IN THE MATTER	of the Resource Management Act 1991
AND	
IN THE MATTER	of an application by Meridian Energy Limited for the resource consents related to the construction of a new channel to enable a permanent diversion of part of the flow of the Waiau Arm and the associated removal of bed material and gravels, together with any maintenance and ancillary activities.

STATEMENT OF EVIDENCE IN CHIEF OF DR DOUGAL CLUNIE

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INTRODUCTION

1. My full name is Thomas MacDougal (Dougal) Clunie, and I am an Associate Principal Engineer at Damwatch Engineering Ltd, and Technical Director of Hydropower/Hydraulics at AusHydro.

2. I hold the qualifications of Bachelor of Engineering (1st Class Honours) in Civil Engineering and PhD (Civil Engineering) from the University of Auckland. I am a member of Engineering New Zealand.

3. I have over 17 years of experience in the civil engineering industry as an engineering consultant. My work has primarily been for hydropower clients, providing engineering advice, analysis, design and planning for the development of new assets and for the maintenance, rehabilitation or improvement of existing assets. I have experience in the design and analysis of hydraulic structures in river systems, including planning of construction around hydrological and other risks.

4. I have carried out hydraulic modelling (1D, 2D and 3D computational modelling and physical scale modelling) for the design or analysis of intakes, conveyance channels, spillways, energy dissipation structures, reservoirs and dam break flood waves. An example of my project experience is the hydraulic design of the Don Sahong Hydropower Project in Laos from 2009 to 2014, which involved various iterations of computational modelling to define available river flows, sedimentation potential, and the design of some 2.8 million cubic metres of rock excavation for the headpond inlet. The project was constructed from 2016 to 2020 and is successfully diverting up to 1600 m^3/s of water for the production of electricity.

5. I confirm that I prepared the Construction Planning – Proposed Methodology (which I will refer to as the **Construction Methodology Report** or **my Report**) attached as Appendix C to Meridian Energy Limited's (**Meridian's**) resource consent applications for the Manapouri Lake Control Structure Improvement Project (**MLC:IP** or **the Project**).

6. I confirm that I have read the following draft statements in preparing my evidence:

   (a) Mr Andrew Feierabend (Meridian);

   (b) Mr Daniel Murray (Tonkin & Taylor);

(c) Dr Jo Hoyle (NIWA);

(d) Dr Mike Hickford (NIWA); and

(e) Dr Kristy Hogsden (NIWA).

7. A description of the Waiau Arm and Manapōuri Lake Control Structure (**MLC**) and their role in the operation of the Manapōuri Power Scheme (**MPS**) is contained in Section 1 of the Assessment of Effects on the Environment (**AEE**) and in Mr Feierabend's evidence, and only pertinent details are described here.

CODE OF CONDUCT

8. Although this is not an Environment Court hearing, I confirm that I have read the 'Code of Conduct for Expert Witnesses' contained in the Environment Court Consolidated Practice Note 2023. I agree to comply with this Code of Conduct. In particular, unless I state otherwise, this evidence is within my sphere of expertise, and I have not omitted to consider material facts known to me that might alter or detract from the opinions I express.

SCOPE OF EVIDENCE

9. My statement of evidence relates to the design of the proposed works for the MLC:IP and the construction methodology developed to undertake the works, including hydraulic modelling which has been done and the trial excavations undertaken in 2023 to inform the channel design.

10. In my evidence I will:

(a) Describe the existing configuration of the Waiau Arm, its hydraulic behaviour and what is needed to successfully pass flows through the MLC (i.e., the existing constraint);

(b) Explain the purpose, methodology and results of the hydraulic modelling which has been undertaken to understand the existing constraints, and to evaluate the increase in reliability from different channel design options;

(c) Explain how the proposed parallel channel option was identified as preferred, through multi-disciplinary workshops and as a result of the trial undertaken in 2023;

(d) Describe the design and key features of the proposed parallel channel;

(e) Describe the Project site and its key features, including the construction footprint, the spoil disposal area, and the contractor's establishment area;

(f) Describe the construction methodology for the MLC:IP, including measures which I have recommended to avoid, remedy or mitigate effects during construction;

(g) Describe the hydrology of the area, and how hydrological effects on the Project will be managed through the construction methodology;

(h) Comment on issues raised by submitters;

(i) Respond to issues in the Officers' Report; and

(j) Provide my conclusions.

SUMMARY

11. The Manapōuri Lake Control structure is a gated structure which controls the rate of flow released from Lake Manapōuri and the Mararoa River into the Lower Waiau River (**LWR**) downstream. Upstream of MLC, over the 1 km reach where the Mararoa River has historically joined the Waiau River (the 'Mararoa Delta'), the Waiau Arm is significantly shallower than the remaining 9 km upstream to Lake Manapōuri. As noted below, this shallow stretch has been found to present a constraint to releasing flows across the MLC.

12. Operational experience of releasing flushing flows into the LWR is that the Lake Manapōuri level needs to be above RL 177.7 m to release a flow of 160 m^3/s from MLC.

13. I investigated the constraint on flow releases across the MLC using a one-dimensional computational hydraulic model. Model results confirmed that when Lake Manapōuri lake levels are low, the Waiau Arm and MLC system do not have the

conveyance capacity to pass the flushing flows that are described in the protocol addressed in Mr Feierabend's evidence, and that energy losses through the shallow Mararoa Delta area are a key part of the conveyance capacity constraint.

14. Excavation of a larger flow area through the Mararoa Delta will increase the conveyance capacity, and thus reliability to be able to release flushing flows through the MLC. Based on modelled scenarios, excavation of a channel to a base elevation of RL 172.0 m was selected as the best balance between volume and cost of excavation and benefit in terms of the ability to release flushing flows at a wider range of lake conditions.

15. Alternative technologies and methodologies to achieve an enlarged flow area through the Mararoa Delta were considered and evaluated by Damwatch engineers, Meridian experts and other external experts in workshop settings. To provide further information on the viability of the different excavation methodologies that were being considered, an instream trial excavation programme was carried out. The trial excavations confirmed a variable channel substrate, and the generation of significant amounts of suspended sediment from in-channel bund construction and excavation.

16. These outcomes led to the preference for a parallel channel excavation arrangement, with the bulk of excavation completed outside the flowing river and instream works minimised, to minimise the potential for suspended sediment release into the LWR.

17. The proposed channel alignment is along the true-left bank of the current Waiau Arm, through an area that the Mararoa River historically occupied, extending from the deeper reach of the Waiau Arm to the present-day confluence of the Waiau Arm and Mararoa River, immediately upstream of the MLC gates. The proposed channel has a constant trapezoidal cross-section, with a 16 m base at elevation RL 172.00 m and 1V:3H side slopes.

18. I developed a conceptual construction methodology and programme for the project, presented in the Construction Methodology Report. The general arrangement of the project site includes the Excavation Footprint, a Spoil Disposal Area, a Contractor's Establishment Area, a Haul Road connecting these areas and Flood Protection Bunds to isolate the Excavation Footprint (Stages 1 and 2) from the Waiau Arm.

19. The excavation is conceptually separated into three stages, with the first two stages encompassing some 85% of the total excavation volume able to be completed remote from the Waiau Arm channel.

20. I anticipate a total on-site construction programme of approximately 19 weeks, assuming normal hydrological conditions.

21. The designed channel is expected to be stable across the range of flows that are passed through the Waiau Arm. Future maintenance requirements for the channel are expected to be limited to the removal of gravels transported by Mararoa River flows and deposited in the area immediately upstream of MLC gates and around the Waiau Arm confluence with the Mararoa River.

22. In reading this evidence, reference should be made to the Construction Methodology Report, including appended drawings E2243-101 to -109.

MY INVOLVEMENT WITH THE MLC:IP PROJECT

23. I began working on the project in March 2021, when Damwatch was engaged by Meridian to undertake computational hydraulic modelling to investigate the constraint on flushing flow releases from MLC at low lake levels. This modelling demonstrated that channel excavation works in the Waiau Arm through the Mararoa Delta area could improve the ability to release greater flow rates through the MLC when the lake is in the lower part of its operating range.

    a. I was subsequently involved in evaluating different construction methodologies to achieve an excavated channel profile through the Mararoa Delta area, including workshop discussions with Meridian and other technical advisors.

24. I assisted in planning and supervising trial investigations, involving excavation at three pilot locations within the Waiau Arm channel, to better understand the channel substrate material and the potential for suspended sediment generation from in-river excavation.

25. I developed two channel excavation arrangements (an instream option and a parallel option), and conceptual construction methodologies for each, and then participated in further workshops in which the alternative arrangement options and methodologies were considered and assessed in terms of potential effects and risks.

As a result of this process, the parallel channel option was identified and agreed as preferred.

26. I prepared the Construction Methodology Report, included as Appendix C to the AEE, and have been involved in the preparation of draft technical specifications for the construction of the Project works.

