DAMWATCH ENGINEERING BEYOND THE SURFACE

Wrights Road Storage Ponds

Technical Specification

26 October 2021

Prepared for Waimakariri Irrigation Limited

Issue 8

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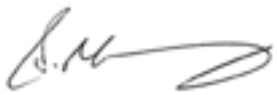
Approved for Issue	Steve McInerney	Signature:	

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1.0 General

1.1 Site Location and Scheme Description

Waimakariri Irrigation Ltd (WIL) owns and operates the Waimakariri Irrigation Scheme, which was built in 1997. The scheme mainly follows the alignment of the stock water scheme, which was first constructed around 1890. Presently the scheme irrigates 18,000 ha between the Waimakariri River and Ashley River in North Canterbury.

WIL plan to construct off-stream irrigation water storage ponds to supplement the existing irrigation demand during periods when supply is restricted due to low flow in the Waimakariri River.

The scheme will provide two main storage ponds and a smaller pond to manage flow to the races (‘the tub’), with a combined capacity of 8.2 million cubic metres.

This specification covers construction of the storage pond intakes, storage ponds, outlets, appurtenant structures and control system.

1.2 Construction Contractual Arrangement

The project will be implemented using a Design, Build, Finance and Transfer (DBFT) Agreement between Rooneys Earthmoving Ltd (REL) and Waimakariri Irrigation Ltd (WIL). REL will be responsible for the design, construction and funding of the project, with WIL being the Principal and irrigation scheme Owner after transfer. Transfer from REL to WIL will take place when the ponds are certified, commissioned and approved for operation.

Accordingly, this specification sets out the materials and construction standards required to meet the design requirements set by the Designer Subcontractor to REL, Damwatch Engineering Ltd (the Designer).

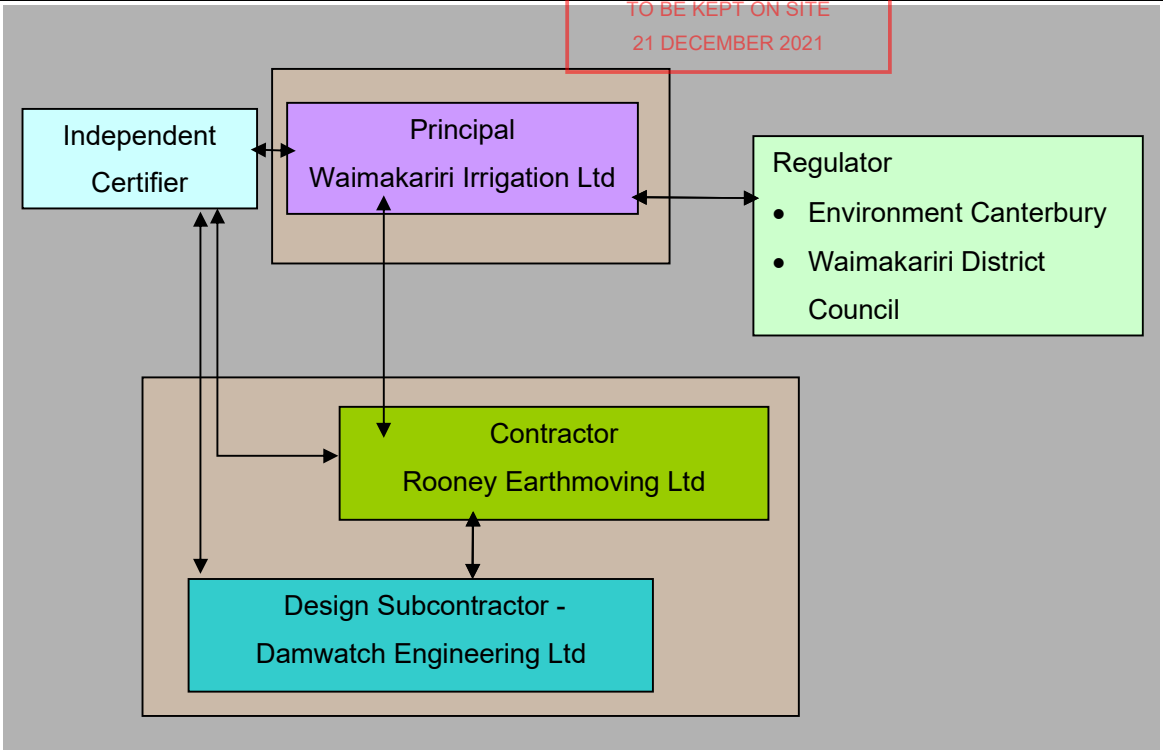

Figure 1: Contractual Relationship for Wrights Road Storage Ponds

The Designer shall make such design changes as necessary during construction to achieve the necessary level of safety and performance and ensure consent conditions are met. Situations can arise particularly during opening up of the foundations, where the need for changes becomes evident. Rooney Earthmoving Ltd as the Contractor shall appoint a responsible experienced Project Engineer, who will liaise with the Designer, as required.

The Designer shall provide full-time design representation / QA supervision on site during the construction of the ponds, in accordance with the Building Consent (BC), Resource Consent (RC) and the NZDSG. The design representative shall be suitably qualified and experienced and will be responsible for inspecting and approving works on a day to day basis.

The Contractor shall ensure documentation of Quality Control systems is implemented in accordance with the consents. Regular audits shall be carried out by the Designer and the Independent Certifier, as discussed in Section 1.3.

Sampling and testing shall be carried out as construction progresses to set appropriate construction parameters for earthworks and confirm as-built construction records.

1.3 Roles and Responsibilities

The roles and responsibilities for all parties involved in the contractual relationship are outlined below.

<u>The Principal: WIL</u>

- Outline the Principal's Requirements.
- Meet the obligations of the Resource Consent.
- Appoint the Independent Certifier.
- Appoint a Principal's Representative to discuss and agree on any variations.
- Review and approving any design changes during construction.
- Liaise with ECan, Independent Certifier and REL.

<u>The Independent Certifier: TBA</u>

- Provide independent review and reporting of the Contractors compliance with design requirements and the RC conditions.
- Review any proposed design changes during construction and provide objection of non-objection commentary.
- Certify all items requiring certification in the RC, as outlined in the table below.
- Liaising with WIL, REL and Damwatch.

The table below outlines the RC conditions relevant to construction and commissioning that require certification from the Independent Certifier and the minimum timeframe for submitting the certification to ECan.

Clause	Items requiring certification from Independent Certifier	Minimum Timeframe
CRC120610		
6(b)	Construction Management Plan (CMP) meets objectives and performance standards (CMP to include QA and QC Plan, Dust Management Plan, Erosion Sediment Control Plan).	3 months prior to construction
13	QA and QC Plan is being complied with at all times	Throughout construction (QA/QC Plan needs to be approved in writing prior to construction)
21	Control system is capable and installed to enable the provision of set warnings	3 months prior to the installation of the system
23	Water Storage Commissioning Plan meets objective and performance standards	3 months prior to first filling
26	Confirming that the structure has performed in accordance with the commissioning plan	On completion of commissioning
32, 33	DSMP and EAP is appropriate and robust and meets NZSOLD guidelines	3 months prior to first filling
41 42, 43	EEP meets objectives and performance standards Testing emergency warning systems described in the EEP.	3 months prior to first filling
44, 45	As-built construction of the dam is in accordance with good engineering practice i.e. NZSOLD, Building Act 2004, CMP,	2 months before first filling

	QA/QC Plan. No filling until as-built certification is complete.	
46	All certificates to be submitted to RMA along with copies of the DSMP, EAP, EEP and Water Storage Commissioning Plan.	2 months before first filling
50	QA reviewer to provide a report to Consent holder, Designer, Contractor and RMA summarizing the results of the QA/QC information received, the supervision of the QA on site, the QA/QC plan and the EAP with an opinion on compliance with the tech spec and RC.	3 months intervals during commissioning
51(b)	Review EAP and EEP	Bi-annually or within 3-months following an event
57	As-built plans, producer statements and completion report	Within 12 months of construction activities ceasing
63	Water Quality Management Plan	30 working days before first filling
CRC122899 - dust		
10	Instrument to measure TSP concentrations and a meteorological monitoring station to be installed.	1 month prior to construction
CRC122900 – Stormwater Discharge		
12	Appropriate erosion and sediment control measures have been constructed in accordance with the plan	1 month prior to commencement of bulk earthworks for the site.

The Contractor: REL

- Deliver the project in accordance with the Consents.
- Prepare the Construction Management Plan (CMP), including the:
  - QA and QC Plan
  - Dust Management Plan
  - Erosion and Sediment Control Plan
  - Water Quality Management Plan
  - Traffic Management Plan
  - Site Safety Plan.
- Construct the project in accordance with the design, technical specification and drawings.
- Implement construction management systems to meet the consent conditions.
- Document construction activities and testing to ensure quality as-built information.
- Complete the PS3 Producer Statement post construction.
- Liaise with WIL, Independent Certifier and Damwatch.
- Transfer quality records and as-builts to WIL when ownership of the asset transfers to WIL.

Design Subcontractor: Damwatch

- Design the permanent works in line with the performance requirements for the Contractor and in accordance with the consent conditions.
- Provide off-site technical support to the Contractor, as required.
- Provide full time design representation / QA supervision during construction,
- Inspect and approve construction activities, including but not limited to the following critical construction stages, as outlined in the Building Consent:
    - Each pipe penetration through a high PIC embankment following installation of pipe and bedding prior to being backfilled.
    - Surface preparation for the liner at the first pipe penetration to be constructed prior to placement of the liner.
    - Completion of construction.
    - Any time where unexpected conditions are encountered.
- Provide construction QA support, as required to meet engineering certification requirements and/or those of the Consents.
- Preparation of:
    - Pre-commissioning procedures/Commissioning Plan
    - Construction report
    - Relevant producer statements
    - Commissioning report
    - Dam Safety Management Plan (DSMP), including Emergency Action Plan (EAP) and Emergency Evacuation Plan (EEP).
- Review Operations, Maintenance and Surveillance Plan (prepared by Contractor).
- Liaise with REL and with Principal's Representative during construction to clarify/change any design/quality issues.

1.4 Nature and Extent of Work

The major components of the works consist of provision of the following elements:

- Intake and outlets including the control gates;
- Two pump stations, one near the intake and the other near the east end of the Tub;
- Excavation and processing of suitable material to enable construction of two storage ponds;
- Embankment construction for the Tub and two storage ponds;
- Low level outlets / inlets between ponds and the Tub;
- One service, three emergency spillways and one fuseplug spillway;
- Two flow measurement Crump weirs and ultrasonic flow measuring equipment on outlet G6, along with all associated structures, plant and equipment; and
- Automatic control system to be designed, supplied and installed by the National Institute for Water and Atmosphere (NIWA).

1.5 Drawings

The drawing numbering format is as follows:

Job Code/Drawing Series/Drawing Number, e.g. WIL1125/30/01. The job code and drawing series are the same on all drawings.

The drawing numbers are allocated as follows:

Overall project layout	1 – 100
Inlet and outlet structures, inter-pond structures	101 – 200
Mechanical Equipment and Installation	200 – 230

The current drawings applicable to this project are included separately. The drawings will be supplemented and revised throughout the period of construction as required.

The Contractor shall maintain an up to date drawing register as part of the quality control system.

Prior to commissioning the Contractor shall survey and locate the final pond layout, location of all appurtenant structures including alignment of penetrating conduits, electrical supply and instrument cables for preparation of as-built drawings.

1.6 Applicable Standards

Applicable Standards means the standards, codes of practice, guidelines and references to be adopted for design, execution and completion of the Works, as are pertinent, consistent and appropriate to the design and/or construction of a particular element of the Works.

The Works shall be designed, manufactured, constructed, commissioned, tested and completed in compliance with Applicable Standards.

Generally New Zealand/Australian Standards, International (ISO) IEC Standards shall be used in preference to standards from other countries. In the absence of relevant New Zealand/Australian, ISO or IEC Standards, other relevant International Standards may be used subject to the Design Subconsultant's approval.

Where New Zealand Standards are referred to in the Specification, the Contractor shall read it as "NZS…. or Australian equivalent" and shall be construed equally as reference to an equivalent one.

The requirements of this specification are to apply unless referred to a specific standard. If nothing is stated, then the Contractor shall apply the following hierarchy:

1. AS/NZ standards;
2. International Standards; and
3. Industry best practice and recommendation / guidelines (for example New Zealand Society on Large Dams Guidelines, American Petroleum Institute (API) guidelines).

1.7 Quality Plan

A Quality Plan as defined in Section 5.18 of the General Conditions of Contract shall be prepared by the Contractor.

All areas of critical importance to meet design intent and achieve embankment safety should be identified in the Quality Plan. Quality Plans shall be agreed between the Designer and Contractor prior to commencement of construction. The Quality Plan should also include key requirements for site inspection by the Designer including:

- Foundation preparation;
- Quality and consistency of key materials used in the works;
- Bedding, jointing, backfilling and protection of any penetrations through the embankment;
- Develop construction methodologies for key areas of construction, particularly compacted earthfill and relative sequencing of construction of pond embankments;
- Embankment construction;
- Installing, protecting and reading instrumentation;
- Installing embedded items for critical items of mechanical equipment including controls and backup systems;
- Adequate protection of the works during construction, including temporary works; and
- Commissioning.

The Quality Plan shall also include requirements for site inspection by a third party CQA (Construction Quality Assurance) inspector to carry out sampling and testing of the geomembrane liner.

As noted in Section 1.3, the full-time on site Designer's representative shall inspect critical construction stages, such as the foundation preparation, earthworks construction and placement of the geomembrane liner (see also Section 1.13).

1.8 Levels and Reference Points

All co-ordinates are to NZGD2000 Mount Pleasant Circuit 2000 and levels to mean sea level, from control Survey Mark B485, Lyttelton Vertical Datum 1937.

1.9 Construction Constraints

The ponds extend over an area of 120 ha and have a maximum water depth of 11 m.

The target volume and depth of the ponds are summarised as:

Pond	Approximate Wetted Footprint (ha)	Approximate Storage Volume (10^6 m^3)	Maximum Water Depth (m)
1	30	2.01	7.5
2	72	6.16	9.9
Tub		0.02	3.9
Total	102	8.2	

The pond embankments are set back from land boundaries and the adjacent roads as follows:

- Approximately 4 m setback from the western boundary; parallel to main race MR4;
- Approximately 5.6 m setback from northern and eastern road boundaries, parallel to Dixons Road (race R3) and Wrights roads respectively; and
- Approximately 20.5 m setback from the southern boundary to accommodate R2 and it is set back 8m from the northern edge of R2

The ponds are located on land previously purchased by WIL to accommodate the ponds. Accordingly, the ponds are located North West of the intersection of Dixons Road and Wrights Road; some 21 m above the Waimakariri River level. The design maximises the stored volume within the constraints of land area and construction cost. The design aim is to maximise the stored volume within the constraints of land area and minimise the construction cost. Hence some flexibility should be anticipated, within the envelope described above, on the final pond footprint constructed. Final pond layout will be described in the as built drawings and construction report.

1 in 100-year ARI flood maps produced by ECAN confirm that there is minimum flood risk at the construction site. Therefore, the Contractor shall adopt the 1 in 100-year flood risk as a minimum when planning construction activities described under Clauses 1.15 and 1.16.

1.10 Traffic Requirements

Prior to commencement of the works the Contractor shall prepare and submit to the relevant local and national authorities a Traffic Management Plan (TMP) that meets all applicable codes of practice, standards and guidelines. No work shall commence on site until the TMP has been approved by all applicable authorities.

The Contractor shall be responsible for operating the TMP, including any traffic control devices that are required (such as signs, cones, signals, flagmen, etc.). All such devices shall comply with all applicable codes of practice, standards and guidelines.

1.11 Hours of Work

Work is likely to occur from Monday to Saturday, from 7am to 7pm inclusive. Works shall not be carried out on Public Holidays.

1.12 Quality Control and Management

The Contractor shall establish and maintain project quality management procedures throughout the duration of the construction. These procedures shall meet the requirements of this Specification and/or relevant standards and include the following processes:

- Quality Planning: Identifying which quality standards are relevant to the project and determining how to satisfy them;
- Quality Assurance: evaluating overall project performance on a regular basis to provide confidence that the project will satisfy the relevant quality standards; and

- Quality Control: monitoring specific project results to determine if they comply with relevant quality standards and identifying ways to eliminate causes of unsatisfactory performance.

The final quality control documentation will form part of the Contractor's record of having completed the project to satisfy the needs for which it was undertaken and therefore meet design requirements.

Where this Specification requires the Contractor to maintain records, these are to form part of the final quality documentation for the project.

The Designer will be notified of all noncompliant test results. Noncompliance will signal a hold point and the following actions will be considered by the Designer:

1. Review construction methodology;
2. Review material type; and
3. Agree upon a solution.

Solutions shall be implemented by the Contractor with suitable engineering guidance as required.

In addition, competency of Rooney Earthmoving Ltd technicians to take soil samples and record NDM test results of the embankment materials shall be confirmed. They shall also log construction photographs and video footage of significant stages or at least once weekly. Sieve analysis shall be carried out by either Rooney Earthmoving Ltd technicians or sub-contracted.

1.13 Quality Control: Designer Inspections

The Designer shall be represented full time on site by a suitably qualified engineer with experience in specific preconstruction and construction control stages. The following are the key stages of the construction that require the Designer's attention and approval:

- Preparation of quality assurance and method statements;
- Preparation of the surface supporting the geomembrane both on the embankment slopes and the pond bottom;
- Preparation of QA/QC plans for the manufacture of Ecotech 500gsm filter cloth;
- Preparation of QA/QC plans for the installation of Ecotech 500gsm filter cloth;
- Preparation of QA/QC plans for the manufacture of the Geomembrane;
- Preparation of QA/QC plans for the installation of the Geomembrane;
- All stages of fill placing trials of Zone 4 material;
- Foundation preparation and inspection for all earthworks and concrete works,
- Embankment construction;
- Construction of low-level embankment conduits (foundation preparation and inspection, conduit backfilling, reinforcement, concrete placement and backfilling, filter cloth and geomembrane placement and geomembrane attachment to concrete penetrations);
- All stages of trial placement and jointing of the geomembrane liner;
- All stages of installation placement, jointing, and anchoring of the geomembrane liner;
- Construction of intake and outlet structures;
- Construction of the service and emergency spillways;

- Construction of flow measuring weirs;
- Installation of gates;
- Installation of automation control systems and water level recording wells; and
- Commissioning of the scheme.

All construction control stages will have hold points to ensure the intent of the design has been met. It is proposed that the Designer and Contractor shall sign off critical construction phases.

Critical to the design of the embankment culvert penetrations is to ensure the backfill material for pipe penetrations is compatible with Zone 4 embankment material and underlying foundations. The Contractor shall ensure a hold point for inspection and carry out sieve analysis of foundation and backfill materials placed around pipe penetrations and concrete transitions at locations determined by the Designer. The Designer shall check that materials conform to the grading curves specified in Section 17 and are not susceptible to suffusion.

1.14 Quality Control: Material Testing and Sampling

The Contractor shall establish and document a quality control and assurance programme which shall include regular inspection and testing of materials and the works to ensure compliance with the requirements of the project.

The Contractor shall provide all necessary logistical assistance in the execution of tests and shall allow for all delays associated with sampling, testing and the reporting of results within the construction programme.

Adequate control of seepage and compatibility of soil materials is fundamental to the successful performance of the project and is based on limited test pit investigation and soils testing. Quality Control of the installation of the pond lining is critical. Full time supervision of construction is required during construction and includes on-going testing of materials. The testing regime shall allow for the following level of testing:

- Compaction trials for each pond to determine optimum and minimum moisture contents and number of passes to achieve the required level of compaction agreed during placement trials on site (refer to Section 4.2);
- Soil / aggregate gradings to determine compliance with zoned material requirements, refer to Section 17.0;
- Regular field sampling moisture contents and degree of compaction;
- In-situ density tests;
- Additional testing where variations in material quality becomes apparent (i.e. noticeable change in grading or moisture content);
- Facilitate independent verification testing;
- Nuclear density testing;
- Third party factory CQA inspection and testing of geomembrane prior to shipment (refer Table 9)
- Regular sampling of strength of pond liner joint installation (refer to Section 6.15);
- Testing and sampling of concrete; and
- Reporting of laboratory testing results.

In the case of a noncompliant test result: results shall be furnished to the Designer and Contractor within 24 hours of the test being carried out. In addition, the Contractor shall produce a weekly quality report incorporating, among others, the following details of numbers and types of tests carried out, a summary of results, staff employed in testing and the forthcoming programme of testing.

1.15 Construction Sequence and Programming

One month prior to commencement of construction, the Contractor shall develop a detailed construction sequence for the execution of the works in accordance with this Specification, Drawings, consent conditions, and the constraints of the site to demonstrate design compliance. The programme shall identify duration of planned works and completion dates. The construction sequence shall be reviewed for compliance with design objectives by the Designer.

The baseline programme shall be updated quarterly during construction in order to form part of the as-built construction record for the project.

1.16 Construction Management Plan

A Construction Management Plan shall be prepared by the Contractor and shall be reviewed by the Independent Certifier. This shall ensure that proposed mitigation measures are put in place, any resource consent conditions are met, and good construction practices are implemented during the work.

As Wrights Road Storage Ponds are assessed as High PIC the capabilities and experience of the design-build construction team, particularly managers and foremen shall demonstrate experience in the construction and successful commissioning of similar Medium or High PIC dams with inclusion of CVs of key management and site staff in the Roles and Responsibilities Section of the Construction Management Plan.

The Construction Management Plan shall include as a minimum:

- Roles and Responsibilities;
- Mitigation measures to minimise environmental effects;
- Hazardous substances management;
- Waste Management Procedures;
- Environmental monitoring requirements;
- Reporting requirements; and
- Environmental Emergency Response Procedures.

The Construction Management Plan shall comply with the AEE submission and Resource Consent conditions applied by Environment Canterbury.

The Contractor shall provide the compliance reporting to WIL who shall manage the relationship with the environmental authorities and shall inform Environment Canterbury within the required response timeframes if any potential or actual noncompliance condition occurs.

1.17 Method Statements

The Contractor shall provide a detailed Method Statement for key activities undertaken during the execution of the Works and all Method Statements shall be reviewed by the Designer and the Independent Certifier.

Method Statements, where requested by the Designer, shall supplement the detail provided in the Construction Management Plan. The method statement is to describe all proposed equipment, proposed materials and detail the construction sequence. The method statement shall form part of the Contractor quality documentation. Prior to commencement of work on site the method statement shall be submitted to the Designer along with any necessary supporting information to confirm that the method statement shall meet this specification. Method statements should be submitted not less than 10 days prior to the commencement of the relevant activity on site.

1.18 Project Reporting

Construction records are important for future safety evaluations of the ponds. The level of minimum detail required in reports shall be in accordance with High PIC for all components of this project

The Contractor shall produce the following reports:

- Weekly Quality Reports;
- Weekly Progress Reports;
- Specific reporting against defined Critical Areas;
- Final Construction Report;
- As-built drawings;
- Operation and maintenance manual; and
- Commissioning Report.

The format and level of detail required for all reports shall be in accordance with the High PIC classification for the ponds as recommended in the NZSOLD Dam Safety Guidelines.

1.19 Technical Specification Precedence

If any clauses of the main body of this Document (Technical Specification) do not agree with, or contradict, the information provided in Appendices A and B then this Technical Specification shall take precedence.

2.0 Enabling Works

The site shall need to be cleared of any buildings, structures, fences, hedges and trees. It is proposed that untreated branches and timber be burnt on site. Other materials shall be removed and appropriately disposed of offsite by the Contractor.

2.1 Tree Removal

Stockpiling of organic material shall be limited to a height of 10 m and located on site. Untreated branches and timber shall be burnt onsite under the Contractor's supervision. The Contractor shall take all practicable measures to minimise the discharge of smoke from the site, including requirements from the relevant resource consent, such as (but not limited to) the following measures:

- Locating fires as far as practicable from neighbouring properties; and
- Lighting fires when winds are forecast to blow away from neighbouring properties.

2.2 Existing Structures

If there are any existing structures within the pond areas, they are to be demolished by the Contractor and disposed of off site. Buildings and foundations shall be demolished to a minimum of 1 m below the final excavation level.

2.3 Cess pits and septic tanks

If there are any, the Contractor shall coordinate the removal and disposal of cess pits and septic tanks located within the footprint of the ponds.

2.4 Disposal

The Contractor shall coordinate the offsite disposal of cleared items.

2.5 Existing Services

The Contractor shall utilise existing electrical service and associated facilities as permanent power source to the ponds automated gates and control system. Such arrangements should be coordinated by the Contractor in advance with the electricity service authorities.

Any services that would hinder permanent installation and/or construction works may require permanent or temporary relocation. Such relocations should be coordinated by the Contractor in advance with the relevant service authorities.

2.6 Existing Structures

A number of existing structures have been identified and are shown on the appropriate construction drawings.

2.6.1 Irrigation and Stock Water through MR4

A corrugated steel pipe culvert exists at the intersection of main race MR4 and Dixons road. This has not been designed to carry unusually heavy loads of construction activities. This will cause construction constraints. The Contractor shall ensure uninterrupted irrigation water supply during irrigation times and stock water supply at all times through the MR4. Any planned outages are to be agreed with WIL at a minimum of 6 weeks in advance.

2.6.2 Irrigation and Stock Water through R2 and R3

Race R3 starts at the intersection of MR4 and Dixons road. Water is diverted to R3 through three corrugated steel pipes with control gates. This will cause construction constraints when excavating and installing the two outlet pipes of G6.

Construction constraints will also result from the following construction activities of G3:

- Excavation and construction of outlet structure;
- Race bed and side slope stabilisation work; and
- Construction of crump weir, its approach channel and appurtenant structures.

Similarly, R2 starts from the buffer pond, southwest of the service spillway into Pond 2, and extends in a south-easterly direction through a culvert under Wrights Road. It will form construction constraints when excavating and installing G2 penstock and further downstream R2C crump weir along with its approach channel and appurtenant structures.

The Contractor shall ensure uninterrupted irrigation water supply during irrigation times and stock water supply at all times through R2 and R3. Any planned outages are to be agreed with WIL at a minimum of 6 weeks in advance.

2.7 Contractor Stockpiles

The Contractor shall plan his work to minimise the use of stockpiles and re-handling of materials for later use.

Excavated material which is not required for immediate use shall be deposited in stockpiles.

The Contractor shall compact, trim and drain stockpiles and spoil dumps as may be necessary to maintain them in a tidy and stable condition.

Particular requirements outlined in relevant resource consents, which should be included and implemented in the Construction Management Plan include (but are not limited to) the following:

- Stockpile heights shall be limited to no more than 10 metres;
- Stockpiles of organic matter including topsoil shall be shaped in order to shed surface water;
- Stockpiles shall not be located within 20 m of any bore, surface water body or artificial watercourse;
- Stockpiled material that will not be disturbed for more than three months shall be vegetated as soon as possible;

- Re-vegetate bare areas that will be undisturbed for more than three months as soon as practicable;
- Using water or dust suppressants on all disturbed areas; and
- Stockpiles shall not occur within 50m of property boundaries.

The Contractor shall allow for all costs related to managing compliance requirements in the Schedule of Prices for the project.

2.8 Haul Roads and Maintenance Access

During dry weather all haul roads and other working areas shall be watered regularly to prevent dust formation. The Contractor shall be responsible for forming his own haul roads as necessary.

Haul roads shall be constructed of suitable materials and maintained on a regular basis. The Construction Management Plan shall align with relevant resource consent conditions. These include measures to control the effects of air discharges as well as re-vegetating bare areas that shall be undisturbed for more than three months, as soon as practicable.

