MECHANICAL AND ELECTRICAL

CATHODIC PROTECTION STANDARD

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Watercare

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DOCUMENT CONTROL

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

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Definitions

Term	Definition
AC	Alternating Current electricity
AMPP	The Association for Materials Protection and Performance (formerly NACE)
Anode	An electrode placed in an electrolyte, to apply cathodic protection to a structure
Bond	A metallic connection between points on the same structure or on different structures
BTP	Bonding test point
Cathodic Protection	The mitigation of corrosion of metal, by making the metal the cathode in an electrochemical cell
CDEGS	Current Distribution, Electromagnetic Fields, Grounding and Soil Structure Analysis - Software package for stray current modelling by Safe Engineering
CHAZOP	Control Hazard and Operability Study
CLS	Cement Lined Steel
CP	Cathodic Protection – Method of protecting metallic structures from corrosion
CSE	Copper/Copper Sulphate Electrode
Cu/CuSO4	Copper/Copper-Sulphate
Cu/CuSO4	Copper/Copper-Sulphate
Cu/CuSO4 Reference Electrode	A reference electrode consisting of copper in a saturated solution of copper sulphate, utilised for field potential measurements
Corrosion	The deterioration of metal caused by an electrochemical reaction with its environment
Coupon	A section of metal of similar size to a coating defect, used to monitor the corrosion of a coated structure that is subjected to CP
DC	Direct Current electricity
DCVG	Direct Current Voltage Gradient survey
DI	Ductile Iron
DMM	Digital Multimeter
ER	Electrical resistance
Electrical Isolation	A joint that breaks the electrical continuity of a structure but does not affect the mechanical integrity
Electrical Resistance (ER) Probe	A corrosion monitoring device, which functions by exposing an element of metal the structure is manufactured from to the environment in which the structure is exposed. As the element corrodes, its cross-sectional area is reduced, thus increasing its longitudinal resistance. The change in resistance is measured with a very sensitive resistance measuring circuit.
FIK	Flange Insulating Kit or Flange Isolation Kit
ft	feet

Foreign Structure	A structure, not owned by the same company and/or intended to be protected with the same CP system, that may be subject to or potentially causing interference arising from the CP of a primary structure and/or foreign structure.
g	gram
Galvanic Anode	An electrode used to protect a structure using galvanic action (electrochemical reaction between dissimilar metals). A galvanic anode is also known as a sacrificial anode
GB	Ground Bed
GSM	Global System for Mobile Communications
GPS	Global Positioning System
HAZOP	Hazard and Operability
HDD	Horizontal Directional Drilled
HDPE	High Density Polyethylene
HDPVC	High density Polyvinyl chloride
HMWPE	High molecular weight polyethylene
HSCI	High Silicon Cast Iron
HSSE	Health, Safety, Security and Environment
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
ICCP	Impressed Current Cathodic Protection
IEEE	The Institute of Electrical and Electronics Engineers
IR	Voltage drop (V=IR)
IFTP	Interference Test Point
Impressed Current	DC current supplied by an external power source to cathodically protect a structure. The electrode connected to the positive terminal of an impressed current power supply
Interference	A significant change in current density and structure potential on a foreign structure caused by a CP system; it may be detected by a resultant potential change on the structure
ISOTP	Isolation test point
ITP	Inspection and Test Plan
JB	Junction box
kV	Kilovolt (1000 Volts)
LRT	Light rail transit
m	Meters
MIJ	Monolithic Insulating Joint
MMO	Mixed Metal Oxide
MODBUS RTU	Client/server data communication protocol
MSDS	Materials Safety Data Sheets
MTP	Monitoring test point
mV	Millivolts
NACE	NACE International; National Association of Corrosion Engineers (now AMPP)

O&M	Operations and Maintenance
ORP	Oxidation-reduction potential
PCR	Polarization cell replacement
ppm	Parts per million
PVC	Polyvinyl chloride
QA/QC	Quality assurance and quality control
RMU	Remote monitoring unit
ROW	Right of way
SCADA	Supervisory control and data acquisition – system used to monitor and control industrial processes
SDI	Single core double insulated
SS	Stainless Steel
Stray Current	Current flowing through paths other than the intended circuit
TR	Transformer rectifier
TUDS	Total Underground Distribution System
V	Volt
VCI	Vapor Phase Corrosion Inhibitors
XLPE	Cross-linked polyethylene

1. Introduction

1.1 Purpose and scope

This standard has been developed to provide minimum requirements for quality, performance, and consistency of Watercare’s corrosion prevention infrastructure. Compliance with current New Zealand legislation, the recognised standards and consideration to site specific constraints shall form the basis of the design.

All materials, equipment, and labour for construction of corrosion control systems shall be furnished and installed in accordance with these specifications and in accordance with the design prepared by a competent Chartered Professional Engineer in the cathodic protection field of design. All persons completing work shall be competent in their work possessing the minimum skill and competency level required by this standard. Any part of this standard that cannot be met must be highlighted in the design report for Watercare’s consideration, with alternative options requiring written approval from Watercare.

This standard outlines the external corrosion prevention requirements for new and existing buried metallic pipelines and associated appurtenances, which are typically non-inspectable. Corrosion prevention of metallic water tank bottoms, water tank metallic internal components, piles, caissons, pipe supports, structural steel, pressure vessels, ocean outfall pipelines or other metallic structures is not covered in this document.

1.2 Applicability

This standard applies to all corrosion prevention design, supply and construction work for infrastructure delivered or vested to Watercare, including new and existing buried metallic pipelines. The minimum design level shall be demonstrated to meet this standard.

1.3 ‘Must’ versus ‘Shall’ versus ‘Will’

a) Where the verbs must, shall and will (or its past tense forms) are used, they describe a requirement for compliance with the statement in which it is used.

b) ‘Shall’ and ‘must’ expresses a mandatory condition or action. ‘Will’ is used to prescribe a performance outcome or intent.

2. Standard documents overview

2.1 Relationship of Watercare standards

Watercare standards comprise of codes of practices, design standards, standard design drawings, construction standards, asset and material standards, and guidance notes.

Watercare standards define requirements additional to nominated national standards, international standards and industry best practice, and in some cases exceed legislative requirements, to accomplish long term operability and good asset management practices to benefit our customers. The interface of these standards with each other and the project specifications are as follows:

2.1.1 Design Standards

The design standard sets a level of design for particular types of infrastructure based on operational area and associated risk. The design standards provide the minimum criteria for:

- Establishing standard design drawings
- Interface design between standard drawings and specific design
- Establishing the correct sizing of components to meet the baseline parameters of the standard drawings
- The basis for developing specific designs

2.1.2 Design drawings

Standard design drawings support the requirements of the design standards. Minimum and maximum criteria are set, and specific standard details are shown. Standard design drawings must not be amended.

2.1.3 Asset and material standards

Asset Information Standards describe the requirements for asset creation, asset numbering, asset capture, production of operational manuals and documentation.

Material standards describe the minimum performance and compliance requirements of materials, products and assemblies supplied for asset acceptance. Often selected materials will have limitations of applicability and requirements specific to the operating environment and infrastructure classification. Additional requirements may be specified based on the specific design.

2.1.4 Construction standards

Construction standards prescribe the methods and requirements for workmanship to be employed when constructing works in accordance with the design requirements, standard drawings, and bespoke designs. To achieve the best outcome the construction requirements, focus on proven methods and best practice to ensure quality is maintained to achieve the design life of infrastructure and that maintainability, health and safety and environmental requirements are met. Where construction standards are used or referred to in contracts they form part of the specification of the contract.

2.1.5 Project specific specification (particular specifications)

These specifications identify mandatory site or project specific requirements that are not covered by the normative construction standards or standard design drawings identified during specific design.

2.1.6 Design build projects

Design-build projects (also known as design & construct) shall follow the minimum requirements set out in all the above standards.

2.1.7 Dispensations

Any departure from the standards for the works shall not compromise quality, whole of life performance, safety, operation and maintenance, and regulatory requirements including health and safety and environmental requirements. Any proposed departure shall be evaluated by completing an Application for Dispensation from / relating to the applicable standard and by demonstrating that the departure complies with the requirements and applicable certification by providing proof of quality documentation.

2.2 Design requirement exemptions

Installation or replacements of like-for-like valves, fittings and meter assemblies with componentry that are fully compliant with the Watercare Material Supply Standard are considered exempt from design requirements.

Design must be reviewed by Watercare here materials or equipment deviates from Watercare's Materials Supply Standard. An Application for Dispensation shall be prepared in these instances and assessed by Watercare's technical governance group.

2.3 Referenced Standards

2.3.1 General

This specification refers to several national and international standards. It is the obligation of users of this document to ensure they make use of the latest version of these standards. Watercare pursues to update this document where standards are replaced however it is expected that the latest recognised replacement by the applicable standard governing body is adopted until such time that this standard can be amended.

This standard must be read in conjunction with the Watercare, national and international standards listed below. Where conflict or ambiguity exists, this standard shall take precedence. Where there is conflict between referenced standards, the most stringent requirements shall take precedence.