PROPOSED CHANNEL IMPROVEMENT

27. The MLC:IP involves the construction of an additional deeper channel in the Waiau Arm through the Mararoa Delta area, parallel to the existing channel. The new channel will increase the available flow area through this reach, reducing the existing hydraulic constraint to passing flows across the MLC, particularly at times when the water level in Lake Manapōuri and the Waiau Arm is lower. The channel arrangement and construction methodology have been refined through modelling, desktop studies, on-site investigations and trial excavations. This iterative process has involved the development and discussion of alternative options at multi-disciplinary workshops, with these options described in more detail in the evidence of Mr Feierabend. As a result, the parallel channel has been selected as the option that minimises the duration and extent of in-stream works, and so minimises the potential for the discharge of sediment into the LWR.

28. The new channel will have a constant trapezoidal cross-section, with a 16 m base at elevation RL 172.00 m and 1V:3H side slopes. The proposed channel will extend from the deeper reach of the Waiau Arm to the present-day confluence of the Waiau Arm and Mararoa River, immediately upstream of the MLC gates.

29. The proposed channel alignment is along the true-left bank of the current Waiau Arm, through an area that the Mararoa River historically occupied, and including areas which were modified during the 1970s, including by construction of the Mararoa River diversion and the MLC approach channel.

30. The proposed channel alignment (outline showing the approximate water surface when completed) is shown in Figure 1.

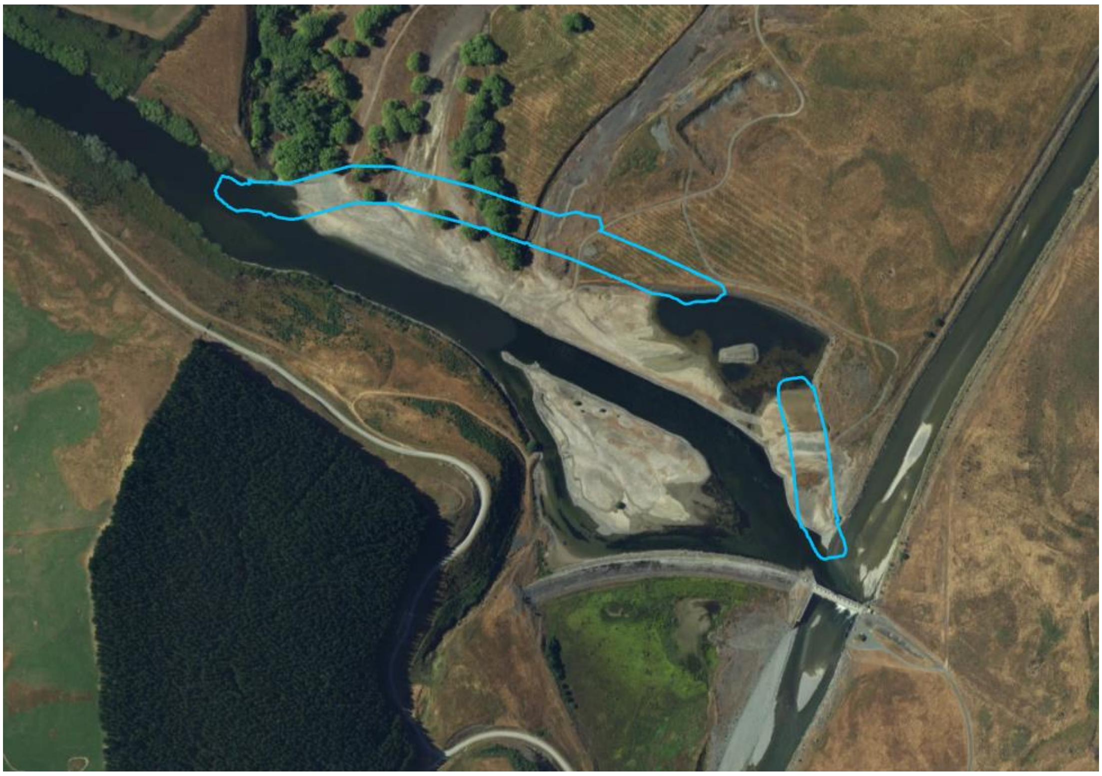


Figure 1: Proposed channel excavation alignment

EXISTING CONFIGURATION OF THE WAIAU ARM AND CONSTRAINT ON MLC DISCHARGE

31. The Waiau River is the natural outlet of Lake Manapōuri. The MLC was constructed across the Waiau River valley in the mid-1970s, downstream of the Mararoa River confluence.

32. The MLC comprises a dam, including a 400 m long overtoppable section and four radial gates which control the rate of flow released to the LWR downstream. The MLC is designed to:

   (a) Control the level of Lake Manapōuri within the range prescribed by guidelines and manage the release of flows down the LWR;

   (b) Divert water from the Mararoa River into Lake Manapōuri, when Mararoa flow is not discoloured by high levels of suspended sediment; and

   (c) Allow floodwaters from Lake Manapōuri and the Mararoa River, that cannot be utilised for generation or stored, to be safely spilled into the LWR.

33. The Mararoa River transports alluvial sediments (sands and gravels), which historically deposited in the Mararoa Delta area. Deposition rates likely increased following MLC construction, due to tranquil flow areas formed by the excavated gate approach channel and by MLC operations holding Waiau Arm levels higher. To preserve the ability to release flow from the MLC at low lake levels, excavation works to realign the Mararoa River were undertaken in 1987, and excavation works to widen and deepen the Waiau Arm channel through the Mararoa Delta were undertaken in 1999 and 2007.

34. The Waiau Arm is the arm of Lake Manapōuri upstream of the MLC. The flow rate in the Waiau Arm is determined by the Mararoa River inflow rate and the MLC discharge. Flow in the arm can be in either direction, from the Mararoa River into Lake Manapōuri, or from Lake Manapōuri out through the MLC to the LWR.

35. The water level in the Waiau Arm reflects the Lake Manapōuri level adjusted for the energy loss of the relevant driving flows, i.e., when Lake Manapōuri water is flowing toward MLC, the Waiau Arm level near the MLC is slightly lower than water level in the main body of the lake.

36. The discharge capacity of the MLC gates is dependent on the water level immediately upstream of the gates, which is a function of both lake level and the flow rate in the Waiau Arm.

37. Flows in the Waiau Arm to MLC pass through the shallow ‘Mararoa Delta’, the 1 km reach over which the Mararoa River historically joined the Waiau. The Mararoa Delta is significantly shallower than the remaining 9 km of the Waiau Arm between the ‘Mararoa Delta’ and the main body of the lake (generally 2 to 4 m deep depending on lake level vs generally 7 to 10 m deep). Much higher energy losses occur in the relatively swift shallow flows through this reach compared to slower deeper flows upstream.

38. Therefore, at lake levels in the lower part of the control range, energy losses through the shallow channel in the Mararoa Delta currently constrain the maximum flow rate that can be released from the MLC. Operational experience when releasing flushing flows into the LWR is that the Lake Manapōuri level needs to be above RL 177.7 m (approximately middle of the normal operating range, historically exceeded some 52% of the time) to release a flow of 160 m^3/s from MLC.

39. The Project aims to address this constraint by providing a deeper channel which will reduce energy losses through the Mararoa Delta. Excavation of an additional, deeper channel through the Mararoa Delta area will increase the available flow area through this reach, resulting in lower velocities, lower energy losses, and therefore, a greater discharge capacity at the MLC for a given Lake Manapōuri water level.

COMPUTATIONAL HYDRAULIC MODELLING – METHODOLOGY

40. To investigate the constraint on MLC flow releases at low Lake Manapōuri levels, I used a one-dimensional (cross-section averaged) computational hydraulic model. I adapted an existing model of the Te Anau and Manapōuri hydraulic system held by Meridian, incorporating bathymetry of the Mararoa Delta area as surveyed in 2020.

41. The model used *Mike11* software (which is widely used for this type of hydraulic modelling and is well accepted by hydraulic engineers around the world), and includes Waiau Arm cross-sections surveyed in 2010, and cross-sections along the two existing channels of the Mararoa Delta extracted from the 2020 survey. Details of the MLC such as flow capacity through the gates at different headwater levels were obtained from Meridian records.

42. The model was calibrated by adjusting a roughness value so that when flows and lake levels from historical (2015 – 2022) measurements were modelled, water levels at the MLC predicted by the model best matched those recorded. The calibrated model was further verified by simulating the river inflows and MLC level recorded throughout a 2019 flood event and seeing that the resultant Lake Manapōuri levels and discharge showed a sufficiently close match to recorded values.

43. A one-dimensional computational model cannot simulate the effects on a flow of distinct topographical features such as a step or a bend. Instead, average flow properties are calculated at each input cross-section, with flow effects in the intervening reach between each cross-section calculated only in aggregate. Such a model is suitably detailed for the purpose of investigating the MLC flow release constraint and defining potential remedial works within the Waiau Arm.

44. A two-dimensional computational model of the Mararoa Delta reach was subsequently developed in *HEC-RAS* software to model detailed flow patterns and velocities in the delta area for the existing case and with the new parallel channel. A two-dimensional model simulates the depth-averaged flow field over a bathymetric

surface, including lateral (turning) currents and a much finer resolution of topographic effects. The two-dimensional model used the same calibration parameters (roughness values) as the one-dimensional model.

