table 2: Standard cable conduit separation

Construction	Phase separation
Trefoil formation	70mm
Flat formation	150mm

Figure 5: Phase separation clearances



4.8.5 Depth of burial

The minimum required (regular) depth of burial for a given design must be in accordance with Table 3, where depths are measured from the finished ground level. Where construction problems are encountered and the minimum required cover cannot be achieved, the following considerations and options are available:

- Install cable/conduits flat to obtain the required cover or,
- Subject to approval from Endeavour, conduits with less than the regular cover may be encased in 15 MPa concrete and 75mm thick on all sides for the reduced cover specified in Table 3.

Table 3: Minimum required burial depths

Category	Scenario	Regular cover	Concrete encased conduits
Open Trench – TfNSW Classified Roads	Existing road	1200mm	1000mm
	Proposed road – assets energised **before road construction completion**	1800mm	1500mm
	Proposed road – assets energised **after road construction completion**	1500mm	1200mm
Open Trench – Other Roads	Local roads	900mm	600mm
Open Trench – not in roadway	Land other than roadways, tracks, etc	750mm	500mm
Underbore Crossing* - TfNSW Classified and local roads	Existing roads	1500mm	-
	Proposed roads	2100mm	-

*Refer to *ETS 0081* for further details

4.8.6 Bedding

In general, bedding for transmission cable trenches shall be 14:1 sand-cement mix with a TR of less than or equal to 1.3° C.m/W. In situations where required cable rating cannot be achieved with sand-cement mix, an approved TSB may be used.

4.8.7 Backfill

Backfilling material should be composed of selected excavated material which is free from all extraneous materials likely to impede compaction and cause future subsidence, e.g. grass sods, tree roots, clods of clay and stones over 75 mm in greatest dimension.

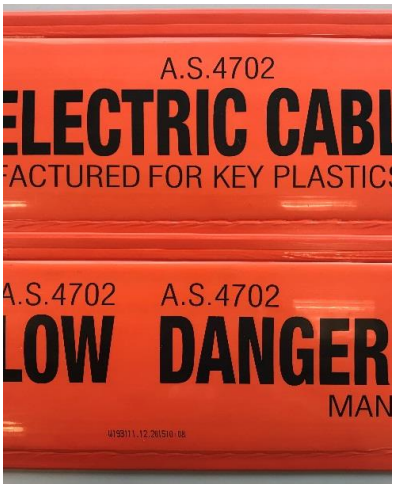
Excavated material that does not conform to the above-mentioned requirement or is otherwise considered unsuitable, must be removed from the site and replaced by suitable excavated natural backfilling material, certified to be free of contaminants (asbestos, PCBs, heavy metals, etc). Local authorities may have special requirements, e.g. layers and materials, which must be adhered to.

4.8.8 Cable protective items

Mechanical protection of underground transmission cables must be either a continuous 75mm thick 15 MPa concrete layer or polymeric cable covers complying with Endeavour specification ETS 0063.

The standard size of polymeric protective cover is 300mm wide and 4.8mm thick as shown in Figure 6. The protective cover must be installed approximately 300mm above top of conduits. To effectively protect the conduits and cables, the covers must be laid side-by-side such there are no large gaps laterally.

Figure 6: Cable protective cover



In addition to the protective cable covers, soft warning tape must also be installed to give a visual warning during excavation. The warning tape must comply with Endeavour specification ETS 0063 and is shown in Figure 7.

The warning tape must be installed approximately 300mm below the finished ground level/pavement/bitumen and installed for all excavations, including trenches, joint bays, and CAT holes.

Figure 7: Marker tape

4.8.9 Surface restoration

Where the cable trench is to cross, or run longitudinally along, where pavement exists, an extra 200mm either side of the trench must be removed and later restored. Refer to drawings 507641 and 290689 for further details.

4.9 Standard trefoil trench profiles

Endeavour's standard trench profiles comprise a single cable circuit in trefoil configuration, detailed in drawing 507641 for trenches in roadways, and drawing 290689 for trenches not within roadways. Specific, depths of cover are detailed in Table 3 of this standard. Typical standard trench profiles are shown in Figures 8 to 11.

