REPORT

Lower Taieri Floodbank System

Structural Integrity Assessment

Prepared for
Otago Regional Council
Prepared by
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Executive summary

General

This report describes a condition assessment of five structures associated with the Lower Taieri Floodbank System, undertaken following a major flood event that occurred from Friday 21 July 2017. A brief description of key points relating to the five structures of interest to Otago Regional Council (ORC) are provided below.

Section 4 of this report contains a summary of recommendations arising from our assessment. The recommendations are presented in tabular form. Recommendations have been categorised and priorities have been assigned to the recommendations made.

The most urgent matter identified is completion of repairs to the Upper Pond rock spillway and gate structure (Riverside Road Spillway).

It is important that all structures are closely monitored by ORC and ORC maintain appropriate emergency action plan measures. This is particularly the case until ORC have an opportunity to address the individual report recommendations.

Silverstream Pumping Station

Floodbank seepage adjacent to the true left abutment was observed by ORC during the recent July 2017 flood event. Based on recent events at the nearby Mill Creek Pumping Station, initial indications are that piping may be developing at Silverstream Pumping Station.

Further assessment and reinstatement work involving subsurface investigation is recommended. The footing supporting the rising main outlet head wall is undermined and requires repair. There is also uncertainty with the condition of the rising mains that requires attention. Rising main leakage may be a contributing factor to seepage and potential floodbank internal erosion at this location.

Other recommendations of note include review of the ability of the structure to remain operational during high landward side water levels, and installation of tell-tale devices to investigate if ongoing displacement is occurring at significant crack locations.

Waipori Pumping Station

The structure is of critical importance to the overall function of the scheme. The structure is generally in good condition. Several recommendation are made including confirmation of the Importance Level of key aspects of the facility in accordance with AS/NZS1170.0:2002 Structural Design Actions, as well as performance of the structure to the appropriate standards (defined as a function of Importance Level). It is important that the assessment includes appropriate consideration of liquefaction and lateral spread as well as the capacity of structural elements and the redundancy of elements such as power supply.

Upper Pond rock spillway and gate structure (Riverside Road Spillway)

The Riverside Road Spillway was refurbished in 2013 and sustained significant damage during the July 2017 event.

The 10 October visit confirmed that a number of repairs had been completed subsequent to the 1 August 2017 visit, but that a range of further urgent repairs to the Riverside Road Spillway are warranted in the short term. Completion of appropriate repairs at this locations is the most urgent matter identified by this assessment. Example works include repairs to the left abutment area and at some locations along the crest.

It is our view that there is considerable uncertainty associated with the performance of this structure at a design level event. It is clear that ongoing repairs will be necessary following significant future overtopping events. The extent of damage being subject to the magnitude and duration of overtopping. Review of performance expectations are recommended and further works may be required subject to the outcome of that assessment.

A1 Gate Outfall from Upper Pond

The A1 Gate Outfall from Upper Pond was in good condition. Several matters of a relatively minor nature were identified specific to this location.

Owhiro Outfall

The Owhiro Outfall was substantially replaced in 2010 and appeared to be in good order. However, some corrosion long the invert of the thin steel culverts within the adjacent Lower Pond Outlet was observed during the site visit of 1 August 2017. Assessment of corrosion at this location is recommended, together with appropriate remedial works.

General issues

A range general issues that relate to one or more structures include the following:

- Health and safety.
- Scheme surveillance and emergency action planning.
- Transformer bunding.
- Bridge signage.

These matters are described in Section 3.0.

1 Introduction

This report describes a condition assessment of five structures that form part of the Lower Taieri Floodbank System undertaken following the major flood event that occurred from Friday 21 July 2017. The work has been undertaken for Otago Regional Council (ORC) as our client.

ORC advice is that the peak flood flow initially recorded was close to 2,000 m^3/s at the Outram water level recorder site at approximately 8 am on Saturday 22 July. However, we understand that because of uncertainties in the rating at high water levels, ORC now consider that the peak flow rate was in the order of 1,700 m^3/s, 18 % less than initially recorded. This compares to the following peak flow estimates from selected other major floods:

- 1980 flood 2,500 m^3/s.
- 2013 flood 1,180 m^3/s.

The condition assessment was conducted on the following structures identified by ORC:

- Silverstream Pumping Station.
- Waipori Pumping Station.
- Upper Pond rock spillway and gate structure (Riverside Road Spillway).
- A1 Gate Outfall from Upper Pond.
- Owhiro Outfall.

Section 2 following outlines in turn our observations and evaluation of each of the five structures.

The focus of the condition assessment is the civil engineering components of the structures (i.e. excluding mechanical, electrical, and control system components) with a view to identifying the potential for, or evidence of:

- Debris accumulation.
- Piping.
- Erosion/scour.
- Undermining.
- Structural distress.

The assessment is a qualitative assessment based on visual observation. It is intended that this component of the assessment is broadly comparable to relevant aspects of a Comprehensive Dam Safety Review (CDSR) in accordance with the New Zealand Dam Safety Guidelines, published by The New Zealand Society on Large Dams (NZSOLD) (the Guidelines)[1] as relates to civil works.

The condition assessment comprised of the following to the extent relevant for individual structures:

- Review of provided drawings (not identified as-built), records, specifications, design reports, and previous condition inspection records pertaining to the structure (all as provided by ORC).
- A walkover condition assessment of the five structures undertaken on 1 August and 10 October 2017.
- Assessment of recent performance against design expectations where information regarding design performance has been made available.

Recommendations for further work and/or matters for ORC to address are listed throughout the report and summarised in Table 1 included in Section 4.0.

[1] The New Zealand Society on Large Dams (NZSOLD); New Zealand Dam Safety Guidelines; May 2015.

There are a number of matters common to one or more of the structures. For example regular infrastructure inspections, health and safety considerations, bridge signage and transformer bunding. These matters are described in Section 3.0 (for example see also photos 16, 20 and 22).

There are a number of limitations with the assessment process due to the nature of the walkover evaluation process and limited availability of design and as-built information. Please refer to Section 5.0 of this report for more information on these matters.

2 Structures visited

2.1 Silverstream Pumping Station

2.1.1 Introduction

The Silverstream Pumping Station is located adjacent to Silver Stream, a little over 500 m upstream from the Riverside Road crossing. The station discharges approximately three cumecs from the Mill Stream and the eastern end of the Upper Pond area to the Silver Stream during flood conditions. We understand that the facility was constructed in the mid-seventies and most of the structure is therefore approximately forty years old.

ORC hold detailed drawings of the facility, albeit that there appear to be some drawings within the set that may be superseded. The status of the drawings are not marked as as-built and therefore the status of the drawings are a little unclear. Nonetheless, we have assumed that the drawings provide a good indication of arrangements, including aspects of the structure below ground level. For example sheet pile cut offs. Some drawings of interest are included in Appendix A. Also, indications are that the adjacent floodbank has been raised since the pumping station was constructed. A riverside parapet wall inferred to be part of the stop bank raise is not shown on the drawings (photos 1 and 2).

Photo 1: Looking downstream along Silver Stream towards River road (10 October 2017). Note cracking in parapet wall on left coincident with inferred extent of sheet pile support to underside of gravity gate and bridge structure.

Photo 2: Looking upstream towards Silver Stream pumping station on 1 August 2017 following the July flood event whilst water levels still elevated albeit dropping.

Drawings provided by ORC indicate there is a sheet pile cut-off wall below the structure that also extends just over 5.0 m into the embankment on either side (see Appendix A). The arrangement is very similar to that at the nearby Mill Creek Pumping Station. A significant piping incident recently occurred at Mill Creek and this was attributed to the sheetpile and embankment fill interface[2].

2.1.2 Seepage reported

Unusual occurrences at the site during the July 2017 flood reported by ORC comprised:

- Seepage emerging from the grouted rock fill on the landward (station intake) true left of the structure below the transformer from an area behind the sheet pile cut off when the water in the Silver Stream was high (photos 3 to 5). ORC[3] have mentioned that "*a reasonable amount was flowing out of the top crack and down the face. Nothing observed flowing from the cracks below, but may have been obscured by the flow from above – was also dark and raining*".
- Flood waters entering the upper portion of the station where the floor level is located below the crest of the parapet wall, including the room housing the pump motors and electrical controls (photos 1 and 6).

This was during pumping when the Silverstream was high. Thereafter the water level in the pond rose to inundate this section.

ORC report that a number of years ago seepage was also reported emerging from the grouted rockfill during flood conditions at the same location where seepage was recently reported. ORC also advise that the historical seepage subsequently ceased following repairs to the adjacent rising main joints and cracking then visible within the pipework.

Indications are that the homogeneous embankment fill contains a significant portion of low plasticity silt. Based on available information, including the recent Mill Creek piping incident located approximately 1.7 km away, the embankment fill is most likely prone to piping.

Photo 3: Grouted rock fill below the station transformer and location of historical seepage and seepage reported during July 2017 flood event.

Photo 4: Cracking in grouted rock fill below the station transformer and location of historical seepage. Understanding is that seepage reported during July 2017 flood event emerged from top crack immediately below formed face of transformer foundation.

[2] Tonkin and Taylor; Mill Creek Pump Station Inspection, T+T reference 1001453.2; September 2017.
[3] ORC, pers. comm.; Floodbank queries; 2 November 2017.

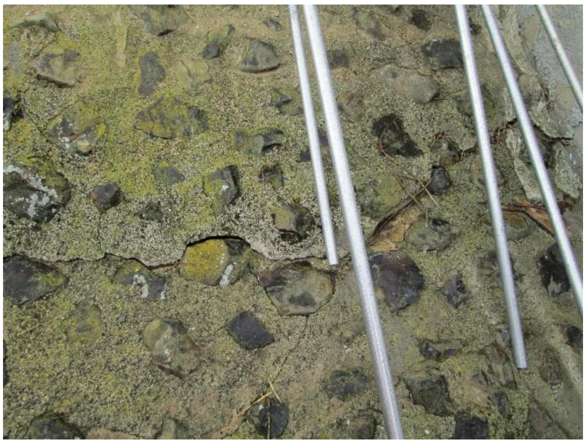

Photo 5: *Cracking in grouted rock fill below the station transformer. Location of historical seepage and seepage reported during July 2017 flood event emerged from above crack shown.*

Photo 6: *Pump motor – ORC report that the water level exceeded the floor level by about 0.2 – 0.3 m during the July 2017 flood event.*

2.1.3 Piping

Piping arises from seepage pressures causing erosion of soil particles. Piping depends on seepage pressures and the nature of the soil. Material can erode to the point that a "pipe" forms, and can result in the failure of earth and water retaining structures. The recent Mill Creek incident being a good example[4].

Seepage reported by ORC during the July 2017 is of concern. This may be associated with initiation of piping within the embankment. The piping may be associated with water entering the embankment from high Silver Stream water levels and/or leakage from the rising mains.

The recent piping incident at the nearby and very similar Mill Creek Pumping Station highlights the following:

- The susceptibility of fill from local silty soils to piping failure.
- The potential for the rapid deterioration of a latent situation that may have been developing for many years.
- The vulnerability of details such as sheet pile cut off arrangements that are now considered dated/inconsistent with current practice and do not feature filter protected drainage.

2.1.3.1 Rising main

Potential rising main leakage may be related to deterioration of aged rubber ring joints and/or cracked pipes and/or deterioration of old repairs. Settlement and/or displacement of the floodbank (inferred to have occurred from cracking of the structure at various locations) may also be a factor contributing to stress on the pipes and pipe joints. See also Section 2.1.3.2 that overviews circumstances associated with undermining of the outlet head wall.

Leakage from the rising mains is of significant concern because of the potential for pressurised water to enter the embankment fill and instigate piping failure.

[4] Tonkin and Taylor; Mill Creek Pump Station Inspection, 1001453.2; September 2017.

We understand that because of the drain configuration upstream of the pumping station, it is not possible to allow upstream water to accumulate to test for seepage coincident with pump operation during normal circumstances outside of a flood situation.

Therefore, unless ORC prefer to devote resources to a short term rising main replacement, we recommend a detailed internal inspection of the rising main pipework together with appropriate hydrostatic pressure testing in accordance with a recognised standard (e.g. AS/NZS4058:2007 Precast concrete pipes (pressure and non-pressure) and/or Christchurch City Council Construction Standard Specification and/or The New Zealand Dam Safety Guidelines or equivalent). Subject to the outcome of the inspection and pressure test, it may then be appropriate for ORC to consider options to repair and/or replace rising pipe work. Options may involve:

- Replacement of one or more of the rising mains with new pipework able to accommodate appropriate movement and potentially coincident with replacement of embankment fill as described below. High density polyethylene may be an appropriate pipe material for new rising mains (noting that ORC may proceed to this option without a pressure test if ORC deem appropriate).
- Assessment if a cured in place pipe (CIPP) is a suitable cost effective option able to provide the appropriate strength to accommodate the future movements.
- Ongoing epoxy (or similar) repairs similar to that previously undertaken.
- Appropriate ongoing condition assessment (refer section 3.2).

Note that a separate recommendation (Section 2.1.3.4) is also provided for replacement of fill in front of the sheet piles near the transformer area. It may be convenient to also replace pipework and review outlet head wall stability at this time.

2.1.3.2 Outlet headwall scour and potential deterioration

The footing supporting the retaining wall containing the raising main outlets and flap gates has experienced significant undermining (photo 7). Likely a result of turbulent flow from rising main discharges. This may be causing wall displacement (or the potential for displacement).

