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 JO HOYLE

TABLE OF CONTENTS

INTRODUCTION

1. My full name is Joanna Toby Hoyle.

2. I hold the qualifications of Bachelor of Engineering (Hons, 1st) in Natural Resources (2001, University of Canterbury) and a PhD in Fluvial Geomorphology (2008, Macquarie University, New South Wales).

3. I have worked as a river geomorphologist at NIWA on a wide range of consultancy and applied research projects for the last 16 years. I have managed the Sediment Processes Group at NIWA for the last 12 years and have coordinated the consultancy work NIWA undertakes for Meridian Energy Limited (**Meridian**) for the last seven years. Prior to my PhD, I worked for three years as a river engineer/manager for MWH in the Tasman District.

4. My area of specialisation is river geomorphology, in particular the role that various natural and anthropogenic disturbances play in altering the geomorphology of streams and rivers, and feedback interactions between hydrology, geomorphology and ecology.

5. To date I have authored 15 peer-reviewed science journal articles or book chapters, and >90 technical reports.

6. I confirm that I have been the lead scientist at NIWA co-ordinating multiple workstreams and assessments which have been undertaken in relation to Meridian's proposed Manapōuri Lake Control Structure Improvement Project (**MLC:IP** or **the Project**). This work has included preparation of the Assessment of Environmental Effects: Freshwater Ecology (which I will refer to as the **Freshwater Ecology Report**) and review of the Phytoplankton Risk Assessment Report (the **Phytoplankton Report**) prepared by my colleague Dr Cathy Kilroy. These reports are attached as Appendices D[1] and E[2] to resource consent applications for the MLC:IP.

7. I am familiar with the area that the Project covers, including the Waiau Arm, MLC, Mararoa River confluence and Lower Waiau River (**LWR**).

---

[1] Appendix D available here.
[2] Appendix E available here.

8. I confirm that I have read the following statements of evidence in preparing my evidence:

(a) Mr Andrew Feierabend (Meridian);

(b) Dr Dougal Clunie (Damwatch Engineering Ltd);

(c) Mr Daniel Murray (Tonkin and Taylor);

(d) Dr Kristy Hogsden (NIWA);

(e) Dr Mike Hickford (NIWA); and

(f) Dr Leigh Bull (BlueGreen Ecology).

CODE OF CONDUCT

9. 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

10. In my evidence I will:

(a) Summarise my involvement in the MLC:IP project;

(b) Describe the existing environment in terms of:

(i) Hydrology and flow variability in the Mararoa River, Waiau Arm and LWR;

(ii) Suspended sediment in the Mararoa River, Waiau Arm and LWR;

(iii) Deposited fine sediment environment in the Project Area of the Waiau Arm and in the LWR;

(c) Describe the assessment methodology used, including:

(i) How the potential for sediment generation from the Project was established;

(ii) How the potential impacts of that sediment were established;

(iii) The rationale behind the monitoring and response to sediment discharges into the LWR arising from the Project (i.e. suggested sediment threshold levels and durations) which have been proposed through conditions of consent;

(d) Summarise the effects of the Project in terms of:

(i) Suspended sediment; and

(ii) Deposited fine sediment;

(e) Comment on issues raised by submitters;

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

(g) Provide my conclusions.

11. I note that the ecological effects of suspended sediment and deposited fine sediment, including issues raised in submissions and by the Council reviewers, are covered by the evidence of Dr Hogsden, Dr Hickford and Dr Bull.

12. The existing configuration of the Waiau Arm, the MLC and the LWR, as well as the proposed Project are described in Sections 2, 4 and 5 of the Assessment of Effects on the Environment (**AEE**) and in Mr Feierabend's evidence and are not repeated in detail here.

SUMMARY

13. Mean annual flow in the Mararoa River is 31 m^3/s, with mean monthly flows tending to be higher in June to October and lower in November to May. Net mean annual flow in the Waiau Arm is 38 m^3/s towards MLC, with mean monthly flows tending to be highest from May to December and lowest in March and April. Mean annual flow

in the LWR is 71 m^3/s, with mean monthly flows tending to be lowest in January to April and highest from May to December.

14. High flows in the Mararoa River are naturally turbid. Under Meridian's resource consents for the Manapōuri Power Scheme (**MPS**), all flows with turbidity >30 NTU[3] are required to be passed through MLC to the LWR so that sediment-laden water does not enter Lake Manapōuri.

15. High flow events in both the Waiau Arm and the Mararoa River tend to be least common in summer. High flows in the LWR can be sourced from Lake Manapōuri and/or the Mararoa River. High flows from Lake Manapōuri include lake floods and summer flushing flows to assist the management of nuisance periphyton and smaller recreational flows. The mean annual flood in the LWR based on the MLC at Tailwater record is 576 m^3/s.

16. Suspended sediment from the Mararoa River enters the upper reaches of the LWR and is measured as turbidity at Meridian's Mararoa at Weir Road monitoring station. Suspended sediment naturally increases during floods and, typically, the greater the flood magnitude, the greater the suspended sediment. Episodes of naturally high turbidity in the Mararoa River are relatively brief, with turbidity typically declining rapidly once the flood peak has passed.

17. Concentrations of suspended sediment in the Waiau Arm are generally low because the water originates primarily from Lake Manapōuri and only from the Mararoa River when turbidity levels are low. Water with turbidity greater than 9 FNU[3] rarely enters the Waiau Arm.

18. The relative flow contributions at MLC determines the levels of naturally occurring suspended sediment delivered to the LWR. When flows in the LWR below MLC are dominated by flood events from the Mararoa River, turbidity tends to reduce in a downstream direction as suspended sediment concentrations become diluted with additional flows from tributaries and coarser fractions of the suspended sediment are deposited on the bed. Note that this may not be the case in a catchment-wide rainfall event or event focused downstream of the MLC and not in the headwaters,

---

[3] Turbidity has traditionally been measured in NTU (Nephelometric Turbidity Units), a relative measure of side-scattered visible light from an incident light beam. If instruments get calibrated to Formazine then the NTU unit gets superseded by FNU (Formazin Nephelometric Units). FNU are the units used to report turbidity measured with instruments that meet the ISO 7027 Standard, which is required for achieving QC600 in the National Environmental Monitoring Standard for Turbidity. There is no physical difference between NTU and FNU.

during which elevated levels of sediment may also enter the LWR from tributaries or land runoff downstream of the MLC.

19. My understanding of deposited fine sediment in the Project Area is based on benthic surveys from 1 March 2022. These surveys showed that deposited fine sediment cover in the lower 900 m of the Waiau Arm (the Project Area) ranged from 5 to 85%. Deposited fine sediment in the upper reaches of the LWR has been monitored monthly since August 2018 by Environment Southland at a site just upstream of Excelsior Creek. Median deposited fine sediment cover at this site is ~22%, but has been highly variable over time, fluctuating from 0% to >75% cover. Deposited fine sediment in the LWR, upstream of Excelsior Creek, is primarily sourced from the Mararoa River and its catchment but is influenced by relative timing of high flows from both the Mararoa and Lake Manapōuri as these flows both deliver and move deposited fine sediment downstream.

20. The trial excavation undertaken in February 2023 highlighted that any instream excavation, and the construction of bunds in the Project Area, both have potential to contribute suspended sediment to the LWR. Given those results, the selected methodology for the Project (i.e., excavation of a parallel channel) avoids working instream as much as possible and minimises the period over which fine sediment may be generated. However, there is still potential to generate suspended sediment, particularly during the Stage 3 breakout phase.

21. Levels of suspended sediment generated from the Project are expected to be within the range of suspended sediment that comes naturally from the Mararoa River during floods. This is because the material to be excavated has primarily originated from the Mararoa River so the nature of the material that will be disturbed during the project is generally the same as that disturbed during flood events in the Mararoa. This provides high-level bounds on expected suspended sediment.

22. The trial was undertaken with a key objective being to provide clearer indication of potential levels of suspended sediment generation.

23. The maximum turbidity recorded during the trial was 36.8 FNU, which is equivalent to what typically occurs in the lower Mararoa River during flows that are exceeded about 10% of the year. Turbidity of this level naturally has a recession time (i.e., time back to normal low turbidity levels) of approximately 40 hours.

24. In my opinion, these trial results provide a good indication of levels of turbidity that may be generated during the Project. However, because excavations during the trial were of much shorter duration than is proposed during the Project, it is possible that higher levels could occur. If levels are higher, I still expect them to still be within the range of suspended sediment generated naturally by the Mararoa.

25. The periods of the Project with the highest potential for generation of suspended sediment (i.e., Stage 3 breakouts) are also the periods with the greatest potential for deposited fine sediment accumulation in the LWR (if left unmitigated). The potential for suspended sediment to deposit on the bed is greater than it would be for an equivalent level of suspended sediment generated naturally from the Mararoa River because suspended sediment generated by the Project may occur during low flows (while the high levels of sediment from the Mararoa occur during flood events).

26. The proportion of suspended sediment that becomes deposited on the bed will depend on the particle size distribution of the material being contributed instream and the flows in the Mararoa River and down the Waiau Arm at the time. Whilst we have some understanding of particle size distributions from the trial and what flows are typical, there is still a level of uncertainty with each of these factors. However, increased levels of both suspended and deposited sediment that arise because of construction can be appropriately managed using the proposed sediment management framework.