Locations and construction details for any permanent haul roads required for maintenance access (i.e. to clean out ponds etc.) during the ponds operational life will need to be agreed with the Designer during the works, refer to Drawing WIL1125/30/5 ‘Permanent Access’ for proposed access layout.

Construction access ramps are provided from crest down to the pond bases. These access ramps shall be removed prior to completion of installation of the liner. Subsequent maintenance access will be achieved as and where required by locally peeling back the liner to provide access over the embankment into the pond. Subsequently the liner shall be reinstated with embankment surface preparation and re-welding of the geomembrane in accordance with this specification.

2.9 Foundation and Surface Drainage

The Contractor shall prepare a drainage plan for the construction period, which shall minimise erosion of excavated surfaces and materials. Particular requirements outlined in the relevant resource consent that shall be included in the drainage plan include (but are not limited to) the following:

- Avoid placing cut or cleared vegetation, debris, or excavated material in a position such that it may enter surface water;
- Strategically located interceptor ponds to trap sediment from the surface runoff;
- Provide suitable spillways to prevent washout of the interceptor ponds in times of heavy runoff;
- Provide protection measures for existing waterways;
- Provide protection to the permanent works; and
- Provide measures for control of runoff from contaminants.

The relevant resource consent provides requirements for discharging water and contaminants into the Waimakariri River in the event of an emergency, which shall be included in the drainage plan. The drainage plan shall form part of the Construction Management Plan.

3.0 Excavations for Embankment Foundations and Reservoir Area

The Contractor shall be responsible for the safety of all excavations and shall carry out all work required to maintain excavations in a safe and stable condition. He shall take all necessary precautions to prevent slips, slumping or erosion, and shall make good any damage caused by any slips or erosion.

Construction of the culverts under the embankments will require trench excavations in the natural ground. These shall be carried out in accordance with the Good Practice Guideline for Excavation Safety (Workplace New Zealand, 2016). The excavation sections shown on drawing WIL1125/30/134 are typical sections and should be modified if ground conditions warrant flatter side slopes or shoring for construction safety.

As far as practicable, all suitable materials from excavations shall be used in the permanent construction required under these specifications.

The Construction Management Plan shall include and implement requirements from relevant resource consents, including (but not limited to):

- Methods used for controlling dust at each source during construction, including contingency methods for extreme weather conditions;
- Carrying out soil removal and spreading operations at times of least vulnerability to neighbours;
- Taking wind conditions and location of neighbours into account in planning and carrying out work to minimise dust dispersion;
- Using water or dust suppressants on all disturbed areas including roads and stockpiles when required;
- Minimising the areas of disturbed ground; and
- Where water is used for dust suppression, settling ponds or sumps shall be used to settle out particulates before discharging to the land surface.

3.1 Strip Topsoil and Silts

Topsoil and underlying silts (where they exist) shall be stripped down to the underlying sandy gravels below the footprint of the pond embankments. Topsoil and silts shall be stockpiled and used subsequently for pond ballast and also for reinstatement and landscaping of the construction site on completion of construction. Refer to Section 2.7 for stockpile requirements.

3.2 Pond Embankment Foundations

Excavation for the pond foundations shall be carried out to grade and level as shown on the drawings. Following excavation, the Designer Representative shall complete mapping of the foundation. The Contractor is to provide notice and allow sufficient time for the mapping. The Contractor shall keep foundation mapping records (including sketches and photographs), as part of the Quality Control record for the embankment construction.

The Designer Representative shall inspect the embankment foundation suitability and may require additional excavation if unsuitable materials are present or if excavation has disturbed an otherwise acceptable subgrade. Where unsuitable material is removed locally, the

excavation shall be backfilled with compacted Zone 4 material (refer to Section 17.0 for grading envelope).

Geotextile shall be placed under the liner instead of sandy silt in areas where the foundation material is too boney and permeable for screened sandy silt to be effective over the liner life, which is approximately 50 years. The Contractor may place 500GSM geotextile as an alternative to the sandy silt throughout the invert, where required.

3.3 Cut Slopes

Significant excavations are required to form the pond embankments. The pond embankments will generally be founded on alluvial sandy gravels.

The available site investigation information is presented in the test pit logs, photos and laboratory test results which are included in the Design Report Appendices A & B. Damwatch shall be responsible for interpretation of the inspection findings referred to in Section 3.2 above.

The site investigation results indicate that the ground conditions are variable. The Contractor shall allow for all appropriate plant, labour and materials necessary to form the excavations based on the site investigation information supplied, site exposures and conditions on site.

Indicative cut slopes and typical sections are shown on the drawings. Overall slopes in the foundations shall be arranged to provide gradual transitions. The Contractor and Designer Representative shall review the ground conditions as excavation progresses and may instruct modifications to the cut slope geometry or may propose additional drainage, as necessary.

3.4 Slips

Material from slips in natural ground shall be removed and used in fills or dumped, as directed by the Design Representative in consultation with the Contractor. Slips which occur prior to completion of subgrade trimming at the location of the slip shall be considered as earthworks cut to waste or fill as appropriate.

The area affected by the slip shall be shaped, trimmed and repaired to a safe, stable and neat condition or to the lines, dimensions and elevations required by the Designer Representative.

3.5 Reinstatement of Excavated Surfaces

After removal of vegetation and topsoil and excavation of available material for pond construction, the excavated surface shall be trimmed level. Any loose material shall be removed. Excavated surfaces shall then be proof rolled using a suitable self-propelled vibrating roller to detect unsuitable material and soft spots prior to fill placement or final surface treatment.

Any unsuitable material or soft spots shall be removed prior to filling with suitable material.

4.0 Embankment Construction

The Contractor shall be responsible for construction of the intakes, pond embankments and outlets in accordance with the Drawings and this Specification. He shall make all necessary corrections during the course of construction to compensate for settlement in order that the completed embankments shall be to the lines, levels and slopes shown on the Drawings. No fill shall be placed in the embankments until their foundations have been dewatered, excavated and suitably prepared. The foundation preparation shall be inspected and mapped by the Designer Representative, in consultation with the Contractor, as discussed in Section 3.2.

For the purpose of these Specifications, the term "pond embankment" includes all portions of the pond embankments as follows:

- Embankment base: Zone 4 granular embankment; and
- Embankment lining (as specified on Drawings) which shall be:
  - HDPE Geomembrane Liner over the pond bottom and water retaining embankments; and
  - Grass vegetation erosion protection of topsoil where lining not specified on the Drawings, such as pond outer embankments.

The Contractor shall ensure that only materials complying with this specification shall be used as fill. Materials that are dry or deteriorated or exceeding optimum moisture content are deemed unsuitable materials and shall be excluded from the granular embankment fill.

The embankment crests shall be surfaced with 300 mm of selected well graded Zone 4 material placed over a layer of Ecotech 500 gsm geotextile, for permanent access road use and durability.

4.1 Embankment Fill Placing Operations

The Contractor shall control fill placing operations in order to obtain fill complying with this Specification.

Zone 4 materials in the pond embankments, shall be constructed continuously and approximately horizontal for the width and length of the embankment at the elevation of the fill being placed. No transverse bonding surfaces (i.e. surfaces perpendicular to the pond embankment centrelines) shall be allowed in the embankment. Steps and joints in any fill shall not exceed one-layer thickness, as specified, in any direction. The Zone 4 portion of the pond embankment is to be constructed initially. It is anticipated that the Zone 4 portion of the embankment shall be constructed to full height prior to placement of the geomembrane lining.

Construction of the Zone 4 portion of the pond embankments shall be such that it is progressively raised in lifts of material spread in approximately horizontal layers along the full length of the embankment section under construction in such a manner as to produce layers of uniform thickness and character. Methods which lead to segregation of the coarser fraction will not be permitted (for example: dozing material to excessive distances).

Zone 4 material is to be sourced from in-situ gravels in the area of the bottom of the ponds. Material placed in Zone 4 shall be placed selectively in order that finer material is placed adjacent to and supports the geomembrane lining layer. The reservoir side of Zone 4 shall be

constructed 250 mm oversize and trimmed. This face shall then be graded to the correct shape to remove segregated Zone 4 material by grading at least 0.25 m from the inside surface. Subsequently, this face shall be further shaped and compacted prior to laying the 500 GSM geofabric and geomembrane.

The embankment fill shall be placed and compacted as shown on the drawings with tolerance of +100 and -0 mm.

Any fill on which water could pond shall be spread and compacted to falls, generally away from the pond centre-line; the falls shall be sufficient to ensure that puddles of water are not permitted to form on the surface of the fill but shall not exceed a gradient of 20H: 1V.

The Contractor shall take such steps as may be necessary to prevent deterioration of placed fill due to weather or exposure. Before placing fresh fill material on previously placed fill material, the Contractor shall remove any material which may have deteriorated. The surface of the existing fill shall be treated as necessary to ensure continuity between existing and fresh fill.

Fill shall not be placed under weather conditions which will have an adverse effect on the quality of the fill. During cold conditions placing may only continue if freshly excavated unfrozen material is placed on unfrozen surfaces. All placing of fill shall cease if the air temperature falls below minus 1°C.

4.1.1 Compaction of Embankment Fill Material

The compaction standard for use in the works shall be determined from field trials described subsequently in Section 4.2.

Guidance for earthworks fill materials for Zone 4 is listed below and will be set in accordance with the field trials:

- The in-situ moisture content shall be within 2% below and 4% above the optimum water content (OWC) as determined by NZ Standard Compaction test 4.1.1 of NZS 4402:1986 “Methods of Testing Soils for Civil Engineering Purposes” for each separate field measurement.
- The in-situ density shall not be less than the dry density determined during the fill placing trials and is anticipated to be a target density of 95% of maximum dry density (MDD) as determined from NZ Standard Compaction Test 4.1.1 of NZS 4402:1986, adjusted for the field particle size distribution (inclusion of large cobble size component) for each set of tests being the average of five separate field measurements.

The frequency and location of the compaction tests for the earthworks of Zone 4 material to be carried out by the Contractor shall be undertaken progressively with at least one set of tests for every 1,000 m^2, refer to Section 4.4.2.

The Contractor may carry out field testing of moisture content and dry density on compacted fills using a Nuclear Density Meter (NDM) subject to demonstrating that the NDM has been calibrated. In parallel to NDM testing the Contractor shall carry out regular testing of moisture contents of the fine fraction of zoned materials, on a daily basis as a minimum initial frequency.

The Designer shall review test results and reserves the right to adjust the testing frequencies. The results of the tests shall be included in the Contractor’s weekly report.

The grading envelope for Zone 4 materials (refer to Section 17.0) shall be confirmed during fill placing trials and kept under review during construction.

4.1.2 Preparation of Embankment Layer Surfaces

If the surface of the prepared foundation or any previously placed layer of earthfill:

- Is too dry or too smooth to bond properly with the next layer, it shall be moistened and disked or scarified in an approved manner to a sufficient depth to provide a satisfactory bonding surface before the next layer is placed;
- Is too wet for proper compaction of the layer, it shall be removed, allowed to dry, or be worked with a disk to reduce the water content to the required amount, and then it shall be re-compacted before the next succeeding layer of earthfill material is placed; and
- Has been heavily trafficked by construction equipment resulting in smooth, hard surfaces and deep ruts in the surface of placed fill it shall be prepared by disking or scarifying.

4.2 Tolerance Design Layer Thickness

The tolerances that shall apply to the compacted layer thickness of fill material for the Zone 4 granular embankment are in Table 1 below.

Table 1: Tolerance Design Layer Thickness

Zone	Nominal Compacted Layer Thickness (mm)	Layer Thickness Tolerance (mm)
Granular embankment Zone 4	400 *(Note1)*	-100 to +100
Note: *(1) Compacted layer thickness will be established by the Designer during the fill placing trials (refer to Section 3).*		

The compacted layer thickness shall be level surveyed to check that the layer thickness is within the above tolerance for the compacted layer thickness established during fill placing trials at the rate of one surveyed check per 1000 m^3 of placed embankment material. This compacted layer thickness check shall be conducted in conjunction with nuclear density testing in order that the layer is to the specified density.

4.3 Fill Placing Trials

Before commencing construction in any section of the works, the Designer shall confirm the compaction standard required for the placement and compaction of Zone 4 bulk embankment fill.

The compaction standard for use in the works shall be determined from a combination of:

- Compaction curves established based on max dry density vs. optimum moisture content characteristics determined by laboratory testing of field samples adjusted to account for the large cobble size in the field scalped from laboratory test samples; and

- Field placing trials to determine in-situ density parameters for a range of moisture contents and applied compactive effort.

The Contractor shall carry out such placement trials as deemed necessary by the Designer to:

- Establish the agreed methodology for placing embankment materials;
- Determine appropriate range of placement moisture content limits for compacted materials;
- Determine acceptable placement layer thickness;
- Determine the target density; and
- Establish the optimum compactive effort required for the fill materials used in embankment construction.

The fill placing trials shall be located at convenient and agreed locations outside the footprint of the pond embankments for determination of Zone 4. Consequently, the fill placing trials will be staged, addressing initial compaction of Zone 4 material. Each trial shall be performed in a manner and using equipment identical with that proposed by the Contractor for the construction of the permanent works.

The trial for Zone 4 material shall have a minimum area of 25 m long and 10 m wide. A series of layers (minimum of 5) shall be placed to establish the amount of compaction effort to be applied to achieve the compaction standard for the works. It is anticipated that the compactive effort required will be a target density of 95% of standard compaction. It is intended that material is wetted to determine optimum moisture content and confirm upper and lower limits of in-situ moisture content assigned by the Designer. Material from the field trial may be used subsequently in the main works.

Compactive effort shall be verified at a number of agreed locations (minimum 5 tests per layer) on each trial layer using nuclear densometer testing by the Contractor and other methods as agreed with the Contractor.

The Designer may require additional testing (independent field or laboratory verification testing) of the field trial or in-situ density tests.

4.4 Quality Control

4.4.1 Laboratory Testing and Sampling

Refer to Section 1.14 for Laboratory Testing and Sampling requirements on site.

4.4.2 Location and Frequency of Routine Testing

Frequency of testing shall be related to the stage of work and to the conditions existing at any particular time. It shall be initially sufficient to establish proper control criteria and assure consistency of construction conforming to these criteria. Routine testing shall be required generally using laboratory testing of selected samples together with simple field tests. The Contractor shall draw up routine testing schedules and arrange that the tests are completed to the approval of the Designer.

The frequency and location of the compaction tests and grading samples for the earthworks of Zone 4 material to be carried out by the Contractor shall be undertaken progressively. Frequency of routine testing indicated in Table 2 below is for guidance purposes only.

Table 2: Frequency of Routine Testing

Zone	Project Test Frequency	Compaction Test Frequency (m^2)	Particle Grading Analysis Frequency (m^3)
Granular embankment Zone 4	Start up	1,000	10,000
	Interim	2,500	20,000
	Long-term	5,000	50,000

It is anticipated that the testing frequency shall reduce once sufficient precedent data for target grading and density has been established specific to this site. The designer shall confirm in writing any change in test frequency. It should be expected that test frequency shall increase if there is a notable change in test results achieved on site or there is a clear change in material grading observed on site.

4.4.3 Method Statement

The Contractor shall agree in advance of construction his methodology for embankment construction with the Designer.

The Method Statement shall include the construction method based on conclusions from fill placing trials, and also testing, sampling frequency and reporting.

Particular attention must be paid to the location and sequencing for construction of any vertical construction joints between longitudinal embankment sections.

4.4.4 Reporting

The Contractor shall prepare and issue weekly reports confirming test results for the period including compliances and non-compliances.

In the case of non-complying test results the Contractor shall inform the Designer without delay so that they can agree the extent of any remedial action required.

The Contractor shall produce the following reports:

- Results of all non-compliant tests shall be furnished to the Designer within 24 hours of the test being carried out;
- Factual test data reports on a weekly basis: quality report incorporating, among others the following details of numbers and types of tests carried out, a summary of results, staff employed in testing and the forthcoming programme of testing;
- Interim reports as required for example compaction field trials or particular testing requirements; and
- As built completion report at the end of the construction period.

4.5 Independent Verification Testing

Independent verification testing shall be undertaken by a suitably accredited soils laboratory as follows:

- In-situ density test of Zone 4 initially when the first 100 m^3 of Zone 4 material is placed, and at 6 monthly intervals thereafter;
- Nuclear Density Meter (NDM) calibration at regular intervals (not greater than 6 months) or as recommended by the manufacturer whichever is the lesser.

4.6 Embankment Preparation for Placement of Pond Liner

The surface of the Zone 4 embankment and pond base materials shall be prepared for placement of the geomembrane liner by proof rolling with a 10 to 12 tonne vibratory steel roller.

Ground preparation for liner installation shall be a smooth compacted surface which conforms to the elements specified in the Table 3. All protruding angular rocks shall be removed and the voids created by their removal or bony areas of Zone 4 (no fines) shall be filled with finer screened material and the surface shall be proof rolled a second time.

Table 3: Embankment Preparation Requirements for Placement of Pond Liner

Requirement	Criteria
Line and level	Undulations over 2m < 100 mm
Surface items likely to damage the geomembrane	No foreign objects such as timber or steel and no broken rocks visible in the surface
Maximum rock fragment size	On pond bottom maximum bare rounded rock face < 6 mm On embankment slope maximum bare rounded rock face in the plane of the finished surface < 75 mm
Surface conditions	No pools or standing water

On embankment slopes the liner shall be supported on a layer of Ecotech 500 GSM geotextile (see Section 5.0 for details), which shall be anchored into the anchor trench along the crest, extend down the embankment slope and a minimum of 1 m out from the embankment toe onto the pond invert, from the base of the embankment up the into the crest anchor trench.

On the pond inverts the liner shall be supported on a 20 mm minimum thickness layer of screened sandy silt proof rolled with a 10 to 12 tonne roller as described above.

The pond embankment crests have permanent maintenance access (as detailed on Drawing WIL1125/30/5). The surface of the crests will be covered with a layer of Zone 4 material (as shown on drawings WIL1125/30/22 – 23).

4.7 Vegetative Erosion Protection

Placement of topsoil and establishment of vegetation on completed batters and berms above operating water levels will be advanced as surfaces are completed and as seasonal conditions permit.

It is planned to reuse topsoil excavated from within the pond footprint in order to establish vegetative erosion protection to the pond embankments above water level, where there is no geomembrane liner. Topsoil shall be generally free of stones and foreign matter however some stones are tolerable up to a single maximum aggregate size of 75 mm diameter.

The grass seed mix appropriate to the local conditions shall be formulated and shall be suitable for establishing vegetation on the pond embankments. The Contractor shall ensure that soil moisture conditions are suitable for good germination and establishment of the seed mix that is adopted.

5.0 Ecotech 500 GSM Geotextile

The Ecotech 500 GSM geotextile, which is a non-woven needle punched polyester (PET) fibre geotextile, shall be placed to support the geomembrane on the inner embankment slopes. The geotextile shall meet the criteria specified in Table 4 below. The Ecotech 500 GSM "geotextile" is also referred to as a "filter cloth" in the Drawings. The Contractor shall provide the Designer with the manufacturer's test certificates prior to commencement of geotextile placement.

Table 4: Ecotech 500 GSM geotextile material specification

	Test	Test Method	Units	Parameter
Physical Properties	Density	AS2001.2.13	g/m^2	500
	Thickness	AS3706.1:2012	mm	4.0
	TNZ F/7 2003 Filtration Classes	AS3706.9:2012	-	1 – 4
	TNZ F/7 2003 Strength Classes	AS3706.3&5, AS2001.2.3	-	A – C
	TNZ F/7 2003 G Rating	-	-	2505
Mechanical Properties	**Test**	**Test Method**	**Units**	**Parameter**
	Wide Strip Tensile Strength (MD/XMD)	AS3706.2:2012	N/mm*	15 / 21.5
	Elongation (MD/XMD)	AS3706.2:2012	%	100 / 90
	Trapezoidal Tear Strength (MD/XMD)	AS3706.3:2012	N	460 / 610
	CBR Burst Strength	AS3706.4:2012	N	2740
	Grab Tensile Strength (MD/XMD)	AS2001.2.3 Method B-88	N	980 / 1270
	Drop Cone Puncture Test	AS3706.5:2000	mm	2500
Hydraulic Properties	**Test**	**Test Method**	**Units**	**Parameter**
	Pore Size	AS3706.7:2003	µm	170
	Permittivity	AS3706.9:2012	s^{-1}	1.30
	Coefficient of Permeability	AS3706.9:2012	m/s	3.87×10^{-3}
	Flow Rate @ 100mm Head	AS3706.9:2012	$l/m^2/s$	130

Notes:
** same as kN/m*
MD = Machine Direction Test,
XMD = Cross Machine Direction Test.

5.1 Installation and Joining

The geotextile shall be placed on prepared embankment slopes (see Section 4.4) and shall extend from the base of the embankment up into the crest anchor trench.

Joining of the geotextile shall be provided by sufficient overlap width between adjacent geotextile rolls. The minimum required overlap width is in Table 5.

Table 5: Minimum required overlap width of Ecotech 500 GSM geotextile

Location of the overlap	Minimum required overlap width [mm]
Embankment at the corner	200
Embankment within 100m from the edge of the rounded corner of the pond	200
Straight section of the embankment	150
Under Zone 1 material	200
Under crest maintenance strip	150

6.0 Geomembrane Liner

Embankment lining (as shown on the Drawings) shall be 1.5 mm white faced HDPE smooth geomembrane liner produced by Solmax (Malaysia) Solmax 460W – 9000, as specified in this document. The following sections specify the HDPE lining and installation.

Prior to commencement of geomembrane liner installation, layout of geomembrane panels shall be planned and drawn with the panels sized to determine configuration and location of field seams, and submitted for approval to the Designer. Each panel shall be given an alpha-numeric identifier. No panel lap joints shall be located in an area of potential stress. Geomembrane placement shall be done when weather conditions are suitable, that is fine – no rain and low wind.

The geomembrane shall be installed in accordance with the manufacturer's instructions. The pond bottom and embankment surfaces shall be prepared for the geomembrane; the area to be lined shall be smooth and free of rocks, deleterious debris, and all vegetation and roots. The area to be lined shall be dry. The Contractor and Designer shall inspect the surface to be lined immediately prior to placement of all geo-membrane or Ecotech 500 gsm filer cloth on embankment slopes and agree the surface is properly prepared for the purpose.

Care shall be taken during installation to prevent penetration of the geomembrane (i.e. sharp objects, vehicles, hard bottom shoes). Contact shall be maximised between the prepared surface and the liner, but the liner shall be placed free of tension or stress. The geomembrane shall be placed by overlapping on all connecting sides to create lap joints, by a width to be determined from site trials (100mm – 300 mm wide overlap). Contact surfaces at the liner joints shall be clean and dry.

The construction methodology shall identify suitable methods to prevent wrinkles and wind uplift of the geomembrane lining during installation. During installation, temporary sandbag (or tyres free from sharp protrusions) ballasts shall be placed to prevent movement of the geomembrane liner prior to securing with the anchor trenches and ballast. Installation shall be uniform, and spread close to the ground to prevent air from becoming trapped under the liner.

Any damage to the surface to be lined caused by installation activities shall be repaired. Vehicles shall not traverse the geomembrane unless it is protected by a layer of ballast material approved by the Designer.

All placed geomembrane panels shall be inspected by the Contractor and Designer prior to joint sealing for any defects or penetrations. All nonconforming areas shall be replaced or repaired prior to joint sealing.

6.1 Reference Standards

Works performed under Section 6.0 shall comply with the general requirements of the following documents and the specification requirements outlined in Section 6.0. These standards shall be adopted unless the Contractor proposes for approval by the Designer acceptable alternatives through the Standards submittal.

The standards are suitable for use with geomembrane manufactured to compatible American Standards:

ASTM Standards:

1. D638-14 Standard Test Method for Tensile Properties of Plastics.
2. D1004-13 Test Method for Initial Tear Resistance of Plastic Film and Sheeting.
3. D1024
4. D1238-13 Standard Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer.
5. D1505-18 Test Method for Density of Plastics by the Density-Gradient Technique.
6. D1603-14 Test Method for Carbon Black in Olefin Plastics.
7. D3895-19 Standard Test Method for Oxidative-Induction Time of Polyolefins by Differential Scanning Calorimetry.
8. D4218-15 Standard Test Method for Determination of Carbon Black in Polyethylene Compounds by the Muffle-Furnace Technique.
9. D4437 / D4437M – 16 (2018) Standard Practice for Nondestructive Testing (NDT) for Determining the Integrity of Seams Used in Joining Flexible Polymeric Sheet Geomembranes.
10. D4833 Standard Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products.
11. D4873 / D4873-17 Standard Guide for Identification, Storage, and Handling of Geosynthetic Rolls and Samples.
12. D5199-12(2019) Standard Test Method for Measuring Nominal Thickness of Geotextiles and Geomembranes.
13. D5397 Standard Test Method for Evaluation of Stress Crack Resistance of Polyolefin Geomembranes Using Notched Constant Tensile Load Test.
14. D5596-03(2016) Standard Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics.
15. D5641-94(2011) Standard Practice for Geomembrane Seam Evaluation by Vacuum Chamber.
16. D5820-95(2011) Standard Practice for Pressurised Air Channel Evaluation of Duel Seamed Geomembranes.
17. D6365-99(2011) Standard Practice for the Non-destructive Testing of Geomembrane Seams using the Spark Test.
18. D6392-12 Standard Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods.
19. D6693-04(2015)e1 Standard Test Method for Determining Tensile Properties of Nonreinforced Polyethylene and Nonreinforced Flexible Polypropylene Geomembranes.
20. D7007-16 Standard Practices for Electrical Methods for Locating Leaks in Geomembranes Covered with Water or Earthen Materials.
21. D7466- D7466M - 10(2015)e1 Standard Test Method for Measuring Asperity Height of Textured Geomembranes.

Geosynthetic Research Institute

1. GRI GM 13 Test Properties, Testing Frequency and Recommended Warranty for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes.
2. GRI GM19a - Standard Specification for Seam Strength and Related Properties of Thermally Bonded Polyolefin Geomembranes.

6.2 Standards

Within one week of being awarded the Contract, the Contractor shall submit to the Designer for approval notification of the intent to adopt the standards provided in this Specification along with the respective standards for material compliance in Tables 6 and 7.

6.3 Raw materials manufacture and delivery

Within two weeks of being awarded the Contract, the Contractor shall provide the Designer with the following information on the resin used in the HDPE manufacture:

1. Suppliers name and production plant address
2. Origin and identification (brand, name, number)
3. Production date
4. Copy of resin supplier quality control certificates
5. Contractors test reports to verify resin quality (as a minimum, to include density and melt index)
6. Statement of percentage of reclaimed polymer added to the resin.

After manufacturing and prior to shipment, the Contractor shall provide a manufacturing Quality Control Certificate for each roll of HDPE. This shall be signed, as a minimum, by the manufacturing Production Manager. This Quality Control Certificate shall include:

1. Name of manufacturer.
2. date of manufacture.
3. Batch number.
4. Roll number and identification.
5. Sampling procedures and quality control test results. As a minimum, test results are required for:
    a. Density.
    b. Thickness.
    c. Yield strength.
    d. Yield elongation.
    e. Tensile strength at break.
    f. Tensile elongation at break.
    g. Carbon black content.
    h. Carbon black dispersion.
    i. Melt index.
    j. Tear resistance.
    k. Puncture resistance.

Within two weeks of Contract awarded, the Contractor shall notify the Designer of the area required for storage facilities, and the minimum roll out area for working.