We recommend that in the short term scour, including the void beneath the wall footing is appropriately reinstated and armour placed to prevent further scour at this location.

A possible remedial solution may involve filling the void with a suitable concrete. Scour beneath the head wall may be causing instability and potentially causing the wall to rotate (or could lead to this outcome if the matter is not addressed). We have noted some displacement at a head wall vertical construction joint near the debris boom and gate outlet, albeit the that movement does not appear to be fresh (photograph 8).

We recommend that ORC install tell-tale devices coincident with joints in the rising main outlet head wall structure and regularly check and record any displacement.

It is also appropriate that ORC confirm and record the wall verticality (possibly by way of a level and plum bob survey) and undertake regular follow up assessments to identify any ongoing instability.

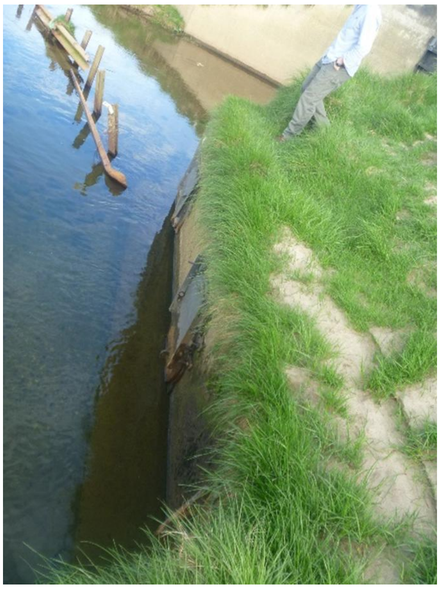

Photo 7: *Outlet head wall, two flap gates located at the rising main outlets are visible. The wall footing below water level has suffered significant undermining, attributed to turbulent flow at the rising main outlets.*

Photo 8: *Construction joint in head wall at rising main outlet. Note apparent movement. Location of interest for tell-tale installation.*

Displacement of the headwall may also be placing stress on the rising main and rising main joints. In principle this may also be contributing to loss of rising main and/or rising main joint integrity.

We recommend that the outlet head wall stability is reviewed coincident with replacement of any pipework and replacement of fill.

The debris boom adjacent to the rising main outlet to prevent debris from Silver Stream impacting on flood gate operation has suffered significant damage (photo 7 and 9).

We recommend that the debris barrier structure is repaired or replaced.

Photo 9: Debris barrier in vicinity of gravity gate out let channel confluence with Silver Stream.

2.1.3.3 Transformer area void

ORC operations staff advise that a number of years ago a void formed under the transformer slab (above the location where seepage was reported) and that this void was filled with concrete. Refer photos 3 and 10. The void appears to have been associated with instability in the embankment and adjacent cracking in the grouted rock fill is still evident. Given the coincident seepage and historical rising main issues, it is reasonable and prudent at this time to infer the slumping was related to a developing piping situation. Repair of concrete immediately below the slab and rising main repairs are not necessarily a long term solution to the piping risk.

Photo 10: Displaced ground below the transformer slab previously repaired by concrete below the original slab in the vicinity of the recent seepage.

Photo 11: Silver Stream pumping station transformer.

The area of interest is located behind the sheet pile cut off and a similar detail was present at the nearby Mill Creek facility. In that instance the piping occurred around the sheet pile cut-off arrangement. Therefore, the sheet pile cut-off is not considered appropriate long term protection for seepage at this location.

2.1.3.4 Piping recommendation

Based on the preceding, we recommend that in addition to internal condition assessment inspection and pressure testing of the rising mains, fill on the Silver Stream/rising main side of the sheet pile cut-off is removed and replaced with suitable low permeability engineered fill with appropriate clay content, permeability, plasticity and strength (potentially with added bentonite). Coincidently investigate the integrity of the sheet pile arrangement and give appropriate consideration to the benefit of filtered drainage behind the sheet piles on the landward side of the stop bank (also able to accommodate high landward side water levels as well as future seepage at the sheet pile and fill interface).

It is recommended that this work occurs in conjunction with the rising main assessment and not instead of the rising main assessment.

It is important that this exercise is undertaken with appropriate engineering input to address issues such as:

- Timing and staging of the work to ensure flood defences are not compromised.
- Specification of materials and construction observation.
- Interpretation and forensic assessment of controlled excavations with the ability to modify proposals to reflect circumstances found on site (including extent of excavations).

- Temporary excavation stability.
- Support of structures including the transformer and transformer slab.
- Identification of underground services in the vicinity of the transformer.

2.1.4 Motor and control system level

The embankment crest level adjacent to the pumping station has been raised since the pumping station was constructed. However, aside from an external parapet wall to match the raised crest, at the time that the stop bank was raised, no effort appears to have been given to protection of the pump motors and associated control system.

During the July 2017 event, the landward side flood level was close to the embankment crest and reported to have been above the motor and control room floor. We understand that this situation resulted in flooding of the room housing the pump motors and controls, and required the pumps to be manually shut off before damage to the motors and/or the controls occurred (Photograph 6).

We recommend that thought is given to protect the motors and equipment in the upper portions of the station.

Possible options are subject to appropriate specialist advice and may include some combination of the following:

- Raising the electrical cabinets and/or key aspects of pump controls and the pump motors.
- Installing a high level cut off to automatically shut down the pumps in the event of extreme high water levels.
- Investigating if it is feasible to tank/seal the upper portion of the station including assessing if it is viable to seal the pumps to prevent water raising up in to the motors and/or installing a high level sump pump to remove water raising through the floor before it can raise to a level that would otherwise cause damage.

2.1.5 Parapet wall movement

The concrete parapet wall apparently added to the riverside of the structure (Photo 1 and 2 and 12-14) does not appear to have been detailed to take account of stiffness discontinuities associated with the concrete structure and associated sheet piles and adjacent fill. The wall has cracked at the inferred interface, likely due to settlement of the fill. It is not clear if the movement is ongoing. ORC operations staff advise that this cracking did not pose concerns when subject to high water levels during the July 2017 flood event.

We recommend that ORC install tell-tale devices across significant cracking in the parapet wall and regularly check and record any displacement and undertake further work as may arise from surveillance data.

Photo 12: Parapet wall cracking from vehicle access. Installation and monitoring of tell-tale device recommended.

Photo 13: Parapet wall cracking coincident with stiffness discontinuity at extent of sheet pile cut off and capping beam. Installation and monitoring of tell-tale device recommended.

Photo 14: Cracking in parapet wall. Note inferred extent of original extent of concrete wheel stop at underside of parapet wall visible to the right of the right of the vertical crack.

2.1.6 Vehicle bridge access

Historical cracking is also present in the bridge structure over the flood gates (photo 15). The cracking has been repaired, ORC advise that a specialist contractor completed this work a number of years ago. ORC have also indicated that the bridge capacity has been rated to reflect the bridge condition and heavy vehicles now use the lower crossing. We recommend that signage is erected to clearly state bridge capacities as outlined in Section 3.4 (photo 1 and 16).

Photo 15: Flood gate bridge cracking – previously repaired.

Photo 16: Lower bridge crossing in the vicinity of pump intake.

2.2 Waipori Pumping Station

Waipori Pumping Station is located at the eastern end of Lake Waipori, south west of Henley Berwick Road, West Taieri. The facility lifts water to Lake Waipori and is located at the downstream end of a large area approximately 7,000 ha in size unable to drain by gravity to Lake Waipori or the Taieri River. The area includes Dunedin Airport at Momona. Construction of the station commenced in 1927 and Waipori Pumping Station has been added to and enhanced a number of times, most recently in 2014. The installed pump capacity is presently four pumps each able to convey a flow of approximately 2 m^3/s.

Photo 17 shows the facility and the Lake Waipori floodbank is visible in the background. We understand that Lake Waipori Water levels are influenced by high tides.

Photo 17: Waipori Pumping Station looking towards Lake Waipori. Pump intake trash racks visible.

Photo 18: Low spot in crest wall approximately 600 mm high associated with pumping station reconfiguration work.

Generally the facility appears in good condition. Comments of note include:

1. There is a low spot along the crest wall adjacent to Lake Waipori related to prior amendments to the facility layout that that is approximately 600 mm below adjacent areas (photo 18). High lake levels could potentially concentrate overtopping at this location. We recommend that ORC review the required free board at this location and modify the structure as may be required. In addition to consideration to the identified low spot, we recommend ORC give consideration to the stop bank crest level at critical locations given that:
   - Lake Waipori water level is subject to tidal influence.
   - Sea level rise is expected long term.
   - Indications are that there may be appreciable long term settlement in the central plains area in the vicinity of the pumping station and adjacent stop banks.
2. Given its location, the facility is critical insofar as the overall performance of the scheme is concerned. Present understanding is Dunedin Airport at Momona is reliant on the integrity and performance of the facility and the adjacent stop banks, in particular to protect against high lake levels. Given the function of the Waipori Pumping Station facility and the adjacent stop banks, we recommend that the Importance Level (IL) in accordance with AS/NZS1170.0:2002 Structural Design Actions is reviewed and confirmed. This will include consideration of the importance of this structure to key infrastructure including Dunedin Airport. For example IL4 level structures include structures with special post disaster functions including:

– Buildings and facilities with special post disaster function.
– Utilities or emergency supplies or installations required as backup for buildings and facilities of IL4.

3 Based on a confirmed IL review expected performance of the structure against appropriate design/performance standards. For example, the NZS1170 requirement is that an IL4 structure can withstand an ultimate limit state 1 in 2,500 year average recurrence interval earth quake.

4 Present understanding is that the facility and adjacent structures are susceptible to foundation liquefaction. In addition to shaking, review of seismic resilience should include assessment of the performance of the structure and adjacent works to withstand design level liquefaction and lateral spread, without uncontrolled flow from the lake to adjacent low lying land. The assessment should also establish that the level of damage is unlikely to result in circumstances preventing pumps from returning to operation within an appropriate time frame.

5 Based on the confirmed IL review the requirement for backup power and redundancy at Waipori Pumping Station.

6 Piping has recently occurred at Mill Creek and is suspected to be developing at Silver Stream pumping station. Aside from sheet pile arrangements that have not proved effective, we are not aware of modern defensive measures to mitigate the effect of piping adjacent to structures at Waipori Pumping Station (e.g. appropriately graded earth filters). However, no reports have been provided of seepage or slumping or other unusual behaviour at this location. Further to section 3.2 we recommend that ORC carry out appropriate inspections at suitable intervals to assist with the early identification of potential piping issues, should they arise.

7 Public access is provided to the facility. ORC have erected signage to warn of some hazards (photos 19 and 20). However, there are no barriers or fences to prevent the public accessing locations where hazards may exist. For example pump intake forebay trash rack areas (photos 20 and 21). We recommend that ORC review signage, fencing, security and barriers against present requirements, including the Health and Safety at Work Act 2015 Act with consideration to what may be "*practicable*". Refer also section 3.1 of this report. Specialist input is recommended.

Photo 19: Waipori Pumping Station signage.

Photo 20: Pump intake area assessable to the public.

Photo 21: Pump intake area assessable to the public.

Photo 22: Waipori Pumping Station transformer.

8 The station transformer is not bunded (photo 22). Refer section 3.0 for further discussion.

2.3 Upper Pond rock spillway and gate structure (Riverside Road Spillway)

2.3.1 Introduction

The Upper Pond rock spillway and gate structure (Riverside Road Spillway) is located on the true left floodbank near the Riverside Road and School Road intersection. The spillway diverts flood waters into the Upper Pond area when the Taieri River water level exceeds the spillway crest level (photo 23). The structure comprises a broad crested overflow weir approximately 550 m long. A relatively short section, approximately a further 75 m long to the north, at the upstream end of the long weir features manually actuated flap gates and a lower crest level (photo 24).

Photo 23: Riverside Road Spillway, long overflow broad crested weir section looking downstream.

Photo 24: Riverside Road Spillway, short gated section looking downstream.

The structure has suffered damage at various times over the years and consequently has been rebuilt, repaired and modified on several occasions.

We understand the following regarding design overtopping flow performance expectations of the 550 m long ungated section of the Riverside Road Spillway from the 2012 – 2013 design and construction documentation provided by ORC:

- The structure was sized to accommodate a flood flow similar to the 1980 flood event, equivalent to a maximum Taieri River flow of 2,500 m^3/s at the nearby Outram water level recorder.
- The equivalent Riverside Road Spillway maximum design overtopping flow is 2.5 $m^3/s/m$, occurring at a maximum overtopping depth of 1.4 m.
- No specific expectation of the duration of overtopping able to be sustained by the structure has been provided, albeit that we have interpreted there is an expectation that the total overtopping time is in excess of 24 hours.
- No performance expectations associated with design conditions (1.4 m deep overtopping flow) are listed, for example: no damage, minor damage repairable within a nominated timeframe, significant damage but no breach, or breach and uncontrolled flow.

2.3.2 July 2017 flood

Based on advice from ORC, we understand that during the July 2017 flood event the estimated flow in the Taieri River was 1,700 m^3/s at the Outram water level recorder site, just over 30% less than the peak associated with the 1980 event. We are advised that the recent peak overtopping depth along the majority of the ungated structure was in the order of 0.6 m adjacent to the gates, increasing to approximately 0.9 m at the right abutment. We also understand that the structure overtopped for a period of about 30 hours. Significant damage to the structure resulted from the recent overtopping. The estimated overtopping depths are in the range of 0.5 to 0.8 m less than the design depth.

