Meridian Energy

Manapōuri Lake Control Improvement Project

Groundwater Assessment

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Prepared By:

Brydon Hughes

For any information regarding this report please contact:

Brydon Hughes

Phone: 021-495229

Email: brydon@landwaterpeople.co.nz

LWP Ltd
PO Box 70
Lyttelton 8092
New Zealand

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Draft	Andrew Feirerabend Dougal Clunie Daniel Murray	

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Executive Summary

Meridian owns and operates the Manapōuri Power Scheme (MPS). The Manapōuri Lake Control (MLC) structure is located southeast of Lake Manapōuri, at the confluence of the Waiau and Mararoa Rivers, forming the downstream control of the outlet of Lake Manapōuri. The MLC is a key component of the MPS, essential to the operation and management of the scheme. Investigations have confirmed the Waiau Arm channel at the MLC does not currently have the flow conveyance capacity to reliably pass flushing flows to the Lower Waiau River (LWR). Meridian is proposing to undertake works to construct a new channel parallel to the current Waiau Arm to enable more reliable flow conveyance and delivery of flushing flows over a wider range of lake conditions.

A methodology has been developed to facilitate the construction of a parallel channel upstream of the MLC. This methodology is intended to enable most of the proposed works to be completed remote from surface water (the Waiau Arm and Mararoa River) thereby minimising the need for in-stream works and the associated potential for suspended sediment release to the Lower Waiau River (LWR).

A thin layer of highly permeable alluvial gravels underlying the Project site hosts a highly permeable unconfined aquifer into which the parallel channel will be excavated. Due to the high degree of hydraulic connection with both the Waiau Arm and the lower reaches of the Mararoa River, groundwater levels in the unconfined aquifer occur at, or close to, river level.

Partial dewatering is an option identified which may be utilised to improve the efficiency of the parallel channel excavation. The decision to undertake dewatering (and accompanying discharge of dewatering flows to land) will ultimately depend on a range of factors including water levels in the Waiau Arm at the time and whether the selected contractor considers it to be a viable and necessary option.

The proposed dewatering methodology involves pumping from sumps excavated adjacent to the parallel channel excavation. Due to natural filtration through the alluvial materials this will significantly reduce the suspended sediment in discharge water. The magnitude of dewatering flows generated for the project will vary according to the magnitude of water level reduction in the parallel channel excavation sought. Estimated dewatering rates range from 120 L/s for a 1-metre reduction in standing water level in the parallel channel excavation to around 220 L/s for a 2-metre reduction in water level.

Dewatering flows will be returned to the Mararoa River via infiltration to ground from a seepage pond constructed along the river margin. The volume of dewatering flows able to be accommodated by ground seepage varies according to river stage and seepage pond area.

Based on available information, it is reasonable to conclude the potential dewatering of the parallel channel excavation will result in less than minor effects on water quantity, water quality and natural hydrological variation in wetland areas identified on the Project site.

1 Introduction

1.1 Purpose of the Project

Meridian Energy Limited (Meridian) releases flows through the Manapōuri Lake Control Structure (MLC) to the Lower Waiau River (LWR) in accordance with existing resource consent conditions. The types of flow released include minimum flows, lake and flood flows, recreational flows and flushing flows. Each of these assists with managing nuisance periphyton growth and has benefits for river health. However, the current channel depth and alignment, and gravel accumulation in the Waiau Arm immediately upstream of the MLC, have been identified as the primary physical constraints affecting flow conveyance and reliability, particularly for flushing flows.

The aim of this Project is to reduce these constraints by constructing a new and deeper channel adjacent and parallel to the Waiau Arm and by removing accumulated gravel, and to provide for any necessary maintenance of the Waiau Arm channels. Following construction of the new and deeper channel, more reliable conveyance of consented flows into the LWR is expected. A more comprehensive description of the Project, and the proposed methodology, is included in the AEE, and the construction methodology report prepared by Damwatch Engineering Ltd.

1.2 Background

1.2.1 Context

Meridian owns and operates the Manapōuri Power Scheme (MPS), the largest single hydroelectric scheme in the country. Water in Lake Manapōuri is used to generate electricity at the underground station at West Arm. The MPS is operated under the Operating Guidelines for Lakes Manapōuri and Te Anau (the Guidelines) which was set in place under the Manapōuri – Te Anau Development Act 1963 (MTADA) and gazetted on 21 November 2002.

The catchment area for the MPS includes Lakes Manapōuri and Te Anau, and water that is diverted into Lake Manapōuri from the Mararoa River catchment at the Manapōuri Lake Control Structure (MLC). Meridian holds a suite of resource consents for water takes, diversions, discharges and maintenance associated with the MPS and the MLC.

The MLC is located southeast of Lake Manapouri, at the confluence of the Waiau and Mararoa Rivers, forming the downstream control of the outlet of Lake Manapōuri. The MLC is a key component of the MPS, essential to the operation and management of the scheme. It assists controlling and managing the level of Lake Manapōuri, diverting water from the Mararoa River into Lake Manapōuri for hydro-electric generation, and controlling the discharge of water to the Lower Waiau River catchment, including for minimum flow, lake and flood spill, recreational and flushing flow purposes. Investigations have confirmed the Waiau Arm channel at the MLC does not currently have the flow conveyance capacity to reliably pass in particular flushing flows to the LWR. This is due to the ongoing bed material that has accumulated over time upstream of the MLC, the existing channel depth and alignment. Hydraulic modelling undertaken by Damwatch in 2022 indicates that deepening the Waiau Arm channel reach and constructing a new channel parallel to the current Waiau Arm channel would allow for more reliable flow conveyance and delivery in particular for flushing flows over a wider range of lake conditions.

1.2.2 Options Selection Process

The selection of the parallel channel methodology has been subject to an extensive assessment and multi-criteria analysis involving multiple technical specialists. The trial investigations undertaken established that a predominantly instream excavation had a high likelihood of suspended sediment generation and discharge into the LWR. For this reason, options involving excavation over several months within the wet area of the Waiau Arm were not progressed further. The proposed parallel channel occurs substantially offline or outside of the wetted area of the Waiau Arm. As such, it has been assessed as the least effects option for releasing suspended and deposited sediment to the LWR during the excavation works, while appropriately managing all other environmental effects

Details of the option selection process are addressed in the AEE, but by way of summary:

- Instream option of deepening of the existing Waiau Arm, using a range of different methodologies and techniques (including excavators working from constructed bunds), was discounted due to the potential high levels of rapid sediment generation over long periods for instream works, which are difficult to practically manage;
- Cutter suction dredging was discounted due to the range of bed materials found in the LWR is unsuitable for this methodology and mobilisation of plant and facilities was considered to be more complex;
- Dragline excavation was ruled out due to limited operators and equipment available;
- Excavation from barges was ruled out due to the relatively confined work area and potential safety issues, complex set up and ability to be dismantled if flooding were forecast;
- Temporary damming structures were ruled out due to constructability and potential safety issues.

1.3 Purpose and Scope of this Report

Partial dewatering is an option identified which may be utilised to improve the efficiency of the parallel channel excavation. The decision to undertake dewatering (and accompanying discharge of dewatering flows to land) will ultimately depend on a range of factors including water levels in the Waiau Arm at the time and whether the selected contractor considers it to be a viable and necessary option.

This purpose and scope of this report is to assess the effects of potential dewatering during Stage 2 of the parallel channel excavation. This includes an estimate of the potential magnitude of dewatering flows as well as an assessment of the likely magnitude and scale of groundwater mounding resulting from the discharge of dewatering flows to ground.

1.4 Report Structure

This report:

- Describes the Project (Section 2)
- Characterises the geological and hydrogeological Setting (Section 3)
- Provides an assessment of potential dewatering flows and seepage discharge (Section 4)
- Assesses the potential effect of the proposed activity on the wider groundwater environment (Section 5)
- Provides an overall summary (Section 6)

2 Description of the Project

2.1 Overview

The Project will involve the construction of a new channel which is parallel to, and largely offline, from the current bed and channel of the Waiau Arm. Approximately 225,000 m^3 of gravel and bed material will be excavated and disposed of on Meridian owned land near the new channel.

Subject to obtaining resource consents, and hydrological conditions, Meridian proposes to undertake the works within a 10-month window of January to October 2025. The overall construction period within this window is envisaged to be approximately 4 to 5 months, with the bulk of the parallel channel excavation occurring over a period of approximately 10 weeks. Works are proposed to occur on a 7-days per week and up to 24 hours per day basis.

The bulk channel excavation works are targeted to the time of year when hydrological conditions are likely most favourable for safe and efficient delivery of the work. The construction window has also been identified to limit disruption to Meridian's monitoring requirements under existing resource consent conditions.

Full details of the Project, and the proposed construction methodology and sequencing, are contained in the AEE.

2.2 Dewatering Activities

The MLC Waiau Arm Channel Excavation Methodology (Damwatch, 2023) outlines a proposed methodology for the parallel channel excavation. This methodology is intended to enable a majority of the proposed works to be completed remote from surface water (the Waiau Arm and Mararoa River) thereby minimising the need for in-stream works and the associated potential for suspended sediment release to the Lower Waiau River (LWR).

The proposed works will proceed in three stages:

- Stage 1 involves excavation of the highest areas along the proposed channel alignment, with the most suitable material utilised to construct haul roads and bunding along the true right of the new channel. During this phase vegetation along the alignment will be cleared and topsoil removed and stockpiled for later use.

- Stage 2 includes the bulk of the excavations required for construction of the parallel channel. It is anticipated that excavation will progress at 2-3 work fronts simultaneously.
- Stage 3 involves in-river works to deepen the approach, inlet and outlet to the parallel channel, followed by removal of bunding, haul roads and general site remediation.

Excavations during Stage 2 will likely encounter groundwater at, or close to, river level. The water level within the excavation will depend on current rainfall and river levels as well as the groundwater level driven by the river levels over recent days or weeks. Depending on this level, partial dewatering of the excavation (i.e., reducing water surface level by up to 2 metres) may be undertaken to ensure that the ultimate excavation depth can be reached and that a significant proportion of the excavation can be undertaken using more efficient standard-arm excavators.

The efficacy of dewatering methods will depend upon the proximity of the excavation to the river or lagoon area, the prevailing groundwater and river levels, and the permeability of the ground. It is considered unlikely that dewatering will be effective for the excavation area to the south-east of the lagoon area.

If determined as being necessary to facilitate construction, dewatering will be undertaken by pumping from large sumps excavated adjacent to the parallel channel. This will significantly reduce the suspended sediment load in dewatering flows compared that those which would result from direct pumping from within the excavation area, due to natural filtration occurring during as water flows through the intervening alluvial materials. If required, impermeable geomembrane lining may be placed on riverside bund slope to reduce seepage from the river.

Dewatering flows will be discharged to ground via a seepage pond constructed adjacent to the Mararoa River. Due to the shallow water table in this area, the dewatering rate may ultimately be limited by the magnitude and extent of groundwater mounding which can be accommodated in the alluvial materials surrounding the seepage pond. The seepage rate achievable (and hence the maximum dewatering rate) will be significantly influenced by the stage height in the adjacent reach of the Mararoa River.

Pumping rates, duration, frequency, volumes and times will depend upon river and local groundwater levels, and the permeability of riverbanks and excavated ground. Especially as the excavation extent increases and gets closer to the river, pumping to make an appreciable difference to water level and construction efficiency within the excavation may not be practicable due to the high rate of groundwater inflow. Due to the increasing spatial extent of the excavation (and corresponding increase in pumping rate required to maintain water levels), it is anticipated that partial dewatering of the excavation may only be practicable during the initial phase of the Stage 2 excavations (a period of approximately 4 weeks).

3 Environmental Setting

3.1 Site Location

The MLC is located approximately 9 km south-east of Lake Manapōuri and the Manapōuri township, at the confluence of the Waiau and Mararoa Rivers. The Project site is bound by the Waiau Arm and farmland to the north and west, the LWR and farmland to the south, and the Mararoa River to the east. A plan showing the location of the Project site is provided in **Error! Reference source not found.**. Full details of the Project site are outlined in the AEE.

3.2 Geological Setting

The geological setting of the Project site is described by GeoSolv (2016)[1], based largely on documentation of geological conditions encountered during construction of the MLC. These investigations indicate the surficial geology of the Project site comprises a thin layer of post-glacial gravels overlying a relatively thick sequence of glaciolacustrine sediments (clays, silts and sand) which accumulated within a glacial lake formed during the Late Quaternary behind the prominent moraine terrace (Ramparts 1 advance) evident along the margins of the Waiau Valley downstream of the MLC.

The surficial alluvial deposits comprise glacial outwash materials deposited and subsequently reworked during entrenchment of the Mararoa River and Waiau Arm over the post-glacial period (last 14,000 years). Test pits TP01 to TP06 (detailed in Attachment 1) excavated along the margin of the Waiau Arm indicate the alluvial materials underlying the Project site typically comprise loose, sandy, fine to coarse gravels containing a varying proportion of cobbles which are interspersed with irregular (possibly lensoidal) layers of fine to coarse sand containing gravels and occasional silt. Such deposits are characteristic of recent (Q1) alluvial deposits in the headwaters of the main river catchments across Southland.

The underlying glaciolacustrine sediments (collectively referred to as the Damsite Formation) are typically 30 to 40 metres thick overlying older lakebed sediments at depth. The Damsite Formation comprises 6 separate units (Members A to F) which generally comprise accumulations of silty fine sand, silt and clay with occasional sand, fine gravel and clasts up to boulder-size. Bedding in these deposits is generally sub-horizontal to gently dipping north of the MLC, rising more steeply (up to 10 to 15 degrees) toward the valley margins.