COMPUTATIONAL HYDRAULIC MODELLING – RESULTS

45. The model results showed that at low lake levels the Waiau Arm and MLC system do not have the conveyance capacity to pass the flushing flows as described in the protocol discussed in Mr Feierabend's evidence. The model confirmed the operational experience that the lake level needs to be above RL 177.7 m to release a flow of 160 m^3/s from MLC.

46. The model identified energy losses through the shallow Mararoa Delta area as a key part of the conveyance capacity constraint, meaning that increasing the flow area through this reach of the Waiau Arm could reduce the constraint.

47. Different excavation profiles for an amended channel through the Mararoa Delta were modelled, with options of progressively larger channel sections showing progressive increases in conveyance capacity, and thus an increase in the reliability of flushing flows releases.

48. Excavation of the existing Waiau Arm channel to 25 m width (an initial 'in-channel' excavation concept) and with a bed elevation of RL 172.0 m was selected as the best balance between volume and cost of excavation and benefit in terms of the ability to release flushing flows at a wider range of lake conditions. A subsequent two-dimensional computational hydraulic model in *HEC-RAS* software (which can better model the effects of flow turning and branching) confirmed that the proposed parallel channel provides the same conveyance benefits as this initial in-channel alternative.

GEOLOGY OF THE MARAROA DELTA

49. An understanding of the composition of the bed material within the Mararoa Delta was required to determine the appropriate arrangement and construction methodology of channel excavation, including the potential for suspended sediment generation from the works.

50. Damwatch conducted a desktop review of available documentation and geological records[1] and confirmed that the MLC is underlain by sequences of glacial lake sediments composed of sands, silts and clays. The left bank is comprised of alluvium historically deposited by the Mararoa River. Much of the near-surface bed material within the Waiau Arm channel and comprising the left bank closer to the MLC is unlikely to be the original *in-situ* ground but is instead comprised of alluvium deposited by the Mararoa River between the mid-1970s and 1987 (when the Mararoa River was diverted). This is due to excavation in this area during construction of the MLC, when a wide approach channel to the MLC gates was excavated through the Mararoa Delta to a level of between RL 172.8 m and 173.1 m for some 600 m upstream.

51. Following the desktop review, I recommended that trial pits be excavated to confirm the geology and ability to excavate the material. Damwatch supervised test pits dug in 2022 on both banks of the Waiau Arm between 200 m and 800 m upstream of the MLC. Laboratory testing was undertaken on selected samples to assist in classifying the materials encountered. This confirmed that the site geology generally consists of older glacial materials and younger alluvial sediments. Further detail on these investigation result can be found in my Report.

CONSIDERATION OF ALTERNATIVE EXCAVATION METHODOLOGIES

52. Alternative excavation technologies for the project were considered by Damwatch engineers and presented to Meridian in April 2022 in a workshop. Considering the project size, location, site constraints and expected bed material, the workshop discussions concluded that excavators ("diggers") working from the channel banks or constructed bunds, would be the safest and most practicable option, and would therefore result in the best outcomes and be the most likely approach preferred by a contractor.

53. A range of different excavation methodologies was considered for an 'in-channel' excavation arrangement using excavators. The alternative methodologies explored different temporary arrangements to allow safe construction whilst mitigating the expected suspended sediment generation and minimising the duration of

[1] Geological maps, MLC design and performance reports, reports from MLC construction, and post-construction observations.

construction activities and associated effects. Instream alternatives developed are detailed in the Construction Methodology Report appendix, and include:

(a) Excavation from bunds;

(b) Excavation from bunds with isolation of the downstream channel reach; and

(c) Excavation within a fully isolated Waiau Arm.

54. A further options workshop was held in May 2022, to determine the best methodology for the in-channel excavation alignment by assessing each option against multiple criteria.

55. An outcome of this workshop was a decision to undertake trial excavations within the river channel, to provide further information on the viability of the excavation methodologies being considered. This is described in more detail in the following section of my evidence.

TRIAL EXCAVATIONS

56. The purpose of the trial excavations undertaken in 2023 was to:

(a) Assess the ability to excavate the riverbed material from a bund platform to a target depth of RL 172 m, including confirmation that a long-reach excavator has sufficient breakout force to excavate the *in-situ* material efficiently;

(b) Quantify the levels of suspended sediment and increase in turbidity resulting from the excavation work; and

(c) Better understand the nature and characterisation of channel substrate material within the proposed excavation footprint.

57. The trial excavations were conducted in February 2023 using a long-reach excavator, with holes excavated from five locations as shown in Figure 2.

Figure 2: 2023 trial excavation locations

58. The bed materials encountered varied with location, as listed in Table 1 below.

Table 1: Bed material encountered in 2023 trial excavations

Site	Description of Location	Bed Material to RL 172 m
Location A	Upper end of delta near historical Mararoa River outlet	Sandy gravels with some cobbles
Location B	Middle reach of delta near historical Mararoa River diversion outlet	Cobbly, sandy gravels to gravels with some sand
Location C	Lower end of delta, outside of 1970s MLC approach channel excavation footprint	Silt/clay with thin veneer of gravels on riverbed surface
Location D	Middle reach of delta near historical Mararoa River diversion outlet	Sandy gravels
Location E	Middle reach of delta near edge of MLC approach channel excavation	Variable mixture of gravels and cohesive silts/clays. Suspected construction fill.

59. At Locations A to C, represented by red markers in Figure 2, bunds were constructed into the river channel from locally-sourced sandy gravels, to allow the excavator to reach locations within the channel at the depths of the proposed deepened bed. Riverbed material was collected from a range of depths at these three locations and their particle size composition was analysed.

60. The trial excavations confirmed that the channel substrate material is variable, including cobbles and boulders, and that hydraulic excavators are expected to be the most appropriate equipment to construct an improved channel arrangement. The trial also confirmed the viability of using long-reach excavators to achieve the target excavation depth of RL 172.0 m.

61. The suspended sediment generated by the trial works (bund platform construction and removal, and hole excavation) was monitored by NIWA, as described in the evidence of Dr Hoyle. Generally, and unsurprisingly, bund construction and removal, and excavation of bed material, caused rapid increases in suspended sediment concentration and decreases in visual clarity downstream. The increases in suspended sediment levels were temporary, persisting for a few hours. The selection of suitable 'clean' material to construct bunds has therefore been identified as an important mitigation in my construction methodology.

SELECTION OF FINAL EXCAVATION METHODOLOGY AND CHANNEL ARRANGEMENT

62. Given the rapid increases in suspended sediment concentrations that were observed during the trial works, an in-stream channel option was considered to be inappropriate from an effects management perspective. The trial results prompted further work by NIWA on an appropriate sediment monitoring and management regime, as explained in Dr Hoyle's evidence. It also resulted in the project team reconsidering the arrangement of the works so that in-stream works would be minimised as far as possible (in both duration and extent).

63. An alternative 'offline' channel arrangement and an associated construction methodology was therefore developed and progressed. This alternative offline ('parallel') channel was sized to provide a similar aggregate flow area through the Mararoa Delta as the initial in-channel excavation arrangement, and then modelled using the two-dimensional *HEC-RAS* model mentioned earlier in my evidence. The purpose of this modelling was to confirm the efficacy of the proposed parallel

channel arrangement in reducing the Waiau Arm's conveyance constraint and to quantify flow velocities in the Mararoa Delta with the new channel. This model was also used by NIWA to assess the potential effects of the new parallel channel on phytoplankton growth within the Waiau Arm. This is further explained in the evidence of Dr Hogsden.

64. The new channel option was discussed in an online workshop held in May 2023. Participants at this workshop included design engineers, planners and effects experts from various fields.

65. The outcome of the series of workshops was the preference for an offline parallel channel excavation arrangement, with the bulk of excavation completed outside the flowing river and instream works minimised. This option minimises the potential volume and duration of suspended sediment release into the Lower Waiau and is the most appropriate option in my view.

CONSTRUCTION PROGRAMME AND METHODOLOGY

66. I developed a conceptual construction methodology and programme for the project, presented in the Construction Methodology Report. It is expected that modifications to this concept will be made by the construction contractor to best suit its available equipment and expertise, and the conditions encountered.

67. A more detailed description of the construction programme and proposed methodology can be found in Section 6 of the Construction Methodology Report. I provide a summary of that report here.

68. The concept methodology considers the sequential completion of excavation in stages, with multiple work fronts progressing in parallel during each stage. The overall construction period is envisaged to be approximately 4–5 months, with the duration of each stage of the excavation works summarised below.

69. The construction work is proposed to be undertaken on a 7 days per week and up to 24 hours per day basis to reduce the overall construction length. This will require artificial floodlighting to be used outside of daylight hours.

70. The general arrangement of the project site is shown in Figure 3. The primary work areas include:

(a) The **Excavation Footprint**, within which the channel is excavated in three Stages described below;

(b) The **Spoil Disposal Area**, within which excavated material will be placed and compacted;

(c) The **Contractor's Establishment Area**, within which the Contractor will construct temporary facilities for the storage, maintenance and fuelling of plant, site offices, power supply, water, ablutions, lunchrooms, etc;

(d) The **Haul Road**, to provide access to transport excavated material from the Excavation Footprint to the Spoil Dispoal Area;

(e) **Flood Protection Bunding**, to isolate the Excavation Footprint (Stages 1 and 2) from the Waiau Arm.