Observations from our visits on 1 August and 10 October 2017 follow:

1 A large quantity of debris was deposited on the crest (photos 25 and 26).

Photo 25: Crest debris from July 2017 flood event.

Photo 26: Crest debris from July 2017 flood event.

2 There was scour damage to the crest, including damage to the geotextile and geotextile anchor trench arising from flow concentration associated with crest debris (photos 27 to 30).

Photo 27: Crest damage.

Photo 28: Crest damage.

Photo 29: *Crest damage.*

Photo 30: *Crest damage.*

3 High Flood flows have resulted in the removal of a large quantity of rip rap rock, particularly smaller rocks, from the downstream face of the weir. Many of these rocks were deposited on farmland significant distances away from the weir (photo 31 and 32). As a consequence of temporary repairs, smaller rocks are now concentrated near the base of the structure (photo 33).

Photo 31: Rip rap rock deposited in paddocks downstream of the spillway following the July 2017 flood.

Photo 32: Rip rap rock deposited in paddocks downstream of the spillway following the July 2017 flood.

Photo 33: *Small rock at the base of the structure – this situation is not considered stable when subject to significant overtopping flow.*

Photo 34: *Damaged rip rap near the crest– note loss of rock.*

4 Significant scour damage to the downstream toe of the structure has occurred (photos 35 to 39).

Photo 35: *Scour damage.*

Photo 36: *Scour damage downstream of spillway gated section.*

Photo 37: Scour damage.

Photo 38: Scour damage.

Photo 39: Scour damage.

5 The right abutment area at the downstream end of the structure suffered significant scour damage (photos 40 to 42). Information provided by ORC indicates that damage previously occurred at this location during earlier flood events. Concentrated damage may have arisen from a low point in the crest and/or as-built edge arrangements (flow outflanking rock and geotextile protection to underlying erodible material).

This damage is of particular concern as a greater depth of prolonged overtopping at this location could have easily resulted in scour, backward erosion and breaching of the erodible embankment fill. This could have given rise to flow outflanking the structure, causing a significant breach and significant uncontrolled flood water flow into the Upper Pond area.

Photo 40: Right abutment damage from the July 2017 flood event. Location at significant risk of further damage.

Photo 41: Right abutment damage from the July 2017 flood event. Location at significant risk of further damage.

Photo 42: Right abutment damage from the July 2017 flood event. Location at significant risk of further damage.

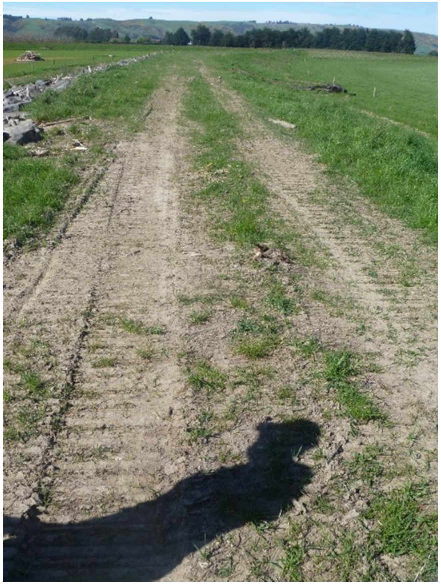

Photo 43: Crest damage arising from repair works. Appropriate grass cover is necessary to minimise the potential for scour erosion.

6 The spillway crest has also suffered damage from repair work construction activities. This area is at risk of further erosion damage until appropriate grass cover is re-established (photo 43).

7 The northern and upstream gated section has performed relatively better, particularly in the vicinity of the gates and crest. Some scour has occurred near the toe and beyond the stilling basin gabion basket and rip rap stilling basin (photo 36).

8 The 10 October visit also confirmed that a number of repairs had been completed subsequent to the 1 August 2017 visit. However, a range of further urgent repairs are warranted in the short term e.g. right abutment area and some locations along the crest.

2.3.3 Design basis and expectations

ORC have provided a number of drawings of the structure, together with related design and tender stage information of the long ungated spillway section where most significant damage occurred during the July 2017 flood. We have assessed this information and we have found that:

1. The initial rip rap design seems to have been based on a method set out in the Austroads waterway design guide developed by California Department of Public Works in 1960. We understand that this formula is intended to estimate rock sizes for flow parallel to an embankment. Whereas in this situation, the flow is overtopping, and directed down the face of the embankment perpendicular to the direction of the embankment. Therefore, this formula is not considered strictly appropriate to estimate rock size for this situation. Nonetheless, provided information indicates that the design rock size based on this approach is 722 kg. We interpret that this mass corresponds to a D_{50} diameter of approximately 800 mm (Meaning that 50% of the rip rap mixture is required to be larger than the nominated D_{50} parameter. The nomenclature applies to other rock size grading requirements too. For example, 85% of the rip rap material is required to be larger than the nominated D_{85} parameter).
2. Opus have reviewed the design and used an alternative method to estimate rock size[5]. Opus have used a method proposed by Knauss to estimate a D_{50} rock size of 650 mm based on the following parameters:
   - Spillway overtopping flow per unit length, q, of 2.5 $m^3/s/m$ associated with a flood equivalent to the 1980 event.
   - Embankment slope of 3.5H:1V (28.6 %).
   - Rock packing factor of 0.65, related to "natural packing, dumped embankment" and at the low end of the recommended range (i.e. conservative given the range suggested).

   Other approaches will result in different estimates for appropriate rock sizes. For example the method proposed by the United States Army Core of Engineers (USACE)[6] for steep slopes without defined tail water will result in a D_{30} parameter greater than the D_{50} estimated by Opus i.e. much larger rip rap rock sizes and a more resilient rock specification (noting that the USACE has some limitations on maximum slope appropriate for their method). It is prudent to use a range of methods and select a specification from a range of estimates rather than relying on an individual result. Present understanding is that quantitative as-built grading data is not available. Performance is also subject to the level of care taken to place rip rap (e.g. an area with a higher concentration of finer material may concentrate damage).
3. The performance of the rock fill is also subject to the grading of the material, for example, by specifying D_{85} and D_{15} parameters. Other than a D_{50} parameter, it is unclear how other aspects of the necessary riprap grading has been determined (e.g. it is possible to have an unsuitable riprap grading even when more than half the rocks are greater than the nominated D_{50} criterion). Rock shape and durability are also important parameters requiring appropriate specification.
4. Based on contract documentation information provided to T+T, including drawings and a specification, it is unclear how design rap grading requirements have been communicated to the constructor.
5. Information we have seen indicates that the design features a 28.6 % (3.5H:1V) slope transitioning to a flatter region termed the stilling basin. No end sill is included. An end sill is

[5] Opus; Design Review- Riverside Spillway, Lower Taieri River Flood Protection Scheme, Reference 3-53030.00; 7 December 2012.
[6] U.S. Army Corps of Engineers; Hydraulic Design of Flood Control Channels, EM 1110-2-1601; 30 June 1994.

a common stilling basin feature. Final design arrangements are unclear, including as they relate to as-built details. For example:

- Revision 01 drawings dated 5 December 2012 show a spillway length of 5.25 m at 28.6% together with a stilling basin 5.75 m long (11.0 m total length).
- The Opus letter of 7 December 2012 recommends a spillway length of 5.95 m at 28.6% together with a stilling basin 5.05 m long (11.0 m total).
- Revision 02 drawings dated 7 January 2013 and marked as for approval, show a spillway length at least 5.95 m at 28.6% together with a stilling basin 3.0 m long (9.0 m total). The stilling basin region is considerably shorter than the original ORC design and significantly less than the 5.05 m length recommended by Opus. The justification for the shorter length remains unclear. Stilling basin arrangements are critical to the performance of the structure.
- Neither construction issue nor as-built drawings have been sighted.

6 Design arrangements for areas such as abutment details are unclear. Often hydraulic structures such as spillways featuring rock armour are vulnerable at interfaces. It is noted that significant damage was recently observed at the right abutment as well as the upstream and downstream rip rap extents.

7 Opus inspected the structure on 8 April 2013 and some Opus comments include[7]:

- "*While there may be a small quantity of slightly under-sized rock, the quality of the rock looked exceptionally good from both sources of supply".*
- *"There are a number of minor defects with the rock armour as placed that should be rectified by the Contractor before he disestablishes from site".*
- *"It would be advantageous to bolster the toe of the rock armoured slope on the spillway with an additional 2-3 m wide strip of rock material in the next year as funding permits".*

1 ORC have also provided information that indicates that the spillway was inspected on 21 June 2013 following an overtopping event just prior to the inspection. Understanding is that the corresponding peak flow in the Taieri River was approximately 1,180 m^3/s albeit that the event had a long duration. Indications are that the structure suffered minor damage at that time at similar locations to that recently experienced although the magnitude was less significant e.g. crest damage at the upper rip rap interface and damage at the right abutment area.

2.3.4 Comments on design and construction

The length of rock fill perpendicular to the slope was measured at three locations on 10 October 2017. At these locations the slope length of rock fill was approximately 10.5 m, 11.0 m and 11.3 m. A slope length of 11.0 corresponds to a plan length of 10.6 m at the design slope of 3.5H:1V, longer than the revision 2 design drawings and a little less than recommended by Opus.

It is hard to identify the change in slope shown on the cross sections from the 28.6 % slope to the flatter stilling basin area. A complicating factor is that rock eroded from the slope appears to have been collected predominantly deposited at the base of the slope. There may also have been constructability issues forming the design slope.

Comments based on recent observations following the July 2017 flood (estimated to be 1,700 m^3/s coincident with a 0.6 to 0.9 m overtopping depth) comprise:

1 Recent observations following the July 2017 flood suggest that the rock appears undersize and/or interface details insufficiently robust relative to present understanding of design

[7] Opus, pers. comm. Webby/Strong; Riverside Spillway - notes from site inspection on 8 April 2013; 11 April 2013.

parameters (2,500 m^3/s Taieri River flow coinciding with a 1.4 m spillway overtopping depth). This is consistent with Opus comments following construction, albeit that Opus identified the rock size matter to be minor.

2 Placement of material at the time of site observations indicated an uneven distribution of rip rap, including gaps in the matrix, and areas with concentrations of smaller size rocks. It is our view that this distribution of rock, as observed, will compromise performance. Opus also noted this matter, although it is unclear what action was subsequently taken. Indications are that the situation has been adversely influenced by high flows and temporary repairs since 2013.

3 We consider that the crest area is vulnerable. Recent observations suggest that further to the design, thought is needed to address issues related to deposition of debris on the crest, including the issue of flow concentration arising from deposition of debris. The interface of grass and rip rap rock is a vulnerable location. Reinstatement of the crest is recommended to address damage to the grass cover arising from recent repair work.

4 Observation of recent performance suggests that performance may be improved if the stilling basin is extended and an end sill provided. Opus provided a similar observation, although it is unclear if the areas identified by Opus identified were addressed (potentially the work was undertaken given site measurements relative to dimensions shown on the 7 January 2013 drawings). Further extensions to the stilling basin may clash with the adjacent cadastral boundary and this matter will require appropriate consideration. Bare earth on the dairy lane adjacent to stilling basin toe may result in an area more prone to erosion than if appropriately vegetated.

5 The right abutment area has not performed well. Specified design details have not been sighted. Concentrated damage may have arisen from a low point in the crest and/or as-built edge arrangements (flow outflanking rock and geotextile protection to underlying erodible material). This damage is of particular concern as a greater depth of prolonged overtopping at this location could have easily resulted in scour and backward heading cutting of erodible embankment fill. This could have given rise to flow outflanking the structure, causing a significant breach and significant uncontrolled flood water flow into the Upper Pond area.

It is clear that ongoing repairs will be necessary following overtopping events. The extent of future damage will be subject to the magnitude and duration of overtopping, noting that it is reasonable to expect damage to increase at a rate greater than liner as flow depth and magnitude increase.

During the July 2017 flood the spillway overtopping depth is understood to have been much less than the design condition. Based on assessment of design information and recent observations from 1 August and 10 October, it is our view that there is significant uncertainty regarding the ability of the Riverside Road Spillway structure to withstand an event similar to the 1980 flood without sustaining major damage. Damage may include a stop bank breach and uncontrolled inflows into the Upper Pond with subsequent flooding towards the Silver Stream area.

Structure vulnerability is enhanced by damage and the condition of the structure from the July 2017 flood as observed on 10 October.

2.3.5 Recommendations

We recommend that further urgent repairs are completed as a priority. Subject to ORC requirements, these may be temporary measures - priority repairs listed below are proposed to provide an improvement to the function of the structure relative to its present damaged condition. The suggested priority repairs will not necessarily ensure appropriate performance in a very large flood, for example including the design flood event.

Key priority repairs to the Riverside Road Spillway include:

1 The right abutment area is repaired as a matter of urgency. It is critical that repairs ensure the crest level has a suitable gradient and the abutment area is robust and not able to be outflanked as may have recently occurred.
2 That grass is re-established on the crest as a matter of urgency.
3 Crest repairs are undertaken to ensure that there is appropriate rock and protection at the top of the slope and that the underlying geotextile is suitably protected.
4 Rip rap rock of appropriate size and durability is replaced as required at all locations where material has been removed and/or is unstable. So long as the slope roughness is maintained, it may be appropriate to use a concrete pump to place concrete locally to assist anchoring new and/or existing rock where rock has been removed and/or is unstable i.e. placement/forming grouted rip rap.
5 Scour downstream of the rock is addressed to eliminate areas where scour may concentrate.