27. The turbidity and deposited fine sediment thresholds that have been recommended as part of the sediment management framework are set at levels and durations aimed to protect all biota from both acute and chronic effects. The framework is also designed to keep suspended sediment and deposited fine sediment within the range of conditions that are experienced naturally in the Project Area and LWR. Both suspended sediment and deposited fine sediment effects are expected to be effectively managed by flushing flows and natural flood events, meaning that the effects of the Project on sediment will be temporary and of short duration. Also, my understanding, based on the evidence of Drs Hickford, Hogsden and Bull, is that any ecological effects of this sediment will also be temporary and of short duration.

28. Meridian's proposed consent conditions attached to Mr Murray's evidence relating to turbidity thresholds and deposited fine sediment (**DFS**) outline the measures that are reasonably practicable to ensure that turbidity and DFS levels and durations are not exceeded, and note that the Applicant is not limited to these mitigation measures. I

consider that these conditions outline actions that will avoid, remedy, or mitigate adverse effects, whilst retaining flexibility for the Applicant to choose the appropriate response according to the given situation.

MY INVOLVEMENT WITH THE MLC:IP PROJECT

29. My role in the MLC:IP Project has been as a sediment processes expert and Project Manager for all NIWA aspects of this Project.

30. My involvement in the Project began in February 2022 when NIWA was engaged to undertake a benthic ecology survey in the lower end of the Waiau Arm, including the Project Area. I managed this NIWA project, analysed sediment samples from the bed of the Waiau Arm, and co-authored a report summarising the results.

31. From April 2022, NIWA was involved in workshops with Meridian and other experts making high level assessments of the potential effects of alternative methodologies for this Project and alternative sediment scenarios. I led the NIWA input, advised on the relative potential for sediment generation from these alternatives, and related the sediment scenarios to what occurs naturally due to sediment inputs from the Mararoa River with support from my colleague Dr Arman Haddadchi (an expert in suspended sediment dynamics and monitoring).

32. To reduce uncertainty in sediment generation potential, a trial excavation was undertaken in the Project Area in February 2023. I developed a sediment monitoring protocol for this trial, to help Meridian comply with the consent conditions under which the trial was undertaken[4], and to capture data to inform the Project. I was on site and involved in the monitoring during the trial.

33. From April 2023, NIWA started contributing to the MLC:IP consent application phase, assessing the environmental effects of the Project on freshwater ecology. I am the Project Manager for this NIWA work and have specifically contributed to aspects on hydrology/flow variability and suspended and deposited fine sediment.

[4] MLC maintenance consent (Permit 204160).

EXISTING ENVIRONMENT

Hydrology and flow variability

Base flows

34. A table summarising average monthly flows in the Waiau Arm, LWR, and Mararoa River is provided in Appendix A (Table A-1) to my evidence.

35. Mean annual flow in the Mararoa River[5] is 31 m^3/s, with mean monthly flows tending to be higher in June to October and lower in November to May.

36. Under normal operations of the MPS, once minimum flow[6] to the LWR has been provided, Mararoa River water is diverted to Lake Manapōuri via the Waiau Arm for power generation. Therefore, flows in the Waiau Arm can be in either direction: positive (towards MLC) or negative (towards Lake Manapōuri).

37. Net mean annual flow in the Waiau Arm is 38 m^3/s towards MLC[7]. Positive flows in the Waiau Arm (towards MLC) tend to be highest from May to December (on average) and lowest in March and April. The annual mean of negative flows (towards the lake) is -10 m^3/s. On average, negative flows are highest from June to September and lowest from December to April.

38. Mean annual flow in the LWR[8] is 71 m^3/s. Mean monthly flows are lowest in January to April and highest from May to December.

High flows

39. High flows in the Mararoa River are naturally turbid. To prevent turbid water entering the Waiau Arm and eventually Lake Manapōuri, all flows with turbidity >30 NTU are required by the MPS resource consents to be passed through MLC to the LWR. Meridian operates conservatively and water with turbidity >9 NTU seldom enters the Waiau Arm. High flow events in both the Waiau Arm and the Mararoa River tend to

---

[5] Based on the Mararoa at Cliffs flow record from 1990 to 2023.

[6] Minimum flows are: 12 m^3/s (May to September), 14 m^3/s (October and April), 16 m^3/s (November to March).

[7] Based on Waiau at MLC flow minus Mararoa at Cliffs flow between September 2012 and June 2023 (i.e., under the current operating regime of the MPS which includes the Manapōuri Tailrace Amended Discharge, MTAD).

[8] Based on the Waiau at MLC at Tailwater record from September 2012 and June 2023.

be lowest in both magnitude and frequency in the summer months, especially February and March.

40. Flows released to the LWR through the MLC comprise a combination of water from the Waiau Arm and from the Mararoa River, and the combination varies over time from 100% water from the Mararoa River to more than 80% water from Lake Manapōuri via the Waiau Arm.

(a) 100% water from the Mararoa River occurs when the Mararoa River is providing all of the LWR minimum flow (and remaining Mararoa water is being diverted for power generation), or during high flows across a range of magnitudes from the Mararoa River (when the Mararoa water is too turbid to be diverted).

(b) Higher proportions of water from Lake Manapōuri occur at minimum flows when flow in the Mararoa River is extremely low, or during large magnitude lake floods (typically >250 m^3/s).

41. The mean annual flood in the LWR is 576 m^3/s[9].

Flushing and recreational flows

42. Flow variability in the LWR is increased during the summer months by the release of relatively large flushing flows for nuisance periphyton management and smaller recreational flow releases. Small to large Mararoa floods add further variability to flows in the LWR.

43. Meridian's current protocol[10] for monitoring and management of nuisance periphyton in the LWR provides for the release of up to four flushing flows in each season (between November and May) in response to high periphyton cover (as quantified by instream surveys). These flow releases generally average at least 120 m^3/s over 24 hours and reach a peak flow of around 160 m^3/s. In the past seven seasons (i.e., November 2016–May 2017 through to November 2022–May 2023), fewer than 1.5

[9] Based on the Waiau at MLC at Tailwater record from September 2012 and June 2023.

[10] Water Permit 206156 condition 7 (Protocol for controlled releases of voluntary supplementary flows from the Manapōuri Lake Control (MLC) structure to the Lower Waiau River Final 13 April, amended 7 November 2014, 12 February 2016 and 16 November 2018).

flushing flows per season have been released (on average), primarily because low lake levels precluded releases of a sufficient size[11].

44. Smaller “recreational flows” (typically 35–45 m^3/s at MLC for 24 hours) are released monthly from October to April. These releases have been provided consistently over the years. Occasionally, a small proportion may have been omitted because of extremely low lake levels[12].

Suspended sediment

Background

45. Suspended sediment can be measured directly as suspended sediment concentration (**SSC**, g/m^3) or via the proxy variable turbidity. Direct measurement of SSC involves collection of a water sample followed by laboratory analysis, which is expensive and time-consuming.

46. Turbidity (an optical measurement that indicates the presence of suspended particles in water) is considered a good proxy variable for both SSC and visual clarity. It is relatively easily measured using logging devices. However, turbidity measurements are instrument dependent, and turbidity units (NTU/FNU) are relative and not standardised units. Therefore, a site-specific relationship between SSC and turbidity must be established before turbidity records can be converted to absolute measures of SSC.

47. Visual clarity (m) is the distance objects can be seen through water. Visual clarity is important in its own right because of its relevance to visual cues for biota. Visual clarity results are directly comparable across sites, which is why visual clarity is used as a compliance measure (e.g., in the National Policy Statement for Freshwater Management). Measurements of visual clarity are usually discrete (e.g., using the black disk method), but a continuous record of visual clarity can be generated from continuous turbidity records if there is an established turbidity vs visual clarity relationship. Because visual clarity is affected by factors other than

[11] Kilroy, C. (2022) Managing nuisance periphyton in the Lower Waiau River. Monitoring and management 2021-22. Client report prepared for Meridian Energy Limited. 2022250CH. 69 p.

[12] Kilroy, C. (2023) Assessment of risk of phytoplankton blooms in the Waiau Arm immediately upstream of the MLC: following excavation of a new parallel channel. Client report prepared for Meridian Energy Limited. 2023306CH. 28 p.

SSC (e.g., particle size, or the amount of dissolved organic matter in the water), it is necessary to establish site-specific relationships with SSC and/or turbidity to enable prediction of one from the other.

48. SSC naturally increases during floods and, typically, the greater the flood magnitude the greater the SSC, although the relationship is typically complicated by hysteresis (refer to Freshwater Ecology Report section 3.6.1 for further details).

Mararoa River

49. Turbidity in the Mararoa River just upstream of the MLC has been characterised using a 3.5-year record[13] of high-frequency (5-minute intervals) turbidity observations from the Mararoa at Weir Road monitoring site[14]. The record is presented as a turbidity duration curve in Appendix B (Figure B-1) of my evidence.

50. This turbidity duration curve provides estimates of the proportions of time turbidity exceeds certain thresholds. Examples of percentages of the time that specific levels of turbidity are exceeded are also presented in Appendix B (Table B-1). This table also shows the equivalent SSC and visual clarity based on established relationships with turbidity.