Within two weeks of being awarded the Contract, the Contractor shall provide Certification to the Designer that the extrudate to be used in any field extrusion welding is comprised of compatible resins and additives as the parent HDPE, and is directly comparable to the information provided in above.

6.4 Panel Layout Plan and Programme

A Panel Layout Plan showing location and type of all seams shall be submitted by the Contractor to the Designer 10 days before commencement of installation.

No installation is to be undertaken until the Designer has given approval in writing to the Contractor that the panel layout submitted is satisfactory.

All installation is to be in strict accordance with the Plan unless the Engineer gives advance approval to any site modifications.

The Plan shall identify:

1. Seam locations.
2. Proposed non-destructive test types for each seam.
3. Means of temporarily securing the geomembrane at the crest prior to placement of the fill over the runout anchor.
4. Unless already specified on the Drawings, details of proposed connections to appurtenant structures.
5. Indicate any variance or additional details differing from the Drawings.

The Plan should be adequate for use as a construction plan, including dimensions, details etc.

Once the Designer has approved the Panel Layout Plan (including any Engineers amendments), the Contractor shall supply two copies to the Engineer for use during the installation process.

Additionally, within two weeks of being awarded the Contract, the Contractor shall provide the Engineer with a proposed installation schedule, cross referenced to the Panel Layout Plan.

6.5 Environmental Conditions

The site is situated between the Waimakariri River and Ashley River in North Canterbury where it is common to experience weather conditions with strong winds and squalls.

The Contractor is to take whatever measures are necessary to ensure the timely and effective geomembrane installation without compromising workmanship, safety or seaming quality. The Contractor shall be responsible for provision of all temporary protection and anchorage for the geosynthetic materials.

6.6 Contractor Qualifications

All geomembrane liner installation work shall be undertaken by a specialist Contractor who can provide evidence of corporate experience of at least 2,000,000 m^2 of similar geomembrane work.

All direct field supervision of geomembrane work will be undertaken by personnel who have individual experience of at least 1,000,000 m^2 of similar geomembrane work.

All field and factory welding and testing of geomembranes shall be undertaken by personnel who have individual experience of at least 500,000 m^2 of similar geomembrane work.

6.7 Method Statement

The Contractor shall prepare and agree in advance of construction his methodology for lining installation with the Designer.

The Method Statement shall include the construction method based on conclusions from either liner placing trials or from previous placement experience with similar liner, pond size and embankment. The Method Statement shall be revised following liner trials and shall confirm the inspection and testing methodology, sampling frequency, progressive placement of ballasting and reporting in accordance with this specification and shall be agreed upon by the Designer and Contractor.

Particular attention must be paid to the placement and jointing of pond corners and fixing to concrete transitions.

6.8 Daily Reports

The Contractor shall provide the Designer with daily reports detailing:

1. the amount and location of HDPE placed.
2. the length and location of seams completed and the operator and equipment used.
3. changes in layout drawings (if applicable).
4. location and results of repairs.
5. location of destructive test samples.
6. destructive test results (if applicable).

6.9 HDPE Geomembrane Specification

All materials supplied shall be manufactured and supplied in accordance with an appropriate quality system.

The raw material used for geomembrane manufacture shall be first quality virgin resin, of the type nominated with no more than 2% factory re-work material and no post-consumer resin.

The required test values for the 1.5 mm thick Solmax HDPE geomembrane are set out in Table 6 and Table 7 below.

Table 6: Raw Material (Polymer Resin) Properties

Property	Test Method[1]	HDPE
Density	ASTM D1505 or D792	0.932 g/cc
Melt Flow Index (minimum) At 190°C / 2.16 kg	ASTM D1238	1 g/10min
Oxidative Induction Time Standard OIT	ASTM D3895	160 mins

Table 7: Finished Geomembrane Properties

Property	Test Method[1]	HDPE 1.50 mm Smooth Solmax 460W - 9000
Thickness – mean Lowest individual of 10 values	ASTM D5199 Or D5994	1.5 mm 1.35 mm
Tensile Properties (minimum average values based on 5 specimens in each direction): Yield Strength Break Strength Yield Elongation Break Elongation	ASTM D6693 Type IV	 23 42 13% 750%
Density (minimum)	ASTM D1505 or D792	0.940 g/cc
Carbon Black Content	ASTM D1603	2.0 – 3.0 %
Carbon Black Distribution (10 different views)	ASTM D5596	Cat 1 or 2
Tear Resistance (minimum)	ASTM D1004	187 N
Puncture Resistance (minimum)	ASTM D4833	556 N
Multi-Axial Tension Test (minimum elongation at burst)	ASTM D 5617	30%
Environmental Stress Crack (ESCR) NCTL test method (use manufacturer's mean for yield) (minimum)	ASTM D5397	1000 hr
Oxidative Induction Time Standard OIT (minimum)	ASTM D3895	160 mins
Dimensional Stability		2%
Asperity Height (mm)	ASTM D7466	0.45
Oven Ageing at 85°C Standard OIT retention after 90 days (minimum percentage retained)	ASTM D5721 ASTM D3895	55%

The testing frequencies for raw material and HDPE geomembrane are provided in Tables 8 and 9.

6.10 Factory Acceptance, Inspection and Testing

This section sets out requirements for testing and test certificates for the geomembrane. Actual test certificates with results are required – a 'certificate of compliance' is not adequate.

6.10.1 Raw Material Properties

Product certificates shall be issued by the resin supplier to the geomembrane manufacturer at the frequencies set out below.

In addition to the resin manufacturers testing certificates, tests shall be carried out by the geomembrane manufacturer in their laboratory and at an independent laboratory acceptable to the Designer and Independent Certifier at the frequencies set out below.

A copy of the certificates shall be submitted to the Designer prior to the geomembrane being delivered to site. These certificates shall include the resin supplier's name, production plant, brand name, batch number and production date of the resin as well as the properties set out in Table 8 below.

Table 8: Raw Material Testing

Property	Method	Resin Manufacturer	Geomembrane Manufacturer	Independent Laboratory
Density	ASTM D1505 or D792	Every 10,000 kg or part thereof.	Every 10,000 kg or part thereof.	Every 50,000 kg
Melt Flow Index	ASTM D1238	Every 10,000 kg or part thereof.	Every 10,000 kg or part thereof.	Every 50,000 kg
Oxidative Induction Time Standard OIT	ASTM D3895	Every 10,000 kg or part thereof.	Every 10,000 kg or part thereof.	Every 50,000 kg

6.10.2 Manufacturer's Quality Assurance and Quality Control

The Contractor shall supply a copy of Manufacturer's the QA/QC Manual which shall include a summary Inspection and Test Plan (ITP) for the geomembrane manufacture. This manual and test plan shall be reviewed for compliance by both the Designer and the Independent Certifier.

As a minimum requirement, the quality system shall include the following:

- Geomembrane manufacturer testing of resin as set out above;
- Sheet thickness measurement and control on every roll to within 10% of the nominated thickness; and
- Sampling procedures and results of in-house and external laboratory testing for geomembrane produced in the same batch or batches as the material supplied for the work as set out in Table 9 below. These test results shall demonstrate compliance with the properties set out in Section 6.9.

Table 9: HDPE Geomembrane Testing

Property	Test Method	Geomembrane Manufacturer	Independent Laboratory
Thickness – nominal	ASTM D5199	Every Roll	Every 20,000 kg or part thereof.
Tensile Properties	ASTM D 6693	Every 3000 kg or part thereof.	Every 20,000 kg or part thereof.
Density	ASTM D1505 or D 792	Every 10000 kg or part thereof.	Every 20,000 kg or part thereof.
Carbon Black Content	ASTM D1603	Every 3000 kg or part thereof.	Every 20,000 kg or part thereof.
Carbon Black Distribution	ASTM D5596	Every 30000 kg or part thereof.	Every 60,000 kg or part thereof.
Tear Resistance	ASTM D1004	Every 10,000 kg or part thereof.	Every 60,000 kg or part thereof.
Puncture Resistance	ASTM D4833	Every 10,000 kg or part thereof.	Every 60,000 kg or part thereof.
Oxidative Induction Time Standard OIT	ASTM D3895	Every 30,000 kg or part thereof.	Every 60,000 kg or part thereof.
Multi-Axial Tension Test (minimum elongation at burst)	ASTM D 5617		Every 60,000 kg or part thereof.
Environmental Stress Crack (ESCR) NCTL test method	ASTM D5397 (manufacturer's mean for yield)	Every 30,000 kg or part thereof.	Every 60,000 kg or part thereof
Oven Ageing at 85°C Standard OIT retention after 90 days	ASTM D5721 ASTM D3895		Every 60,000 kg or same formulation in last 12 months

6.11 Geomembrane Supply

Each roll of geomembrane shall bear a label which identifies the following:

- Manufacturer.
- Product identification.
- Roll number.
- Raw material.
- Batch number.
- Roll width.
- Roll length.

Extruded rod or pellet material for welding shall be manufactured from the same resin type used for the geomembrane.

6.11.1 Packaging and Delivery

Transportation of the HDPE shall be undertaken in accordance with ASTM D4873. Responsibility for all freight, transportation to site, handling and storage, including security shall be agreed between the geomembrane manufacturer and the Contractor.

Geomembrane and geotextile material shall be stored in such a manner that there will be total protection from ultraviolet rays, abrasions, cuts or distortions or other forms of damage to the rolls.

No more than two rolls of geomembrane shall be stacked one on top of the other. The Designer Representative may direct the Contractor to make adjustments to the stored materials if evidence of damage is observed. Any defects or damage detected shall be repaired to acceptable standards or totally replaced.

6.11.2 Extruded Material for use in Secondary Welding

The Manufacturer shall provide certified test data with each roll of extruded rod to certify that the material properties of the extrusion material are the same as those for the geomembrane. These shall include results for density, carbon black content and melt flow index.

Extruded material shall be packaged in a manner that will not allow the ingress of moisture and other contamination. Each roll of extrusion rod may be tested for moisture content and where contamination has occurred; the Manufacturer shall be responsible for drying or replacing the same.

Where extremes of temperature, humidity and/or rainfall are encountered, the Contractor shall ensure that all extruded rods shall:

- Be kept in a storage area that will prevent contamination by moisture; or
- In the event that operations are being undertaken in the field, suitable moisture extraction methods shall be applied to the rod so that contamination does not occur.

Any evidence of uncontrolled moisture in the extruded weld beads shall be grounds for rejection. It will remain the responsibility of the Contractor to totally eliminate moisture from the welding area.

6.12 Site Storage

The Contractor shall provide for an area to store the geomembrane liner on site after delivery. The onsite storage area shall be protected from the sun, excessive heat or cold, puncture or other damaging conditions. The liner will be delivered with packaging. The Contractor shall provide for a waste area for and disposal of the liner packaging once unpackaged. The Contractor shall inspect the liner upon delivery to ensure there is no visual damage to the packaged liner.

6.13 Placement of Geomembrane Liner

6.13.1 Excavation of Anchor Trench

An anchor trench shall be excavated on the crest of the embankment as shown on the drawings.

The anchor trench lines shape and dimensions shall be as shown on the drawings. The finished excavation shall be trimmed and cleaned. The trench leading edge shall be rounded and free from projecting rocks, sticks or other materials that could damage the geomembrane. No loose soil shall underlie the geomembrane in the anchor trench.

If the anchor trench is excavated in a clay soil susceptible to desiccation or sandy soil likely to become loose and friable, the amount of trench excavated at any one time shall be limited to that which will be covered with geomembrane in that day.

6.13.2 Backfilling the Anchor Trench

An anchor trench along the pond embankment crests shall be provided to prevent liner uplift when water level in the ponds is low. Crest anchoring of the geomembrane shall be achieved by excavating a trench 0.5 m wide by 0.75 m deep, set back at least 1 m from the embankment slope (see drawings WIL1125/30/22 and 23). The trench shall be cleared of all sharp rocks, or debris and loose soil. The top of the geomembrane shall be laid in place in the trench and the trench shall be reinstated with excavated material and compacted. Backfill activities shall take care to prevent damage to the liner. The proposed placement methodology shall be confirmed as part of the liner placement trial.

Generally, the excavated material from the anchor trench will be used as backfill over the geomembrane in the trench. Where this material is unsuitable, it shall be removed and replaced by sand fill.

The fill shall be placed and suitably compacted, in horizontal layers not exceeding 150 mm in thickness to an approved density.

If directed by the Designer, the anchor trench shall remain open with appropriate temporary ballasting until the associated pond has been filled and hydrostatically tested to allow the subgrade to consolidate.

Prior to anchor trench backfilling, the geomembrane liner shall be checked to ensure that it does not contain folds or other irregularities. The geomembrane shall be in a stress free, 'layflat' state over the entire area.

The anchor trench shall only be backfilled whilst the geomembrane is at its lowest temperature over the daily cycle. This may require backfilling at night after the geomembrane has cooled down or in the early morning before the geomembrane temperature has increased significantly.

6.13.3 Site Water Control and Dewatering

All collected storm water shall be removed and site dewatering undertaken in the geomembrane areas. All practicable measures necessary to reduce the potential for stormwater damage to finished surfaces shall be taken.

6.13.4 Sheet Layout

Preliminary drawings showing a layout of the geomembrane panels shall be submitted for approval by the Designer prior to commencing work. Any changes to the preliminary drawings shall only be made with Designer's approval.

Geomembrane lining materials shall be supplied in lengths to suit the approved layout. Each roll of geomembrane shall be supplied in the widest practicable widths which shall be a minimum width of 7 m unless otherwise approved. Panel layout shall be continuous sheets down embankments and across the base as far as practicable, limited by the manufacturers maximum roll length and the requirement for a seam in the floor adjacent to the embankment in one direction. The sheets shall be overlapped over adjacent membrane sheets by a minimum of 100 mm for double wedge fusion welds and 75mm for extrusion welds.

6.13.5 Liner Properties and Layout at Pond Corners

Only rolls of geomembrane whose test results have strength and elongation properties equal to or greater than those stated in Table 10 below shall be used in pond corner areas. The testing may be done either at the factory or after delivery to site. The Contractor shall choose the preferred test location and make the necessary arrangements to have the testing done and the rolls of geomembrane with enhanced strength and elongation properties identified, sufficient to line the corner areas shown on Drawing WIL1125/30/24. Accordingly, rolls of geomembrane from which sample test results are equal or higher than summarised in Table 10 will be used to line pond embankment corner areas and 100 m either side of the corner of all ponds including the Tub.

The Quality Assurance of this activity is critical and the Contractor needs Quality Control procedures for identifying and managing the suitability of the geomembrane at all times.

Table 10: Enhanced Geomembrane Tensile and Elongation Properties

Property	Test Method	HDPE 1.50 mm Smooth Solmax 460W - 9000	
		Machine Direction	Cross Direction
Tensile Properties (minimum average values based on 5 specimens in each direction):	ASTM D6693 Type IV		
Yield Strength		24 kN/m	26 kN/m
Break Strength		49 kN/m	50 kN/m
Yield Elongation		18%	16%
Break Elongation		800%	800%

6.13.6 Geomembrane Lining As Constructed Drawings

As the work progresses, the Contractor shall maintain an up-to-date set of 'as constructed' drawings. These drawings shall detail all the elements of the sheet layout; the anchoring, the location of all primary and secondary welds and all areas tested. The points where failure of the non-destructive tests were detected, the type of secondary weld employed to effect the repairs, and the date and time the patch was tested and approved shall be shown.

On the completion of the works, the Contractor shall provide to the Designer, a complete set of 'As Constructed' drawings.

6.13.7 Geomembrane Joint Details

No horizontal or near horizontal welds shall be permitted on an embankment. Weld seams shall be oriented parallel to the line of maximum slope. No cross direction floor seams shall be closer than 1.5m to the toe of the embankment or the crest of an adjacent slope, except where approved by the Designer Representative.

No seams shall be located in areas of potential stress concentrations. All panels shall have a finished over lap of 125mm minimum i.e. seams shall be at least this distance form the edge of the panel.

Unless approved by the Designer the connection of the embankment geomembrane to the floor membrane shall be by primary welding as defined in Section 6.14.1. This shall only be carried out in the presence of the Designer's representative.

Crossover welds from adjacent connecting geomembranes shall be offset at least 300 mm. Weld crossovers shall be welded using primary welding where practicable in addition to secondary welding of each tee.

Secondary welding of tees and of patches over primary (double wedge) seams shall be performed by cutting the outer flap back on each leg of the tee for a distance of 200 mm and extending welding over the cropped flap a distance of 150 mm along each leg. The preparation and welding shall ensure that the double wedge air gap is sealed off. Secondary welding shall be carried out after air pressure testing of the primary welds.

In corners and odd-shaped geometric locations, the number of field seams shall be minimised.

6.13.8 Sheet Deployment

The geomembrane shall be placed on the soil surface so that the material is able to respond to thermal changes with minimal buckling, wrinkling or tensioning. The membrane shall be allowed to 'relax'.

Allowances shall be made to accommodate predictable differential settlements of the subgrade and variations in temperature.

Care shall be taken during installation of the membrane to ensure that the surface of the membrane after installation is as free as possible from buckles, wrinkles, ripples, creases and folds. The Contractor shall ballast and weld the membrane fully taking into account moisture, temperature and membrane expansion effects so that on completion of the membrane

installation, prior to the placement of any covering or commencement of filling, the membrane is free from creases and folds.

Creases or folds shall not be permitted in the membrane.

Vehicles shall not be trafficked over the liner and care shall be taken during the course of placement of the membrane to avoid trafficking the membrane by workmen with hard or spiked shoes. Workmen shall work in soft soled footwear whilst working in the membrane area. Should any damage take place to the membrane, then suitable patches shall be applied, welded and tested to the base membrane. Spikes shall not be used to secure the membrane to the stabilised sand layer or soil.

6.13.9 Geomembrane Ballasting

Unless specified otherwise, the Contractor shall design, supply and install the geomembrane temporary ballasting system to ensure that the liner will not be adversely affected by wind and/or thermal movement during installation of the lining system.

Temporary ballast shall consist of heavy-duty polyethylene bags measuring approximately 300 mm diameter x 500 mm long, which shall be filled with clean sand or other approved materials. These bags shall be temporarily placed on the base and embankments of the pond as required during construction to ensure that the geomembrane is not adversely affected by wind and/or thermal movement during installation. The temporary ballast shall be removed at the completion of the pond unless otherwise approved.

The pond inverts require permanent ballasting to anchor the geomembrane liner when the ponds are empty. Pond invert ballasting shall be achieved by placing an equivalent in weight of 35 mm thick cover layer of silt material over the top of the geomembrane liner as detailed on the pond layout drawings. The silt shall be clear of rocks, vegetation, and other sharp material to prevent penetration of the liner. The ballast material shall be hauled form the onsite stockpile. Distribution of the permanent ballast shall be approved by the Designer.

A perimeter ballast shall be placed as a continuous strip of ballast material along the toe of the embankment slope. It shall be equivalent to 0.5 m^3 of ballast material per metre of pond perimeter, as shown on the pond layout drawings WIL1125/30/22 and 23.

6.14 Jointing of Geomembrane Liner

A complete description of the welding procedure (or procedures) to be employed shall be provided, in the Contractor's Method Statement, including the type of equipment proposed for the welding operations. Only welding procedures and equipment that are approved shall be used. The Contractor shall demonstrate that the welders and equipment are satisfactory. Specimens of welds shall be submitted for testing prior to commencing welding on site.

Approval shall also only be given where the Contractor can demonstrate the competency of his welders and the suitability of the equipment.

Jointing of the geomembrane panels shall be in accordance with the manufacturers method for joining the panels, which shall be agreed with the designer prior to commencement of geomembrane placement.

Joint sealing of the geomembrane liner panels shall not be conducted during any precipitation and the geomembrane shall be free of moisture and shall be clean and free of deleterious debris. Joint sealing shall not occur during excessively hot (>35ºC) or cold (<5ºC) temperatures.

Key Designer inspections shall be:

- Initial liner placement trials; and
- Placement and welding of the liner at concrete transitions penetrating the membrane.

Critical areas of jointing the liner will be the area around the corners of the ponds and the areas of lining penetration (i.e. pond culverts). Drawing WIL1125/30/129 and 130 detail the geomembrane fixing method adopted for all penetrations through the lining.

Two types of geomembrane welding methods are acceptable:

- Primary (fusion or wedge welding); and
- Secondary (extrusion welding).

6.14.1 Primary Welding

Primary welding (fusion welding or wedge welding) shall fuse (by heat) the overlapping parts of the upper and lower sheets. The split wedge weld method gives access to parallel weld zones for the purpose of in-field weld pressure testing.

The welding equipment shall consist of a combination split head wedge and pressure nipping roller assembly. All functions shall be protected by controls which will prevent the unit operating in the event of the failure of any critical function which would adversely affect the weld. The welding machine shall drive itself along the length of the weld.

6.14.2 Secondary Welding

For secondary welding (extrusion welding), extruded material shall be cast over the upper and lower section of the weld zone which has been preheated with hot air. The minimum width of the extruded bead shall be 25 mm unless nominated otherwise by the geomembrane manufacturer's recommendations. This method shall only be used for the purposes of making repairs or gaining access to welding those areas which are inaccessible to primary welding.

The secondary welding equipment shall consist of a combination sheet pre-heat and extruder assembly or employ, a combination dynamic mixing assembly and an extruder. The welding equipment shall be capable of continuously monitoring and controlling the extrudate temperature and preheat temperature or the barrel temperature and mixer temperature in the base of a dynamic mixer type. Only welding equipment which utilises the extrusion fusion process shall be used.

6.14.3 Extruded Rod for use in Secondary Welding

The Manufacturer shall provide certified test data to the Designer for each roll of extruded rod or granule to certify that the material properties of the extrusion material are the same as those for the geomembrane.

6.14.4 Geomembrane Weld Preparation

The subgrade upon which the welding is to take place shall be free from surface water which could adversely affect the weld quality.

The surface of the geomembrane within the proposed weld area shall be dry, clean and free from any foreign materials such as dust, clay and sand.

All welding surfaces for secondary (extrusion) welding shall be adequately abraded and bevelled using approved mechanical equipment, not more than 30 minutes prior to the commencement of the welding operation.

Care shall be taken to ensure that the abrasion does not reduce the geomembrane thickness by more than 5%. Where over-grinding is observed, this shall be rectified using a method approved by the Manufacturer and agreed by the Designer's Representative. This may include the removal of the affected area.

6.14.5 Site Procedure for Primary Welding

The nipping pressure, welding speed range and wedge head temperature parameters of the proposed welding equipment, shall be submitted to the Designer prior to acceptance of the welding unit for any work.

The Contractor shall demonstrate the total welding operation to the Designer's Representativeprior to the commencement of any welding on site. Specimens of welds shall be destructively tested by the Contractor and approved in writing prior to commencing welding on site.

The width of the lap weld shall be:

- Sheet overlap — minimum 80 mm.
- Wedge head plate width — minimum 12 mm each.
- Homogeneous weld zone — minimum 10 mm.
- Central non-weld air pressure zone — minimum 15 mm.

The following shall be recorded for each primary weld:

- Wedge temperature.
- Wedge welder speed.

6.14.6 Site Procedure for Secondary Welding

The Contractor shall demonstrate the secondary welding process to the Designer prior to its use on site. Approval to use the equipment on the work shall be required. Failure to meet this requirement shall be grounds for rejection of all secondary weld areas.

Prior to the commencement of every start up, new weld or following a delay in operation of more than one minute, the machine shall be purged for at least 30 seconds. This procedure shall ensure that all the extruded material is pumped through the extrusion barrel thus avoiding ageing and polymer degradation.

Prior to the execution of any secondary (extrusion) welding, the areas to be welded shall be buffed with a mechanical grinder to remove the oxidised layers. Overlapping membrane surfaces shall be clean and dry prior to welding. Where the temperature of either the extruded material or the air stream are shown to be excessive, the weld section shall be removed, repaired and the weld redone.

The upper and lower geomembrane sections shall be held together by tacking using a hot air welding device. This is to prevent differential thermal movement between the upper and lower surfaces of the geomembrane materials during the welding operation.

Where differential movement is observed, the weld in that region shall be ground back and an approved method of repair shall be carried out.

The temperature, rate of travel and extruded material ejection rate shall be suitably calibrated such that the extruded material is not overheated and the extruded bead of material does not distort or result in thermal flow of the top or bottom sheet material.

The welder shall ensure that the extruded casting head follows the exact line of the overlap edge without meandering or allowing the machine to rock or tilt. Failure to cast the extruded material centrally over the leading upper edge of the lap will result in rejection of that weld.

Suitable pressure shall be applied to the machine head. The rate of machine travel shall be sufficient to provide a clean, smooth casting with no surplus extruded edge flow. Should the extruded flow or the extruded mass be such that the geomembrane sheet buckles or there is excessive sheet flow beneath the weld zone, then such a weld will be rejected.

Failure to maintain suitable control over the welding machine shall be cause for the operation to be stopped. The welder shall be replaced with a competent welder.

The following shall be recorded:

- Pre-heat airstream temperature at the nozzle.
- Extruded material temperature, barrel and tip.
- Pre-heat airstream temperature.

The airstream shall not overheat the surface of the sheet and affect the crystallinity of the geomembrane material.

The dimensions of the extruded weld shall be:

- Sheet overlap minimum 80 mm.
- Extruded width minimum 25 mm.
- Homogeneous weld zone minimum 15 mm.

6.14.7 Weld Crossovers

All welded crossovers shall be offset by at least 300 mm.

The main areas where weld crossovers will occur are:

- Pond corners.
- Embankment to base seams.

- Base seaming primary welds.

Crossover welds shall be carefully prepared to ensure that no loose ends or weld flaps are left, such that voids will be left in the weld zone at the crossover. Following the preparation and the placement of the sheet to which the crossover will be welded, the entire length shall be inspected by the Designer's representative. Following inspection and approval, the execution of the primary weld may proceed.

Weld crossovers shall be tested in accordance with Section 6.15.10. Should any pressure be lost during the pressure test and be attributed to the crossover shoulders, each crossover shall be vacuum box tested. Where a leakage is confirmed, a patch shall be applied locally over the crossover. The patch shall be a minimum of 300mm diameter and be welded to the primary sheet over its entire surface. Care shall be taken to clean and prepare the area of patching to ensure that no leak paths can develop at the weld shoulders. Each patch shall be vacuum box tested.

6.15 Geomembrane Field Weld Testing

All welding of test specimens and field weld testing shall be carried out in the presence of the Designer's Representative.

Acceptance of welds or test reports by the Designer's Representative shall in no way relieve the Contractor of responsibility for the integrity, quality and performance of the welded liner.

6.15.1 Preparing Test Weld Specimens

Test weld specimens shall be made as follows:

- Prior to the commencement of each shift for each operator.
- Prior to recommencement (after equipment has been shut down).
- Each time the extrusion or thermal controls are altered.
- After every 5 hours of operation of the welding machine.

Test weld specimens shall be made by seaming two pieces of liner from the same batch of liner as being or which is about to be used for the seamed installation. Test weld specimens shall measure at least 3.0 m in length x 300 mm wide. The specimens shall be clearly marked to identify the time of the test and the ambient temperatures and prevailing environmental conditions (wind, dust, rain, cloud etc) that may influence the performance of the weld and the operator.

Each test weld specimen shall be suitably labelled and identified against the control sheet layout drawing identification of the field welding carried out before and after the test weld specimen.

The weld specimens shall be subject to destructive testing using a portable electronic digital tensiometer located on site. Ten percent of the weld specimens shall also be tested by an independent testing authority. Calibration certificates by an approved authority shall be supplied with the site-based tensiometer. Periodic calibration testing shall be done in order that these certificates shall not be more than 3 months old.