Figure 8: Standard 132kV trench - in roadway

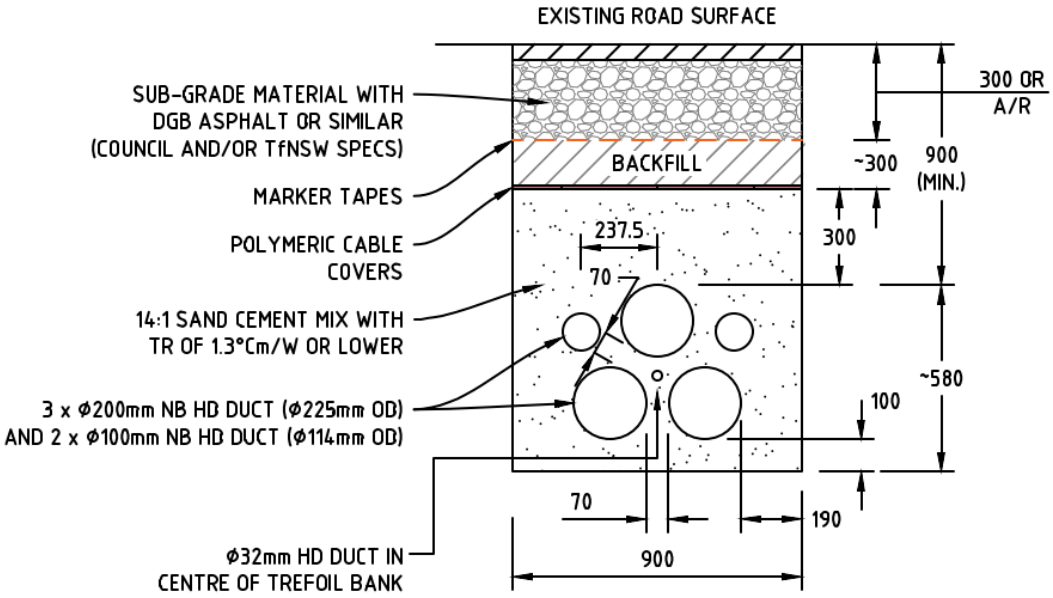


Figure 9: Standard 132kV trench - not within roadway

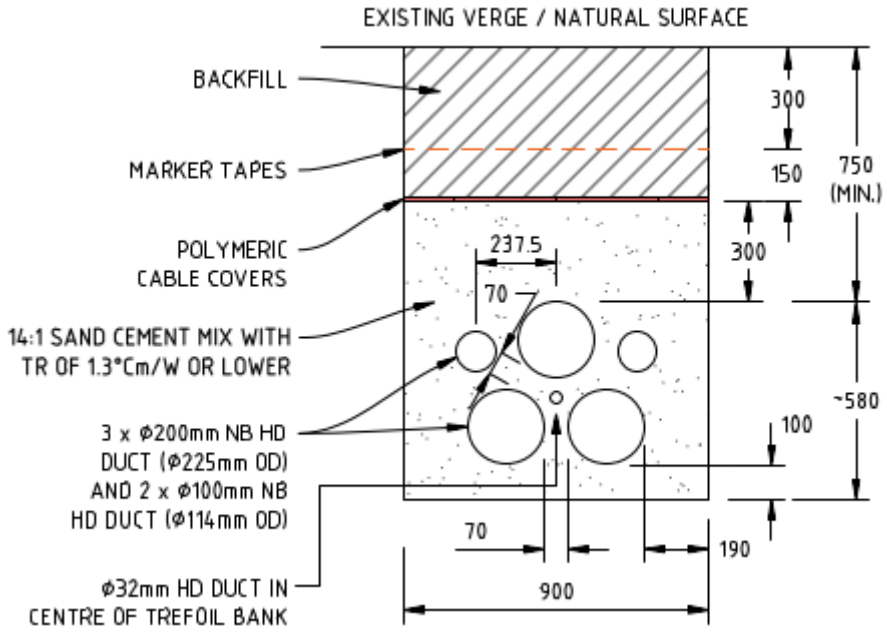


Figure 10: Standard 33kV & 66kV trench - within roadway

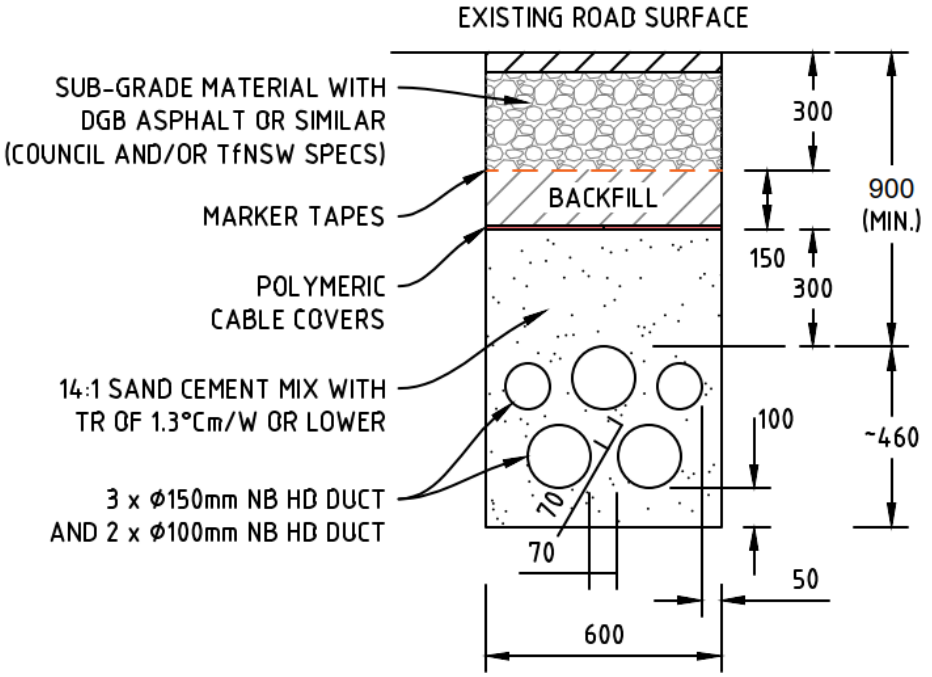
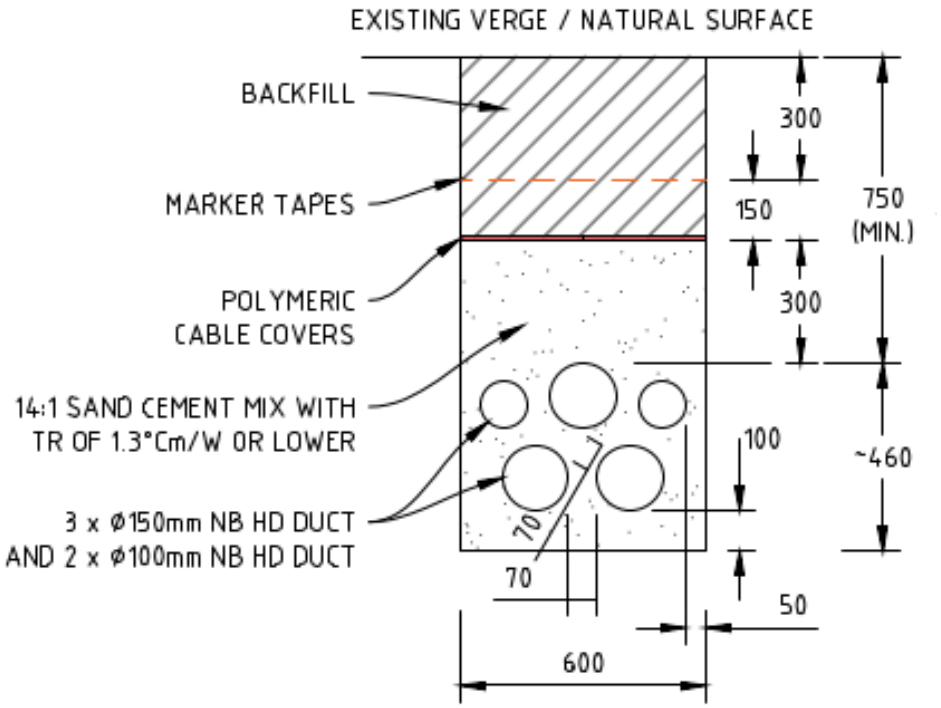