2.3.2 Watercare standards

- DP – 10: Safety in Design guide
- ESF-500-STD-401 (DP-19): General plant layout and equipment selection principles
- ESF-500-STD-502 (DP09): Electrical design standard
- ESF-500-STD-601 - Material supply standard
- ESF-600-STD-703 (EC) – General electrical construction standards
- ESF-500-STD-701: General mechanical construction standard
- ESF-700-STD-501(AI): Asset information and data standard
- ESF-500-STD-502: Standard for producing CAD and Geospatial Drawings
- ESF-700-STD-801: Code of practice for commissioning
- ESF-600-STD-301 (CG): General civil construction standard

2.3.3 Watercare drawings

- ESF-500-FOR-701: Cathodic protection mechanical and civil drawing set
- ESF-500-FOR-702: Magnetic flowmeter Endress and Hauser
- ESF-500-FOR-103: Pipelines for water greater than 250mm diameter
- ESF-500-FOR-710: Cathodic protection – Test station details

2.3.4 National standards

- AS/NZS 61386.21 – Conduit systems for cable management (supersedes AS/NZS 2053)
- AS 2239 – Galvanic (sacrificial) anodes for cathodic protection
- AS/NZS 3000 - Australian/New Zealand Wiring Rules
- AS 2832.1 –Cathodic protection of metals Part 1: Pipes and Cables
- AS/NZS 5000.1 – Electric cables - Polymeric insulated - For working voltages up to and including 0.6/1 kV
- AS/NZS 4853 - Electrical hazards on metallic pipelines
- AS/NZS 4832:2007 – Installation of galvanic sacrificial anodes in soil
- NZS 3101 – Concrete structures standard
- NZS 3109 – Concrete construction
- NZS 3112 – Methods of test for concrete

The following standards are applicable to cathodic protection for other structures not presently included in this buried piping document, but are included as a potential reference:

- AS 2832.2 – Cathodic protection of metals Part 2: Compact buried structures
- AS 2832.3 – Cathodic protection of metals Part 3: Fixed immersed structures
- AS 2832.4 – Cathodic protection of metals Part 4: Internal surfaces

2.3.5 International standards – AMPP (formerly NACE) and IEEE

- SP0169-2013 (formerly RP0169) - Control of External Corrosion on Underground or Submerged Metallic Piping Systems
- SP0177-2019 – Mitigation of Alternating Current and Lightning Effects on Metallic Structures and Corrosion Control Systems
- SP21424-2018 – Alternating Current Corrosion on Cathodically Protected Pipelines: Risk Assessment, Mitigation, and Monitoring
- IEEE Standard 80-2013 – IEEE Guide for Safety in AC Substation Grounding

2.4 Protection criteria (AS 2832.1)

The following criterion applies when there is no substantial voltage (IR) gradient in the electrolyte (soil) between the structure and reference electrode, or any effects by stray current or significant galvanic corrosion couples. The elimination of the IR component is achieved by interrupting the output from anodes and taking measurement within 1 second of the current being interrupted (“Instant Off”).

- Maintain an IR free (“Instant Off”) potential equal to, or more negative than - 850 mV with respect to a copper / copper sulphate (Cu/CuSO4) reference electrode (Section 2.2.2.2).
- Maintain an “Instant Off” potential on all parts of the structure, which is at least 100 mV more negative than the depolarized potential (Section 2.2.3).

The IR free (“Instant Off”) potential on the structure shall not be more negative than – 1200 mV with respect to a copper / copper sulphate (Cu/CuSO4) reference electrode.

3. Design guidance and considerations

3.1 General

3.1.1 Responsibilities

The Chartered Professional Design Engineer shall be responsible for the design of corrosion protection systems, including but not limited to, evaluating and selecting materials, coatings and linings.

3.1.2 Quality control and quality assurance

The final design report, inclusive of the calculations and design outputs, shall be supported by a design compliance statement (CS 1). It is the designer's responsibility to ensure compliance with the agreed Building Code, Watercare standards, legislative requirements and that the desired performance requirements are met.

General engineering document submittals include:

- Preliminary design report
- Detailed design report
- Producer statements
- Equipment tag lists
- Specific design drawings
- Consents and legal transfers
- Material specification
- Equipment tag lists
- Compliance statements
- HAZOP/CHAZOP records
- O&M manual
- Standard operating procedures

3.1.3 Design report contents

The level of detail should reflect the complexity and scale of the project. The following sections shall be mandatory:

- Project description
- Planning considerations and level of service performance
- Analysis of alternatives
- Design criteria

- Resilience analysis
- Assumptions and non-compliance
- Engineering calculations
- Material selection
- Value engineering that includes, constructability analysis, simplification, innovation and life cycle costing with expected design life
- Legal considerations
- Operations and maintenance applications

3.1.4 Material selection at design

Material selection shall be completed by the designer on the following principles:

a) Feasible materials shall be shortlisted based on their limitations of use to ensure reliability, future maintenance and the cost of repair is kept to a minimum. The consideration to technical advantages shall only be taken on the shortlisted materials. Function and maintainability take precedence.

b) The selected material shall be fit for purpose and proposed to Watercare for approval before commencing with detailed design.

c) As part of the design output, the designer shall complete the procurement schedules for the products and identify any design specific requirements over the minimum requirements stated by Watercare's Material Supply standard.

3.2 Coatings and linings

All interior linings and exterior coating of steel and ductile iron pipes shall follow the requirements outlined in the materials standard.

a) Only those persons qualified, proficient and competent in the design of corrosion control using coatings and cathodic protection shall evaluate and select coating, encapsulation and lining systems taking into consideration the factors specific to the intended application, installation and service conditions. Coating, lining and encapsulation system evaluations and selections shall be documented.

3.3 Cathodic protection

3.3.1 Corrosivity

3.3.1.1 Initial evaluation

a) During or prior to detailed design, the following should be undertaken and evaluated:

- For steel pipe, an applied effective high-quality bonded external coating in conjunction with cathodic protection (CP) is required.
- For ductile iron (DI) pipe, a corrosion assessment is required to determine the risk to the externally coated fusion bonded epoxy (FBE) fittings or zinc coated pipe and determination of the requirement for CP or additional coatings.

b) A corrosion allowance is typically utilised for corrosion protection on DI pipe and should be included even if CP or coatings are being utilised on the pipe. Support structures and piles should also incorporate a corrosion allowance based on the soils and environment encountered, as piles are typically bare (uncoated). A corrosivity analysis should be undertaken to determine if additional protection is required in addition to the corrosion allowance. If required, the application of impressed current systems can be utilised.

3.3.1.2 Corrosion assessment

A Soil Corrosivity Assessment consists of lab testing of soil samples at pipe depth for testing of soil resistivity, chlorides, sulphates, sulphides, pH, redox potential and moisture content. These soil sample and soil resistivity location selection and execution are best obtained through the geotechnical program of the project, with additional consideration required at waterways, wetlands, or when soil conditions vary. In addition to soil samples and lab testing, Wenner 4-pin soil resistivity testing is strongly recommended for the most accurate soil resistivity values and for confirmation of the saturated lab soil resistivity test. While soil resistivity and moisture content are the predominant factors in determining corrosivity for buried bare metallic structures, the other testing results are used in conjunction to better understand site conditions and identify any additional or supplemental requirements that may be required.

a) Soil Resistivity

Soil resistivity is an electrical characteristic of the combination of soil and ground water (electrolyte). The soil resistivity affects the ability of corrosion currents to flow through the electrolyte. Soil resistivity is a function of soil moisture, texture and concentrations of ionic soluble salts, and is a comprehensive indicator of soil corrosivity. During lab testing, samples are often saturated and measured values do not always reflect in-situ conditions. Soils in the field are subject to varying moisture content due to weather and other factors. Wenner 4-pin testing offers a better indication of soil resistivity values at site and is required for cathodic protection and AC mitigation designs.

The degree of corrosivity within each range can be determined through Table 1 (Pierre R. Roberge, Corrosion Basics: An Introduction, Second Edition 2006).

Table 1: *Soil Resistivity – Degree of Corrosivity*

<1,000	Extremely corrosive
1,000 to 3,000	Highly corrosive
3,000 to 5,000	Corrosive
5,000 to 10,000	Moderately corrosive
10,000 to 20,000	Mildly corrosive
>20,000	Essentially non-corrosive

- Sample and lab testing
  - Both as received and saturated paste samples shall be tested.
- Wenner 4-pin method
  - Testing at a single pin spacing gives limited information because the average resistance is measured for the depth of the set pin spacing. In practice, the top few inches or feet of soil is normally dry compared to pipe depth. Measurements at multiple pin spacings for each location are recommended to allow calculation of layer resistivity values and more accurate results.
  - When possible, pin spacing should be as perpendicular as possible to any buried pipelines, structures, or powerlines.
  - Typical pin spacing for CP are 1, 2, 3, 4, and 6 m, provided pipe depth is not deeper than 6 m. For AC or stray current modelling, or deeper Horizontal Directional Drilled (HDD) locations, the addition of 8, 16 and 32 m pin spacings are required. AC related resistivity testing locations are at a minimum located at the start and end of any parallel sections but are to be determined through the AC screening process. For CP design purposes, the quantity and location of resistivity measurements are based on project specifics and available physical space available along the project route.

b) Chlorides

Chloride ions break down passive oxide layers on metal surfaces, especially ductile iron and steel, and can contribute to Stress Corrosion Cracking (SCC).

- For Ductile Iron (DI) and steel pipe, <500 ppm is the chloride threshold.

c) Sulphates

Sulphates in the presence of moisture can attack iron and steel causing accelerated corrosion. Soils with high sulphate concentrations are particularly aggressive towards buried ductile iron and steel pipes. The corrosion rate increases with sulphate concentration, especially when combined with low pH and high moisture content.

- For Ductile Iron (DI) and steel pipe, <150 ppm is the sulphate threshold.

d) Sulphides

Sulphides can pose serious corrosion risks to buried ductile iron and steel pipes. Sulphides are a key factor in Microbiologically Influenced Corrosion (MIC).

e) pH

Acidic soil conditions are highly corrosive to metals.

- For Ductile Iron (DI) and steel pipe, >6.5 is Neutral to alkaline (no corrosion risk).

f) Redox Potential

Redox potential (also known as oxidation-reduction potential or ORP) indicates the tendency of a substance to gain or lose electrons, which influences corrosion.

- For Ductile Iron (DI) and steel pipe, readings more positive than +400 mV is non-corrosive.

g) Moisture content

Moisture content plays a crucial role in corrosion. Corrosion relies on the presence of water or moisture to facilitate the electrochemical reactions that lead to metal degradation. Corrosion rates tend to increase as moisture content rises, reaches a peak, and then decrease with further increase in water content.

- For Ductile Iron (DI) and steel pipe, moisture content less than 10% is non-corrosive.

3.3.1.3 Electrical hazard analysis (stray currents)

a) Stray current sources can include, but not limited to, High Voltage Alternating Current (HVAC) powerlines, High Voltage Direct Current (HVDC) powerlines, light rail transit (LRT), and third- party CP systems.

b) A risk analysis of electrical hazards shall be carried out as specified in AS4853 - Electrical hazards on metallic pipelines, for all metallic water pipelines that:

- Are longer than 300m, and
- Have high voltage cables, within 150m of the pipeline(s) for a total aggregate distance of 300m or longer, or
- Have high voltage system pylons, transformer earth beds or similar earth discharge structures within 50m of a pipeline chamber or exposed pipe section, or
- Have high voltage system pylons, transformer earth beds or similar earth discharge points within 10m of the pipeline.

c) High voltage means 1000V or higher and includes electrified railway networks. Overhead transmission lines 60 kV or greater pose the greatest corrosion risk to parallel or proximity pipelines (refer to Section 5.4 for additional information).

d) Refer to Watercare material standards for suitable suppliers to complete the analysis.

