CIVIL AND STRUCTURAL

MICROTUNNELLING AND PIPEJACKING SPECIFICATION FOR NON-PRESSURE PIPELINES

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The purpose of this document is to provide general requirements for microtunnelling and pipejacking for non-pressure pipelines.

The methodologies listed in this document may not be applicable for all sites. Other methodologies, not described in this document, may also be more appropriate for different sites. It shall be the Designer and/or the Contractor's responsibility to select appropriate methodologies, on a case-by-case basis, as required.

More information

If you have further queries, please contact the Asset Lifecycle team at standards@water.co.nz

DOCUMENT CONTROL

Document owner	Principal Asset Lifecycle Engineer (Standards)
Contributors	Jacobs (Engineering Consultants), Stephen Grace

Version history

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1.0	First release	W Strydom	13/10/2025

This document takes effect on the date of release and supersedes all prior versions.

Contents

1 General

1.1 Introduction

1.1.1 This Performance Specification includes the minimum requirements for the microtunnelling and pipejacking for non-pressure pipelines. Methods of installation covered under these requirements include the following:

a) Microtunnelling, using all types of MTBM equipment

b) Mechanised pipejacking, using all types of MTBM/TBM equipment, boring equipment

c) Pipejacking by excavation within a shield or cutting shoe, e.g. by hand operated tools, excavators, mechanical back actor, backhoes, cutter boom or similar.

1.1.2 These requirements apply only to the installation of pipelines to be used for non-pressure flow applications and are not applicable to pressure pipe applications.

1.1.3 These requirements do not apply to the design and installation of combined casing and carrier pipes, whereby carrier pipes are installed within a jacked casing pipe.

1.1.4 These requirements are not applicable to 'Direct Pipe' and similar proprietary systems.

1.1.5 These requirements do not apply to non-jacked installation of pipelines using other trenchless systems, such as Horizontal Directional Drilling (HDD).

1.2 Definitions and Acronyms

1.2.1 All of the definitions in the Contractor's contract documents shall apply, plus the following:

- **Interjack pipes:** Two specially designed pipes used with the intermediate jacking station.
- **Intermediate Jacking Station (IJS):** A fabricated steel shield incorporating hydraulic jacks designed to operate between interjack pipes to provide I thrust load as necessary.
- **Jacking pipe:** A pipe designed specifically for jacking and incorporating a flexible joint.
- **Jacking shield:** A fabricated steel cylinder from within which the excavation is carried out either by hand or machine. Incorporated within the shield are facilities to allow the shield to be adjusted to control line and level.
- **Launch/thrust/jacking pit:** A working shaft at the beginning of the jacked section of pipeline, in which the jacking equipment is installed, and from which the jacking operations are carried out. Note, the words 'pit' and 'shaft' are used interchangeably within the specification
- **Lubrication:** Injection of a fluid such as bentonite to reduce pipe friction whilst jacking.
- **Packing:** Material placed within pipe joints to distribute the jacking load.
- **Reception pit:** A shaft at the end of the jacked section of the pipeline from which the jacking shield is recovered.
- **Thrust/reaction wall/pad:** Normally a wall within the thrust pit, generally in reinforced concrete, designed to spread the reaction loads to the ground adjacent to the thrust pit.

- **Thrust ring:** A steel ring that is placed against the cross sectional area of the concrete pipe to ensure that the jacking forces are spread around its circumference.

1.2.2 The acronyms listed in Table 1.1 are used herein:

Table 1.1: Acronyms

Acronym	Definition
ECBF	East Coast Bays Formation; a geological material (weak rock) commonly found in the Auckland area.
EPBM	Earth Pressure Balance Machine
GBR	Geotechnical Baseline Report
GFR	Geotechnical Factual Report
GIR	Geotechnical Interpretive Report
GRP (FRP)	Glass Reinforced Plastic (Fibreglass Reinforced Plastic)
HSW	Health, Safety and Welfare
HSWA	Health and Safety at Work Act (2015)
HSWMP	Health, Safety and Wellness Management Plan
MOQO	Health and Safety at Work (Mining Operations and Quarrying Operations) Regulations (2016); and subsequent amendments
MTBM	Microtunnel Boring Machine; this term is generally used in relation to slurry systems or other systems which do not involve routine personnel entry, e.g. small diameter systems such as auger boring.
OPC	Ordinary Portland Cement
PE	Polyethylene
TBM	Tunnel Boring Machine
WSL	Watercare Services Ltd
CPL	Corrosion Protection Lining
MIC	Microbial Induced Corrosion

1.3 Relationship to Watercare Standard Documents

1.3.1 This specification details the design and construction requirements for sections of pipeline installed using pipe jacking and microtunnelling techniques. It should be read in conjunction with Watercare's General Civil Construction Standard. However, where there is any conflict this Performance Specification will take precedence.

1.3.2 Where the Principal's Specifications state the minimum level of materials standard this is provided as a guide and in no way relieves the Contractor from meeting the fitness-for-purpose, durability, and Design Life requirements of the Contract.

1.4 List of Applicable Standards, Codes, Guidelines, Regulations

1.4.1 The following table lists the applicable Standards, Codes, Guidelines, Regulations and similar documents relevant to this section of the Principal's Requirements. The latest edition of these standards/codes/guidelines/regulations shall be used during design and construction.

Table 1.2: Standards, codes, guidelines, and regulations.