Figure 11: Standard 33kV & 66kV trench - not within roadway



4.10 Flat formation trench profiles

Cables should only be installed in flat formation in the following situations:

- Cables transitioning to and from joint bays
- To achieve required feeder ratings, subject to approval from Endeavour.
- Where regular depth of cover cannot be achieved, subject to approval from Endeavour.

Design details for typical flat formation cable trench profiles are provided in Figures 12 and 13.

Figure 12: Typical 132kV flat formation trench - within roadway

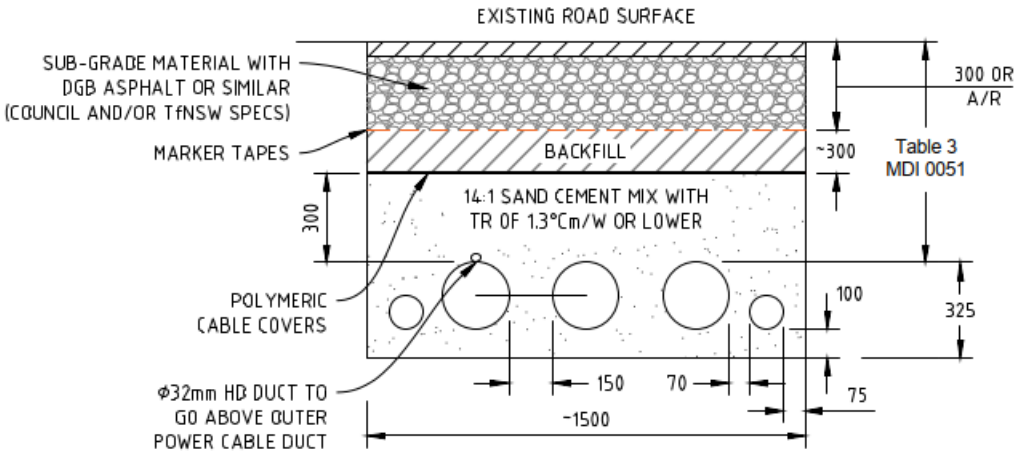
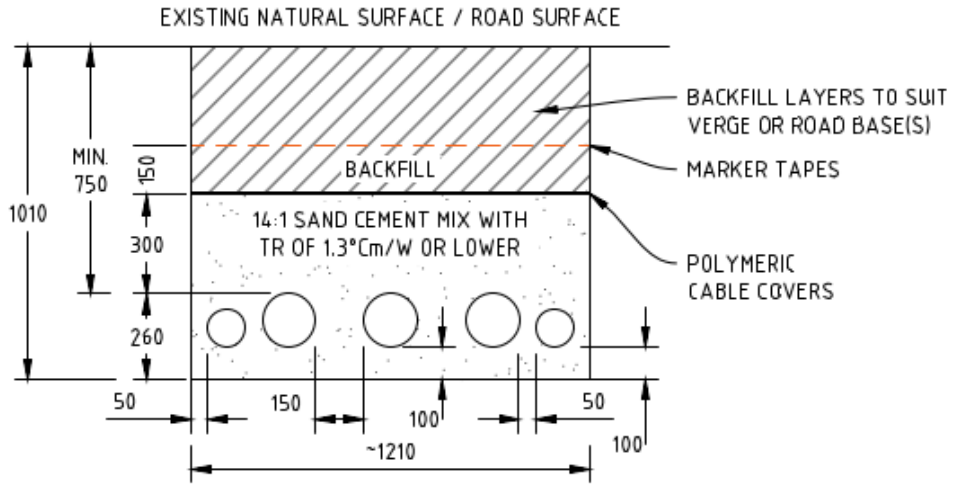


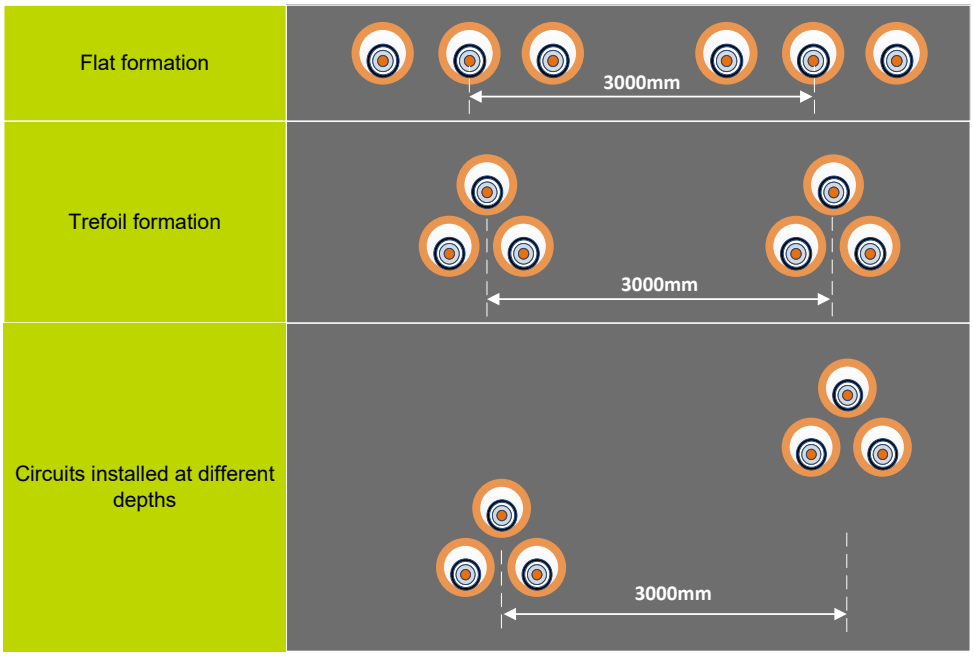
Figure 13: Typical 33-66kV flat formation trench - not within roadway



4.11 Separation between adjacent circuits

Separation between two adjacent cable circuits shall be no less than 3m as shown in Figure 14.