3.3.2 Determining CP requirements

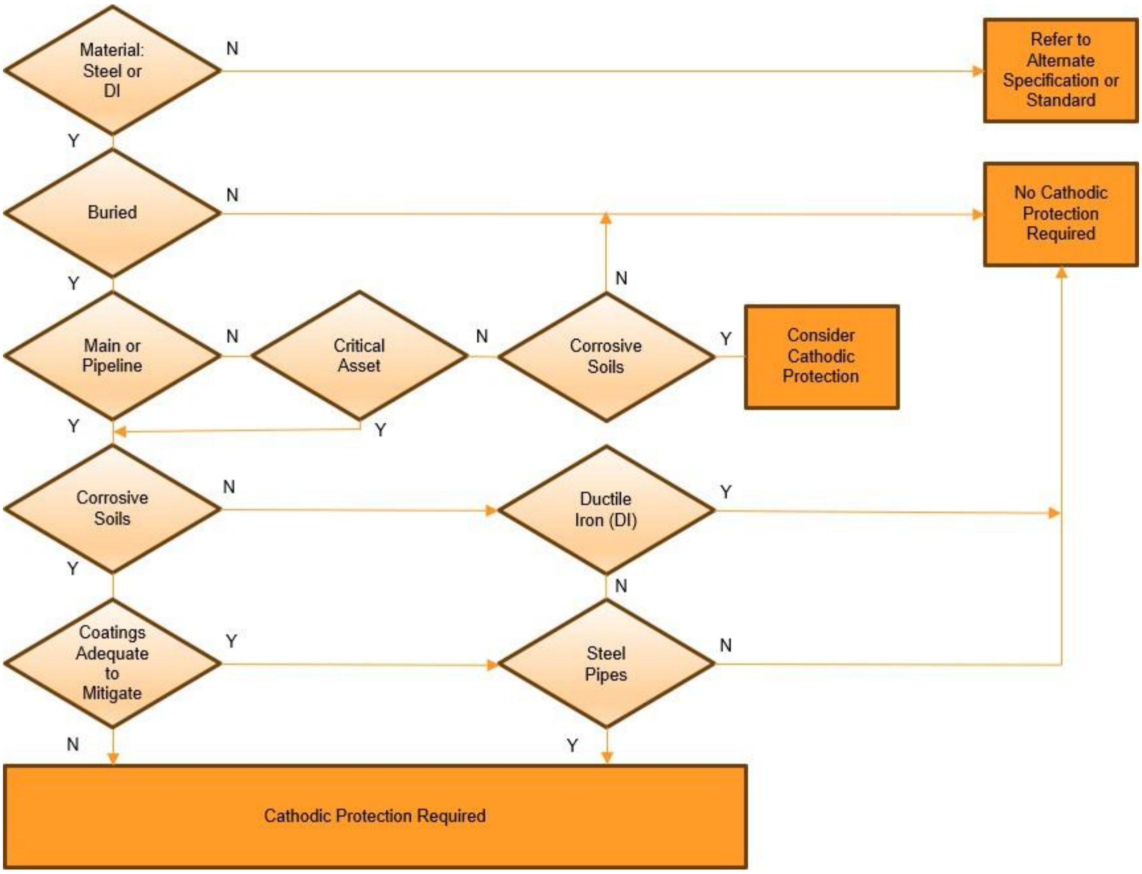

Figure 1: *Determining CP Requirements.*

3.3.3 CP System selection – galvanic vs impressed current

Both galvanic and impressed current anodes should be investigated where CP is required. Consideration to the following information, including but not limited to, should be included in the design decision.

Table 2: *Comparison of Galvanic and Impressed Current CP Systems*

	Advantages	Disadvantages	Applications
Impressed	Useful when space is limited (deep anode beds)	Power source is required	Larger pipeline projects
	Variable voltage output depending on conditions	Some maintenance of rectifier is required	Large CP current requirements
	Fewer current sources required	Initial installation cost is slightly more expensive	Areas with high resistivity soil
	Easier to monitor remotely	Bi-monthly inspection required	Projects where remote monitoring is desired
	Easier to survey	Risk of working with electrical devices	Projects where future expansion is expected
	Ability to compensate for expansion, electrical shorts or poor coating	Only qualified personnel are able to inspect, check or repair rectifiers	Poorly coated pipelines (exterior)
	Easier to replace in a congested corridor or long ROW	Can cause interference to foreign structures	
	Operates in wider range of soil/electrolyte resistances		
	Easier to interrupt current sources		
Galvanic	No power source required	Driving voltage is limited (fixed) to the type of anode used	Shorter buried sections of pipeline
	Generally lower cost	Not suitable for high resistivity soil	Localized protection
	Low risk of overprotection due to limited voltage output	Ground bed replacement is required more frequently	Remote areas where power is unavailable
	Low maintenance/no bi-monthly inspections required	More difficult to interrupt/ survey	Low resistivity soils
	Can be utilised for AC and telluric mitigation	Complete electrical isolation is required from all other structures	Well coated pipes (exterior)
	Does not cause interference with other CP systems	Logistics of ground bed replacement	

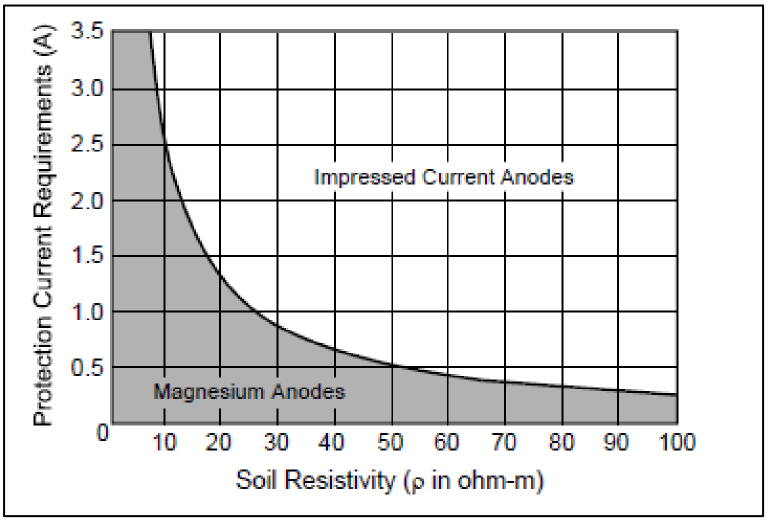

Figure 2: *Relative economic range for galvanic and impressed current systems as a function of current required and soil resistivity (reference: NACE course manual).*

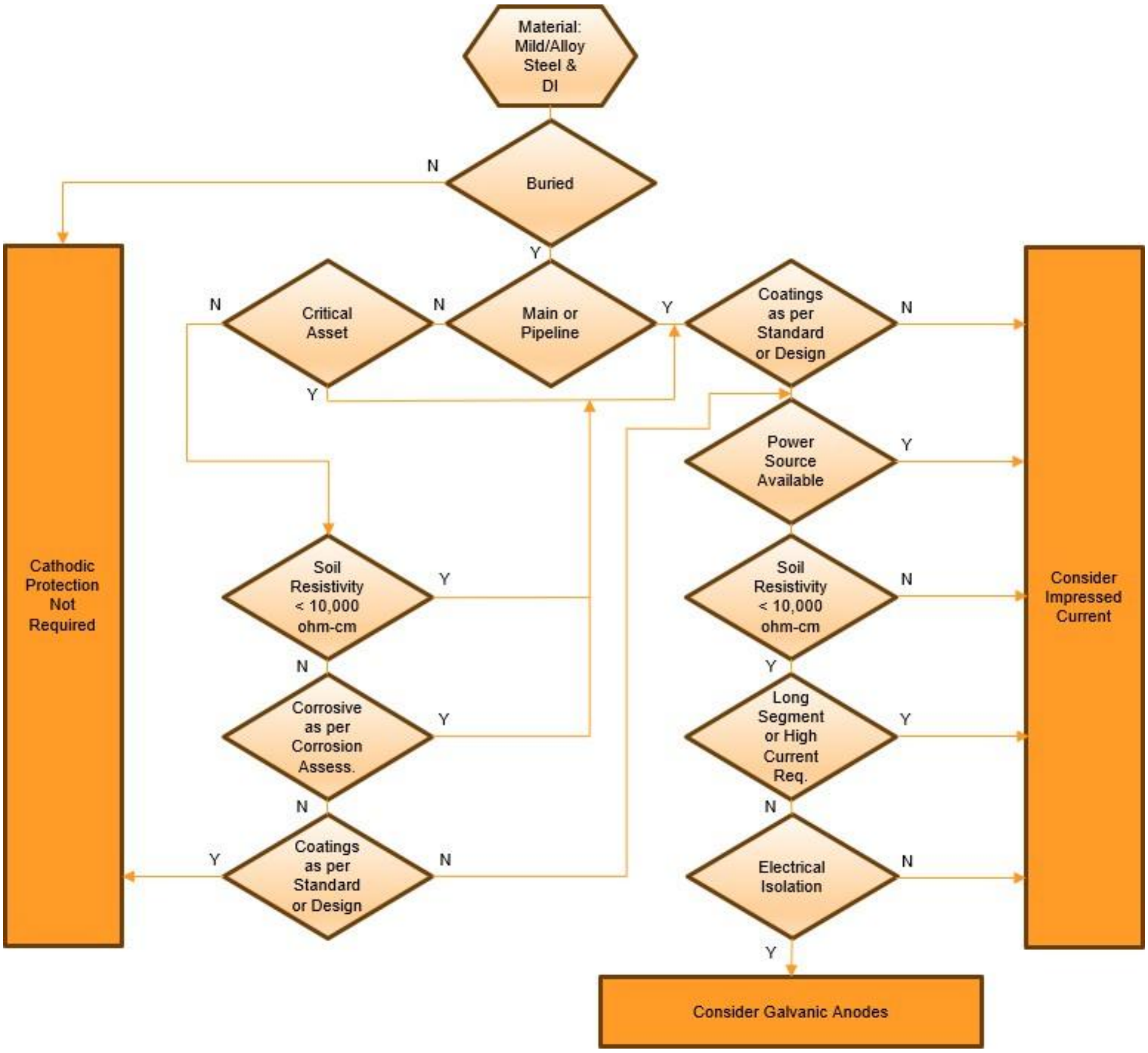

Figure 3: *Cathodic protection selection criteria for buried piping.*

3.3.4 Impressed current anode ground beds

a) Individual anode cables shall be brought up into a junction box or TR with no splices.

b) Ground bed shall be designed for 50-year operation at design current.

c) The design for ICCP systems shall avoid positioning anodes within 50m of foreign or non- continuous metal structures of any kind including reinforced concrete.

d) The designer shall inspect the site before installation of the anode ground bed to ensure that there are no metal structures that are not shown on the design drawings, which may include site visits and locates.

e) Exceptions may only be made if the metal structures are explicitly part of the CP design or with written permission from Watercare.