It is important that there is an appropriate level of engineering input to this work.

We also recommend that ORC review the following matters:

1 ORC review and confirm performance expectations for the structure. This will likely result in requirements for upgrades if it is necessary for the structure to sustain a flood similar to the 1980 flood with minimal damage.
2 It is appropriate that the review of the long ungated section include, but not necessarily be limited to, consideration of the following:
   - Design performance definition including duration of overtopping and damage expectations associated with design events.
   - Given present industry practice, including advances in two dimensional flow modelling, that design conditions are appropriately understood (for example flow depth and velocity).
   - That the crest is robust including the rock fill and geotextile interface and able to accommodate flow concentration from observed debris deposition (consideration of a concrete slab on grade may be appropriate).
   - Crest gradient to suit the river hydraulic grade line and evaluation if this matter is related to concentration of damage at the downstream of structure.
   - That the abutments are robust and have appropriate durability.
   - Rip rap grading and placement is appropriate to handle design conditions (including slope profile).
   - Energy dissipation arrangements are robust including the downstream transition to adjacent farmland.
3 It is appropriate that the review of the short gated section include, but not necessarily be limited to, consideration of the following:
   - Energy dissipation structure.
   - Area downstream of the stilling basin.

2.4 A1 Gate Outfall from Upper Pond

The A1 Gate Outfall from the Upper Pond (A1 Outfall) is located on the true left of the Taieri River stop bank adjacent to the Silver Stream and Taieri River Confluence (photo 44).

Photo 44: View of structure from the downstream. Missing hand rail and flood debris on gate visible.

The structure appeared to be generally in good order. Comments from the 10 October visit comprise:

1. Assess need to replace the missing handrails on both sides of the structure and replace as required (photos 44 and 49).
2. Safely remove remaining debris as appropriate to avoid interference with gate operation and to prevent unsuitable debris entering the river (photo 44).
3. A minor level of scour has occurred between the structure and river. Some recent repairs are evident albeit the basis for placement of the rock is unclear. Ongoing monitoring is recommended with further action as warranted by ongoing review (photos 45 and 46). Refer Section 3.2

Photo 45: View towards Taieri River from A1 Outfall. Note recent scour and recent placement of rip rap rock.

Photo 46: Recent scour and recent placement of rip rap rock.

4 Damage to the floodbank crest in the vicinity of the structure is evident. Our understanding is that ORC have scheduled future repairs/enhancement comprising spreading gravel along crest areas where vehicle use appears to have caused damage (photo 48). We agree that this work is warranted. We suggest the floodbank at the A1 Structure true right landward side abutment is monitored for stability and potential stock damage (photo 47).

Photo 47: Damage to floodbank earth fill adjacent to the structure right hand side abutment.

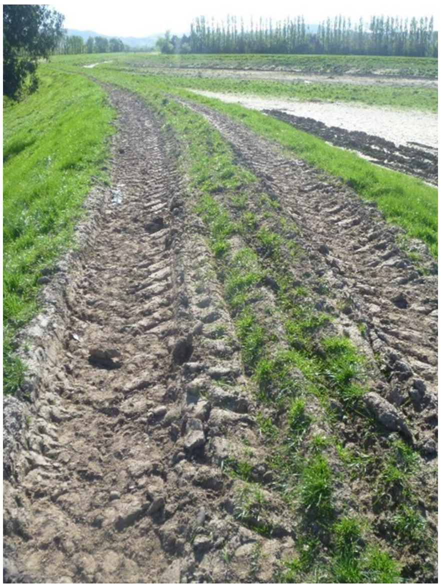

Photo 48: Floodbank crest damage in the vicinity of the A1 Outfall structure.

5 Given the presence of sheep and lambs on the Silver Stream floodbank at the time of the visit, assess requirement for a stock proof gate at the A1 Structure true left hand side abutment (photo 49).

Photo 49: True left abutment gate. Review requirement for stock (sheep) proof gate at this location.

6 Ongoing surveillance is recommended as described in Section 3.2.

2.5 Owhiro Outfall

The Owhiro Outfall is located near the Main South Railway Line and the East Taieri township of Allanton. Provided information indicates that the culvert comprises a double barrel, 2.55 m diameter culvert. Flood gates feature at the outlet head wall. An older Armco thin steel plate culvert was recently replaced in 2010. Photo 50 to 52 illustrate arrangements.

The culvert is adjacent to the Lower Pond Outlet.

Photo 50: Owhiro Outfall.

Photo 51: Owhiro Outfall.

Photo 52: Owhiro Outfall.

Because of its close proximity to the Owhiro Outfall, the Lower Pond Outfall was also briefly viewed. While not on the list of structures scheduled for assessment, some observations incidental to the Owhiro Outfall assessment are listed.

The Lower Pond Outlet comprises a twin barrel Armco culvert with an upstream gabion basket headwall (photo 53). The culvert material is similar to the original Owhiro Outfall that has been replaced. Based on photos provided by ORC, likely because of corrosion and other deterioration of the steel pipework.

Thin steel culverts of the sort incorporated into the Lower Pond Outlet are prone to corrosion along the invert. Corrosion is present along the invert of the true right hand side barrel. The corrosion has resulted in a rust hole at one location (photo 54). Because of debris the full invert area of the right hand side barrel was not able to be viewed. Other defects not observed may exist.

Photo 53: Inlet to the Lower Pond Outlet culvert.

Photo 54: Corrosion at the invert of the Lower Pond Outlet invert near the inlet headwall. Indications are that a void is present behind the rust hole in the steel culvert and repair is warranted.

Indications are that there is a cavity beneath the corrosion hole albeit that the extent of this is difficult to establish because of the small size of the hole at this time. We are aware of other New Zealand situations where piping has occurred associated with old thin steel plate culverts. The gabion head wall is not a robust piping defence.

The true left hand side barrel was not able to be viewed because of the presence of standing water.

We recommend that ORC:

1 Drain the left hand side culvert and both barrels are cleaned and inspected for corrosion damage.
2 Inspect for cavities where any rust holes exist. It is important that any cavities are subject to appropriate engineering assessment and suitably repaired.
3 Consider options to mitigate invert corrosion. Subject to appropriate hydraulic performance and resolution of upstream drainage, options may include placement of a concrete slab on grade in one or both barrels together with the possibility of additional upstream fill.
4 Undertake appropriate condition assessment inspections as outlined in Section 3.2.

3 General issues

The following matters are, in general terms, common to a range of the structures assessed. These matters may also apply to other structures outside the scope of the assessment.

3.1 Health and safety

The structures were designed and built many years prior to the implementation of present health and safety expectations and legislation (for example the Health and Safety at Work Act 2015). There may be some areas where further focus is warranted to ensure infrastructure meets present health and safety requirements. Issues include the following (noting that this is not considered a comprehensive list and specialist assessment is warranted to ensure all relevant issues are identified):

- Silver Stream Pumping Station bridge areas.
- Waipori Pumping Station recognising that there is public access adjacent to this site including locations without handrail protection where it is necessary for operations staff to rake pump intake screens (Photos 17, 20 and 21).
- A1 Outfall structure handrail (Photo 44).

We recommend that ORC review all relevant facilities against present health and safety requirements and address recommendations arising from this work (including structures outside the scope of this report). Specialist assessment is recommended.

3.2 Scheme surveillance and emergency action planning

The Guidelines state that owners of stop banks should consider applying the Guidelines to stop banks. We recommend that ORC develop procedures similar to a Dam Safety Management System (DSMS) for appropriate aspects of the infrastructure to include the likes of:

- Procedures for the regular inspection and documentation of inspection out comes by operations staff.
- Procedures for regular inspection and documentation of inspection out comes by engineering staff, for example similar to aspects of the Intermediate and Comprehensive Dam Safety Review process outlined in the Guidelines.
- Procedures for Emergency Action Planning as discussed previously with ORC[8].
- Procedures for inspection following significant flood and earthquake events.
- Procedures for the resolution of identified issues.

3.3 Transformer bunding

We have observed that the transformer installations at Waipori and Silverstream pumping stations are not bunded (photos 11 and 22).

Transformers are often bunded to protect the adjacent environment from the consequences of an unforeseen oil discharge. Often requirements are subject to the type and quantity of oil within the transformer, as prescribed by district and regional plan requirements. Industry practice is also a consideration for some organisations. We recommend that ORC review transformer arrangements against relevant plan requirements as well as industry practice.

3.4 Bridge signage

We recommend that ORC erect appropriate signage to clearly state bridge capacities.

For example, industry standard MOTSAM RH-4 (heavy vehicle - bridge limits) signage to clearly state allowable maximum axle and percentage of Class 1 load limits. Example structures include the two bridges at Silverstream Pumping Station and the A1 Outfall bridge as illustrated in photos 1, 16, 44 and 49.

[8] T+T, pers. comm. Sutherland/Mackey; ORC Floodbanks - potential Outram piping and other potential hazards - emergency preparedness; 7 September 2017 &
T+T; Mill Creek Pump Station Inspection, Reference 1001453.2; September 2017.

4 Recommendations

Issues identified from the assessment are collated below in Table 1. The identified issues for action on each component of the project are numbered, referenced to the section in this report where they arise and categorised in a manner similar to that described in the Guidelines as:

- Physical infrastructure issues – Issues where equipment, access, instrumentation, communications or maintenance is insufficient to verify satisfactory performance.
- Potential or confirmed floodbank safety deficiencies – Where performance requirements may not be met (unknown, or require further investigation/assessment) and confirmed floodbank safety deficiencies where adverse performance has been observed, or will definitely occur under normal conditions.
- Non-conformances – where floodbank safety management system processes and procedures have not been followed or appropriate established dam safety practices have not been implemented.

The identified issues have been prioritised in Table 1 below as follows:

- U (Urgent) we recommend that these matters are addressed as soon as possible.
- N (Necessary) we recommend that these matters are addressed as a priority (within 12 months or less where stated) or regularly.
- D (Desirable) we recommend that these matters are addressed at a suitable time before the next assessment.

Table 1 Recommendations

Reference	Report section	Issue identified	Category	Priority
Silverstream Pumping Station				
2017.1	2.1.3.1	Undertake a detailed internal inspection of the rising main pipework together with appropriate hydrostatic pressure testing in accordance with a recognised standard (unless resources are devoted to rising main replacement in the short term). Undertake further work arising from the initial recommendation as may be necessary.	Physical infrastructure issue	N
2017.2	2.1.3.2	Repair the void beneath the outlet head wall footing and place armour/provide appropriate protection to prevent further scour at this location.	Potential or confirmed floodbank safety deficiency	N
2017.3	2.1.3.2	Install tell-tale devices coincident with joints in the rising main outlet head wall structure and regularly check and record any displacement. Confirm the wall verticality (possibly by way of a level and plum bob survey) and undertake regular follow up assessments to identify any ongoing instability.	Physical infrastructure issue	N
2017.4	2.1.3.2	Repaired or replace the debris barrier structure.	Physical infrastructure issue	D

Reference	Report section	Issue identified	Category	Priority
2017.5	2.1.3.2 2.1.3.4	Remove and replace fill on the Silver Stream/rising main side of the sheet pile cut-off with suitable low permeability engineered fill with appropriate clay content, permeability, plasticity and strength (potentially with added bentonite). Coincidently investigate the integrity of the sheet pile arrangement and give appropriate consideration to the benefit of filtered drainage behind on the landward side of the stop bank (also able to accommodate high landward side water levels as well as future seepage at the sheet pile and fill interface). Review the outlet head wall stability coincident with replacement of any pipework and replacement of fill.	Potential or confirmed floodbank safety deficiency	N
2017.6	2.1.4	Assess the need to protect the motors and equipment in the upper portions of the station.	Physical infrastructure issue	D
2017.7	2.1.5	Install tell-tale devices coincident with significant cracking present in the parapet wall apparently added to the original structure and regularly check and record any displacement. Undertake further work as may arise from surveillance data.	Physical infrastructure issue	N
Waipori pumping station				
2017.8	2.2	Review the required free board in the vicinity of the Waipori Pumping Station and modify the structure as may be required.	Potential or confirmed floodbank safety deficiency	N
2017.9	2.2	Given the nature of the Waipori Pumping Station facility and adjacent flood banks, review and confirm the facility Importance Level in accordance with AS/NZS1170.0:2002 Structural Design Actions.	Potential or confirmed floodbank safety deficiency	N
2017.10	2.2	Based on a confirmed Importance Level review expected performance of the infrastructure against appropriate design standards, including ability to with stand liquefaction and lateral spread.	Potential or confirmed floodbank safety deficiency	N
2017.11	2.2	Based on Importance Level review the requirement for backup power and redundancy at Waipori Pumping Station (including underpinning or other liquefaction mitigation measures).	Potential or confirmed floodbank safety deficiency	N