Reference	Document Title
BS 6164	Health and safety in tunnelling in the construction industry – Code of practice
NZTS	Small Diameter Tunnels and Pipejacks; A Reference Guide for New Zealand
BTS	Specification for Tunnelling, 3rd Edition (joint publication of BTS and ICE)
ITA-AITES	A code of practice for risk management in tunnel works; International Tunnelling and Underground Space Association (ITA-AITES) International Association of Engineering Insurers (IMIA)
DWA-A 125E	Pipe Jacking and Related Techniques
AS/NZS 3725	Design for installation of Buried Concrete Pipes.
AS/NZS 4058	Precast Concrete Pipes (pressure and non-pressure).
NZS 3104	Specification for concrete production
NZS 3111	Methods of test for water and aggregate for concrete
NZS 3112	Methods of test for concrete
AS 3571	Plastics piping systems – Glass-reinforced thermoplastics (GRP) systems based on unsaturated polyester (UP) resin
NZS 4402	Methods of testing soils for civil engineering purposes
BS 5911:1	Concrete pipes and ancillary concrete products; Part 1: Specification for unreinforced and reinforced concrete pipes (including jacking pipes) and fittings with flexible joints (complementary to BS EN 1916:2002)
Concrete Pipe Association of Australasia	Pipe Jacking Design Guidelines.
Concrete Pipe Association of Australasia	Technical Brief Concrete Pipe Jacking
HSWA (2015)	Health and Safety at Work Act 2015
MOQO (2016)	Health and Safety at Work (Mining Operations and Quarrying Operations) Regulations (2016); and subsequent amendments

Reference	Document Title
Mines Rescue Act 2013	Mines Rescue Act 2013 ((Public act 2013 No 96) New Zealand Government)
Mines Rescue (Levy) Regulations 2014	Mines Rescue Regulations including Levy Structure
MBIE (2013)	Safe Mines: Safe Workers, Nov. 2013 (Ministry of Business, Innovation & Employment Nov. 2013)
WorkSafe	Approved Code of Practice and Guidelines that are applicable to tunnelling and micro tunnelling (WorkSafe New Zealand)
MinEx (2017)	A Guide to Worker Health in Extractives
DIN 18319	German construction contract procedures (VOB) - Part C: General technical specifications in construction contracts (ATV) - Trenchless pipelaying
ISO 25780	lastics piping systems for pressure and non-pressure water supply, irrigation, drainage or sewerage — Glass-reinforced thermosetting plastics (GRP) systems based on unsaturated polyester (UP) resin — Pipes with flexible joints intended to be installed using jacking techniques
BS EN 1916	Concrete pipes and fittings, unreinforced, steel fibre and reinforced

1.4.2 These requirements shall be read and applied in conjunction with the national and international standards listed. Where there is a conflict between referenced standards, local standards shall take precedence.

1.4.3 This section makes reference to various legisaltion, codes and standards to which the work is to conform. In all cases, the standards referred to are the latest editions including all current amendments.

2 Microtunnelling and Pipejacking - General

2.1.1 The Contractor is responsible for selecting the method of microtunnelling or pipejacking, to suit the anticipated ground and groundwater conditions, and to manage settlement and ground movements to acceptable levels and consent requirements. The Principal shall provide pipe size requirements to the Contractor. This Specification shall be used for microtunneling and pipejacking typically in the range of DN200 to DN3000 pipe diameter, dependent on construction methodology.

2.1.2 The Contractor is responsible for all design of the temporary and permanent works associated with microtunnelling and pipejacking, including as follows

a) All temporary pits and structures required to install the jacked pipeline.

b) All other temporary works including equipment, supports, foundations and similar to support the Contractor's microtunnelling and pipejacking activities.

c) Design of the permanent pipes and pipelines, subject to the Project's Requirements. This includes design of all special pipes, whether temporary or permanent, to be used in the microtunnelling and pipejacking installation.

2.1.3 In selecting and developing its methods, the Contractor shall consider the following:

a) The available geotechnical and site investigation data and reports; including the Contractor's GIRs (refer Section 1).

b) NZTS (2017)

c) PJA (1995)

d) ITA-AITES (2023)

e) As a minimum, the Contractor shall conduct its investigations, design, and construction in accordance with ITA-AITES (2023).

2.1.4 Geotechnical Information

2.1.5 The Geotechnical Baseline Report (GBR-A) and the Principal's Geotechnical Factual Reports (GFRs) shall be obtained during project development.

2.1.6 The project requirements may state that the Contractor is responsible for preparing its own Geotechnical Interpretive Report (GIR), and its Geotechnical Baseline Report (GBR-B) during the bid/pricing phase. Following Contract negotiation and agreement, the GBR-B is superseded by the GBR-C, which establishes the baselines to be used in the Contract.

a) It is noted that the GBRs are risk allocation documents, not design documents.

b) Where the Contractor deems the geotechnical information provided by the Principal to be insufficient, it is the responsibility of the Contractor to undertake additional geotechnical investigation to supplement the information provided in the GFR. Such additional GFRs shall be submitted to the Engineer for information within two (2) months of completion of the investigations.

2.1.7 The Contractor shall update and finalise its GIR following any additional investigations which it undertakes and submit to the Engineer for review and approval within two (2) months of commencement.

3 Design Requirements

3.1 Pipes

3.1.1 Pipes shall comply with the WSL Material Supply Standard. Pipe materials for pipe jacking installation shall be reinforced concrete complying with EN1916; or GRP complying with ISO 25780. Also refer to DIN 18319 for general pipe packing requirements. The Contractor may propose the use of pipes other than OPC reinforced concrete or GRP, if the parameters of the alternative pipe material can be shown to meet or exceed the properties of reinforced concrete jacking pipe. Embedded mechanically anchored PE membranes in OPC pipes are acceptable, subject to Engineer's approval of material and demonstration that the solution achieves the stipulated Design Life. PE membranes shall demonstrate compliance with the Projects material requirements. The performance specification for PE membranes shall be developed as part of the Project Specification.

