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Specification for

Trenchless Installation of Electrical Conduits by a BC Hydro Contractor

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	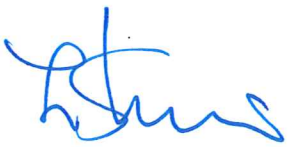	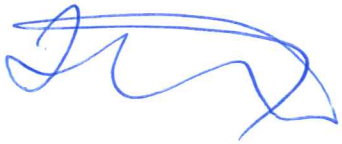
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Date: Jan 29, 2013	Date: Jan 29, 2013	Date: Jan 29, 2013

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1.0 Scope

This specification applies to the requirements for installation of electrical conduits by a specified trenchless method by a BC Hydro appointed contractor. It includes sections specific to installation by Horizontal Directional Drilling (HDD), and the Jack and Bore (JABU) method.

1.1 Related Sections

The following BC Hydro requirements are covered by this specification:

1) Horizontal Directional Drilling (Section 3)
2) Jack and Bore (Section 4)

2.0 General Requirements

2.1 Geotechnical Factual Report

A Geotechnical Factual Report included in Appendix A is provided for the contractor's information only. The responsibility for interpretation of this report, and the consequences arising therefrom, lies entirely with the contractor.

2.2 Material and Services Furnished by the Contractor

The contractor shall supply:

1) A complete spread of all equipment, tools, supplies and components, in working order sufficient and all-encompassing to operate the equipment and the tools, and enable the project to be carried out and completed as specified herein in a continuous and uninterrupted manner.
2) All material, supervision and labour, including consumables and materials of a temporary nature which are not specifically provided by BC Hydro.
3) All other services and work documents as required for the work and in accordance with the requirements set forth in the Contract Documents.
4) Unless otherwise specified: a temporary field office; heating in the field office; sanitation facilities, telephone and internet services for the duration of the Contract; electricity and water, as required.
5) Other requirements specific to the particular method of installation to be used for this project are included in Section 3 and Section 4.
6) The contractor shall provide experienced and competent crews to operate all specialised equipment to be used to carry out the work(s)

2.3 Material and Services Furnished by BC Hydro

BC Hydro shall supply:

1) Survey control points along alignment.
2) A Geotechnical Factual Report.

2.4 Meetings

1) BC Hydro's representative will arrange and conduct a project kick-off meeting with the contractor, their representative and any subcontractors, prior to initiation of the project.
2) During the construction, the contractor shall attend weekly progress meetings with BC Hydro's representative and the relevant key personnel on safety, construction progress issues and public impact remediation requirements.

2.5 Construction

2.5.1 General

1) The work described in the Contract Documents shall be carried out by a specialist contractor (including subcontractors) of recognized ability having experience in the supervision and execution of the work. All work shall be performed only by operators experienced in the use of the equipment chosen and under the direct control of knowledgeable, trained and skilled personnel experienced in conditions similar to those expected to be encountered during the course of execution of the specified work(s).
2) The contractor's activities shall be confined to the works area and access accepted by BC Hydro.
3) During the process of the work(s), the contractor shall assist BC Hydro's representative by providing suitable and safe access to effectively monitor site operations, equipment and processes.

2.5.2 Right-of-Way Requirements

The right-of-way configuration shown on the drawings form part of the Contract Documents. Both permanent and temporary working areas have been identified. The contractor is advised that all operations must be strictly confined to the specified works areas and additional areas he may have acquired at his cost.

2.5.3 Surveying

1) BC Hydro will stake or pin, once only, on ground surface, to establish sufficient control points to facilitate layout. It is the contractor's responsibility to ensure that these temporary markers are maintained, and for replacement of any of the stakes or pins disturbed by their construction operations. In the event that the contractor should disturb, deface, alter, destroy or remove any legal survey markers, BC Hydro will have markers replaced by a Registered Land Surveyor at the contractor's expense.

2) The contractor shall place and maintain their own benchmarks, survey monuments and other positioning aids as required for the duration of the work(s). The contractor shall be responsible for providing the necessary construction surveys required to complete work(s) required under these specifications.

2.5.4 Access to Site

1) Access to the works area shall be through existing public roadways and possibly through private properties.

2) Except as specifically noted in these specifications, uninterrupted vehicle traffic movement shall be maintained at all times on all public and private roads and private access points. Safe and adequate passage along existing public walkways or paths shall be maintained at all times and, should the project require temporary blockage or disruption to walkways or paths, signage and personnel shall be stationed to direct the public to alternative safe passage. The contractor shall identify within his work plan the proposed site preparation work, equipment and procedures to satisfy this requirement.

3) The contractor shall be responsible for all traffic control work in accordance with municipal requirements, and obtaining traffic control permits and notifying the municipal authorities and other affected parties as required.

4) When the project operations conflict with normal traffic, the contractor shall provide suitable detours. All detours shall be clearly marked to the satisfaction of the affected parties and BC Hydro's representative. The contractor shall furnish and maintain all necessary day and night warning signs, flares, lanterns, barricades and flagmen when working on or near roads, highways or traffic ways, to protect all persons from injury and property from damage, and to warn the drivers of vehicles of the obstruction.