Reference	Report section	Issue identified	Category	Priority
Riverside Road Spillway				
2017.13	2.3.5	Undertake priority repairs to the Riverside Road Spillway. Key repairs include: • That the right abutment area is repaired as a matter of urgency. It is critical that repairs ensure the crest level has a suitable gradient and the abutment area is robust and not able to be outflanked as may have recently occurred. • That grass is re-established on the crest as a matter of urgency. • Crest repairs are undertaken to ensure that there is appropriate rock and protection at the top of the slope and that the underlying geotextile is suitably protected. • Rip rap rock of appropriate size and durability is replaced as required at all locations where material has been removed and/or is unstable. So long as the slope roughness is maintained, it may be appropriate to use a concrete pump to place concrete locally to assist anchoring new and/or existing rock where rock has been removed and/or is unstable i.e. placement/forming grouted rip rap. • Scour downstream of the rock is addressed to eliminate areas where scour may concentrate. It is important that there is an appropriate level of engineering input to this work.	Potential or confirmed floodbank safety deficiency	U
2017.14	2.3.5	Review and confirm performance expectations for the structure. This will likely result in requirements for upgrades if it is necessary for the structure to sustain a flood similar to the 1980 flood with minimal damage. Some matters for consideration are described in the report text.	Potential or confirmed floodbank safety deficiency	N
A1 Gate Outfall from Upper Pond				
2017.15	2.4	Assess need to replace the missing handrails on both sides of the structure and replace as required.	Physical infrastructure issue	N
2017.16	2.4	Safely remove remaining debris as appropriate to avoid interference with gate operation and to prevent unsuitable debris entering the river.	Physical infrastructure issue	N
2017.17	2.4	Spreading gravel along crest areas where vehicle use appears to have caused damage.	Physical infrastructure issue	N
2017.18	2.4	Monitor the floodbank e.g. scour downstream of the structure and at the A1 Structure true right landward side abutment for stability and potential stock damage.	Non-conformance	N

Reference	Report section	Issue identified	Category	Priority
2017.19	2.4	Assess need for stock proof fencing.	Physical infrastructure issue	D
Owhiro Outfall				
2017.20	2.5	At the Lower Pond Outlet located adjacent to the Owhiro Outfall: • Drain the left hand side culvert and clean both barrels and inspect for corrosion damage. • Inspect for cavities where any rust holes exist. It is important that any cavities are subject to appropriate engineering assessment and suitably repaired. • Consider options to mitigate invert corrosion. Subject to appropriate hydraulic performance and resolution of upstream drainage, options may include placement of a concrete slab on grade in one or both barrels together with the possibility of additional upstream fill.	Physical infrastructure issue	N
General recommendations that relate to more than one structure and other locations				
2017.21	3.1	We recommend that ORC review all facilities against present health and safety requirements and address recommendations arising from this work. Specialist assessment is recommended.	Physical infrastructure issue	N
2017.22	3.2	We recommend that ORC develop procedures similar to a Dam Safety Management System (DSMS) for appropriate aspects of the infrastructure (including structures outside the scope of the assessment). Some example matters include (but are not limited to): Silverstream Pumping Station seepage, Waipori Pumping Station seepage; A1 Gate Outfall scour and flood bank condition and Lower Pond Area outfall culvert.	Non-conformance	N
2017.23	3.3	We recommend that ORC review transformer arrangements against relevant plan requirements as well as good industry practice.	Physical infrastructure issue	D
2017.24	3.4	We recommend that at ORC erect appropriate signage to clearly state bridge capacities.	Physical infrastructure issue	N

5 Applicability

This report has been prepared for the exclusive use of our client Otago Regional Council, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

The structure condition assessments are limited to a visual inspection of the five structures nominated by Otago Regional Council to the extent permitted by safe foot access at each location.

There is potential for latent defects, such as the initiation of piping, to be present in structures and adjacent embankments that may not be detected by this walk over visual inspection.

It is possible that unidentified defects (i.e. those not detected by the visual evaluation and provided documentation) may have the potential to limit the integrity and resilience of structures. The scope of this assessment does not provide sufficient information for the as-built structures in their present condition to be certified as complying with current standards.

Site circumstances and the conditions of structures will change with time. Ongoing inspection and evaluation of the structures and other aspects of the schemes by Otago Regional Council is necessary to assist with the early identification of emerging issues.

Tonkin & Taylor Ltd

Report reviewed by:	Authorised for Tonkin & Taylor Ltd by:
....	....
Barry McDowell	Tim Morris (CPEng)
Senior Engineering Geologist	Project Director

tgm
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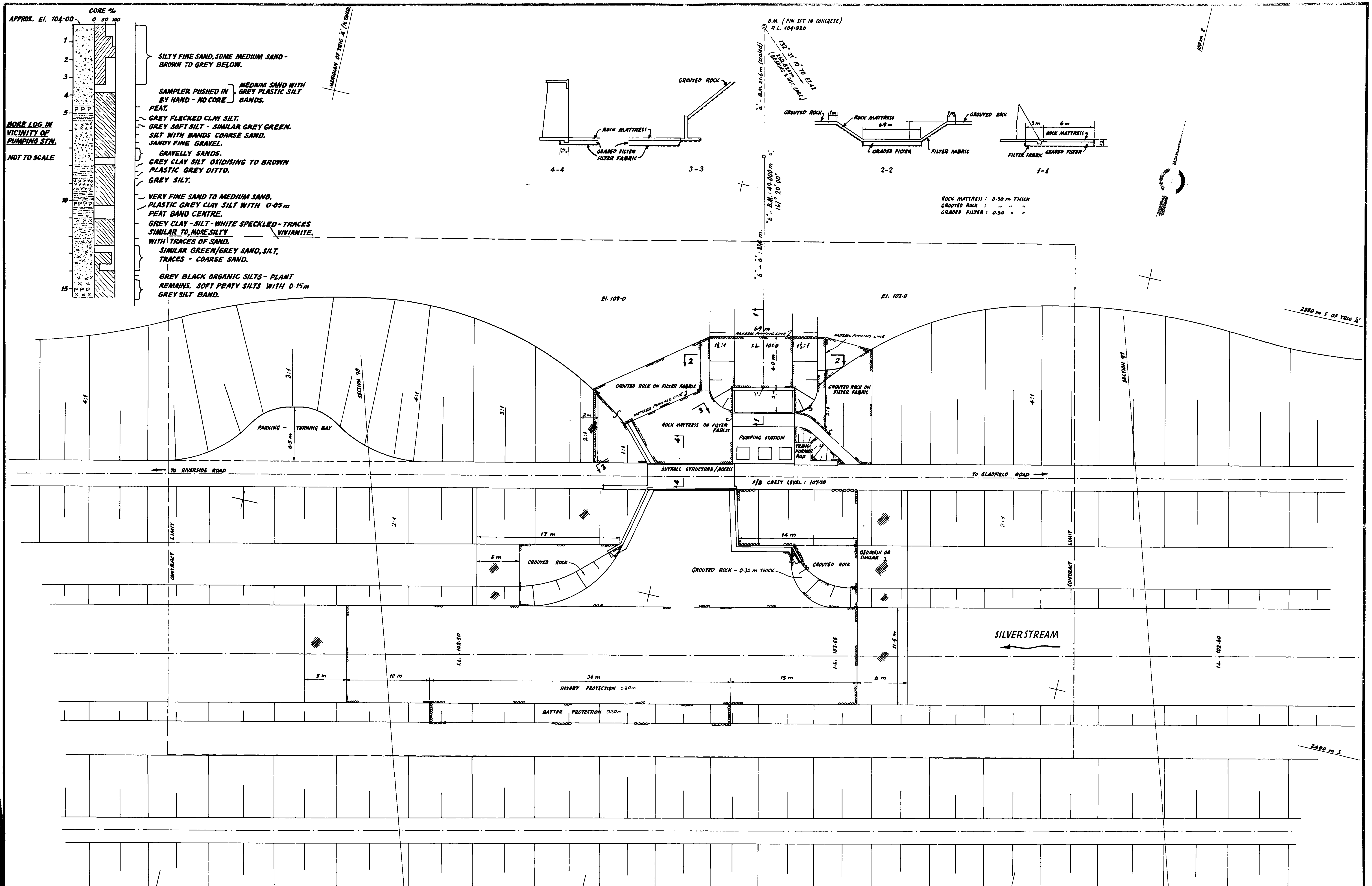
Appendix A: Selected Silverstream Pumping Station drawings[9]

[9]Drawing status not confirmed.



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	(A) SETTING-OUT DATA ADDED		14/1/1976
SOIL AND WATER CONSERVATION FARM PLAN No.			

	NAME	DATE
SURVEYED		
AERIAL PHOTO REF		
DRAWN	E. HELLENDOORN	SEPT. 1975
TRACED	"	SEPT. 1975
DESIGNED	" , I.M. SCARF	SEPT. 1975
CHECKED	I.G.S. SHARPE, I.M. SCARF	25·9·1975
RECOMMENDED	[signature]	3-10

APPROVED
A. J. GILLIES
B.E., B.Sc., A.N.Z.I.E., M.I.C.E.
CHIEF ENGINEER

OTAGO CATCHMENT BOARD

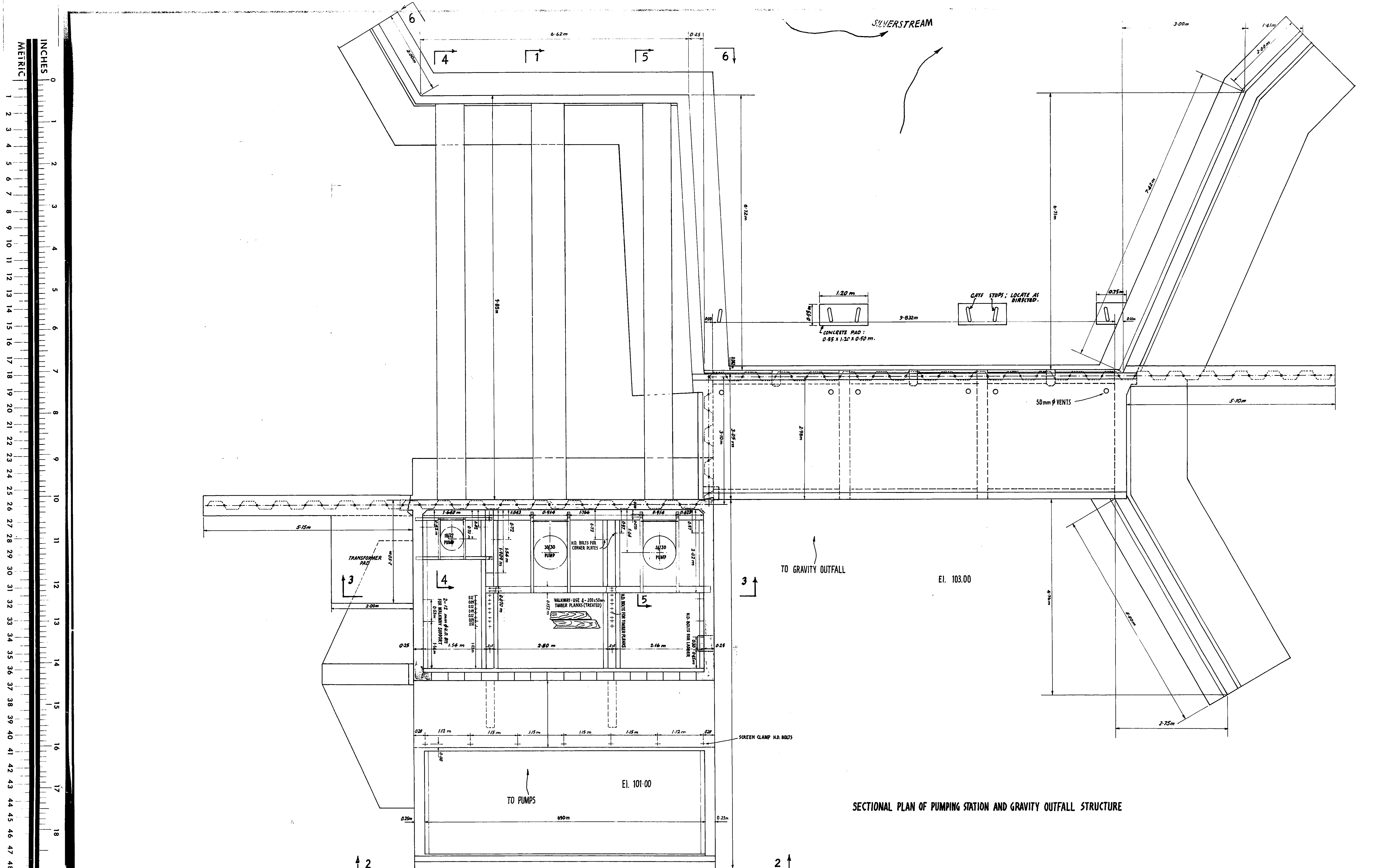
SILVERSTREAM PUMPING STN

SCALE: 1 : 200

JOB No. 5/822/14/1

C. No. 743090

L 8022/1 (A)



SECTIONAL PLAN OF PUMPING STATION AND GRAVITY OUTFALL STRUCTURE

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SURVEYED		
AERIAL PHOTO REFER.		
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TRACED	L.J. MILLER	SEPT. 1975
DESIGNED	I.M. SCARF, E.H.	SEPT. 1975
CHECKED	I.G.S. SHARPE, I.M.S.	25/9/75
RECOMMENDED	[signature]	3.10