6.15.2 Test Welds - Specimen from Completed Work

Destructive Test specimens shall be removed from completed work at an initial frequency of one per 200 m of weld completed. The Contractor shall remove the test specimens at locations nominated or approved by the Designer for testing.

The Contractor may propose a method of reducing the destructive test frequency based on a history of passing results and he may adopt this method if approved by the manufacturer and agreed with the Designer.

6.15.3 Destructive Testing

The purpose of non-destructive testing is to check seam continuity. Destructive testing shall be carried out in accordance with ASTM 4437. One test piece (at least 900 mm long) shall be taken from each test specimen (both prepared specimens and from the completed work) for the purpose of destructive testing. The weld shall run parallel to and be central between the long edges. The test pieces shall be cut into three sections, each at least 300 mm long.

First Specimen Section

Tests shall be made on test strips taken from the first specimen section of all specimens taken from completed work and 10% of prepared test weld specimens by an independent testing authority as follows:

- 3 peel tests.
- 2 shear tests.

Second Specimen Section

The second specimen of all specimens from completed work and all prepared test weld specimens shall be field tested by the Contractor. This test shall be executed for prepared test weld specimens prior to any additional welding being carried out and as soon after the weld is made as possible. In the case of specimens from completed work the test shall be carried out as soon as practicable after the seam was welded. The test shall be carried out in the presence of the Designer.

Tests on the second specimen shall be as follows:

- 3 peel tests.
- 2 shear tests.

Third Specimen Section

The third specimen section shall be considered to be a reference sample. The Contractor shall hold this specimen section for possible future reference. The specimen shall be matched and accompanied by the field test report and ultimately by a copy of the independent testing authority report.

The Contractor shall be responsible for ensuring that the independent testing authority is provided with the necessary samples. The Contractor shall also provide the Designer with a copy of each report from the independent testing authority within 2 days of receipt.

6.15.4 Tensiometers

The tensiometer shall be capable of sustaining a constant cross head speed of 51 mm per minute for HDPE. It shall be fitted with jaws suitable for clamping of 25-mm wide specimens without causing jaw damage and premature failure. The machine shall have digital readout capable of peak hold and a scale of 0.1 kN increments. A copy of a current calibration test certificate from an independent laboratory shall be submitted for approval.

6.15.5 Test Procedures - Welds

Each weld shall be covered by a quality assurance test report. Where faults are found within a weld, they shall be clearly detailed on the quality assurance test report and identified on the 'as constructed' drawings.

6.15.6 Weld Shear Test

All field weld shear tests shall be carried out following the procedure of ASTM D4437. If the specimen has ductile failure in the sheet material before the weld fails and the tensile strength achieved in the test exceeds the geomembrane manufacturers specified minimum yield strength for the geomembrane sheet, then the weld shall be acceptable.

Laboratory tests shall use the seam tests methods nominated for the particular material under Section 8, of ASTM D4437.

6.15.7 Weld Peel Test

All field weld peel tests shall be carried out in accordance with ASTM D4437. If the specimen has ductile failure of the sheet material before the weld fails and the tensile strength achieved in the test exceeds 75% of the geomembrane manufacturers specified minimum yield strength for the geomembrane sheet, then the weld shall be acceptable.

6.15.8 Seam Test Criteria

The minimum seam test values are summarised in Table 11.

Table 11: Minimum Seam Test Values for HDPE Geomembrane

Thickness				**1.0 mm**	**1.5 mm**	**2.0 mm**
Test	**Method***	**Units**	**Max/ Min**	**Value (N/25mm)**		
Hot wedge dual track seams						
Shear strength (1)	GRI GM19	N/25mm	Min	350	525	701
Shear elongation (2)	GRI GM19	%	Min	50	50	50
Peel strength (1)	GRI GM19	N/25mm	Min	263	333	530
Peel separation	GRI GM19	% of weld area	Max	25	25	25
Extrusion fillet seams						

Shear strength (1)	GRI GM19	N/25mm	Min	350	525	701
Shear elongation (2)	GRI GM19	%	Min	50	50	50
Peel strength (1)	GRI GM19	N/25mm	Min	225	340	455
Peel separation	GRI GM19	% of weld area	Max	25	25	25

[1]Shear and peel strength values are for 4 out of 5 test specimens. The 5th specimen must be at least 80% of the value.
[2]Elongation measurements should be omitted for field testing.

6.15.9 Procedure Following Destructive Test Failure

Following the failure of a test weld specimen by destructive testing, the seam represented by the specimen shall be considered to be defective and the extent of the defect shall be determined. The section of defective seam shall be determined by removing and testing additional specimens from completed work from each side of the defective specimen. If the specimens from the completed work pass the tests, then the seam between the locations of the satisfactory specimens from completed work nearest to the failed test location shall be replaced or repaired.

If the prepared specimens on each side of the original failed specimen fail, then continue to take successive adjacent prepared specimen tests to determine the extent of defective seam. The seam between the two satisfactory specimens shall be replaced or repaired.

The new welds shall be tested using tests appropriate to the weld procedure.

6.15.10 Primary Welds - Pressure Test

At the completion of each length of primary weld, the weld length shall be tested in accordance with ASTM 5820. The testing shall be in the presence of the Designer.

Both ends of the seam to be tested shall be sealed and an air pressure applied from one end via a needle or similar device to achieve the pressure set out in Table 12.

Table 12: Primary Welds Pressure Test

HDPE Geomembrane Thickness (mm)	Minimum Pressure (kPa)	Maximum Pressure (kPa)
1.00	170	210
1.50	190	250
2.00	210	250
2.50	210	250

Observe and record the pressure 2 minutes after the initial reading. If the loss of pressure exceeds that shown in Table 13, or if the pressure does not stabilise, the faulty area shall be

located and repaired. The pressure differential after 2 minutes shall be not more than that given in Table 13.

Table 13: Primary Welds Pressure Difference

HDPE Geomembrane Thickness (mm)	Max Pressure Difference (kPa)
1.0	25
1.5	20
2.0	10
2.5	10

At the conclusion of all pressure tests, the other end of the air channel to where the pressure gauge is located shall be cut to release the air pressure and demonstrate the continuity of the air channel by loss of pressure at the gauge. If this is not demonstrated the air channel will be considered 'blocked' and the test shall be repeated from the point of blockage. If the point of blockage cannot be found, the air channel shall be cut in the middle of the seam (inspection cut) and each half-treated as a separate test.

Remove the needle (or other approved pressure feed device) and seal the opening by secondary welding.

Record the location of the pressure-tested weld on the Daily Progress Reports.

6.15.11 Primary Welds - Failure of a Pressure Test

If a primary weld fails a pressure test as nominated in Section 6.15.9, a visual inspection of the weld shall be done to identify any obvious defect. If no defects are evident then the air channel shall be filled with high-pressure air to identify the source of leakage.

If a single leak or multiple leaks are detected within a 1 m section, the weld shall be repaired and retested (see Section 6.16.3 for repairs). If multiple leaks are detected over a distance exceeding 1.0 m, the weld (over the length that the pressure test was conducted) shall be removed and replaced in accordance with Section 6.16.2.

The primary weld shall be sealed on both sides of the defective area and both sides shall be pressures tested. Failure of the tested sections shall result in the entire seam of that section being removed and replaced in accordance with Section 6.16.2. If the two sections on each side of the defective area pass the individual pressure tests, the balance of the primary weld shall be deemed to have passed the pressure test.

A patch shall be placed over the defective section. The patch shall be vacuum box tested and passed or replaced.

6.15.12 Secondary Welds

Each secondary weld shall be subjected to 100% continuous vacuum box testing as described below or to mechanical probe/lever testing if not accessible to vacuum box. Testing shall be carried out in the presence of the Designer.

The **test equipment** shall comprise the following:

- A vacuum box assembly consisting of a rigid housing, a transparent viewing window; a soft neoprene gasket attached to the bottom, port hole or valve assembly; and a gauge to indicate chamber vacuum.
- A steel vacuum tank and pump assembly equipped with a pressure controller and pipe connections.
- A rubber pressure/vacuum hose with fittings and connections.
- A bucket containing soapy water and wide brush or spray assembly.

The test procedure shall be:

- Start the vacuum pump to reduce the tank pressure to approximately 35 kPa of vacuum.
- Wet an area of geomembrane approximately 0.3 m x 1.2 m with soapy water.
- Place the vacuum box over the wetted area.
- Close the bleed valve and open the vacuum valve.
- Ensure a leak-free seal is created.
- Through the viewing window, examine the geomembrane for the presence of soap bubbles (about 10 to 15 seconds).
- Close the vacuum valve and open the bleed valve.

Repeat the process (if required) in an adjacent area, ensuring at least a 75 mm overlap with the tested area. Areas where soap bubbles were seen, shall be marked and repaired in accordance with Section 6.16.

The vacuum tested welds shall be recorded on the Daily Progress Report.

6.15.13 Non-Destructive Weld Testing

The Contractor may apply to the Designer in writing to carry out additional non-destructive testing on completed welds. The procedure for such testing shall be nominated by the Contractor.

6.16 Repairs to Liner

Any portion of the geomembrane lining system failing a destructive or non-destructive weld test, or showing some other defect, shall be repaired to the satisfaction of the Designer. The details and location of the defect shall be marked on the 'as constructed' drawing.

6.16.1 Repair of Secondary Welds

Generally, secondary welds shall be repaired by grinding back the extruded material to the geomembrane sheet. Each end of the weld section remaining, shall be bevelled to provide a smooth transition between the existing and replacement weld sections. The ground-out section shall be rewelded.

The Designer may approve minor secondary weld repairs be done by applying an additional run of extruded material over the existing weld.

Secondary welds which have been repaired and have failed subsequent testing shall be repaired by patching in accordance with Section 6.16.3.

6.16.2 Repair of Primary Welds

Any welds which fail destructive testing shall be replaced or repaired as directed or approved by the Designer's Representative. Where the Designer directs a weld to be replaced, the original seam shall be removed and replaced with a strip of new material with a minimum width of 0.3 m which shall be welded with primary welds where possible, or secondary welds on all sides.

6.16.3 Repairs to Failed Pressure Tested Primary Welds

Faults Detected Visually

If a fault is identified visually in the exposed weld, the Contractor shall repair the fault by the application of a surface patch. The free edge of the overlap section shall be trimmed to the edge of the weld zone to a distance of 200 mm along the seam from the fault into the competent weld section. The trimmed edge shall be welded with a secondary weld to the sheet below for the full length of the trimmed section. A patch of the same material and thickness as the geomembrane shall be placed over the fault zone and shall extend a distance of 150 mm from the fault zone towards the competent weld. The patch shall have a minimum width of 200 mm located centrally over the faulty weld. The patch shall have rounded corners with a minimum radius of 25 mm. The patch shall be welded around all edges by secondary welding.

Faults Detected by High Pressure Air Testing

If the leak is identified by the high-pressure air test to occur on the internal seam, the Contractor shall cut through the seam at the fault. The loose edge of the fault shall be peeled back each side of the inspection cut, until competent fusion is achieved across the weld.

6.16.4 Patching

Where approved, patching shall be used to repair holes, tears, destructive test weld specimen areas and defective seams in geomembranes. The edge of the patch shall extend at least 150 mm beyond any defect and shall have rounded corners with a minimum radius of 25 mm. The patch shall be fully welded to the original geomembrane liner using secondary welding techniques.

6.17 Penetrations

All penetrations of pipes through the HDPE liner are to be tested using spark testing or other method approved by the Designer to demonstrate an effective seal.

6.18 Liner Placement and Jointing Trial

The placing trials shall be located at agreed locations on a section of constructed pond embankment to determine appropriate procedure for construction installation of the geomembrane lining. At least one placing trial shall be located on a pond corner.

Trial methods shall include for:

- Confirm procedure to achieve a suitable surface to support the geomembrane (refer to Section 4.4);
- Anchor trench construction and installation (refer to Section 6.13.1);
- Geomembrane placement methodology (refer to Section 6.13);
- Lap jointing geometry (overlap width);
- Joint sealing (refer to Sections 6.14 and 6.15);
- Patch repair methodology (refer to Section 6.16); and
- Assessment of QA/QC methodology (discussed in Section 6.21).

6.19 Fixing Liner to Concrete Structures

To fix geomembrane to the concrete structures an element called Maxlock and produced by Solmax shall be adopted. Maxlock shall be installed in accordance with manufacturer's instructions.

It is essential that Maxlock shall be produced from the same resin as the liner to assure their compatibility.

All joints of the liner to Maxlock shall be welded by extrusion welding. Accordingly, the Maxlock insert shall form a continuous perimeter water retaining strip.

The Maxlock joints at the outer corners of the concrete structures shall be mitred first and then extrusion welded in the same manner as described above. The tension/slack balance shall be controlled in the corner connections to prevent stretching.

The HDPE Geomembrane shall be extrusion welded to the Maxlock element embedded to concrete structures during placement of the liner.

Air release holes shall be provided behind the Maxlock strip to prevent formation of air pockets behind the cast.

6.20 Certificates and Records

The Contractor shall provide all Quality System certificates and records as required, including the following:

- An ITP outline which shows the tests and frequencies
- Raw Material Testing Reports.
- Geomembrane Production Test Reports.
- Register of Key Personnel.
- Geomembrane Roll Reports (Sheet Defect).
- Acceptance of Subgrade Certificates.
- Panel and Welding Layout Drawings.
- Welding Equipment and Methods.
- Daily Operating Control Report (for each welding unit).
- Trial Weld Reports.
- Pre-Weld Test Certificates.
- 'As Constructed' Drawings.

- Daily Weld Vacuum Box Test Reports.
- Daily Weld Specimen Destructive Test Report.

6.21 Quality Control

Representatives from both the Designer and Contractor shall be present throughout the geomembrane installation process, including placement trial, installation and routine inspection and testing.

Quality System Documentation shall be reviewed weekly by the Designer's Representative and Contractor jointly, in order to manage any defects and other issues. Periodic review of Quality System Documentation along with Quality Control Documentation shall be kept up to date with revisions made in accordance with modifications arising from periodic reviews.

6.21.1 Laboratory Testing and Sampling

Refer to Table 14 and Section 6.21.2, for Laboratory Testing and Sampling on site requirements, particular to the HDPE liner.

6.21.2 Location and Frequency of Routine Inspection and Testing

Routine testing will be required generally using laboratory testing of selected samples together with simple field tests. The Contractor and the Designer's Representative shall inspect and test the stages of geomembrane liner as outlined in Table 14. All inspection and testing stages and results shall be included in the Contractor's QA/QC Report. All tests carried out shall be clearly marked on the geomembrane adjacent to a panel lap joint.

Table 14: Contractor and Designer Routine Inspection and Testing

QA/QC Procedure	Stage	Frequency
Visual Inspection	Site Delivery (packaged)	Upon delivery
	Liner (unpackaged)	Each unit as unpackaged
	Liner Placement	Each panel
	Anchor Trenches	Entire installation
	Joint sealing	Each joint
Site Tests	Joints: Destructive	*Discussed below
	Joints: Non-destructive	Full length each panel joint
	Liner panel: Non-destructive	Each panel
	Repairs: Non-destructive	Each repair
Notes: **The frequency and location of the joint destructive test sampling shall start with a defined sample interval (1/150m) for testing, and depending on the amount of failure tests, the spacing interval for sampling shall be adjusted by agreement between the Designer and Contractor (i.e., many failures, closer sampling, no failures the sampling intervals widen). All destructive joint tests shall be carried out as the jointing progresses and not at the completion of all installation jointing.*		

Liner visual inspection shall include confirming the proper geomembrane material and thickness has been provided by the manufacturer, back checking the QA/QC sheets provided by Solmax to confirm factory Quality Control of each panel.

All panel jointing (over the full joint length) shall be non-destructively tested. Tests and inspections shall be carried out as installation progresses and not at the completion of all installations. Procedures and requirements of Standard ASTM D4437 shall be utilized to non-destructively test lap jointing for HDPE geomembrane.

6.21.3 Reporting

The Contractor shall produce the following quality control reports:

- Factual test data reports on a weekly basis: quality report incorporating, among others the following details of numbers and types of tests carried out, a summary of results, staff employed in testing and the forthcoming programme of testing; and
- As-built completion report, including layout plan (locating with identification code all panels, seams, tests, repairs and patches), at the end of the construction period.

6.22 Provision for Future Liner Performance Testing

Ten A2 size coupons of the liner geomembrane material shall be welded to the geomembrane surface at the full supply level of the lining in Pond 1, allowing for 60 years of monitoring with testing of a coupon sample every 5 years, commencing at end of year 10.

Further, two A2 size coupons shall be welded to the geomembrane surface at the bottom of Pond 1 allowing for testing over 5 years at the time samples from full supply level indicate the need for liner replacement.

Location of all twelve coupons shall be recorded on the as-built drawings.

6.23 Pond Safety Ladders

This item is for supply and installation of access ladders to support safe access and egress in the pond. Pond access ladder locations are shown on Drawing WIL1125/30/21. The ladders shall extend the full height of the embankment, from pond base to embankment crest, at each location and shall be sufficiently secured in place to prevent movement or damage from the wind or other loading. Rungs shall be slip resistant.

The ladders shall be fabricated from PE and fitted to the finished pond HDPE liner. Ladders shall be highly visible.

Table 15 below indicates the number of ladders required and their corresponding lengths.

Table 15: Pond Safety Ladders

Pond	Number of Safety Ladders	Length of each Ladder (m)
Pond 1	14	25.3
Pond 2	16	32.8
Service Spillway	4	12.4
Tub	4	13.9

Construction of Pipelines Culverts and Ancillary Works

This section covers the execution of all permanent work necessary for drainage, energy dissipation and flow measurement as specified herein and as shown on the Drawings, including but not limited to the following:

- Culverts in embankments and road crossings
- Inlet and outlet transitions
- Energy dissipaters
- Crump Weirs

7.1 Embankment Concrete Pipe Penetrations

The placement of conduits or outlet pipes through earth embankments is a common cause of piping failure and accidents particularly in small embankments without filters. The methodology for construction of culverts in embankments shall align with the pipe performance requirements, be agreed with the Designer prior to commencement of construction and meet acceptance testing.

Pipe penetrations of the embankment are to be installed as follows:

a) The excavated pipe trench is to be dewatered and mapped prior to pipe laying or backfilling.
b) The pipe is to be placed in a trench, freshly cut into the initial section of compacted embankment and foundation where the pipe section extends into the foundation.
c) The trench is to be backfilled carefully with specified fill material (refer to Drawing Number WIL1125/30/134).
d) Pipe bedding and backfill material shall be:
    - Controlled Low Strength material (CLSM) trench bottom to the pipe springline (refer Drawing Number WIL1125/30/134)
    - Type 1 backfill material, AP20 material shall be well graded and have fines content (fine sand and smaller) of less than 5% and maximum particle size of 20mm placed and compacted above the pipe springline and around ends of the pipeline as shown on Drawing Number WIL1125/30/134 (refer to Section 17.0 for material grading);
e) Construction Drawing WIL1125/30/134 shows the extent of CLSM and Type 1, backfill and provide typical cross section details. Further this drawing shows the backfill detail for both upstream and downstream concrete transitions with compacted Type 1 material.
f) Processed backfill material shall comply with required gradings (refer to Section 17.0). Prior to placement, the Contractor shall provide grading curves of both foundation and backfill materials to the Designer to confirm material compliance (refer to Section 1.13).
g) Pipes are to be resistant to crushing. Concrete pipes shall be RCRRJ, Class as shown on the Drawings, complying with the NZS 3109:1997 Concrete Construction.
h) All pipe installations through earth embankments shall be constructed with watertight joints.

7.2 Steel Pipe Installation

7.2.1 Steel Pipe Penetration to Proposed Power Station

There is potential to construct a hydro-power station near the intersection of Wrights and Coffey Roads. The proposed power station will generate power under approximately 12 m of head between the level of Pond 2 and the future power station. The future power station will discharge into a tailrace canal delivering to a further power station located near the Waimakariri River (Refer to Drawings WIL1125/30/1 & 2).

A 1930 mm OD steel penstock is provided under Pond 2 embankment to accommodate the potential development of hydropower described above. A connection from the penstock delivers flow to R2 through a 1350 mm diameter steel branch pipe ending at an impact type energy dissipater as described in Section 7.7. Both 1930 mm and 1350 mm OD steel pipes shall be spiral welded “High-specification” Grade B steel wall thickness 12mm, by Steelpipe NZ Ltd or approved equal. The pipe sections shall have a factory-applied internal epoxy coating of minimum dry film thickness 400µm and an external coating of Polyken YGIII corrosion protection system. Fittings, such as bends and tees, shall be fabricated by the pipe manufacturer (refer to Drawings WIL1125/30/103 – 105 and also WIL1125/30/134 for backfilling detail) with coatings and protection as for the pipe sections. The number of site-welded connections shall be minimised to the extent possible.

A minimum of 1m of fill must be placed over the penstock (not including the AP20 surround material) before construction traffic is permitted over it. Backfilling of the penstock pipeline shall be in accordance with Section 7.1 above and drawings WIL1125/30/106 & 107.

Prior to development of the hydro-power station, the flow into R2 will be controlled by the inlet gate. If and when the power station is constructed, flow into R2 will be controlled by a 1350 mm diameter valve (refer to Drawing WIL1125/30/106). A new intake gate may also be required subject to the requirements and specification of the hydropower provider.

7.2.2 Steel Pipe to Pump Stations

The following spiral welded steel pipelines extend through the crest of the pond embankments and deliver water from Pond 2 and Buffer Pond:

- Pond 2 Pump Station Outlet: 2x OD 762mm wall thickness 8mm Grade 250 spiral welded steel pipe (refer to Drawing WIL1125/30/135 to 138);
- Buffer Pond Pump Station outlet3x OD 568mm wall thickness 8mm Grade 250 spiral welded steel pipes (refer to Drawing WIL1125/30/139 to 140)

All steel pipes shall be spiral welded high specification steel by Steelpipe NZ Ltd or approved equal and the fittings, such as bends and tees, shall be fabricated by the pipe manufacturer.

7.2.3 Corrosion Protection of Steel Pipes to Pump Stations

The steel pipes for the pump stations shall have epoxy coating externally and internally. Epoxy coating shall have minimum thickness of 400 microns. The Contractor shall design and submit the installation methodology and commissioning procedure to the Designer for review and approval prior to installation of the steel pipes.

7.2.4 Handling of Coated Steel Pipes

The Contractor shall transport, handle and install the steel pipes as per the Steelpipe NZ Ltd Guidelines, Product Brochure and the relevant AS/NZS Standards stated therein. The Guidelines of Steelpipe NZ Ltd., is provided in Appendix A.

The pipes shall be handled in such a manner as to protect the pipe and coating system. All pipe-handling equipment such as web belts, slings and/or hooks shall be designed not to damage the coated pipe. Web tie-downs shall be used to secure coated pipe to the transport vehicle. Chains, cables or metal strapping shall not be used.

7.2.5 Welded Joints and Repairs

The steel pipes shall be jointed with plain butt welded joints. The pipe ends to be jointed must be free from dirt or any other deleterious material.

All site lining and coating repairs at welded joints and for isolated damage shall be carried out both inside and outside of the pipe in accordance with Steelpipe NZ Ltd., Guidelines (refer to Appendix A) relating specifically to internally and externally coated pipes as specified in Section 7.2.3. All site coating and lining material shall be the thickness and material as provided by the manufacturer in accordance with Section 7.2.3.

Prior to backfilling, the site welded joints in the penstock pipeline including the 1350 mm diameter irrigation supply line shall be corrosion protected internally and externally in accordance with the Steelpipe Information Catalogue and AWWA C214. Finally, the entire corrosion protective coating shall be free of faults when tested with a 5kV High Voltage spark tester. The coating shall be free from moisture prior to testing.

7.2.6 Quality Assurance of Site Welded Joints

Prior to any welding works, the Contractor shall provide the Designer, his Quality Assurance (QA) methodology for the welded joints. This shall cover the Quality Control (QC) procedure that is required to ensure the quality aspects of the joint welding and repairs to the pipe coating.

The QC procedures shall cover at least the following aspects:

- Welder's name and qualifications;
- Welding procedures;
- Repair procedures; and
- Inspection before, during, and after welding fabrication.

The Contractor shall develop welding sequences and shall furnish the necessary supervision to ensure that the planned sequences are followed. Welding sequences shall include:

a) Inspection of the weld preparation and pipe prior to the start of welding;
b) Welding procedure to be applied; and
c) Sequence of pipes or components to be welded.

7.2.7 General Requirements of Joint Welding

All welding shall be carried out with the pipework in a clean and dry condition and shelters shall be provided to protect the weld area from inclement weather.

Butt welds must be full penetration and welds must be radiographically tested.

Welds joining temporary attachments to the pipeline must be to the same quality as the final weld. Temporary attachments must be removed carefully and the area visually inspected for any surface flaws and finally tested with a 5kV High Voltage spark tester prior to backfilling.

7.2.8 Non-Destructive Test Requirements for Site Joint Welding

As part of the QC procedure, the Contractor shall ensure:

- All welds are to be 100% visually inspected by the Designer's Representative;
- All welds are to be 100% radiographically tested; and
- Certified as meeting the acceptance standards.

As part of the works commissioning, the Contractor shall:

- Submit weld maps and inspection checklists for all welds (field and shop)
- Submit weld maps and test certificates for all welds tested by non-destructive methods

7.2.9 Protection of Welded Joints

Prior to welding all the welded joints must be wire-brushed from inside and outside and completely clean and dry from any moisture. The Contractor shall protect the weld joints as per the procedures outlined in Steelpipe NZ Ltd Guidelines (refer to Appendix A).

7.2.10 Bedding and Backfilling for Steel Pipes

Before the pipes are laid, the bottom of the trench shall be checked for any protrusions and materials that may damage the coating. Bedding and backfilling shall be done as shown in the drawings. Care shall be taken with subsequent backfill, not to overload the pipe with wheel and other construction loads.

7.2.11 Field Pressure Test of Steel Penstock Pipe

Prior to repair of coating and lining at joints, the penstock steel pipe shall be pressure tested. The Contractor shall carry out the tests in conformity with Section 6 of AS/NZS 2566.2:2002 Buried flexible pipelines - Installation and other relevant standards specified therein.

Following inspection and approval by the Designer, the Contractor shall seal off the ends of completed pipe sections with approved blank flanges/stop-ends. The pipeline shall be filled with water and pressurised to 0.5 MPa (5 bar) measured at the lowest point at the downstream end. The dimensions of flanges, number of bolt holes and sizes shall suit for the test pressure and the Contractor shall be responsible for the design and fitness for purpose of the pressure test set-up. The pipeline shall be accepted if the leakage does not exceed 1 litre per 10 mm of pipe diameter per 1,000 m of pipe per 7 hour period. The Contractor shall repair and make good any leakage or faulty workmanship in order to satisfy the field pressure test

7.3 Fill against Structures and Around Buried Pipes

Fill materials placed against structures and around buried pipes shall be as described in Section 7.1. Fill material shall be compacted with suitable vibratory compaction plant or equipment to achieve the specified densities and properties and ensure close contact between the fill and the structure or pipe.

Fill material against structures and around buried pipes shall be placed in layers not exceeding 200 mm thick after compaction and the in-situ dry density for such fill shall not be less than 95% density ratio (refer to Section 4.1.1 for compaction moisture content).

Fill placing shall be performed in a manner to prevent damage to structures. Adjacent to structures all fill materials shall be placed in such a way as to ensure that they can be satisfactorily placed and compacted without damage to structures. Compaction shall be undertaken using hand operated compaction equipment, in layers sufficiently shallow to allow full compaction to meet all requirements of the specification. No fill material shall be placed or compacted adjacent to concrete less than ten days after placing the concrete without written consent from the Designer.