3.3.5 Galvanic (sacrificial) anode ground-beds

a) Individual anode cables shall be brought up into a junction box or test station with no splices.

b) Anodes shall be rated for minimum 25 years operation for magnesium and 50 years for zinc.

c) Magnesium anodes are typically used in electrolyte resistivities up to 10,000 ohm-cm, where are zinc anodes are typically used in electrolyte resistivities up to 2,500 ohm-cm.

d) The design for galvanic systems shall avoid positioning anodes within 600 mm of the protected structure and 3m of foreign or non-continuous metal structures of any kind including reinforced concrete, without prior Watercare approval.

e) The designer shall inspect the site before installation of the anode ground bed to ensure that there are no metal structures that are not shown the design drawings.

f) Exceptions may only be made if the metal structures are explicitly part of the CP design or with written permission from Watercare.

3.3.6 Cables and connections

3.3.6.1 Cable requirements

a) All cabling shall meet the requirements of the latest version of AS/NZS 5000.1. Insulation shall be rated at 0.6/1.0 kV grade

b) All cabling to be multi stranded, annealed copper

c) Cables shall be installed in conduit

d) Refer to Section 6.2.4 for additional cabling requirements.

3.3.6.2 Cable identification

a) All cables shall be labelled as per Watercare General Electrical Construction Standard, Section 12

b) All cables shall be labelled using a Grafoplast system

3.3.6.3 Splicing

a) All cables shall be installed as continuous single length cables without field splices or joints.

3.3.6.4 Cable connections

Connections to pipe or structure

a) Connections shall be completed utilizing one of the following methods (Refer to Watercare drawing 2001979.091):

- Exothermic/Thermite weld
- Welded bolt connection (non-buried connection)
- Bolted weld lug connection (non-buried connection)
- Tapped connection (non-buried connection)
- Pin brazing

Connections to test station, junction box or power supply

a) All test station and junction box cable connections shall be completed via mechanical lugs with a set screw or threaded bolts/nuts.

b) All power supply cable connections shall be completed utilizing mechanical lugs with a set screw.

c) All lugs, bolts and nuts shall be brass, copper, or stainless steel, with tin plating optional.

3.3.7 Test stations

3.3.7.1 Test station locations

a) Test Stations, including test boxes and test posts, should be installed at regular intervals, as identified in the cathodic protection detailed design, to ensure adequate connection points and testing locations along the service length.

b) Poured concrete can be utilised for test boxes, test posts and flush mount test stations for added support depending on location and land usage.

c) Test points shall be designed for the following locations:

- SCADA monitored sites
- Line valves
- Scour valve outlet chambers
- Pipe ends
- Insulating joints
- Crossings of other metallic pipelines (including existing Watercare mains), except where the foreign metallic pipe is less than 30m in length

- Rail crossings
- Major road crossings
- Stray current locations
- Geographic features where potentials and corrosion rates can be expected to be at variance to other parts of the pipeline, including estuary verges, major river crossings, swamps, etc.
- The following maximum separations shall apply, if none of the above features listed exist in the specified lengths of pipe:
  - Rural: 3000m
  - Semi-rural: 1500m
  - Suburban: 1000m
  - High density: 500m

a) Test stations consist of four (4) main types:

- Standard monitoring (MTP) (Refer Watercare standard drawing 2001979.158)
  - Utilised along the pipeline route that enables monitoring of CP potentials
  - Test leads (2 x 6 mm^2) minimum
  - Can include monitoring only, or the addition of monitoring/protection devices including galvanic anodes, ER probes, coupons (AC and DC) and/or reference electrodes
- Interference/foreign crossing (IFTP) (Refer Watercare standard drawing 2001979.159)
  - Utilised where a foreign metallic service crosses the primary pipework and/or where potential interference is expected and/or measured
  - The TP is used to determine level of potential influence/interference between 2 structures
  - 2 test leads to each pipe (1 x 6 mm^2 and 1 x 10 mm^2 for each pipe)
  - Contains reference electrode and optional galvanic anodes, ER Probes, and coupons (AC and DC)
- Isolation/bonding (ISOTP/BTP) (Refer Watercare standard drawing 2001979.156)
  - Utilised where electrical isolation is present
  - The TP is used to determine measure protection levels on each side of isolation device or isolated devices and allow determination of isolation effectiveness
  - 2 test leads to each side of isolation device or isolated device (1 x 6 mm^2 and 1 x 10 mm^2 for each pipe)
  - Contains reference electrode and optional galvanic anodes, ER Probes and coupons (AC and DC)

Cased Crossing (XTP) (Refer Watercare standard drawing 2001979.157)

- Utilised where cased crossing is present
- The TP is used to determine measure protection levels on both the casing and the carrier pipe and allow determination of isolation effectiveness
- 2 test leads to each of the casing and pipe (1 x 6 mm^2 and 1 x 10 mm^2 for each structure)
- Contains reference electrode and optional galvanic anodes, ER Probes and coupons (AC and DC)

3.3.7.2 *Test station enclosures*

a) Test stations must be installed in easily accessible locations that do not expose technicians to any undue risks, require confined space entry or traffic management. Test stations shall be in order of preference for urban, suburban and semi-rural use:

- Watercare Standard Transnet Ecopillar (Refer to Watercare drawing 2001979.113)
- Wall mounted
- Watercare Standard TUD pit, or
- Flush Fink (Refer to Watercare drawing 2001979.089)

b) Pillar mount test stations are preferred over flush mount. Flush mount shall only be ordered for sites where a pillar would block access or traffic (i.e. maintained grass or landscaping near roadways) and where wall mounting is not suitable.

c) For Rural use Big Fink pillar test points (Refer to Watercare drawing 2001979.094) may be used in place of Transnet Ecopillars.

d) Wall mounted enclosures may be used where it is practical to mount the test station on a Watercare building.

e) The enclosure ordered shall be as specified in the design or if not specified shall suit the site conditions, be sufficiently vandal proof, include non-conductive or insulated mounting plates and be of a suitable size to accommodate the required fittings.

3.3.7.3 *Ground access test stations (flush mount)*

a) Drop tubes shall be designed with a minimum of 300mm (vertical) of native soil in the base where no direct access to native soil is available (i.e. pavement).

b) In cases where native soil is too hard to be compacted in the tube or too free draining to enable contact, the fill shall be:

- For corrosion coupons: Washed sand
- Buried references and other installations: 50% gypsum / 50% bentonite mix

c) Fill shall not be scoria, gravel or a similar free draining material.

3.3.7.4 Test station cabling

a) For all test points with cables terminated in a test station, each monitored structure shall have two cables connected separately to the structure and terminated separately in the test station. In most cases these are expected to be a potential monitoring cable and a bond/current carrying cable, regardless of whether bonding is required.

b) In the case where it is unlikely that there will ever be a need to bond the structure or have current carrying capabilities, then two potential monitoring cables shall be installed.

3.3.7.5 Interference test station

a) Interference (also called foreign service) test points shall be located as close as practicable to the crossing point or anticipated stray current interference location in an easily accessible location that will not expose technicians to any undue risks.

b) Where the test station is ≥3m from the crossing a permanent zinc reference shall be installed exactly mid-way between the protected pipe and the foreign service, ensuring that the cell is not closer than 100mm from either.

c) Galvanic anodes and interference bonds are commonly utilised for the mitigation of DC and AC stray current interference and may be specified as a result of field testing or as part of either the CP or AC mitigation design.

d) Third party stray current on Watercare assets is not a concern if:

- No CP on third party pipelines
- Galvanic anodes used for CP on third party pipelines
- Non-metallic pipes (HDPE, PVC, etc.) are utilised

3.3.7.6 Coupons

a) AC and DC coupons shall be installed for enhanced testing and monitoring at locations where the Project pipe parallels or crosses a foreign pipeline (DC) or powerline (AC).

b) Coupons allow for “IR” free readings in locations where current interruption is impractical and allow for current density measurements to better understand CP current distribution.

c) Coupons are also useful for pipelines where electrical isolation devices are protected by over voltage devices that influence current interruption testing.

3.3.7.7 Reference electrodes

a) Permanent buried reference electrodes to be considered for enhanced testing and monitoring for public or private property, especially where portable reference electrodes cannot be placed directly over the pipe, pipe is under concrete or asphalt, high depth of cover is present, or congested corridors are present (multiple structures or companies).

3.3.8 Equipment labelling

a) Labels shall comply with the general requirements in Section 12 of Watercare's General Electrical Construction Standard, except as altered in this section.

b) Equipment to be labelled are:

- Insulating flanges
- Test stations
- Junction boxes
- TRs

a) Equipment labels on TRs, pillar and wall mounted test stations and junction boxes shall be Satin Metalphoto 25x90x0.8, with the following text:

WATERCARE

CATHODIC PROTECTION SITE ###

Phone: 09 442 2222

b) Equipment labels for Flush test stations shall be as above with the following text:

CP SITE

WATERCARE

###

c) All equipment labels shall incorporate a CP Site ID number, represented by'###' above. CP Site IDs should be indicated on design drawings. If not specified, the contractor shall request issue of the numbers from Watercare.

3.3.9 Electrical isolation

a) Electrical isolation ensures that any structures not intended for protection that would otherwise create an electrical current sink or drain are isolated and can also be used to avoid dissimilar metal contact/corrosion.

b) Electrical isolation locations can include, but not limited to, station to mainline connections, tie- in points, structural supports, electrical grounding, electrically operated equipment (i.e. valves) and above-grade to buried piping transition.

c) Electrical isolation devices may include flange isolation kits (FIK), isolation unions, monolithic insulating joints (MIJ), insulating couplings, insulating corporation valves, insulating unions and non-metallic spools.

d) All buried isolation shall contain a high-quality manufacturer applied coating and/or be adequately coated or wrapped with a CP compatible coating system to cover all exposed items (i.e. bolts) and gaps or crevasses to ensure no water or material ingress.

e) Electrical isolation shall be designed to accommodate the pipeline design and operating conditions, including but not limited to maximum design pressure, temperature, vibration, movement, and fluids transported.

f) Insulating joints shall have lightning arrestors installed across the insulated joint to protect the joint.