GeoSolv (2016) notes a planar erosional surface on the Damsite Formation in the vicinity of the MLC at around RL 177.7 m (583 feet)). This is consistent with excavations within the Waiau Arm channel which encountered clay around RL 172 m at Locations A and B (approximately 800 and 500 metres upstream of the MLC respectively), rising to around RL 174 m at Location C (approximately 140 m upstream of the MLC) (Dougal Clunie, Damwatch, *pers comm*).

[1] GeoSolv, 2015; Geological Assessment Manapouri Lake Control Structure. Report prepared for Damwatch Ltd, October 2016.

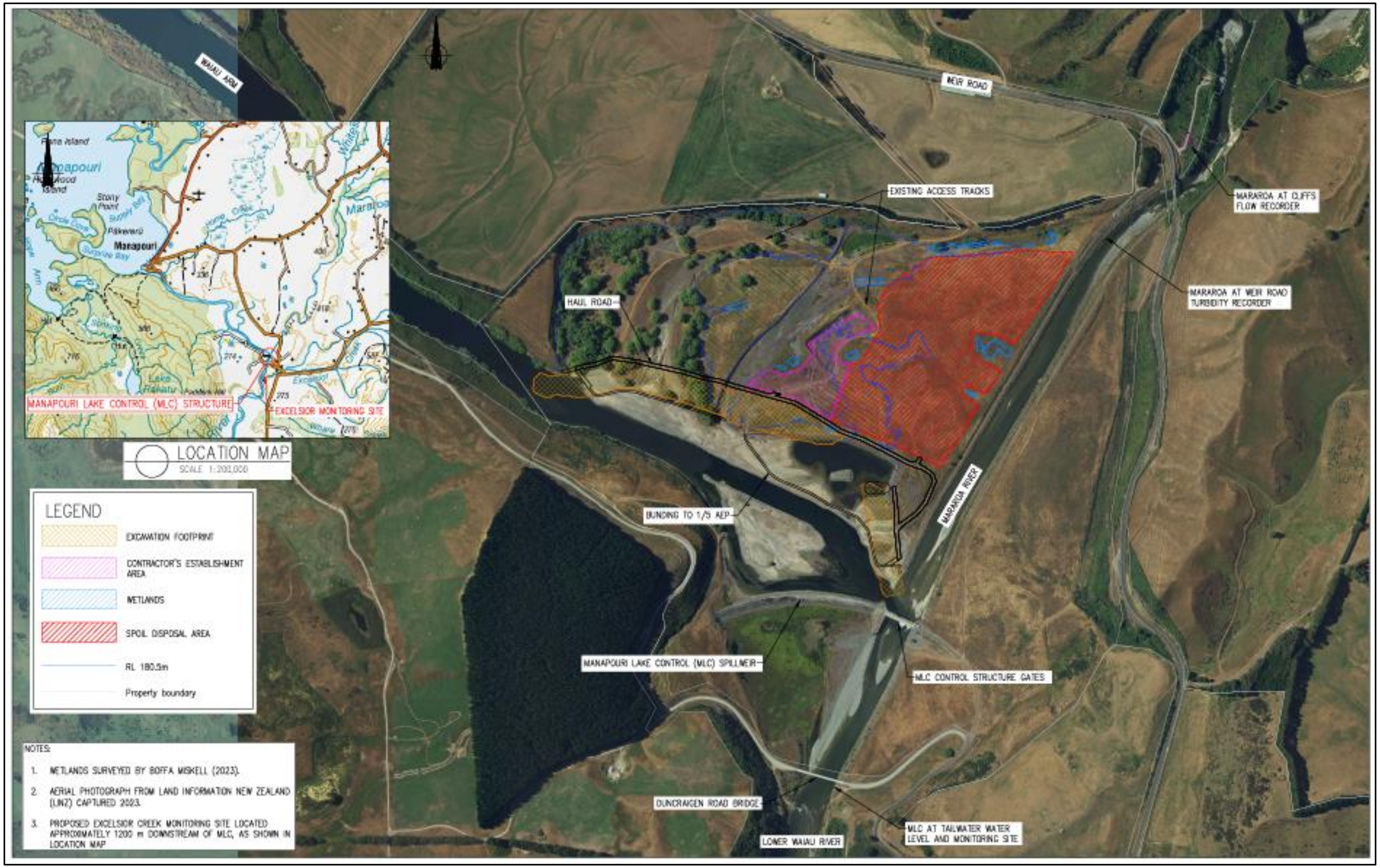


Figure 1. Location of the Project site showing the main project components.

3.3 Hydrogeology

The alluvial deposits underlying the Project area host a thin unconfined aquifer which is hydraulically connected to the Waiau Arm and the Mararoa River. The saturated thickness of the aquifer will vary according to river stage but is typically of the order of 5 to 6 metres. Groundwater levels were observed at shallow depths (<1 m bgl) in test pits excavated along the true left bank of the Waiau Arm. Due to impounding of water behind the MLC, the hydraulic gradient across the Project area is likely to be limited, although it is likely that relative groundwater levels will respond rapidly to changes in river stage. A limited component of throughflow may also occur from shallow groundwater in glacial till and outwash deposits forming the higher terrace to the north of the site.

3.3.1 Aquifer Hydraulic Properties

No aquifer test data are available to characterise the hydraulic property of the alluvial materials underlying the Project site.

The likely range of hydraulic conductivity in the unconfined aquifer was estimated using grainsize analysis undertaken in the ten test pits excavated across the site in x and y. The grainsize data were analysed using the HydroSieveXL program (Devlin, 2015)[2]. This program calculates hydraulic conductivity values based on grainsize distribution curves using a total of 15 alternative methods. The program assesses the suitability of individual assessment methodologies to different grainsize distributions, and representative values calculated for individual samples utilising the most applicable methods.

Grainsize analysis and hydraulic conductivity estimates were made for samples recovered from discrete depths in three test pits (TP01, TP04 and TP05) dug along the true left bank of the Waiau Arm across the Project area. These materials are considered as likely to be

[2] Devlin, J.F., 2015; HydroSieveXL: an Excel-based tool to estimate hydraulic conductivity from grain-size analysis. Hydrogeology Journal 23, 837-844 (2015).

representative of the materials present between the Waiau Arm and the parallel channel excavation (i.e., through which water will flow in response to the proposed dewatering). Hydraulic conductivity estimates were also derived from a total of ten bulk samples recovered from two in-river trial holes excavated into the base of the existing West Arm channel. Figure 2 shows the location of samples utilised to estimate hydraulic conductivity.

Figure 2. Location of sample sites utilised to estimate hydraulic conductivity.

Results of the grainsize and hydraulic conductivity analyses are outlined in Table 1 below[3]. Results indicate geometric mean hydraulic conductivity values from test pits ranging from 62 to 526 m/day, with a geometric mean of 304 m/day for the whole data set. Values from the bulk samples indicate slightly lower values ranging from 50 to 532 m/day, with a geometric mean of 214 m/day.

Table 1. Uniformity co-efficient and calculated hydraulic conductivity for alluvial materials derived from test pits and bulk samples across the Project site.

Sample Location	Depth Interval	Uniformity co-efficient	Geometric Mean Hydraulic Conductivity (m/day)
Test Pits			
TP01	0.2-1.0m	2.6	62
TP01	1.0-1.4m	24.1	512
TP04	0.0-0.5m	43.2	526
TP05	0.7-1.1m	58.9	317
TP05	1.1-1.4m	24.5	492
		Geometric Mean	**304**
Bulk Samples			
A1	RL 173.75-173.25	82.5	138
A2	RL 173.25-172.75	20.3	50
A3	RL 172.75-172.25	32.4	90
A4	RL 172.25-171.75	8.9	103
B1	-	95.4	264
B2	RL 174.56-174.06	24.5	411
B3	RL 174.06-173.56	24.8	532
B4	RL 173.56-173.06	29.1	415
B5	RL 173.06-172.56	25.0	408
B6	RL 172.56-172.06	41.0	324
		Geometric Mean	**214**

[3] It is noted that individual methods used to estimate hydraulic conductivity from grainsize often result in estimated values which range in excess of one order of magnitude. Geometric mean values best represent the average tendency of multiple estimates which are often unevenly distributed.

The range in estimated hydraulic conductivity values reflects the overall textural variability of the gravel materials. For example, the uniformity co-efficient (calculated from the ratio of the grain diameter for which 60 percent of the sample is finer (D_{60}) to the grain diameter for which 10 percent of the sample is finer(D_{10})) ranges from 3 to 95, reflecting significant variations in the overall texture of the alluvial sediments. Such variability is characteristic of alluvial materials throughout the Southland Region.

Given the overall variability of estimated hydraulic conductivity, it is considered that a value of the order of 250 m/day is likely to reflect the bulk permeability of the alluvial materials. Assuming a saturated thickness of 6 metres (which will vary depending on river stage), this equates to a transmissivity value of 1,500 m^2/day.

No data is available to estimate the specific yield of the alluvial materials. Based on textbook values for similar materials[4] (sandy gravel with variable fines), a value of 0.15 is considered representative for the overall sediment texture.

4 Calculation of Dewatering and Seepage Flows

The following sections provide generalised estimates of flow rates, drawdown and groundwater mounding associated with the proposed abstraction of groundwater and discharge of dewatering flows to land during the initial phase of Stage 2 excavations.

4.1 Stage 2 Dewatering

To calculate the likely magnitude of dewatering flows generated during the initial phase of Stage 2 excavations, the W_15 function described by Hunt (2011)[5] was used to calculate the abstraction rate required to achieve a target drawdown below static groundwater level across the parallel channel excavation. This calculation was set up to calculate the cumulative effects of abstraction from a grid of 12 pumping wells arranged to simulate abstraction from an elongated dewatering sump running alongside the parallel channel excavation. Drawdowns from the individual pumping wells are summed across a grid to estimate the likely magnitude of drawdown in the surrounding aquifer. The Waiau Arm is simulated as a hydraulically connected river, set back the requisite distance from the dewatering sump. The assumed layout of the river, parallel channel excavation and dewatering sump are based on the schematic layout of works shown on Cross Section E2243-107 (appended as Attachment 2).

It is recognised that the layout of the dewatering scenario modelled will vary from actual conditions as the extent of the excavation increases. However, it is considered suitable for providing an indicative estimate of dewatering flows required to reduce water levels in the parallel channel up to two metres below those in Waiau Arm during the initial phase of the Stage 2 works. It is also noted that variations in the stage height in the Waiau arm will make a significant difference to the volume of dewatering flows required to achieve a given water

[4] E.g., Fetter, C.W., (2004). Applied Hydrogeology; Kruiseman and de Ridder (2000). Analysis and Evaluation of Pumping Test Data; Morris, D.A. and A.I. Johnson, (1967). Summary of hydrologic and physical properties of rock and soil materials as analyzed by the Hydrologic Laboratory of the U.S. Geological Survey.

[5] Hunt, B., (2011). Groundwater analysis using Function.xls. University of Canterbury, January 2012.

level in the parallel channel and maintenance of lake stage close to the lower end of the nominal operating range (i.e., RL 176.8m) is likely to significantly reduce dewatering required for the parallel channel excavation.

To account for potential effects of stage height variation in the Waiau Arm, two dewatering Scenarios were assessed. Scenario 1 simulates the pumping rate required to achieve a drawdown of 2 metres across the full width of the parallel channel excavation after 14 days continuous pumping (representing high stage conditions). Scenario 2 simulates the pumping rate required to achieve a 1 metre drawdown over the same period (representing moderate to low stage conditions)[6]. The assessment was undertaken utilising the parameters listed in Table 2. It is noted that the aquitard K'/B' value (representing Damsite Formation members A to E) and transmissivity and storativity values assigned to the semi-confined aquifer (representing Damsite Formation member F) effectively limits simulated groundwater flow to the shallow unconfined aquifer.

Table 2. Parameters used for dewatering assessment.

Parameter	**Unit**	**Value**
Hydraulic Conductivity		250
Saturated Thickness	m	6
Transmissivity	m^2/day	**1,500**
Specific Yield		**0.15**
Stream Width (Waiau Arm)	m	50
Thickness of Clogging Layer	m	1
Vertical Hydraulic Conductivity	m/day	4
Streambed Conductance	m/day	**200**
Aquitard Vertical Hydraulic Conductivity	m/day	0.005
Aquitard Thickness	m	40
Aquitard K'/B'	Day^{-1}	**0.00125**
Semi-confined Aquifer Transmissivity	m^2/day	**1**
Semi-confined Aquifer Storativity		**0.0001**
Pumping Duration	days	**14**

Results of the assessment indicate dewatering at a rate of the order of 120 L/s to achieve a 1 metre drawdown across the parallel channel excavation, increasing to 220 L/s to achieve a drawdown of 2 metres (copies of the corresponding worksheets are provided in Attachment 3).

It is also noted that the model calculates drawdown occurring in saturated alluvium (with an assumed specific yield of 0.15). As the excavation proceeds an increasing volume of the alluvial materials will be removed, effectively increasing storage to unity (i.e., 1). This increase in storage will enable a greater volume of water lost from the Waiau Arm to be

[6] It is however possible that dewatering requirements may drop close to zero if stage height in the Wauau Arm is consistently maintained near the bottom of the normal operating range (i.e., RL 177.0 m).

retained within the parallel channel compared to the that possible with the alluvial materials in situ. In addition, given the limited saturated thickness of the alluvial materials, lowering of the water table will decrease the effective transmissivity of the unconfined aquifer. This reduction in aquifer transmissivity will both increase the magnitude of drawdown around the dewatering sump and reduce the rate of flow loss from the Waiau Arm, effectively reducing the dewatering rate required to achieve the nominated reduction in water levels.