51. The relationship between flow and turbidity in the Mararoa River is presented in Appendix B (Figure B-2). There is high variability in turbidity at flows between about 12 m^3/s and 100 m^3/s in the Mararoa River, within the expected positive relationship (i.e., mean daily flow at Mararoa at Cliffs explains only about 20% of the variance in daily mean turbidity). Turbidity is generally low up to about 12 m^3/s (96% of mean daily turbidity <5 FNU) (Figure B-2).

52. Episodes of naturally high turbidity in the Mararoa River are relatively brief, with turbidity typically declining rapidly once the flood peak has passed.

[13] November 2019 to May 2023.

[14] Note: Mararoa water level and flow data are based on measurements from the Mararoa at Cliffs monitoring station. Turbidity is now monitored ~300 m downstream at the Mararoa at Weir Road monitoring station with the turbidity sensor located just downstream of the Weir Road Bridge. However, for existing reporting with respect to turbidity compliance (NTU reporting) the Mararoa monitoring stations are collectively referred to as Mararoa at Cliffs.

Waiau Arm

53. Concentrations of suspended sediment in the Waiau Arm (i.e., Project Area) are generally low (and hence water clarity is relatively high) because the water originates primarily from Lake Manapōuri and water is sourced from the Mararoa River only when turbidity levels are low.

54. Preventing turbid water from the Mararoa River being diverted into the Waiau Arm ensures that Mararoa River water with turbidity greater than 9 FNU rarely enters the Waiau Arm. Data from the Waiau Arm water quality monitoring programme can be used to summarise typical turbidity in the Waiau Arm. This 12 years of monitoring during summer (January to March) shows turbidity has exceeded 3 FNU on only three occasions at a site 2.3 km upstream of the MLC and was less than 2 FNU in >95% of measurements.

55. Water clarity in the Waiau Arm is typically lower than that in the lake because of the effect of nutrient-enriched tributary inflows into the Waiau Arm, which may exacerbate phytoplankton growth, especially in summer. Notwithstanding this, the Waiau Arm is still characterised by relatively high water-clarity and low turbidity compared to the Mararoa River.

Lower Waiau River

56. The relative flow contributions at MLC determines the levels of naturally occurring suspended sediment delivered to the LWR.

57. The Mararoa River is the primary source of suspended sediment to the upper reaches of the LWR because flows from the Waiau Arm are lake-fed with low SSC. Therefore, turbidity in the upper reaches of the LWR tends to reflect that observed in the Mararoa River because all turbid Mararoa River flows are passed through to the LWR. However, there may be some dilution by additional flows from the Waiau Arm, so, Mararoa levels of suspended sediment can be considered an upper limit for each frequency of occurrence in the LWR.

58. When flows in the LWR are dominated by flood events from the Mararoa, turbidity tends to reduce in a downstream direction as suspended sediment concentrations become diluted with additional flows from tributaries and coarser fractions of the suspended sediment are deposited on the bed. Note that this may not be the case in

a catchment-wide rainfall event or event focused downstream of the MLC and not in the headwaters, during which elevated levels of sediment may enter the LWR via tributaries or land runoff downstream of the MLC.

Deposited fine sediment

Background

59. As suspended sediment falls through the water column it is naturally deposited on the river bed. The lower the velocity of the water, the greater likelihood that suspended sediment will become deposited on the bed.

60. Coarser (i.e., heavier) fractions of the suspended sediment will be deposited first, with finer fractions being carried further downstream.

61. Deposited fine sediment (**DFS**) can be re-suspended into the water column as velocities increase during freshes and floods, and subsequently re-deposited further downstream as velocities fall again.

62. DFS cover can vary greatly over space and time as result of natural spatial and temporal variability in hydraulic parameters (e.g., depth, velocity, shear stress).

Waiau Arm

63. On 1 March 2022, four transects (T1–4) across the wetted channel were surveyed within the Project Area and a further two transects (C1–2) were surveyed upstream in the Waiau Arm for comparative purposes. The locations of the transects and proximity to the Project Area are presented in Appendix C (Figure C-1) of my evidence.

64. These surveys captured information on benthic ecology (covered in the evidence of Dr Hogsden) and divers also recorded percentage cover of sand and finer substrates (<2 mm), gravel (2–16 mm) coarse gravel (16–64 mm), cobble (64–256 mm) or boulder (>256 mm)[15]. Three sediment samples were also collected per

[15] de Winton M., Hoyle J., Smith B. Hogsden K, Lambert P. (2022) Benthic ecological survey of the lower Waiau Arm. NIWA Client Report prepared for Meridian Energy Limited. 2022057CH_v2.

transect, including one in each half transect and one in the middle of the channel. These samples were analysed in the laboratory.

65. In the vicinity of both the upstream and downstream breakout areas (Transects 1 and 4 respectively) the bed sediments comprised 5–20% DFS cover. In the reach between the breakout areas (covered by Transects 2 and 3) the bed material varied from 5–85% DFS cover.

Lower Waiau River

66. Environment Southland have carried out monthly surveys of DFS in the LWR since August 2018 at a site just upstream of Excelsior Creek, within the wadeable reach.

67. Median DFS cover at this site[16] is 22%, but cover has been highly variable over time, fluctuating between 0% and >75% cover.

68. The variability over time can be partly explained by preceding flows. Analysis of DFS against a range of flow metrics[17] showed that high cover by DFS (~50% cover on average) was strongly associated with the recent occurrence (fewer than 11 days prior to a survey) of small to medium-sized flows of Mararoa-dominated water (which typically have high turbidity). Also, low cover by DFS (less than 5% on average) was associated with longer periods elapsing since small to medium-sized Mararoa-dominated events, in combination with a relatively recent large lake-dominated flows (up to ~3 months prior to a survey).

69. These associations suggest that the DFS in the LWR upstream of Excelsior Creek is primarily sourced from the Mararoa River and its catchment.

70. Analysis of spatial and temporal variability of DFS between the MLC and Sunnyside[17] found that cover by DFS was generally greater in the upper reaches closer to the MLC, with consistently high levels (i.e., >70% especially near the water's edge) around Excelsior Creek, Whare Creek, and the Jericho Farm angler's access.

[16] Based on data from August 2018 to March 2023.
[17] Described in the Freshwater Ecology Report Appendix D to the AEE.

71. High DFS cover was patchy (i.e., not covering the whole bed in these areas) and was typically found close to the bank in low velocity environments.

ASSESSMENT METHODOLOGY

Methodology for assessing potential for sediment generation

72. The potential for sediment generation from the Project was recognised early in the development of the construction methodology. The trial excavation was undertaken with key objectives being to help quantify the potential level and characteristics of suspended sediment and DFS resulting from excavation work, and to better understand the nature of channel substrate material within the Project footprint (i.e., extent of clay and suitability of gravels for bund building).

73. The trial is described further in Dr Clunie's evidence, and details relating to sediment monitoring during the trial are described in Hoyle et al. (2023)[18]. Here I will summarise the results of the sediment monitoring.

74. There were three components to the suspended sediment monitoring during the trial: 1) continuous monitoring of turbidity, 2) suspended sediment gauging, and 3) measuring visual clarity.

75. Turbidity is currently continuously monitored at the Mararoa at Weir Road gauge using a Hach Solitax sensor. For the trial NIWA installed an additional temporary monitoring station 140 m downstream of Duncraigen Bridge on the true right bank, equipped with a Hach Solitax turbidity sensor and also an acoustic back scatter sensor (which better captures coarse silt and sand). Data from the two monitoring stations enabled NIWA to back calculate turbidity coming from the Waiau Arm trial excavation.

76. Suspended sediment gaugings were undertaken from the Duncraigen Bridge over the first four days of the trial excavation, with samples sent to the NIWA Water Quality laboratory to determine SSC for a range of size fraction classes. The gaugings enabled the surrogate records (turbidity and acoustic backscatter) from the monitoring station to be calibrated, enabling generation of a total discharge-weighted cross-section averaged SSC record and also a SSC record for individual

[18] Hoyle J, Haddadchi A, Sutton H, Grant B. (2023). Sediment monitoring during the Waiau Arm excavation trial. Client report prepared for Meridian Energy Limited. 2023058CHv2. pp 50.

size fraction classes. This record could then be used to assess the impact of specific excavation activities (e.g., bund building and hole excavation) on sediment mobilisation and transport.

77. Visual clarity during the trial was measured upstream and downstream of the works using a portable beam transmissometer. This monitoring was undertaken to check compliance under the MLC maintenance consent condition 4(a).

78. DFS resulting from the trial excavation was assessed by taking measurements at a series of transects upstream and downstream of Duncraigen Bridge on the day prior to works commencing (12 February 2023) and on the last day of the trial close to works finishing (17 February 2023[19]). Additional measurements at the same transects were also taken approximately six weeks after the trial (4 April 2023).

79. The DFS measurements followed the SAM2 standard sediment monitoring protocol (Clapcott et al. 2011[20]).

Methodology for assessing potential impacts of sediment generation

80. The potential impacts of sediment generation on biota depends on the tolerance of different species to fine sediment. NIWA developed understanding of this tolerance in two ways: 1) by reviewing available literature (this is covered by the evidence of Drs Hogsden and Hickford), and 2) by developing understanding of what biota present around the Project Area and downstream in the LWR are naturally exposed to (covered later in my evidence).