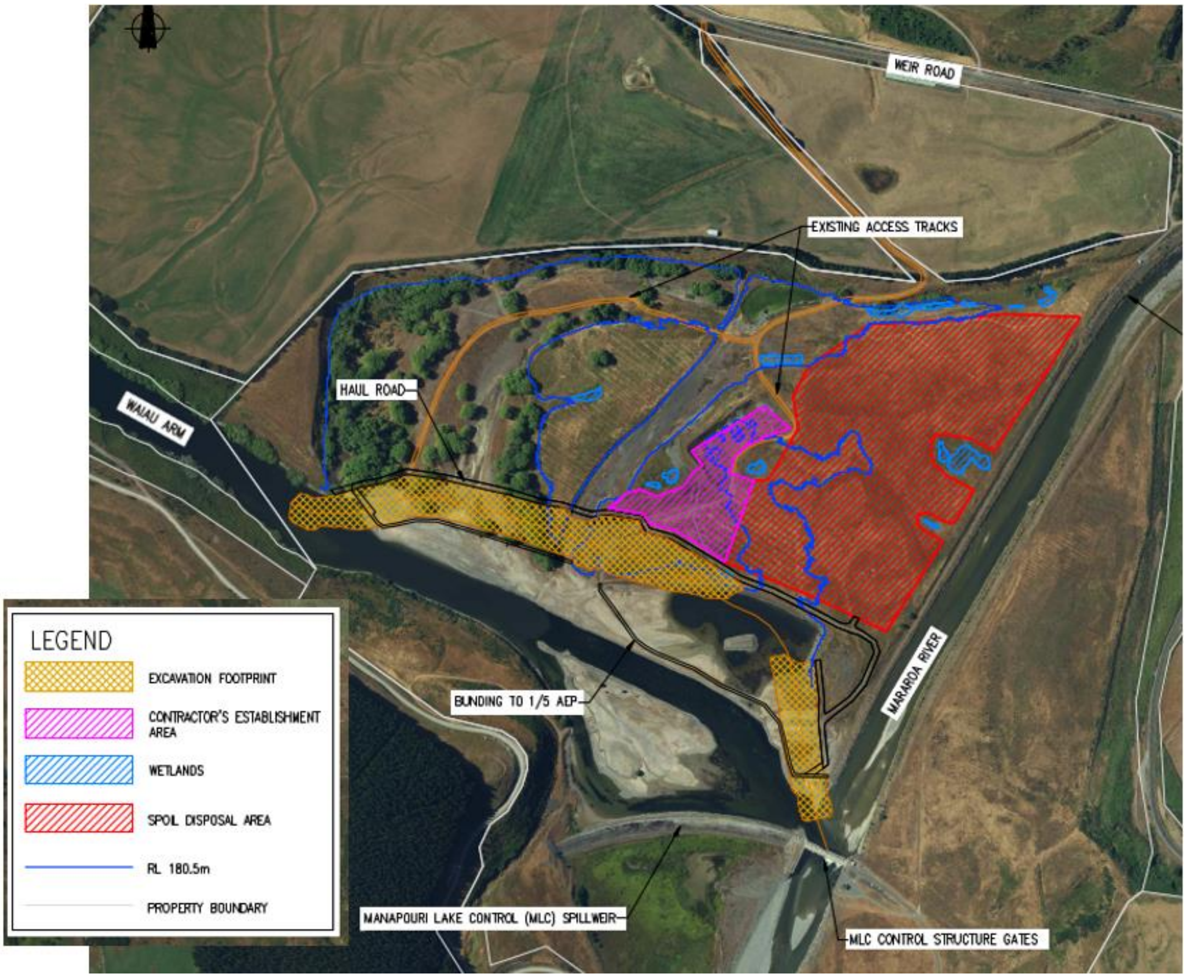


Figure 3: General Site Arrangement

71. A key objective behind the excavation arrangement and construction methodology is to minimise the volume and duration of sediment release into the LWR.

72. The excavation is conceptually separated into three stages, with the first two stages encompassing some 85% of the total excavation volume. These stages are completed remote from flowing water in the existing Waiau Arm channel.

73. Initial site works will include establishment of the site, preparation of the contractor's temporary facilities, transport of construction plant to site, and initial preparation of the spoil area.

74. The initial site clearance work includes the stripping and stockpiling of topsoil from all work areas. The topsoil stockpiles will be utilised to form perimeter bunds around the Spoil Disposal Area, to control sediment and stormwater runoff. Following completion of the excavation works, stockpiled topsoil will be recovered and spread for surface rehabilitation of the Spoil Disposal Area and Contractor's Establishment Area and seeded with pasture grass.

75. During excavation, clean gravels which are suitable for reuse as a construction resource will be preferentially placed in the 'gravel stockpile cell', being a portion of the Spoil Disposal Area. The intention is that this may provide an accessible future source of gravels for local contractors.

Excavation Stages

76. Stage 1 includes site clearance and excavation of areas of the parallel channel alignment above likely flood levels (to RL 179.3 m). The excavated material, as well as other locally-won gravel materials, will be used to construct the Haul Road and riverside Flood Protection Bunds. The location of the Stage 1 works is shown in Figure 4.

77. Construction of the Flood Protection Bunds will isolate the lacustrine wetland channels to the north for the duration of the excavation works. Prior to their construction, a Freshwater Fauna Management Plan (including fish salvage) as addressed in the evidence of Dr Hickford will be implemented. Culverts will be installed under the Haul Road during its construction to provide hydraulic connectivity to the lacustrine wetland channels to the north once the parallel channel is in service.

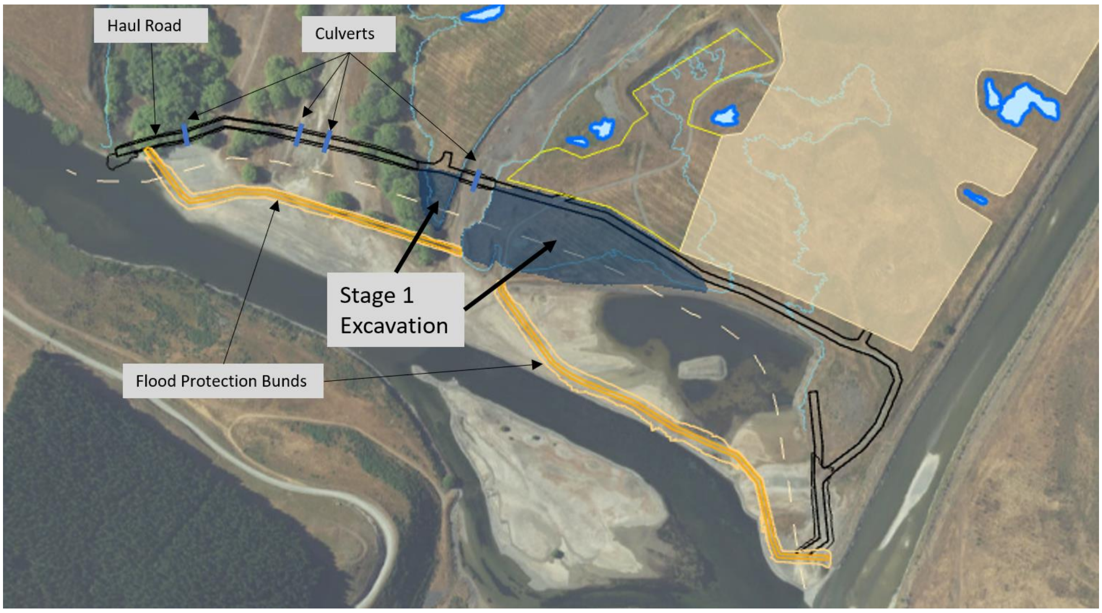


Figure 4: Location of Stage 1 Excavation, Haul Road and Flood Protection Bund construction.

78. Stage 2 includes excavation of the majority of the channel, offline from flowing water, with flood protection bunds separating the excavation area from the existing Waiau Arm channels. The location of the Stage 2 excavation is shown in Figure 5.