APPROVED

A.I. GILLIES, B.E., BSc, F.N.Z.I.E., M.I.C.E.
CHIEF ENGINEER

OTAGO CATCHMENT BOARD

SILVERSTREAM PUMPING STN

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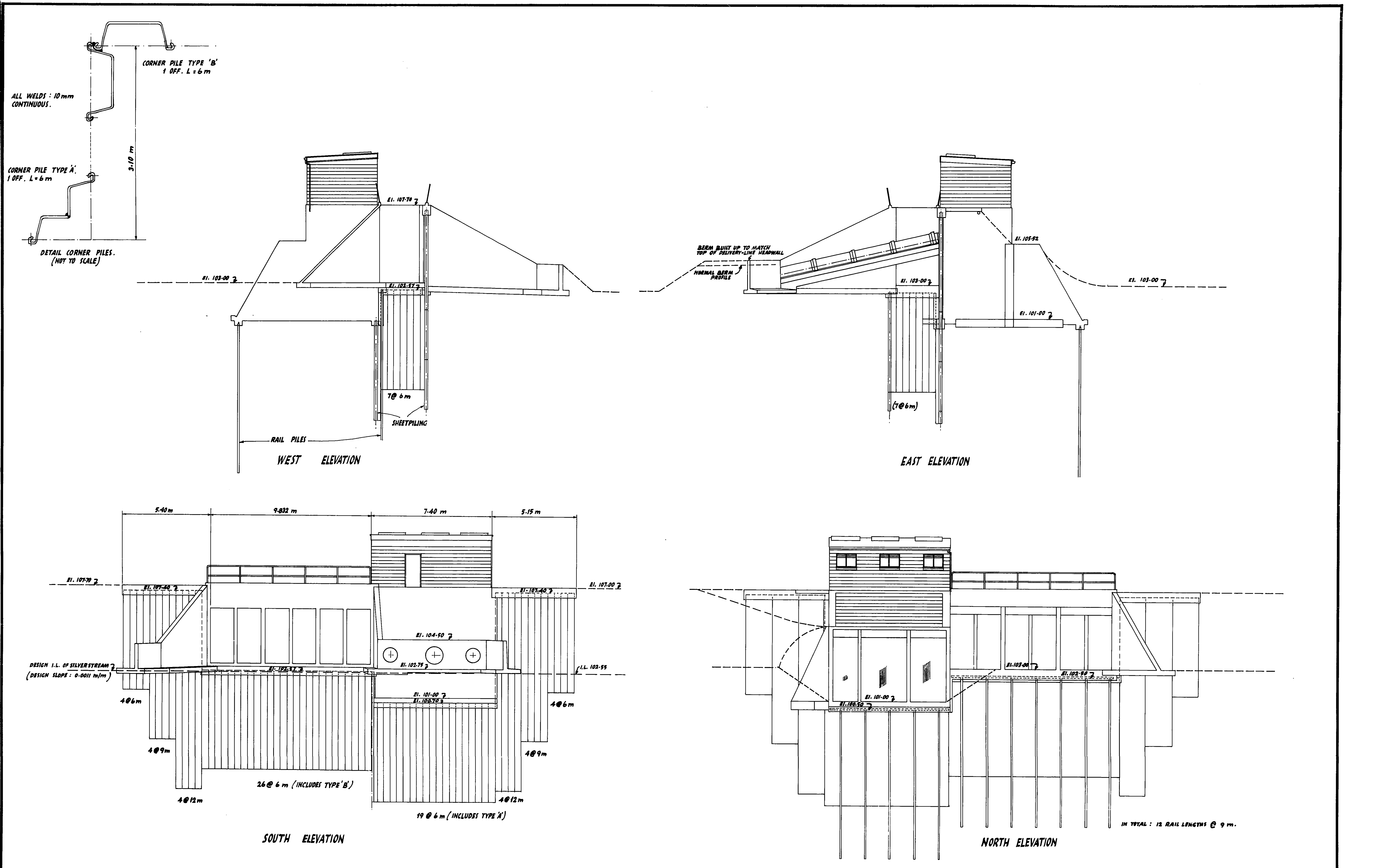
L 8022/3



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				DESIGNED	” , I.M.SCARF		CHIEF ENGINEER
				CHECKED	I.G.S. SHARPE . I.M.SCARF	2-10-1975	
				RECOMMENDED	[signature]	3-10	

OTAGO CATCHMENT BOARD

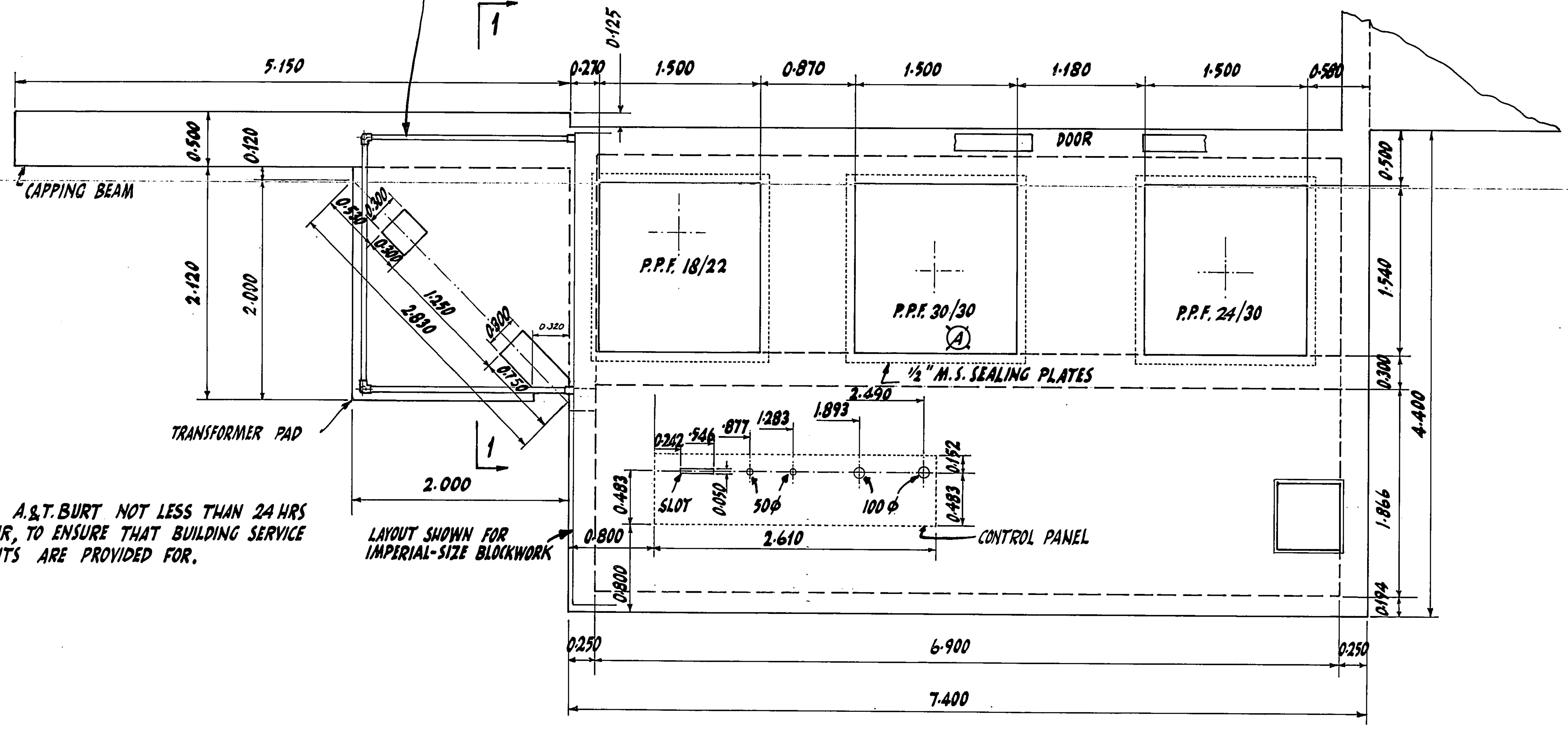
SILVERSTREAM PUMPING STN

SCALE: 1:100

JOB No 5/822/14/1 C No 743090

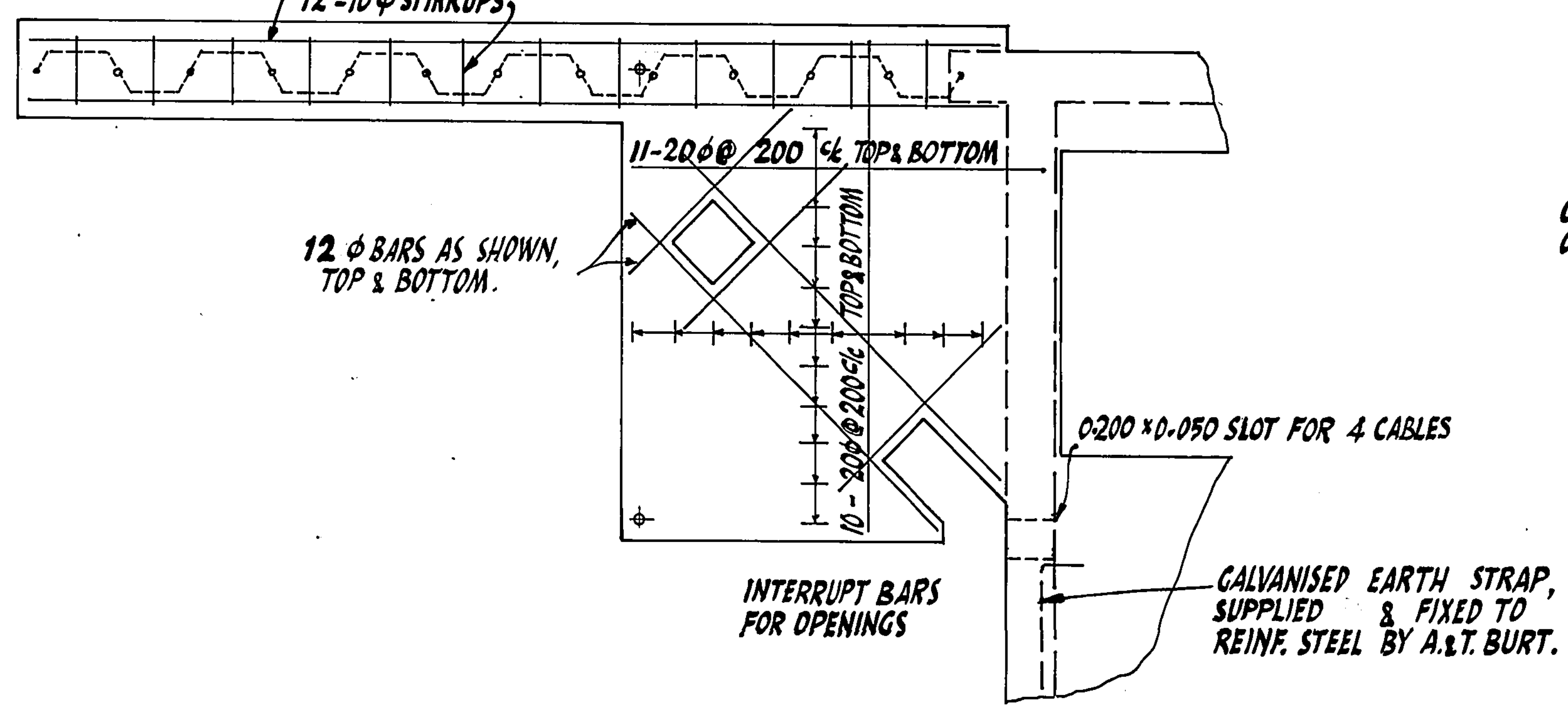
L 8022/2

FB LB

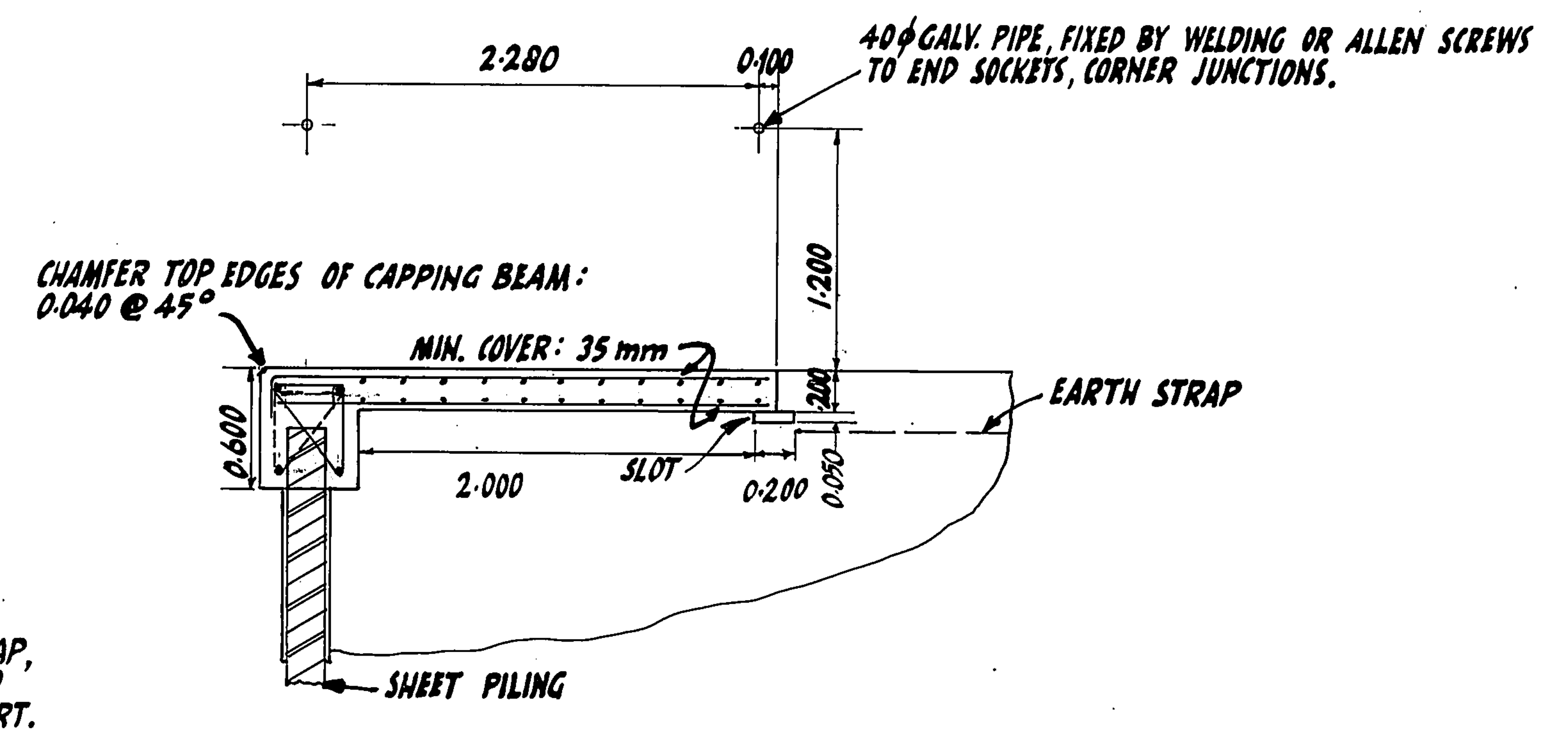


NOTE: CHECK WITH A.&T. BURT NOT LESS THAN 24 HRS BEFORE POUR, TO ENSURE THAT BUILDING SERVICE REQUIREMENTS ARE PROVIDED FOR.