3.1.2 Pipe and fitting material tolerances are to comply with the relevant specifications, codes and standards listed in Sections 1.3 and 1.4 above.

3.1.3 Unless otherwise approved by the Engineer, all jacking pipes shall be of the butt jointed type, having a collar (in an appropriate grade of steel, or GRP, details of which shall be confirmed by the Contractor) on the female face which also functions as the sealing face for rubber ring gaskets installed on the male face.

3.1.4 Other jacking pipe designs may be permitted by exception by the Engineer, subject to its approval of the relevant design report.

3.1.5 All female faces shall be covered over using Medium Density Fibreboard (MDF) or similar packer, of minimum thickness 12mm, and covering the entire female joint surface inside the collar.

3.1.6 As a minimum, every 5th pipe shall be designated a lubrication pipe and incorporate a minimum of three injection ports with non-return valves, located at 120° radial spacings.

3.1.7 After annulus grouting, all ports within lubrication pipes require to be reinstated with a suitable plug and demonstrate that the required watertightness is met.

3.2 Drive Lengths and Distances Between Manholes/Chambers

3.2.1 The Contractor shall develop its designs and construction methodology to limit maximum jacking drive lengths. This design shall consider the project requirements in relation to permanent structures, as well as considering the use of temporary works which may be necessary to achieve drive lengths within the capacity of selected machinery and pipe components, safety, survey accuracy, etc.

3.2.2 The Contractor shall consider the maximum jacking drive lengths for various diameters stated in NZTS (2017) Appendix A. The maximum jacking drive lengths may be exceeded if approved by the Principal, depending on whether the Contractor has a demonstrated track record, experienced supervisors, and carries out extra safety measures (e.g., caches of SCSRs, firefighting, first aid equipment).

3.2.3 The Contractor shall develop its designs such that the maximum distances between permanent manholes are in accordance with the project requirements. This may consider the Watercare's Standard Document 'Design principles pipelines over 300mm diameter' (ESF-500-STD-206).

3.3 Jacking Pipes

3.3.1 The Contractor is responsible for the selection of the pipe class and selection and/or design of pipe thickness and reinforcing and jointing details. If *the Projects Requirements* does not indicate that the Principal requires a specific pipe material (e.g. reinforced concrete or GRP), then the Contractor shall select and propose the pipe material as part of its 'Design of Jacking Pipes' design report. Refer to Section 3.5 for further details of design submittals requirements.

3.3.2 The Contractor shall submit a 'Design of Jacking Pipes' design report to the Engineer for review and approval. The design report is required to demonstrate that the selected pipe is adequate for all load cases including handling and jacking loads during construction.

3.3.3 The Contractor is responsible for determining appropriate permanent and temporary design loads for selection of pipes installed using pipe jacking and microtunnelling techniques. These loads are to be fully documented in the Design of Jacking Pipes' design report, including calculations and submitted to the Engineer for review and approval.

3.3.4 As part of its design, the Contractor shall determine ground loads using data from the available geotechnical reports, live factors, and superimposed loads for the pipe design in the temporary and permanent case. the Contractor is to adopt an appropriate engineering method for design of pipes for the temporary jacking loads.

3.3.5 The design load cases shall include for the worst-case combinations of internal and external hydrostatic heads, where relevant taking account of projected sea level changes and the potential for artesian groundwater pressures.

3.4 Corrosion Protection Linings

3.4.1 All concrete surfaces otherwise potentially exposed to Microbial Induced Corrosion (MIC) shall be protected by a Corrosion Protection Lining (CPL) or other inert material that fulfils the design life durability requirements. It is acceptable to have unprotected concrete surfaces where these are demonstrated to be permanently inundated by dry weather flows in the pipe and not subject to MIC.

3.4.2 The Contractor shall submit a design for the CPL systems to the Engineer for approval. See Section 3.5 below for requirements for design submissions for CPL systems. If modifications to design are required during construction, the Contractor shall submit for the Engineer's approval revised design information delineating requested modifications including reasons for the modifications.

3.4.3 For microtunneling, CPL shall be taken to mean a mechanically anchored PE membrane, cast into the concrete lining, and providing the primary means of protection against Microbial Induced Corrosion (MIC) on the intrados (interior) lining of the pipe. The CPL may be cast directly into the precast concrete segments, or into a second pass cast in-situ lining.

3.4.4 For reinforced concrete jacked pipe with CPL, CPL shall be taken to mean a mechanically anchored PE membrane, cast into the concrete pipe, and providing the primary means of protection against Microbial Induced Corrosion (MIC) within the pipeline.

3.4.5 Requirements for CPL PE membranes include material properties, manufacture and supply, installation, and testing of the PE membrane; as well as the procedures for post installation repair of defects.

3.4.6 The CPL shall be resistant to MIC generated in sewers and shall not contribute to the growth of sewage bacteria in the wall slimes, over and above normal levels for OPC concrete.

3.4.7 The PE membrane shall be AGRU UltraGrip or an approved equivalent with a minimum thickness of 2.5mm for jacked pipe. AKS Lining Systems “Anchor Knob Sheet” is an acceptable approved equivalent to AGRU Ultragrip for precast applications only.

3.4.8 The PE membrane shall be chemically inert and able to resist chemical attack and abrasion for the maintenance-free service life, and for maximum flow velocity of 3 metres/second.

3.5 Design Submittals

3.5.1 All reports shall include design calculations, drawings and specifications, and shall be submitted to the Engineer for Approval before detailed construction drawings are finalised and the physical works begin.