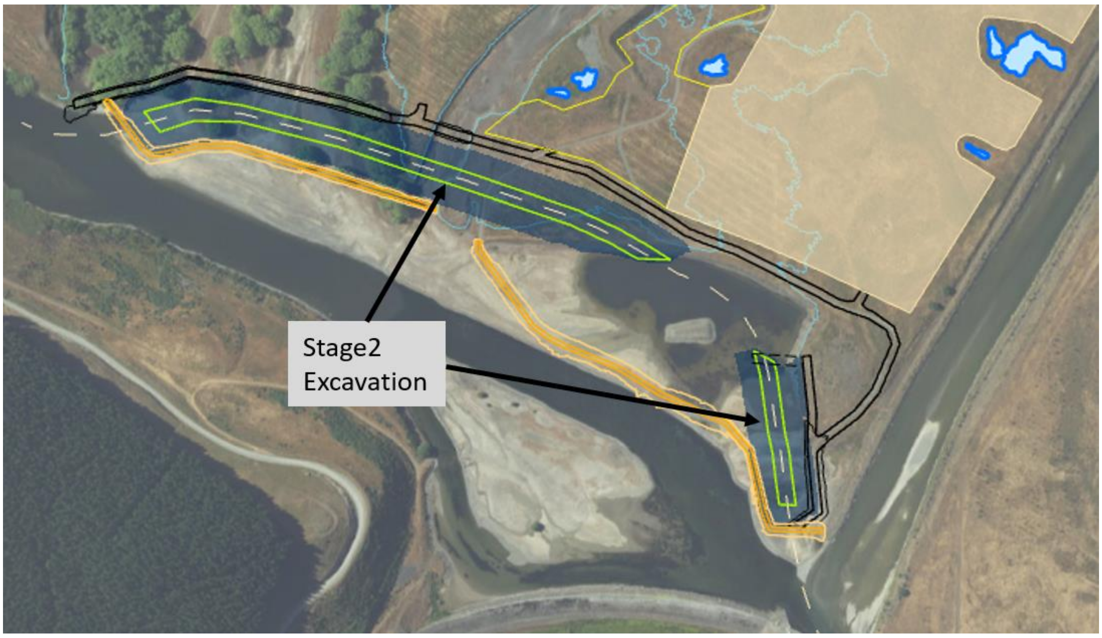


Figure 5: Location of Stage 2 Excavation, with channel base at RL 172 m in green outline.

79. As Stage 2 excavation proceeds to elevations below the river level in the adjacent Waiau Arm, it is expected that the excavation will encounter groundwater. The excavation may be completed using long-reach excavators working from above the water level. However, partial dewatering of the excavation may be considered to improve construction efficiency. Such dewatering would involve the pumping of

groundwater from wells or sumps adjacent to the excavation area to a remote seepage pond on the eastern side of the Spoil Disposal Area, as shown in Figure 6.

Figure 6: Possible excavation dewatering provisions during Stage 2.

80. Stage 3 of the excavation is the in-river works, including removal of the flood protection bunds, construction of finger bunds into the Waiau Arm channel to provide access to excavate the extremities of the new channel, removal of the finger bunds, and excavation of the final 'plugs' separating the offline excavated channel and the Waiau Arm.

81. Prior to commencement of the Stage 3 excavation, the Freshwater Fauna Management Plan shall be effected to recover and relocate fish and kākahi potentially affected by the works as discussed in the evidence of Dr Hickford and Dr Hogsden.

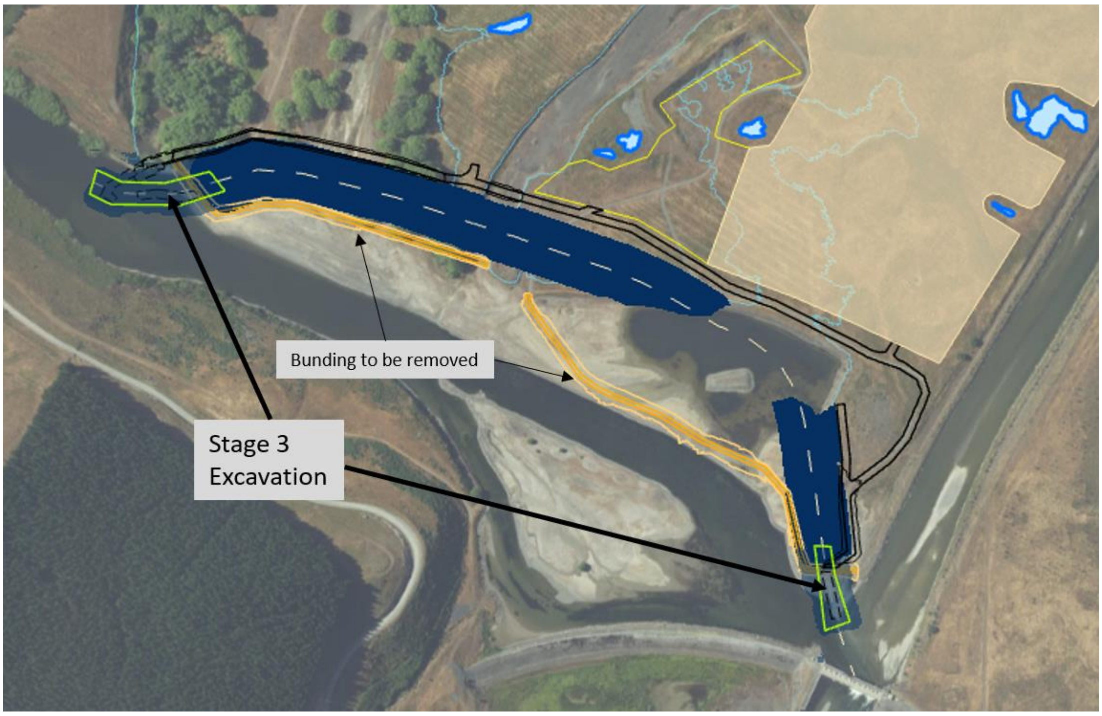


Figure 7: Location of Stage 3 Excavation, with channel base at RL 172 m in green outline.

82. Excavated material will be transported by dump trucks to the Spoil Disposal Area, where it will be dried and blended as required for stability, placed and compacted.

83. Throughout the works, continuous turbidity monitoring and periodic deposited fine sediment monitoring in the LWR will be undertaken as described in the evidence of Dr Hoyle.

Site Rehabilitation

84. Following completion of the excavation works, the Spoil Disposal Area, Contractor's Establishment Area, and the bank of the Waiau Arm will be shaped and profiled to be sympathetic to the contours of the surrounding landscape. The Haul Road will be left in place to provide future access to the channel, with the exception of the western-most end of the road which will be removed to restore hydraulic connection to the western lacustrine channel.

85. Estimated durations of each stage of the construction programme are provided in Table 2. These durations assume occasional (not continuous) 24-hour workdays to provide flexibility to complete critical stages of the works and contingency against adverse working conditions such as high rainfall or high flow disruptions.

Table 2: Estimated construction programme

Activity	Duration (Approximate)
Site Establishment, including initial setup of spoil areas	2 weeks
Stage 1 excavation, including haul road and bund construction	2 weeks
Stage 2 excavation	8 weeks
Stage 3 excavation	5 weeks
Site rehabilitation and demobilisation	2 weeks
Total on-site duration	**19 weeks**

PROPOSED DESIGN MITIGATIONS

86. The key element of the construction methodology and design which minimises effects from the construction of the channel is that the proposed arrangement allows the majority (85%) of excavation to be completed ‘off-line’ from the river. This will minimise the duration over which suspended sediment may be discharged into the Lower Waiau River.

87. Further measures which have been taken to reduce or mitigate effects include:

(a) Avoidance of 11 of the 12 identified palustrine wetland areas. As noted in Mr Hooson’s evidence, the wetland that will be lost is small, and has been assessed as having low-ecological value;

(b) Timing the project so that it can be completed outside bird nesting and elver migration seasons, and when hydrological conditions are more favourable;

(c) Flood protection bunds to keep flowing water out of work areas and minimise the associated possibility of debris and sediment release into the LWR due to high lake levels and flood flows.

HYDROLOGY OF THE PROJECT AREA AND HIGH-FLOW MANAGEMENT

88. The Waiau Arm is the natural outflow point for the Lake Te Anau and Lake Manapōuri catchments. With the development of MPS, there are now two outflow points, the Waiau Arm to the LWR and Manapōuri Power Station to Doubtful Sound.

89. The level of Lake Manapōuri is controlled by MLC, and generally maintained within the main operating range of RL 176.8 m to 178.6 m. Within this lake range, flow releases from MLC are generally at Meridian's discretion and are optimised for energy production.

90. If inflows to Lake Manapōuri are greater than the discharge capacity of Manapōuri Power Station, the lake level rises if flows are not released at MLC. Once the Lake level is above the main operating range (or at lower levels if Manapōuri Power Station output is constrained), flows must be released at MLC with discharge rates prescribed by the Flood Rules.

91. Historical water levels recorded in the project area[2] are plotted by month of year in Figure 8. This shows that the lake level can vary across its main operating range throughout the year, but high water levels are more commonly experienced in October to December.

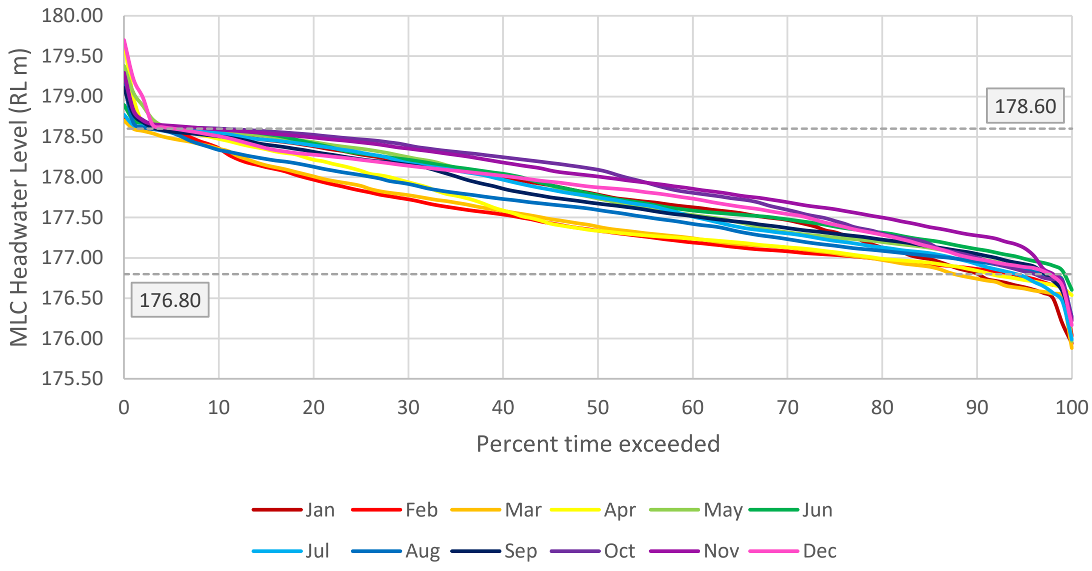


Figure 8: Historical MLC headwater level (1996–2022) duration curves by month of year.