It is not possible to incorporate either the change in storage or reduction in transmissivity occurring in response to the proposed dewatering and excavation into the analytical model utilised for the assessment. However, given both of these factors have the potential to reduce dewatering rates, it is considered they will add a degree of conservatism to the potential dewatering flows calculated.

4.2 Discharge of Dewatering Flows

As illustrated on the indicative dewatering layout shown on Attachment 2, a seepage pond will be constructed adjacent to the Mararoa River approximately 400 metres north-east of the parallel channel excavation. Infiltration of water from the seepage pond into the underlying aquifer will be limited by the head difference between the pond invert and the underlying water table.

Stage height in the adjacent reach of the Mararoa River is typically maintained in the range of RL 177.0 to 178.6 m. The seepage pond will be constructed with an invert at approximately RL 180 m, with bunds constructed to facilitate a head of up to 2 metres in the pond. This provides a maximum separation of between 1.4 and 3.0 metres between the pond invert and the underlying water table.

The dewatering rate will be managed by a pump control system to prevent overtopping. Regular monitoring of pond level will also be undertaken to identify any significant changes in pond level which may indicate a reduction in seepage rate due to the accumulation of suspended sediment on the pond base. If required, the accumulated suspended sediment will be removed by mechanical excavation to restore initial seepage rates.

The indicative seepage rate able to be achieved from the pond was calculated using the W_6 function described by Hunt (2012). This function (as utilised for this application) describes the rise of a groundwater mound around a recharge basin discharging at a nominated rate (equal to inflow/pond footprint). The model was set up to simulate groundwater mounding around a recharge basin assuming the same aquifer hydraulic properties utilised for the dewatering assessment (i.e., K = 250 m/day, S = 0.15, b = 6m and t = 14 days). The model was run to identify the infiltration rate corresponding to a 1.4 and 3.0 metre rise in the water table under the pond invert (effectively simulating potential seepage rates at the upper and lower end of the normal operating range of the Mararoa River). Scenarios were also run simulating potential seepage rates from a 50 x 50 m (2,500 m^2) pond and a 100 x 100 m (10,000 m^2) pond.

Results of the four pond seepage scenarios analysed are outlined in Table 3 below (copies of the full worksheets are provided in Attachment 4). The results indicate potential pond seepage rate ranging from 53 to 113 L/s depending on Mararoa River stage for a 50 x 50 m seepage pond, increasing to between 65 and 139 L/s for a 100 x 100 m seepage pond (i.e., a 50 percent increase in seepage rate for a four-fold increase in pond area).

Table 3. Results of pond seepage scenarios.

Scenario	Pond Dimensions (m)	Mararoa River Stage (RL m)	Maximum mounding (m)	Seepage Rate (L/s)
1	50 x 50	178.6	1.4	53
2	50 x 50	177.0	3.0	113
3	100 x 100	178.6	1.4	65
4	100 x 100	177.0	3.0	139

Overall, the assessment indicates that rates of seepage achievable from a single pond are likely to be lower than projected dewatering flows required to achieve a 2-metre reduction in water level in the parallel channel excavation[7], even if river stage is close to the lower end of the normal operating range. Dewatering flows required to achieve a 1 metre drawdown in groundwater level can potentially be accommodated by a seepage pond with an area exceeding 2,500 m^2 if river stage is close to the bottom end of the normal operating range but are likely to exceed seepage capacity at high river stage.

One option for increasing seepage to ground canvassed was to construct multiple seepage ponds. However, modelling indicates that mounding of the groundwater table will extend over a relatively wider area surrounding each individual seepage pond. For example, under Scenario 4, 1.7 m of mounding is calculated at a distance of 100 m from the pond margin, with 1.1 m of mounding 200 metres from the pond margin. This mounding would act to decrease the effective thickness of the unsaturated zone and therefore reduce the seepage rate achievable from each individual pond unless they were located a several hundred metres apart across the site. Depending on the location of the seepage pond associated groundwater mounding could also serve to increase the rate of dewatering required to achieve the target drawdown in the parallel channel excavation. These factors reduce the practicality of utilising multiple seepage ponds.

4.3 Discussion

Calculations of dewatering flows and seepage rates outlined in the previous sections are intended to provide an indicative assessment of the potential magnitude of dewatering and seepage flows. These calculations indicate that dewatering flows required to lower the standing water level in the parallel channel excavation by 1 metre can likely be discharged to ground provided Mararoa River levels are toward the bottom end of the historical range, while dewatering flows required to reduce water levels in the parallel channel excavation by

[7] This is entirely consistent with the principle of superposition which requires that the magnitude and extent of groundwater mounding have the same spatial extent but opposite magnitude to drawdown occurring in response to dewatering (assuming equivalent aquifer parameters). Due to the proposed dewatering methodology, drawdown in excess of 2 metres is required over a relatively wider area to achieve a 2 metre reduction in water level across the full width of the parallel channel. Consequently, seepage of an equal discharge to ground will result in mounding of greater than 2 metres over an equally extensive area.

2 metres may exceed the seepage capacity of a single pond, even if constructed with a relatively large surface area.

It is noted that the dewatering and seepage calculations presented cannot account for the heterogenous properties of the alluvial gravel aquifer (for example, as outlined in Table 1 above). This inevitably introduces a level of uncertainty into the calculations presented. In addition, limitations in the analytical modelling techniques utilised are not able to replicate some of the factors that will inevitably exert a significant influence on dewatering and seepage rates.

For example, due to the limited saturated thickness of the aquifer, a reduction in groundwater level under the parallel channel excavation will reduce the transmissivity of the unconfined aquifer resulting in a reduction in the rate of groundwater flow from the Waiau Arm into the excavation. Similarly, mounding calculations do not account for the presence of the Mararoa River adjacent to the seepage pond. Due to the high degree of hydraulic connection between the unconfined aquifer and the river, the river will act as a constant head effectively reducing the magnitude of groundwater mounding enabling higher rates of seepage that those calculated. Consequently, the dewatering calculations are likely to over-predict steady-state dewatering rates required and under-predict seepage rates achievable, thus providing a 'worst case' estimate of the possible dewatering operations.

Given these limitations, the actual performance of the potential dewatering system can only reliably be established through its practical implementation. However, the calculations of potential dewatering and seepage rates are considered suitably conservative to provide a basis for the assessment of potential effects on the environment outlined in the following section.

5 Effects on the Environment

5.1 Effects on Surface Water Quantity

The proposed dewatering of the parallel channel excavation will result in the depletion of flow from the adjacent reach of the Waiau Arm. Due to the high degree of hydraulic connection with the unconfined aquifer and the proximity of the parallel channel excavation to the river channel, the rate at which flow is depleted from the Waiau Arm will approximate the rate of dewatering (i.e., q/Q ~ average dewatering flow rate).

Dewatering flows generated will be discharged to ground adjacent to the Mararoa River. Given stage height in the Waiau Arm and lower reaches of the Mararoa River are controlled by the MLC, the proposed take and take and discharge of water will effectively occur contemporaneously from and to the same waterbody.

It is therefore reasonable to conclude the proposed abstraction and discharge of groundwater represents a non-consumptive use of water so effects on surface water quantity will be negligible.

5.2 Effects on Surface Water Quality

The proposed groundwater abstraction will occur from sumps excavated adjacent to the haul road running along the northern boundary of parallel channel excavation. Groundwater flowing into the dewatering sumps from the parallel channel excavation will therefore have to flow through the intervening ~20 metres of alluvial materials. Dewatering flows discharged to ground from the seepage pond will have to infiltrate through a minimum of 20 metres of alluvium to reach the Mararoa River.

Due to practical difficulties undertaking reliable field measurements of suspended sediment transport in groundwater, few studies are available to characterise transport of suspended sediment in suspended sediment through alluvial aquifer systems. Thorpe (1996)[8] reported a study undertaken to characterise the transport of suspended sediment through an alluvial aquifer (similar in texture to the alluvial materials on the Project site) down-gradient of dredge operating in the Grey River Valley. Results of the study showed a rapid reduction in the particle size of suspended sediment in groundwater within a short distance of the source, with a majority of particles >1µm removed after the first 30 to 40 metres of flow. Colloidal-size particles (<1µm) were however detected up to 200 metres down-gradient of the source.

Groundwater pumped from the dewatering sumps will therefore contain a suspended sediment load appreciably lower than that present within the parallel channel excavation itself. The suspended sediment content of the discharge will be further reduced in water by settling within the seepage pond, with further attenuation of suspended sediment accruing as water infiltrates from the seepage pond through the underlying aquifer prior to reaching the Mararoa River.

Overall, combined with settlement in the seepage pond, the passage of dewatering flows through alluvial materials between the parallel channel excavation and the dewatering sump and from the seepage pond mean dewatering flows are likely to result in less than minor effects on the suspended sediment load in the Mararoa River.

5.3 Effects on Groundwater Allocation

The Project area is located within the Te Anau groundwater management zone defined in the Regional Water Plan for Southland (RWPS) and the equivalent zone (albeit with a modified spatial extent) defined in the Proposed Southland Water and Land Plan. Environment Southland recorded the current allocation status of the Te Anau groundwater management zone as Low[9].

As noted in previous sections, the proposed take and discharge of groundwater for dewatering purposes will occur for a limited duration (likely to be no longer than 4 weeks) and be effectively non-consumptive, with a majority of abstraction effectively taken from and

[8] Thorpe, H.R., 1996; *Alluvial gold dredging: a case study of effects on groundwater turbidity*. Transactions of the Institute of Mining and Metallurgy; 106. Jan-Apr 1997.

[9] **https://www.es.govt.nz/environment/water/groundwater/groundwater-management-zones/te-anau** (wherein Low allocation is defined as meaning *"...a low proportion of the unconfined aquifer water available has been allocated*").

returned to the Waiau Arm/Mararoa River. Effects on groundwater allocation will therefore be less than minor.

5.4 Effects on Existing Groundwater Users

The Environment Southland Beacon application records a single bore (CE08/0002) within 2 kilometres of the Project site. This bore is assigned '*proposed'* status (indicating it may yet to be drilled) with its indicative location being adjacent to the Mararoa River bridge on Weir Road, approximately 900 metres from the Mararoa River.

CE08/0002 is assigned a nominal depth of 40 metres indicating it is likely be screened in older glaciolacustrine sediments of the Damsite Formation, based on geological investigations undertaken in the vicinity of the MLC. However, due to the low yield of the underlying strata (Member E and Member F of the Damsite Formation which are recorded as generally comprising "*sand and gravelly silty sand, with occasional beds of sandy gravel*" (GeoSolv, 2015)), the bore (if constructed) may ultimately be screened in shallow reworked alluvial deposits associated with post-glacial entrenchment of the Maraoa River.

The potential for CE08/0002 to be adversely impacted by the proposed parallel channel excavation is minimal. If CE08/002 is screened at a depth close to 40 m bgl (as proposed), it will likely access groundwater older coarse-grained deposits in the lower part of the Damsite Formation. These deposits host a low-yielding semi-confined aquifer system which has limited hydraulic connection to the shallow alluvium from which abstraction is proposed[10]. However, if CE08/0002 were to be screened in the shallow alluvium, the potential for it to experience drawdown resulting from proposed dewatering operations will be minimal due to the high degree of hydraulic connection unconfined aquifer and the Mararoa River (effectively providing a constant head which will offset any drawdown).

5.5 Effects on Wetlands

The Boffa Miskell Wetland Assessment Report (Boffa Miskell, 2023) identifies a total of 12 wetland areas across the Project area. The report characterises these areas as follows:

> *There are 12 small areas of palustrine marsh that support wetland vegetation in the vicinity of the spoil disposal and contractor's establishment areas. All these wetland areas are likely to be only infrequently wet, supported only weakly hydrophytic vegetation and were dominated by exotic plant species, although some supported indigenous wetland plant species.*
>
> *Some of these areas contain sufficient wetland vegetation (based on vegetation plot assessment) to be considered wetlands in terms of the RMA and NPS-FM. In many cases this was because single large individuals or clumps of wetland species such as wīwī rushes (Juncus edgariae and J. sarophorus) dominated the small 2x2 m vegetation plots.*

[10] The lack of hydraulic connection between the shallow alluvium and deeper water-bearing layers is illustrated by the artesian pressures recorded in water-bearing layers within the

All were small areas of palustrine marsh (44 – 1,588 m^2 in extent) dominated by exotic plant species. Most areas found to be wetlands supported only weakly hydrophytic vegetation, with the dominant cover comprising Facultative / FAC or Facultative Wetland / FACW plant species rather than Obligate / OBL species.

The report notes:

Wetlands typically occupied small faint hollows in the generally hummocky terrain where it is likely that water impounds following rain; all areas are likely to be only infrequently wet and were dry at the time of the survey.

However, it also identifies that:

Four of these areas (Wetlands 6, 7, 8, and 9) occur on land that is below (and would at times be connected to) the maximum permitted operating level of Lake Manapōuri….they are hence considered part of the bed of the lake.

Figure 3 shows the location and spatial extent of the wetland areas identified. Wetlands 1 through 7, 10 and 12 are assessed as having low ecological value, while wetlands 8, 9 and 11 are assessed as having Low-Moderate ecological value reflecting a greater range of indigenous plant species.

The proposed dewatering of the parallel channel excavation will lower natural groundwater levels across a significant proportion of the project site during the initial phase of Stage 2 excavations. However, given the wetland areas identified are characterised as '*infrequently wet*' containing only '*only weakly hydrophytic vegetation'* any hydraulic connection between the wetlands identified and the underlying water table is likely to occur on an infrequent basis during periods when lake levels are above their normal operating range. Consequently, a temporary reduction in groundwater levels associated with the proposed dewatering of the parallel channel excavation is likely to result in a less than minor effect on the hydrology of these features.