3.5.2 Unless specified otherwise, all reports shall be submitted to the Engineer for review and approval at least 1 month prior to ordering pipe or commencing pipe fabrication.

3.5.3 Design Report – Selection of Pipejacking Equipment (submitted to the Engineer for Approval). This report shall include but not be limited to consideration of the following:

i. Proposed equipment and specifications

ii. Manufacturer track record, equipment reliability and support

iii. Refurbishment and remaining life assessment for used equipment

iv. Health and safety and environmental considerations

v. Compatibility of equipment with anticipated geotechnical conditions as well as the selected pipe

vi. Method Selection Report (detailing the reasons for proposed equipment selection)

vii. Ground and groundwater pressure assessment

viii. Overcut, thrust, torque, allowable jacking forces on pipe and reaction systems

ix. Cutterhead design

x. Alignment control

xi. Compliance with limits on groundwater infiltration (and impact on surrounding ground)

xii. Equipment operating parameters

xiii. Settlement limits (as stated in the Project’s Requirements)

xiv. Spoil and spoil handling

xv. Risk of hydrofracture (frac-out)

xvi. Process fluids and planned conditioning requirements for operations

xvii. Existing utility services

xviii. Consent conditions

b) Design Report – the Design of Jacking Pipes (submitted to the Engineer for Approval); covering permanent works design related to the following as a minimum:

i. Loadings from: ground and groundwater; surcharges and other loads including seismic, handling and jacking loads, including eccentric jacking loads.

ii. Determination of the maximum permissible jacking forces on the pipe for permitted pipe joint angles needed to negotiate curves, and to determine the IJS frequency to keep the loads within the proposed pipe within acceptable tolerances.

iii. Design to prevent groundwater infiltration, including gasket selection.

iv. Durability, including CPL or sacrificial thickness) requirements (refer to Watercare's Material Supply Standard (ESF-500-STD601), Section 13.1.1 for sacrificial layer requirements). For CPL systems the design shall clearly note the following: Applicable design standards, Loading conditions, Durability criteria. Design methodology, Design assumptions, Suitable materials, Joint design and welding methods, Patch design

v. Provide calculations to show that the strength of the pipeline and pipe joints is adequate to withstand estimated construction forces. The calculations shall take into consideration the frictional characteristics of the ground and the pipe material, the type of lubricant, the depth and diameter of the pipe and the required length of the drive.

vi. Joint and gasket seal designs.

c) Design Report - Launch/reception structures (submitted to the Engineer for Approval); covering temporary works design (including ground support system(s), access/egress methods, use of plant, air quality etc.) related to the following as a minimum:

3.5.4 Reaction/thrust walls, frames and pits

I. Headwalls, seals

II. Ground improvement

3.5.5 Compliance Statements

a) The following Principal's Compliance Statements are required for permanent works pipelines installed by microtunnelling and pipejacking: CS1, CS2, CS3 and CS4. The compliance statement is to include all deliverables including the design report and project drawings. No exclusions are permitted without the express approval of the Principal.

Refer to Watercare's 'Compliance Statement Policy for producing water and wastewater infrastructure' for further details.

Table 3.1 summarises the design phase submittals required:

Table 3.1: Design phase submittals.

Submittal	To Engineer For	Frequency
Contractor's GIR and GBR-B, if required	N/A	During the bid/pricing phase
Additional GFRs, if required and if geotechnical information provided by the Principal is insufficient	Information	Within two (2) months of completion of the investigations.

Design Reports (including design calculations, drawings and specifications)	Review and Approval	Min 1 month prior to ordering pipe or commencing pipe fabrication
Compliance Statements	Information	Subsequent to Engineer approving design reports

4 Construction Requirements

4.1 Microtunnelling and Pipejacking Equipment

4.1.1 The following requirements apply to all MTBMs, TBMs, pipejacking shields and associated equipment used to excavate and install jacked pipelines:

[Choose one of the following clauses, based on recommendation from the Consultant's geotechnical engineer's. The Contractors submittals are to be clear about which method is used in the works.]

a) The work shall be conducted using a pressurised face shield Tunnel Boring Machine, in a pipejacking configuration. The Contractor shall determine the selection of whether to use an EPBM or slurry MTBM/TBM. The MTBM/TBM shall be selected/designed to be capable of resisting the ground and groundwater pressures anticipated during jacking based on the conditions described in the Geotechnical Baseline Report (GBR) and those determined from the Contractors analysis of the ground conditions and prepared GIR. Or

b) The work may be conducted using an open shield or pressurised face TBM

4.1.2 MTBMs/TBMs shall be new or refurbished. In the case of refurbished equipment, warranties and/or certificates as appropriate shall be provided from the manufacturer confirming that all key components have been refurbished.

4.1.3 In the case of MTBMs/TBMs which are not remote controlled machines, i.e. not slurry machines, but which are sized to permit routine personnel entry (refer Section 5.2.1), MTBMs/TBMs shall incorporate an airlock, which in addition to facilitating compressed air access to the cutterhead, shall be capable of functioning as a fire/smoke refuge for personnel located within the TBM during emergency scenario during tunnelling.

4.1.4 Where required by the Consents, or where it is anticipated that construction noise will exceed the consented noise limits or pose a hazard to the health of construction staff, then the Contractor shall implement acoustic protection to:

a) Shaft heads and spoil load-out and handling areas.

b) Slurry separation plant (if slurry system is selected).