2.5.5 Work Area Fencing

1) Unless otherwise specified, temporary fencing shall be erected around the entire perimeter of the works area. The fencing shall meet the following requirements:

   a) It shall be a minimum 2.4 m in height;

   b) It shall be securely anchored to the ground, and

   c) Fence panels shall be securely fastened together to form a continuous physical barrier between the works area and the surrounding private and public areas.

2) BC Hydro may elect to fix signage and posters to the fencing panels, including project information boards.

2.5.6 Site Restoration

Upon completion of the pipe installation, all debris, equipment and materials shall be removed from the works area(s), and the works area(s) shall be restored to its original condition or better, unless otherwise specified on the drawings. The restoration shall be to the satisfaction of BC Hydro and the owners of the works area(s) property.

2.6 Codes and Standards

In addition to all codes and standards referenced elsewhere in the Contract Documents, all materials and equipment supplied and work performed herein shall conform to the latest edition of the applicable industry codes, standards, references and recommended practices listed below. In case of conflict, the requirements of this Specification shall prevail.

1) API RP 5C1 Recommended Practice for Care and Use of Casing and Tubing.
2) API RP 52 Land Drilling Practice for Protection of the Environment.
3) API BULL 5C2 Bulletin on Performance Properties of Casing, Tubing and Drill Pipe.
4) BC Hydro Class of Work Specification (COWS) 1322 R8.

3.0 Horizontal Directional Drilling

3.1 Scope

1) The work(s) specified in this section includes installation of a duct or duct bundle across by Horizontal Directional Drilling (HDD). It also includes all associated works including site restoration, as shown on the Contract Drawings and as required under these specifications including, but not limited to grouting, mud pits backfilling and site restoration for projects with a bore diameter of up to 900 mm and drive length of 1000 m.
2) This specification shall be read in conjunction with Section 2, General Requirements.
3) The contractor shall furnish all labour, equipment, material and supplies and shall perform all works necessary to provide BC Hydro with completed installation of the duct/duct bundle.
4) The completed works shall conform to the profile and grade shown on the Contract Drawings. Deviations from the specified profile and grade shall not exceed the tolerances specified under the 3.5.3 Drilling Profile Tolerances clause in this Section.

3.2 Definition of Terms

The following definitions of terms shall have the meaning assigned to them except when the context otherwise requires:

Annulus: The space between the conductor casing and the outside diameter of the duct/duct bundle, or between the finished reamed hole and the duct/duct bundle.

Borehole: A hole created by mechanical excavation of soil/rock along the bore path.

Conductor Casing: A hollow steel casing installed at the entry and/or exit end(s) of the bore path, to facilitate directional drilling and installation of the duct/duct bundle, without being hindered by obstructions or unstable ground.

Duct: A hollow cylinder of polymer used to house electrical cables; also called pipe.

Duct Bundle: A bundle of ducts configured and formed to the satisfaction of BC Hydro and installed inside the borehole.

Drill String: A continuous length of pipe made by fusing different pipe sections.

Entry: The area where the drill rig is located and the drill string enters the ground.

Entry Angle: The angle between the drill stem and the ground surface at the surface entry or exit point.

Exit: The area where the drill string exits the ground.

Frac-out: An inadvertent release of drilling slurry outside the circumference of the bore path.

Horizontal Directional Drilling (HDD): a trenchless surface-launched method of installing pipes below ground, using a surface mounted drill rig that launches and installs a drill string at a shallow angle to the surface and has tracking and steering capabilities.

Obstructions: Boulders larger than 600 mm in maximum dimension encountered along the design bore path.

Slurry: A fluid, or mud, comprised of water and additives (bentonite and/or polymers) used in transporting the drill cuttings to the surface and stabilizing the borehole.

Thrust: The capacity of the drilling rig to push the drill string into the ground without rotating.

Torque: The capacity of the drilling rig to apply rotational force to the drill string.

Tracking System: Surveying tools used for tracking the position and orientation of the downhole cutting tool in X, Y and Z components.

3.3 Submittals

3.3.1 Submittal Requirements

The contractor shall provide the following for BC Hydro’s review within ten (10) calendar days of the award of the contract:

1) Complete methodology of the drilling and duct/duct bundle installation, including:
    a) equipment specifications and capabilities, including the thrust and torque capacity of the drill rig certified by the manufacturer;
    b) the size of the pilot hole;
    c) the number and size of the pre-reams;
    d) the pipe pull back force, with calculations;
    e) the type, accuracy and limitations of the downhole and surface surveying equipment, real time data recorders and their valid calibration certificate;
    f) the number of sections in which the duct/duct bundle is to be installed;
    g) sample daily data recorder forms showing drill pressure, torque and rates in terms of revolutions per minute, and drilling speed in inches/centimetres per minute;
    h) sample duct fusion forms;
    i) methods of minimizing and/or preventing gouging of the duct during handling and pull back;
    j) a quality control plan including methods of testing the quality of fusion of weld pipe joints and methods of verifying the capacities of the installed duct/duct bundle;
    k) the method of dealing with potential obstructions that may be encountered along the bore path, and
    l) the wall thickness, diameter and length of the conductor casings, should they be used.
2) A detailed schedule of work(s).
3) A drawing(s) showing the location and footprints of drill rigs, the service trailer, site lab, mud handling equipment and drilling slurry containment areas in the works area.
4) Details of noise mitigation measures.
5) A statement of whether partial or full closure of roadways (if any) is required during duct fusion and pull back; if necessary providing a traffic diversion plan, and stating its duration.
6) A slurry pumping, management and containment plan, including management of slurry spillage from Frac-out, recycling/transport and approved disposal site.
7) Emergency procedures for inadvertently boring into a live power line, natural gas line, water line, sewer line or fiber-optic cables. Procedures must comply with B.C. Regulations.
8) The method of disposal of excess water.

9) Duct manufacturer's data regarding tensile strength and recommended minimum bending radius.

10) A method of grouting the annulus.

11) A settlement monitoring plan.

12) An Environmental Management Plan (EMP)

3.3.2 Submittal Review

BC Hydro shall comment on the contractor's submittals within ten (10) working days after the date of receipt of the submittals. BC Hydro's review of the submittals shall not relieve the contractor of his duties and responsibilities as specified under the contract.

3.4 Products

3.4.1 Duct

1) The duct shall be made from polyethylene resin compound, with a minimum cell classification of PE 345464C for PE3408 material, or any other material accepted by BC Hydro.

2) The inside diameter of the duct shall not be less than as specified in the drawing.

3) The tensile strength of the duct, including all butt-fused joints, shall be a minimum of two times the theoretical maximum pull back force required to install the pipe.

4) The duct shall be free from visual defects such as foreign incisions, concentrated ridges, pittings, discoloration, varying wall thickness and other deformities.

3.4.2 Grout

The grout shall have a minimum 28 day compressive strength of 1 MPa. It shall be non-toxic, of low heat of hydration, of thermal resistivity not greater than 90 $^{\circ}$C-cm/W and meet the requirements of the B.C. Waste Management Act. The individual ducts in the duct bundle shall not displace from their designed position, deform or be damaged due to the heat of hydration generated by the grout.

3.5 Execution

3.5.1 Equipment

1) The contractor shall be responsible for the selection of the HDD rig and all other ancillary equipment(s) required to complete the work(s). The contractor shall confirm that the drilling rig and mud mixing system have the capacity required to successfully complete the installation.

2) The drilling rig shall be equipped with an electrical strike safety package. The package shall include a warning sound alarm, grounding mats and protective gear.

3) The contractor shall provide a drilling rig, mud pumps and screening tanks of adequate capacity, and Measurement While Drilling (MWD) survey tools and other necessary equipment to complete the installation, including survey data recorders, readout instrumentation and steering tools. The instruments must be able to provide data on the X,Y,Z axis on pilot hole location, drill pressure, torque, rpm and rate of progress of drilling/reaming activity in real time, at all times. All measuring equipment shall have valid calibration documentation.

4) The operating range and degree of accuracy of the proposed tracking system shall be adequate to meet project conditions. Tracking/steering equipment shall allow for continuous monitoring of the drilling head along the entire proposed alignment. If the signals from the drill head to the ground are expected to be weak at some sections of the route (a poor contact with the ground), this should be communicated to BC Hydro prior to commencement of construction.

5) The contractor shall provide duct fusion equipment, adequate pipe support rollers, cradles, side booms and cranes for the product line during pull back of the duct/duct bundle. The rollers, cradles and side booms shall be of a type that will prevent damage to the duct/duct bundle, and will be of sufficient number to prevent over-stressing of the duct/duct bundle due to sag bends during the pull back.

3.5.2 Installation

1) The contactor shall locate all subsurface utilities along and on either side of the proposed drill path and notify the utility owners of the impending work.

2) The contractor shall prepare the site, including the conduct of dewatering if necessary, mobilize the drilling equipment, design and construct the drill anchor system as necessary, erect the drill rig and, if directed by BC Hydro, install noise control system on both entry and exit sides.

3) The contractor shall set up a temporary site laboratory to facilitate testing of slurry characteristics such as viscosity, flowability, gel strength and density. The contractor shall also provide access to the site laboratory to BC Hydro and its representatives.

4) The contractor shall install conductor casings if required.

5) The contractor shall drill the pilot hole and ream the hole to sufficient size to install the duct/duct bundle. During drilling of the pilot hole, the contractor shall track the orientation of the hole in real time as the drilling progresses and report progress to BC Hydro at the end of each day’s shift. The real time survey data of the orientation of the drill hole on the X,Y,Z axis shall be provided to BC Hydro at the end of each day’s shift. Only trained operators

shall be permitted to operate the drilling equipment in accordance with the manufacturer's operating instructions and safety practices.