The Contractor shall confirm to the Designer, details of plant and methodology to be used to achieve the specified requirements. Compaction plant proposed may include vibrating plate compactors.

7.4 Unsuitable Foundation Material

Where the Designer considers that the foundation material below the pipes or structures is unsuitable, this material shall be removed to a depth specified by the Designer. Unsuitable foundation material shall be replaced with approved compacted material.

7.5 Dewatering

The Contractor shall keep excavations free from water at all times and shall provide all such pumping plant and drainage systems as may be required for this purpose.

Sumps formed for the purpose of dewatering shall be kept outside the line of pipe trenches and away from structure and embankment foundations. When finished with, they shall be backfilled with suitable compacted fill.

7.6 Inlet and Outlet Transitions and Energy Dissipater

The Contractor shall install reinforced concrete headwall, wing wall and apron structures for the culverts and pipelines as shown in the Drawings. Hynds Pipe Systems Ltd or similar approved precast headwall units will be acceptable.

At the completion of construction/installation, the Contractor shall backfill behind the wing walls and headwall with compacted material as detailed on the Drawings and Section 7.3. Any further required backfilling shall be carried out using fill material from on site, to the profile shown on the Drawings.

7.7 Energy Dissipater

The irrigation steel pipe that branches of from the hydro-power steel penstock ends with an impact type energy dissipater transition. The Contractor shall construct this energy dissipater with an inverted L-beam of high strength concrete (50 MPa). The Contractor shall pay special attention to ensure this beam is completed as per Drawing WIL1125/30/106. At the completion of construction, the Contractor shall backfill behind the dissipater with compacted material as detailed on drawing WIL1125/30/104 and Section 7.3.

7.8 Crump Weirs

To measure the flows in both distribution races R2 and R3, downstream of the outlet transitions and energy dissipater, two RC Crump weirs are to be constructed. The Contractor shall construct the Crump weirs as shown in Drawings WIL1125/30/110 and 127. The Contractor shall pay special attention to the accuracy of the level and alignment of the crest.

The two crump weirs have been designed based on the limited survey information available. In order to ensure accuracy of the flow measurements, assumed topographic survey information needs to be verified before starting of crump weir works, the Contractor shall provide the Designer with cross sections, bed levels and bank levels of R2 and R3 races. The distance shall be from the proposed Crump weir location downstream to the first drop structure. The Contractor shall coordinate this work with the Designer prior to start of this survey.

7.9 Quality Control

7.9.1 Inspection

The Designer shall inspect all culvert excavations and pipe installations including backfill around pipes.

Representatives from both the Designer and Contractor shall be present during the culvert installation, including excavation inspection prior to, pipe placement, back filling next to structures and buried pipes.

The Contractor shall confirm the quality control test methodology and report format with the Designer.

Inter-pond pipe culvert inverts shall be level surveyed and the levels shall be recorded on the as-built drawings.

7.9.2 Pipe Inspection

All pipelines shall be free of debris and flushed within 24-hours prior to inspection by the Designer.

The Contractor shall confirm the inspection methodology and report format with the Designer.

7.9.3 Compaction Testing

Refer to Sections 4.1 and 4.3 for testing requirements.

8.0 Concrete, Formwork and Reinforcement

8.1

8.1 General

This specification covers the materials, plant, mixing, placing and testing of concrete for construction of culverts, spillways, weirs and low-level outlets between ponds in the embankments as part of the permanent works for Waimakariri Irrigation Ltd., Wrights Rd Ponds.

The extent of concrete works is detailed on the construction drawings. The requirements of NZS 3109: 1997 Concrete Construction shall apply unless modified below.

8.2 Abbreviations and Definitions

The following abbreviations apply specifically to this section:

DPM	Damp proof membrane
MPa	Megapascal
CCANZ	Cement and Concrete Association of New Zealand

The following definitions apply specifically to this section:

ACRS Australian Certification Authority for Reinforcing Steels – An independent certification scheme for reinforcing steel and structural steel, by product and manufacturer/processor. Certifies compliance with Australia/New Zealand Standards.

Web site - www.steelcertification.com

8.3 Concrete - common requirements

This section deals with general matters relating to all aspects of concrete work.

8.3.1 Reference Standards

The following standards, with their latest issue date, shall form part of the contract documents and shall be read in conjunction with this specification:

- AS 1366.3 Rigid cellular plastics for thermal insulation - Rigid cellular polystyrene - Moulded (RC/PS - M)
- AS 1478: 1992 Chemical admixtures for concrete
- AS/NZS 1554.3 Structural steel welding - Welding of reinforcing steel
- AS/NZS 2269.0 Plywood - Structural - Specifications
- NZS 3101.1 Concrete Structures Standard
- NZS 3104 Specification for concrete production
- NZS 3109 Concrete construction
- NZS 3111 Method of Tests for Water and Aggregate for Concrete
- NZS 3112.1 Methods of test for concrete - Tests relating to fresh concrete
- NZS 3113 Chemical admixtures for concrete

- NZS 3114 Specification for concrete surface finishes
- NZS 3117 Pigments for Portland cement and Portland cement products
- NZS 3121 Specification for water and aggregate for concrete
- NZS 3122 Specification for Portland and blended cements (General and special purpose)
- NZS 3125 Specification for Portland-limestone filler cement
- NZS 3402 Steel Bars for Reinforcement of Concrete
- NZS 3404:1997 Steel Structures Standard
- NZS 3415:1995 Hot-rolled products of non-alloy structural steels – Technical delivery conditions
- NZS 3422:1975 Specification for welded fabric of drawn steel wire for concrete reinforcement
- NZS 3604 Timber-framed buildings
- NZS 3603 Timber Structures Standard
- NZS 3631 New Zealand timber grading rules
- AS/NZS 3678:1990 Structural Steel – Hot Rolled Plates, Footplates and Slabs
- AS/NZS 3725:2007 Design for Installation of Buried Concrete Pipes
- NZS 3916 Conditions of Contract for Building and Civil Engineering – Design and Construction
- NZS 4402: 1986 Methods of Testing Soils for Civil Engineering Purposes
- NZS 4407: 1991 Methods of Sampling and Testing Road Aggregates
- NZS 4229 Concrete masonry buildings not requiring specific engineering design
- AS/NZS 4357 Structural laminated veneer lumber
- AS/NZS 4671 Steel reinforcing materials
- AS/NZS ISO 9001 Quality management systems - Requirements
- Alkali aggregate reaction (Cement and Concrete Association)

*** A copy of NZS 3109 Concrete Construction, must be held on site.**

8.3.2 Requirements

Qualifications: Workers should be experienced, competent and familiar in the fabrication and erection of formwork and with the materials and the techniques specified.

Inspections: Refer to section 8.3.4 for type of inspection.

Records: Make and keep record of mix, time, date and location of each pour and make available on request together with delivery dockets. Cross reference delivery dockets in pour records.

Producer statements: Provide Producer Statements where required by the Building Consent Authority and where required by this specification.

8.3.3 Performance

Testing on site

Carry out sampling and concrete acceptance tests during construction to NZS 3109: section 9, Concrete acceptance tests during construction, noting that concrete may be rejected for:

- Non-compliance with this specification.
- Non-compliance with NZS 3109, section 9, Concrete acceptance tests during construction.
- Showing by appearance when in place that it does not comply with this specification, especially in respect of surface finish, segregation, or low density and which cannot acceptably be made good.

Conduct 7-day strength tests. After a 7-day test result of less than 60% of the specified strength, concrete placement to stop until it is shown the suspect concrete complies with the specification. Make all test records available.

Confirm steel reinforcing compliance

Provide a Producer Statement confirming that the steel reinforcing supplied complies with the grades specified on the drawings by producing test results to AS/NZS 4671.

Control tests

Carry out slump tests, yield tests and air content tests to NZS 3112.1, sections 4, 5, and 9 respectively and evaluate to NZS 3104: section 2.15, Control tests and their evaluation, keeping a record of all tests at the plant and making them available on request.

Strength tests

Carry out to NZS 3112.2, section 10 and evaluate to NZS 3104: section 2.15, Control tests and their evaluation, keeping a record of all tests at the plant and making them available on request.

Quality assurance

Carry out the whole of this work to the requirements of NZS 3109 and under the regime of a quality systems model for quality assurance in production and erection to AS/NZS ISO 9001.

Quality assurance procedures to include all aspects of concrete construction including:

- Formwork quality
- Reinforcing steel placing
- Cast in items
- Concrete quality
- Concrete finishes
- Construction tolerances

Advise name of the suitably experienced and qualified representative who is responsible for quality control of the concrete work. The representative is to sign a written quality control

checklist for each on site concrete pour. Provide a copy to the construction reviewer in sufficient time for a pre pour inspection.

8.3.4 Inspections

Inspection notification requirements

24 hours minimum notice required prior to all concrete pours.

Inspections by Designer's Representative.

Pre pour inspections of all in-situ and precast concrete elements.

Inspections by Building Consent Authority

To be advised by others.

8.4 Concrete quality control

8.4.1 Abbreviations and definitions

The following definitions apply specifically to this section:

Primary Concrete	Concrete required for structural purposes in tunnel linings, inverts, walls, floors, plinths and piers
Finishing Concrete	High strength concrete which is poured against primary concrete for embedding steelwork and achieving fine dimensional tolerances with smooth finishes and durability
TELARC Registered Laboratory	(TRL) Any testing laboratory recognised by the Testing Laboratory Registration Council of New Zealand

8.4.2 Reference Standards

- AS 1478 Chemical Admixtures for Concrete
- NZS 3104 Specification for concrete production
- NZS 3109 Concrete construction
- NZS 3111 Methods of test for water and aggregate for concrete
- NZS 3112.1 Methods of test for concrete - Tests relating to fresh concrete
- NZS 3121 Specification for water and aggregate for concrete
- NZS 3122 Specification for Portland and blended cements (General and special purpose)
- AS/NZS 4671 Steel reinforcing materials
- ASTM C88 05 Standard Test Method for Soundness of Aggregates by use of Sodium Sulphate or Magnesium Sulphate

8.4.3 Requirements

Qualifications

Workers to be experienced, competent trades people familiar with the materials and techniques specified.

Concrete mix design

Not later than eight weeks before commencing concreting operations, submit a concrete mix design certified by a Registered Engineer for each type of concrete specified herein.

Include the following details in addition to those required by NZS 3109.

- Mix Designation
- Target Strength
- Target Water/Cement Ratio by weight
- Batch weights of cement and aggregate
- Type and brand of cement
- Type, purpose and quantity of admixtures and rate and method of application
- Typical allowances made for aggregate moisture content
- Target slump
- Amount of air entrainment
- Batch size and yield

8.4.4 Compliance information

Information required for code compliance

Provide the following compliance documentation: -

- Producer Statement - Construction from the Contractor
- Producer Statement - Design from the Contractor
- Producer Statement - Construction Review from an acceptable suitably qualified person
- Other information required by the BCA in the Building Consent Approval documents.

8.4.5 Concrete Classes

The classes of concrete listed in Table 16 shall be used for the structures as shown on the drawings and as required by the Designer. Compressive strength shall be determined in accordance with NZS 3112:1986.

Structural concrete shall have a minimum 28-day compressive strength of 30 MPa.

Table 16: Concrete Classes

Minimum Compressive Strength		Exposure Class [NZS 3101]	Nominal Maximum Aggregate Size [mm]	Maximum WC [by weight]	Location And Use	Concrete Plant Type [NZS 3109]
MPa	Days					
10	28	n/a	20	0.70	Blinding C	Ordinary Grade
30	28	A2	20	0.55-0.60	Structural C	High or Special Grade
50	28	A2	20	0.45-0.55	Structural C	High or Special Grade

8.4.6 Quality control and assurance

The concrete manufacturing process shall follow the sampling, testing and control requirements of NZS 3104:2003, unless modified below.

The proposed ready-mix concrete plant shall hold a current quality certificate of audit issued in compliance with NZS3104:2003. A copy of the current certificate of audit shall be held on site. The Contractor shall confirm the proposed concrete quality control regime as part of the mix design proposal. The quality control regime shall comply with the NZS standards NZS 3104:2003, NZS 3112 Part 2:1986 and NZS 3109:1997.

Reports and records

Maintain daily records of concrete placement, including but not limited to, delivery records, concrete volumes, lengths of pours, time of pours, slump, and cylinder sample preparation.

Submit reports and records to the Designer's Representative within 24 hours.

Concrete Placement Records

During concrete placement the following shall be recorded:

- Observations during the pour
- Additives added on site
- Minimum conditions for concrete pour e.g. air temperature
- Contractor / Designer satisfaction that all parameters are complied with during concrete placement operations

Certificates

Provide laboratory test results for aggregates and certification of compliance with contract requirements; test to NZS 3121.

Provide a certificate of compliance indicating that each of the following conform to the appropriate standards.

- Portland Cement to NZS 3122
- Fly Ash - Pozzolan to AS 3582.1
- Reinforcing Steel to AS/NZS 4671

- Water to NZS 3111

Testing records

In addition to NZS 3109, 9.5.5, submit;

- a record of each slump test in written form as single results and the mean of the last six results.
- a record of compressive strength test results in written form as single results and in control chart form. The control chart form shall show the mean of the last six results, the target strength, the specified strength, and the cautionary and rejection limits in accordance with NZS 3109.
- a record of each air content test.
- submit a verification of registration from the TELARC laboratory, for all the specified tests in this section.

Compression Tests

Compressive strength shall be determined from specimens moulded, cured, capped where necessary, and tested in accordance with NZS 3112: Part 2.

Each day during the placing of concrete for each 75 m³ of concrete or part thereof produced, at least two samples shall be taken for the preparation of compression test specimens for evaluation for acceptance of concrete. At least one sample shall be taken for each structural element poured during a day.

A set of three test specimens shall be made from each sample of concrete. The compression test specimens shall be tested as follows:

- 2 compression test specimens at age 28 days;
- 1 compression test specimens at age 7 days;

The frequency of testing is dependent on the quality of test results achieved during the construction period.

Quality reports on concrete testing shall be made available to the Designer at regular monthly intervals.

Reports shall include:

- Supply source;
- Mix identification and specified compressive strength;
- Location in structure;
- Batch or truck number;
- Time and date concrete mixed;
- Time specimens prepared;
- Slump of concrete at the time of mixing and at the time of placing concrete for selected concrete loads (in accordance with NZS3109);
- Time and date laboratory curing commenced;
- Time and date specimen tested;

- Compressive strength to nearest 0.5 MPa; and
- Relevant comments.

8.4.7 Materials

Cement

All cement to NZS 3122, and AS 3972. Refer to SELECTIONS for types.

Aggregates

To NZS 3111, NZS 3104 and NZS 3121, from a source approved by the Designer.

Minimum density NZS 3111, Test Number 12 - 2500 kg/m³.

Reactivity ASTM C 289: Innocuous (All Rc and Sc points plotting left of the solid line on the dissolved silica versus reduction in alkalinity plot).

Sodium Sulphate Soundness of Coarse Aggregate Only, to ASTM C88 05.

5 cycles: cumulative loss not greater than 12%.

Grading to NZS 3104.

Sand

To NZS 3111, NZS 3104 and NZS 3121, from a source approved by the engineer.

Minimum density NZS 3111, Test Number 16: -2500 kg/m³.

Reactivity ASTM C 289: Innocuous (All Rc and Sc points plotting left of the solid line on the dissolved silica versus reduction in alkalinity plot).

Sodium Sulphate Soundness of Coarse Aggregate Only, to ASTM C88 05.

5 cycles: cumulative loss not greater than 12%.

Reinforcement

Strength Grade 300 and 500 deformed steel bars and welded reinforcing fabric (WRF) conforming to AS/NZS 4671.

Ductility Class N and E.

8.4.8 Components

Admixtures

To AS 1478.

Use air-entrained agent in accordance with ASTM C 260 to provide a total air content of 4% ± 1.5%, provided that, when the mean daily ambient air temperature in the vicinity of the work

falls below 5°C for more than one day, the total air content provided shall be of 6% ± 1.5%. Add air-entraining agent to the batch in a portion of the mixing water.

Additional admixtures may be added to concrete or grout at the Contractor's option, to control the set, to reduce the heat of hydration, effect water reduction, improve pumpability and increase workability. Admixtures shall be approved by the Designer and shall comply with the following requirements;

- The quantity of admixture used and the method of mixing shall be in accordance with the manufacturer's instructions and recommendations.
- Low range water reducer shall be either a hydroxylated carboxylic acid type or a hydroxylated/polymer type.
- Admixtures containing calcium chloride will not be permitted.
- For difficult locations of limited access (such as in secondary concreting) a superplasticiser admixture may be used.

Water

To NZS 3121, except that chloride ion concentration shall not exceed 50 ppm.

Bonding agent between primary and secondary concrete.

Joint preparation, mix design and placing methods which do not rely on bonding agents to give a long term reliable bond between the primary and secondary concrete are preferred. The use of bonding agents will only be permitted when approved in writing by the Designer, for a specific location.

8.4.9 Accessories

Cement grouts

Cement mixed with the minimum quantity of water to obtain a suitable consistency. Grout cement shall be low alkali to NZS 3122. Use grout within 30 minutes of preparation.

Non shrink grout

Pre-packed proprietary product, mixed with water on site to the required consistency. The grout must not bleed or segregate, must be non-metallic and chloride free. Positive expansion shall occur while the grout is plastic and the grout must also be compensated for shrinkage in the hardened state. The compressive strength of the grout must exceed 30MPa at 7 days and 50MPa at 28 days.

Use admixtures in accordance with the grout manufacturer's instructions.

8.4.10 Equipment

Concrete vibrators

Electrically or pneumatically driven immersion type vibrators with operating speeds of 6000 - 7000 rpm and with a diameter capable of passing through reinforcement and anchorages for embedded steelwork.

8.4.11 Execution

Delivery, storage and handling

Take delivery of all materials. Store all materials including coarse aggregate and sand on site under dry covered shelters to minimise moisture content variability in the stockpiled materials.

Concrete mix design

Proportion the mix to minimise water content consistent with achieving the required slumps and strengths specified herein. Design the mix to produce a concrete capable of being placed and consolidated without segregation so as to obtain maximum density and minimum shrinkage. Where placed in forms, mix shall have good consolidation properties and meet the surface smoothness standards required for the finish levels specified.

Mix design changes

Change the mix proportions whenever necessary to obtain the required results. Submit all mix design changes to the Designer's Representative for review prior to use.

Slump

Measure slumps in accordance with NZS 3112, 5, unless otherwise approved by the Designer's Representative, based on the Contractors demonstration that a greater slump is required for proper placement.

Standards and tolerances

All permissible dimensional deviations shall comply with NZS 3109 unless modified by this specification as follows.

Concrete tolerances: If not shown on the drawings, dimensional tolerances on concrete work shall comply with the following;

- maximum deviation shall not be more than 13mm from a 3.0m long straight-edge, placed on a longitudinal surface.
- maximum length and height deviation shall be ± 3mm for primary concrete and +0mm and -2mm for secondary concrete, from dimensions shown on the drawings.
- maximum overall thickness deviation shall be not more than 1mm or less than 2mm from dimensions shown on drawings.
- maximum deviation from square shall be not more or less than 6mm for primary concrete and 2mm for secondary concrete, from dimensions shown on drawings.

Concrete production

Demonstrate the initial grade of production in terms of the criteria given in NZS 3104, 2.13, Target mean strengths and variability control, and the capability of the plant to consistently achieve the grades of concrete specified.

Except where the mixing water is heated, add water prior to, during and following the mixer charging operations. When heated water is used during cold weather, place approximately

75% of the hot water in the mixer either ahead of the aggregates or with them. Add the cement after the aggregates. Add the final 25% of the water at a moderate rate as a final component.

If the plant is not attaining the standards required for High Grade concrete production to NZS 3104, cease concrete delivery until it is shown that the corrective action has been taken.

8.4.12 Quality Control - Execution

Aggregate quality

Carry out coarse aggregate and sand gradation tests at the frequency required by NZS 3104, using methods specified in NZS 3111. Perform aggregate quality tests to confirm compliance with this specification during the course of the work. Take test samples on site from each 250m³ of fine of fine aggregate and each 500m³ of coarse aggregate delivered to the concrete batch plant.

Impurities

Various impurity levels contained in the aggregate/cement shall be limited by the following standards;

- sugar to AS 2758.1
- silt, clay and dust to NZS 3111
- coal, wood and other lightweight materials to NZS 3111
- chloride to NZS 3109

Concrete quality

Take concrete samples for strength testing at the rate of 1 sample/50 m³, or with a minimum of one sample/ shift. Carry out tests, including numbers of tests and procedures, to NZS 3109. Sample collection, field tests and laboratory test shall be carried out by a TELARC Registered testing laboratory accredited for the specific tests.

The Designer's Representative may carry out additional testing on both aggregate and concrete. Ensure the Designer's Representative has access to sample aggregates at the batching plant and concrete at the worksite.

Moulding and curing of compression test cylinders shall be in accordance with NZS 3112, 3.

Sample concrete at the location where it is to be placed. If concrete is pumped, representative samples for approval tests shall be taken from the placement end of the pump line.

Acceptance or rejection of concrete

Acceptance or rejection of concrete on compressive strength will be determined from the 28 day compressive strength of random specimens to NZS 3109, or from such earlier or accelerated tests as may be agreed with the Designer's Representative.

When concrete is liable to rejection in accordance with the single result criteria to NZS 3109, the Designer's Representative may order the concrete represented by the particular test or tests to be removed from the work.

When concrete is liable to rejection, the Contractor may elect to take cores in accordance with NZS 3109, 9.5.7. Within one week of the rejection order and before taking any action the Contractor shall notify the Designer's Representative in writing of his intention to cut cores. The Designer's Representative will select the locations where cores will be taken. Cores shall be cut at the Contractors expense. Cores shall be as large as is practicable up to a maximum of 100mm diameter. The compression testing of cores shall be undertaken by a testing authority approved by the Designer's Representative. The test results shall be corrected for shape of specimen by multiplying the compressive strength obtained by the appropriate factor in accordance with the following table.

Shape Corrections for Compressive Testing

Ratio of Length of Core to Diameter (L/D)	Shape Correction Factor
2.00	1.00
1.75	0.99
1.50	0.97
1.25	0.94
1.00	0.91

Cores tested shall have dimensions which provide L/D values within the range of the table. Intermediate values shall be obtained by linear interpolation. Apart from shape factor corrections, no other correction factors shall be applied to the compression strength test results from cores.

If the corrected compressive strength is in compliance with NZS 3109, 9.5.7, the concrete will be deemed to be satisfactory and the structure will be accepted after the core holes have been repaired to the satisfaction of the Designer's Representative.

If concrete does not meet specification, stop delivery until rectified.

8.4.13 Selections

Cement type

Cement type: GP (General Purpose Portland Cement)

8.5 Formwork for concrete

This section relates to the design and construction of formwork necessary to support and confine the concrete and shape it to the required dimensions.

8.5.1 Abbreviations and definitions

The following definitions apply specifically to this section:

- Jump formwork Incrementally moved formwork
- Lost formwork Void creating sacrificial formwork
- Slip formwork Continuously slipped or moving formwork
- Table forms Prefabricated and re-useable formwork systems for slabs and beams

8.5.2 Requirements - Design by Contractor

Shop drawings

Provide shop drawings for design of formwork to show the general arrangement including, but not be limited to:

- Position and type of construction joints.
- Layout of panel joints where exposed to view.
- Layout of form tie holes where exposed to view.
- Means of sealing panel joints, tie holes and construction joints.
- Form surfaces for each finish specified.

Submit shop drawings for review to the Designer's Representative within 7 working days (at least) before fabrication is planned to commence, provide shop drawings for review.

Complete shop drawing review before commencing fabrication.

Design documentation

For other than profiled steel sheeting composite formwork, submit certification by a qualified structural engineer experienced in formwork design verifying conformance of the design.

Execution documentation

Submit calculations by a qualified structural engineer experienced in formwork design to show that allowable concrete stresses will not be exceeded, and formwork capability will be maintained if it is proposed that:

- Formwork procedures or loadings differ from the information included in the project documentation.
- Props above a floor do not coincide with the props below.
- Project documentation does not include formwork shoring or stripping procedures or allowable loadings from stacked materials.

Submit certification by a qualified structural engineer experienced in formwork design and construction verifying conformance of the completed formwork, including the suitability of the formwork for the documented surface finish class.

8.5.3 Conditions

Inspections

Give notice so that inspection may be made of the following;

- Completed formwork before concrete placing.
- Used formwork, after cleaning and before re-use.

8.5.4 Products

Timber falsework

No. 2 framing radiata pine to NZS 3631 or as required to construct the required formwork.

Timber boards

Dressing or merchantable grade radiata pine to NZS 3631 for shutter face, to obtain the concrete finish specified.

Openings

In vertical forms provide openings or removable panels for inspection and cleaning, at the base of columns, walls and deep beams.

8.5.5 Finishes

Release agent

A release agent that will not stain or adhere to the concrete, contaminate reinforcing steel or construction joints, or have a detrimental effect on any applied finishes.

Surface retarder

A surface retarder that will not have long term detrimental effects on the concrete or on any applied finishes.

8.5.6 Execution

Provide all formwork

Provide all formwork necessary to support and confine the concrete and shape it to the required dimensions.

Visually important surfaces

For concrete of surface finish classes 1, 2 or 3, set out the formwork to give a regular arrangement of panels, joints, bolt holes, and similar visible elements in the formed surface.

Accuracy

Unless stated otherwise on the drawings permissible deviations from established lines, grades, dimensions and cambers to remain within the tolerances laid down in NZS 3109: table 5.1, Tolerances for precast components and table 5.2, Tolerances for in situ construction.

Tolerances of concrete surface finishes

Unless stated otherwise on the drawings, permissible abrupt, offset and gradual deviations for the specified surface finish to remain within the tolerances laid down in NZS 3114: table 3, Tolerances for abrupt deviations or offsets and gradual deviations.

Loadings

Design and construct formwork and falsework in accordance with sound engineering principles to withstand the worst combination of:

- Dead loads of formwork, reinforcement, concrete and precast elements such as floor planks.
- Construction loads including dynamic effects of placing, compacting and construction traffic.
- Wind and snow loads.

Falsework

Carry strutting down to a construction sufficiently strong and stable to afford the required support without permissible stress or deflections being exceeded. Prop through to other floors if the construction load on a particular floor exceeds the design load.

Cambers

Cambers shown on the drawings or specified, relate to the concrete immediately before formwork is struck. Unless otherwise shown on drawings, construct forms to achieve the following:

- maximum deflection of face materials between strutting: 1/240th of span, but not exceeding 6mm, or within the tolerances specified for surface finish in concrete placement;
- maximum deflection of beams: 1/900th of span; and
- maximum deflection of cantilevers supporting construction loads: 1/300th of cantilever length.

Construction joints

To NZS 3109: clause, 5.6 Construction joints. Clean face of previously hardened concrete at construction joints.

Use surface retarders to provide a key at construction joints. Use in accordance with the manufacturer's stated requirements. Remove laitance, contamination and cracked or dislodged aggregate before placing the continuing shutters and forms. Keep joints clean and undamaged until placing concrete.

Location of construction joints

Unless otherwise shown on the drawings locate the joints at positions listed in selections.

Joints in forms

Construct joints to prevent loss of grout between joints in form linings, as well as between forms and completed work. Seal the joints consistent with the surface finish class. Column forms to have full height linings so that no horizontal joints occur on exposed faces.