Figure 14: Minimum separation between adjacent circuits



In a typical roadway, where there is a requirement to install two sub-transmission conduit banks, these shall be installed in separate kerb-side lanes (e.g. north-bound and south-bound) closest to the kerb or bitumen edge as per trench offsets specified in Clause 4.8.1

In situations where it is not practicable to install dual circuits in separate kerb-side lanes and there is insufficient space within the shoulder of the roadway for 3m separation, dispensation may be sought from Endeavour to reduce the 3m separation in accordance with alternative conduit arrangements detailed in Figures 15 to 20.

Figure 15: 132kV trefoil - dual circuits

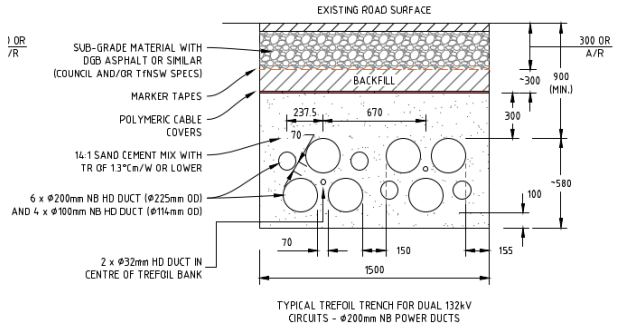


Figure 16: 132kV trefoil - two cables per phase

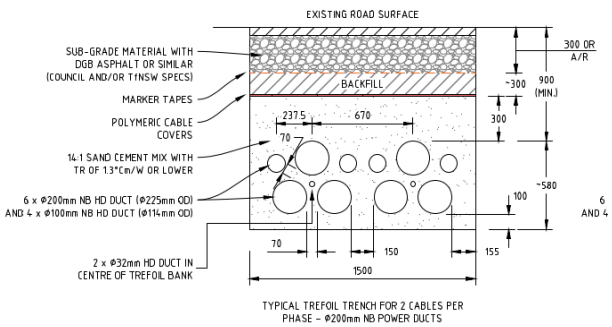


Figure 17: 33-66kV trefoil - dual circuits

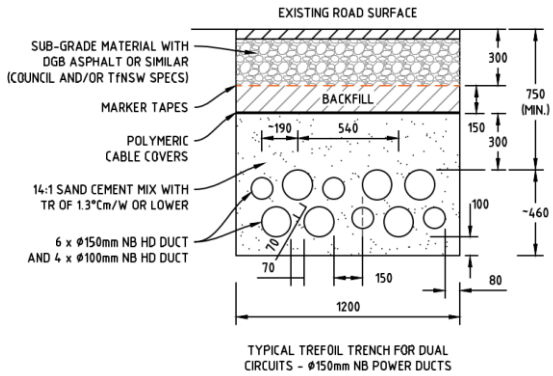


Figure 18: 33-66kV trefoil - two cables per phase

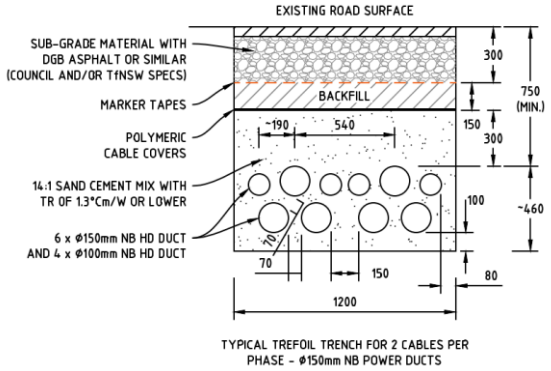


Figure 19: 132kV flat – dual circuits

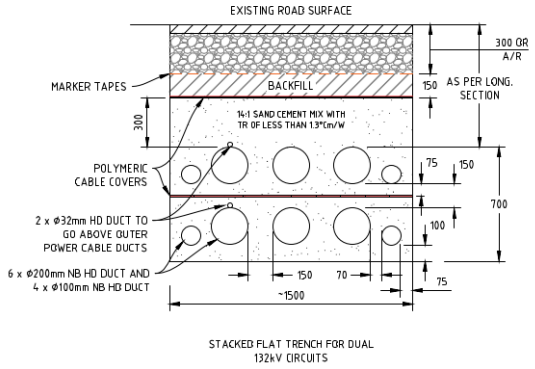
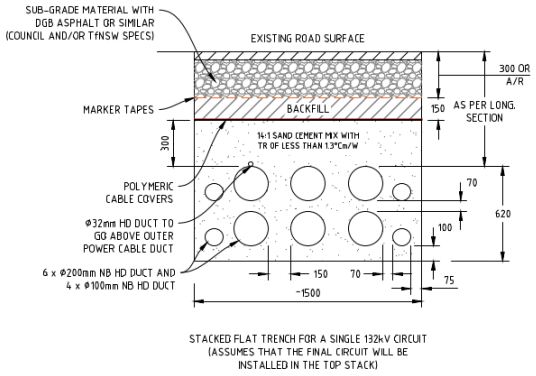