4.2 Health, Safety and Welfare Specific Requirements

4.2.1 The works shall be designed and constructed with respect to HSW requirements in accordance with the following standards, codes and guidance, in order of precedence:

a) MOQO (2016)

b) WorkSafe ACOPS and guidance documents

c) BS 6164:2019

d) NZTS (2017)

4.2.2 No routine personnel entry is permitted within jacking pipes or shields having an internal diameter less than 1.2m. Personnel entry below 1.2m ID may be permissible in the event of infrequent maintenance, breakdown, or similar, subject to:

a) The Engineer's approval of the Contractor's method statement, and relevant HSW documentation.

b) The Contractor's notification and acceptance/no objection from WorkSafe.

c) The HSWA MOQO (2016) mining regulations are applicable, and all the relevant documentation and approvals required therein apply. All documents to be submitted to WorkSafe under the MOQO (2016) regulations shall be submitted to, and accepted by, the Engineer prior to transmitting to WorkSafe.

4.2.3 The Contractor shall allow for the risk of encountering ground conditions which may impact air quality and worker safety, and account for this within its plans and procedures relating to air quality.

4.3 Contractor Qualifications

4.3.1 All pipe installation by pipe jacking and microtunnelling shall be undertaken by construction personnel that have the required tunnel Certificates of Competency, skills and experience required by the Mining Regulations. As a minimum the key workers should have 10 years' experience of this type of work including length of drive and pipe diameter. Refer to Section 4.3.3 for requirements to provided resumes of key personnel.

4.3.2 The Contractor shall provide an organization chart for all key company and subcontractor personnel who will work on this project. The organization chart shall list the name, title and function for each person.

4.3.3 The Contractor shall provide the names and resumes for all key personnel to be employed in the execution of this project including managerial, supervisory, operational and design personnel. At a minimum this shall include project manager, microtunnel operator(s), construction superintendent and/or foreman, surveyor, mud engineer and lead designer.

4.3.4 The Contractor shall provide qualification documents for all subcontractors including those supplying tunnel equipment, guidance instrumentation, slurry mixing equipment and cuttings separation equipment (if applicable).

4.4 Construction Submittals and Data

4.4.1 The following sections set out specific construction submittal requirements for microtunnelling and pipejacking, which are additional to any specific project requirements and Watercare's General Civil Construction Standard.

4.4.2 Method Statement

a) The following activity specific requirements shall be addressed:

b) A method statement shall be submitted to the Engineer for review and approval, at least two (2) months before microtunnelling or pipejacking is to commence.

c) The method statement shall include, but is not limited to the following:

i. General description of the construction methodology including work sites, sequence of operations and durations of work hours. This should include specific regard to minimising site footprint, truck movements, and noise associated with the works.

ii. Confirmation of proposed installation length and alignment.

iii. Confirmation of drive sequence and directions, including related drawing.

iv. Daily work hours and scheduled hours for the operations.

v. Confirmation of means of tunnel face support and groundwater infiltration management.

vi. Details of tunnelling machine, including manufacturer, machine capabilities, general arrangement drawings, details of type and number of cutting tools including configuration of any cutting wheels and overcut tolerances

vii. Details of specialist sub-contractors to be used and details of their competency.

viii. Launch, break in and break out methodology; details of the methods and ground improvements to be used to prevent groundwater entry to shafts, to facilitate the exit of the pipe jack from the jacking shaft and its entry to the reception shaft.

ix. Thrust ram type and capacity.

x. Number of interjacks and installation locations.

xi. Equipment maintenance programme.

xii. Spare parts list and availability of spare parts for the machine and system.

xiii. Number and positioning of the lubrication ports and grout ports and drawings of the ports, description of automatic lubrication system.

xiv. Details of how equipment will be transported along the pipe and supported from the pipe so that damage to the pipe surface is avoided (the pipe shall not be damaged by the movement of equipment along the pipe internally)

xv. Information on all proposed drilling fluids, additives, lubricants and conditioning agents. Submittals shall include material safety data sheets on each material along with a description of where the material will be used and its purpose in the construction process. All drilling fluids and lubricants shall be bio-degradable.

xvi. Means of protection of adjacent watercourses and wetlands, particularly from hydrofracture and lubrication or slurry escape.

xvii. Type and location of all surface features, e.g. pipes/basements/chambers lying within the zone of influence of the pipe jacking and microtunnelling operations, along with all acceptances required for drilling in the vicinity of such features.

xviii. Geotechnical instrumentation and monitoring plan including details of monitoring frequency, calculation of expected movements, and alert and alarm limits.

xix. Method of spoil transportation from the tunnel face to the entry shaft, spoil handling and storage on site, spoil muck-out to disposal haulage, disposal locations.

xx. Description of the means of regular checking of the volume of excavated material removed compared with the calculated volume as a safeguard against excessive loosening or loss of material beyond the pipe jack dimensions.

xxi. Activities requiring man-access to MTBM and any envisaged man-access to cutterhead or face. Describe the methodology and how such activities will be executed with respect to health and safety.

xxii. Power supply to be used (noting that the Principal expects mains power to be used where available).

xxiii. Lighting and ventilation along the pipeline and in the shield.

xxiv. Detection, monitoring and alarming of toxic or explosive gas in the shield and along the pipe barrel.

xxv. Description of the guidance, alignment control, and steering systems with manufacturer's literature, drawings.

xxvi. Pipe lifting details.

xxvii. Pipe joint packer details.

xxviii. Pipe gasket fixing details, if fixed on site.

xxix. Detail the type and location of all existing underground services within the zone of influence of the pipe jacking and microtunnelling operations, along with all relevant acceptances required from relevant authorities for drilling adjacent to their services and details of any special measures to be adopted to mitigate damage to these services.

xxx. Means of compliance with all relevant consent conditions, Auckland Council plans and bylaws, particularly construction noise regulations.

xxxi. Details of reinstatement of the site working areas.

xxxii. Contingency plans documenting potential problems and measures which will be taken to resolve the problems should they arise. This shall include for example, equipment stoppage or breakage, damage to jacked pipes or joints during installation and other potential problems as identified by the Contractor. Equipment and materials for clean-up and contingencies must be provided by the Contractor and stored on-site.

xxxiii. HSW risk assessment, pre and post mitigation, with descriptions of mitigations.