81. Given the intrinsic flow variability of most rivers (including the Mararoa River), river biota are adapted to variability in suspended sediment and DFS, and the taxa present would be expected to be generally tolerant of the range of SSC and DFS typically experienced in a particular river or stream (Franklin et al. 2019)[21]. If either

---

[19] Note Hole E (the last activity) was completed at 10.28 am NZST on 17 February 2023, after the ‘after excavation’ deposited fine sediment measurements. Therefore, these measurements will not capture this activity, but do cover all other activities.

[20] Clapcott, J.E., Young, R.G., Harding, J.S., Matthaei, C.D., Quinn, J.M., Death, R.G. (2011) Sediment Assessment Methods: Protocols and guidelines for assessing the effects of deposited fine sediment on in-stream values. Cawthron Institute, Nelson, New Zealand.

[21] Franklin, P., Stoffels, R., Clapcott, J., Booker, D., Wagenhoff, A., Hickey, C., (2019) Deriving potential fine sediment attribute thresholds for the National Objectives Framework. NIWA Report 2019039HN for the Ministry for Environment.

or both of SSC or DFS start to exceed the upper limits of existing variation, then changes to biota can be expected.

82. The extent of any changes to biota will depend on all three of: (a) the magnitude of the departure from existing conditions (of fine sediment), (b) the duration of the departure from existing conditions, and (c) the responses of individual taxa to elevated SSC or DFS.

83. To understand what sediment conditions biota present in the Project Area and downstream in the LWR are adapted to, I refer back to the existing environment in the Mararoa River, Waiau Arm and upper reaches of the LWR.

DEVELOPMENT OF SEDIMENT THRESHOLDS

84. Sediment thresholds have been proposed for both suspended sediment and DFS.

85. I note that the development of the sediment thresholds and proposed sediment monitoring framework has been designed following input from:

(a) Ecological assessments by NIWA;

(b) Hydraulic modelling by Dr Dougal Clunie at Damwatch;

(c) Analysis of Mararoa flow and turbidity data by my NIWA colleague Dr Arman Haddadchi, and

(d) The 2023 trial excavation in the Waiau Arm, described above.

86. The proposed suspended sediment thresholds are outlined in Table 1. Note each threshold has a turbidity level which may be exceeded but only for limited duration.

Table 1 Proposed suspended sediment thresholds

Threshold	**Turbidity level (FNU)[3]**	**Total duration (hours)**	**Consecutive duration (hours)**
Turbidity 1	>330	36	12
Turbidity 2	>160 to ≤330	95	32
Turbidity 3	>30 to ≤160	504	168
Turbidity 4	>12.4 to ≤30	945	315

87. The DFS threshold is an additive increase of no more than 20% cover (based on a four-week rolling average of weekly observations) on a baseline DFS value (established prior to commencing excavation of the parallel channel).

88. Below I describe the rationale and methodology used to develop these thresholds.

Rationale behind proposed sediment thresholds

89. Each threshold is based on metrics that can be monitored during the Project so that mitigation action can be taken if any of the thresholds are at risk of being exceeded beyond specified durations.

90. The detrimental effects of suspended sediment on biota can range from acute to chronic, therefore, a set of "nested" turbidity thresholds is proposed. High threshold concentrations permitted for short durations (protecting against potential acute effects, including sublethal stress effects on fish) are nested within lower thresholds permitted for longer durations (protecting against chronic and longer-term stress effects on fish and macroinvertebrates).

91. Limits for both consecutive duration of threshold exceedance and total duration of threshold exceedance over the period of works are specified to provide further protection against acute and chronic effects.

92. Each sediment threshold is based on a sediment level that has an expectation of a potential adverse biological effect, but exposure durations are limited to the range of conditions that could occur naturally within the upper reaches of the LWR.

93. The premise is that by keeping sediment generated from the Project within levels and durations of natural occurrence, the effects should be considered no more than minor and temporary. This recognises that river biota already experiences periodic disruptive, high turbidity events (i.e., Mararoa floods), and recover from these events.

94. The duration of exceedance allowances for each threshold have been calculated based on what occurs naturally within an average year. Exceedance allowances also consider that natural levels of turbidity will continue to enter the LWR from the Mararoa in addition to anything contributed from the Project. Exceedance allowances take this into account and are set at a level that endeavours to keep the total combined suspended sediment from the Mararoa and from the Project within

the range of what occurs naturally. This will likely be greater than the average year. However, many years have turbidity levels that are greater than the natural average, so biota are adapted to recover from these levels.

95. The proposed Project window is 10 months (although greatest potential for sediment generation is during the five-week breakout phase). The threshold exceedance allowances do not change if the works take a greater or lesser time within the proposed 10-month window.

Methodology for establishing suspended sediment thresholds

96. The approach taken in establishing reasonable turbidity thresholds was to allow exceedances of specified turbidity levels, but only for durations that represent the approximate upper limit of that which would occur naturally.[22]

97. The allowances for threshold exceedance durations for the Project are calculated as 0.75 times the exceedance durations that occur naturally during an average year (i.e., from the Mararoa). This means that, if sediment generated from the Project exceeds these thresholds for the allowed durations and the Mararoa also supplies sediment at levels equivalent to an average year, the total sediment supplied to the receiving environment will be 1.75 times that which occurs during an average year. This level of suspended sediment is within the range of suspended sediment that has been generated historically from the Mararoa (i.e. some years the Mararoa produces greater than average levels of suspended sediment). Each of these levels and durations is outlined in Table 3-1 in the NIWA Freshwater Ecology Report.

98. The turbidity data available to support development of the proposed turbidity thresholds is a relatively short time series (~3.5 years), and it is unlikely that the period covered (November 2019 to May 2023) encompasses all of the natural flow variability (and therefore turbidity variability) in the river.

99. To get a better understanding of natural flow and turbidity variability in the Mararoa River (i.e., beyond the turbidity record), NIWA[23] examined 33 years of annual flow

[22] Note that 'exceedance events', refer to periods when specified turbidity levels are exceeded, however, the intention is that the specified durations for each threshold are not exceeded. These durations may be referred to as 'exceedance allowances'.
[23] Described in the Freshwater Ecology Report Appendix D to the AEE.

statistics calculated from the Mararoa at Cliffs flow record. NIWA estimated variability in turbidity in earlier years based on two steps.

100. Step 1 was to establish links between flow metrics and turbidity thresholds using the available turbidity record (November 2019 to May 2023). Although the relationship between turbidity and flow has high variability (Figure B-2), the data showed clear differences in turbidity associated with different ranges of flow (<40 m^3/s, 40–100 m^3/s, 100–200 m^3/s, and >200 m^3/s).

101. Assuming that the relationships between flow and turbidity established from the turbidity record apply to all years (which is a reasonable assumption), under natural conditions:

(a) Turbidity exceeds 12.4 FNU for about 1% of the time when flows are <40 m^3/s and about 59% of the time when flows are >40 m^3/s;

(b) Turbidity exceeds 30 FNU for about 33% of the time when flows are greater than 40 m^3/s;

(c) Turbidity exceeds 160 FNU for about 6.3% of the time when flows are greater than 40 m^3/s; and

(d) Turbidity exceeds 330 FNU for about 5% of the time when flows are between 100 and 200 m^3/s, and about 70% of the time when flows are >200 m^3/s.

102. Step 2 was to apply the rates of exceedance summarised above to durations of flow in each flow band (i.e., less than 40 m^3/s, etc.) in all full years of flow record (January to December) from 1990 to 2022 to estimate annual exceedances of the turbidity thresholds as total hours (or days) per year.

103. Rates of exceedance of each of the numeric thresholds in each year are shown in Appendix B (Table B-2), with overall ranges shown at the bottom of the table.

Methodology for establishing deposited fine sediment thresholds

104. My understanding of natural variability in DFS in the upper reaches of the LWR is based on a 4.5-year record of monthly observations (August 2018 to March 2023) from the Waiau River upstream of Excelsior Creek monitoring site (1.5 km downstream of the MLC). This time series was used to describe variability of DFS over time under existing conditions.

105. The DFS threshold of an increase in 20% cover above a baseline is based on the ecological literature (refer to evidence of Dr Hogsden and Freshwater Ecology report).

106. During the Project, DFS exceedances above baseline in the Waiau River upstream of Excelsior Creek may be caused by the Project or by natural events in the Mararoa. Meridian only needs to manage DFS exceedances above baseline if they are attributable to the Project. Therefore, NIWA undertook an analysis to assess what conditions typically lead to high levels of DFS in the Waiau River upstream of Excelsior Creek.

107. This analysis involved:

(a) examining the DFS record from the Waiau River upstream of Excelsior Creek monitoring site to identify instances of high DFS (>20% cover) over the period since there has been a turbidity record at Mararoa River at Weir Road (i.e., since November 2019),

(b) identifying flow events in the Mararoa in the month preceding those instances of high DFS cover,

(c) examining the turbidity record for each of those events to identify the duration of turbidity exceedances above the threshold levels already being monitored for the Project (12.4, 30, 160, 330 FNU), and

(d) averaging these durations for each threshold level.

108. NIWA found that the results were most consistent (narrowest range) for the 30 FNU turbidity threshold level. The average duration of turbidity >30 FNU that was associated with DFS >20% cover was 37 hours.