Figure 20: 132kV flat – two cables per phase



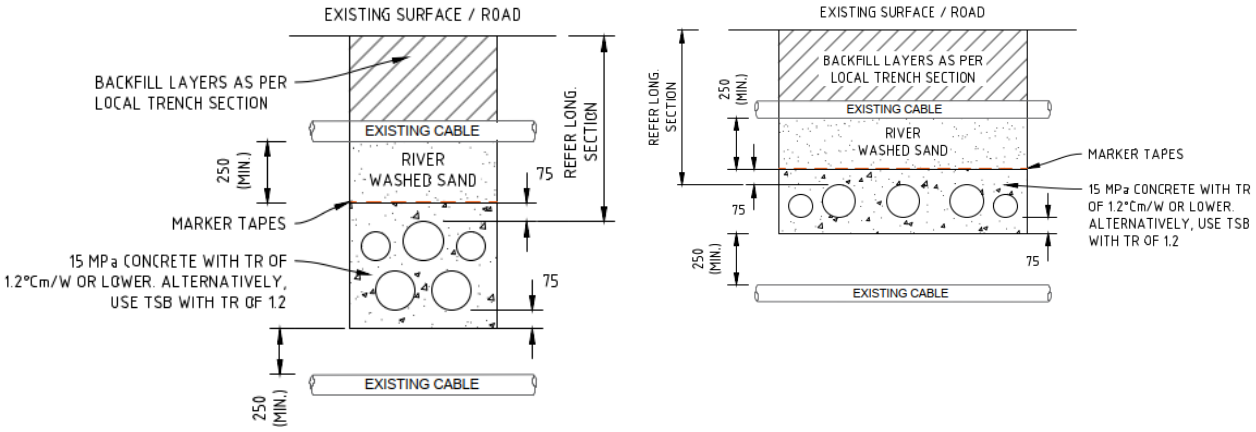
Dispensation to approve the above arrangements must consider effect on circuit ratings, N-1 reliability criteria and constructability issues, and that any required de-rating is approved by Endeavour's Network Planning Manager.

4.11.1 Crossing of other Endeavour cables

Where a circuit is to cross an existing Endeavour Energy underground cable, the separation distance required to maintain the rating of the existing circuit must be calculated and achieved. Where the existing circuit rating cannot be maintained, approval shall be sought from Endeavour for the de-rating of the existing circuit. A minimum separation of 250mm from the bottom of the concrete encasement to the conduit will apply in all cases.

At the point of crossing, extended out 500mm, the cables must be concrete encased, where it is practical, as shown in Figure 21 and includes greenfield sites, or where the new circuit is being installed above an existing circuit.

Figure 21: Concrete encasement of cables within 250mm of existing cable assets



The rating of both the top and bottom circuit must be calculated in accordance with *MDI 0046* and *IEC 60287-3-3.* The angle of crossing also effects the rating of the cable with 90° being the best-case scenario and an angle crossing of less than 15° would be effectively modelled as two parallel circuits.

4.11.2 Clearances to other utilities and services

Third party assets are generally not permitted within Endeavour Energy's easements for underground cables nor is it generally acceptable to have assets installed longitudinally above transmission underground cables.

Where this is unavoidable for certain conduit sections (after all other options have been exhausted), a dispensation request shall be submitted to Endeavour for the shortest possible route length with longitudinal encroachments, accompanied by an approval letter or equivalent document from the impacted utilities, or vice-versa.

Where third party assets coming within the easement is unavoidable, recommended clearances are provided in Table 4. The same clearance requirements will be applicable elsewhere. The most onerous of the vertical and horizontal requirements should be implemented, but not less than the minimum requirements stipulated in Table 4, following consent from other asset owners. For oil/fuel pipelines, railway and major third-party electrical asset crossings, the clearances shall be negotiated with the relevant utility owner.

Where trenchless excavations are proposed, it is recommended to add an additional 500mm of vertical separation to allow for inaccuracies in above-ground surveys and tracing of the drill head. This should be in addition to the 500mm vertical inaccuracy allowance of any quality level B underground utility survey.

Trenchless excavations should be independent of other utilities, i.e. the borehole should not share assets with other utility providers to maintain line security. Where all other avenues have been exhausted and there is a considerable case for a shared arrangement, this shall be agreed between Endeavour and the third party via a dispensation request. Clearances Table 4 will apply before and after the trenchless excavation pits.

The minimum horizontal separation between bore holes shall be the greater of 500mm or the horizontal separation value specified in the table below. This separation is subject to a trenchless excavation analysis. Clearances stipulated are measured to the outer side of third-party pipes or their equivalent concrete encasements from the bottom, top or side of transmission conduits.

Conduits shall be encased in a 75mm thick layer of 15 MPa concrete or wet TSB when allowable separation is less than 325mm from a third-party service.

Table 4: Clearances to third party assets

Utility	Asset	Minimum clearance (mm) - Typical 3rd party utility requirement [1]		Minimum clearance (mm) - Endeavour Energy requirement[2]		Remarks
		Vertical	Horizontal	Vertical[3]	Horizontal[4]	
Gas	Low / medium pressure plastic mains	300	300	325	325	Separations to be reduced only with utility consent. For conductive pipes, appropriate LFI and EHA studies will be required for EE and utility approval. Primary and trunk mains clearances to be negotiated with utility.
	High pressure secondary gas main (including any steel mains)	500 (33kV-66kV) 1500 (132kV)	500 (33kV-66kV) 4000 (132kV)	500	1000 (to non-conductive pipes) 4000 (to conductive pipes)	
Electricity	Transgrid, HVC cables	To be negotiated	To be negotiated	325	3000	Horizontal separations to be reduced in negotiation with third-party, performing cable de-rating calculations and acquiring EE consent.
ITS	ITS assets within roadways	300	300	325	325	
Railway	Underground railway cables and assets	To be negotiated	To be negotiated	To be negotiated	To be negotiated	
Comms.	Telecommunication assets	300	300	325	325	
Water and wastewater	Low pressure water main	300	500	325	325	Separations to be reduced only with utility consent. For conductive pipes, appropriate LFI and EHA studies will be required for EE and utility approval. Sydney Water may require specialist approvals for sub-transmission asset crossings as per BOA document SW269 08/21.
	High pressure water main	600	1000	500	1000 (to non-conductive pipes) 4000 (to conductive pipes)	
Stormwater	Stormwater pipes, culverts, pits	300	300	325	325	
The most onerous of the vertical and horizontal requirements should be implemented, but not less than the minimum requirements of EE; following consent from other asset owners.						