3.3.10 Conduits

a) All cables shall be installed in HDPVC conduits at a minimum depth of 600 mm from ground level and a cable marking tape or board installed 200 mm above the conduit in accordance with AS/NZ 61386.21 or Watercare standard procedures and requirements.

b) Suitable cable adapters, conduit entries, end caps and / or sealant shall be utilised to prevent water entry into conduit system.

c) All conduits shall be suitably sized to accommodate the number of cables required to be installed. The minimum size shall be 32 mm diameter.

3.3.11 Cased crossing

a) Cased crossing to be avoided unless required by client being crossed and/or regulatory requirements.

b) Cased crossings shall utilize casing isolators (spacers) that are appropriately sized and spaced in accordance with casing isolator manufacturer's recommendations to centre the pipe within the casing.

c) Cased crossings shall utilize casing end seals at each end of the casing to ensure a water- tight seal.

d) Determination of CP and/or external coatings on buried metallic casings to be completed on a case-by-case basis or as required by the client being crossed and/or regulatory requirements.

e) Reduced corrosion risk to the carrier pipe within a cased crossing can be achieved by the addition of grouting or the installation of Vapor Phase Corrosion Inhibitors (VCI).

3.3.12 Remote monitoring

a) Remote monitoring units (RMU) should be considered for all critical current sources, including but not limited to ICCP power sources, critical bonds, and stray current locations.

3.3.13 Polyethylene mesh separator pad

a) Where separation distances between pipes or structures is not sufficient or to separate different layers of materials between the pipelines and surrounding soil, a mesh separator should be utilised.

3.4 AC Study and mitigation

a) High voltage AC powerlines may present safety and integrity risks to existing or proposed metallic pipelines that parallel or cross their right of way. An AC interference study may be required to address these risks, in accordance with AS/NZS 4853:2012 – Electrical Hazards on Metallic Pipelines. A summary of AC powerline effects on nearby metallic pipelines are shown in Table 3.

Table 3: *Summary of AC powerline effects on nearby metallic pipelines*

Powerline Condition	Risk	Assessment
Steady-State	Shock Hazard	Touch voltage evaluation in accordance with AS/NZS 4853 and NACE SP0177 at all test stations and above-grade appurtenances.
	AC Corrosion	Evaluation per AS/NZS 4853 and NACE SP21424, based on AC and DC current density calculations for a 1 cm² holiday.
Phase-Ground Fault	Shock Hazard	Touch and step voltage assessment as per IEEE Standard 80, referenced in AS/NZS 4853.
	Coating Damage	Coating stress voltage evaluation per NACE SP0177, in conjunction with guidance in AS/NZS 4853.
	Electrical Arcing	Safe separation distance assessment based on AS/NZS 4853 and NACE SP0177 (CEA Report 239 T 8177 formula).

b) Transmission powerlines operating at 60 kV or greater are the primary concern. The effects of distribution powerlines (less than 60 kV) can be difficult to model and are typically evaluated during commissioning or annual cathodic protection surveys.

c) An AC interference study in accordance with AS/NZS 4853 Section 2 may need to be initiated under the following situations. Typically, the party installing a new system is responsible for performing a study to ensure existing utilities are not impacted.

- A new pipeline constructed on or near a powerline ROW
- A new powerline constructed on or near a pipeline ROW
- A lateral being built from an existing pipeline exposed to AC interference
- An extension to a pipeline on or near an existing AC powerline ROW
- High voltages or AC corrosion found on existing pipeline on or near an existing powerline ROW

d) The need for AC interference studies with paralleling transmission powerlines > 60 kV is dependent on the length of parallel and the separation distance between the pipeline and powerline. In general, studies are required when:

- The parallel is > 5 km at separation < 1000m
- The parallel is > 1 km at separation < 300m
- The parallel is > 300 m at separation < 100m

Configurations outside these ranges are typically low risk, but real-world conditions (e.g. transient loads or abnormal operating conditions) may still require attention. Continuous monitoring of AC voltages and corrosion risk is recommended.

e) If the parallel criteria are not met, a crossing or proximity study may still be required (see AS/NZS 4853 Clause 3.3). Only powerline fault conditions need to be considered for these, typically required when:

- The powerline crosses over the pipeline
- Powerline structures (including substations) are within 100 meters of the pipeline
- Underground phase conductors are withing 9 meters of the pipeline

f) AC interference from distribution powerlines <60 kV is typically lower, but difficult to model due to taps, imbalances, and harmonics. AS/NZS 4853 recommends site-specific evaluation, especially during CP commissioning or annual surveys. Special cases with long parallels or harmonics should not be ignored.

g) AC interference modelling shall be performed with the CDEGS software suite or an equivalent tool, as mentioned in AS/NZS 4853 Clause 5.4.4. Powerline data such as conductor heights, phasing, loading, grounding, and fault levels must be included. Where possible, projected loading should be used.

h) Soil resistivity measurements shall be taken using the Wenner 4-pin method in accordance with AS/NZS 4853 Clause 5.4.1. Typical probe spacings of 1, 2, 4, 8, 16 and 32 m should be used as per AS/NZS 4853 Clause L.2.1.

i) A steady-state touch voltage of 15 V RMS or more with respect to local earth at accessible pipeline locations is typically considered a shock hazard, consistent with AS/NZS 4853. Mitigation is required for all locations where this threshold is exceeded.

j) AS/NZS 4853:2012 does not reflect the latest research findings on AC corrosion. In accordance with NACE SP21424-2018, AC corrosion risk is managed as follows based on the maximum allowable AC current density based on a 1 cm^2 holiday:

- 30 A/m^2 if DC current density > 1 A/m^2
- 100 A/m^2 if DC current density < 1 A/m^2
- If DC density is unknown, use 30 A/m^2 conservatively

Monitoring via coupons and corrosion probes is recommended per both AS/NZS 4853 and NACE standards.

k) Under fault conditions, safety limits should be calculated per IEEE Standard 80, and risk of coating damage or arcing shall be evaluated, per AS/NZS 4853 Clauses 3.3-3.5 and Appendix C.

l) AC mitigation systems shall be designed according to AS/NZS 4853, and typically include:

- Earth electrodes connected via test stations
- Dead-front test stations

- Electrical continuity in accessible areas
- Existing CP systems may act as AC mitigation systems, but modelling is required to confirm

***Table 4**: Minimum safe separation distances to reduce arcing risk from grounded structures (adapted from NACE SP0177).*

Powerline Voltage (kV)	Maximum Arc Length (m)
60-72	6
138-144	11
230-260	21
345	28
500	41

***Note**: Values above represent worst-case conditions. With shield wires installed, 10 m is typically considered a safe separation.*

b) Construction or maintenance near powerlines presents additional hazards. As per AS/NZS 4853 Section 6 and NACE SP0177-2019, a competent person ("safety watch") shall be present during work, equipped with appropriate meters and protective gear. Controls may include continuity bonding, gradient mats, and pipe grounding.

c) All assessments, mitigation designs, and safety evaluations described herein shall be reviewed for compliance with the latest version of AS/NZS 4853– Electrical Hazards on Metallic Pipelines and shall also conform to relevant local authority and utility requirements. An AC interference study shall follow the three-level risk-based methodology defined in the standard. Soil resistivity, pipeline data, and powerline parameters must align with the input requirements. All assessments shall be reviewed at least every 5 years as required by Clause 7.3.

4. Materials

4.1 General

4.1.1 Material requirements

a) A manufacturer's name and product number must be provided for the purpose of establishing a standard of quality for the materials and equipment installed.

b) All products and materials specified herein shall be new.

c) Material and equipment shall be a standard product of a manufacturer regularly engaged in the manufacture of the product.

4.1.2 Materials delivery, storage and handling

a) Store CP materials and equipment on level ground so that it is level when stored.

b) Store CP materials and equipment according to manufacturer recommendations.

c) Store CP materials and equipment so that it is not susceptible to weather or outside damage.

4.2 Materials

4.2.1 Impressed current anodes

a) Shall be ordered as per the design and shall be mixed metal oxide coated titanium (MMO), or high silicon cast iron (HSCI) cathodic protection anodes. Both anode types can be utilised in bare form with impressed current backfill or pre-packaged in a canister anode.

b) Designed for 50+ years operation at the design current.

c) Minimum cable size of 10 mm^2 (#8) single core double insulated (SDI) XLPE/PVC to be to be utilised for anode cable tail connections and shall be fabricated by the manufacturer.

d) Cable colour shall be red or black.

e) No buried splices are allowed.

4.2.2 Impressed current backfill

a) All ICCP anodes are to include calcined coke backfill to improve conductivity, increase the effective surface area of each anode and lower ground bed resistance.

b) The quantity of product required to fill the GBs shall be calculated during design and confirmed by the contractor on a case-by-case scenario.

c) Preferred backfill: Loresco SC3 calcined coke backfill or equivalent.

4.2.3 Galvanic anodes

a) Meet AS2239 Galvanic (sacrificial) anodes for cathodic protection.

b) Be as specified in the design.

c) Sized for the application to allow a minimum design life of 25 years for magnesium anodes, and 50 years for zinc anodes, at the design current.

d) Anode cable tail minimum 6 mm^2 (#10) cable.

e) Cable colour shall be blue (magnesium) or white (zinc).

f) Anodes shall be supplied with suitably long cable tails; no mid length joins or splices shall be permitted.

g) All anodes shall be supplied pre-packaged in permeable calico / cotton bags or cardboard tubes filled with special low resistance of gypsum / bentonite / sodium sulphate backfill material, in accordance with AS 2239.

h) Backfill shall be vibratory packaged by anode manufacturer.