109. Therefore, if DFS in the Waiau River upstream of Excelsior Creek exceeds the baseline by 20% cover, and the Project alone has contributed a turbidity > 30 FNU for 37 hours consecutively, it is feasible that the Project may have caused the increase in DFS.

Calculating effectiveness of flushing flows

110. NIWA undertook an analysis to assess how managed flow releases down the Waiau Arm of varying magnitude might be effective in diluting suspended sediment discharged into the LWR from the Project. The aim of this analysis was to provide guidance to Meridian such that, if suspended sediment exceedance events occur, Meridian could make management or mitigation decisions based on the size of flushing flow required to reduce turbidity levels sufficiently to avoid exceeding the threshold durations.

111. This analysis assumes that flows down the Waiau Arm all have zero turbidity (i.e., the flushing flows contribute no additional suspended sediment). Also, the turbidity from the Mararoa is calculated at various flows based on the turbidity versus flow relationship for Mararoa at Weir Road. This is important because the level of dilution provided by a flushing flow will depend on the suspended sediment being contributed from the Mararoa.

EFFECTS OF PROJECT ON SEDIMENT GENERATION

Suspended sediment

Suspended sediment results from trial

112. The trial excavation is largely described in Dr Clunie's evidence with results from the sediment monitoring during the trial described in Hoyle et al. (2023)[18]. Here I describe only the results that summarise the potential risks of the Project in terms of instream suspended sediment generation.

113. The trial concluded that instream bund construction and removal, and instream excavation of bed material, can each cause rapid increases in SSC (and corresponding decreases in VC). As Dr Clunie describes in his evidence, this led to the decision to progress a parallel channel option with the majority of excavation completed outside the flowing river.

114. Maximum turbidity recorded during the trial was 36.8 FNU, which is equivalent to a SSC of 25.7 g/m^3 and a minimum VC of 0.5 m.

115. These values typically occur in the lower Mararoa River during flows that are exceeded about 10% of the year (i.e., equivalent frequency to that of flows of 62 m^3/s and over). Turbidity of this level has a recession time (i.e., time back to normal low turbidity levels) of approximately 40 hours.

Potential for suspended sediment generation during Project

116. The selected methodology for the Project avoids working instream as much as possible, and also minimises the period over which fine sediment may be generated.

117. As the proposed methodology for the Project involves excavation of a parallel channel that is largely isolated from the current Waiau Arm (refer to Figure 4 in Mr Feierabend's evidence), the highest potential for generation of suspended sediment is during the Stage 3 breakout phase. This stage is expected to take five weeks.

118. The greatest concentration of sediment release is expected at the final step when the downstream 'breakout' is completed, exposing the excavated channel to through-flow for the first time, flushing out suspended sediments contained within, and scouring fines from, the new bed.

119. Earlier stages of the Project involve no instream works and are not anticipated to generate high levels of suspended sediment. However, the bunds constructed during Stage 1 are in an area that can become inundated during high lake levels or high flows down the Waiau Arm. My understanding is that it is highly unlikely that these bunds could be overtopped, but during high lake levels or high flows down the Waiau Arm, it is possible that some fine sediment could be eroded out of the new temporary bunds and released downstream during Stages 1 or 2. I note, however, that this situation would be associated with an increase in low turbidity water from Lake Manapōuri, and this dilution would mean that SSC should remain low.

120. Suspended sediment will likely also be generated during future maintenance works. However, the extent of excavation required for maintenance will be significantly less than during the construction phase and I anticipate that the sediment effects related to maintenance should be very similar to that which occurs during the currently

consented MLC maintenance. I understand existing maintenance undertaken under that consent to be relatively minor and of short duration.

121. Whilst the relative potential for generation of suspended sediment during different stages of the project is understood, absolute levels of suspended sediment remain uncertain. This is why an adaptive sediment management approach has been recommended and is reflected in the proposed conditions of consent.

Suspended sediment management

122. The proposed suspended sediment management thresholds are presented earlier in Table 1.

123. The numeric thresholds for suspended sediment are expressed as values of turbidity (FNU) that should not be exceeded for more than a specified duration, because turbidity is what can be continuously measured in a monitoring programme.

124. High flow events in the Mararoa River, large enough to increase turbidity to exceed one or more of the thresholds (e.g., >~40 m^3/s), may occur during the Project. The turbidity from these events will be excluded from the exceedance allowances. This can be achieved by subtracting the turbidity measured at the Mararoa at Weir Road monitoring station (upstream monitoring station, UMS) from the turbidity measured in the Waiau River upstream of Excelsior Creek (downstream monitoring station), which isolates turbidity originating from the Waiau Arm and Project Area. It is important that the turbidity sensors used at both monitoring stations are the same type of sensor (Hach-Solitax sensors). The location of the proposed upstream and downstream monitoring stations is shown in Appendix D, Figure D-1 of my evidence.

125. All turbidity levels can be monitored by daily calculation of cumulative exceedances starting from day 1 of the Project.

126. The proportion by which turbidity (or SSC) generated from the Project will be reduced by a series of Waiau Arm flow scenarios is summarised in Appendix E, Table E-1 of my evidence. For example, if flows in the Mararoa River are 15 m^3/s, then release of a small flushing flow of 45 m^3/s should reduce turbidity generated by the Project by 75%.

127. In the unlikely event that excavation activities need to occur over two seasons, then exceedance durations would reset, as long as there was a six-month break between

significant sediment generating activities (i.e., activities generating >160 FNU). Excavation should not recommence until the majority of the elver migration was completed (refer to Dr Hickford's evidence).

Residual effects of the Project on suspended sediment

128. Levels of suspended sediment are expected to remain within the range experienced normally in the lower Mararoa River and upper reaches of the LWR. This expectation is considered reasonable because suspended sediment levels generated during the trial were within this range (maximum turbidity recorded during the trial was 36.8 FNU) and most of the material to be excavated has originated from the Mararoa River and should therefore have similar characteristics to suspended material measured in the lower Mararoa River.

129. The Project could potentially add suspended sediment to the LWR at low flows over a maximum period of 4–5 months, but the highest likelihood of elevated suspended sediment is over a week or two during the Stage 3 breakout period.

130. This means that elevated suspended sediment has potential to be generated over longer durations and at lower flows than would happen naturally during floods.

131. If this occurs, the effect can be mitigated through flushing flows which are expected to be effective at reducing suspended sediment concentration by dilution.

Deposited fine sediment

Deposited fine sediment results from trial excavation

132. Monitoring of DFS over the trial showed DFS increased by only 2.3% cover.

133. Based on the high proportion of sand in the excavated material (as covered in Dr Clunie's evidence) and the significant proportion of sand in the suspended sediment sampling, I would have expected the trial excavation to have had a larger impact on DFS.

134. Hoyle et al. (2023)[18] describes several confounding influences that may have affected results and suggests that these monitoring results are considered inconclusive.

Potential for deposited fine sediment generation

135. The periods of the Project with the highest potential for generation of suspended sediment (i.e., Stage 3 breakouts) are also the periods with the greatest potential for DFS.

136. The potential for suspended sediment to deposit on the bed is greater than it would be for an equivalent level of suspended sediment generated naturally from the Mararoa River. This is because suspended sediment generated by the Project may occur during low flows (and associated low velocities), relative to equivalent levels of suspended sediment that are naturally generated from the Mararoa River during high flows.

137. The potential for DFS depends on the particle size distribution of the material being contributed instream (i.e., from temporary bunds during high flows, or from the parallel channel following breakout completion), and the flows in the Mararoa River and down the Waiau Arm at the time. Each of these factors is highly uncertain but, if DFS occurs as a result of the Project, it can be managed. This is because flows down the Waiau Arm can be managed by Meridian, to a degree, and increasing flows will help flush and disperse the fine sediment downstream.

Residual effects of the Project on deposited fine sediment

138. If high levels of suspended sediment are generated by the Project, there is high potential for at least a proportion of that sediment (i.e., silt and sand fractions) to be deposited on the bed downstream.

139. However, occasional floods and flushing flows are expected to re-mobilise DFS both during and following the Project.

140. Any DFS generated from the Project is expected to be within the range of DFS that occurs naturally and will be temporary.

Deposited fine sediment management

141. The proposed DFS management threshold is an exceedance allowance of an increase of no more than 20% cover, based on a rolling four-week average of weekly observations in the Waiau River upstream of Excelsior Creek (the long-term monitoring site), over the baseline value at the start of the excavation.

142. To establish the baseline DFS value, % cover will be monitored weekly at the Waiau River upstream of Excelsior Creek monitoring site for at least six weeks prior to commencing the parallel channel excavation works. The average % cover over this monitoring period will form the baseline.

143. The rolling four-weekly average allows for short term variability in DFS, which occurs naturally in the LWR, but aims to prevent a persistent increase in DFS and/or a shorter-term significant increase.

144. It is known that turbidity >30 FNU at Mararoa at Weir Road sustained for 37 hours or more is related to DFS of >20% cover at the Waiau u/s Excelsior Creek monitoring site. Therefore, these turbidity conditions, whether generated from the Mararoa River or the Project, are expected to result in increases in DFS. The Project will be deemed responsible for a DFS increase if the Project alone[24] generates this level and duration of turbidity.