4.4.3 Inspection and Testing Plan (ITP)

a) An ITP shall be submitted to the Engineer for review and approval, at the same time as the method statement.

b) The ITP shall include Witness and Hold Points for the Engineer's representatives as follows:

i. Witness Points:

a. Fabrication factory inspection within one month of commencement of fabrication of jacking pipes (may be dependent on whether the pipe is made in NZ and the pipe internal diameter);

b. Walkthrough inspection of pipe barrel, within two weeks of MTBM/TBM shield recovery (may be dependent on whether the pipe internal diameter is >=1.2m);

c. Inspection of materials once they have been delivered to site

d. Inspections of CPL welding and spark testing, if CPL liner is relevant.

e. Walkthrough inspection, (for pipes having internal diameters >= 1.2m) or CCTV inspection (for pipes having internal diameters < 1.2m) after grouting and making good lubrication ports.

ii. Hold Points:

a. Demonstration measurement of infiltration passing the acceptance criteria.

b. Final walkthrough ('go dark'), where pipe has internal diameters >= 1.2m, all snags complete and accepted, all debris and temporary works and materials removed, ready for introduction of flow.

4.4.4 Daily jacking reports: submitted to the Engineer for information within 24 hrs of the end of the day to which the report relates. Reports should be detailed and at minimum include the following, for each pipe jacked:

a) Operator, supervisor

b) Pipe number, pipe advance start/stop times.

c) Recorded thrust forces and angular deflections (recorded at TBM steerage), related to allowable.

d) Joint deflection assessment throughout drive

e) Any damage to pipes or other unusual observations.

f) Any noted changes to ground type.

g) Spoil Volume/ Mass balance

h) Any exceptional additives to drilling fluids.

i) Details of any planned or unplanned downtime.

4.4.5 Drive reports: submitted to the Engineer for information within one (1) week of the end of the drive to which the report relates.

4.4.6 Real time TBM position and data: the Engineer and Principal shall be provided with web-based access to real time TBM position and data, such as jacking force, torque, alignment etc.

4.4.7 Weekly geotechnical instrumentation reports (settlement, groundwater, inclinometers, etc).

4.4.8 Monthly QA/QC reports and certificates on pipe manufacture.

4.5 Groundwater

4.5.1 The Contractor's methodology shall determine how groundwater will be controlled to permit the construction of shafts, tunnels, pipelines and connections, while ensuring that there is no damage to existing services and structures, and that the consent conditions are complied with. Apart from the Method Statement, this is expected to be submitted in the form of both a Principal Hazard Management Plan and a Groundwater & Settlement Monitoring & Contingency Plan.

4.5.2 The Contractor is responsible for complying with all necessary permits for discharging water arising from tunnelling, pipejacking and excavation activities, having taken account of potential contamination from construction plant and operations, and possible need for treatment prior to discharge.

4.5.3 All dewatering flows and discharges shall comply with requirements of the Consent Conditions and Assessment of Environmental Effects and as detailed in the *Contractor's Environmental Management Plan* for the Project. Removed groundwater shall be disposed of in accordance with the requirements of the consents, the Local Authority, and in accordance with the Contractor's Approved Erosion and Sediment Control Plan. Water that does not meet relevant environmental standards shall not be discharged into any waterway or water body.

4.5.4 The Contractor's working methods and systems shall be designed to limit groundwater drawdown, and where necessary to remove water from the pit and pipeline excavation. Removal of groundwater shall be undertaken in such a manner as to not cause damage to the Works or to the property of third parties. In particular the Contractor should note if separate aquifers and variable soil layers such as ECBF; Parnell Grit; Auckland Volcanic Field materials; Tauranga Group comprising peats, organic material, clays, silts, sands and gravels as identified in the boreholes are present at locations along the alignment. The Contractor shall specifically identify these items in their GIR, and its GBR, where these documents are required.

4.5.5 Where there is the possibility of perched and artesian ground water along the alignment, quantities of groundwater flow will be variable, potentially increasing in rate and quantity within strata. Where groundwater is removed, the Contractor shall assess the rate of removal, along with any indications of fines being removed, and shall report this to the Engineer on a daily basis.

4.6 Protection of Adjacent Watercourses and Wetlands

4.6.1 The Contractor is responsible to ensure drilling works are operated in a manner to eliminate the discharge of water, drilling mud and cuttings to the wastewater and stormwater systems, waterways, beach, ocean or land areas, and comply in all respects with the consent conditions.

4.6.2 All appropriate means of protection are to be installed by the Contractor prior to commencement of tunnelling. Details of the proposed means of protection are to be included in the Contractor's method statements submitted to the Engineer.

4.6.3 The Contractor shall include a management and response plan should construction fluids be discharged to any receiving environments, with special regard to waterways, beach or ocean.

4.7 Launch and Reception Pits/Shafts

4.7.1 The Contractor shall provide and maintain all the jacking and associated equipment and machinery required to carry out the pipeline installation. The Contractor shall also be responsible for the design and construction of shafts and chambers required to facilitate the pipeline installation, and for their removal and reinstatement on completion of the works where they do not form part of the permanent works.