The Boffa Miskell report also identifies:

…..three lacustrine 'channels' on the northern bank of Waiau Arm…..The southern ends of these channels are within the construction footprint of the proposed parallel channel. The distribution and extent of wetland plant communities within these 'channels' is driven by inundation from the Waiau Arm, to which they are connected. The extent and frequency of this inundation is dependent on water levels in Lake Manapōuri (and Waiau Arm). The eastern-most and middle 'channels' dry out entirely when lake levels are very low.

But notes that these areas:

…are not 'wetlands' and therefore are also not 'natural inland wetlands.'.

The lacustrine 'channels' are likely to exhibit some connection to groundwater (given the close relationship between river stage and groundwater levels). However, most areas described appear to be subject to intermittent/extended drying during periods of low lake levels. Consequently, a temporary reduction in groundwater levels associated with the proposed dewatering is unlikely to represent a departure from normal hydrological conditions occurring in these areas.

Temporary mounding of the water table around the seepage pond may result in a net positive effect on the hydrology of Wetland 3 by elevating the water table to a level typically only occurring during high stage events in the Mararoa River.

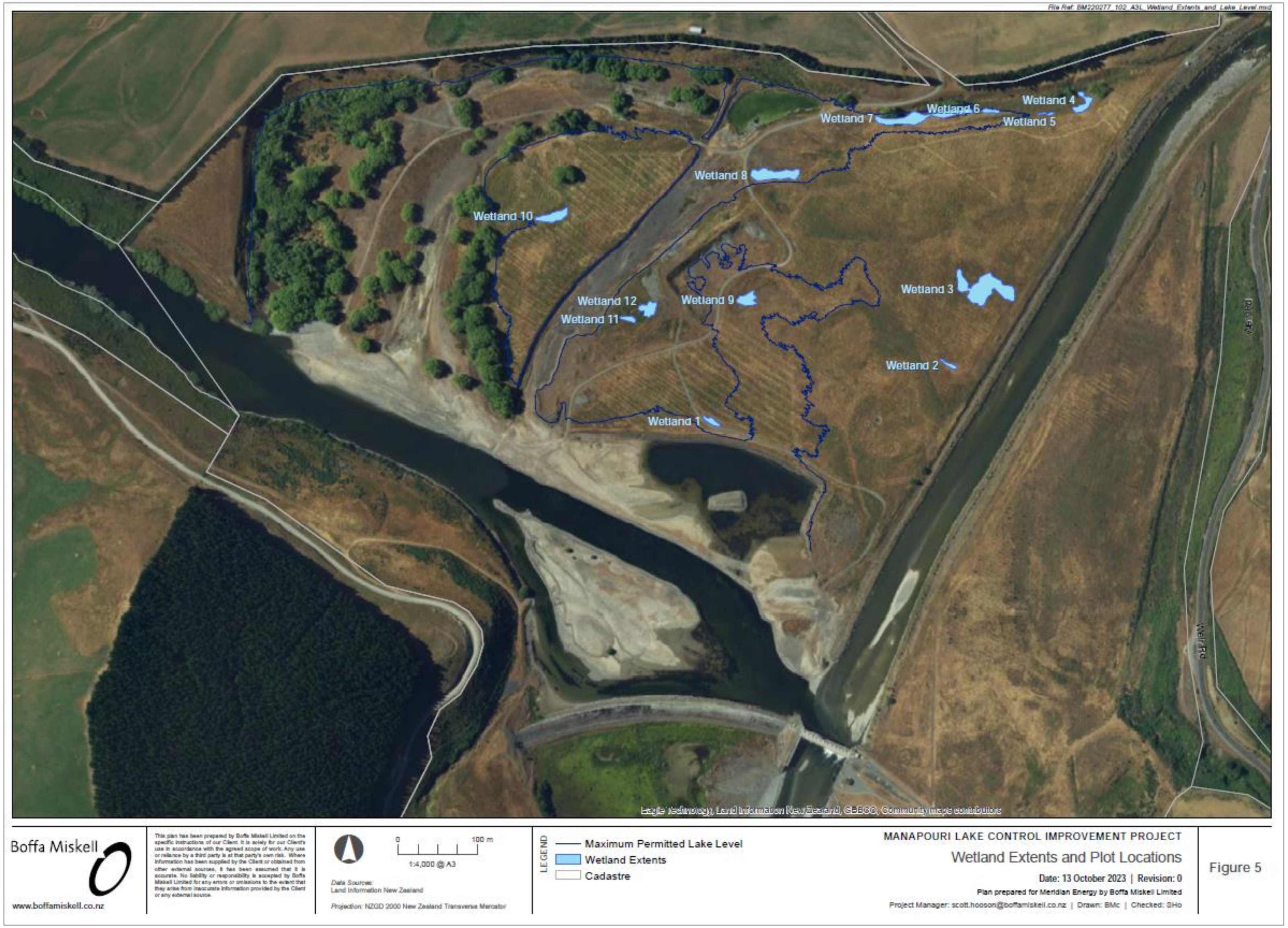


Figure 3. *Areas of wetland vegetation on the project site (reproduced from Boffa Miskell, 2023)*

6 Summary and Conclusions

A methodology has been developed to facilitate the construction of a parallel channel upstream of the MLC for the Manapōuri Lake Control Improvement Project. This methodology is intended to enable most of the proposed works to be completed remote from surface water (the Waiau Arm and Mararoa River) thereby minimising the need for in-stream works and the associated potential for suspended sediment release to the Lower Waiau River (LWR).

A thin layer of highly permeable alluvial gravels underlying the Project site hosts a highly permeable unconfined aquifer. Due to the high degree of hydraulic connection with both the Waiau Arm and the lower reaches of the Mararoa River, groundwater levels in the unconfined aquifer occur at, or close to, river level. To ensure that the ultimate excavation depth can be reached, and that the majority of the excavation can be undertaken by more efficient standard-arm excavators, partial dewatering of the parallel channel excavation (i.e., reducing water surface level by up to 2 metres, depending on river stage) may be undertaken during initial stages of construction.

The proposed dewatering methodology involves pumping from sumps excavated adjacent to the parallel channel excavation. Due to natural filtration through the alluvial materials this will significantly reduce the suspended sediment in discharge water. The magnitude of dewatering flows generated for the project will vary according to the magnitude of water level reduction in the parallel channel excavation sought. Estimated dewatering rates range from 120 L/s for a 1-metre reduction in standing water level in the parallel channel excavation to around 220 L/s for a 2-metre reduction in water level.

Dewatering flows will be returned to the Mararoa River via infiltration to ground from a seepage pond constructed along the river margin. The volume of dewatering flows able to be accommodated by ground seepage varies according to river stage and seepage pond area.

Based on available information, it is reasonable to conclude the potential dewatering of the parallel channel excavation will result in less than minor effects on water quantity, water quality and natural hydrological variation in wetland areas identified on the Project site.

Attachment 1 – Test Pit Logs

DAMWATCH ENGINEERING BEYOND THE SURFACE

80 The Terrace
PO Box 1549
Wellington 6140

Ph:+64 4 381 1300

INVESTIGATION LOG

Job No.:	E2193
No.:	**TP01**
Sheet:	1 of 1
Date:	21/02/22

Client: Meridian	**Coordinates:** E 1,185,535.00 N 4,935,434.00	**Ground Level:** 178
Project: MLC Lower Waiau Arm Investigation	**Location:** Manapouri Lake Control	

Geological Interpretation (refer to separate Geotechnical and Geological Information sheet for further information)	Samples	Depth (m)	Water
Clayey SILT, some fine to medium sand, trace gravel; dark brown. Firm to stiff. Sand is fine to medium. Gravel is fine, well-rounded. Frequent rootlets (TOPSOIL)		0.0–0.2	
SAND, trace gravels; mixed light grey and light brown. Loose to very loose, moist (ALLUVIUM)	B	0.2–1.0	
Sandy fine to coarse GRAVELS, some cobbles, mixed colours. Very loose, wet. Gravels are sub-rounded to rounded. Sand is fine to coarse. (ALLUVIUM)	B	1.0–1.4	IN 1.00m
PIT COLLAPSE EOH:1.4m			

Depth scale (m): 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4, 1.6, 1.8, 2.0, 2.2, 2.4, 2.6, 2.8, 3.0, 3.2, 3.4, 3.6, 3.8, 4.0, 4.2, 4.4, 4.6, 4.8

Legend

Scala Penetrometer (Blows / 100mm): 2 4 6 8 10 12 14 16 18

Hand Shear Vane (Uncorrected)

Linked PointIDs

Water
- Standing Water Level
- Out flow
- In flow

Investigation Type
- ☐ Hand Auger
- ☑ Test Pit

Contractor:	Rig/Plant Used:	Logged By:	Checked By:	Hole Depth:
Downer	Komatsu PC130	CD	KB	1.40 m

INVESTIGATION LOG

DAMWATCH ENGINEERING BEYOND THE SURFACE
80 The Terrace
PO Box 1549
Wellington 6140
Ph:+64 4 381 1300

Job No.:	E2193
No.:	**TP02**
Sheet:	1 of 1
Date:	21/02/22

Client: Meridian	**Coordinates:** E 1,185,616.00 N 4,935,409.00	**Ground Level:** 178
Project: MLC Lower Waiau Arm Investigation	**Location:** Manapouri Lake Control	

Geological Interpretation
(refer to separate Geotechnical and Geological Information sheet for further information)

Geological Interpretation	Depth (m)	Water
SILT, some clay, some sand, minor gravel; dark brown. Firm to soft, moist. Sand is fine to coarse. Gravel is fine to coarse, rounded. Abundant roots and rootlets. (TOPSOIL)	0.0 – 0.2	
Gravelly fine to medium SAND, trace cobbles; grey. Loose, moist to wet. Gravel is fine to coarse, rounded to well rounded. Abundant roots and rootlets	0.2 – 1.2	IN 1.20m
Silty fine to coarse SAND; blue grey. Damp / organic smell to soil. Rubber bucket encountered. Likely old landfill (ANTHROPOMORPHIC FILL)	1.2 – 1.5	
PIT COLLAPSE EOH:1.5m		

Scala Penetrometer (Blows / 100mm): 2 4 6 8 10 12 14 16 18

Hand Shear Vane (Uncorrected)

Depth scale (m): 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4, 1.6, 1.8, 2.0, 2.2, 2.4, 2.6, 2.8, 3.0, 3.2, 3.4, 3.6, 3.8, 4.0, 4.2, 4.4, 4.6, 4.8

Linked PointIDs

Water
- Standing Water Level
- Out flow
- In flow

Investigation Type
- [ ] Hand Auger
- [x] Test Pit

Contractor:	Rig/Plant Used:	Logged By:	Checked By:	Hole Depth:
Downer	Komatsu PC130	CD	KB	1.50 m

INVESTIGATION LOG

DAMWATCH ENGINEERING BEYOND THE SURFACE
80 The Terrace
PO Box 1549
Wellington 6140
Ph:+64 4 381 1300

Job No.:	E2193
No.:	**TP03**
Sheet:	1 of 1
Date:	21/02/22

Client: Meridian	**Coordinates:** E 1,185,709.00 N 4,935,372.00	**Ground Level:** 178
Project: MLC Lower Waiau Arm Investigation	**Location:** Manapouri Lake Control	

Geological Interpretation (refer to separate Geotechnical and Geological Information sheet for further information)	Samples	Depth (m)	Legend	Scala Penetrometer (Blows / 100mm)	Hand Shear Vane (Uncorrected)	Water
Gravelly fine to coarse SAND, some cobbles; grey. Medium dense to loose, dry to moist. Gravels are fine to coarse, rounded, occasionally subangular, cobbles <200mm, sub-rounded. No apparent bedding. (ALLUVIAL GRAVELS)		0.0–1.5				IN 1.30m
PIT COLLAPSE EOH:1.5m		1.5				

Depth scale: 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4, 1.6, 1.8, 2.0, 2.2, 2.4, 2.6, 2.8, 3.0, 3.2, 3.4, 3.6, 3.8, 4.0, 4.2, 4.4, 4.6, 4.8

Scala scale: 2 4 6 8 10 12 14 16 18

Linked PointIDs

Water
Standing Water Level
Out flow
In flow

Investigation Type
☐ Hand Auger
☑ Test Pit

Contractor:	Rig/Plant Used:	Logged By:	Checked By:	Hole Depth:
Downer	Komatsu PC130	CD	KB	1.50 m

DAMWATCH
ENGINEERING BEYOND THE SURFACE

80 The Terrace
PO Box 1549
Wellington 6140

Ph:+64 4 381 1300

INVESTIGATION LOG

Job No.:	E2193
No.:	**TP04**
Sheet:	1 of 1
Date:	21/02/22

Client: Meridian	**Coordinates:** E 1,185,839.00 N 4,935,303.00	**Ground Level:** 178
Project: MLC Lower Waiau Arm Investigation	**Location:** Manapouri Lake Control	

Geological Interpretation (refer to separate Geotechnical and Geological Information sheet for further information)	**Samples**	**Depth (m)**	**Legend**	**Scala Penetrometer** (Blows / 100mm) 2 4 6 8 10 12 14 16 18	**Hand Shear Vane** (Uncorrected)	**Water**
Sandy fine to coarse GRAVEL, some cobbles, trace boulders, grey. Loose to medium dense, dry to moist. Gravel is well rounded to sub-rounded. Sand is fine to coarse. Cobbles are <200mm, well rounded. Boulders are granite, <400mm, rounded. Rootlets in surface 0.05m. (ALLUVIAL GRAVELS)	B	0.2 0.4 0.6 0.8 1.0 1.2				IN 1.00m
PIT COLLAPSE EOH:1.3m		1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0 3.2 3.4 3.6 3.8 4.0 4.2 4.4 4.6 4.8				