RESPONSES TO ISSUES IN SUBMISSIONS

145. I have read all the submissions lodged on the Project relevant to my area of expertise. To the extent not already addressed in my evidence, I will respond to submissions that raised issues or concerns related to suspended sediment and/or, DFS.

146. The **Department of Conservation** submission raises concerns regarding the proposed turbidity management thresholds being set “in accordance with impacts on salmonids not threatened and at-risk indigenous species”, and requests that: a) turbidity levels should be re-set to protect the threatened and at-risk indigenous freshwater fauna that will be impacted; b) and/or other conditions imposed to avoid, remedy, or mitigate adverse effects, on indigenous fish species; and c) proposed

[24] Turbidity from the Project is calculated from turbidity at the Waiau at Excelsior Creek monitoring station minus turbidity at the Mararoa at Weir Road monitoring station.

consent conditions should address what actions must occur in the event that turbidity levels, and DFS levels, are exceeded. I understand that these concerns have largely been addressed through pre-hearing discussions between Meridian and the Department, drawing on expert advice, and that the Department's concerns are now confined to the conditions on the proposed Freshwater Fauna Management Plan which will set out programme for fish relocation in the breakout areas.[25] However, for completeness, I address the points made in the Department's submission which are relevant to my area.

147. In response to a) I refer to paragraphs 80–83 in my evidence where I outline that turbidity threshold levels were assessed based on the literature for all biota potentially affected by the Project, including threatened and at-risk indigenous freshwater fauna, and durations of exceedance are based on what occurs naturally in the LWR. Specific linkages between turbidity thresholds and salmonids are made based on the literature, which highlights that salmonids are particularly sensitive to suspended sediment, and more so than indigenous fish species (refer to evidence of Dr Hickford).

148. In response to c) I refer to Meridian's proposed consent conditions attached to Mr Murray's evidence, relating to turbidity thresholds and DFS. The turbidity threshold conditions read together outline durations over which specified turbidity levels shall not be exceeded. There are also conditions that outline measures that are reasonably practicable to ensure that these turbidity and DFS levels and durations are not exceeded, and these conditions note that the Applicant is not limited to these mitigation measures. I consider that these conditions outline actions that will avoid, remedy, or mitigate adverse effects, whilst retaining flexibility for the Applicant to choose the appropriate response according to the given situation.

149. The **Waiau Working Party** submission raised several points which are relevant to the proposed sediment management regime. I understand that Meridian and the WWP have been engaged in pre-hearing discussions, and the WWP is no longer pursuing these submission points[26]. However, for completeness, I address each of these points below.

---

[25] S99 2nd Pre-Hearing Meeting Report APP-20233670.

[26] Maurice Rodway letter on behalf of Waiau Working Party (dated 22 July 2022) referred to in Point 3. of S99 2nd Pre-Hearing Meeting Report APP-20233670.

150. I note the **Waiau Working Party** submission supports the recommendations in the AEE for the control and monitoring of suspended and DFS as set out in the Freshwater Ecology Report but requests the addition of a minimum permitted interval between turbidity exceedance events.[27]

151. In response, I understand that specifying a minimum permitted interval between exceedance events may have the benefit of providing greater surety of recovery time for biota, particularly if conditions in the river get close to a consecutive duration threshold. However, I consider the following:

(a) Prolonging the excavation works also prolongs the period of potential effects (refer to other evidence);

(b) Naturally, flood events that generate high levels of sediment can occur in close succession;

(c) The greatest risk of threshold exceedance events is during the final stages of the breakout phase and, at this point, stopping work and having a specified minimum interval between exceedances would unlikely be of benefit. Once the breakout area is opened, the most effective action would likely be a flushing flow to dilute suspended sediment and move DFS; and

(d) With reference to the evidence of Drs Hickford and Hogsden, I understand that the proposed sediment management framework provides sufficient protection for biota against major adverse effects.

152. Therefore, on balance, I consider that specifying a minimum permitted interval between exceedance events is an unnecessary layer to an already multi-layered sediment management framework that should be sufficient.

[27] I note that the Guardians of Lakes Manapōuri, Monowai & Te Anau (Guardians) have made a similar submission point, but I understand 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.

153. I note the **Waiau Working Party** submission queries the relationship between turbidity levels expected to potentially cause an exceedance in the DFS threshold (i.e., more than 37 hours consecutively at turbidity >30 FNU) and the 30 FNU turbidity threshold and request further context and clarity on how a DFS threshold exceedance will be addressed in practice.[28]

154. In response, I note that the turbidity thresholds and DFS thresholds have been developed independently based on the potential for an adverse effect on biota. Comparing these two thresholds highlights that there is a higher risk that the DFS threshold will be met than the 30 FNU turbidity threshold. Also, turbidity of 30 FNU for 37 hours consecutively will not necessarily cause exceedance of the DFS threshold, but the data tells us that it is possible. The most effective response to exceedance of the DFS threshold will be a flushing flow, as increased flows are expected to remobilise DFS and disperse that sediment downstream.

155. I note that the **Guardians and Waiau Working Party** submission both refer to the location of the DFS monitoring site. The Guardians suggest that this monitoring site be shifted to downstream of Excelsior Creek for the duration of the Project, due to the fact that the proposed site is occasionally difficult to access due to channel geometry. In contrast, the Waiau Working Party does not support shifting the monitoring site to downstream of Excelsior Creek as this would introduce Excelsior Creek as a potentially confounding source of sediment.

156. In response, I agree with the Waiau Working Party that the monitoring station should remain upstream of Excelsior Creek to avoid the potential for a confounding source of sediment. The proposed frequency of monitoring is weekly, so the risk of missing an increase in DFS is much lower than in the monthly monitoring programme. I agree with the Waiau Working Party that monitoring be coordinated with suitable flows. i.e., if, during the scheduled weekly monitoring, the site is unable to be accessed, the site should be revisited as soon as possible after flows recede sufficiently for the site to be accessed.

[28]I note this submission point appears in the Guardians' submission also.

RESPONSE TO SECTION 42A REPORT

157. 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 report of Dr Burrell.

158. I note that in paragraph 3.2.14 in the S42A Report, and paragraph 22 in Dr Burrell's report, concern is raised that proposed turbidity limits could result in more than double the historic measured values. In response, I refer to paragraphs 94 and 97 in my evidence that outline how proposed thresholds relate to what occurs naturally. The proposed thresholds mean that if the Mararoa River produces suspended sediment at levels typical of an average year, and the Project stays within the proposed thresholds, then the receiving environment should only experience suspended sediment levels within the range of that which has occurred historically. However, I do acknowledge that the Mararoa River may generate greater levels of suspended sediment during the Project than occurs in an average year and, therefore, total suspended sediment (the combination of natural levels in the Mararoa River and that caused by the Project) may potentially exceed levels that have occurred historically.

159. Paragraph 3.2.15 in the S42A report and paragraph 22 in Dr Burrell's report, comment that it can be very difficult to avoid large turbidity increases during instream works. I agree and note this is why the Project avoids working instream as much as possible, will complete instream works as quickly as possible, and also proposes consent conditions to mitigate high levels of turbidity if this occurs.

160. I note that paragraph 3.2.15 in the S42A report and paragraph 22 in Dr Burrell's report suggest that an alternative way to mitigate the effects of instream works would be to limit the amount of time that in-river works can occur, and the number of consecutive days that work can occur. In response, I consider that:

   a. determining appropriate limits on durations of work and intervals between work would depend on the turbidity generated by those works and that this is uncertain, making it difficult to link this condition to an effect. The proposed conditions achieve the same endpoint (limiting durations of sediment exposure), but each duration limit is directly linked to levels of sediment that may cause an adverse effect.

b. limiting consecutive periods of work may result in prolonged exposure to elevated turbidity, albeit at lower levels.

c. The proposed conditions have been developed with the aim of completing works as quickly as possible to minimise the duration of effects, while endeavouring to ensure that levels of turbidity do not become excessive.

161. I note that paragraph 23 in Dr Burrell's report refers to a proposed condition relating to DFS[29] and notes concerns with this condition. An updated set of conditions is appended to Mr Murray's evidence. I acknowledge that there is not a strong relationship between antecedent turbidity and DFS and, therefore, there needs to be a clear statement in the conditions identifying when a mitigation action is required. NIWA has identified turbidity conditions in the Mararoa that have historically led to an increase in DFS of 20% cover (see paragraph 144 in my evidence, with further detail provided in Appendix B of the NIWA Freshwater Ecology Report) and these data have been used to develop a rule relating to Project generated sediment, specifying when a mitigation action is required. This rule has been incorporated into the updated proposed conditions. I consider that these conditions relating to DFS are relatively easy to monitor and identify when a mitigation action is required. Collectively, the DFS conditions compare DFS measured at the DMS during and following the Project with a baseline DFS and if DFS exceeds the baseline by a level that may potentially cause adverse effects, and the increase is feasibly due to the Project, then a mitigating action is required.

162. I agree with the point made in section 3.2.17 in the S42A Report that effects due to discharge of sediment will also result from maintenance activities but consider that the level of effect will be significantly less than during construction works (refer to paragraph 120 in my evidence).

CONCLUSIONS

163. Elevated levels of suspended sediment and DFS are part of the natural conditions in the LWR.

164. Subject to the Project methodology and sediment management regime proposed, levels of suspended sediment resulting from the Project are expected to remain

[29] Condition 12 in Revised conditions- draft 15 July

within the range experienced normally in the lower Mararoa River and upper reaches of the LWR.