4.7.2 The thrust wall ('jacking rig reaction surface') shall be normal to the proposed line of thrust and of sufficient size and strength to repeatedly accept the maximum permitted jacking force without undue movement. The magnitude of movement is to be predicted and reported in the Contractor's design submittals and shall not exceed the movement tolerance of the pipeline and connections. The Contractor shall not thrust directly off any permanent part of the shaft, chamber or pumping station unless this structure has been specifically redesigned to withstand the jacking reaction. The design of the thrust wall and any other associated temporary Contract Works shall be such as to prevent damage to any part of the Contract Works.

4.7.3 The Contractor shall demonstrate through calculations that the jacking forces transferred to the ground, through the jacking (drive) shaft structure (the soil reaction face), do not exceed the allowable bearing capacity of the ground. Thrust wall calculations shall be included in the Contractor's design submittals to the Engineer.

4.7.4 The designs shall comply with the Project's Requirements for the temporary support for shafts, but where procedures contradict each other, this document shall take precedence.

4.7.5 The temporary works shall be constructed in accordance with the designs approved by the Engineer.

4.8 Installation

4.8.1 The Contractor shall propose and provide a basis for selection of the spacing and number of IJS to be used for each drive.

4.8.2 The annulus gap between the pipe barrel and excavated overcut shall be filled during jacking by a suitable lubricant fluid, e.g. bentonite. In addition to lubrication, the fluid supports the ground and restricts groundwater inflows, thereby limiting settlement. Where applicable for the selected pipe diameter, the fluid shall be injected through the shield and through lubrication ports incorporated into the jacking pipes.

4.8.3 Lubrication fluids shall be non-toxic to the environment.

4.8.4 The Contractor shall monitor the pressure of cutterhead fluids and lubrication fluids and:

a) Ensure these are kept below the maximum allowable pressures to avoid hydrofracturing and loss of fluid along pre-existing fissures in rock.

b) Investigate loss of pressure as to the risk of inadvertent discharge, e.g. to basements, pipelines, drainage, road subbase, or the general environment.

4.8.5 Annulus grouting

a) Where required by the project requirements, as soon as jacking has been completed and all intermediate jacking stations closed with the pipe in its final position, any remaining annulus void around the periphery of the installed pipe is to be filled under pressure with a cement-based grout. The Contractor is to attempt to place grout even when the annulus is known to contain lubricant and is to demonstrate to the Engineer that no grout is being taken before requesting cessation of the grouting operations. If it is not possible for grouting to be done as soon as tunnelling stops, it must be done within 5 days.

b) The purpose of annulus grouting is to provide bedding support for the pipelines and seal against groundwater.

c) All pipe barrel overcut annulus voids shall be grouted within two months of the retrieval of the MTBM/TBM/Shield from a drive.

d) Grout material shall be a minimum 1MPa cementitious grout, injected at a maximum of 2 times the theoretical hydrostatic groundwater pressure.

e) The grout shall have a minimum 100-year life expectancy.

f) Annulus grouting shall extend right up to the launch/reception headwalls.

4.8.6 All lifting anchors/eyes similar shall be designed and tested in accordance with the relevant New Zealand standards.

4.8.7 All pipes incorporated into the works shall be clearly identified with a consecutive spray-painted number on the top of the pipe, clearly visible from time lapse cameras.

4.8.8 During jacking operations, the Contractor is to monitor pit bottom and inter jack thrust forces and will ensure that thrust forces do not exceed the thrust capacity of the pipe and jacking wall.

4.8.9 A suitable joint packing material in accordance with the pipe manufacturer's recommendations is to be inserted at each pipe joint and at any jacking station, to assist in even distribution of thrust loads at the pipe joints.

4.8.10 Jacking pits or trenches excavated to install pipe shall be reinstated by the Contractor a quickly as practicable upon completion of pipe installation operations. The order of closing shall be from the tunnelling shield working backwards. The pipe joints in the intermediate jacking pit shall be sealed, the receiving joint face re-packed and the joint closed by jacking the upper-end pipe forward. It is not acceptable to form a pipe joint in the intermediate jacking pit with a pipe cut in.

4.8.11 The Contractor is responsible for the disposal of spoil generated during the microtunnelling and pipejacking works as well as disposal of groundwater and fluids produced during the works.

4.9 Damaged Pipes

4.9.1 All pipes shall be inspected for damage within 24 hours of delivery to site. This inspection shall be on the surface prior to installation. All damaged pipes shall be subjected to a quarantine process, and determined whether able to be repaired, or rejected and are to be removed from the Contract Works. Prior to any repairs being undertaken, the criteria for repair/reject shall be submitted as a defect repair matrix, including methodologies, to the Engineer for approval.

4.9.2 Should any pipe be damaged beyond repair within the pipe jack barrel, it shall be replaced by pushing through to the end of the line or broken out and where ground conditions permit replaced by pushing up the adjacent pipe after completion of the pipe jack. If such a remedial action cannot be readily achieved, the Contractor shall provide a detailed method statement for replacement of the damaged section for review and acceptance by the Engineer.

4.10 Slurry Separation Plant

4.10.1 If slurry shield excavation method is utilised, then the excavated material from the face that is crushed and mixed with the slurry shall be separated and the water recycled or disposed of at a location agreed by the Engineer. Assessment shall be made of the spoil volume removed. Cleaning of the slurry shall be achieved by using either:

4.10.2 Settling tanks, where the tank is cleaned by an excavator, sucker truck or grab, the water is recycled and the solid material is disposed of off the site; or Separation plant, where a separate unit of screens, cyclones and centrifuge (or belt filter press) continuously removes the solids and recirculates the slurry for further use or disposal.