6) If directed by BC Hydro, the contractor shall verify the accuracy of the MWD Tracking System by using a ground survey grid system such as by Tru-Tracker or equivalent.

7) If a borehole must be abandoned, the hole shall be grouted as directed by BC Hydro at the contractor's expense.

8) Suitable non-toxic slurry shall be used to support the drilled/reamed borehole.

9) The drilling/reaming shall be carried out such that the possibility of frac-out is minimal. The contractor is responsible for dealing with any environmental and other consequences arising from frac-out and shall provide a frac-out contingency plan to BC Hydro for review and approval.

10) Ground heaving shall not be caused by reaming or duct/duct bundle installation.

11) Duct/duct bundle installation shall be performed in a manner that minimizes the stressing and straining of the pipe in excess of the limits specified by the manufacturer, and in excess of the allowable stress recommended in the design, whichever is less.

12) Depending on the conditions at the site and the design of the bore path, if required, pipe rollers, skates or other protective devices shall be used during duct/duct bundle handling on the ground and their pull-back, to protect the duct/duct bundle from damage.

13) Following successful installation of the duct/duct bundle, the slurry in the annulus shall be completely replaced with low thermal resistivity and low heat-of-hydration cementitious grout, unless otherwise directed by BC Hydro. The duct/duct bundle must not be disturbed or damaged, including due to heat of hydration, during grouting or execution of any works associated with grouting.

14) Copies of daily bore path profile measurement records in an easy readable format shall be submitted to BC Hydro at the end of every day's work shift.

15) The installed duct/duct bundle shall be mandrel-tested to BC Hydro Standards.

16) As-Built Drawings shall be constructed from actual field records.

3.5.3 Drilling Profile Tolerances

1) The centre of the completed reamed borehole shall be no more than +/- 1.0 m of the centreline of the design alignment and profile.

2) The off-set of the completed borepath shall nowhere be more than 1.0 m from the design vertical and horizontal alignment. The radius of any unintended curvature along the bore path shall not be less than 1200 times the outside diameter of the drill rod.

3.5.4 Slurry Collection and Disposal

1) The contractor is responsible for disposing of excess slurry in an approved site.
2) When working in an area of contaminated ground, the slurry shall be tested for contamination and disposed of in a manner which meets the B.C. Waste Management Act.
3) All necessary precautions shall be taken to prevent drilling slurry from entering roadways, manholes, sanitary and storm sewers, and other drainage systems, including streams and rivers.
4) Recycling drilling slurry will be acceptable if appropriate screening processes are incorporated to prevent clogging of the drilled hole or the mud injection system.
5) The contractor shall make all diligent efforts to minimize the amount of drilling slurry and cuttings spilled during the drilling operation, and shall provide complete clean-up of all slurry overflows or spills.

3.5.5 Pipe/Duct Joining

1) The duct/duct bundle shall be assembled and joined within the works area.
2) Duct fusion shall be accomplished using the butt-fusion method by qualified fusion technicians in strict conformance with the pipe manufacturer's specifications.
3) The duct joints shall have a smooth, uniform, double rolled-back bead made while supplying the proper melt, pressure and alignment. If directed by BC Hydro, the internal beads shall be removed so that the inside surface of the joints is clear and smooth. All joints shall be made available for inspection by BC Hydro before pipe pull back.
4) All duct fusion welded joints shall be X-rayed. Any defective joints will be rejected. The contractor shall re-do any rejected joints at their own expense.

3.6 Acceptance

Any borehole and installed duct/duct bundles which do not comply with the following requirements will be rejected:

1) The alignment and grade tolerances specified in 3.5.3.
2) Successful mandrel test specified in clause 3.5.2.15.
3) Providing BC Hydro with a set of As-Built Drawings showing the duct/duct bundle alignment, profile and inverts. The Drawings shall be constructed from actual field records. All As-Built Drawings should be signed and sealed by a Professional Engineer.

4.0 Jack and Bore

4.1 Scope

1) The work specified in this section includes:
   a) Installation of a steel casing for projects with a bore diameter of up to 1000 mm and drive length of less than 100 m by tunnelling, with the Jack and Bore Method or any other method accepted by BC Hydro.
   b) Installation of a duct/duct bundle as shown on the Drawings and grouting of the annulus between the casing and the duct/duct bundle.
   c) All associated works including backfilling the shafts and site restoration as shown on the Drawings and as required under the specifications.
2) The contractor shall furnish all labour, equipment, material and supplies, and shall perform all works necessary to provide BC Hydro with completed installation of the duct/duct bundle and appurtenances.
3) This specification shall be read in conjunction with Section 2, General Requirements.

4.2 Definition of Terms

In this section of the specification, the following words and expressions shall have the meaning hereby assigned to them, except when the context otherwise requires:

Advance Length: The length of tunnel in each excavation and support cycle.