165. The Project could potentially add suspended sediment to the system at low flows over a maximum period of 4–5 months, but the highest likelihood of elevated suspended sediment is over a week or two during the Stage 3 breakout period. This means that elevated suspended sediment has potential to be generated over longer durations and at lower flows than would happen naturally during floods.

166. If this occurs, the effect can be mitigated through flushing flows which are expected to be effective at reducing SSC by dilution.

167. If high levels of suspended sediment are generated by the Project, there is high potential for at least a proportion of that sediment (i.e., silt and sand fractions) to be deposited on the bed downstream.

168. However, occasional floods and flushing flows are expected to re-mobilise DFS both during and following the Project.

169. Any DFS generated from the Project is expected to be within the range of DFS that occurs naturally and will be temporary.

Jo Hoyle

2 September 2024

APPENDIX A – FLOW DATA

Table A-1: Mean flow in the Waiau Arm, Lower Waiau River and Mararoa River by month. Means are averages within months from 2012 to 2023 for Waiau Arm and LWR (post MTAD) and 1990 to 2023 for Mararoa (based on Mararoa at Cliffs record). Positive flow towards MLC, negative flow towards Lake Manapōuri.

	Average of flow in each month (m^3/s)												Mean annual flow
Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	
Waiau Arm (MLC flow minus Mararoa flow)													
Positive	48	36	13	11	121	87	52	106	114	158	123	116	**71**
Negative	-6	-6	-6	-5	-8	-12	-15	-13	-10	-11	-9	-5	**-10**
Net flow	41	29	11	7	60	36	14	28	28	71	65	66	**38**
Lower Waiau													
	62	50	24	24	107	80	60	70	69	113	100	90	**71**
Mararoa River													
	21	18	16	22	34	39	36	38	41	41	36	26	**31**

APPENDIX B – SUSPENDED SEDIMENT DATA

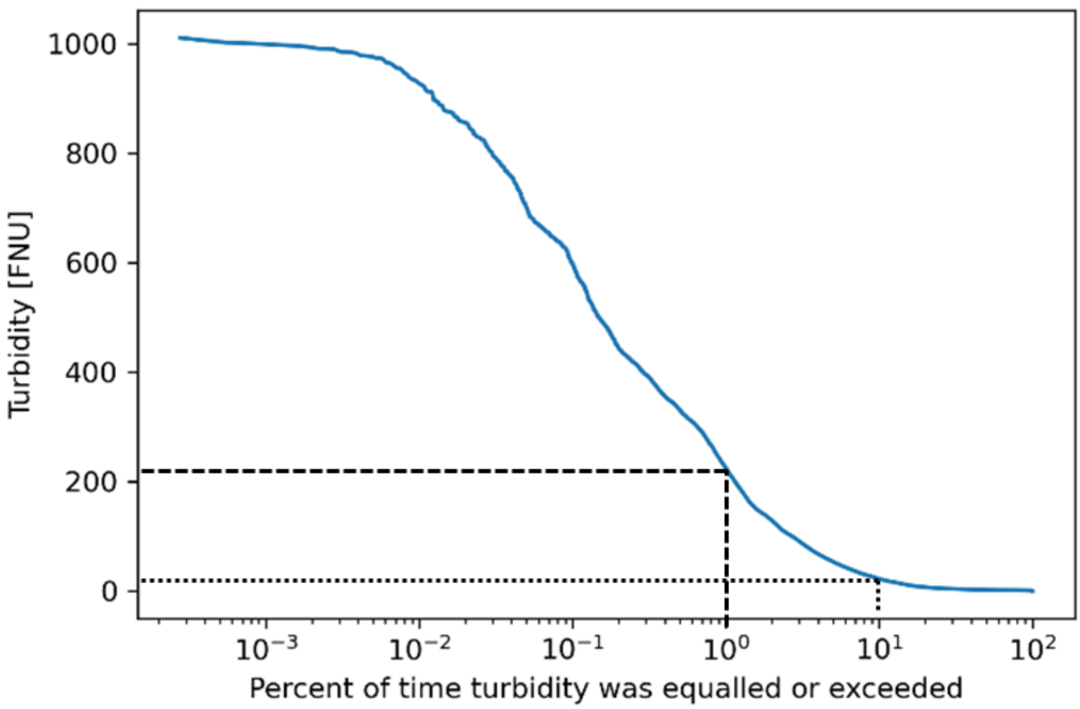

Figure B-1: Duration curve for turbidity in the Mararoa River at Weir Road. Data from 6 November 2019 to 22 May 2023. The horizontal axis is log-transformed to show the typical distribution of turbidity over time more clearly, i.e., very small proportions of time with high turbidity. The dashed and dotted lines show turbidity exceeded for 1% (10^0) and 10% (10^1) of the time (refer to text).

Table B-1: Values of turbidity (and the equivalent VC and SSC) based on established relationships that are exceeded in the Mararoa River for specified percentages of time. Percentages are also shown as the equivalent numbers of hours or days per year.

Percent of time equalled or exceeded	Equivalent no. hours or days per year (on average)	Turbidity (FNU)	VC (m)	SSC (g/m^3)
0.01	<1 hour	921	0.07	686
0.1	9 hours	598	0.09	446
0.5	~2 days	331	0.13	246
1	~4 days	225	0.16	168
2.5	~9 days	105	0.26	79
5	~18 days	53	0.39	40

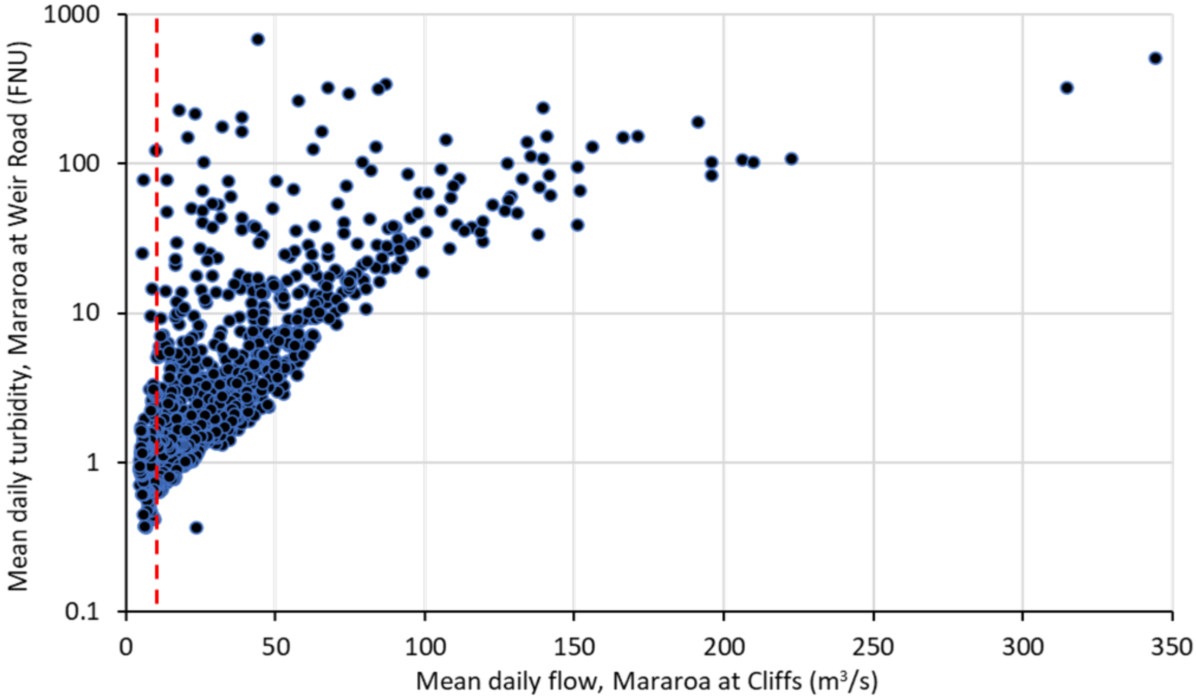

Figure B-2: Log-transformed mean daily turbidity (Mararoa at Weir Road) plotted against mean daily flow at Mararoa at Cliffs. Data from November 2019 to February 2023. The red dashed line at 12 m^3/s shows that turbidity at lower flows is typically <5 FNU with only a few outlying higher values.

Table B-2: Estimated hours per year that thresholds were exceeded in the Mararoa River 1990 to 2022. Estimates based on relationships between turbidity and flows. Shaded rows are years with turbidity data.