1 These are typical clearances provided as a guide only. Designer shall verify third-party clearance requirements.

2 Where EE allowable separations are less than the third-party requirements, the lower values will only be acceptable with consent of the other utility. All clearances are from any side of EE transmission conduit to third-party asset or their own concrete encasement.

3 Additional 500mm vertical separation to be added for trenchless excavations (HDD and thrust bores).

4 Consideration shall be given to increasing the horizontal separation adjacent third-party accessible pits, valves, hydrants, CP test points, induction loops or similar**,** to allow for safe maintenance and operation of all assets. Consideration shall also be given to sub-transmission assets being placed on the edge of existing and/or future underground cable easements. Horizontal separations may need to be measured from the edge of EE or other relevant easement boundaries.

Horizontal separations to high-pressure conductive pipelines can be reduced to 1000mm if LFI and EHA calculations as per AS4853 or similar permit, also in conjunction with the other asset owners.

4.12 Approaching a UGOH termination

Where an approaching underground transmission cable is within three (3) metres of a UGOH termination structure, the trench profile must be in accordance with Drawing 507643. The backfill for the cables approaching a UGOH termination is specified in Clause 4.8.7, and conduits are no longer required. Conduit ends must be sealed with a suitable foam or mastic material that prevents moisture ingress into the conduit.

Mechanical protection for the cables must be installed as close as possible to where the cable becomes vertical. The cables may need to be installed with a greater depth to be able to accommodate the bending radius of the cable, to be able to be installed on the pole. In addition to the vertical bending required, a final 'loop' shall be installed in the cable, where practical. This is to aid future possible repairs or moving of the structure which may require an extra length in the cable.

4.13 Cables within bridges

Cable installations within bridges must be avoided where possible. Where cables are to be installed within a bridge:

- The civil design must be assessed and approved by both TfNSW and Endeavour.
- Spare conduits must be installed.
- The bridge must have warning signs both at the beginning and end of the bridge, as well as regular intervals on the bridge warning of the presence of the high voltage cables.

Where distribution and transmission circuits are required to be installed on the same bridge, it is preferred to install the two systems on opposite sides of the bridge. Where this is not possible, the separation between the two systems must be such, that the transmission and/or distribution cables will not be de-rated by being within the bridge.

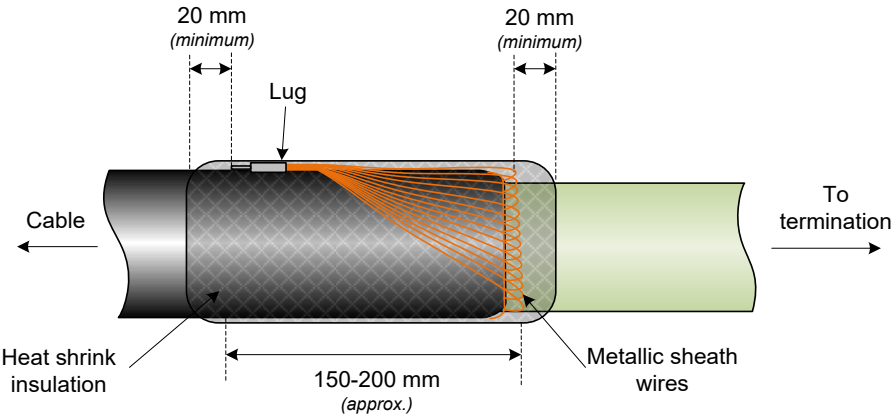
Rating calculations clearly illustrating the location of each conduit and cables, as well as the maximum current rating (and all assumptions used) must be submitted to Endeavour for review/approval prior to certification and/or approval of the design drawing.

Cables must not be suspended and/or installed in a cable tray system of any sort. The transmission conduits are to be installed closest to the roadway unless the location of the mains in the street dictates otherwise.

4.14 Special requirements for horizontal terminations

Where a termination of a cable is horizontal, and the metallic screen wires are to be left floating, to avoid the possibility of moisture ingress, the metallic screen wires must be terminated as shown in Figure 22.

Figure 22: Metallic sheath termination at floating end



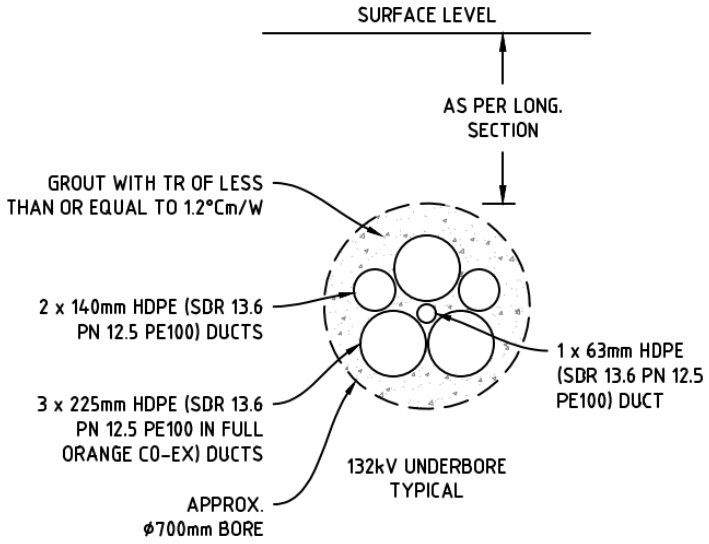
4.15 Directional drilling (underboring)

Installation of conduits using directional drilling (also known as underboring) must only be undertaken where:

- the open trench method is impractical for safety or environmental reasons or causes undue inconvenience to the public or local council.
- specifically required by TfNSW, e.g. within state roads or rail corridors.