[2] MLC Headwater water level gauge

92. Historical Waiau Arm flow rates recorded in the project area show a similar pattern, with high flows most common from October to January, though also apparent for over 10% of the time in May–June.

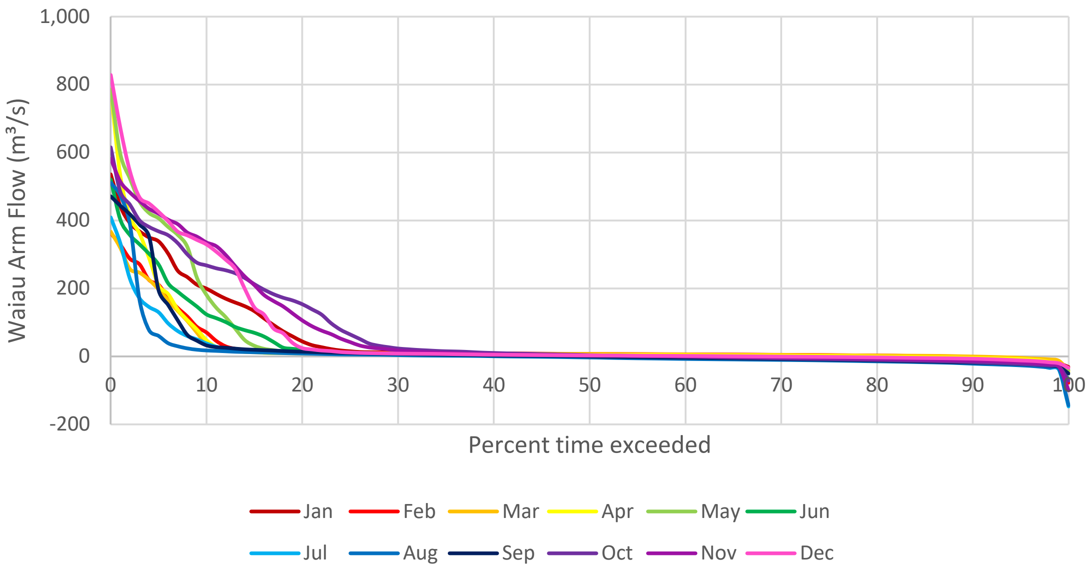


Figure 9: Historical Waiau Arm flowrates (1996–2022) duration curves by month of year. Positive from Lake Manapōuri to MLC, negative from MLC (Mararoa) to Lake Manapōuri.

93. The risk of high water levels or floods disrupting the works has been minimised by planning the construction works to begin in late summer, avoiding the late Spring (October to December) period.

FLOW AND LAKE LEVEL MANAGEMENT DURING CONSTRUCTION

94. Flow and lake levels will be managed within existing operating parameters throughout and following construction of the MLC:IP. It is intended that the MLC gates will be operated during the works to avoid flows toward Lake Manapōuri.

95. The Waiau Arm will be continuously discharging Lake Manapōuri water during construction (i.e., Waiau Arm flow will always be ‘downstream’ and there will be no capture of Mararoa River flows) to ensure that:

(a) Minimum flow requirements into the LWR are always met; and

(b) There is no potential for suspended sediment generated by the works to flow toward Lake Manapōuri.

96. It is anticipated that Meridian will aim to manage the lake level to be low for the start of construction works, to minimise exposure to water on the banks when installing culverts and constructing flood protection bunds.

97. During construction of the Project works, Lake Manapōuri Flood Rules will be followed in the event of high lake levels. This means that if the level of Lake Manapōuri exceeds its maximum control level, discharge down the Waiau Arm will be required.

98. Flooding of the work area caused by high inflows to Lake Manapōuri is a risk to the project, although is mitigated for smaller floods by the flood protection bunds constructed around the majority of the work area to approximately a 1/5 AEP river stage (approximately 800 m^3/s MLC discharge).

99. Lakes Manapōuri and Te Anau provide attenuation of high inflows, meaning flood level rise will be relatively slow (generally days rather than hours) but that flood outflows could persist for days or even weeks. Meridian has a system providing reliable forecasting of catchment inflows 4–5 days in advance. This, coupled with the slow flood level rise, means that Meridian and the contractor will have ample time to recognise and respond to the risk by withdrawing works from the Arm ahead of flood rises and flood flow releases.

100. Construction work will be suspended in the event of high flood discharges, with all plant to be moved to the establishment area ('go line') which will be situated on high ground well above potential flood levels. Meridian will have the option of managing lake levels within the parameters of the operating guidelines to reduce the likelihood of high flood discharges during construction.

101. In-river works would be exposed to Waiau Arm flows, and work will be suspended if Waiau Arm flows exceed 50 m^3/s. It is anticipated that Meridian will aim to manage the lake level to be in the lower part of its main operating range in advance of in-river construction and/or this stage may be delayed until the lake level is suitably low to minimise the risk of Flood Rules being triggered and subsequent flow releases disrupting construction.

102. Discretionary increased MLC flow releases may be considered if required to manage the effects of sediment generated by the works, primarily during the in-stream (Stage 3) excavation. This is explained in further detail in the evidence of Dr Hoyle.

MAINTENANCE

103. Sands and gravels are transported by the Mararoa River and have historically deposited near the Mararoa confluence with the Waiau River. In recent decades, periodic removal of relatively small volumes of gravels from immediately upstream of the MLC gates has been undertaken by Meridian approximately every 5–10 years, as outlined in Mr Feierabend's evidence.

104. Similar maintenance via periodic excavation of deposited alluvial material from immediately upstream of the MLC gates, including from the downstream end of the newly excavated channel and areas around the Waiau Arm confluence with the Mararoa River, is expected to be required into the future. I understand this is provided for in the draft conditions attached to Mr Murray's evidence. Although there is uncertainty based on the size and occurrence of flood flows in the Mararoa River which transport these gravels, it is expected that overall, future maintenance will be at a similar frequency and involve removal of similar volumes of material as has been undertaken in recent decades.

105. Meridian will determine maintenance requirements based on the effect that any buildup of material is having. For example, where it presents any disruption to operations or risk of damage to the MLC gates or other facilities.

106. Maintenance requirements are expected to be minimal for most of the newly excavated channel. The need to remove material will be considered if there is a discernible reduction in channel conveyance over time. If reductions in conveyance are observed (through interrogation of water level and flow records), or otherwise suspected, the channel bed could be surveyed and flows modelled to determine the need for any maintenance excavation.

107. If material is to be excavated from areas around the Waiau Arm confluence with the Mararoa River or immediately in front of the MLC gates, this will likely be undertaken using excavators working from a low-level temporary gravel bund.

108. Given that the water from Lake Manapōuri does not contain high concentrations of sediment, and the upstream reach of the Waiau Arm is deep with tranquil flows, there is no likelihood that sediment will be transported and deposited in the new channel from the upstream Waiau Arm. Channel maintenance work in the upper reach of the excavated channel is therefore unlikely to be required.

109. The channel side slopes have been designed to be stable across the range of flows that are passed through the Waiau Arm, meaning it is unlikely that any erosion repairs would be required.

RESPONSES TO ISSUES IN SUBMISSIONS

110. I have reviewed the submissions which raise issues that are relevant to construction methodology, and the design and hydraulics of the proposed parallel channel. I have also been asked to consider and respond to two further points raised during the pre-hearing meetings between the parties, which I address first and second in the sections below.

Rock Armouring of the Channel

111. The Waiau Working Party (**WWP**) queried whether erosion at the corner of the new channel might occur, and so require rock armouring. As noted earlier in my evidence, the channel has been designed with stable side slopes and the erosion risk is low. I consider that rock armouring is not required.

112. I understand that the WWP accepted this position at the second pre-hearing meeting, based on confirmation of this position.

Conveyance Capacity of the Existing Channel Post-construction

113. In the second pre-hearing meeting WWP raised a concern that the reduced proportion of flow in the existing channels though the Mararoa Delta may result in turbid Mararoa water entering the Waiau Arm when MLC is operating to release all Mararoa inflows plus 5 m^3/s from the Arm. There was some concern that this scenario had not been modelled, and that additional monitoring might be needed to address the risk of turbid water entering the existing Waiau Arm channel and causing adverse effects such as the deposition of sediment.