8.5.7 Application

Fabrication

Fabricate formwork and falsework in a manner permitting its easy removal without damage to the concrete. Provide positive means of adjustment to ensure the formwork is secured in its correct position.

Provide a 20mm x 20mm chamfer to all corners unless detailed or noted otherwise. Protect corners from damage during and after stripping.

Securely fix

Securely fix and brace to ensure sufficient strength and rigidity to support in safety all loads arising during construction and to maintain the specified dimensional tolerances.

Work below ground

Provide formwork to vertical faces below ground level.

Form ties

Use proprietary form ties and spreaders. Wire ties are not permitted.

Chases, holes, nibs, rebates and reveals

Form chases, fillets, holes upstands and nibs as shown on the drawings. Position accurately at time of casting concrete.

Cast in items, structural steel

Securely fix structural steel cast in items and hold down bolts shown on drawings. Position accurately at time of casting concrete.

Traps and washout ports

To NZS 3109: clause 7.3, Preparation for concreting.

Removable bolts

Must be removable without causing damage to the concrete.

Bolt hole filling

Position formwork tie bolts left in the concrete so that the tie does not project to within 50mm of the finished surface. Provide filling material that has the durability and colour matching the concrete. When carrying out recessed filling, fill or plug the hole to 6mm below the surface.

Embedments

Fix embedments through formwork to prevent movement, or loss of slurry or concrete during concrete placement.

8.5.8 Finishing

Release agents

Use the same type and brand throughout the entire area of any one finish. Apply evenly to form faces using the minimum amount necessary to obtain a clean release. Do not allow the release agent to come in contact with reinforcement, hardened concrete or other materials not part of the form face. Ensure compatibility with subsequent finishes being applied to the concrete.

Thoroughly clean any reinforcement coming in contact with release agent to remove all traces of release agent.

8.5.9 Completion

Striking formwork

Ensure the safe removal of all or any part of the formwork. Remove formwork without shock or vibration or damage to the concrete and in such a manner as to take the imposed stresses gradually to NZS 3109: clause 5.4, Removal of forms and shores. Stripping times to NZS 3109: table 5.3, Minimum formwork stripping times - in situ concrete for type GP cement. Make appropriate allowances for modified concrete.

Table 17: Formwork Stripping

Structure	Minimum Compressive Strength Before Stripping [% minimum 28-Day Compressive Strength]
Bulkheads and vertical construction joints	10
Beam and slab sides	20
Beam and slab undersides *- Cantilever beam and slab* Up to 2 m span More than 2 m span	 70 100
Beams and slabs supported at both ends Up to 2 m span 2 to 8 m span more than 8 m span	 50 70 100
Walls up to 5 m lift more than 5m lifts	 30 50

Partial striking

If this is required, retain supports undisturbed as follows:

- to soffit or beams where side forms are struck
- to slabs where soffit forms are struck.

Loading before striking

Do not erect masonry walls or other brittle elements on beams and slabs while they are still supported by formwork.

8.6 Reinforcement for concrete

This section relates to the supply, cutting, bending and fixing of steel bar and steel welded reinforcement for concrete.

8.6.1 Requirements

Selections and diagrams

Provide schedules and diagrams of bars and bar bending.

8.6.2 Products

Grade 300E steel

To AS/NZS 4671. Round bars are shown by symbol "R" and deformed bars by symbol "D", followed by the diameter in millimetres.

Grade 500E steel

To AS/NZS 4671. Round bars shown by symbol "HR" and deformed bars by symbol "HD" followed by diameter in millimetres.

Tying wire

Mild drawn steel wire not less than 1.2mm diameter.

Spacers and chairs

Precast concrete or purpose made moulded PVC to approval. Where concrete spacer blocks are used in exposed concrete work use blocks matching surrounding concrete.

8.6.3 Execution

Handle and store

Handle and store all reinforcing steel and accessories without damage or contamination. Store on timber fillets on hard ground in a secure area clear of any building operation. Lay steel fabric flat.

Deliver all bundles

Deliver all bundles of steel to the site clearly marked or tagged with numbers relating them to the bending schedule and drawings.

Cleanliness

Keep reinforcement clean so that at the time of placing concrete it is free of all loose mill scale, loose rust and any other contamination that may reduce bonding capacity.

Projecting reinforcement

Protect projecting reinforcement from the weather where rust staining of exposed concrete surfaces may occur.

Protect and/or mark any projecting reinforcement where it provides a potential hazard to site personnel.

8.6.4 Assembly

Cut and bend

Cut and bend bars using proper bending tools to avoid notching and to the requirements of NZS 3101.1, 8 and NZS 3109: 3.3 Hooks and bends. Minimum radii of reinforcement bends to NZS 3101.1, 8 and NZS 3109: table 3.1, Minimum radii of reinforcement bends. Do not rebend grade 500E bars. Where rebending is necessary for grade 300E bars, use a purpose built tool, proper preparation and preheating.

Adjustments

Use a purpose built tool for on-site bending and to deal with minor adjustments to steel reinforcement.

Tolerances, bending

To NZS 3109: clause, 3.9 Tolerances for reinforcement.

8.6.5 Application

Secure reinforcement

Secure reinforcement adequately with tying wire and place accurately, supported adequately and secured against displacement when concreting. Bend tying wire back well clear of the formwork.

Spacing

Spacing as dimensioned on the drawings but if not shown then the clear distance between parallel bars in a layer, or the distance between layers, or the spacing of other steel to the minimums laid down in NZS 3109: clause 3.6, Spacing of reinforcement.

Tolerances, spacing

To NZS 3109: clause 3.9, Tolerances for reinforcement.

Lapped splices

Length of laps were not dimensioned on the drawings in accordance with NZS 3101.1, 8.7 Splices in reinforcement, refer to Section 7.4.7. Increase laps for plain round steel by 100%. Provide laps only where indicated on the drawings. Tie all lapping bars to each other.

Welded splices

No Quench and Tempered (QT) reinforcing bar shall be welded or preheated. For Microalloy reinforcing bars, carry out only if either specified on the drawings or after written approval from the Construction reviewer and then to the requirements of AS/NZS 1554.3 and NZS 3109: clause 3.7.2, Welded splices, in respect of developed strength and location. Welds shall not be permitted at bends in bars, and welding shall be carried out so that no undercutting of bar sizes occurs.

Mechanical splices

Use only where shown on drawings. Use the appropriate sleeve size and length, swaged onto the bars using correct die and hydraulic press all to the manufacturer's requirements. Notify when ready for inspection and carry out tests if required.

Steel spacers

Fix spacers between layers of wall reinforcement at 1.0 metre centres minimum.

Reinforcement cover

Minimum cover to all reinforcing bars, stirrups, ties and spirals, as shown on drawings. Where cover is not shown on drawings provide minimum cover to NZS 3101.1, table 3.6, Minimum required cover for a specified intended life of 50 years. Sub-soil cover to NZS 3101.1, to suit soil and groundwater conditions.

Tolerances, cover

Tolerances on cover relative to the values in NZS 3109: clause 3.9 Tolerances for reinforcement. Tolerances shall be +5mm all positions, but in no case shall cover be less than that shown on the drawings.

Fix chairs

Fix chairs for top reinforcement in slabs at 1.0 metre centres or to ensure adequate support.

Concrete spacer blocks

Where spacer blocks are required in exposed concrete work, make from same materials and mix as the surrounding concrete.

Welded wire fabric

Hard drawn steel wire spot welded to AS/NZS 4671, smooth or deformed and to the spacing and dimensions either specified or shown on the drawings. Laps to NZS 3101, lap one mesh square plus 50mm minimum (do not count bar extensions beyond the outermost wire).

8.6.6 Completion

Remove all debris, unused materials and elements from the site.

8.6.7 Selections

Where reinforcement laps are not shown on the drawings, lap as follows:

Bar Diameter	Grade 300E deformed	Grade 500E deformed
10mm	400mm	650mm
12mm	500mm	750mm
16mm	650mm	1000mm
20mm	800mm	1250mm
25mm	1000mm	1600mm
32mm	1200mm	2000mm

8.7 Concrete placement

This section relates to the handling, placing and curing of concrete. The Contractor shall prepare a method statement for the placement of concrete above and it shall be reviewed by the Designer prior to commencement of work on site. The method statement shall cover the following:

- Project mix designs including additives and water cement ratios;
- Conveyance and Placement Methods;
- Plant and Equipment;
- Compaction;
- Temperature Control: concrete construction in hot and cold weather (for example curing methods and formwork removal)
- Construction Joints; and
- Inspection and Testing.

8.7.1 Products

Concrete mixes

Refer to Section 7.7: Concrete production.

Vibration equipment

Provide vibration equipment as required by NZS 3109.

8.7.2 Execution

Unfavourable conditions

Do not place concrete in high winds or other unfavourable conditions. Refer to NZS 3109: 7.2 Unfavourable conditions, for when concrete may not be placed. Remove and make good concrete damaged by frost, dry and wet conditions.

Defects

Reject concrete with structural defects. Immediately after stripping formwork, identify all defects and obtain direction. Do not carry out any repair work until directed and then only in

accordance with the direction. Repair defects by cutting out, making good and replacing, or otherwise as directed.

Existing work

Protect existing work from damage and make junctions to existing work as detailed.

Inspections by building consent authority

Notify for inspection sufficiently in advance before placing concrete and any necessary rectification of formwork, reinforcement and construction joint stops. Pour concrete only between properly positioned stops.

Inspections by construction reviewer

Submit Concrete pour schedule to the Designer and re-submit amendments as necessary. Notify for inspection sufficiently in advance before adjustment of formwork, reinforcement and construction joint stops, and placing concrete. Pour concrete only between properly positioned stops.

Preparatory work

Ensure at the time of placing, that surfaces to receive the concrete are clean, free of debris and with no free water present. Thoroughly clean reinforcement to remove any release agent or other deleterious surface deposit.

Wetting of formwork

To NZS 3109: clause 7.3, Preparation for concreting, subclause 7.3.2.

8.7.3 Application

Build in fixings

Refer to Section 8.3, Concrete common requirements.

Construction joints

To NZS 3109: clause 5.6, Construction joints, 5.6.3, Types of joints, Type B, unless directed otherwise for particular minor areas. Prepare joints to produce the required type B roughened surface.

Protect concrete work

Protect formwork, reinforcement, 'built in' items and fresh concrete from damage, as the pour is placed, making good any damage if it occurs.

Transport concrete

Transport concrete from agitator to final placement within 2 hours of batching, using means that avoid segregation or alternative period as agreed with the Designer.

Place concrete

Place concrete in layers not more than 500mm deep, compacted and vibrated. Do not place fresh concrete against the preceding layer after more than 45 minutes, or such lesser time as required by the circumstances, to NZS 3109: clause 7.4, Handling and placing. When placing concrete on steel form decks ensure that free water is displaced rather than trapped.

Do not pour on ground if temperature is below 5°C.

Compact concrete

To NZS 3109: clause 7.6, Compaction. Compact by vibration of the concrete to expel entrapped air and until settlement of the concrete is visibly evident over all areas of the surface. Maintain vibration until settlement ceases and coarse aggregate at the surface is embedded. Do not continue vibration beyond reaching this condition.

Vibrators

Use sufficient immersion vibrators, with one spare for emergency; to ensure that vibration is achieved throughout the entire volume of each layer of concrete, and until complete compaction is reached, to NZS 3109: clause 7.6, Compaction. Insert vibrators at points approximately 500mm apart and withdraw slowly after compaction.

8.7.4 Finishing

Screed the surface

Screed the concrete surface by straight edge or vibrating screed immediately after compaction and to tolerances in NZS 3109: table 5.2, Tolerances for in situ construction.

Tolerances in NZS 3109 are not always appropriate. Modify the above clause to include specified tolerances when justified.

Saw cuts

Cut slabs where indicated on the drawings and as required to control shrinkage cracking. Carry out cutting as soon as possible, without causing tear-out of aggregate and before shrinkage cracking has occurred, generally within 24 hours of pouring. Where saw cuts are made, cut out 100mm of every second wire of the mesh for a length of 50mm each side of the saw cut position. Saw cuts: 1/3rd slab depth or 30mm minimum.

8.7.5 Curing

Curing method by contractor

The Contractor shall develop a suitable methodology for curing concrete with the Designer. The proposed methodology for curing and protection of concrete shall meet the requirements described in NZS3109 Clause 7.8.

The exposure classification for this area is A2 which requires a minimum curing period of 3 days. In cold or wet weather, concrete shall be protected from the elements during the curing period using an agreed methodology.

Curing period

Cure all concrete of normal cement type and mixing proportions for a minimum of 7 days. Keep time between placing of concrete and the start of curing to an absolute minimum. Ensure curing is continuous.

Keep formwork moist

Keep formwork left in place continuously moist by sprinkling with water over the curing period. Continue sprinkling the exposed surface if the formwork is removed before the end of the curing period.

Secure coverings

When covering with sheet materials, ensure that edges are well secured throughout the specified curing period, to prevent draughts passing over the surfaces of the concrete.

Cold Weather

Do not use coverings employing water at times of freezing weather.

Curing Compounds

Membrane curing compounds shall conform to ASTM C309 or AS 3799. The compound shall be of uniform consistency and quality within each container of each shipment. Toxic curing compounds shall not be used in confined spaces.

8.7.6 Protection

Protect Plastic Concrete

Protect plastic concrete from indentation and surface marking.

Protect Hardened Concrete

Protect surfaces of stripped concrete from damage especially at arises.

Protect Exposed Surfaces

Protect from rust marks and other surface disfigurements.

8.7.7 Defects

Reject concrete with structural defects. Immediately after stripping formwork, identify all defects and obtain direction. Do not carry out any repair work until directed and then only in accordance with the direction. Repair defects by cutting out, making good and replacing, or otherwise as directed.

Surface Defects

Make good surface defects immediately after forms are stripped. Make good hollows or bony areas with 1:2 mortar or plaster, finished to the same tolerances as the parent concrete. Fill any tie rod holes with 1:2 mortar.

8.7.8 Completion

Clean Out

Clean out saw cuts.

Remove

Remove all unused materials and all concrete and reinforcing debris from the site.

9.0 Embankment and Foundation Instrumentation

Piezometers, survey monuments and a Time Domain Reflectometry (TDR) system are required to be installed in the embankments and along the crest for long term dam safety monitoring to comply with the NZSOLD Guidelines.

Instruments shall be installed at locations agreed with the Designer prior to commissioning of the works.

The Contractor shall confirm that the instrumentation, the method of installation and commissioning produces a system fit for purpose. Method statements covering working practices shall be submitted for agreement with the Designer prior to commencing the work.

9.1 Standpipe Piezometers

Standpipe Piezometers are used to measure pressure head and ground water level under the lining of the ponds. Fourteen standpipe piezometers shall be installed by a suitably experienced sub-contractor, as shown on drawing WIL1125/30/21.

This section describes the installation and monitoring requirements for standpipe piezometers. The height to which the water rises in the hose is a direct measure of the water pressure of the soil at the depth the piezometer tip is installed. Standpipe piezometers are used for long term monitoring of ground water tables in proposed cut and fill areas. They are also useful in determining whether there is an upward or downward gradient of water.

9.1.1 Piezometer

The type of standpipe piezometers used will be slotted (open). Location of piezometers shall be as shown on the drawings. Piezometers inclination is vertical.

Required depth of piezometers will be at least 2 metres below the foundation base, or adjacent pond bottom level at the instrument location. Slotted section of the piezometer is the last 2m section of the piezometer installation (i.e. deepest section).

Piezometer tubing shall be 25mm ID ABS diameter (or similar).

9.1.2 Drilling Methodology

The drilling method selected will need to consider embankment protection. It has been assumed that a combination of down the hole hammer drilling (or similar will be used) and temporary steel or odex casing systems will be used to drill holes. Contractor is to agree on methodology with the Designer.

9.1.3 Piezometer Installation Methodology

A typical methodology has been provided below.

Slotted Piezometer Preparation:

- Using a hack saw, cut a slot one third of the way into and perpendicular to the 25 mm plastic pipe, 75 mm from one end. Continue to cut slots 50 mm apart along the entire length except for 75 mm from the other end. Turn the pipe over and cut the same kind of slots starting at 100 mm from each end. The result should be alternating slots 25 mm apart.
- Glue an end cap at one end and a coupling with a 25 x 25 mm insert coupling at the other end.
- Allow the glue to harden.
- Screw in the 25 x 25 mm insert adapter.
- The remaining assembly is done during installation.

Slotted Piezometer Installation:

- Drill borehole to depth.
- If casing is used, the piezometer may have to be installed before the casing is removed.
- Clean hole.
- Place the screen sock (filter) over the piezometer and fill it with clean sand. Wrap the top of the sock around the hose and fix securely.
- Install piezometer.
- Pour clean sand down the hole to create a sand pack around the piezometer. Use a weighted cloth measuring tape to check that the sand has reached a point 0.6 m above the top of the piezometer.
- Pour bentonite pellets down the hole to form a layer 0.5 m thick above the sand pack. Use a weighted cloth tape to determine the proper layer thickness.
- Backfill the hole using suitable fill material.
- Mark the piezometer number on a post and place it in the ground near the hole.

9.1.4 Standpipes

Standpipes shall be installed with a lockable cover at the collar of each instrument and finished at the crest maintenance strip level.

Readings can be measured directly in meters from ground surface.

9.1.5 Reporting

Installation procedures should be recorded on a "Piezometer Installation Data" report form.

Readings in an open piezometer hose are taken using a water level meter. The probe is lowered down the tube until it contacts the water, completing an electric circuit as indicated on the gauge. Hold the cable at the point at which it touches the top of the piezometer hose, then pull the cable out and extend it along the outside of the hose to ground level. The depth is then recorded at the top of the piezometer hose using the markers on the outside of the cable attached to the probe. This results in water depths that are recorded from ground elevation and not the top of the exposed piezometer hose.

Readings should be taken at agreed frequencies (normally monthly) however during commissioning and impoundment readings will be read more frequently (i.e. daily).

All data collected should be forwarded to Designer and Contractor weekly.

9.2 Surface Survey Monuments

Supply and install surface survey monuments on embankments for long term dam safety monitoring of the embankments. Monuments to be installed by a suitably experienced sub-contractor.

Six bench markers and fifteen survey markers shall be installed by a suitably experienced sub-contractor. Their locations are shown on drawing WIL1125/30/21.

The Contractor shall record the horizontal and vertical location of each reference mark with respect to established bench marks at the time of installation, and every 60 calendar days thereafter until completion of the works. Frequency may change during impoundment and will be agreed as part of the commissioning plan. Survey tolerance shall be vertical +/- 2 mm and horizontal +/- 10 mm.

Any reference mark disturbed or damaged due to construction operations shall be replaced or repaired and the correct horizontal and vertical locations provided.

9.3 TDR System

Supply and install Time Domain Reflectometry (TDR) system manufactured by Campbell Scientific Limited (or approved alternative supplier) for automatic detection of an embankment breach.

General arrangement of the TDR system is shown on Drawing WIL1125/30/25.

The TDR system shall be capable of providing a low-level alert (deformed cable indicating small movement) and a high-level alert (sheared cable and possible large magnitude slope failure).

The Contractor shall supply all necessary components for measurement and control of the TDR System and for integration into the Control System (refer to Section 14.0).

9.3.1 System Layout

The system consists of lengths of coaxial cable, varying in length from 800 to 1800 metres, placed in trenches along the crest of the embankments, encased in low strength concrete (CLSM), as shown on drawing WIL1125/30/25.

A short rise time electromagnetic pulse is sent along each cable and the reflected wave is analysed, mainly in comparison with previous base readings. The reflected signal is affected by changes in impedance, along which are caused by stress in the cable. The reflected wave can be divided into more than 10,000 data points to locate the position of any stress points along the cable.

Prior to installation, the cable will have crimps placed at 100 m intervals, causing stress at these points, which can be used for calibrating the position of subsequent stresses. The location of these crimps will be surveyed at the time of installation.

The cable is available in 500m rolls and will need to be joined on site to achieve the lengths required. This is a specialised task to be completed by a technician from the supplier (Scottech). Where possible, more than one join will be made at each site visit by the technician.

The cable layout is shown on Drawing WIL1125/30/25. There will be two TDR monitoring stations, which will communicate via radio frequency modems, one monitoring point will contain the master datalogger and the second station will contain a slave datalogger.

The Master datalogger will be connected to the PLC in the nearby pump station and will also have backup communication via a satellite modem.

9.3.2 Installation

The enclosures for the two TDR stations will be installed prior to the cables being laid in the trenches, and the dataloggers and TDR readers will then be installed in the enclosures. Each TDR station will have a mast installed adjacent to the enclosure for the solar panel and radio aerial.

Prior to the installation of the cables in the trenches, all cables will be laid out and cut to length. Crimps and connectors will be installed on all cables and each cable run will be connected to its TDR reader and tested. The cables will then be disconnected, rerolled onto the drums and labelled with the position of the cable.

The cables can then be laid in the trenches by site staff and the connections between each cable can be made by site staff. The connections will consist of plugging the two cables together and wrapping the joint in self amalgamating tape and then Denso tape.

The cable is to be laid in a 700mm deep by 300mm wide trench along the outside edge of the embankment as shown on Drawing WIL1125/30/25. The cable should be approximately in the centre of the CLSM layer and it is proposed to place the cable on concrete chairs prior to pouring of the CLSM in each section of trench. Other methods can be trialled on site such as pouring half of the CLSM in the section of trench and then laying the cable on the wet CLSM before placing the second half, some initial set of the first layer would be required to avoid displacement of the cable.

A method statement for the installation of the TDR system will be prepared by the Designer during construction and agreed with the Contractor and Supplier.

9.3.3 Type 3 Backfill

Type 3 backfill consists of controlled low strength mix material (CLSM), in accordance with AS/NZS 3725:2007. Each layer of CLSM shall be vibrated by means of an electric or pneumatic vibrator. See section 17.5 for CLSM specification details.

10.0 Log Boom

The boom details are shown on drawings WIL1125/30/197 to 199. The log boom is be installed at about 40° angle with the canal bank.

The log boom can be fabricated by the Contractor on site under Designer supervision and approval. It will consist of two 100 mm dia PVC pipes filled with expanded polystyrene which are held together by stainless steel brackets at about 2.2 m spacing. The steel brackets are connected together by a 16 mm dia backbone wire rope. The wire rope shall be a stainless steel wire rope of 16 mm nominal dia (SWR 6x36 type). The backbone wire rope is extended across the canal and connects to the anchor points on either bank. The total length of the wire rope is estimated to be about 30m, but the final length should be determined once the ground levels at the anchor points have been confirmed by the Contractor. As per the standard practice, 1% of extra rope length should be allowed for each 10 m up to a maximum of 5%.

The anchor points are to be Manta Ray type anchors. The Manta Ray anchors are driven into the ground and after reaching the required depth, the driving tool (drive steel) is removed. The anchor is then tipped and proof tested to present its bearing area to the soil. This is called “load locking” and provides an immediate proof test of each anchor. The type of Manta Ray anchor is expected to be the Manta Ray MR-SR anchors. The anchor type will be confirmed when the ground conditions at the anchoring sites have been confirmed.

11.0 Seismic Loading for Supplier Designed Components

Components requiring Supplier design input are:

1. Hydraulic gates and associated mechanical electrical equipment; and
2. Mounts and attachments for pumps and associated mechanical electric equipment and the control system componentry.

Section 4.5.4 of the Design Report sets out the requirements of the NZSOLD Guidelines with respect to seismic design. Briefly, with respect to the Supplier designed components, the Guidelines require;

1. The dam (or in this case the ponds) to retain the stored water in a SEE earthquake event, albeit with some damage; and
2. The dam to sustain, either no damage, or minor repairable damage in an OBE earthquake event.

Equipment items designated as dam safety critical shall be designed according to the above requirements assuming a design level equivalent to High PIC.

Equipment not designated as dam safety critical shall be designed in accordance with AS/NZS1170.5 assuming Importance Level 2 with a design life of 50 years. The SEE seismic design load for non-critical equipment in that case be the 1 in 500-year event.

Equipment mounted inside a building shall be designed in accordance with NZS 4219 “Seismic Performance of Engineering Systems in Buildings” corresponding to the above design event levels.

Which earthquake event is appropriate for seismic design depends on whether the equipment being designed is critical to the safe performance of the ponds post a SEE earthquake event or not. For the Wrights Road Ponds the seismic loading and structures to which the loading applies is tabulated in Table 17 below.

Table 17 Equipment and Seismic Design Level

Design item	Design Level
Pumps and associated mechanical electrical equipment mounts and attachments	SEE – non critical OBE
Hydraulic gates and associated mechanical equipment and the control system componentry	SEE – critical OBE

The headwalls to which the gates are mounted have been designed for Peak Horizontal Ground Acceleration of 1.06 x g m/s^2. Where g is the acceleration due to gravity.

12.0 Control Gates

12.1 General

This section of the specification covers the performance, functional and serviceability requirements for seven (7) flow control gates for the Wright's Road Pond Storage Scheme.

The control gates are rectangular steel vertical slide gates each operated by a hydraulic cylinder mounted on the gate frame. They will be intermittently; above water, partly or fully submerged depending on variation of pond water levels.

Hydraulic power units, power boards, control panels and cabinets for operating the gates will be housed in a prefabricated concrete services building constructed on the pond embankment crest close to each gate, as shown on the drawings.

Gate operation is managed by the scheme SCADA system.

12.2 Control Gates Specification Precedence

If any clauses of the main body of this Technical Specification do not agree with, or contradict, the information provided in this Section 12.0 (Control Gates) of the Technical Specifications, then this Section 12.0 of the Technical Specification shall take precedence.

12.3 General Operational Description

Gated inlet culvert G1 is a single barrel 1,800 mm diameter with concrete inlet and outlet transitions as shown on Drawing WIL1125/30/101. Gate G1 is a 1,800mm fully automated gate, managed by the control system to maintain the water level in the Buffer Pond. Initially, Pond 1 is filled by gravity until it approaches Buffer Pond water level. Once the Buffer Pond level approaches the Buffer Pond service spillway level Gate G1 is closed so that the Buffer Pond Pump Station can continue to fill Pond 1.

There are two inter-pond gated culverts sized to convey inter-pond flows managed by the control system. They are G4, discharging water from Pond 2 to the Tub and G5 discharging water from Pond 1 to the Tub. Both are single barrel gated culverts, each fitted with a 1,800mm control gate as shown on Drawings WIL1125/30/113 to 116. Gate G4 is located at the downstream end of its culvert in the Tub, and Gate G5 is located at the upstream end of its culvert in Pond 1.

There are three pond outlet gated culverts, G2, G3 and G6, to release irrigation discharges to the various races. Culvert G2 releases water from Pond 2 to Race R2 and is over-sized at 1,930mm diameter to provide for a possible future hydropower station, as shown on drawing WIL1125/30/103. Culvert G3 releases water from Pond 2 to Race R3 and comprises a single 1,600mm diameter culvert as shown on drawing WIL1125/30/110. Culvert G6 has twin 1,600mm diameter barrels discharging from the Tub to Race MR4 as shown on drawing WIL1125/30/117. Control gates to suit each culvert size are mounted at the upstream end of each culvert, with Culvert G6 having two gates (G6a and G6b) – one for each barrel.

The control gates and their relationship to other components of the storage scheme for pond water control are shown schematically in Figure 2. The Buffer Pond is shown as the “Existing Pond” in Figure 2.