The conduits/cables can be installed with a casing pipe or sleeve or within the borehole itself. The conduits/cables must be installed as per Drawing 507646. A typical 132kV underbore construction is shown in Figure 23.

Figure 23: Typical 132kV underbore construction



Entry and exit angles when installing conduits using directional drilling are to maintain a smooth transition to existing or additional works.

All trenchless drilling works must be in accordance with Endeavour specification ETS 0081 – Installation of conduits using trenchless techniques.

4.16 Cable Joints and Joint bays

4.16.1 General requirements

All cable joints must be installed within joint bays and must comply with the requirements of Endeavour specification ETS 0103 and approved under current Endeavour contract or AML. The number of cable joints must be minimised as much as practicable.

The trench profile must transition from trefoil to flat formation over 12 metres leading up to and leading away from the joint bay. The minimum cover to top of conduits when transitioning to joint bays must be 900mm.

Transmission power cable joints must be staggered in the joint bay in an arrow formation, with the outer joints at one end of the joint bay, and the centre phase joint at the opposite end of the joint bay.

The bedding for joints must be suitably graded sand mixtures, in accordance with Clause 4.8.7, to 300mm above the joints The river washed sand shall be placed very carefully into the joint bay in layers of 150mm

(max. 200mm) and compacted using light-duty hand-held tampers until the level reaches 300mm above the joint enclosures.

Where joint bays are installed in road carriageway, backfill above hard marker tapes for the joint enclosures shall be 14:1 sand/cement mix, otherwise should be the same as the adjacent trench section.

In joint bays with concrete end walls, power cable conduit entries/exits must be via bell-mouth penetrations cast into the end walls. In 33kV joint bays with bulkheads in lieu of concrete end wall, power cable conduits shall extend 100mm into the joint bay. ECC, DTS and communication cable conduits must either be continuous through the joint bay or extend to the link box pit or fibre optical pit, as required.

Where a power cable extends out of a conduit more than 1200mm, it must be supported on sandbags.

Power cables shall be suitably sealed to stop ingress of moisture.

All conduits entering or exiting the joint bay must be sealed with an approved mastic type sealant product listed on Endeavour's AML, and in accordance with manufacturer's instructions, to reduce the ingress of water The use of foam sealers or other non-approved products is not permitted.

4.16.2 Joint bay design

Joint bay designs must comply with Drawing 297281. Typical joint bay dimensions are provided in Table 5.

Table 5: Typical joint bay dimensions

Cable Type	Width (m)	Length (m)
33kV XLPE / TTJ – normal and staggered	2	6
33kV XLPE / TTJ – stacked conduits future cut-ins	2	8
66-132kV XLPE – to suit transportable joint shed	3	8
66-132kV XLPE – stacked conduits for future cut-ins	3	12

Additional joint bay design requirements are provided in Table 6.

Table 6: Additional joint bay design requirements

Category		Requirement
Type		Precast or in-situ
Floor		150mm* concrete without hollows or sharp projections
Side walls		150mm* concrete without hollows or sharp projections
End walls	**33kV**	Bulkhead (sandbags) or 150mm* concrete without hollows or projections
	66-132kV	150mm* concrete without hollows or projections
Sump pumps		1 at each end of joint bay (66-132kV bays only)

*200mm for joint bay depth > 1.5m and < 3m or as required by site-specific design.

4.16.3 Joint bay earthing

Joint bays must be earthed in accordance with joint bay drawing 297281. An earthing design is to be performed for all transmission UG cable designs for earthing compliance and to confirm the local earthing resistance of each joint bay. Where there is no stipulated earthing resistance requirement in the design, the local earth system must have a resistance 10Ω or less.

Link boxes shall be bonded to the local earthing system and ECC, where installed, as shown in Figures 24 and 25.

Figure 24: Earthing for cross-bonded system

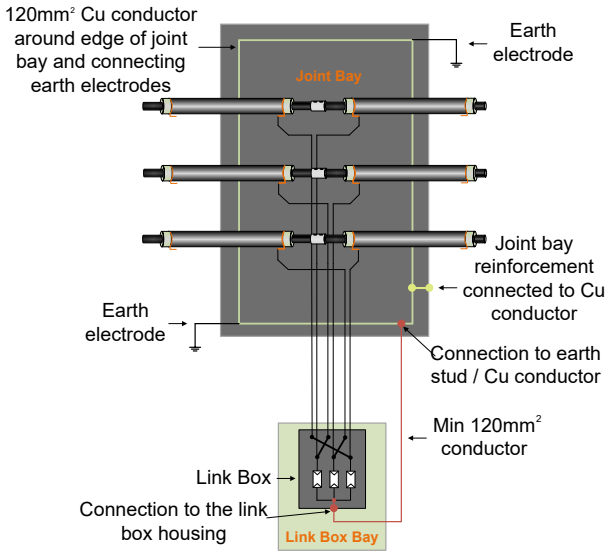
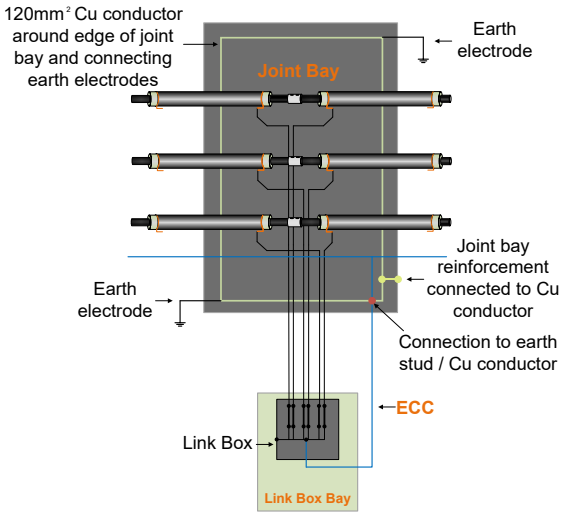


Figure 25: Earthing for single point bonded system



Endeavour currently uses the four link box types specified in Table 7.