114. I can confirm that this flow scenario was modelled by Damwatch – see below excerpts from Figures 11 and 27 in the Damwatch memo Hydraulic Modelling of Alternative Channel (June 2023), showing flow patterns for the existing and proposed cases respectively.

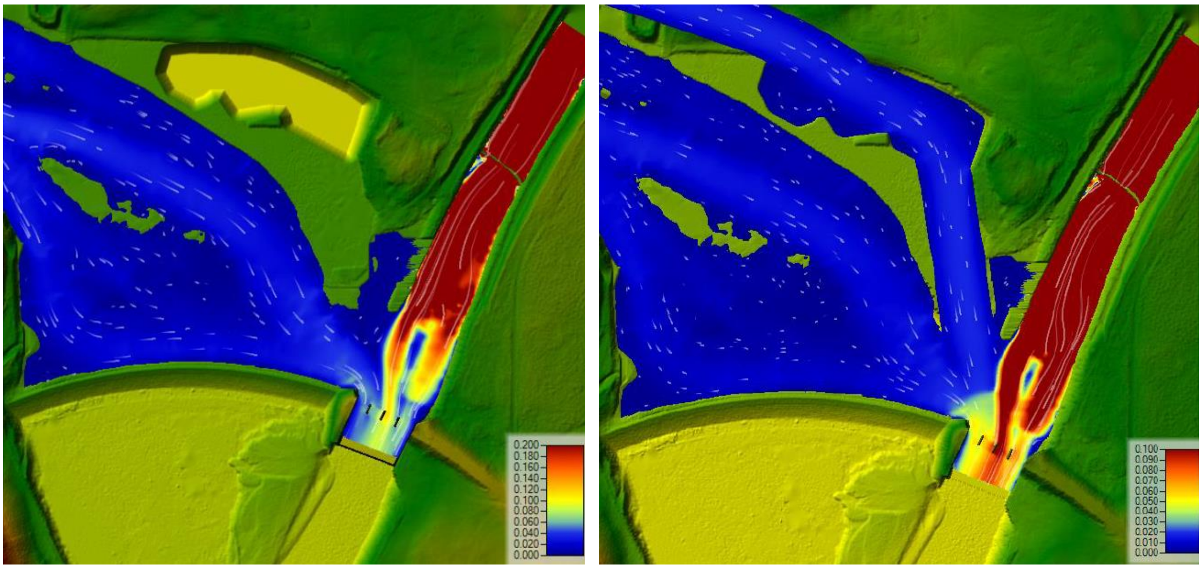


Figure 10: Excerpts of 2D modelling results from Damwatch memo (June 2023), showing flow patterns with 5 m³/s passed down Waiau Arm, for existing channel (left) and with the proposed new channel (right). 80m wide 'gap' between the MLC and Mararoa training groyne highlighted.

115. In both cases, where 5 m³/s is being discharged down the Waiau Arm and towards the MLC, although the flow spreads out as it passes through the Delta area, it then converges again at the 80 m wide 'gap' between the MLC and the Mararoa training groyne. This 5 m³/s flow will create a flow velocity toward the MLC gates. The modelling confirms that flow is distributed across this width, i.e., there is no flow recirculation or reverse currents back up the Waiau Arm. In essence, the modelling shows that the turbid Mararoa waters will continue to be diverted over the MLC under this flow scenario, and that there will be no current into the Waiau Arm which could present a risk of turbid water entering the Waiau Arm.

116. In either case it is unlikely that any significant volume of suspended sediment will be able to pass through this gap against the current and continue upstream into the Waiau Arm channels.

117. Further, as noted earlier in my evidence, the water being discharged from Lake Manapōuri itself has low concentrations of suspended sediment and the fact that it will be spread out across the existing Waiau Arm and the new parallel channel will therefore not result in increased sediment deposition within the Arm.

118. Meridian has an established monitoring programme for turbidity within the Waiau Arm. If this monitoring shows increased turbidity in the Arm attributable to Mararoa flows then gate operation, specifically the flow rate released down the Waiau Arm during Mararoa turbidity events, can be refined as necessary to increase flow velocities to prevent the ingress of turbid water. This monitoring and management response system will be maintained following construction of the MLC:IP and will appropriately manage any residual risk.

Slipway Ramp

119. Real Journeys Limited (**RealNZ**) lodged a neutral submission which noted the proposed channel excavation will require it to move an existing temporary slipway. I understand that the location of this structure is subject to an existing agreement between RealNZ and Meridian, and that RealNZ is primarily concerned that space for the alternative slipway, with appropriate access and riverbank gradient, is allowed for in the Project design.

120. I can confirm that the design includes a space for a “slipway ramp” which has been designed in consultation with RealNZ, to provide a suitable alternative location at which RealNZ can establish a temporary slipway once it has obtained the necessary resource consents. The location and details of the slipway ramp are shown in drawings E2243-102 and E2243-109 respectively, included in Appendix A of my evidence.

Construction Effects

121. One submitter (Landcorp Farming Limited / Pamu) raises the issue that the proposed works may create potential adverse effects, including from dust and noise, for persons at nearby properties. I have been advised that dust discharges and construction noise are authorised under the Manapouri – Te Anau Development Act 1963 (**MTADA**), rather than being a matter for consideration through this RMA consenting process. However, I understand that Meridian has been engaging directly with Pamu as to the appropriate measures to ensure that dust discharges are controlled, and do not result in an offensive, objectionable, noxious and/or dangerous effect at the dwellings on the Pamu properties.

122. For instance, it is anticipated that a dedicated water cart (truck-mounted water tank and sprayer) will be on site for the duration of the project to suppress dust as required on the Haul Road, the Excavation Footprint (where above groundwater levels) and the Spoil Disposal Area.

123. Further, the Contractor shall be required to prepare a Construction Management Plan to Meridian's approval prior to any construction works commencing. The plan shall include a dust management plan and measures to manage and mitigate noise from construction activities.

Reliability of Flushing Flows

124. One submitter (Guardians of Lakes Manapouri, Monowai & Te Anau) seeks clarification on the reported flushing flow reliability of 70% which is expected to be achieved by the Project.[3]

125. The flushing flow reliability estimates are derived from the results of the one-dimensional computational modelling described in paragraphs 41 to 49 of my evidence. The results of the modelling at different Lake Manapōuri levels were compared to hydrological conditions during historical nuisance periphyton 'Red' status periods, where a flushing flow might be warranted under the protocol to control nuisance periphyton levels. The conveyance capacity of the new channel under these same hydrological conditions was then used to determine an average flushing flow reliability metric.

126. As described in my evidence above, the flow rate capacity of MLC gates is dependent on the water level immediately upstream of the gates, which the proposed excavation aims to increase for a given lake level and discharge rate by providing greater flow area through the Waiau Arm channels.

127. Channel improvement works will not be able to provide 100% reliability to discharge 160 m^3/s through MLC gates over the normal control range (RL 176.8 to 178.6 m). The MLC gates require a headwater level of at least 177.0 m to pass 160 m^3/s when fully open, which will not always be available depending on inflows and the operation of the lake under its normal control range. However, as explained earlier,

[3] I note that the legal standing of the Guardians of Lakes Manapōuri, Monowai & Te Anau to participate in these processes is disputed. This submission point has therefore been addressed in my evidence for completeness while this issue is outstanding.

the new parallel channel has been designed to optimise flow conveyance as far as practicable.

RESPONSE TO SECTION 42A REPORT

128. I have reviewed the section 42A Officer's Report prepared by Bianca Sullivan, resource management consultant with Environment Matters Limited, on behalf of Environment Southland, and the supporting technical reports from Mr Ramon Strong and Dr Greg Burrell.

129. At paragraph 3.2.15 of the S42A report, Ms Sullivan notes that Dr Burrell suggests that a key way to mitigate the effects of high turbidity during in-river works would be to limit both the amount of time that in-river works can occur, and the number of consecutive days that work can occur. Dr Hoyle's evidence addresses this proposition, but I note that imposing a pause on construction would increase project costs with workers and machinery standing idle and would prolong the exposure of temporary works and partially-completed works to the risk of high river flows which may cause damage including the generation of suspended sediment. If not needed to address actual observed effects, requiring pauses to the in-river works is not appropriate in my view.

CONCLUSIONS

130. I undertook computational hydraulic modelling to investigate the constraint on MLC flow releases at low Lake Manapōuri levels which has been apparent in operational experience of attempted flushing flow releases. The modelling results demonstrated that energy losses through the shallow Mararoa Delta area as a key part of the conveyance capacity constraint, and that a larger channel sections through this area will increase conveyance capacity, and thus reliability to be able to release flushing flows when desired.

131. A comprehensive options analysis was undertaken to select an appropriate construction methodology and design arrangement to improve flow conveyance through the delta area. This included information gathering through geotechnical investigations and trial excavations, and workshop discussions with various experts to identify key construction effects and select a construction methodology and arrangement which minimises the release of sediment into the Lower Waiau River.

132. This process identified a parallel channel excavation arrangement as the preferred option, with the bulk of excavation completed outside the flowing river and in-stream works minimised.