4.11 Monitoring for Settlement and Surface Heave

4.11.1 The Principal shall provide the requirements for geotechnical instrumentation and monitoring of ground movement.

4.12 Obstructions and Loss of Ground

4.12.1 In the event of encountering an obstruction to tunnelling, or loss of ground causing instability of the microtunnel, the Contractor is to take immediate steps to protect the safety and integrity of the Works, determine causes and report the problem to the Engineer and comply with the Mining Regulations. The Contractor is to then submit details of a suitable means of advancement for the review of the Engineer.

4.13 Grade and Alignment Tolerances

4.13.1 Pipelines installed using pipe jacking and microtunnelling methods are to satisfy the following tolerances:

a) Angular deflection measured as the deflection between the two longitudinal axes of two adjacent pipes is to not exceed 0.5 degrees for fixed collar type pipes.

b) Angular deflection is to be derived by using direction cosines on line and level survey data and by using joint gap measurements at three equidistant points around the pipe circumference.

c) Where a pipeline is required to be straight between end points, the maximum deviation of the longitudinal axis from the design alignment of the pipe barrel shall be:

i. Vertical position: a maximum deviation of 25mm from the design level.

ii. Horizontal position: within 0.3% of the drilled distance from the design position at the end of the drilled section(s) to a maximum of 100mm.

d) Where a pipeline is shown on the Drawings as being straight between manholes, it will not be accepted unless a light can be sighted through the whole length concerned.

e) The finished pipeline shall not result in sharp changes of vertical alignment where air or sediment could accumulate. A change in grade greater that 1:300 is considered a sharp change.

f) Stepping between pipes shall not exceed 5mm.

g) No backfalls or ponding will be allowed.

h) Infiltration / leakage:

i. Visual inspection acceptance criteria shall be "no visible in-flowing or dripping water". Any visible leaks detected shall be repaired and the pipeline shall be retested.

ii. Maximum infiltration shall not exceed 1 litre per millimetre of pipe diameter per kilometre of pipe per day.

iii. At least six tests of consecutive 10-minute intervals each shall be monitored to estimate (through extrapolation) the maximum infiltration over a 24-hour period.

Table 4.1: Construction phase submittals.

Drive No.	Location	Test 1 (L/min)	Test 2 (L/min)	Test 3 (L/min)	Test 4 (L/min)	Test 5 (L/min)	Test 6 (L/min)	Ave (L/min)	Pipe Dia. (mm)	Pipe Length (m)	Allowable infiltration	Pass / Fail
1	Start / Finish											
2	Start / Finish											
3	Start / Finish											

Note: The number of tests and durations should be confirmed with Watercare.

4.14 Acceptance Tests and Records

4.14.1 Where the pipes incorporate a CPL, testing shall be in accordance with Projects requirements for Corrosion Protection Linings.

4.14.2 Upon completion of pipe installation, the Contractor is to undertake infiltration testing for each drive and the entire pipeline as follows:

a) Visual inspection for pipes not less than 1.2m ID; and

b) Measurement of infiltration flow within the pipelines via v-notch weirs or similar

i. Infiltration tests shall only be carried out after completion of pipe annulus grouting, lubrication port sealing, and finishing of any Corrosion Protection Lining or similar. Any dewatering shall have been discontinued for at least 3 weeks prior to test.

ii. For the infiltration flow measurement test, the pipeline shall be tested in lengths between manholes or such shorter lengths as the Engineer may permit, and up to a maximum length of 1 km. The volume of water infiltrating into the pipe within the test section shall be accurately measured for a minimum period of 1 hour. Contractor shall seek agreement with the Engineer if infiltration is tested for periods less than 1 hour.

4.14.3 All acceptance testing results shall be submitted to the Engineer for review as a report, within one week of the acceptance test being performed.

4.14.4 For pipes having internal diameters of 1.2m or greater, the following are required:

a) Walkthrough - final snagging, no debris, etc Visual inspections shall be conducted with the Engineer (or delegate) and submitted for the Engineer's approval.

b) Video and photographic records, including pipe numbering / chainage system etc

4.14.5 For pipes having internal diameters less than 1.2m, full CCTV video records are required to be submitted to the Engineer for review and acceptance.

4.15 As-Builts

4.15.1 As-builts shall be submitted in accordance with Watercare's Data and Asset Information standard.

4.15.2 As-builts shall be submitted to the Engineer for approval within two (2) weeks of completion of grouting for each drive.

4.15.3 The minimum requirements for As-Built survey for jacked pipes are as follows:

a) Include information on minimum spacing / number of pipes between XYZ survey points

b) Contractor shall conduct 3D scans, to confirm levels on every 3rd pipe joint, to confirm vertical tolerances

4.16 Construction Submittals

Table 4.2 summarises the Construction phase submittals required:

Table 4.2: Construction phase submittals.

Submittal	To Engineer For	Frequency
Contractor Qualifications	Review	Min 1 month before work commences
Permanent Works Design Report	Review	Min 1 month before work commences
Temporary Works Design Report	Review	Min 1 month before work commences
Method Statement	Review	Min 1 month before work commences
Inspection and Testing Plan	Review	Min 1 month before work commences
Daily jacking reports	Information	Daily, within 24 hours
Drive report	Information	Each drive, within one week of the completion of jacking for the drive
Real time MTBM/TBM data	Information	Continuous web-based data accessibility
Geotechnical Instrumentation Report	Information	Monthly, within one week of the end of the calendar month
Acceptance Test Reports	Review	Within 1 week of completion of test
As-builts	Review	Progressively, within 1 month of completion of work element
QA/QC Reports	Information	Monthly, within one week of the end of the calendar month
Video and CCTV recordings	Information	Progressively, within 1 month of completion of drive.
As-builts	Review	Within two (2) weeks of completion of grouting for the drive.