4.2.4 Cabling

a) The Contractor shall provide all cables in a length which accommodates the installation, with no field splices or joints.

b) All cabling shall meet the requirements of the latest version of AS/NZS 5000.1. Insulation shall be rated at 0.6/1.0 kV grade.

c) Continuity joint bonds shall be installed on non-welded metallic pipe joints or fittings as identified or shown in drawings. All joints to be bonded with minimum two single core double insulated (SDI) insulated copper cables. Cables shall be as short as practicable to avoid unnecessary voltage drop in the cable. Wire size shall be:

- 35 mm^2 for piping larger than 914.4 mm,
- 25 mm^2 for 406.4 mm to 914.4 mm piping,
- 16 mm^2 for piping smaller than 406.4 mm.

d) Where cables may be exposed to high chloride levels, extra precautions must be taken to ensure the operating life of the cables and terminations.

e) Cable insulation types shall be appropriate for the location and conditions.

f) The minimum standard of insulation for impressed current cable tails or feeder cables is XLPE, HMWPE or equivalent.

g) Buried cables shall be installed in conduit.

h) Unless otherwise shown in the specific drawings, the cable summary is shown in Table 5 below.

***Table 5**: Cable summary*

CABLE USE	CURRENT CARRYING	CONDUCTOR SIZE (min)	AWG CABLE SIZE (min)	CABLE COLOR(S)	CABLE TYPE
Positive - Galvanic anode (magnesium)	Yes	6mm²	#10	Blue (black alt)	Single core double insulated (SDI)**
Positive - Galvanic anode (zinc)	Yes	6mm²	#10	White (black alt)	Single core double insulated (SDI)**
Positive - Galvanic anode (header cable)***	Yes	10mm²	#8	Blue or white***	Single core double insulated (SDI)**
Positive - Impressed current (anode)	Yes	10mm²	#8	Red or Black	Single core double insulated (SDI)**
Positive - Impressed current (header cable)	Yes	16mm²	#6	Red	Single core double insulated (SDI)**
Negative - Negative cable (galvanic)	Yes	6mm²	#10	White	Single core double insulated (SDI)**
Negative - Negative cable (impressed current)	Yes	16mm²	#6	White	Single core double insulated (SDI)**
Test lead (chamber) - U/S (WSL)	No	4mm²	#12	Black	Single core insulated*
Test lead (chamber) - U/S (STN)	No	4mm²	#12	White	Single core insulated*
Test lead (chamber) - D/S (CUSTOMER)	No	4mm²	#12	Blue	Single core insulated*
Test lead (chamber) - U/S bond (WSL)	Yes	16mm²	#6	Black	Single core double insulated (SDI)**
Test lead (chamber) - D/S bond (CUSTOMER)	Yes	16mm²	#6	Blue	Single core double insulated (SDI)**
Test lead (piping)	No	4mm²	#12	Black	Single core insulated*
Test lead (casing)	No	4mm²	#12	Green	Single core insulated*
Reference electrode	No	2.5mm²	#14	Yellow	Single core insulated*
DC Coupon (carbon steel)	Yes	2.5mm²	#14	Red or black	Single core insulated*
AC Coupon	Yes	2.5mm²	#14	Green	Single core insulated*
Pipe Joint bonding cable****	Yes	16/25/35mm²	#6/#4/#2	Black	Single core double insulated (SDI)**

* Single core insulated = XLPE insulation material
** Single core double insulated = XLPE insulation material and PVC jacket material
*** Color depends on anode type
**** Cable size depends on pipe size

4.2.5 Cable connections

4.2.5.1 Connections

a) Above ground and chamber connections can be completed utilizing tapped, bolted weld lug, welded bolt or thermite weld connections. Refer to drawing 2001979.091 for additional information.

b) All buried pipe connections shall be completed using exothermic welds (thermite weld).

- Thermite weld equipment and materials shall be specifically designed by the manufacturer for weld surface and application and shall be properly sized for the cable size used.
- Thermite weld materials shall consist of graphite moulds, weld metal, adapter sleeves and igniting tools
- Thermite weld charge used for each thermite weld shall be 15 g
- The spacing between thermite welds shall be a minimum of 50 mm
- All thermite welds shall maintain the cable flush against the steel surface
- Preparation of pipe surfaces, thermite weld and coating of the completed weld and surrounding exposed pipe surfaces shall be in accordance with project documentation, the coating manufacturer, and the thermite weld manufacturer's procedures
- Thermite weld manufacturer:
  - nVent, Erico Cadweld

  - Hubbell, thermOweld

a) Cable and connections shall be tested to ensure continuity and condition prior to recoating connection and backfilling.

b) Test station wire connections:

- Test station terminal lugs shall be one-hole, compression terminal lugs (eyelet) for 6.35 mm (0.25 inch) bolt size

4.2.5.2 Connection coating

a) All pipeline connections shall be coated with an approved and compatible coating.

b) For buried thermite weld connections, follow Watercare Repair Procedure (refer to Section 5.2.11).

c) For non-buried connections in chambers and above ground, recoat connection area with Polyken 937 brushable mastic.

4.2.6 Cable labelling

a) All cables shall be labelled using Grafoplast system.

4.2.7 Cathodic protection test stations

a) Four (4) main types of test stations:

- Standard monitoring (MTP)
- Interference/foreign crossing (IFTP)
- Isolation/bonding (ISOTP/BTP)
- Cased Crossing (XTP)

b) The enclosure ordered shall be as specified in the design or if not specified shall suit the site conditions, be sufficiently vandal proof, include non-conductive or insulated mounting plates and be of a suitable size to accommodate the required fittings.

c) Test station terminal lugs shall be 6mm (0.25”) bolt size.

d) Ordering information (Test Station Type Order Code / Detail Supplier):

- Ecopillar EP0WSLSTD Ideal Electrical
- TUD pit Watercare Std TUD pit Ideal Electrical
- Flush Fink Black Cathodic Protection New Zealand Ltd
- Big Fink Dark Green Cathodic Protection New Zealand Ltd

4.2.8 Test box concrete

a) Poured concrete for the flush-mounted test station slabs shall be ready-mix conforming to the following standards:

- NZS3101
- NZS3109
- NZS3112

b) Portland cement shall be Type 1

4.2.9 Shunts for current measurement

a) Issued with a certificate of calibration.

b) Clearly marked with calibrated resistance.

c) 0.1 ohm (2 A capacity) for galvanic anode cables.

4.2.10 Switches for manual interruption of bond current

a) Rated for minimum twice the design current.

b) Normally closed.

c) Momentary action.

d) IP68 rated when located underground, IP56 when located above ground. Protection can be provided by installing the switch within an appropriately rated enclosure and using appropriate glanding.

e) Rated for 1,000,000 cycles.

4.2.11 Reference electrodes

a) Can be zinc or copper

- Zinc: Shall be Anode Engineering AEZR-1, or equivalent
- Copper/Copper-Sulphate

b) Shall be pre-packaged with gypsum bentonite backfill enclosed in a cotton or calico bag.

c) Designed for use as a permanent buried reference electrode.

d) Supplied with calibration certificate.

e) Rated for operation for longer than 30 years.

4.2.12 Cathodic protection – electrical probes and corrosion coupons

a) Corrosion coupons shall be Rohrbak Cosasco Systems; Smart Test Station ER Probes. Ordered as 'foot only,' to be installed with the specified test station.

- Normal installation is without an in-built reference. Ordering code is:
  - STF-1-LL, where LL is the length of cable in feet, 1 metre = 3.3 feet
- Where the design specifies supply with an in-built reference the ordering code is:
  - STF-0-LL, where LL is the length of cable in feet, 1 metre = 3.3 feet

4.2.13 Cathodic protection flange insulation kits

a) Whether a flange gasket is required and whether it is to be potable or wastewater rated.

b) Number of full-length sleeves and washers (double washer set).

c) Mylar or G-10, or better, sleeve and washers and inner and/or outer diameter.

d) Sleeve length enough to overlap midway into both steel washers (full length sleeves).

4.2.14 Cathodic protection monolithic insulation joints

a) The insulating coupling materials shall include an insulating gasket and a "full boot" plastic tubular insulator inside the middle ring to prevent contact of pipe-ends isolated from one another. Insulation shall be provided to both ends of the coupling.

b) The insulating corporation valves (stops) shall consist of a brass fitting with a nylon insulator.

c) The insulating unions shall consist of a high-test, air-refined malleable iron nut and body with an integral moulded nylon insulator. Unions are to be used for above-ground locations only.

4.2.15 Insulating couplings, corporation valves, or unions

a) The insulating coupling materials shall include an insulating gasket and a "full boot" plastic tubular insulator inside the middle ring to prevent contact of pipe-ends isolated from one another. Insulation shall be provided to both ends of the coupling.

b) The insulating corporation valves (stops) shall consist of a brass fitting with a nylon insulator.

c) The insulating unions shall consist of a high-test, air-refined malleable iron nut and body with an integral moulded nylon insulator. Unions are to be used for above-ground locations only.

4.2.16 Cathodic protection power supplies

a) Meet New Zealand electrical regulations for extra low voltage DC power sources – including technician access to terminals for installation of a portable interrupter.

b) Be robust and rated for 50 years operation.

c) Include a RS485 MODBUS RTU port.

d) Include a GPS synchronised interrupter, operable via the RS485 port.

e) Have a minimum of the following output control options:

  i) Constant current, and

  ii) Constant pipe potential (Auto-Control)

f) Be continuously adjustable down to ≤1% of maximum current.

g) Output smoothed DC ripple to be ≤5% of output voltage.

h) Include facilities for installing a portable interrupter.

i) Weather resistant cabinet.

4.2.17 Junction box

a) Shall be suitably sized to allow all cables connections and components to fit properly while allowing maintenance and readings as required.

b) Shall be installed at the end of the ground bed location.

c) Shall facilitate terminations of the positive header cable from the CP power supply (also known as CP transformer rectifier units, TR or TRU) and the anode tails. 0.1-ohm test shunts shall be installed between the anode tails and the positive header cable to allow individual anode current measurements.

d) Shall be lockable and of minimum Stainless steel 304 materials (316 SS is also acceptable).

e) All terminations shall be isolated from the outer Junction Box (JB) housing via an insulated mounting plate.

f) All anode tail terminations shall be isolated from each other at their initial termination.

g) Shall be mounted on a suitable post, minimum ~1 m above ground level.

4.2.18 Conduit

a) All cables shall be installed in HD PVC electrical conduits and shall meet the more stringent requirements of AS/NZS 61386.21 or Watercare Standards.

b) Suitable cable adapters, conduit entries, end caps and / or sealant shall be utilised to prevent water entry into conduit system.

c) All conduits shall be suitably sized to accommodate the number of cables required to be installed. The minimum size shall be 32 mm diameter.