Casing: A pipe installed as an internal protection to the product pipe(s)/duct(s)/ duct bundle and/or as a protection to a tunnel.

Duct Bundle: A bundle of ducts configured and formed to the satisfaction of BC Hydro and installed inside the primary support of the tunnel.

Drive Length: The continuous length of a tunnel between two consecutive shafts.

Entrance Ring: A ring constructed opposite a thrust wall to guide and align trenchless tunnelling equipment into the ground to be tunnelled.

Entry Shaft: A vertical or sloped excavation constructed to launch the tunnelling equipment.

Exit Shaft: A vertical or sloped excavation constructed to receive the tunnelling equipment.

Face: The undisturbed soil immediately in front of the cutting head of the tunnel excavating equipment.

Full Face Control: Complete support of the excavated face at all times.

Inner Annulus: The void between the inside walls of the casing and the duct bundle.

Jack and Bore: A technique of tunnel excavation by horizontal auger boring and installing primary support to the tunnel by jacking a casing from the entry shaft. Alternative methods of tunnel excavation may be used.

Jacking Shaft(s): Vertical or sloped excavation(s) constructed to set up equipment at the beginning of a tunnel drive. This includes hydraulic jacks, thrust wall(s) and entrance ring(s).

Outer Annulus: The over-cut.

Over-cut: The difference between the diameter of the cutting head of the tunnelling equipment and the casing.

Primary Support: A support system selected by the contractor to support the tunnel excavation. This can be steel casing(s), or segmental concrete pipes, or steel liner plates, or cylindrical pipes of any other material.

Reception Shaft(s): A vertical or sloped excavation constructed to receive the tunnelling equipment.

Rescue Shaft(s): A vertical or sloped walled shaft constructed to rescue a stalled cutting head.

Shaft(s): A generic word to describe all shafts: jacking shaft, reception shaft and rescue shaft.

Thrust Wall: A structure designed to distribute the loads from jacking into the adjacent soil.

Tunneller: Tunnel excavating equipment.

4.3 Submittals

Unless otherwise specified, within ten (10) working days after the award of the contract, the contractor shall submit the following for BC Hydro's review.

4.3.1 Drawings

1) Completed drawings and written descriptions identifying details of the proposed methods of construction and the sequence of operations to be performed during construction. The drawing and descriptions shall be sufficiently detailed to demonstrate to BC Hydro that the proposed material and procedures will meet the requirements of this section.
2) All drawings shall be legible, in English, with dimensions in metric units.

4.3.2 Environmental Management Plan

An Environmental Management Plan (EMP)

4.3.3 Settlement Monitoring Plan

A detailed settlement monitoring plan.

4.3.4 Shafts

1) The design of shafts including thrust walls and floor slab. Unless otherwise agreed by BC Hydro, the shafts and the thrust walls shall be designed by a Professional Engineer registered in the Province of British Columbia and the construction drawings shall be signed and sealed by the designer. The thrust wall shall be designed to a Factor of Safety of 3 on the estimated thrust. The estimated maximum working load on the thrust wall and the basis of this estimation shall be shown on the drawings or provided separately. The design shall comply with the requirements of WorkSafe BC.
2) A plan showing the location and shape of the shafts.
3) The detailed method of construction of the shafts including: description of equipment to be used; method of installing the excavation support system; method of dewatering; method of spoils disposal from the excavation, and backfilling of the shafts.
4) A plan showing the extent of the work area(s) required for the tunnelling operation, including the spoil storage area required.

4.3.5 Tunnelling

The submittals shall include:

1) A dewatering plan, including the location of the drawdown monitoring wells (piezometers).
2) The arrangement drawings and technical specifications of the tunneller and trailing equipment (including any modifications).
3) The magnitude of over-cut proposed.
4) The method of controlling line and grade of the tunnelling operation.
5) The number of personnel permitted in the tunnel at one time.
6) The tunnel ventilation plan.
7) The tunnel rescue plan.
8) The schedule of tunnelling work, including shaft excavation, and casing guide rail or jacking frame setup. The tunneller setup, launch, exit and removal for each drive length.
9) The method and details of spoil removal. This includes: equipment type, surface storage, processing and disposal; calculations for volume of soil removed per metre of installed casing, and the spoil disposal location.
10) The proposed contingency plans for critical phases of the tunnelling including:
    a) Dealing with a strong hydrocarbon-like smell detected in the spoils from excavation;

b) Dealing with buried debris or a boulder of such size or type that the cutting head cannot break or bore through, and

c) Maintaining the target laser if it is distorted by heat and/or humidity, or has been knocked out of alignment.

11) The grouting techniques to be used for over-cut, if any, including grouting equipment, pumping and injection procedures, pressure grout types and mixtures.

12) The details of the jacking method, including jack setup, and jack thrust reaction bearing installation.

13) The details of the method proposed to cushion and distribute jacking forces at casing joints to prevent damage.