PLAN MOTOR FLOOR
SCALE= 1:40



REINFORCEMENT DETAIL



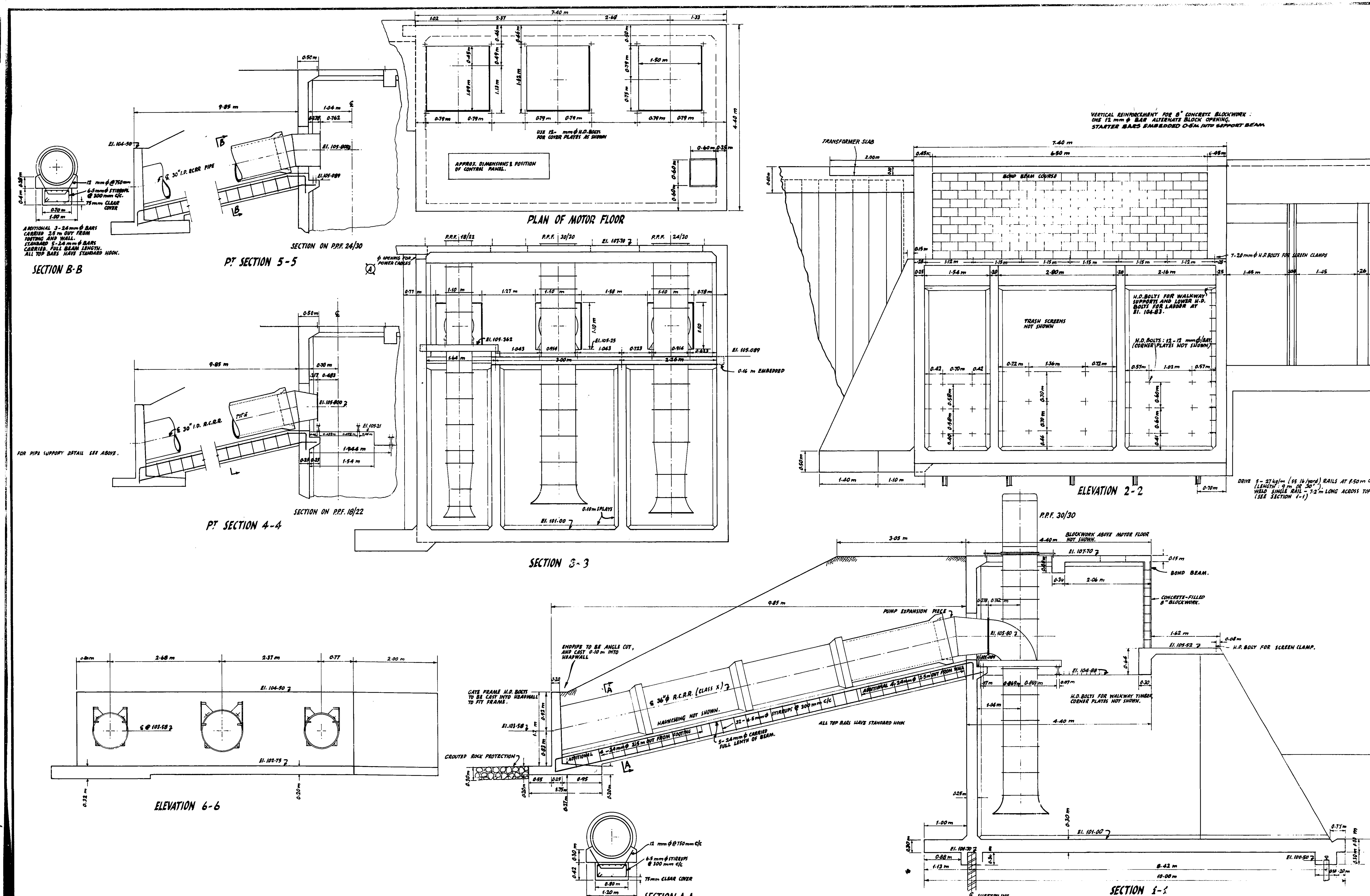
SECTION 1-1

(A) POSITION PPF 30/30 CORRECTED 16.9.76	COMPILED: E. HELLENDOORN 7-4-1976 RECOMMENDED 27.5.76.	APPROVED A.J. GILLIES CHIEF ENGINEER	OTAGO CATCHMENT BOARD **SILVERSTREAM PUMPING STN TRANSFORMER ARRANGEMENT** SCALE: AS SHOWN

JOB Nº 5/822/14/1 C.743090

M 8223 (A)

L.B. F.B.



ENGINEERING REF. No.	AMENDMENTS	APPD	DATE
	(A) REFER M 8223 FOR OPENINGS TO CABLES		18.5.1976
SOIL AND WATER CONSERVATION FARM PLAN No.			

	NAME	DATE
SURVEYED		
AERIAL PHOTO REF		
DRAWN	E. HELLENDOORN	JULY 1975
TRACED	" I.M. SCARF	AUGUST 1975
DESIGNED	" I.M. SCARF	JULY 1975
CHECKED	I.G.S. SHARPE I.M. SCARF	25.9.1975
RECOMMENDED		3.10

APPROVED

A.J. GILLIES
B.E., B.Sc., F.N.Z.I.E., M.I.C.E.
CHIEF ENGINEER

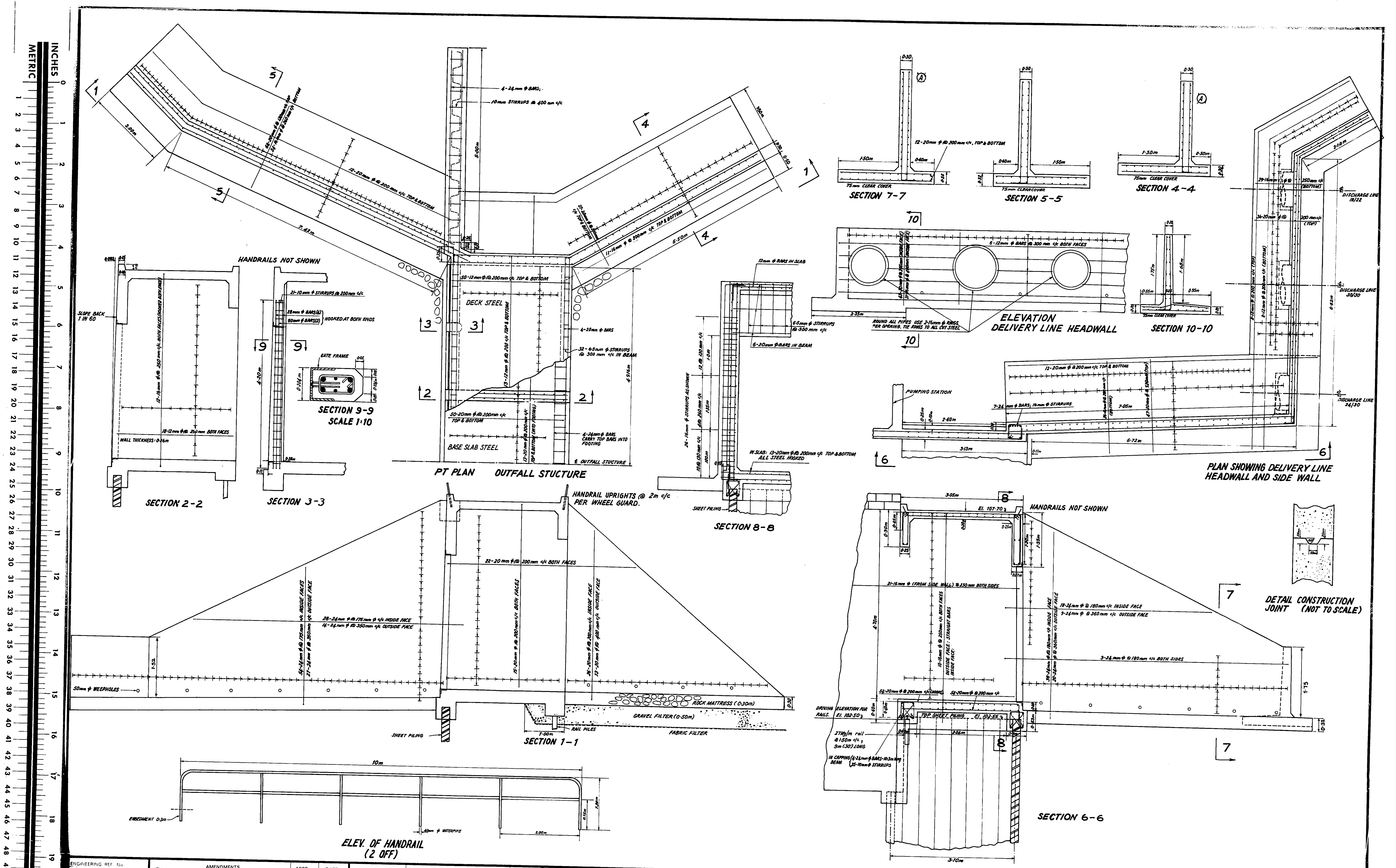
OTAGO CATCHMENT BOARD

SILVERSTREAM PUMPING STN

SCALE: 1 40

JOB No. 5/822/14/1 C No. 743090

L 8022/4 (A)



ENGINEERING REF. No	AMENDMENTS	APPD	DATE		NAME	DATE	APPROVED
	(A) WALL REINFORCING POSITION CORRECTED (SEE SECTIONS 4-4, 7-7)	[signature]	18-5-1976	SURVEYED			
				AERIAL PHOTO REF			
SOIL AND WATER CONSERVATION FARM PLAN No				DRAWN	E. HELLENDOORN	SEPT. '75	A.J. GILLIES B.E., B.Sc., F.N.Z.I.E., M.I.C.E. CHIEF ENGINEER
				TRACED	L.J. MILLER	SEPT. '75	
				DESIGNED	I.M. SCARF	SEPT. '75	
				CHECKED	I.G.S. SHARPE	25/9/75	
				RECOMMENDED	[signature]	3-10	