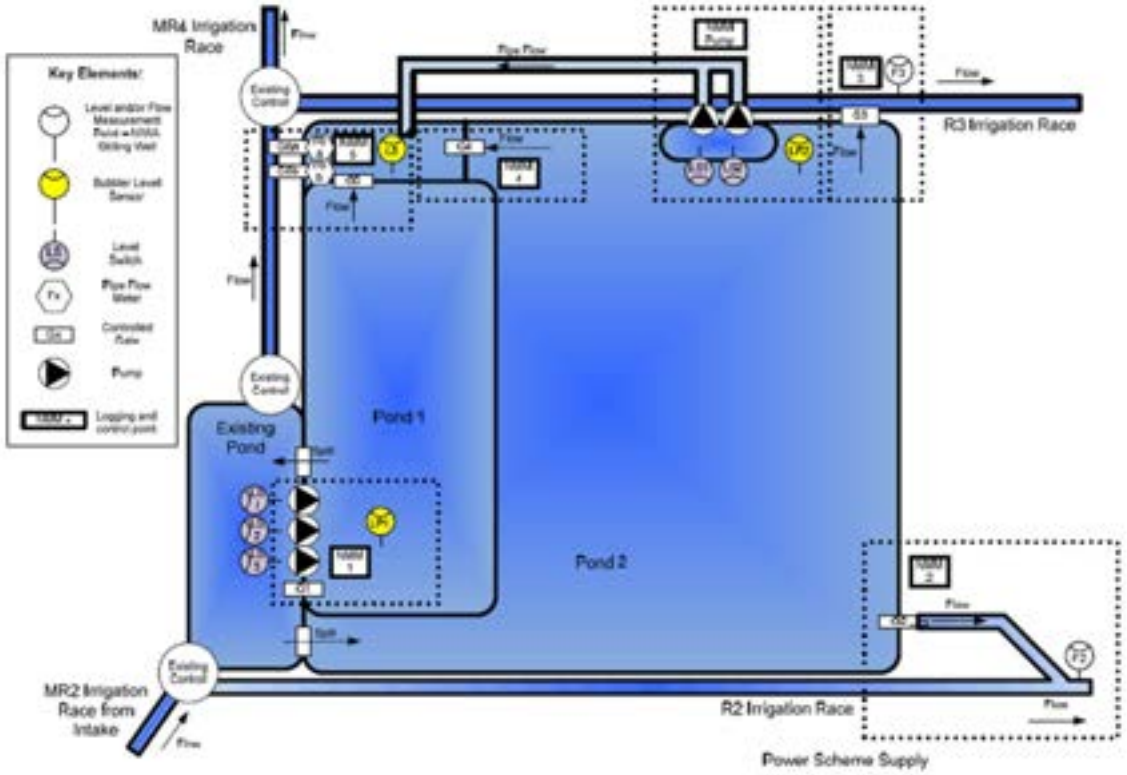

Figure 2: Storage Ponds Control System Overview

An alarm system will notify the race-man of any alarm conditions, failed gates or pumps or any overfilling scenarios.

Communication between all the gates will be real time and continuous. A Wi-Fi system with boosters will provide the continuous feed of information between the gates and pump stations.

The automation will be run from mains power. Cables will be laid to all the automated sites. A power backup source will also be provided at all automated sites. This will consist of battery and invertor, with sufficient capacity to carry out both the following functions without requiring recharge:

1. Enable shutdown (if necessary) after prolonged mains power supply failure.
2. Enable opening of those control gates designated as being required for emergency dewatering in case of a dam safety emergency.

12.4 Contractual Arrangements and Responsibilities

The Gate Supplier is responsible for the Works described in this Specification and is a Subcontractor to the Contractor. For the Gate Supplier's information only, other Subcontractors that may interface with the Gate Supplier are anticipated to be as follows:

- Designer (Damwatch Engineering Ltd) – scheme design overall except for specific design carried out by other Subcontractors
- Electrical Subcontractor – design, supply installation and commissioning of power supplies, instrumentation and local control systems including gate position monitoring
- Control System Subcontractor – supply, configuration, installation and commissioning of automated control systems and equipment

12.5 Scope and Interfaces

The works to be carried out by the Gate Supplier generally comprise the detailed design, supply, delivery, installation, testing and commissioning, complete with frames, fixings, hoisting equipment, hydraulic power units (HPU) and associated controls and instrumentation, hydraulic pipework in suitable ducting of;

- One (1) hydraulically operated vertical slide control gate to suit a 1,930mm diameter culvert inlet
- Three (3) hydraulically operated vertical slide control gates to suit a 1,800mm diameter culvert inlet
- Three (3) hydraulically operated vertical slide control gates to suit a 1,600mm diameter culvert inlet

all as per the Specifications.

The Gate Supplier scope includes supply, installation and connection of all hydraulic pipework between a HPU and a gate hydraulic cylinder including supply and installation of suitable conduits suitable for intermittent submergence and exposure to weather. Conduit is to be laid directly on the HDPE liner and clamped using HDPE straps welded to the liner. Supply and fixing of the straps will be by the lining supplier. The services control building housing the HPU and any necessary penetrations will be by others.

The Gate Supplier scope includes supply and installation of a local control system including: local PLC, HMI, gate status monitoring and control instrumentation and associated cabling, panels and terminations.

The following works are to be supplied and/or carried out by others:

- Foundations, civil, site and preparation works
- Site access, services, facilities and cranage for the Gate Supplier's use during site activities
- Supply and construction of the services control buildings for each gate, along with any necessary ducting, conduits, pits and penetrations for the control cabling
- Electrical design and installation including permanent power supplies, cabling and terminations at the Gate Supplier's equipment

- SCADA system design, installation and integration for automatic operation of the control gates terminated at the Gate Supplier's equipment.

The Gate Supplier is required to interface and collaborate with those responsible for the above related works and to provide sufficient design information on the gate components and equipment so that other related service providers can complete their related or connected designs.

12.6 Contractor's Reference Design and Specifications

The Contractor has prepared a reference design for the control gates, which is shown on the Drawings WIL1125/30/201 to 206. The reference design drawings are to be considered as indicative to show the intended arrangement and form of the control gates.

The gate is formed with a steel skinplate stiffened by horizontal beams which are fixed to the skin plate with bolts in blind tapped holes. Water load on the skinplate is supported by the vertical edges bearing on UHMWPE slider blocks which extend over the full travel of the gate. A horizontal UHMWPE strip is used as a bearer and top seal for the closed gate. The bearers are bolted to a fabricated steel column frame with an overhead beam to support the lifting cylinder and ram connected to the gate. The frame is anchored to the intake concrete headwall with stainless steel sleeve anchors. The gate lifting hydraulic rams will operate submerged when the ponds are at full supply level.

12.7 Gate Supplier's Design

The Gate Supplier shall be responsible for detailed design of the control gates and associated equipment as per this Specification and shall provide design submittals to the Design Subcontractor for review and coordination with other scheme design aspects in accordance with Section 12.13.6.

Unless stated otherwise, the design of the Works, as documented in the design documents and elsewhere, shall:

a) comply with Applicable Standards (refer 10.8), and

b) achieve and comply with the Principal's Requirements set out in the Design Report.

Notwithstanding that certain design details are shown on the reference design, the Gate Supplier shall be responsible for determining the fabrication procedures, methods, tolerances and dimensions necessary to provide a fully functioning and fit-for-purpose installation that will meet the performance, functionality and service life requirements of this Specification.

The gates, frames, lifting equipment and fixings shall be designed for the following loads and conditions:

- Static hydrostatic forces from maximum pond levels as provided in Table 18 below.
- Hydrostatic load with downstream pond assumed drained.
- Safety Evaluation Earthquake of 1.06g, as provided in Section 4.5.5 of the Design Report.
- Hydrodynamic load computed using the SEE.

Table 18: Hydrostatic Forces

Hydrostatic Conditions	G1 (MN)	G2 (MN)	G3 (MN)	G4 (MN)	G5 (MN)	G6 (MN)
Hydrostatic Thrust (MN)	0.26	0.46	0.3	0.1	0.28	0.12
Hydrostatic Pressure (kPa)	74.2	113.6	106.4	28.8	78.5	44.1

Gates are dam safety critical components of the scheme. Performance criteria for all gates, their lifting equipment, controls, and power supplies are that:

- for the Operating Basis Earthquake (OBE) there is no damage
- for the Safety Evaluation Earthquake (SSE) they must be able to operate post-earthquake. This means if a gate is open during the earthquake, it must be able to close and if closed during the earthquake it must be able to be opened if that is necessary post-earthquake. Limited damage is acceptable but must not prevent these post-earthquake performance criteria being met.

12.8 Applicable Standards – Gate Supplier

The requirements for use of Applicable Standards are given in Section 1.5 of the Technical Specifications.

Standards that may be considered as Applicable Standards for the control gates are given below.

Applicable Standards

NZSOLD	NZSOLD (2015) Dam Safety Guidelines
DIN 19704	German Standard for Hydraulic Steel Structures, Parts 1, 2 and 3
EM 1110-2-2105, USACE	USACE Design of Hydraulic Steel Structures
AS 1111.1 and .2	ISO metric hexagon bolts and screws – Product grade C – (1) Bolts and (2) Screws
AS/NZS 1554.1	Structural Steel Welding Standard, Part 1: Welding of steel structures
AS/NAS 1627	Code of Practice for preparation and pre-treatment of Steel surfaces (Parts 1, 2 and 4)
AS/NZS 3678	Structural steel – Hot-rolled plates, floor-plates and slabs
AS/NZS 3679.1	Part 1: Hot-rolled bars and sections
NZS 3404	Steel Structures Standard

12.9 Quality Assurance, Planning and Control

Refer to previous sections of this Technical Specification for general requirements related to quality assurance, planning and control. A Quality Plan will be prepared by the Contractor and reviewed by the Designer prior to construction. The Gate Supplier shall comply with the Quality Plan.

12.10 Dam Safety Function

The control gates shall be designed on the basis that they are appurtenant structures as defined by the Building Act and the NZSOLD (2015) dam safety guidelines (NZDSG), in that they shall be considered as being required for the safe containment and control of the reservoir contents under any, and all, loading conditions.

The dam safety critical function of each control gate shall be taken as per Table 19 below:

Table 19: Dam Safety Critical Functions of Control Gates

Gate	Emergency dewatering (open function)	Overtopping protection (open function)	Isolate culvert in case of culvert leakage (close function)
G1	No	No	Yes
G2	Yes		
G3	Yes		
G4	No		
G5	Yes		
G6a/b	Yes		

Detailed explanations of the dam safety critical functions of each gate are provided in Section 3 of the Design Report.

All embankments forming the ponds have been classified as High PIC under the NZDSG except for the West embankment containing the Buffer Pond, Pond 1 and the Tub, and the North embankment of the Tub, both of which are currently Medium PIC. All gates with dam safety functions are to be considered as High PIC for design purposes.

The control gates shall be designed to comply with the NZDSG to satisfy the relevant dam safety critical function from Table 19 above under all relevant load conditions including normal (static), flood and seismic. The design levels for each load condition shall correspond to a High PIC classification, as follows:

- Flood condition: PMF event
- Seismic condition: Safety Evaluation Earthquake (SEE) = 1:10,000 AEP event

Those control gates that have an emergency dewatering function shall be designed to be capable of opening following a SEE seismic event and any associated aftershocks.

The HPU shall be designed with fittings to allow connection of a backup portable hydraulic motor/pump if required (portable equipment not included in Gate Supplier scope).

12.11 Future Hydropower Duty

Gate G2 discharge into race R2 will initially be by upstream gated control. Subsequently, as part of a possible future hydro-power development, control would move downstream to a valve installed at the outlet to R2 (Ref Drawing WIL1125/30/106), and Gate G2 would operate as a guard gate for the hydropower waterway and equipment.

The duty requirements for Gate G2 to operate as a hydropower waterway guard gate are not presently known but are expected to be different to the initial irrigation release duty, including a headgate capable of gravity closure. Accordingly, Gate G2 shall be designed to release irrigation flows only with no requirement to account for hydropower operations. A new gate would be provided if/when a hydropower facility was installed if necessary.

12.12 Design Life

The various components of the control gate system shall have a design service life before major maintenance or replacement is required as follows:

- Pumps, motors and controls 20 years
- Hydraulic pipework and conduit – submerged service/weather 50 years
- Electrical switchboards and controls 25 years
- Electrical cabling 25 years
- Electronics & PLCs 15 years
- Gate leaf and frame 50 years
- Fixings and fastenings – submerged service/weather 50 years
- Corrosion protection systems 25 years

12.13 Design and Performance Criteria

12.13.1 Gate Flow Capacity

The gate opening dimensions and culvert sizes shown on the reference design drawings have been sized by the Contractor to meet the Principal's Requirements in regard to flow capacity and are not to be adjusted.

12.13.2 Gate Flow Control and Position

Each control gate is required to fully open or fully close with the reservoir at maximum operating level, and to be able to remain partially open in any position for any length of time.

Gates shall be fitted with gate position monitoring to monitor:

- Gate open position (0 to 100%)
- Gate fully closed
- Gate fully open
- Gate hydraulic repump required

The hydraulic ram shall have sufficient stroke such that when a control gate is in the fully open position, its lower edge shall sit not less than 50mm above the gate lintel frame.

Hydraulic re-pump is to automatically occur to return a gate to its fully open position once it creeps to 30mm of its fully open position. Re-pump to hold a gate in any part-open position is not required.

12.13.3 Gate Sealing

The gates are not required to seal drop-tight. Allowable leakage of any gate under its normal maximum pond water level shall be a maximum rate of 30 l/minute. Allowance shall be made for leakage rates to be proven during commissioning at the Contractor's discretion and subject to available pond water levels.

If leakage testing is carried out at water levels below pond FSL, the allowable leakage rate shall be adjusted down at an appropriate proportion of the head on the gate.

Measures shall be taken in design, manufacturing, and installation to ensure compliance with the maximum leakage requirements can be achieved, including the following:

- Deflection of the gate limited to 1/600th of the gate horizontal span
- Machining of the gate lower edge and potentially the lower frame section
- Means of accurately aligning the gate frame during installation

12.13.4 Lifting/Lowering Forces

The gates shall be operated to open and close by a suitably rated hydraulic cylinder hoist. The gates are not required to gravity close.

In calculating gate lifting and lowering capacities and requirements for hoist design, the following assumptions and allowances shall be applied as a minimum:

1. Hydrostatic pressure shall be computed assuming the maximum upstream water level with no downstream backpressure, and with the gate in any position.
2. Friction factors for materials in sliding contact shall be taken at the upper end of the range quoted by manufacturers and shall allow for any long-term degradation that may occur over the design service life.
3. Hydraulic downpull forces may be calculated by any recognised means, or alternatively may be taken as a minimum of 20% of the total vertical lifting load (exclusive of safety factors).
4. Hydraulic downpull shall be ignored for calculation of lowering forces.
5. Factor of safety of 1.5 to be applied to calculated vertical friction forces and hydraulic downpull forces.
6. Minimum factor of safety of 1.3 to be applied as a mechanical design margin.
7. Seismic loads may be ignored for purposes of calculating lifting/lowering forces.

12.13.5 Hydraulic Hoist System

The gate actuator hydraulic rams shall as per REL Drawings 201-206. The hydraulic rams are to be marine grade capable of operating submerged for extended periods of time and shall comply with the design life requirements in Section 12.12.

Electrically driven power packs are to operate with single phase 220 volt power supply. The power packs shall operate with a maximum 2000 psi with down pressure to 1500 psi. The HPUs shall be mounted in weatherproof concrete service control buildings located on the embankments above flood water level (building supply and penetrations by others).

Two types of installation are involved:

- Multiple gates and associated individual hydraulic rams in close proximity which may be operated with a common power pack (at outlet control G6); and
- Single gates with individual hydraulic ram operated with a single power pack (located at the inlet and each of the inter pond connections and outlet structures).

Hydraulic reservoirs shall have a working capacity of at least 110% of the oil required for the gate cylinders.

The HPU shall be sized so as to produce a gate movement rate of not less than 180mm/minute for lifting or lowering.

The oil reservoir of the HPU shall be fully bunded to contain the total quantity of oil in the hydraulic system with at least 50mm of freeboard.

12.13.6 Document Submittals

The gate Supplier shall submit to the Contractor the following drawings, information, manuals and instructions for review and non-objection or approval as appropriate:

- Detailed design calculations sufficient to show the design criteria adopted and compliance with the performance, functional and serviceability requirements
- Detailed design drawings to component assembly level including toleranced dimensions and materials schedules
- Schematic drawings of the gate hydraulic operating circuits showing interfaces with power supplies and controls systems
- Manufacturer’s drawings and data for any proprietary items
- Quality assurance documentation showing how quality requirements and compliance will be achieved
- Quality control documentation showing the results of inspections, measurements, testing, test certificates and any other applicable quality verification documentation
- Health and Safety Plan which shall be developed to align with the Contractor’s health and safety planning and policies.
- Programme of works in Gantt Chart format showing key dates and milestones through the design, procurement, manufacturing, delivery, installation, testing and commissioning processes, which shall be developed and refined in collaboration with the Contractor to suit the Contractor’s overall project implementation programme.

- Installation method statement for the gate frames, gate structures and hydraulic actuators
- Installation instructions for works to be carried out by the Contractor or another subcontractor that will affect the Gate Supplier's installation activities.
- Operation and Maintenance Manuals for the control gates, which shall be provided written in the English language and in sufficient detail to allow the principal to afterward operate and maintain the control gate works, order replacement parts and dismantle and reassemble the equipment to the extent necessary. The O&M Manuals shall include:
    - Operating instructions
    - Maintenance instructions and frequencies
    - Routine testing
    - Dismantling and reassembly instructions
    - Equipment specifications, data sheets and technical information
    - Drawings required for the O&M Manual to be appropriately used.
- Testing and commissioning procedures.
- Commissioning test report.
- As-built drawings.

All information shall be submitted in form with sufficient time available for review and non-objection or approval by the Contractor, Design Subconsultant and/or Principal, allowing also for document updating and one resubmittal for further review, and subsequent finalisation by the Gate Supplier.

Review for "non-objection" means that the review shall not relieve the Gate Supplier of its obligations and responsibilities under the Subcontract.

12.14 Fabrication

12.14.1 General

All steelwork fabrication shall comply with NZS 3404, Section 16.

All sharp edges shall be rounded to a minimum of 1 mm radius.

All welding shall comply with AS/NZS 1554.

All welds shall be continuous and Category GP unless shown otherwise on the drawings.

Welds shall undergo 100% visual inspection to detect gross defects and to ensure compliance with specification and drawings. Other means of non-destructive examination may be used to supplement the examination where necessary.

12.14.2 Fittings and Fastenings

All bolts and nuts for securing the panels to the embedded frame shall be stainless steel. Zinc-sprayed or galvanised fastenings are generally not to be used unless compliance with the design life requirements in Section 12.12 can be demonstrated.

Galvanic corrosion between dissimilar metals shall be prevented by the use of suitable electrolytic isolating components or materials.

12.14.3 Corrosion Protection of Steel Surfaces

All mild steel items shall be painted for corrosion protection after fabrication.

All gate and gate frame steelwork shall be protected with a high-build epoxy paint system of 400 micron dry film thickness. The paint system to be used shall be “Interzone 954” by International Paints product or an equivalent approved product. Paint shall be applied by a qualified applicator. The applicator shall consult with the New Zealand agent prior to carrying out any surface preparation or application to confirm the procedure to be used is suitable.

Epoxy coating colour shall be N53 Blue Grey, or equivalent other approved by the Designer’s Representative.

12.15 Gate Installation Methodology

The gate installation methodology will be prepared by the Gate Supplier and reviewed by the Designer.

All documentation shall be submitted in form to the Designer with sufficient time available for review and approval by the Contractor, Designer and/or Principal. Time shall also be allowed for document updating and one resubmittal for further review, and subsequent finalisation by the Gate Supplier.

12.16 Operation and Maintenance of Scheme

The Gate Supplier must consider the operation and maintenance (O&M) of the control gates. Key requirements that are to be considered include, but are not limited to, reliability, access for O&M and optimisation of OPEX vs CAPEX).

Sufficient access shall be provided to enable all mechanical and electrical equipment to be isolated, inspected, maintained and/or removed.

The Gate Supplier shall provide a complete and comprehensive O&M Schedule for the control gates, identifying all plant and machinery which must be maintained by the scheme Operator, and a full description of the frequency and methodology of planned or emergency maintenance activities.

12.17 Testing, Commissioning and Handover

Each gate shall be operated as necessary over its opening and closing range in order to determine and set the travel limits in conjunction with the electrical control system commissioning.

During gate testing it is necessary to ensure that:

- All tests are conducted in the presence of the Contractor;
- The bearing strip does not undergo excessive abrasion damage which can be minimised by the generous use of water as a lubricant during movements; and
- Travel of the gate is even and smooth and without jerky movements.

Measurements taken that verify compliance with the Specifications shall include (but are not necessarily limited to):

- Time taken to move gate from full open to various selected openings and full closure (and vice versa)
- Water leakage rate at the prevailing pond water level

The commissioning shall also include at least three repeated cycles of manual opening and closing of the gates under the prevailing pond water level which shall demonstrate repeatable, consistent, and reliable performance to the Contractor's satisfaction.

13.0 Pump Stations and Pumps

13.1 General

This section of the specification covers the performance, functionality and serviceability requirements for the two pump stations of the Wright's Road Pond Storage Scheme.

There are two pump stations. They are:

- the Buffer Pond Pump Station to fill Pond 1; and
- the Pond 2 Pump Station to lift water from Pond 2 into the main race MR4 (via the Tub and G6) and indirectly even-out distribution of water in all three directions.

Both pump stations are connected to the main control system. All the pumps are operated according to the control system instructions, which are based on the feedback received from the level sensors in the Buffer Pond, Ponds 1 and 2, and the Tub.

The power boards, control panels and cabinets for each pump station will be housed in prefabricated concrete service buildings. The sizing and locations of these buildings will be determined by the Designer during construction.

Pump operation is managed by the scheme SCADA system.

The pump station and pumps shall comply with any specific requirement and conditions of the resource consent and building consent.

13.2 Pump Station and Pump Specification Precedence

If any clauses of the main body of this Document (Technical Specification) do not agree with, or contradict, the information provided in this section of the Technical Specifications, then this section (Pump Stations and Pumps) of the Technical Specification shall take precedence.

13.3 Scope and Interfaces

The Pump Supplier scope includes the design/selection, supply, delivery, installation, testing and commissioning, of the following:

- 3x pumps and electric drives for the Buffer Pond Pump Station;
- 2x pumps and electric drives for the Pond 2 Pump Station;
- Suction strainers/screens for each pump;
- Any and all base plates, frames, mounting brackets, fasteners and other components/fixings required to securely install the pumps and associated equipment to the civil structures detailed in the referenced drawings;
- Local control cabinets for manual control of each pump;

Note: All equipment and mounting arrangements shall be designed to withstand the seismic design levels specified in Section 11.0 of this Specification.

The following works are to be supplied and/or carried out by others:

- Foundations, civil, site and preparation works;
- Site access, services, facilities and cranage for the Pump Supplier's use during site activities;
- Connection of rising main pipelines to pump discharge flanges;
- Supply and construction of the services/control buildings for each pump station, along with any necessary ducting, conduits, pits and penetrations for the power and control cabling;
- Power supply and remote control hardware supply and installation including, cabling, distribution boards, and power/control cable terminations at the Pump Supplier's equipment; and
- SCADA system integration, including local control panel, local PLC, HMI, instrumentation and associated cabling, panels and terminations at the Gate Supplier's equipment.

The Pump Supplier is required to interface and collaborate with those responsible for the above related works and to provide sufficient design information on the pump components and installation interfaces so that other related service providers can complete their related or connected designs.

13.4 Contractor's Reference Design Drawings

The Contractor has prepared a reference design for the pump stations, which is detailed in the reference drawings noted below. The reference design drawings are to be considered as indicative to show the intended general arrangement and form of the pump stations.

Dwg. Ref.	Title
WIL1125/30/1	General Arrangement Property Title Appellation and Ownership
WIL1125/30/135	Pump Structures – Pond 2 Pump Station Inlet Details
WIL1125/30/136	Pump Structures – Pond 2 Pump Station Inlet Isometrics
WIL1125/30/137	Pump Structures – Pond 2 Pump Station Outlet Details
WIL1125/30/138	Pump Structures – Pond 2 Pump Station Outlet Isometrics
WIL1125/30/139	Pump Structures – Buffer Pond Pump Station Outlet Through Embankment Details
WIL1125/30/140	Pump Structures – Buffer Pond Pump Station Outlet Isometrics
WIL1125/30/179	Pump Structures – Pond 2 Pump Station Outlet – Reinforcement Details
WIL1125/30/180	Pump Structures – Buffer Pond Pump Station Isometric – Reinforcement Section Locations
WIL1125/30/181	Pump Structures – Buffer Pond Pump Station Inlet and Access Stairs – Reinforcement Details
WIL1125/30/182	Pump Structures – Buffer Pond Pump Station Wet Well and Apron – Reinforcement Details
WIL1125/30/183	Pump Structures – Buffer Pond Pump Station Outlet – Reinforcement Details
WIL1125/30/184	Pump Structures – Pond 2 Pump Station Inlet Isometric – Reinforcement Section Locations
WIL1125/30/185	Pump Structures – Pond 2 Pump Station Inlet – Reinforcement Details

13.5 Buffer Pond Pump Station

Pond 1 is initially filled from the Buffer Pond by gravity, until it reached the Pond 2 Service Spillway crest level (RL 222.5 m), then Gate 1 (G1) will close.

Pond 1 is further filled by the Buffer Pond Pump Station, which consists of three shared duty vertical shaft turbine pumps, located between the Service Spillway and existing control gates of the Buffer Pond (see Drawing WIL1125/30/1). The pumps are to be installed within a wet well. See above mentioned reference drawings for typical details of the installation. Each pump will have independent discharge pipework connection to the outlet structure within Pond 1.

The pumps will operate at static head between 0 m and 4.7 m. The selected pumps shall each have a discharge capacity of no less than 325 l/s at a nominal net discharge head of 5.5 m.

The wet well inlet pipe is at a centre line of RL 220.5 m, with the invert and top of the wet well chamber at RL 220.0 m and RL 224.5 m, respectively. The discharge flange of each pump shall connect to separate DN450 rising mains at a centreline RL 225.1 m. The pumps shall be capable of pumping to a minimum wet well level of RL 221.5 m without vortex entrainment or cavitation risk.

An inlet screen shall be fitted at the suction end of each pump. The arrangement of screen and sizing of openings shall be in accordance with the pump manufacturers recommendation for the particular type of pump impellor/propellor. The screen shall be sized to prevent risk of cavitation with half of the screen area blocked.

Pump inlet screens shall include differential pressure (dP) measurement that may directly interface with the SCADA system. The Pump Supplier shall liaise with the Contractor in order to confirm the control system interface details.

A control structure will be provided to house the electrical and control panels. The size and location of the housing will be determined by the Designer during construction.

The pumps shall be fully automated and operated by the Ponds Control System, based on water levels transmitted by level sensors installed in the Buffer Pond. Buffer Pond pumps are set to start and stop at different (adjustable) water levels in Buffer Pond. The following preliminary start/stop levels will be used:

	Buffer Pond Level (RL)	
	Start	Stop
First pump	222.10	222.00
Second pump	222.30	222.20
Third pump	222.50	222.40

Depending on availability of water in the Buffer Pond, the three pumps will pump water into Pond 1 up to its full supply level RL 226.70m. The pumps shall be rated for continuous operation. It will take approximately 12-13 days to fill Pond 1 to the full supply level.

Staging the starting of pumps at three Buffer Pond water levels allows small amounts of excess water to be captured without excessive pump start/stops.

Three pumps were chosen so that one pump may be out of service without a major impact on the filling operation.