14) The estimated jacking loads.

15) The type of pressure/load measuring devices to be used for jacking, and their calibration certificate valid to the date of proposed completion of the jacking works.

16) The contingency plan if the casing is damaged.

17) The lubrication system, including calculations for volume of lubrication to be used per metre of casing and type of lubrication materials to be employed.

18) Any geotechnical investigations performed by the contractor as relevant to tunnelling.

19) The quality control methods proposed for the tunnelling operation. The submittal shall include supervisory control to ensure that work is performed in accordance with the Contract Documents.

20) An estimate of maximum deformation (settlement/heave) of the thrust wall and the ground immediately behind it during excavation of the tunnel and jacking of the casing.

21) The method of fabrication of the duct/duct bundle and its installation inside the casing.

22) The method of grouting the annulus.

23) A cross section showing the duct/duct bundle and the grout inside the casing.

4.3.6 Duct/Duct Bundle Fabrication

1) Sample duct fusion forms

2) Method of minimizing and/or preventing gouging of the duct during handling and pull back.

3) A Quality Control Plan including methods of testing the quality of fusion of weld pipe joints and methods of verifying the capacity of the installed duct/duct bundle.

4.3.7 Grouting of the Overcuts and Annulus

The method of grouting the overcut and the inner annulus shall be submitted a minimum of 5 working days before the scheduled day of commencement of such works. The submission shall include a description of the method of grouting with details such as venting, detailed grout mix design and maximum grout pressure to be applied.

4.3.8 Submittal Review

BC Hydro will comment on the contractor's submittals within ten working days after the date of receipt. Excavation shall not commence before BC Hydro's review of the contractor's submittals. BC Hydro's review of the submittals does not relieve the contractor of his duties and responsibilities specified under these specifications.

4.4 Products

4.4.1 Casing

The casing shall be made of mild steel and shall be capable of withstanding the jacking forces and the live and dead loads it will be subjected to during its service life.

4.4.2 Duct

1) The duct shall be made from polyethylene resin compound, with a minimum cell classification of PE 345464C for PE3408 material, or any other material accepted by BC Hydro.
2) The inside diameter of the duct shall be as per the drawings.
3) The tensile strength of the duct, including all butt-fused joints, shall be a minimum of two times the theoretical maximum stress it will be subjected to during its installation and grouting of the inner annulus.
4) The duct shall be free from visual defects such as foreign incisions, concentrated ridges, pittings, discoloration, varying wall thickness and other deformities.
5) The duct bundle shall be formed as shown on the drawing(s).

4.4.3 Grout

1) The grout shall have a minimum 28 day compressive strength of not less than 1 MPa. It shall be non-toxic and meet the requirements of the B.C. Waste Management Act.

2) The thermal resistivity of the grout shall not be greater than 90 °C-cm/W and meet the requirements of the B.C. Waste Management Act.

3) The individual ducts in the duct bundle shall not displace from their designed position, deform or be damaged due to the heat of hydration generated by the grout.

4.5 Construction

4.5.1 Shafts

1) The location of the jacking and reception shafts shall be as shown on the Drawings.

2) The contractor shall provide all labour, material and equipment required to construct, operate and maintain the shafts, and shall comply with the following requirements in addition to all the other requirements of the specifications:

   a) Conducting suitable dewatering to maintain the stability of the shaft(s).

   b) Installing a minimum of one piezometer to monitor the groundwater drawdown. The location of the piezometer and its design shall be accepted by BC Hydro. The piezometer shall be monitored a minimum of two times every day and the monitoring results submitted to BC Hydro for review.

   c) Constructing and maintaining all cofferdams, drains, sumps, separators, temporary diversion and protective works, and furnishing, installing, maintaining and operating all necessary pumping and other equipment for dewatering the various parts of the shaft(s), regardless of the source of water. Specifically, the shaft(s) and all equipment in it shall be protected from any flooding due to surface runoff from the ground level or due to groundwater inflow. Any adverse effect on the stability of the shaft(s) or damage to material and equipment inside the shaft(s) shall be the responsibility of the contractor. BC Hydro will not compensate the contractor for costs incurred from any flooding.

   d) Fencing all shafts with chain link fencing to provide safety to the public.

   e) Should blasting be required during excavation, exercising extreme care, and limiting the use of explosives to such charges that will not cause damage to persons, structures, railway tracks, pipe lines and other utilities. Blasting shall be conducted by personnel accustomed to, and qualified and licensed for, the work.

   f) The compliance with all regulations regarding the use and storage of explosives shall be the responsibility of the contractor, and they shall be responsible, and receive no payment, for any accidents, loss or damage which may occur through the blasting.

g) Processing of the spoil from excavation to meet the B.C. Waste Management Act, and disposal of the spoil.

h) No gasoline-powered equipment shall be permitted in the shaft(s). Diesel, electrical or air-powered equipment will be acceptable, subject to applicable federal and provincial regulations.