4.2.19 Cased crossing

4.2.19.1 Spacers

a) Casing insulators (spacers) shall contain polymer plastic runners that are a minimum 2 inches wide.

b) Casing insulators shall be sized in accordance with the casing insulator manufacturer's recommendations to centre the pipe within the casing.

c) The number of casing spacers and the distance between them shall be in accordance with the recommendations of the manufacturer of the casing spacers, however a minimum of three casing spacers (one at each end and one at the midpoint of the pipe) shall be required for each section of pipe.

d) The insulated casing spacers shall be sized by the pipeline designer to be capable of supporting the weight of the pipe filled with water.

4.2.19.2 End seals

a) Casing end seals shall be made of 3.2mm (1/8”) thick rubber and shall be full conical in shape.

b) The casing end seal shall be configured to the exact dimensions of the piping and casing.

c) The rubber end seals shall fully enclose the end of the casing and shall be watertight.

4.2.20 Remote monitoring units (RMU)

a) The adjustable DC power supplies will be coupled with remote electronic surveillance and monitoring systems via satellite or a GSM communications system.

b) Weilekes MiniTrans Plus, or equivalent will be utilised to monitor and adjust the DC power supply’s output.

c) Mobiltex can be considered to monitor and remotely interrupt the DC power supplies (direct power with RMU3) as well as monitor and/or interrupt test stations (10-year battery life with RMU1), including but not limited to bonds, foreign crossings, ER probes and coupons via cellular or satellite communication.

4.2.21 Polyethylene mesh separator pad

a) The mesh separator pad shall be a flexible polyethylene/PVC mesh pattern webbing pad, with no cathodic protection shielding properties. The pad shall be manufactured for the purpose of external pipeline protection.

4.2.22 Repair of damage to pipe coating

a) The pipe shall be properly prepared, cleaned and dry prior to the application of coating.

b) Pipe shall be primed using Polyken 1027.

c) Repair area over primer with Polyken 942- 955 combination tape.

d) Where a small area of wrapping has been damaged, the use of Canusa Wrapid Bond visco elastic tape is acceptable.

e) Refer to Section 5.2.11 for additional information on the requirements for coating repair.

5. Corrosion control construction

5.1 General

5.1.1 Contractor responsibilities

a) Be responsible for the procurement and supply of all materials (unless free issue by Watercare), equipment, labour, installation, testing and commissioning in accordance with this Specification and associated documents, as well as applicable electrical codes, standards and manufacturer's instructions.

b) Prepare all prestart documentation (HSSE, Quality, Environmental, Contractual) as defined in the contract.

c) Prior to manufacture and/or purchase, submit to the Engineer for review details of all materials, components and equipment proposed to be used for the system (e.g. manufacturer/supplier technical data sheets, compliance certificates/evidence of compliance with relevant standards and specifications, Materials Safety Data sheets (MSDS's) where applicable).

d) Obtain up-to-date service records and arrange for the location, confirmation and marking out of all the buried services/utilities on site before commencing any excavation.

e) All costs associated with the identification and location of buried foreign services (oil & gas, water, electricity and communications relating to CP infrastructure).

f) The restoration of lands to the satisfaction of the responsible authority.

g) Be responsible for identification of and obtaining Traffic management where required.

h) Prepare and submit for the Engineer, a Quality Inspection and Test Plan (ITP).

i) The pre-commissioning testing of all components of the system in accordance with the cathodic protection Inspection and Test Plan (ITP).

j) Commissioning of the CP system and subsequent commissioning report including obtained test data, system components and materials information, and "As-built" drawings of the system.

k) All work shall appear neat and professional. The system shall be installed with consideration given to aesthetic value of the location and comply with Watercare QA/QC requirements.

l) All material and equipment shall be installed and used in accordance with the manufacturer's recommendations and safety procedures, as well as details outlined in project drawings.

m) Ensure extreme care taken to ensure no damage to the cathodic protection system or materials until and after installation is complete. Contractor responsible for replacement of any damage that occurs prior to final turnover, at no cost to Watercare.

n) Confirm all measurements and dimensions.

5.2 Installation

5.2.1 Anode ground beds

a) Anodes shall not be lowered using their cable tails or dropped into the trench.

b) Care shall be taken to protect the anode and cable prior to, and during all aspects of installation.

c) Should the anode or the anode cable tail insulation be damaged during supply, storage or installation, the anode shall be removed, and the complete assembly (anode and cable tail) replaced at the contractor's expense.

d) The cable between the anode and above ground TR unit, junction box or test station shall be continuous. Mid length splices shall not be permitted.

e) Following installation but prior to termination of the pipe cable the Contractor shall inspect the insulation to ensure it is free from nicks and cuts that may be detrimental to the longevity of the system. Cables found with such defects shall be replaced for the whole length at the cost of the contractor.

f) Care shall be taken during backfilling operations to ensure undue stress is not exerted on the cables or conduits, or damage caused to insulation of cables.

g) The contractor shall attempt to reinstate the backfill material to approximately its original layer (i.e. the top 1m layer gets reinstated to the top 1m). Any large rocks (larger than 50mm) shall be kept out of the backfill closest to the coke backfill or anodes.

h) Anodes shall be located as per the drawings.

5.2.1.1 Impressed current ground beds

a) Shall be hand placed and centred into the calcined coke backfill.

b) Installed calcined coke backfill shall be lightly compacted by hand only.

c) Above the coke backfill, the native soil can be reinstated. Specific care must be taken when reinstating and compacting 300mm above the coke backfill to prevent disturbance of the material.

5.2.1.2 Galvanic anode ground beds

a) Prepackaged galvanic anodes shall have all plastic shipping covers removed from the anode (the prepackaged cotton bag or prepackaged cardboard box shall not be removed) prior to soaking or installation.

b) Anode shall be pre-soaked as per manufacturer's instructions prior to backfill. Prepackaged cotton bag anodes can be inserted into a bucket of water and left to absorb the water, whereas prepackaged cardboard tubes require water to be poured over them while in place to ensure anode integrity.

c) Anodes shall be installed as per design drawings in the bottom corner of pipe trench resting on native soil. Where anodes are installed outside the trench it shall be in native soil

d) Anodes shall not be laid on scoria, bedding sand or other free draining material.

e) The anode bed may be connected temporarily to ensure operation. Following the check, the anode bed must be disconnected until pre-commissioning has been completed or as otherwise specified by Watercare.

5.2.2 Cables and connections

a) All cable connection methods shall be made in accordance with project drawings, Watercare standard drawings and manufacturer's directions and recommendations, using the proper combination and size of equipment for the pipe and wire size being connected.

b) Cables shall be installed as continuous single length cables without splices or joints.

c) For buried thermite weld connections, follow Watercare Repair Procedure (refer to Section 5.2.11).

d) Buried connections shall be thermite weld, except where a foreign service owner specifies otherwise for connections to their service or structure.

e) All welding/connection materials and equipment shall be the product of a single manufacturer.

f) Personnel applying the connection shall be properly trained and competent in the equipment and application method and shall use appropriate safety measures.

g) Negative bonds shall be visually inspected by Watercare's representative. The contractor shall provide completed QA/QC documentation to Watercare representative demonstrating that all requirements have been met.

h) Watercare representative shall be present to witness and inspect the final installation prior to backfill.

i) All pipe connections to foreign or third-party structures shall be completed once notification and approval to third-party owner has been completed. Connections shall be undertaken only in presence of third-party owner representative unless specified in writing by third-party owner.

j) All pipe connections to foreign or third-party structures shall be made in chambers or above ground unless otherwise noted.

k) All connections shall be adequately coated with a compatible and approved coating.

l) All buried cables shall be installed in PVC conduits at a minimum depth of 600 mm from ground level and a cable marking tape or board installed 200 mm above the conduit in accordance with client standard procedures and requirements.

m) Following installation but prior to termination, the contractor shall test the insulation resistance and continuity of the cables to ensure insulation is free from nicks and cuts that may be detrimental to the longevity of the system. Cables found with such defects shall be replaced for the whole length.

n) All cables shall be labelled at all end connection points using Watercare approved labelling system.

o) Un-welded pipe joints within buried cathodically protected sections of pipeline shall be bridged with a continuity bond cable.

p) The bond cable shall be as short as practicable to reduce voltage drop and located such that there are no mechanical joints between the connection point and the pipe being bonded.

5.2.3 Test stations

a) Install test stations at the locations indicated on drawings.

b) Test boxes/stations/posts are to be located directly over the pipeline except in areas that would place the test station in a roadway. Locate those test stations three feet back-of-curb in a non- paved area adjacent to roadway.

c) Attach test wires as indicated using the proper method, as well as proper material and equipment for the wire size and respective pipe material.

d) All test station wires shall be routed (horizontal trench) a minimum of two feet below finished grade. Maintain sufficient slack in the test wires so that the wires can extend a minimum of 457 mm (18 inches) from the test box or test post.

e) The test boxes shall be set in poured concrete, with a total concrete dimension of 600 mm x 600 mm x 100 mm thick reinforced with D12 rebar (Grade 500-E). The flush mounted test box lids shall be free of concrete and not cemented over.

f) Where test leads are installed horizontally outside of the pipe trench, the test lead wires shall be routed under the roadway to the test box or test post through minimum 25 mm (1 inch) diameter PVC conduit. Install cable warning tape 300 mm (12 inches) above conduit.

5.2.4 Reference electrode

a) Install reference electrodes at the test stations indicated on drawings.

b) Native trench material shall be used to backfill the reference electrode for a minimum of six inches.

c) Prior to installation, remove the plastic shipping cover from the reference electrode. The cloth bag containing the special backfill shall remain intact.

d) Prepackaged reference electrode shall be thoroughly soaked prior to backfill.

e) Reference electrode to remain a minimum of 5 m (15 ft) from nearest galvanic anode.

5.2.5 Corrosion coupons and electrical resistance probes

a) The test station foot shall be buried in the pipe trench in the same bedding and surround material as the pipe, facing down towards the pipe invert.

b) Wherever practicable a drop tube shall be provided. Configuration options in order of preference are:

- Single unit with probe foot directly below test station, with a drop tube in the test station connected to the foot
- Probe foot with drop tube and flush access box buried separately near test station
- Probe foot buried with permanent zinc reference (supplied with the probe) and no

drop tube

c) The manufacturer's installation methodology shall be followed, except that the fill in the drop tube shall comply with Section 5.3.7.3.