Linked PointIDs

Water	**Investigation Type**
▼ Standing Water Level	☐ Hand Auger
◁ Out flow	☑ Test Pit
▷ In flow	

Contractor:	**Rig/Plant Used:**	**Logged By:**	**Checked By:**	**Hole Depth:**
Downer	Komatsu PC130	CD	KB	1.30 m

80 The Terrace
PO Box 1549
Wellington 6140

Ph:+64 4 381 1300

INVESTIGATION LOG

Job No.:	E2193
No.:	TP05
Sheet:	1 of 1
Date:	21/02/22

Client: Meridian	**Coordinates:** E 1,186,172.00 N 4,935,115.00	**Ground Level:** 178
Project: MLC Lower Waiau Arm Investigation	**Location:** Manapouri Lake Control	

Geological Interpretation (refer to separate Geotechnical and Geological Information sheet for further information)	Samples	Depth (m)	Water
Gravelly SAND, some cobbles, grey. Loose, moist, some apparent sub-horizontal bedding. Rare brown silty CLAY lenses <20mm thick, predominantly (ALLUVIUM)		0.0–0.7	
Fine to coarse SAND, some gravels, trace cobbles, brown grey. Loose, moist to wet. Sub-horizontal upper and lower contacts. Gravel is fine to coarse, predominantly fine to medium, rounded to well rounded. (ALLUVIUM)	B	0.7–1.1	
Sandy fine to coarse GRAVELS, grey to brown grey. Loose. Gravel is well rounded to sub rounded. Sand is fine to coarse. (ALLUVIAL GRAVELS)	B	1.1–1.4	IN 1.20m
PIT COLLAPSE			
EOH:1.4m			

Depth scale (m): 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4, 1.6, 1.8, 2.0, 2.2, 2.4, 2.6, 2.8, 3.0, 3.2, 3.4, 3.6, 3.8, 4.0, 4.2, 4.4, 4.6, 4.8

Scala Penetrometer (Blows / 100mm): 2 4 6 8 10 12 14 16 18

Hand Shear Vane (Uncorrected)

Legend

Linked PointIDs

Water
- Standing Water Level
- Out flow
- In flow

Investigation Type
- ☐ Hand Auger
- ☑ Test Pit

Contractor:	Rig/Plant Used:	Logged By:	Checked By:	Hole Depth:
Downer	Komatsu PC130	CD	KB	1.40 m

DAMWATCH ENGINEERING BEYOND THE SURFACE
80 The Terrace
PO Box 1549
Wellington 6140
Ph:+64 4 381 1300

INVESTIGATION LOG

Job No.:	E2193
No.:	TP06
Sheet:	1 of 1
Date:	22/02/22

Client: Meridian	**Coordinates:** E 1,185,873.00 N 4,935,360.00	**Ground Level:** 180
Project: MLC Lower Waiau Arm Investigation	**Location:** Manapouri Lake Control	

Geological Interpretation (refer to separate Geotechnical and Geological Information sheet for further information)	Samples	Depth (m)	Legend	Scala Penetrometer (Blows / 100mm)	Hand Shear Vane (Uncorrected)	Water
Fine to coarse SAND & fine to medium GRAVEL (predominantly fine), grey. Well sorted, loose. Gravel is sub-rounded to rounded, uniformly graded. (ALLUVIUM) 0.6m: Occasional cobbles and boulders		0.0–1.5				
Clayey SILT, trace gravels, dark blue grey. Firm to stiff, moist, low plasticity. Gravels sub-angular to sub rounded, fine to medium. (ALLUVIUM)		1.5–1.8				
Gravelly SAND with minor cobbles and trace silt, mixed grey. Loose to medium dense. Sand is fin eto coarse and well graded. Gravel is fine to coarse, sub-rounded to rounded.(ALLUVIUM) 2.2m: Some cobbles, sub-rounded to sub-angular		1.8–2.9				
PIT COLLAPSE EOH:2.9m						Groundwater Not Encountered

Depth scale: 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4, 1.6, 1.8, 2.0, 2.2, 2.4, 2.6, 2.8, 3.0, 3.2, 3.4, 3.6, 3.8, 4.0, 4.2, 4.4, 4.6, 4.8

Scala Penetrometer scale: 2 4 6 8 10 12 14 16 18

Linked PointIDs

Water
- ▼ Standing Water Level
- ◁ Out flow
- ▷ In flow

Investigation Type
- ☐ Hand Auger
- ☑ Test Pit

Contractor:	Rig/Plant Used:	Logged By:	Checked By:	Hole Depth:
Downer	Komatsu PC130	CD	KB	2.85 m

DAMWATCH ENGINEERING BEYOND THE SURFACE

80 The Terrace
PO Box 1549
Wellington 6140

Ph:+64 4 381 1300

INVESTIGATION LOG

Job No.:	E2193
No.:	TP07
Sheet:	1 of 1
Date:	22/02/22

Client:	Coordinates:	Ground Level:
Meridian	E 1,185,628.00 N 4,935,261.00	190
Project:	**Location:**	
MLC Lower Waiau Arm Investigation	Manapouri Lake Control	

Geological Interpretation (refer to separate Geotechnical and Geological Information sheet for further information)	Samples	Depth (m)	Legend	Scala Penetrometer (Blows / 100mm)	Hand Shear Vane (Uncorrected)	Water
Sandy SILT, minor gravel, brown grey to grey brown. Firm to stiff, low plasticity, moist, abundant rootlets (TOPSOIL)						
SILT, some gravel, some sand, minor cobbles, brown grey to grey. Firm to stiff, friable, low to no plasticity. Gravels are fine to coarse, angular to rounded, occurring in sub-horizontal bands ~20cm thick. (MEMBER D)		0.2 – 1.2				
Clayey SILT, some sand, trace gravels, trace cobbles, grey to blue grey. Stiff to firm, slightly plastic, moist. Sands are fine to coarse. Gravels are fine to medium, well rounded, likely drop stones. Cobbles are well-rounded. (MEMBER E)		1.4 – 2.2				
Sandy SILT, minor clay, trace cobbles, trace boulders; brown. Soft to firm, low plasticity, friable. Sand is fine. (MEMBER E / F)		2.4 – 3.2				
MACHINE LIMIT — 3.3m: Band of cobbles and boulders. EOH:3.3m		3.4 – 4.8				Groundwater Not Encountered

Scala Penetrometer scale: 2 4 6 8 10 12 14 16 18

Linked PointIDs

Water
- Standing Water Level
- Out flow
- In flow

Investigation Type
- ☐ Hand Auger
- ☑ Test Pit

Contractor:	Rig/Plant Used:	Logged By:	Checked By:	Hole Depth:
Downer	Komatsu PC130	CD	KB	3.30 m

LWP landwaterpeople

INVESTIGATION LOG

DAMWATCH ENGINEERING BEYOND THE SURFACE
80 The Terrace
PO Box 1549
Wellington 6140
Ph:+64 4 381 1300

Job No.:	E2193
No.:	**TP08**
Sheet:	1 of 2
Date:	22/02/22

Client:	Coordinates:	Ground Level:
Meridian	E 1,185,700.00 N 4,935,207.00	190

Project:	Location:
MLC Lower Waiau Arm Investigation	Manapouri Lake Control

Geological Interpretation (refer to separate Geotechnical and Geological Information sheet for further information)	Samples	Depth (m)	Legend	Scala Penetrometer (Blows / 100mm)	Hand Shear Vane (Uncorrected)	Water
Sandy SILT, some gravels, grey brown. Firm to stiff, friable, dry to moist, abundant rootlets (TOPSOIL)		0.0–0.2				
SILT, some gravel, some sand, minor cobbles, minor boulders, brown grey. Loose / friable, dry. Gravels are fine to coarse, well rounded to sub-angular. Boulders are <450mm. Gravel band in middle of unit.)		0.2–0.9				
Clayey SILT, minor to trace sand, trace gravels, trace cobbles, blue grey. Stiff to firm, slightly to moderately plastic. Gravels coarse, well rounded. Cobbles well rounded. (MEMBER D)	B	0.9–3.0				
Fine to coarse SAND, some gravel to gravelly, minor silt, trace cobbles and boulders, grey. Gravel is fine to coarse, sub rounded to sub angular. Cobbles are sub-rounded. (MEMBER E/F)	B	3.0–3.8				
MACHINE LIMIT — 3.8m: End of pit - reaching limit of arm extension EOH:3.8m		3.8				Groundwater Not Encountered

Depth scale (m): 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4, 1.6, 1.8, 2.0, 2.2, 2.4, 2.6, 2.8, 3.0, 3.2, 3.4, 3.6, 3.8, 4.0, 4.2, 4.4, 4.6, 4.8

Scala Penetrometer scale: 2, 4, 6, 8, 10, 12, 14, 16, 18

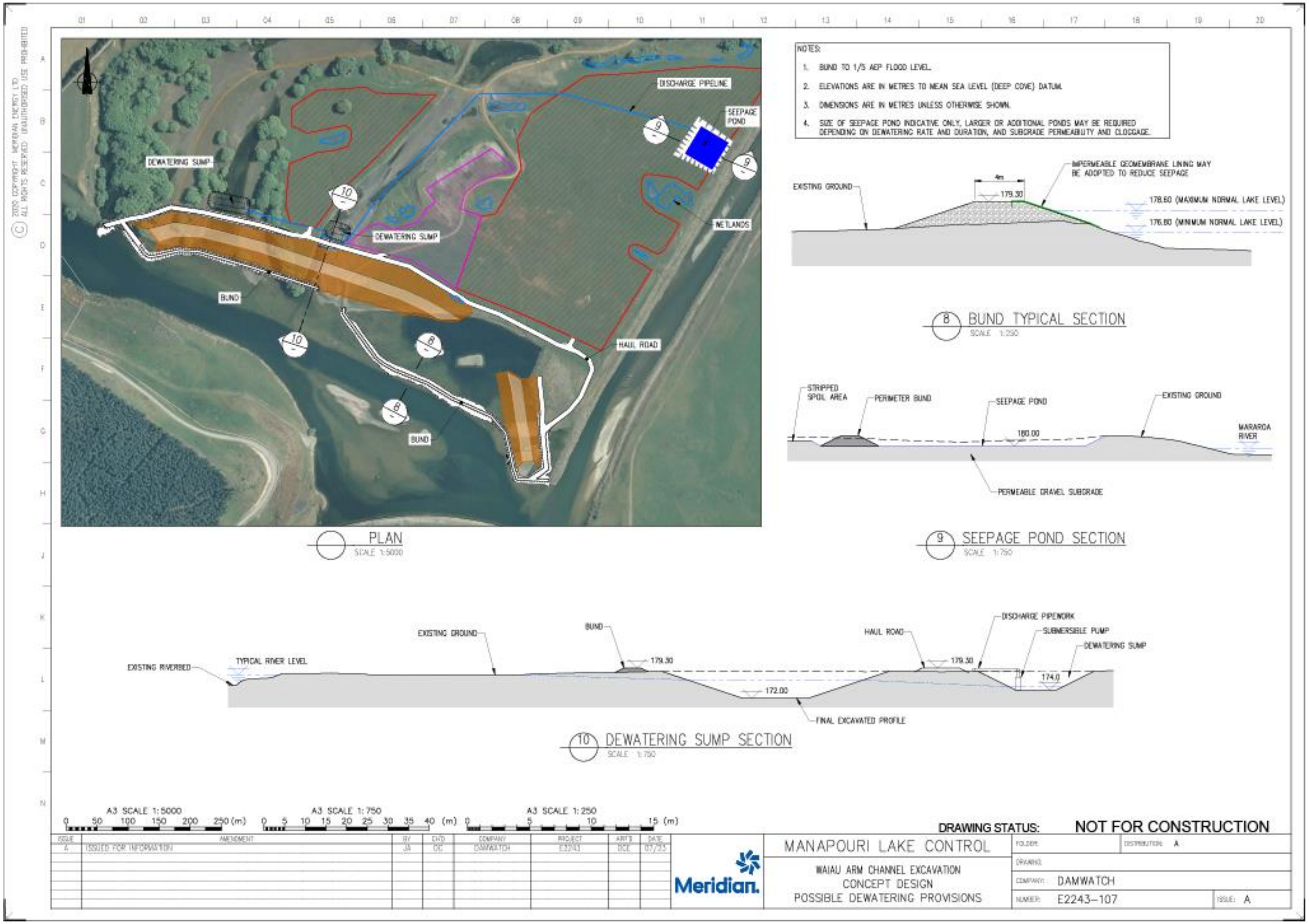
Linked PointIDs

Water
- Standing Water Level
- Out flow
- In flow

Investigation Type
- [ ] Hand Auger
- [x] Test Pit

Contractor:	Rig/Plant Used:	Logged By:	Checked By:	Hole Depth:
Downer	Komatsu PC130	CD	KB	3.80 m

Attachment 2 – Schematic Layout of Proposed Dewatering


NOTES:
1. BUND TO 1/5 AEP FLOOD LEVEL.
2. ELEVATIONS ARE IN METRES TO MEAN SEA LEVEL (DEEP COVE) DATUM.
3. DIMENSIONS ARE IN METRES UNLESS OTHERWISE SHOWN.
4. SIZE OF SEEPAGE POND INDICATIVE ONLY, LARGER OR ADDITIONAL PONDS MAY BE REQUIRED DEPENDING ON DEWATERING RATE AND DURATION, AND SUBGRADE PERMEABILITY AND CLOGGAGE.
DISCHARGE PIPELINE
SEEPAGE POND
DEWATERING SUMP
WETLANDS
BUND
HAUL ROAD
PLAN
SCALE 1:5000
EXISTING GROUND
IMPERMEABLE GEOMEMBRANE LINING MAY BE ADOPTED TO REDUCE SEEPAGE
4m
179.30
178.60 (MAXIMUM NORMAL LAKE LEVEL)
176.80 (MINIMUM NORMAL LAKE LEVEL)
8 BUND TYPICAL SECTION
SCALE 1:250
STRIPPED SPOIL AREA
PERIMETER BUND
SEEPAGE POND
EXISTING GROUND
180.00
MARAROA RIVER
PERMEABLE GRAVEL SUBGRADE
9 SEEPAGE POND SECTION
SCALE 1:750
EXISTING RIVERBED
TYPICAL RIVER LEVEL
EXISTING GROUND
BUND
179.30
172.00
HAUL ROAD
DISCHARGE PIPEWORK
SUBMERSIBLE PUMP
DEWATERING SUMP
174.0
FINAL EXCAVATED PROFILE
10 DEWATERING SUMP SECTION
SCALE 1:750
A3 SCALE 1:5000
A3 SCALE 1:750
A3 SCALE 1:250
DRAWING STATUS: NOT FOR CONSTRUCTION
ISSUE A ISSUED FOR INFORMATION
Meridian.
MANAPOURI LAKE CONTROL
WAIAU ARM CHANNEL EXCAVATION
CONCEPT DESIGN
POSSIBLE DEWATERING PROVISIONS
DISTRIBUTION: A
COMPANY: DAMWATCH
NUMBER: E2243-107
ISSUE: A

Attachment 3 – Dewatering Scenarios

Dewatering Scenario 1 - Figures indicate calculated drawdown (m) across a 10 x 10m grid. Red shading indicates simulated position of the dewatering sump, blue shading indicates extent of the parallel channel excavation, blue line indicates position of the Waiau Arm. Q = 220 L/s.