133. The proposed channel alignment is along the true-left bank of the current Waiau Arm, through an area that the Mararoa River historically occupied, extending from the deeper reach of the Waiau Arm to the present-day confluence of the Waiau Arm and Mararoa River, immediately upstream of the MLC gates. The proposed channel has a constant trapezoidal cross-section, with a 16 m base at elevation RL 172.00 m and 1V:3H side slopes.

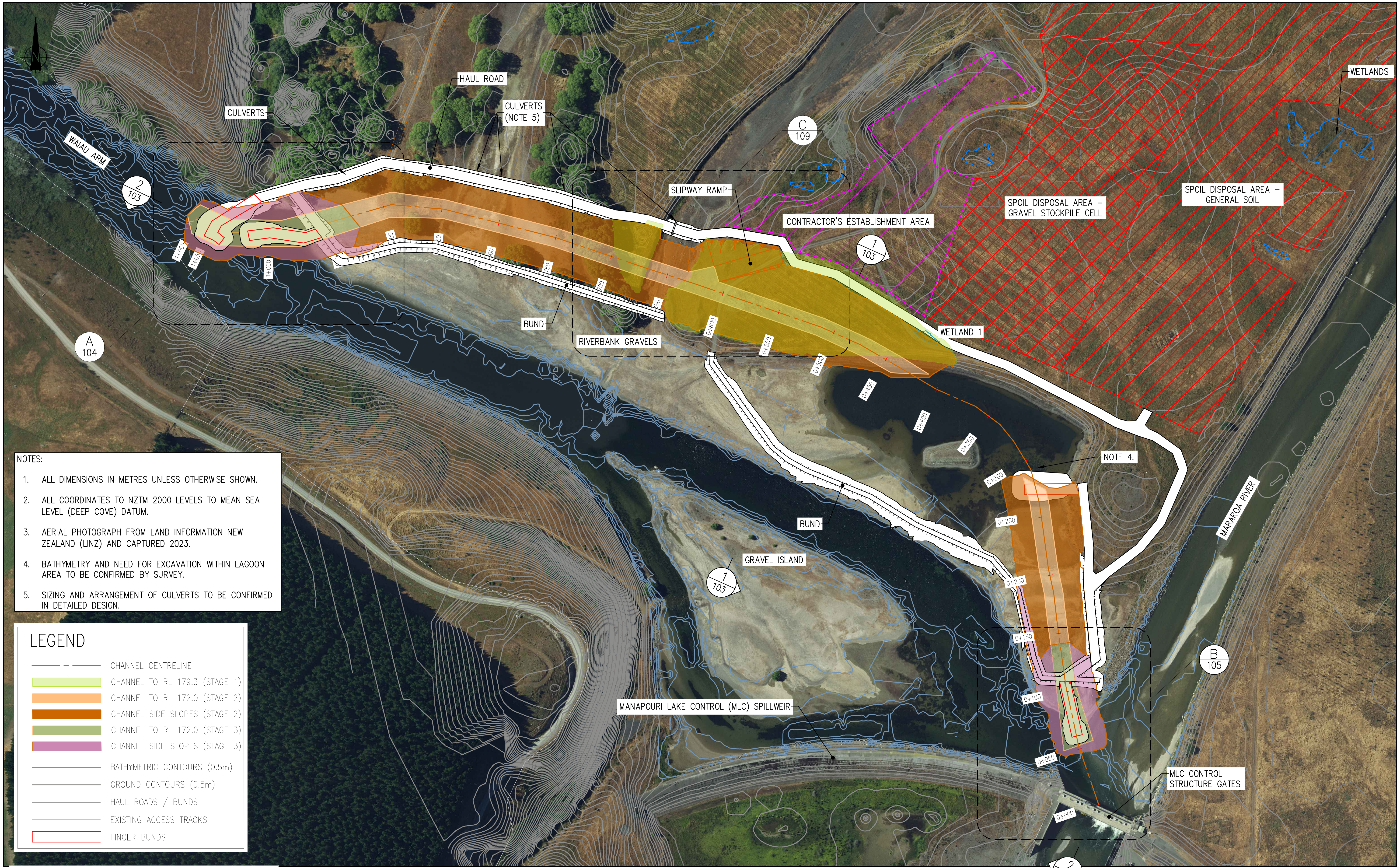
134. I have developed a conceptual construction methodology and programme for the project, with excavation separated into three stages such that 85% of the total excavation volume can be completed remote from the Waiau Arm channel.

135. Development of the construction methodology considered and included appropriate measures to avoid or minimise adverse environmental effects, whilst maintaining a safe and efficient plan for construction of the works.

Dougal Clunie

3 September 2024

APPENDIX A – SELECTED DESIGN DRAWINGS



NOTES:

1. ALL DIMENSIONS IN METRES UNLESS OTHERWISE SHOWN.
2. ALL COORDINATES TO NZTM 2000 LEVELS TO MEAN SEA LEVEL (DEEP COVE) DATUM.
3. AERIAL PHOTOGRAPH FROM LAND INFORMATION NEW ZEALAND (LINZ) AND CAPTURED 2023.
4. BATHYMETRY AND NEED FOR EXCAVATION WITHIN LAGOON AREA TO BE CONFIRMED BY SURVEY.
5. SIZING AND ARRANGEMENT OF CULVERTS TO BE CONFIRMED IN DETAILED DESIGN.

LEGEND

- CHANNEL CENTRELINE
- CHANNEL TO RL 179.3 (STAGE 1)
- CHANNEL TO RL 172.0 (STAGE 2)
- CHANNEL SIDE SLOPES (STAGE 2)
- CHANNEL TO RL 172.0 (STAGE 3)
- CHANNEL SIDE SLOPES (STAGE 3)
- BATHYMETRIC CONTOURS (0.5m)
- GROUND CONTOURS (0.5m)
- HAUL ROADS / BUNDS
- EXISTING ACCESS TRACKS
- FINGER BUNDS

A3 SCALE 1:3000

0 50 100 150 200 (m)

PLAN ON WAIAU ARM

DRAWING STATUS: **NOT FOR CONSTRUCTION**

ISSUE	AMENDMENT	BY	CH'D	COMPANY	PROJECT	APP'D	DATE
A	ISSUED FOR INFORMATION	JA	DC	DAMWATCH	E2243	DCE	07/23
B	ISSUED FOR INFORMATION	JA	DC	DAMWATCH	E2243	DCE	10/23
C	ISSUED FOR INFORMATION	JA	DC	DAMWATCH	E2243	DCE	11/23

Meridian.

MANAPOURI LAKE CONTROL

WAIAU ARM CHANNEL EXCAVATION
CONCEPT DESIGN
EXCAVATION PLAN

FOLDER: DISTRIBUTION: C
DRAWING:
COMPANY: DAMWATCH
NUMBER: E2243–102 ISSUE: C

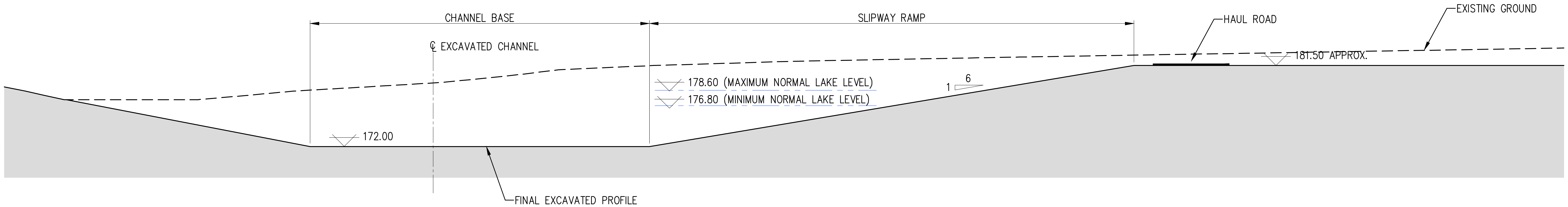
NOTES:

1. BUND TO 1/5 AEP FLOOD LEVEL.
2. ELEVATIONS ARE IN METRES TO MEAN SEA LEVEL (DEEP COVE) DATUM.

LEGEND

- WETLANDS
- CHANNEL TO RL 172.0 (STAGE 2)
- CHANNEL SIDE SLOPES (STAGE 2)

C / 102 SLIPWAY EXCAVATION PLAN
SCALE 1:1000



7 SLIPWAY EXCAVATION SECTION
SCALE 1:500

A3 SCALE 1:1000 — 0 5 10 15 20 30 40 50 (m)

A3 SCALE 1:500 — 0 5 10 15 20 25 (m)

DRAWING STATUS: NOT FOR CONSTRUCTION

ISSUE	AMENDMENT	BY	CH'D	COMPANY	PROJECT	APP'D	DATE
A	ISSUED FOR INFORMATION	JA	DC	DAMWATCH	E2243	DCE	11/23

Meridian.

MANAPOURI LAKE CONTROL

WAIAU ARM CHANNEL EXCAVATION
CONCEPT DESIGN
SLIPWAY PLAN & SECTION

FOLDER:
DISTRIBUTION: A
DRAWING:
COMPANY: DAMWATCH
NUMBER: E2243-109
ISSUE: A