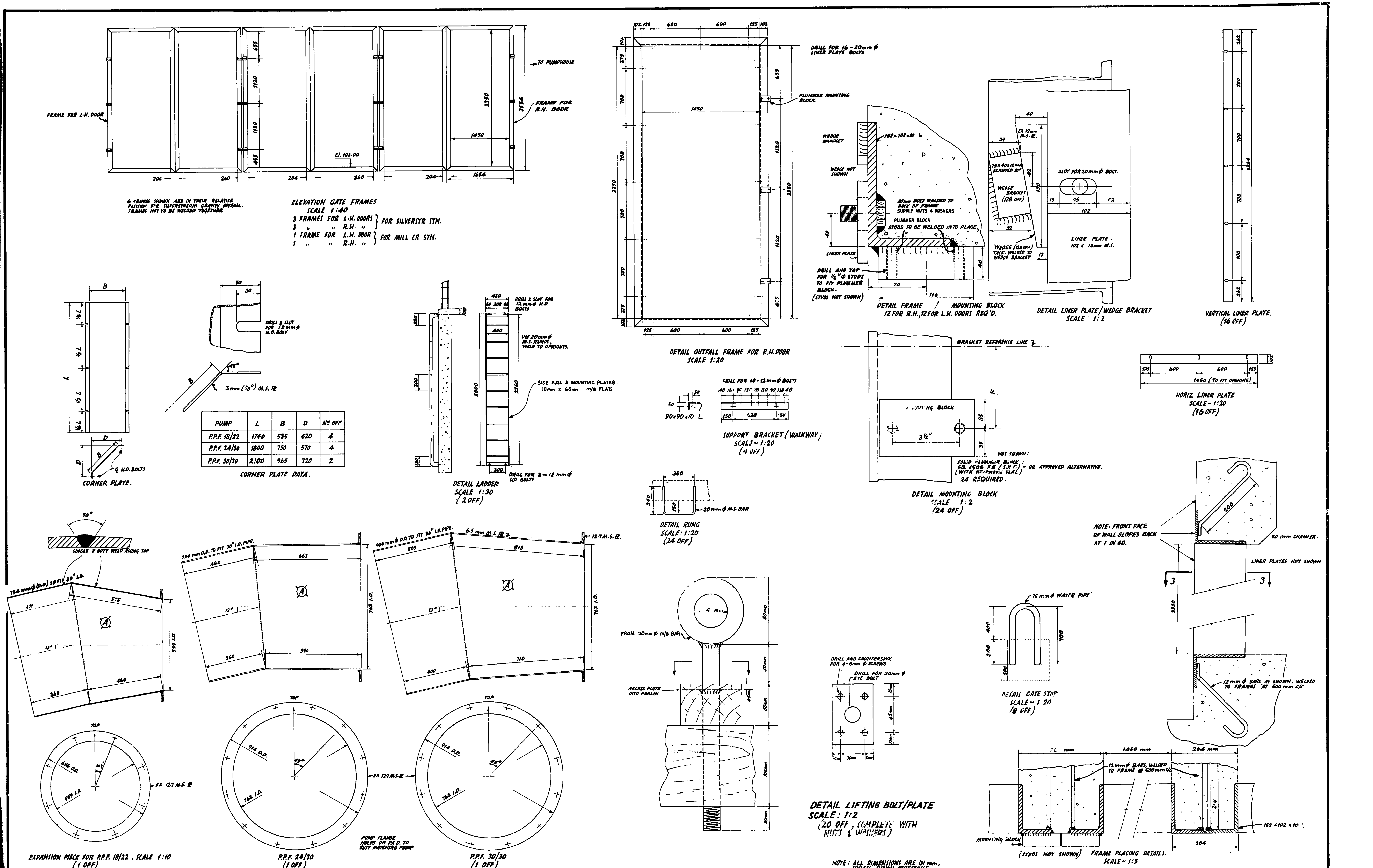
OTAGO CATCHMENT BOARD

SILVERSTREAM PUMPING STN

SCALE: 1·10, 1·40

JOB No. 5/822/16/1 C. No. 743090

L 8022/6 (A)



PUMP	L	B	D	Nº OFF
P.P.F. 18/22	1740	535	420	4
P.P.F. 24/30	1800	750	570	4
P.P.F. 30/30	2100	965	720	2

CORNER PLATE DATA.

ENGINEERING REF. No	(A) AMENDMENTS	APPD	DATE
	EXPANSION PIECES AMENDED (SEE L 8022/10)		3-12-1975

SOIL AND WATER CONSERVATION FARM PLAN No.

	NAME	DATE
SURVEYED		
AERIAL PHOTO REF		
DRAWN	E. KELLENDOORN	JULY 1975
TRACED	"	AUG. 1975
DESIGNED	" , L.M. SCARF	JULY 1975
CHECKED	I.G.S. SHARPE	25-9-1975
RECOMMENDED		2-10-75

APPROVED
A.J. GILLIES
B.E., B.Sc., F.N.Z.I.E., M.I.C.E.
CHIEF ENGINEER

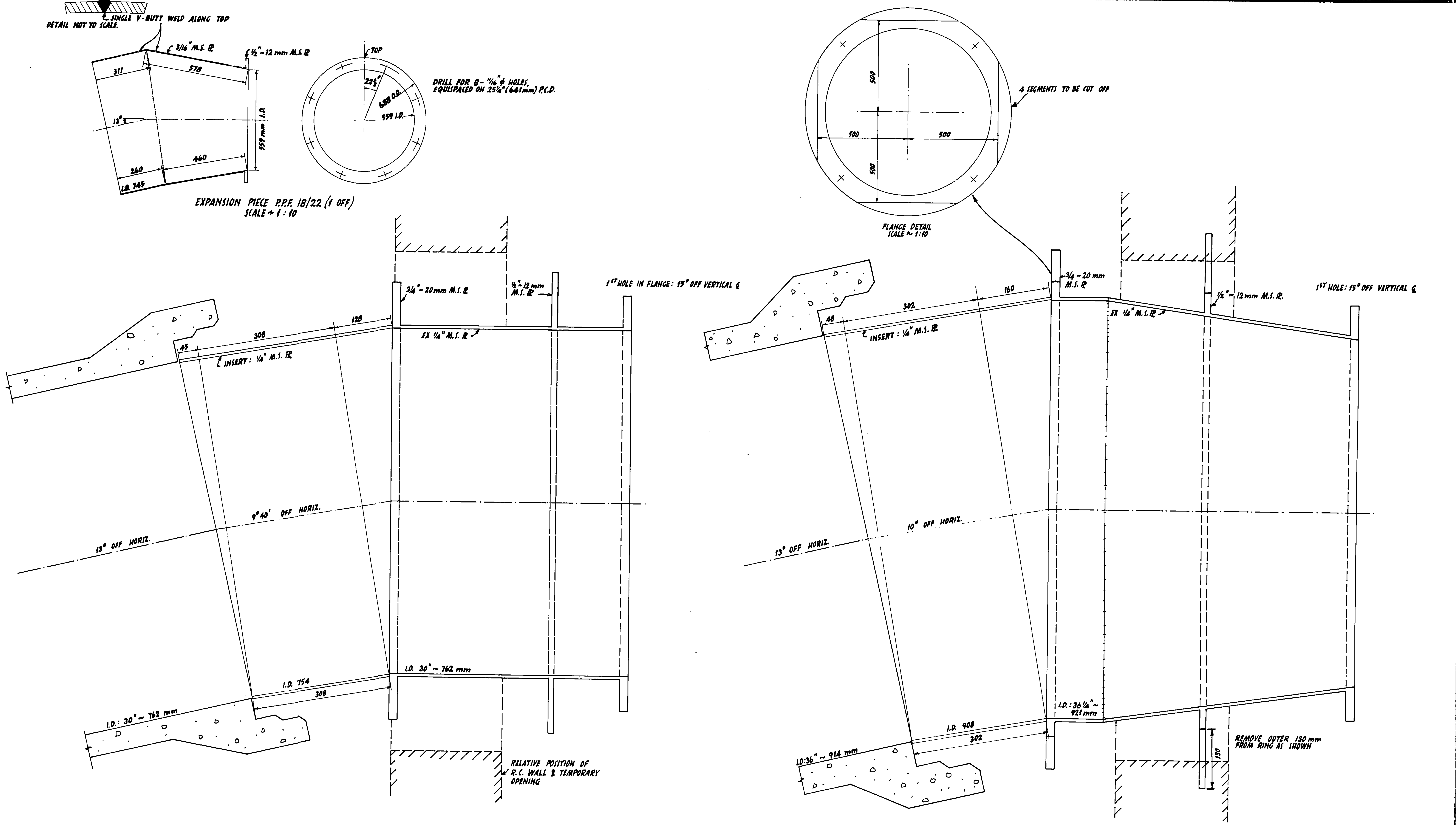
OTAGO CATCHMENT BOARD

SILVERSTREAM PUMPING STN

SCALE: 1:2, 1:5, 1:10, 1:20, 1:30, 1:40

JOB No 5/822/14/1.2 C No 743090

L 8022/8 (A)



NOTE RE WELDING: WELDS TO BE AT LEAST AS THICK AS THINNER OF ANY TWO PARTS TO BE WELDED TOGETHER

NOTE RE PAINTING: ALL BARE OR BURNT M.S. SURFACES TO BE FINISHED (AFTER CLEANING FROM RUST AND SCALE) WITH TWO COATS OF ZINC RICH PAINT.

ENGINEERING REF. No.	AMENDMENTS	APPD	DATE		NAME	DATE	APPROVED
				SURVEYED			
				AERIAL PHOTO REF			
SOIL AND WATER CONSERVATION FARM PLAN No.				DRAWN	E.H.	1.12.1975	A.J. GILLIES. B.E, B.Sc., F.N.Z.I.E., M.I.C.E. CHIEF ENGINEER
				TRACED	"	1.12.1975	
				DESIGNED	"	1.12.1975	
				CHECKED	I.M.S.	3.12.1975	
				RECOMMENDED	(signature)	3.12.75	

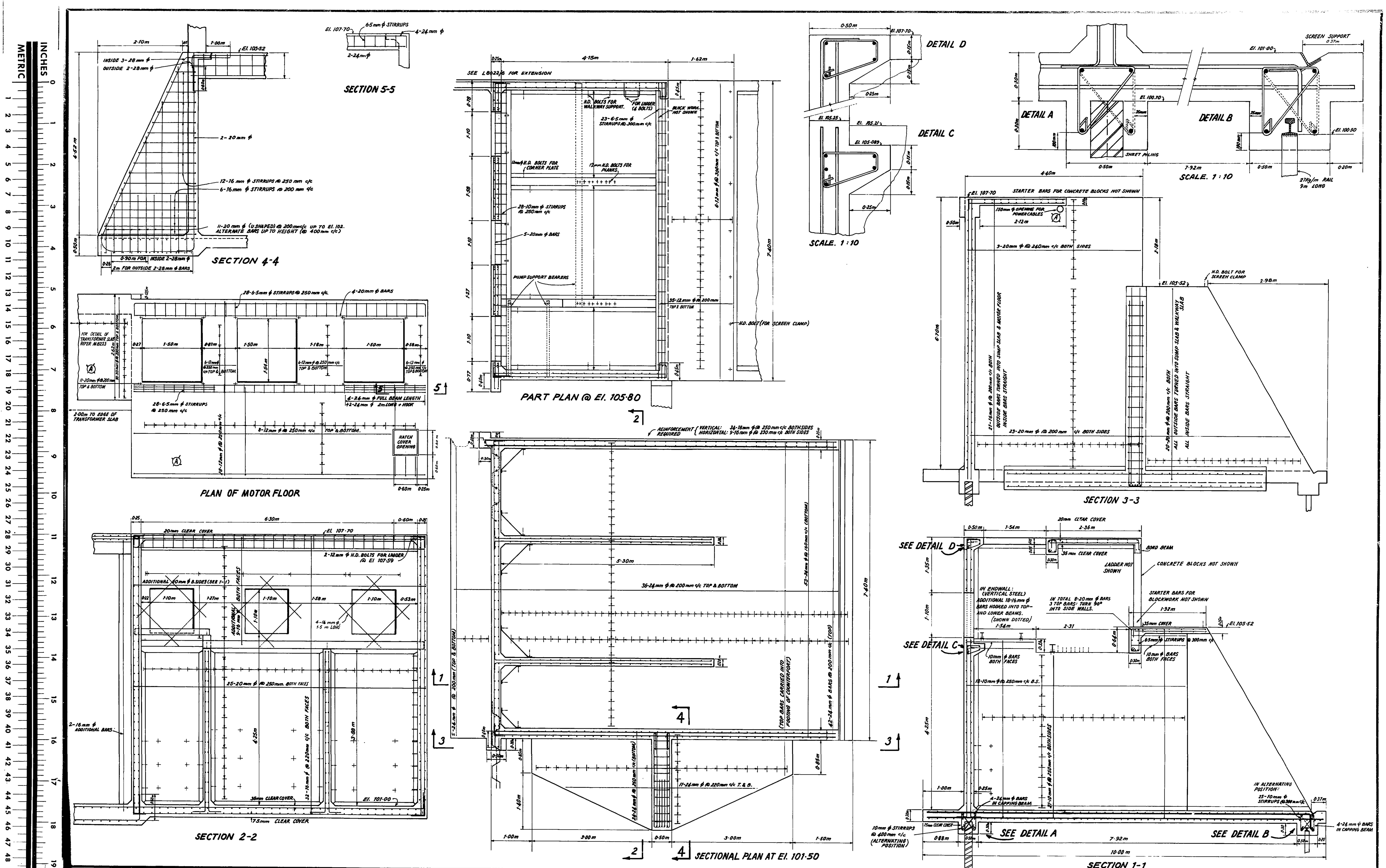
OTAGO CATCHMENT BOARD

SILVERSTREAM PUMPING STN
MODIFIED EXPANSION PIECES

SCALE: 1:4 , 1:10

JOB No. 5/822/14/1 — No. 743090

L 8022/10



ENGINEERING REF No	AMENDMENTS	APPD	DATE		NAME	DATE	APPROVED
	(A) SEE M8223 FOR CABLE SLOTS & OPENINGS		18-5-1976	SURVEYED			
				AERIAL PHOTO REF			
SOIL AND WATER CONSERVATION FARM PLAN No				DRAWN	E. HELLENDOORN	SEPT. '75	A.J. GILLIES BE, B.Sc., F.N.Z.I.E., M.I.C.E. CHIEF ENGINEER
				TRACED	L. J. MILLER	SEPT. '75	
				DESIGNED	I. M. SCARF	SEPT. '75	
				CHECKED	I. G. S. SHARPE, I.M.S.	25/9/75	
				RECOMMENDED		3.10	

OTAGO CATCHMENT BOARD

SILVERSTREAM PUMPING STN

SCALE: 1:10, 1:40

JOB No 5/822/74/1 — 743090

L 8022/5 (A)