4.5.2 Ground Movement

Ground movement in the form of settlement or heave may occur during dewatering, shaft(s) and tunnel excavation. The contractor shall:

1) Monitor the settlement/heave of the ground in the vicinity of the shaft(s) at locations and a frequency determined by BC Hydro.

2) Monitor the settlement/heave of the ground directly above the tunnel and its vicinity at locations and a frequency determined by BC Hydro.

3) The monitoring shall be to an accuracy of $\pm$ 2mm.

4) Inform BC Hydro if the cumulative settlement/heave at any location is greater than specified in the permits or 12 mm, whichever is less.

4.5.3 Tunneller

1) The tunneller, including the jacking system, shall be suitable to install the casing as required by these specifications.

2) The tunneller shall meet the following requirements:

a) Be capable of handling the various anticipated ground conditions identified in the Geotechnical Factual Report and other possible variations;

b) Be capable of maintaining the tunnel face under wet, moist and dry and adverse soil conditions, and preventing loss of ground through the machine. Shall provide satisfactory support to the excavated face at all times;

c) Have provisions to protect electric or hydraulic motors and operating controls against water inflows to prevent potential hazards and failure of equipment, and

d) Be capable of correcting tunnel grade as and when necessary.

4.5.4 Jacking Equipment

1) The equipment used to push the tunneller and the casing forward shall meet the following requirements:

a) Have the primary jacks mounted in a jacking frame located in the jacking shaft;

b) Have a jacking frame which successively pushes the tunneller along with a string of connected casing towards a receiving shaft;

c) Have sufficient jacking capacity to push the tunneller and the casing through the ground for the length specified;

d) Have hydraulic cylinder extension rates which are synchronized with the excavation rate of the tunneller, as determined by the soil conditions;

e) Have suitable arrangements to develop a uniform distribution of jacking forces on the end of the casing by use of spreader rings and packing, and

f) Provide and maintain a casing lubrication system at all times to lower the frictional forces developed on the casing surface during the jacking process.

4.5.5 Tunnelling/Jacking the Casing

1) The contractor shall furnish all items including, but not limited to: the tunnelling equipment; spoil transportation systems; spoil processing, if required; transportation required to haul the spoil from the work area(s); hoists; signal systems; safety equipment; survey controls, and the lubrication system necessary to excavate and advance the tunnel and install the casing and duct/duct bundle by the method accepted by BC Hydro.

2) The contractor shall be responsible for the means and methods of the tunnelling and jacking operations, including the design and installation of intermediate jacking stations, and shall ensure the safety of the work and the contractor's employees, the public and adjacent property, whether public or private.

3) The contractor shall maintain clean working conditions inside the jacking/reception shaft(s), and remove all spoil, debris, equipment and other material not required for the operation.

4) The contractor shall dispose of all excavated materials, including the slurry used for lubrication, only after pre-treatment if so required to meet the B.C. Waste Management Act. The disposal shall be carried out in authorized disposal sites arranged by the contractor.

5) The casing shall be jacked in a manner that will provide square and watertight joints, and maintain the specified line and grades within the acceptable tolerances.

6) The tunnelling operations shall not cause ground settlement or heave in excess of 12 mm, or any other smaller amount as specified in the permit issued by the owner. The completed casing shall have full bearing against the earth; no voids or pockets shall be left in any portion of the work. If loss of ground occurs, the resulting void shall be filled with suitable material, such as grout, as accepted by BC Hydro.

7) All excavation below the groundwater table shall incorporate provisions to deal with cohensionless soils, even if such soils are not indicated on the Geotechnical Factual Report.

4.5.6 Jacking Operation Data

The contractor shall record and provide BC Hydro with copies of the following:

1) A record of construction events and observations.
2) The location of the tunnelling equipment face by station and progress of the tunnel drive during shift. Hours worked per shift.
3) Completed field forms for checking line and grade, with achieved tolerance relative to design alignment.
4) Jacking load records completed in the prescribed form.
5) Amount of casing lubrication pumped per metre of casing and the cumulative total. The records shall record any slurry losses or other unusual occurrences.
6) The amount of spoil removed per metre of casing and the cumulative total.
7) Groundwater control operations and piezometric levels.
8) Observations of lost ground or other ground movement.
9) Indications of damaged casing joints and proposed corrective action.
10) Operation shut-down periods or other interruptions in the work, with explanations.
11) Jacking loads at the end of shifts versus first loads on the following day.
12) Maximum deformation of the thrust wall and the ground adjacent to it, monitored a minimum of four times in a 10 hour day, at a minimum of three locations. BC Hydro may stop the jacking should the deformation exceed the limits of acceptable deformation of the thrust wall/ground. The capacity of the thrust wall shall be enhanced at the contractor's cost to prevent its out-of-tolerance deformation.