The order of pump operation will be adjustable via the control system (SCADA) to allow balancing of the running hours between pumps.

13.6 Pond 2 Pump Station

The Pond 2 Pump Station consists of two inclined axial flow Fluid Engineering FE575-700 pumps installed at the north-west corner of Pond 2, approximately 23 m from the Tub (see Drawing WIL1125/30/1). The pumps are to be installed within the inclined concrete channels that run down the face of the Pond 2 embankment. See above mentioned reference drawings for typical details of the installation. Each pump will have an independent discharge pipework connection to the outlet structure within the Tub.

The pumps will operate at static head between 0 m and 7.2 m. The selected pumps shall each have a discharge capacity of no less than 1000 l/s at a nominal net discharge head of 9m.

The pump drives shall be installed above the embankment crest level of RL 224.0 m. The discharge flange of each pump shall connect to separate DN750 rising mains at a centreline RL 222.72 m. The pumps shall be capable of pumping to a minimum level of RL 215.8 m in Pond 2, without vortex entrainment or cavitation risk.

An inlet screen shall be fitted at the suction of each pump. The arrangement of screen and sizing of openings shall be in accordance with the pump manufacturers recommendations for the particular type of pump impellor/propellor. The screen shall be sized to prevent risk of cavitation with half of the screen area blocked.

Pump inlet screens shall include differential pressure (dP) measurement that may directly interface with the SCADA system. The Pump Supplier shall liaise with the Contractor in order to confirm the control system interface details.

A control structure will be provided to house the electrical and control panels. The size and location of the control structure will be determined by the Designer during construction.

13.7 Contractual Arrangements and Responsibilities

The Pump Supplier is responsible for the Works described within Section 13 of this Specification and is a Subcontractor to REL. For information only, other Subcontractors that may interface with the Pump Supplier are anticipated to be as follows:

- Design Subcontractor (Damwatch Engineering Ltd) – scheme design overall except for specific design carried out by other Subcontractors;
- Electrical Subcontractor – design, supply installation and commissioning of power supplies, instrumentation and local control systems;
- Control System Subcontractor – supply, configuration, installation and commissioning of automated control systems and equipment.

13.8 Pump Supplier's Design

The Pump Supplier shall be responsible for detailed design of the pumps and associated equipment as per this Specification and shall provide design submittals to the Design Subcontractor for review and coordination with other scheme design aspects in accordance with Section 13.12.

Unless stated otherwise, the design of the Works, as documented in the design documents and elsewhere, shall:

a) comply with Applicable Standards (refer 13.9), and

b) achieve and comply with the Principal's Requirements, as set out in the Design Report.

Notwithstanding that certain design details are shown on the reference design, the Pump Supplier shall be responsible for design/selection of pumps and associated equipment necessary to provide a fully functioning and fit-for-purpose installation that will meet the performance, functionality and service life requirements of this Specification.

The Pump Supplier shall provide comprehensive design information to the Designer, as specified in Section 13.12.

No specific water quality data is available, however the pumped water is expected to be of a quality that does not require the selection/design of any non-standard arrangements in terms of abrasion/erosion resistance and corrosion protection. For the purposes of design and selection of pump components the Pump Supplier may assume clean water service. However, siltation along the pond invert is expected after a period of operation, therefore, some allowance should be given to pumping suspended silts.

13.9 Applicable Standards

The requirements for use of Applicable Standards are given in Section 1.5 of the Technical Specifications.

The Pump Supplier shall include in its design submission to the Design Subcontractor the standards to which the pumps will be designed, manufactured, installed, tested and commissioned. The nominated standards should preferably be internationally recognised (e.g., ISO, AS, NZS, US, JIS, Euro), or if an alternative standard is proposed its equivalent internationally recognised standard must be given.

13.10 Design Service Life

The various components of the Pump Stations shall have a design service life before major maintenance or replacement as follows:

- Pumps, motors and controls 20 years
- Electrical switchboards and controls 25 years
- Electrical cabling 25 years

- Electronics & PLCs 15 years
- Fixings and fastenings – submerged service/weather 50 years
- Corrosion protection systems 25 years

13.11 Design and Performance Criteria

Electric Drives (Motors)

Pump electric drives shall be 3~ high efficiency TEFC type, rated for continuous operation at ambient temperatures up to 40°C. Motors starting method shall be suitable to allow up to 10 start/stop cycles per hour.

Motors shall be suitable for outdoor installation meeting the required design service life.

Full technical specification of the proposed pump drives (including motor protection functions) shall be submitted to the Design Subcontractor for review and approval.

Pumps

Pump design duty points for the Buffer Pond and Pond 2 Pump Station pumps are defined in Section 13.5 and 13.6.

The Pump Supplier shall submit to the Design Subcontractor technical and performance details of the selected pump/motor for review. Submissions shall include all technical and performance information required to demonstrate compliance with the requirements of this specification.

Local Control Panel

The requirements for local control panel to be supplied with each pump will be developed in conjunction with the Design Subcontractor, based on the interfaces and designs of the Electrical and Control System Subcontractors.

Fittings and Fastenings

All bolts and nuts for securing the pump mounting equipment to concrete structures shall be stainless steel. Zinc-sprayed or galvanised fastenings are generally not to be used unless compliance with the design life requirements in Section 13.10 can be demonstrated.

Galvanic corrosion between dissimilar metals shall be prevented by the use of suitable electrolytic isolating components or materials.

Corrosion Protection of Steel Surfaces (non-stainless)

As noted in Section 7.2.3, all mild steel items shall be painted for corrosion protection after fabrication with an epoxy paint system of minimum 400 micron dry film thickness.

Full product details of protective coatings and coating specifications shall be submitted to the Design Subcontractor for review.

Paint shall be applied by a qualified applicator, and surface preparation shall be according the coating manufacturer's recommendations.

13.12 Document Submittals

The Pump Supplier shall submit to the Contractor the following drawings, information, manuals and instructions for review and non-objection or approval as appropriate:

- Design documentation:
    - Full technical details of the selected pumps including: pump curves, efficiency plot, cavitation limits, NPSH requirements, maximum transient design pressures, materials, bearing types, lubrication systems for selected pump arrangement;
    - Full technical data sheets and performance charts for the selected electric drives;
    - Details of all loads and forces applied by the pump to its supports under all required loading conditions;
    - General arrangement of the pump systems, including details of all mounting components sufficient to allow pump station civil designs to be finalised;
- Quality assurance documentation:
    - Quality assurance plan detailing how quality requirements and compliance will be achieved;
    - Quality control documentation showing the results of inspections, measurements, testing, test certificates and any other applicable quality documentation;
    - Installation method statements for the pumps;
- Health and Safety Plan which shall be developed to align with the Contractor's health and safety planning and policies;
- Programme of works in Gantt chart format showing key dates and milestones through the design/selection, supply, delivery, installation, testing and commissioning processes, which shall be developed and refined in collaboration with the Contractor to suit the Contractor's overall project implementation programme;
- Requirements for laydown areas, craneage, construction power, and any other facilities or services necessary for the Pump Supplier to install, test and commission the Pumps within the pump station civil structures;
- Installation instructions for works to be carried out by the Contractor or another subcontractor that will affect the Pump Supplier's installation activities.
- Testing and commissioning:
    - Detailed testing and commissioning plan and procedures;
    - Commissioning test report;
- Operation and Maintenance Manuals for the pumps (in English language) with sufficient detail to allow the Principal to operate and maintain the pumps, order replacement parts, and dismantle and reassemble the equipment to the extent necessary. The O&M Manuals shall include:
    - Operating instructions

  - Maintenance instructions and frequencies
  - Routine testing
  - Dismantling and reassembly instructions
  - Equipment specifications, data sheets and technical information
  - General assembly drawings and other drawing relevant to the operation and maintenance of the pumps.
- List of recommended spares for each pump type;
- Warranties for all supplied equipment, detailing all conditions and exclusions;
- Cavitation guarantee details and conditions for each pump type;
- As-built drawings of pump arrangement (following completion of works);
- As-built markups (red-line markups) of drawings (by others) that include details of the pump installation, i.e. supports, mounting arrangement, discharge pipework connection.

All information shall be submitted in form with sufficient time available for review and non-objection or approval by the Contractor, Design Subconsultant and/or Principal, allowing also for document updating and one resubmittal for further review, and subsequent finalisation by the Pump Supplier.

No review shall relieve the Pump Supplier of its obligations to meet the requirements of this Specification.

13.13 Pump Installation

The Pump Supplier shall install the pumps within the pump stations. Access required to the pump station locations will be provided by the Contractor. The pump supplier shall advise the Design Subcontractor of its requirements for laydown areas, construction power, and any other facilities or services necessary to complete the installation, testing and commissioning of the pumps.

13.14 Operation and Maintenance

The Contractor shall provide a complete and comprehensive O&M Manual and Schedule for the pumps, identifying all plant, which must be maintained by the scheme Operator and a full description of the frequency and methodology of planned or emergency maintenance activities.

13.15 Testing, Commissioning and Handover

Each pump shall be tested as necessary over its operating range in order to determine compliance with the requirements of this Specification and the correct operation of the pump automatic controls and protection.

The Pump Supplier shall cooperate with the Contractor and its Electrical and Control Subcontractors during the testing and commissioning activities in order to complete the activities defined in the agreed testing and commissioning procedures.

The pump supplier shall be responsible for the following measurements to verify compliance with the Specifications:

- Pump flow and net head,
- Motor current and voltage (including inrush current during motor start-up).

13.16 Warranty and Defects Liability

The Pump Supplier shall provide details (coverage, conditions, exclusions) of any and all equipment warranties offered on the supplied equipment (a minimum 2-year warranty is expected). A specific pump impellor cavitation guarantee shall be provided by the Pump Supplier. The Pump Supplier shall submit details of the cavitation guarantee to the Design Subcontractor for review.

The Pump Supplier shall also guarantee its fabrication and installation works against any defect for a period of 2 years following completion of the testing activities. The Pump Supplier shall, at its own expense, make good or re-perform any works found to be defective according to the Specification or Contract. Any rectification work shall be subject to a further period of 2 years from the completion of the rectification.

14.0 Control System

Refer to Design Report Appendix G for the design requirements and specification of the Control System. Note the detailed design of the Control System is not yet completed.

15.0 Operation, Maintenance and Surveillance Manual

15.1 Operation and Maintenance Manual

An Operations, Maintenance and Surveillance Manual shall be prepared by the Contractor during the construction period and prior to the commissioning phases. This shall comprehensively cover all operation and maintenance aspects of the scheme.

The Contractor shall submit the operation and maintenance section of the manual to the Designer at least two weeks prior to commencement of commissioning for review.

In accordance with NZDSG, an operations, maintenance and surveillance manual will cover the following principal areas:

- Summary description of dam with selected drawings and references to other documents (e.g. as-built drawings);
- Procedures for operating functional components;
- Owner's health and safety requirements;
- Routine equipment and structure maintenance procedures;
- Equipment overhaul requirements;
- Inspection and monitoring requirements;
- Evaluation procedures, definition of unacceptable behaviour and actions to be taken; and
- Emergency procedures including special safety assessment inspections required to be carried out after earthquakes.
- Minimum list of back-up replacements required to be maintained on site.

In addition, an annual mass balance check of water into and out of the ponds shall be conducted as part of Intermediate Dam Safety Review (IDSR). The purpose of this check is to annually detect for gross leakage from the ponds. This should be done by observing the pond water level, with the ponds close to full and no inflows or outflows over a period of 24 hours, then comparing the change in water level with allowance for precipitation and evaporation.

15.2 Dam Safety Management Plan

A Dam Safety Management Plan (DSMP) will be prepared by Damwatch Engineering Ltd during construction and prior to commissioning. The objectives of which shall be to minimise the risks from the ongoing operation of the ponds.

Monitoring and inspections are a fundamental part of operation. These range from routine daily observations to special safety review inspections.

In accordance with RC and NZDSG, the Dam Safety Management Plan shall cover the following components:

- Governance and people;
- Dam and reservoir operation and maintenance;
- Surveillance and control systems

- Monitoring the condition and performance of the geomembrane liner;
- Appurtenant structures and gate and valve systems;
- Intermediate dam safety reviews;
- Comprehensive dam safety reviews;
- Special dam safety reviews;
- Emergency preparedness (including an Emergency Action Plan and Emergency Evacuation Plan);
- Identifying and managing dam safety issues;
- Information management;
- Audits and reviews.

16.0 Commissioning

Prior to impoundment of the ponds the commissioning plan prepared by Damwatch will be updated jointly by the Contractor and the Designer in accordance with the requirements of the Building Act and the NZDSG

17.0 Grading Envelopes for Pond Materials

This Section provides grading envelopes for the pond embankment materials.

17.1 Zone 1 Rip Rap

Table 20 provides grading envelope for Zone 1 material. Refer to Figure 3 for grading curves. Nominal layer thickness 400 mm.

Table 20: Zone 1 Grading Envelope

Particle Size (mm)	Zone 1 - RIP-RAP Percentage Passing (%)	
Dx	Min	max
600	NA	100
400	NA	50
300	100	0
200	50	NA
150	0	NA

17.2 Zone 4 Embankment Fill

Table 21 provides grading envelope for Zone 4 material, refer to Figure 3 for grading curves.

Table 21: Zone 4 Grading Envelope

Particle Size (mm)	Zone 4 - Embankments Percentage Passing (%)	
Dx	Min	max
400	100	100
60	50	100
20	35	90
7	20	75
2.36	12.5	59
0.075	0	10

17.3 Type 1 Backfill

Table 22 provides grading envelopes for Type 1 material, refer to Figure 4 for grading curves.

Table 22: Type 1 Backfill Grading Envelope

Particle Size (mm)	Type 1 Backfill Percentage Passing (%)	
Dx	Min	max
37.5	100	100
19	100	100
9.5	40	100
4.75	25	85
2.36	17	72
0.6	5	45
0.3	3	32

Particle Size (mm)	Type 1 Backfill Percentage Passing (%)	
Dx	Min	max
0.15	1	18
0.075	1	5

17.4 Type 2 Backfill

Table 23 provides grading envelopes for Type 2 material, refer to Figure 4 for grading curves.

Table 23: Type 2 Backfill Grading Envelope

Particle Size (mm)	Type 2 Backfill Percentage Passing (%)	
Dx	Min	max
63	100	100
37.5	100	100
31.5	55	100
19	35	93
9.5	25	82
4.75	15	70
2.36	9	59
0.6	5	37
0.3	3	26
0.15	1	16
0.075	1	5

17.5 Type 3 Backfill

Type 3 backfill consists of controlled low strength mix material (CLSM), in accordance with AS/NZS 3725:2007. Each layer of CLSM shall be vibrated by means of an electric or pneumatic vibrator.

17.6 Fuseplug Sand

Figure 4 provides grading curve for fuseplug sand material.

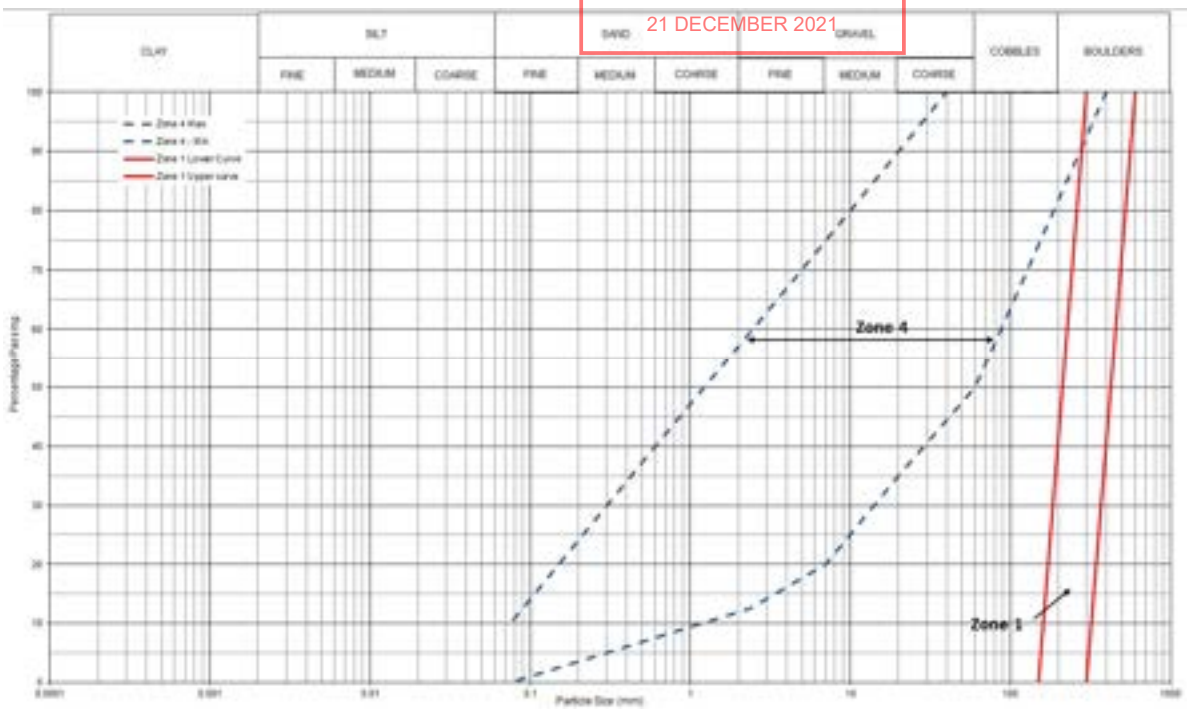

Figure 3: Grading Envelopes for Zone 1 and Zone 4 Materials

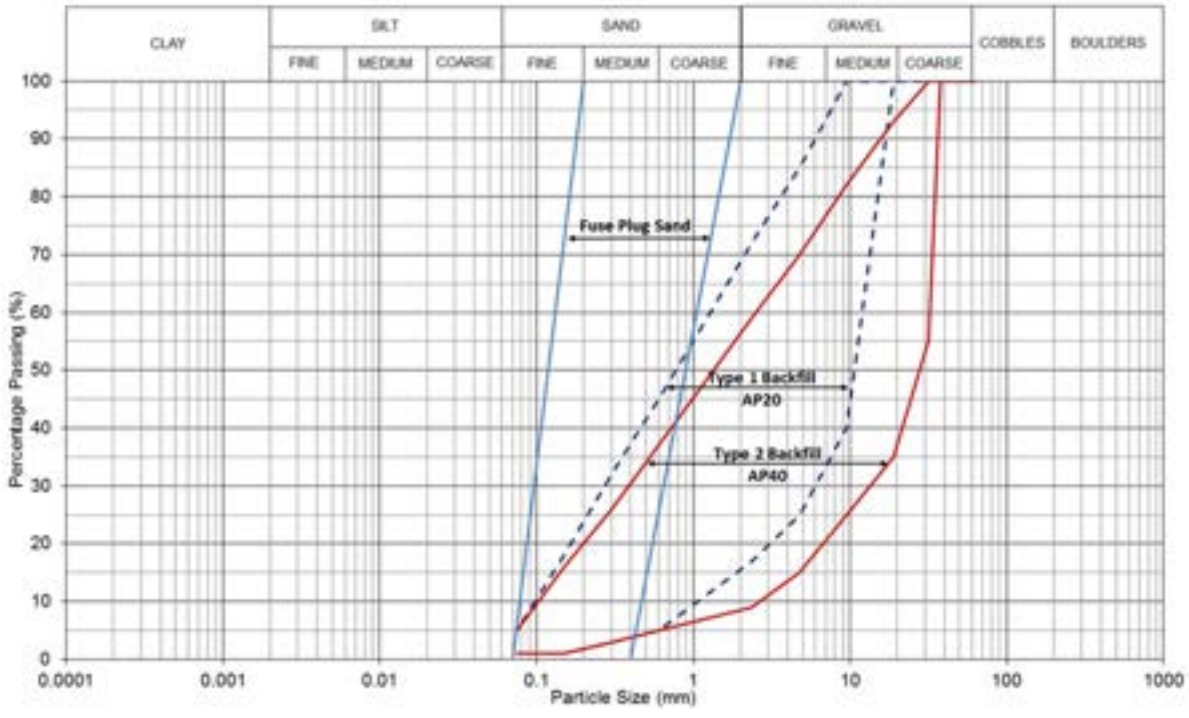

Figure 4: Grading Envelopes for Fuseplug Sand, Type 1 and 2 Backfill Materials

18.0 Electrical

18.1 General

This section of the specification covers the performance, functionality and serviceability requirements for electrical installation at the Wright's Road Pond Storage Scheme.

The Electrical Subcontractor shall be responsible for the design, supply, installation, testing and commissioning of the electrical systems required to support the operation and control of the pump stations, control gates, and any other facilities requiring a permanent power supply at the Wrights Road Pond Storage Scheme.

18.2 Electrical Specification Precedence

If any clauses of the main body of this Document (Technical Specification) do not agree with, or contradict, the information provided in this section of the Technical Specifications, then this section (Electrical) of the Technical Specification shall take precedence.

18.3 Scope and Interfaces

The Electrical Subcontractor shall be responsible for the design, supply, installation, testing and commissioning of the electrical systems required to support the operation and control of the pump stations, control gates, and any other facilities requiring a permanent power supply at the Wrights Road Pond Storage Scheme.

The Electrical Subcontractor and Contractor shall liaise with the local Power Authority in order to agree the limits of scope, and interfaces with the local network. The Electrical Subcontractor shall provide all interface designs and hardware required to be connected to any equipment for protection and control functionality provided by the local Power Authority.

The Electrical Subcontractor shall liaise with the Contractor regarding interface points and terminations to equipment provided by other Subcontractors. Such interfaces shall be confirmed and fully detailed in the detailed design of the electrical installation.

The Electrical Subcontractor shall install all control and instrumentation cabling in accordance with the drawings and installation instructions provided by the Control System Subcontractor. The required control and instrumentation cabling will be provided free issue to the Electrical Subcontractor.

Typical arrangement details for each type of cable installation proposed shall be submitted to the Contractor for review and approval prior to finalising the detailed design.

The Electrical Subcontractor shall design and install all necessary plinths and foundations and anchoring details for electrical equipment it supplies. The Electrical Subcontractor shall consider seismic design criteria in its design. The seismic criteria shall be the more stringent criteria of any applicable standards, or the OBE level seismic criteria.

18.4 Power Supplies

The Electrical Subcontractor shall provide for all hardware and requirements to provide the necessary power to all powered items supplied under this Contract.

Where this connection is to the local Power Authority all transmission line extensions, transformers, hardware, tariff metering and the like shall be included, as required.

18.5 Power Supply Reliability

The designs shall include for the possibility of loss of power at any section of the Works for a maximum of 24 hours. The Electrical Subcontractor shall provide at minimum:

- Backup power to every plant item or control area to maintain the control and monitoring connection to the SCADA system for at least 24 hours; and
- Supply backup power to energise all critical plant power items required to ensure the safety of the irrigation system under normal supply outage.

The Contractor will provide details to the Electrical Subcontractor of the required power supplies to all major plant items and areas of the site, and the back-up power requirements for those plant items deemed to be critical.

18.6 Local Service Transformer

Any local service transformer shall be constructed and supplied to IEC or AS standards and shall be rated for the maximum site load plus 10% minimum spare capacity and with a nominal secondary off load voltage of 415V. The transformer shall be mineral oil insulated and contain lockable off load tap-changers. The surface preparation, and manufacturing standards shall be to a high standard and suitable for the environmental conditions at the site.

The transformer shall comply with the Minimum Energy Performance Standards (MEPS) requirements which are set out in AS 2374.1.2-2003.

All ground mount transformers shall be mounted on a plinth within a bunded area capable of containing no less than 110% of the total transformer oil volume and an approved means of eliminating an oil spillage to the local environment. The Electrical Subcontractor shall be responsible for the design and construction of any plinths required for transformer installation.

Ground mount transformers transformer shall include at minimum:

- pressure relief protection and trip contacts;
- over temperature devices for oil temperature complete with alarm and trip contacts;
- off load tap-changer;
- oil filling, sampling, and recirculation outlet points and isolation valves;
- earth points; and
- hold down and jacking points.

18.7 Electrical Distribution Arrangement

The Electrical Subcontractor shall design and supply a complete MV and LV distribution system from the interface point with the local Power Authority to the pump stations, control gates, and any other facilities on site that require a permanent power supply.

All supply items for the main MV and LV distribution system shall be Type Tested and certified to the appropriate fault levels.

18.8 MV Switchgear

Any Indoor MV metal clad switchgear systems provided for the site shall:

- Comply with the necessary IEC standards;
- Have supplier representation in New Zealand;
- Be fully Type Tested and certified for the required level of fault withstand;
- Allow for isolation and earthing of equipment and cables;
- Contain all necessary voltage and current transformers appropriately sized for the protection, indication and metering systems provided;
- Include any necessary protection relays (separately mounted if required);
- Include for power monitoring on each breaker;
- Include for all necessary controls for local and remote operation as required; and
- Include for remote indication to the SCADA system of each breaker status, and the alarms, metered values, protection function alarms and trips associated with each breaker.

18.9 LV Switchgear

Any Indoor LV metal clad switchgear systems provided shall:

- comply with the necessary IEC standards;
- have supplier representation in New Zealand;
- be fully Type Tested and certified for the required level of fault withstand for any supply rating greater than 250kVA;
- provide a suitably rated breaker connection to the local service transformer LV terminals;
- provide for single phase lighting connections and maintenance power outlets.

18.10 Harmonics

All items that can transmit harmonics to the local Power Authority's system shall be fitted with active or passive front-end filters to limit the supply of harmonics onto the local area network. All harmonic levels at the point of common coupling to the Local Authorities supply point shall comply with the harmonic level requirements of the Local Power Authority or if these are not available to the lesser limits of ECP 36 or IEC standards.

18.11 Earthing

The Electrical Subcontractor shall design and supply an integrated earth system consisting of all necessary equipment to completely earth any powered structure. This shall include for building structure earths, earth mats, touch and step potential mitigation as appropriate.

18.12 Cabling Systems

All LV cabling designs and supply shall comply with the requirements of AS/NZS 3000 and AS/NZS 3008.1.2:2010. All MV cable supply shall comply AS/NZS 1429.1 or IEC 60502.2 and be installed to best industry practices.

18.13 Local Service Lighting and Power

All powered structures shall have suitable local service lighting to allow for man access, operation, and light maintenance works at night.

18.14 Electrical System Testing and Commissioning

The Electrical Subcontractor shall commission all of the electrical Works; this shall include all necessary tests to confirm compliance to AS/NZS 3000 and the NZ Wiring Regulations, provision of a COC for the installation, and then livening and post livening tests on all items.

The Electrical Subcontractor shall verify the correct operation, status and alarm operation of all electrical items it supplies.

All test results shall be provided to the Contractor prior to Practical Completion.

18.15 Drawings for Power Systems

Prior to Practical Completion, the Electrical Subcontractor shall provide a complete electrical design package detailing all of the interconnections of all equipment it supplied. This shall include at a minimum:

- Single Line Diagrams suitable for operation, isolation and earthing;
- protection and metering diagrams;
- schematics of all systems and any other electrically connected entity showing the complete terminal to terminal connections of all items in schematic form;
- wiring diagrams or lists showing the cable connections and terminations between all entities;
- cable lists;
- motor schedules showing manufacturer, type (details to be provided by Contractor);
- instrument schedules showing manufacturer, type and range (details to be provided by Contractor);
- location drawings of all electrical plant items; and
- local service layout drawings.

Appendix A – Guidelines for the Handling and Installation of Steel Pipes

Appendix B – Pump Specifications

Appendix C – Resource Consent Conditions