Table 7: Link box details and Endeavour Material Codes

Link Box Type	Arrangement	Bonding Scheme	Material Code
Type 2	3-way + direct earth	Single point bonding	1000006243
Type 4	3-way + earth via SVL	Single point bonding	1000006244
Type 6	6-way + earth via SVL	Cross bonding	1000008930
Type 7	3-way direct earth + 3-way earth via SVL	Combination of cross and single point bonding	1000010333

Sheath bonding arrangements are outside the scope of this document and instead covered in Endeavour's design standard MDI 0045.

4.16.4 Joint bay location

Joint bays must be located such that:

- Access for installation and future repairs, as well as clearances to existing overhead infrastructure, is maintained.
- There is at least 6m clearance from driveways, road intersections and corners.
- Bays are not within 2m from the base of poles.
- Bays are not within 8m of a telecommunications asset (pit or above-ground pillar).

All joint bay locations shall be established via trial hole excavation (potholing) to confirm that the location is suitable for the joint bay construction intended.

In local roads, joint bays may be located within the roadway, subject to safe access and impact on the local traffic. Where access or impact on local traffic is unacceptable, the joint bays shall be located within the road shoulder, even where the cable route diverts towards the centre of the road.

Joint bays must not be located within the carriageway of major roads except with the approval of Endeavour's Asset Engineering Manager and TfNSW. If approval is granted, the joint bay must be located within the kerb side land and on the opposite side of the carriageway to the gas and water mains.

4.17 CAT holes

CAT hole trenches must be constructed as per Drawing 297280. CAT holes must be a minimum of 3000mm in length, and a trench width of 1750mm, or 500mm from the edge of the trench to the nearest outer conduit, whichever is greater. The conduits must have a minimum clearance to the bottom of the trench of 250mm.

On projects with 200mm conduits, the CAT hole length and width may need to be increased to 4000mm and 2400mm respectively. Where two CATs are required in tandem, the length of the CAT hole will need to be 6000mm.

The depth of a CAT holes will depend on the depth of the installed conduits. Where the burial depth is greater than 1500mm, the trench sides and floor must be 15MPa concrete.

The transition between the typical trefoil construction to the flat formation required for the CAT hole will occur over six (6) metres on approach and leaving the CAT hole. The conduits entering and exiting the CAT hole must be in flat formation and be continuous within the CAT hole.

4.18 Link box and fibre optic pits

Link box and optical fibre pits must be positioned within the electricity footpath allocation. This position should be at the back of the kerb line and flush with the finished footpath surface. Where possible, the distance between joint bays and link boxes shall be minimised such that bonding lead length does not exceed 10m.The typical dimensions of these pits are given in Table 8.

Detailed requirements for link box and fibre optic pits are provided in Drawing 297281.

Table 8: Typical pit dimensions

Type	Width (mm)	Length (mm)	Depth (mm)	Material
Link Box Pit	1400 lid &1200 opening	1400 lid &1200 opening	900	Glass-reinforced Concrete with Class D lid
Optical Fibre Pit	545	1355	895	HDPE (P8 typical)

4.19 Design requirements for cable pulling

4.19.1 Minimum cable bending radii

The minimum bending radii of the cable, as specified in AS 1429.2, where d_0 is the outside diameter of the cable, is:

- $20d_0$ during installation.
- $15d_0$ after installation.

All conduits along the route will shall have a minimum 6 metre bending radius.

4.19.2 pulling tension and sidewall pressure

The cable pulling plant for transmission cables must use tension limited devices that physically limit excessive tensions being applied to cables. Cable pulling tension must be restricted to 80% of the cable manufacturer's maximum pulling tension.

Where horizontal and/or vertical bends are proposed, the manufacturer's maximum cable sidewall bearing pressure (SWBP) and minimum cable bending radius must be considered to determine the maximum cable pulling tension.

Maximum pulling tension through a bend can be determined as follows:

T_{max} (kN) = Cable or Conduit Bending Radius x Max SWBP x 9.81/1000

Where horizontal and/or vertical bends are proposed, the maximum sidewall pressure of the cable and minimum bending radius of ducts shall be considered to determine the maximum cable pulling tension.

4.20 Drawings

Drawing No.	Amendment	Subject
290689	I	Cable trench cross section 33, 66 and 132kV cables – not within roadways
297280	D	Transmission cable CAT hole cross section
297281	H	Transmission cable joint bays for 33, 66 or 132kV cables
303319	A	Underground HV cable route marker post
507641	E	Cable trench cross section 33, 66 and 132kV cables – within roadways
507643	A	Underground to overhead termination cable trench profile
507646	C	Cross section drawing for under-bore construction
507647	A	Link box pit construction details

5 Authorities and Responsibilities

General Manager Future Grid & Asset Management has the authority and responsibility for:

- Approving major changes to this standard
- Making all decisions concerning compliance with this standard delegating any of these authorities and responsibilities to the Head of Asset Planning & Performance.

Head of Asset Planning & Performance has the authority and responsibility for:

- Approving minor changes to this standard
- Making recommendations to the General Manager Future grid & Asset Management for major changes in respect to this standard.

Asset Engineering Manager has the authority and responsibility for:

- Reviewing and updating this standard in accordance with company policy and procedures.
- Managing dispensation requests for variations to requirements of this standard.
- Approval of equipment and materials within the scope of this standard.

Designers and Project Managers have the authority and responsibility for:

- Designs meeting the requirements of this standard.
- Incorporating safety in design (SID) principles into all designs.
- Confirming that personnel engaged to perform work have appropriate qualifications.

Endeavour Energy staff and contractors have the authority and responsibility for:

- Implementing the requirements of this standard.
- Working in accordance with local and statutory requirements.
- Maintaining a high level of public safety.
- Working in accordance with Endeavours policies and procedures.
- Confirming that personnel engaged to perform work have appropriate qualifications.

Accredited Service Providers have the responsibility for:

- Confirming that their staff have available and use the latest issue of this standard and other related standards.

Endeavour Energy

POWER together