4.5.7 Control of Line and Grade

1) The contractor shall establish, and be responsible for, the accuracy of control for the construction of the tunnelling operation, including access shaft locations, structures, excavation and casings. Control points shall be established at a sufficient distance from the tunnel operation as to not be affected by ground movement.
2) The contractor shall check baseline and benchmarks provided by BC Hydro at the beginning of the work, and report any errors or discrepancies to BC Hydro.

3) The contractor shall use the baseline and benchmarks established by BC Hydro to furnish and maintain reference control lines and grades for the casing installation. These lines and grades shall be used to establish the exact location of the tunnel face and installed length of casing.

4) The contractor shall maintain records of initial setup.

5) The contractor shall record the exact position of the tunneller cutting head at 10 metre intervals, or a minimum of once per shift, to ensure that the alignment is within tolerances, and maintain daily surveying records of alignment and grade. One copy of these records shall be submitted to BC Hydro within 24 hours of the operation. The contractor, however, remains fully responsible for the accuracy of the work and the correction of it, as required.

6) The contractor shall check the primary control for the tunneller against an above-ground undisturbed reference at least once per week and once for each 15 metres of tunnel constructed, or more as needed or directed by BC Hydro.

7) The contractor shall perform a verification survey of the installed casing from jacking shaft to reception shaft after removal of the tunneller, and document measured conformance to design line and grade of the duct/duct bundle, together with locations and deviation (distance and direction) of any out-of-tolerance locations.

4.5.8 Duct Bundle Fabrication and Pull Back

1) The duct bundle shall be assemble and joined within the works area.

2) Duct fusion shall be accomplished using the butt-fusion method by a qualified fusion technician in strict conformance with the pipe manufacturer's specifications.

3) The duct joint shall have a smooth, uniform, double rolled-back bead made while supplying the proper melt, pressure and alignment. If directed by BC Hydro, the internal beads shall be removed so that the inside surface of the joints is clear and smooth. All joints shall be made available for inspection by BC Hydro before pipe pull back.

4) All duct fusion welded joints shall be X-rayed. Any defective joints will be rejected. The contractor shall re-do any rejected joints at their own expense.

5) The duct/duct bundle installation shall be performed in a manner that minimizes the stressing and straining of the pipe in excess of the limits specified by the manufacturer, and in excess of the allowable stress recommended in the design, whichever is less.

6) Depending on the conditions at the site and if required, pipe rollers, skates or other protective devices shall be used during duct/duct bundle handling

on the ground and their pull-back, to protect the duct/duct bundle from damage.

4.5.9 Grouting

1) The contractor shall fill voids in the outer annulus, should the over-cut be greater than 19 mm, and any other void created by ground loss, to the satisfaction of BC Hydro.
2) The contractor shall fill the inner annulus using a grout accepted by BC Hydro.
3) The contractor shall be responsible for placing the grout such that no voids are left in the annular space and the integrity of the casing and the duct/duct bundle is maintained at all times throughout this operation.
4) The contractor shall continuously monitor and record the grouting pressure applied during the injection of the grout and the volume of grout used. This record shall be submitted to BC Hydro at the end of the grouting operation.
5) The thermal resistivity of the grout to be used for filling the inner annulus shall be proven by testing grout mix samples. The test results shall be provided to BC Hydro.

4.5.10 Mandrel Testing

1) The installed duct/duct bundle shall be mandrel-tested to BC Hydro Standards.

4.5.11 Casing Alignment and Profile Tolerances

1) The casing shall be installed to the line and grade as specified in the Drawings. The deviation from the specified line shall not be more than 300 mm left or right of the design centreline of the casing.
2) The casing shall have an overall gradient as shown on the Drawings. Its invert shall not vary from the design invert by more than 100 mm anywhere along the line.

4.5.12 Backfilling

1) Shafts that will not be utilized for chamber or manhole construction shall be backfilled following the completion of the duct/duct bundle installation. The backfill shall be placed as per COWS 1322 R8.
2) Should the contractor decide to remove the shaft(s) excavation support system prior to, during or upon completion of backfilling, it shall be carried out in a way that will not compromise the stability of the shaft(s) walls or disturb the duct/duct bundle that has been installed. BC Hydro will not compensate the contractor for the withdrawal of the excavation support system.

3) End tipping of the backfill material from the edge of a shaft will not be permitted.

4) Rescue shafts shall be backfilled no later than seven (7) days following the reinstatement of the tunnelling process.

4.6 Acceptance

Acceptance is based on successfully completing the entire defined work. Successful completion includes: the casing; duct/duct bundle; successfully completing the mandrel testing and pressure testing of the pipe; installing all connector couplings on the end of the casing pipe; backfilling, and acceptable site restoration. Installations which do not comply with the following requirements will be rejected:

1. The borepath and reamed borehole must meet the alignment and grade tolerances specified in 4.5.11
2. The mandrel test must be successfully completed.
3. BC Hydro must be provided with a set of As-Built Drawings showing the duct/duct bundle alignment, profile and inverts. The Drawings shall be constructed from actual field records. All As-Built Drawings should be signed and sealed by a Professional Engineer.