5.2.6 Isolating flanges, couplings and corporation valves

a) Refer to Watercare general mechanical installation standard for flange installation requirements.

b) Isolating flanges, isolating couplings, and isolating corporation valves shall be installed as shown on the specific drawings.

c) The Contractor shall carefully align and install the isolating components according to the isolator manufacturer's instructions. Before backfilling of buried isolators, the Contractor shall test across each isolator for electrical isolation. If the isolator is not properly isolated, the Contractor shall, at their expense, repair or replace all defective components. Isolation that passes for effective isolation during the pre-backfill test but does not render positive isolation results during the acceptance testing must be repaired by the Contractor at no additional cost to the Owner. The Contractor shall provide the Engineer a minimum notice of one week prior to the conducting the testing of the isolation.

d) All buried isolation devices shall be fully coated with an approved and compatible coating solution for a minimum of 300 mm (12 inches) on either side of the device. The isolator shall be coated after verification of proper electrical isolation.

e) Isolating joints shall have lightning arrestors installed across isolating joint where required.

- If polarization cell (PCR) or equivalent is specified, a lightning arrestor shall be installed as well.
- Where the isolation joints are adjacent to a valve, the arrestor shall be connected to the outside pipe flanges, not to the valve body.

5.2.7 Conduit

a) All cables shall be installed in HDPVC conduits at a minimum depth of 600 mm from ground level and a cable marking tape or board installed 200 mm above the conduit in accordance with AS/NZS 61386.21 or Watercare standard procedures and requirements.

b) The CP Contractor shall confirm the required length of conduit by on site measurement prior to ordering conduit materials.

c) Suitable cable adapters, conduit entries, end caps and / or sealant shall be utilised to prevent water entry into conduit system.

d) All conduits shall be suitably sized to accommodate the number of cables required to be installed.

5.2.8 Casing spacers and end seals

a) Each length of pipe within the casing shall be supported and electrically isolated from the casing using insulating spacers (supports). The number of casing spacers and the spacing between them shall be in accordance with the recommendations of the casing spacer manufacturer but no fewer than three (one at each end and one at the midpoint of the pipe) shall be used to support each section of pipe. The insulating spacers shall be of sufficient dimension to centre the carrier pipe within the casing and to serve as runners to slide the carrier through the casing.

b) After the carrier pipe is installed within the casing, the Contractor shall test the electrical isolation between the casing and the carrier pipe. If the carrier pipe is not electrically isolated from the casing, the Contractor shall, at no cost to Watercare, remove the carrier pipe from the casing, replace all defective or damaged casing spacers and reinstall the carrier pipe in the casing. This process will continue until the casing is tested to be electrically isolated from the carrier pipe. Pipe to casing isolation that passes for effective isolation during the pre-backfill test but does not render positive isolation results during the acceptance testing must be repaired by the Contractor at no additional cost to Watercare. The Contractor shall provide the Engineer a minimum notice of one week prior to the completion of the installation of piping within a casing.

c) Install casing end seals at both ends of the casing after the casing isolation has been confirmed as effective. The casing end seals shall be installed in accordance with the written instructions of the end seal manufacturer.

5.2.9 Cathodic protection power supplies (TR)

a) TRs shall be mounted on a concrete plinth that complies with the concrete structure requirements in Watercare's general civil construction standard and the following:

- Extend beyond the side of the TR cabinet by a minimum of 100mm
- Concrete thickness of minimum 150mm and have 12mm reinforcing at mid-level of the plinth
- Sloped from the centre of the plinth to 1:100 – if the TR base is an open frame
- Sloped from the side of the TR cabinet of 1:100 – if the TR base is enclosed and sealed against water ingress
- Provided with minimum 4x 50NB uPVC penetrations for earth peg and cables

5.2.10 Earthworks

***Note**: This section shall be read in conjunction with Watercare's General Civil Construction Standard (ESF-600-STD-301 / CG).*

a) All trench excavation to be undertaken in accordance with Watercare requirements or project specific specification.

b) Pavement and surface reinstatement must comply with roading authority requirements.

c) The Contractor shall obtain all permits and approvals necessary to perform the excavations.

d) Shall avoid any disruption to public and private areas and access to the maximum extent possible. Any interruptions to the public shall be confirmed with the Engineers prior to mobilization.

e) Shall have all existing buried services located and marked prior to any earthworks occurring, and for the duration that any earthworks could potentially occur at that location. Any utilities or structures damaged by the contractor shall be the sole responsibility of the contractor to repair at no cost to the owner.

f) All surfaces disturbed to enable installation of CP infrastructure shall be reinstated to pre-works condition following installation. The contractor will be responsible for all maintenance of all disturbed surfaces (roads, curbs, footpaths, fields) for the duration of the defect liability period.

g) Pre work and Post work photographs shall be taken of each site from multiple angles for future reference.

h) All traffic control, in accordance with appropriate standards and project specifications, is the responsibility of the Contractor.

5.2.11 Repair of damage to pipe coating

5.2.11.1 Preparation

Exposed exterior metal shall be thoroughly cleaned of grease, rust, mud, loose or burnt paint or other foreign matter. The steel surface shall be prepared by cleaning to SP3 or SP6 as required. Visible oil and grease shall be removed with a suitable solvent. The pipe surface shall be free of dust and flash rust and thoroughly dry before application of primer. Kerosene shall NOT be used for cleaning the pipe surfaces.

SP-1 Solvent cleaning

Removal of all detrimental foreign matter such as oil, grease, dirt, soil, salts, drawing and cutting compounds, and other contaminants from steel surfaces by the use of solvents, emulsions, cleaning compounds, steam or other similar materials and methods which involve a solvent cleaning action.

SP-3 (St 3) Power tool cleaning

Removal of all rust, scale, mill scale, loose paint and loose rust by power wire brushes, power impact tools, power grinders, power sanders or by a combination of these methods. The substrate should have a pronounced metallic sheen and also be free of oil, grease, dirt, soil, salts, and other contaminants. The surface should not be buffed or polished smooth.

SP-6 (Sa 2) Commercial blast cleaning

Removal of mill scale, rust, rust scale, paint, or foreign matter by the use of abrasives propelled through nozzles or by centrifugal wheels. A commercial blast cleaned surface finish is defined as one from which all oil, grease, dirt, rust scale and foreign matter have been completely removed except for slight shadows, streaks, or discolouration’s caused by rust stain, mill scale oxides or slight, tight residues of paint or coating that may remain. If the surface is pitted, slight residues of rust or paint may be found in the bottom of pits. At least two-thirds of each square centimetre of surface area shall be free of all visible residues and the remainder shall be limited to the light discolouration, slight staining or tight resides mentioned above.

a) Bevel the edge of the existing coating and remove any loose coating.

b) The Polyken 1027 primer is to be thoroughly mixed and must not be thinned or diluted. Apply a complete coat of primer to the whole of the bare steel surface and to 150mm over the existing wrapping. Primer must be tacky to touch immediately before the wrapping tape is applied. If the primer has hardened, the whole surface must be recoated and allowed to become tacky before proceeding.

5.2.11.2 Coating repair

The clean dry area is to be primed using Polyken 1027, overlapping the damaged area by a minimum of 150mm. Allow the primer to become tacky to the touch before applying Polyken 942- 955 combination tape.

Where it is practical, apply full circumferential wrap as for coating of an external joint.

Where a small area of wrapping has been damaged, apply strips of Canusa Wrapid Bond visco elastic tape in accordance with the manufacturer's specification. Firmly push the tape into the damaged area and overlap by a minimum of 100mm onto sound wrapping. Ensure that there are no air bubbles under the repair tape. Apply trimmer strips of tape over the ends of the repair tape to seal the repair area.

5.3 Testing and pre-commissioning plan

5.3.1 Pre-commissioning testing

a) The contractor shall undertake pre-commissioning testing of all components of the system, including but not limited to:

- Inspect components and layout conform with specification and drawings, including but not limited to labelling, cable colours and cable sizes.
- Inspect cabling – housing and insulation condition as well as cable terminations (secure).
- Inspect JB – mounting post (stability and condition), lid and seal.
- Inspect connections/terminations – all connections to the pipeline (secure), maximum resistance of exothermic connections to the pipeline prior to backfilling shall be 0.1 Ohms, coating of welds / connections to pipes, route.

b) The contractor shall supply the results to the Engineer prior to system commissioning.

5.3.1.1 Isolation joint testing

a) For pre-installation and post-installation testing refer to Section 13.6.1 of the Watercare General Electrical Construction Standard.

5.3.1.2 Cathodic protection power supplies (TR)

a) For pre-installation and post-installation testing refer to Section 13.6.2 of the Watercare General Electrical Construction Standard.

5.3.1.3 Cable connection to pipework

a) For pre-installation and post-installation testing refer to Section 13.6.3 and 13.6.4 of the Watercare General Electrical Construction Standard

5.3.2 Final inspection

a) All components of the CP system shall be inspected following completion of the installation program and "As Built" Drawings supplied by the contractor along with an installation report that includes all appropriate measurements including those required in this specification.

b) All defective or improperly installed systems or components shall be replaced by the Contractor at no additional cost to the Watercare.

c) Recommended maintenance plan that consists of maintenance tasks and frequencies in a format that is acceptable to Watercare for upload into the EAM maintenance system.

5.3.3 Clean-up

a) The Contractor shall be responsible for clean-up and removal of all debris, extra material, and equipment utilised for installation of the corrosion control/corrosion monitoring.

5.3.4 Qualifications and personnel

a) The installation, testing and reporting of all CP related works shall be performed by or under the direction of suitably qualified corrosion technicians with experience and qualifications in the installation and testing of cathodic protection systems. Work shall be undertaken under the direction of a qualified corrosion technologist accredited by either the Australasian Corrosion Association or NACE/AMPP and be acceptable. Alternatively, Watercare may approve the installation of CP system components by suitably qualified electrical and instrumentation technicians.

b) The contractor shall supply details of the personnel who are to be employed on the project to the Engineer at tender stage and confirmed at commencement of the contract. The contractor shall notify the Engineer of any proposed changes in personnel to be employed on the project and such personnel shall not commence work on the project without the permission of the Engineer.