Direction x (m)

Direction y (m)	-300	-290	-280	-270	-260	-250	-240	-230	-220	-210	-200	-190	-180	-170	-160	-150	-140	-130	-120	-110	-100	-90	-80	-70	-60	-50	-40	-30	-20	-10	0	10
-100	1.72	1.80	1.88	1.96	2.04	2.12	2.19	2.27	2.33	2.37	2.39	2.38	2.35	2.29	2.21	2.10	1.97	1.84	1.69	1.54	1.39	1.24	1.09	0.94	0.79	0.63	0.48	0.33	0.18	0.04	0.00	0.00
-90	1.79	1.87	1.96	2.06	2.15	2.25	2.34	2.43	2.51	2.58	2.61	2.60	2.57	2.51	2.41	2.28	2.13	1.97	1.81	1.65	1.48	1.32	1.15	0.99	0.83	0.67	0.51	0.35	0.19	0.04	0.00	0.00
-80	1.85	1.95	2.05	2.16	2.26	2.38	2.49	2.60	2.71	2.81	2.88	2.91	2.87	2.78	2.64	2.47	2.30	2.12	1.93	1.75	1.57	1.39	1.21	1.04	0.87	0.70	0.53	0.37	0.20	0.04	0.00	0.00
-70	1.92	2.02	2.13	2.25	2.38	2.50	2.64	2.78	2.92	3.06	3.19	3.30	3.26	3.09	2.89	2.68	2.47	2.26	2.05	1.85	1.65	1.46	1.27	1.09	0.91	0.73	0.55	0.38	0.21	0.04	0.00	0.00
-60	1.98	2.09	2.21	2.34	2.48	2.63	2.79	2.96	3.14	3.33	3.53	3.75	3.71	3.43	3.16	2.89	2.64	2.40	2.17	1.95	1.73	1.53	1.33	1.13	0.94	0.76	0.58	0.39	0.22	0.04	0.00	0.00
-50	2.03	2.15	2.28	2.42	2.58	2.74	2.92	3.12	3.34	3.58	3.86	4.19	4.16	3.76	3.41	3.09	2.80	2.53	2.28	2.04	1.81	1.59	1.38	1.17	0.98	0.78	0.59	0.41	0.22	0.04	0.01	0.00
-40	2.08	2.20	2.34	2.49	2.66	2.84	3.04	3.26	3.52	3.80	4.14	4.56	4.53	4.04	3.63	3.27	2.94	2.65	2.37	2.12	1.87	1.64	1.42	1.21	1.00	0.81	0.61	0.42	0.23	0.04	0.01	0.00
-30	2.11	2.25	2.39	2.55	2.73	2.92	3.14	3.38	3.66	3.98	4.35	4.81	4.77	4.25	3.80	3.41	3.06	2.74	2.45	2.18	1.93	1.69	1.46	1.24	1.03	0.82	0.62	0.43	0.23	0.04	0.01	0.00
-20	2.14	2.28	2.43	2.60	2.78	2.98	3.21	3.47	3.76	4.09	4.48	4.94	4.90	4.37	3.91	3.51	3.14	2.81	2.51	2.23	1.96	1.72	1.48	1.26	1.04	0.84	0.63	0.43	0.24	0.04	0.01	0.00
-10	2.16	2.30	2.45	2.62	2.81	3.02	3.25	3.52	3.82	4.16	4.55	4.98	4.94	4.44	3.98	3.57	3.19	2.85	2.54	2.26	1.99	1.74	1.50	1.27	1.05	0.84	0.64	0.44	0.24	0.04	0.02	0.00
0	2.16	2.30	2.46	2.63	2.82	3.03	3.27	3.54	3.84	4.18	4.56	4.98	4.95	4.46	4.00	3.59	3.21	2.87	2.55	2.27	2.00	1.74	1.50	1.28	1.06	0.85	0.64	0.44	0.24	0.04	0.02	0.00
10	2.16	2.30	2.45	2.62	2.81	3.02	3.25	3.52	3.82	4.16	4.55	4.98	4.94	4.44	3.98	3.57	3.19	2.85	2.54	2.26	1.99	1.74	1.50	1.27	1.05	0.84	0.64	0.44	0.24	0.04	0.02	0.00
20	2.14	2.28	2.43	2.60	2.78	2.98	3.21	3.47	3.76	4.09	4.48	4.94	4.90	4.37	3.91	3.51	3.14	2.81	2.51	2.23	1.96	1.72	1.48	1.26	1.04	0.84	0.63	0.43	0.24	0.04	0.02	0.00
30	2.11	2.25	2.39	2.55	2.73	2.92	3.14	3.38	3.66	3.98	4.35	4.81	4.77	4.25	3.80	3.41	3.06	2.74	2.45	2.18	1.93	1.69	1.46	1.24	1.03	0.82	0.62	0.43	0.23	0.04	0.01	0.00
40	2.08	2.20	2.34	2.49	2.66	2.84	3.04	3.26	3.52	3.80	4.14	4.56	4.53	4.04	3.63	3.27	2.94	2.65	2.37	2.12	1.87	1.64	1.42	1.21	1.00	0.81	0.61	0.42	0.23	0.04	0.01	0.00
50	2.03	2.15	2.28	2.42	2.58	2.74	2.92	3.12	3.34	3.58	3.86	4.19	4.16	3.76	3.41	3.09	2.80	2.53	2.28	2.04	1.81	1.59	1.38	1.17	0.98	0.78	0.59	0.41	0.22	0.04	0.01	0.00
60	1.98	2.09	2.21	2.34	2.48	2.63	2.79	2.96	3.14	3.33	3.53	3.75	3.71	3.43	3.16	2.89	2.64	2.40	2.17	1.95	1.73	1.53	1.33	1.13	0.94	0.76	0.58	0.39	0.22	0.04	0.01	0.00
70	1.92	2.02	2.13	2.25	2.38	2.50	2.64	2.78	2.92	3.06	3.19	3.30	3.26	3.09	2.89	2.68	2.47	2.26	2.05	1.85	1.65	1.46	1.27	1.09	0.91	0.73	0.55	0.38	0.21	0.04	0.00	0.00
80	1.85	1.95	2.05	2.16	2.26	2.38	2.49	2.60	2.71	2.81	2.88	2.91	2.87	2.78	2.64	2.47	2.30	2.12	1.93	1.75	1.57	1.39	1.21	1.04	0.87	0.70	0.53	0.37	0.20	0.04	0.00	0.00
90	1.79	1.87	1.96	2.06	2.15	2.25	2.34	2.43	2.51	2.58	2.61	2.60	2.57	2.51	2.41	2.28	2.13	1.97	1.81	1.65	1.48	1.32	1.15	0.99	0.83	0.67	0.51	0.35	0.19	0.04	0.00	0.00
100	1.72	1.80	1.88	1.96	2.04	2.12	2.19	2.27	2.33	2.37	2.39	2.38	2.35	2.29	2.21	2.10	1.97	1.84	1.69	1.54	1.39	1.24	1.09	0.94	0.79	0.63	0.48	0.33	0.18	0.04	0.00	0.00

Direction y (m) \ Direction x (m)	-300	-290	-280	-270	-260	-250	-240	-230	-220	-210	-200	-190	-180	-170	-160	-150	-140	-130	-120	-110	-100	-90	-80	-70	-60	-50	-40	-30	-20	-10	0	10
-100	0.93	0.97	1.01	1.06	1.10	1.14	1.19	1.22	1.26	1.28	1.29	1.29	1.27	1.24	1.19	1.13	1.07	0.99	0.91	0.83	0.75	0.67	0.59	0.51	0.42	0.34	0.26	0.18	0.10	0.02	0.00	0.00
-90	0.97	1.01	1.06	1.11	1.16	1.21	1.26	1.31	1.36	1.39	1.41	1.41	1.39	1.36	1.30	1.23	1.15	1.07	0.98	0.89	0.80	0.71	0.62	0.53	0.45	0.36	0.27	0.19	0.10	0.02	0.00	0.00
-80	1.00	1.05	1.11	1.17	1.22	1.28	1.35	1.41	1.47	1.52	1.56	1.57	1.55	1.50	1.43	1.34	1.24	1.14	1.04	0.95	0.85	0.75	0.66	0.56	0.47	0.38	0.29	0.20	0.11	0.02	0.00	0.00
-70	1.04	1.09	1.15	1.22	1.28	1.35	1.43	1.50	1.58	1.66	1.73	1.78	1.76	1.67	1.56	1.45	1.34	1.22	1.11	1.00	0.89	0.79	0.69	0.59	0.49	0.39	0.30	0.21	0.11	0.02	0.00	0.00
-60	1.07	1.13	1.20	1.27	1.34	1.42	1.51	1.60	1.70	1.80	1.91	2.02	2.01	1.85	1.71	1.56	1.43	1.30	1.17	1.05	0.94	0.83	0.72	0.61	0.51	0.41	0.31	0.21	0.12	0.02	0.00	0.00
-50	1.10	1.16	1.23	1.31	1.39	1.48	1.58	1.69	1.80	1.94	2.09	2.27	2.25	2.03	1.84	1.67	1.51	1.37	1.23	1.10	0.98	0.86	0.75	0.63	0.53	0.42	0.32	0.22	0.12	0.02	0.00	0.00
-40	1.12	1.19	1.27	1.35	1.44	1.54	1.64	1.76	1.90	2.06	2.24	2.47	2.45	2.18	1.96	1.77	1.59	1.43	1.28	1.14	1.01	0.89	0.77	0.65	0.54	0.44	0.33	0.23	0.12	0.02	0.00	0.00
-30	1.14	1.21	1.29	1.38	1.47	1.58	1.70	1.83	1.98	2.15	2.35	2.60	2.58	2.29	2.05	1.84	1.65	1.48	1.32	1.18	1.04	0.91	0.79	0.67	0.56	0.44	0.34	0.23	0.13	0.02	0.01	0.00
-20	1.16	1.23	1.31	1.40	1.50	1.61	1.74	1.87	2.03	2.21	2.42	2.67	2.65	2.36	2.12	1.90	1.70	1.52	1.36	1.20	1.06	0.93	0.80	0.68	0.56	0.45	0.34	0.23	0.13	0.02	0.01	0.00
-10	1.17	1.24	1.33	1.42	1.52	1.63	1.76	1.90	2.06	2.25	2.46	2.69	2.67	2.40	2.15	1.93	1.73	1.54	1.37	1.22	1.07	0.94	0.81	0.69	0.57	0.46	0.35	0.24	0.13	0.02	0.01	0.00
0	1.17	1.25	1.33	1.42	1.52	1.64	1.77	1.91	2.08	2.26	2.47	2.69	2.67	2.41	2.16	1.94	1.73	1.55	1.38	1.22	1.08	0.94	0.81	0.69	0.57	0.46	0.35	0.24	0.13	0.02	0.01	0.00
10	1.17	1.24	1.33	1.42	1.52	1.63	1.76	1.90	2.06	2.25	2.46	2.69	2.67	2.40	2.15	1.93	1.73	1.54	1.37	1.22	1.07	0.94	0.81	0.69	0.57	0.46	0.35	0.24	0.13	0.02	0.01	0.00
20	1.16	1.23	1.31	1.40	1.50	1.61	1.74	1.87	2.03	2.21	2.42	2.67	2.65	2.36	2.12	1.90	1.70	1.52	1.36	1.20	1.06	0.93	0.80	0.68	0.56	0.45	0.34	0.23	0.13	0.02	0.01	0.00
30	1.14	1.21	1.29	1.38	1.47	1.58	1.70	1.83	1.98	2.15	2.35	2.60	2.58	2.29	2.05	1.84	1.65	1.48	1.32	1.18	1.04	0.91	0.79	0.67	0.56	0.44	0.34	0.23	0.13	0.02	0.01	0.00
40	1.12	1.19	1.27	1.35	1.44	1.54	1.64	1.76	1.90	2.06	2.24	2.47	2.45	2.18	1.96	1.77	1.59	1.43	1.28	1.14	1.01	0.89	0.77	0.65	0.54	0.44	0.33	0.23	0.12	0.02	0.00	0.00
50	1.10	1.16	1.23	1.31	1.39	1.48	1.58	1.69	1.80	1.94	2.09	2.27	2.25	2.03	1.84	1.67	1.51	1.37	1.23	1.10	0.98	0.86	0.75	0.63	0.53	0.42	0.32	0.22	0.12	0.02	0.00	0.00
60	1.07	1.13	1.20	1.27	1.34	1.42	1.51	1.60	1.70	1.80	1.91	2.02	2.01	1.85	1.71	1.56	1.43	1.30	1.17	1.05	0.94	0.83	0.72	0.61	0.51	0.41	0.31	0.21	0.12	0.02	0.00	0.00
70	1.04	1.09	1.15	1.22	1.28	1.35	1.43	1.50	1.58	1.66	1.73	1.78	1.76	1.67	1.56	1.45	1.34	1.22	1.11	1.00	0.89	0.79	0.69	0.59	0.49	0.39	0.30	0.21	0.11	0.02	0.00	0.00
80	1.00	1.05	1.11	1.17	1.22	1.28	1.35	1.41	1.47	1.52	1.56	1.57	1.55	1.50	1.43	1.34	1.24	1.14	1.04	0.95	0.85	0.75	0.66	0.56	0.47	0.38	0.29	0.20	0.11	0.02	0.00	0.00
90	0.97	1.01	1.06	1.11	1.16	1.21	1.26	1.31	1.36	1.39	1.41	1.41	1.39	1.36	1.30	1.23	1.15	1.07	0.98	0.89	0.80	0.71	0.62	0.53	0.45	0.36	0.27	0.19	0.10	0.02	0.00	0.00
100	0.93	0.97	1.01	1.06	1.10	1.14	1.19	1.22	1.26	1.28	1.29	1.29	1.27	1.24	1.19	1.13	1.07	0.99	0.91	0.83	0.75	0.67	0.59	0.51	0.42	0.34	0.26	0.18	0.10	0.02	0.00	0.00

Dewatering Scenario 2 - Figures indicate calculated drawdown (m) across a 10 x 10m grid. Red shading indicates simulated position of the dewatering sump, blue shading indicates extent of the parallel channel excavation, blue line indicates position of the Waiau Arm. Q = 120 L/s.

Attachment 4 – Groundwater Mounding Scenarios

Scenario 1 – 50 x 50 m pond, 1.4m mounding (= Mararoa River stage ~RL 178.6m)

Transient Groundwater Mounding within an Unconfined Aquifer

After Hunt (2012) using Function W_6

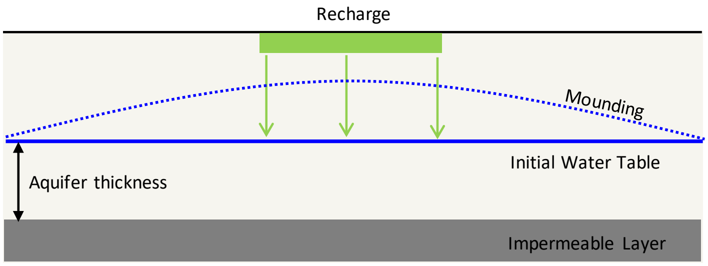
Aquifer thickness	B	6	m
Hydraulic conductivity	K	250	m/d
Transmissivity	T	1,500	m^2/d
Specific yield	Sy	0.15	-

T = KB

Constant average recharge volume	Q	4,550	m^3/d
Constant average recharge rate	R	1.820	m/d
Time since start of recharge	t	14	d

= 52.7 L/s

Width of recharge area in x direction	x_a	50	m
Width of recharge area in y direction	y_a	50	m
Total recharge area	A	2,500	m^2



x direction (m)

y direction (m)	-100	-90	-80	-70	-60	-50	-40	-30	-20	-10	0	10	20	30	40	50	60	70	80	90	100
-100	0.67	0.70	0.72	0.74	0.76	0.78	0.80	0.82	0.83	0.83	0.84	0.83	0.83	0.82	0.80	0.78	0.76	0.74	0.72	0.70	0.67
-90	0.70	0.72	0.75	0.77	0.80	0.82	0.84	0.86	0.87	0.88	0.89	0.88	0.87	0.86	0.84	0.82	0.80	0.77	0.75	0.72	0.70
-80	0.72	0.75	0.78	0.81	0.84	0.86	0.89	0.91	0.93	0.94	0.94	0.94	0.93	0.91	0.89	0.86	0.84	0.81	0.78	0.75	0.72
-70	0.74	0.77	0.81	0.84	0.87	0.91	0.94	0.97	0.99	1.00	1.01	1.00	0.99	0.97	0.94	0.91	0.87	0.84	0.81	0.77	0.74
-60	0.76	0.80	0.84	0.87	0.91	0.95	0.99	1.03	1.05	1.07	1.08	1.07	1.05	1.03	0.99	0.95	0.91	0.87	0.84	0.80	0.76
-50	0.78	0.82	0.86	0.91	0.95	1.00	1.05	1.09	1.13	1.16	1.17	1.16	1.13	1.09	1.05	1.00	0.95	0.91	0.86	0.82	0.78
-40	0.80	0.84	0.89	0.94	0.99	1.05	1.11	1.17	1.22	1.26	1.27	1.26	1.22	1.17	1.11	1.05	0.99	0.94	0.89	0.84	0.80
-30	0.82	0.86	0.91	0.97	1.03	1.09	1.17	1.25	1.33	1.38	1.40	1.38	1.33	1.25	1.17	1.09	1.03	0.97	0.91	0.86	0.82
-20	0.83	0.87	0.93	0.99	1.05	1.13	1.22	1.33	1.45	1.53	1.55	1.53	1.45	1.33	1.22	1.13	1.05	0.99	0.93	0.87	0.83
-10	0.83	0.88	0.94	1.00	1.07	1.16	1.26	1.38	1.53	1.62	1.65	1.62	1.53	1.38	1.26	1.16	1.07	1.00	0.94	0.88	0.83
0	0.84	0.89	0.94	1.01	1.08	1.17	1.27	1.40	1.55	1.65	1.68	1.65	1.55	1.40	1.27	1.17	1.08	1.01	0.94	0.89	0.84
10	0.83	0.88	0.94	1.00	1.07	1.16	1.26	1.38	1.53	1.62	1.65	1.62	1.53	1.38	1.26	1.16	1.07	1.00	0.94	0.88	0.83
20	0.83	0.87	0.93	0.99	1.05	1.13	1.22	1.33	1.45	1.53	1.55	1.53	1.45	1.33	1.22	1.13	1.05	0.99	0.93	0.87	0.83
30	0.82	0.86	0.91	0.97	1.03	1.09	1.17	1.25	1.33	1.38	1.40	1.38	1.33	1.25	1.17	1.09	1.03	0.97	0.91	0.86	0.82
40	0.80	0.84	0.89	0.94	0.99	1.05	1.11	1.17	1.22	1.26	1.27	1.26	1.22	1.17	1.11	1.05	0.99	0.94	0.89	0.84	0.80
50	0.78	0.82	0.86	0.91	0.95	1.00	1.05	1.09	1.13	1.16	1.17	1.16	1.13	1.09	1.05	1.00	0.95	0.91	0.86	0.82	0.78
60	0.76	0.80	0.84	0.87	0.91	0.95	0.99	1.03	1.05	1.07	1.08	1.07	1.05	1.03	0.99	0.95	0.91	0.87	0.84	0.80	0.76
70	0.74	0.77	0.81	0.84	0.87	0.91	0.94	0.97	0.99	1.00	1.01	1.00	0.99	0.97	0.94	0.91	0.87	0.84	0.81	0.77	0.74
80	0.72	0.75	0.78	0.81	0.84	0.86	0.89	0.91	0.93	0.94	0.94	0.94	0.93	0.91	0.89	0.86	0.84	0.81	0.78	0.75	0.72
90	0.70	0.72	0.75	0.77	0.80	0.82	0.84	0.86	0.87	0.88	0.89	0.88	0.87	0.86	0.84	0.82	0.80	0.77	0.75	0.72	0.70
100	0.67	0.70	0.72	0.74	0.76	0.78	0.80	0.82	0.83	0.83	0.84	0.83	0.83	0.82	0.80	0.78	0.76	0.74	0.72	0.70	0.67

References

Hunt, B. (2012). Groundwater analysis using Function.xls. Civil Engineering Department, Canterbury University.

Scenario 2 – 50 x 50 m pond, 3.0m mounding (= Mararoa River stage ~RL 177.0m)

Transient Groundwater Mounding within an Unconfined Aquifer

After Hunt (2012) using Function W_6

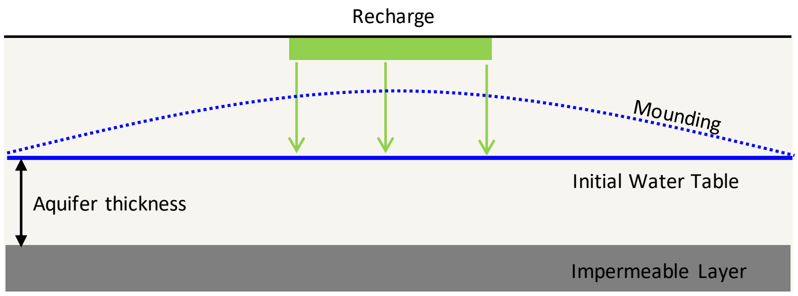
Aquifer thickness	B	6	m
Hydraulic conductivity	K	250	m/d
Transmissivity	T	1,500	m^2/d
Specific yield	Sy	0.15	-

T = KB

Constant average recharge volume	Q	9,750	m^3/d
Constant average recharge rate	R	3.900	m/d
Time since start of recharge	t	14	d

= 112.8 L/s

Width of recharge area in x direction	x_a	50	m
Width of recharge area in y direction	y_a	50	m
Total recharge area	A	2,500	m^2



x direction (m); y direction (m)

y \ x	-100	-90	-80	-70	-60	-50	-40	-30	-20	-10	0	10	20	30	40	50	60	70	80	90	100
-100	1.44	1.49	1.54	1.59	1.63	1.68	1.72	1.75	1.77	1.79	1.79	1.79	1.77	1.75	1.72	1.68	1.63	1.59	1.54	1.49	1.44
-90	1.49	1.55	1.60	1.66	1.71	1.76	1.81	1.84	1.87	1.89	1.90	1.89	1.87	1.84	1.81	1.76	1.71	1.66	1.60	1.55	1.49
-80	1.54	1.60	1.67	1.73	1.79	1.85	1.90	1.95	1.99	2.01	2.02	2.01	1.99	1.95	1.90	1.85	1.79	1.73	1.67	1.60	1.54
-70	1.59	1.66	1.73	1.80	1.87	1.94	2.01	2.07	2.11	2.14	2.15	2.14	2.11	2.07	2.01	1.94	1.87	1.80	1.73	1.66	1.59
-60	1.63	1.71	1.79	1.87	1.96	2.04	2.13	2.20	2.26	2.30	2.31	2.30	2.26	2.20	2.13	2.04	1.96	1.87	1.79	1.71	1.63
-50	1.68	1.76	1.85	1.94	2.04	2.15	2.25	2.34	2.42	2.48	2.50	2.48	2.42	2.34	2.25	2.15	2.04	1.94	1.85	1.76	1.68
-40	1.72	1.81	1.90	2.01	2.13	2.25	2.38	2.50	2.62	2.69	2.72	2.69	2.62	2.50	2.38	2.25	2.13	2.01	1.90	1.81	1.72
-30	1.75	1.84	1.95	2.07	2.20	2.34	2.50	2.68	2.85	2.96	3.00	2.96	2.85	2.68	2.50	2.34	2.20	2.07	1.95	1.84	1.75
-20	1.77	1.87	1.99	2.11	2.26	2.42	2.62	2.85	3.11	3.27	3.33	3.27	3.11	2.85	2.62	2.42	2.26	2.11	1.99	1.87	1.77
-10	1.79	1.89	2.01	2.14	2.30	2.48	2.69	2.96	3.27	3.47	3.53	3.47	3.27	2.96	2.69	2.48	2.30	2.14	2.01	1.89	1.79
0	1.79	1.90	2.02	2.15	2.31	2.50	2.72	3.00	3.33	3.53	3.59	3.53	3.33	3.00	2.72	2.50	2.31	2.15	2.02	1.90	1.79
10	1.79	1.89	2.01	2.14	2.30	2.48	2.69	2.96	3.27	3.47	3.53	3.47	3.27	2.96	2.69	2.48	2.30	2.14	2.01	1.89	1.79
20	1.77	1.87	1.99	2.11	2.26	2.42	2.62	2.85	3.11	3.27	3.33	3.27	3.11	2.85	2.62	2.42	2.26	2.11	1.99	1.87	1.77
30	1.75	1.84	1.95	2.07	2.20	2.34	2.50	2.68	2.85	2.96	3.00	2.96	2.85	2.68	2.50	2.34	2.20	2.07	1.95	1.84	1.75
40	1.72	1.81	1.90	2.01	2.13	2.25	2.38	2.50	2.62	2.69	2.72	2.69	2.62	2.50	2.38	2.25	2.13	2.01	1.90	1.81	1.72
50	1.68	1.76	1.85	1.94	2.04	2.15	2.25	2.34	2.42	2.48	2.50	2.48	2.42	2.34	2.25	2.15	2.04	1.94	1.85	1.76	1.68
60	1.63	1.71	1.79	1.87	1.96	2.04	2.13	2.20	2.26	2.30	2.31	2.30	2.26	2.20	2.13	2.04	1.96	1.87	1.79	1.71	1.63
70	1.59	1.66	1.73	1.80	1.87	1.94	2.01	2.07	2.11	2.14	2.15	2.14	2.11	2.07	2.01	1.94	1.87	1.80	1.73	1.66	1.59
80	1.54	1.60	1.67	1.73	1.79	1.85	1.90	1.95	1.99	2.01	2.02	2.01	1.99	1.95	1.90	1.85	1.79	1.73	1.67	1.60	1.54
90	1.49	1.55	1.60	1.66	1.71	1.76	1.81	1.84	1.87	1.89	1.90	1.89	1.87	1.84	1.81	1.76	1.71	1.66	1.60	1.55	1.49
100	1.44	1.49	1.54	1.59	1.63	1.68	1.72	1.75	1.77	1.79	1.79	1.79	1.77	1.75	1.72	1.68	1.63	1.59	1.54	1.49	1.44

References

Hunt, B. (2012). Groundwater analysis using Function.xls. Civil Engineering Department, Canterbury University.

Scenario 3 – 100 x 100 m pond, 1.4m mounding (= Mararoa River stage ~RL 178.6m)

Transient Groundwater Mounding within an Unconfined Aquifer

After Hunt (2012) using Function W_6

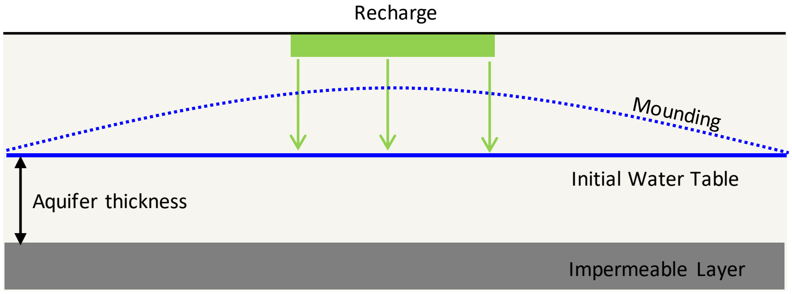
Aquifer thickness	B	6	m
Hydraulic conductivity	K	250	m/d
Transmissivity	T	1,500	m^2/d
Specific yield	Sy	0.15	-

T = KB

Constant average recharge volume	Q	5,600	m^3/d
Constant average recharge rate	R	0.560	m/d
Time since start of recharge	t	14	d

= 64.8 L/s

Width of recharge area in x direction	x_a	100	m
Width of recharge area in y direction	y_a	100	m
Total recharge area	A	10,000	m^2



x direction (m); y direction (m)

y \ x	-100	-90	-80	-70	-60	-50	-40	-30	-20	-10	0	10	20	30	40	50	60	70	80	90	100
-100	0.83	0.86	0.89	0.91	0.94	0.96	0.99	1.00	1.02	1.02	1.03	1.02	1.02	1.00	0.99	0.96	0.94	0.91	0.89	0.86	0.83
-90	0.86	0.89	0.92	0.95	0.98	1.01	1.04	1.06	1.07	1.08	1.09	1.08	1.07	1.06	1.04	1.01	0.98	0.95	0.92	0.89	0.86
-80	0.89	0.92	0.96	1.00	1.03	1.07	1.10	1.12	1.14	1.15	1.15	1.15	1.14	1.12	1.10	1.07	1.03	1.00	0.96	0.92	0.89
-70	0.91	0.95	1.00	1.04	1.08	1.12	1.16	1.19	1.21	1.22	1.23	1.22	1.21	1.19	1.16	1.12	1.08	1.04	1.00	0.95	0.91
-60	0.94	0.98	1.03	1.08	1.13	1.18	1.23	1.26	1.29	1.31	1.31	1.31	1.29	1.26	1.23	1.18	1.13	1.08	1.03	0.98	0.94
-50	0.96	1.01	1.07	1.12	1.18	1.25	1.30	1.35	1.38	1.40	1.41	1.40	1.38	1.35	1.30	1.25	1.18	1.12	1.07	1.01	0.96
-40	0.99	1.04	1.10	1.16	1.23	1.30	1.38	1.43	1.47	1.49	1.50	1.49	1.47	1.43	1.38	1.30	1.23	1.16	1.10	1.04	0.99
-30	1.00	1.06	1.12	1.19	1.26	1.35	1.43	1.49	1.54	1.56	1.57	1.56	1.54	1.49	1.43	1.35	1.26	1.19	1.12	1.06	1.00
-20	1.02	1.07	1.14	1.21	1.29	1.38	1.47	1.54	1.58	1.61	1.62	1.61	1.58	1.54	1.47	1.38	1.29	1.21	1.14	1.07	1.02
-10	1.02	1.08	1.15	1.22	1.31	1.40	1.49	1.56	1.61	1.64	1.64	1.64	1.61	1.56	1.49	1.40	1.31	1.22	1.15	1.08	1.02
0	1.03	1.09	1.15	1.23	1.31	1.41	1.50	1.57	1.62	1.64	1.65	1.64	1.62	1.57	1.50	1.41	1.31	1.23	1.15	1.09	1.03
10	1.02	1.08	1.15	1.22	1.31	1.40	1.49	1.56	1.61	1.64	1.64	1.64	1.61	1.56	1.49	1.40	1.31	1.22	1.15	1.08	1.02
20	1.02	1.07	1.14	1.21	1.29	1.38	1.47	1.54	1.58	1.61	1.62	1.61	1.58	1.54	1.47	1.38	1.29	1.21	1.14	1.07	1.02
30	1.00	1.06	1.12	1.19	1.26	1.35	1.43	1.49	1.54	1.56	1.57	1.56	1.54	1.49	1.43	1.35	1.26	1.19	1.12	1.06	1.00
40	0.99	1.04	1.10	1.16	1.23	1.30	1.38	1.43	1.47	1.49	1.50	1.49	1.47	1.43	1.38	1.30	1.23	1.16	1.10	1.04	0.99
50	0.96	1.01	1.07	1.12	1.18	1.25	1.30	1.35	1.38	1.40	1.41	1.40	1.38	1.35	1.30	1.25	1.18	1.12	1.07	1.01	0.96
60	0.94	0.98	1.03	1.08	1.13	1.18	1.23	1.26	1.29	1.31	1.31	1.31	1.29	1.26	1.23	1.18	1.13	1.08	1.03	0.98	0.94
70	0.91	0.95	1.00	1.04	1.08	1.12	1.16	1.19	1.21	1.22	1.23	1.22	1.21	1.19	1.16	1.12	1.08	1.04	1.00	0.95	0.91
80	0.89	0.92	0.96	1.00	1.03	1.07	1.10	1.12	1.14	1.15	1.15	1.15	1.14	1.12	1.10	1.07	1.03	1.00	0.96	0.92	0.89
90	0.86	0.89	0.92	0.95	0.98	1.01	1.04	1.06	1.07	1.08	1.09	1.08	1.07	1.06	1.04	1.01	0.98	0.95	0.92	0.89	0.86
100	0.83	0.86	0.89	0.91	0.94	0.96	0.99	1.00	1.02	1.02	1.03	1.02	1.02	1.00	0.99	0.96	0.94	0.91	0.89	0.86	0.83

References

Hunt, B. (2012). Groundwater analysis using Function.xls. Civil Engineering Department, Canterbury University.

Scenario 4 – 100 x 100 m pond, 3.0m mounding (= Mararoa River stage ~RL 177.0m)

Transient Groundwater Mounding within an Unconfined Aquifer

After Hunt (2012) using Function W_6

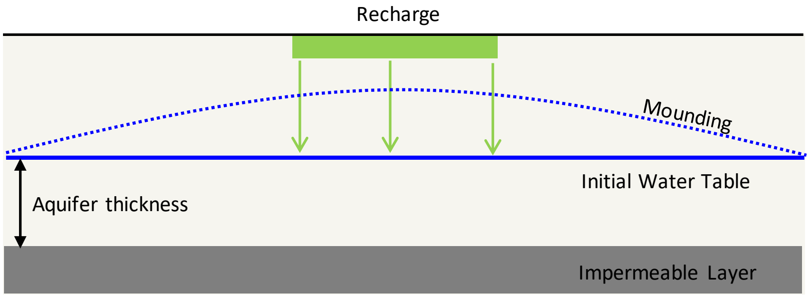
Aquifer thickness	B	6	m
Hydraulic conductivity	K	250	m/d
Transmissivity	T	1,500	m^2/d
Specific yield	Sy	0.15	-

T = KB

Constant average recharge volume	Q	12,000	m^3/d
Constant average recharge rate	R	1.200	m/d
Time since start of recharge	t	14	d

= 138.9 L/s

Width of recharge area in x direction	x_a	100	m
Width of recharge area in y direction	y_a	100	m
Total recharge area	A	10,000	m^2



x direction (m)

y direction (m)	-100	-90	-80	-70	-60	-50	-40	-30	-20	-10	0	10	20	30	40	50	60	70	80	90	100
-100	1.78	1.84	1.90	1.96	2.02	2.07	2.11	2.15	2.18	2.19	2.20	2.19	2.18	2.15	2.11	2.07	2.02	1.96	1.90	1.84	1.78
-90	1.84	1.91	1.98	2.04	2.11	2.17	2.22	2.27	2.30	2.32	2.33	2.32	2.30	2.27	2.22	2.17	2.11	2.04	1.98	1.91	1.84
-80	1.90	1.98	2.05	2.13	2.21	2.28	2.35	2.40	2.44	2.47	2.47	2.47	2.44	2.40	2.35	2.28	2.21	2.13	2.05	1.98	1.90
-70	1.96	2.04	2.13	2.22	2.31	2.40	2.48	2.55	2.59	2.62	2.63	2.62	2.59	2.55	2.48	2.40	2.31	2.22	2.13	2.04	1.96
-60	2.02	2.11	2.21	2.31	2.42	2.53	2.63	2.71	2.77	2.80	2.82	2.80	2.77	2.71	2.63	2.53	2.42	2.31	2.21	2.11	2.02
-50	2.07	2.17	2.28	2.40	2.53	2.67	2.80	2.90	2.97	3.01	3.02	3.01	2.97	2.90	2.80	2.67	2.53	2.40	2.28	2.17	2.07
-40	2.11	2.22	2.35	2.48	2.63	2.80	2.95	3.07	3.15	3.20	3.22	3.20	3.15	3.07	2.95	2.80	2.63	2.48	2.35	2.22	2.11
-30	2.15	2.27	2.40	2.55	2.71	2.90	3.07	3.20	3.29	3.34	3.36	3.34	3.29	3.20	3.07	2.90	2.71	2.55	2.40	2.27	2.15
-20	2.18	2.30	2.44	2.59	2.77	2.97	3.15	3.29	3.39	3.45	3.46	3.45	3.39	3.29	3.15	2.97	2.77	2.59	2.44	2.30	2.18
-10	2.19	2.32	2.47	2.62	2.80	3.01	3.20	3.34	3.45	3.50	3.52	3.50	3.45	3.34	3.20	3.01	2.80	2.62	2.47	2.32	2.19
0	2.20	2.33	2.47	2.63	2.82	3.02	3.22	3.36	3.46	3.52	3.54	3.52	3.46	3.36	3.22	3.02	2.82	2.63	2.47	2.33	2.20
10	2.19	2.32	2.47	2.62	2.80	3.01	3.20	3.34	3.45	3.50	3.52	3.50	3.45	3.34	3.20	3.01	2.80	2.62	2.47	2.32	2.19
20	2.18	2.30	2.44	2.59	2.77	2.97	3.15	3.29	3.39	3.45	3.46	3.45	3.39	3.29	3.15	2.97	2.77	2.59	2.44	2.30	2.18
30	2.15	2.27	2.40	2.55	2.71	2.90	3.07	3.20	3.29	3.34	3.36	3.34	3.29	3.20	3.07	2.90	2.71	2.55	2.40	2.27	2.15
40	2.11	2.22	2.35	2.48	2.63	2.80	2.95	3.07	3.15	3.20	3.22	3.20	3.15	3.07	2.95	2.80	2.63	2.48	2.35	2.22	2.11
50	2.07	2.17	2.28	2.40	2.53	2.67	2.80	2.90	2.97	3.01	3.02	3.01	2.97	2.90	2.80	2.67	2.53	2.40	2.28	2.17	2.07
60	2.02	2.11	2.21	2.31	2.42	2.53	2.63	2.71	2.77	2.80	2.82	2.80	2.77	2.71	2.63	2.53	2.42	2.31	2.21	2.11	2.02
70	1.96	2.04	2.13	2.22	2.31	2.40	2.48	2.55	2.59	2.62	2.63	2.62	2.59	2.55	2.48	2.40	2.31	2.22	2.13	2.04	1.96
80	1.90	1.98	2.05	2.13	2.21	2.28	2.35	2.40	2.44	2.47	2.47	2.47	2.44	2.40	2.35	2.28	2.21	2.13	2.05	1.98	1.90
90	1.84	1.91	1.98	2.04	2.11	2.17	2.22	2.27	2.30	2.32	2.33	2.32	2.30	2.27	2.22	2.17	2.11	2.04	1.98	1.91	1.84
100	1.78	1.84	1.90	1.96	2.02	2.07	2.11	2.15	2.18	2.19	2.20	2.19	2.18	2.15	2.11	2.07	2.02	1.96	1.90	1.84	1.78

References

Hunt, B. (2012). Groundwater analysis using Function.xls. Civil Engineering Department, Canterbury University.