Year	Mean flow (m^3/s)	Estimated hours per year when turbidity threshold exceeded			
		12.4 FNU	**30 FNU**	**160 FNU**	**330 FNU**
1990	31.5	1545	829	158	26
1991	38.7	1540	826	158	99
1992	28.6	945	487	93	26
1993	31.0	1214	641	122	36
1994	48.0	2343	1283	245	66
1995	44.8	2274	1244	238	47
1996	34.3	1258	666	127	50
1997	32.8	1413	754	144	37
1998	42.6	2181	1191	227	53
1999	30.3	1052	548	105	105
2000	32.1	1331	707	135	26
2001	22.1	680	337	64	31
2002	36.6	1440	769	147	78
2003	30.0	1269	672	128	36
2004	33.4	1261	668	127	26
2005	25.3	595	288	55	29
2006	29.4	974	505	96	36
2007	27.7	1016	528	101	42
2008	24.7	684	339	65	30
2009	29.7	971	503	96	56
2010	34.9	1409	752	144	102
2011	25.2	795	403	77	26
2012	28.1	1133	595	114	51
2013	34.0	1148	604	115	75
2014	31.2	1222	645	123	35
2015	31.0	1280	678	129	26
2016	30.8	1208	637	122	56
2017	21.8	701	349	67	30
2018	34.0	1444	772	147	35
2019	38.7	1567	842	161	75
2020	31.1	1052	548	105	62
2021	32.6	1440	770	147	43
2022	27.5	973	504	96	40
Range:	Minimum	595 (25 days)	288 (12 days)	55 (2 days)	26 (1 day)
	Maximum	2343 (98 days)	1283 (53 days)	245 (10 days)	105 (4 days)

APPENDIX C – DEPOSITED FINE SEDIMENT DATA

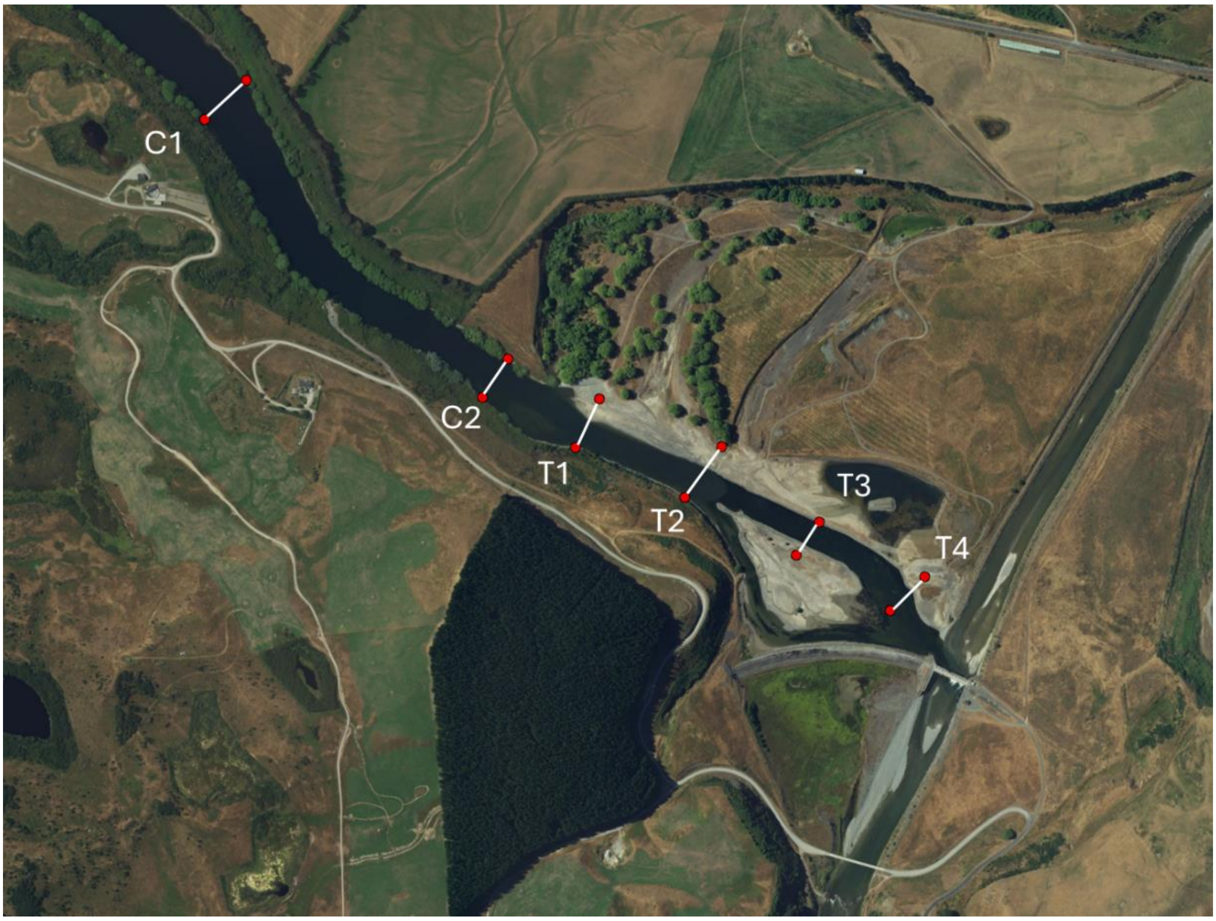

Figure C-1: Location of transects covered by benthic survey in close proximity to Project Area.

APPENDIX D – LOCATIONS OF MONITORING SITES

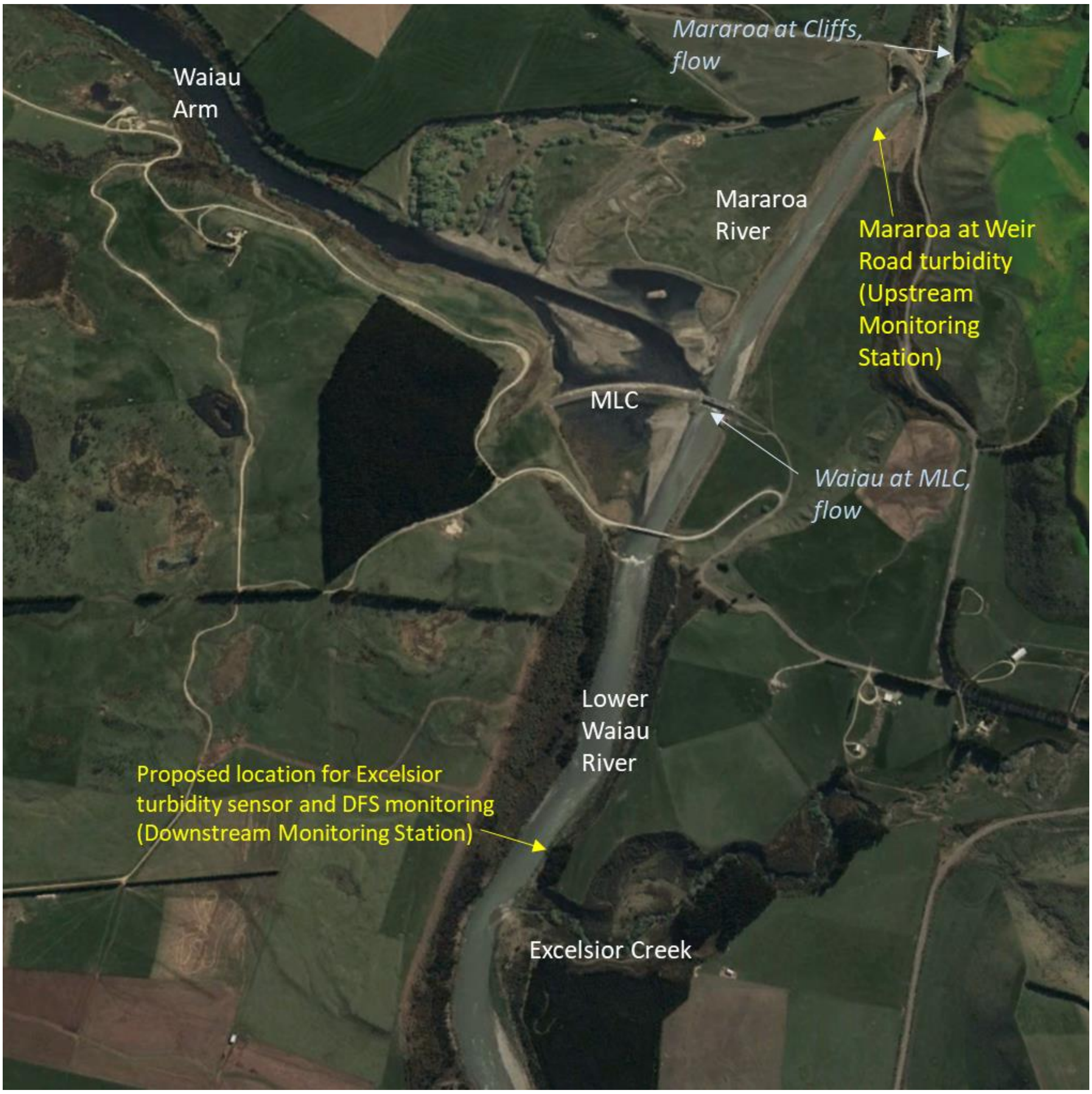

Figure D-1: Location of upstream and downstream monitoring stations.

APPENDIX E – FLUSHING FLOWS

Table E-1: Proportion reduction of turbidity (or SSC) due to the Project under different Waiau Arm and Mararoa flow scenarios.

		Mararoa Flow (m^3/s)									
		5	**15**	**25**	**35**	**45**	**60**	**75**	**100**	**150**	**200**
Waiau Arm Flow (m^3/s)	**5**	50%	25%	17%	13%	10%	8%	6%	5%	3%	2%
	10	67%	40%	29%	22%	18%	14%	12%	9%	6%	5%
	15	75%	50%	37%	30%	25%	20%	17%	13%	9%	7%
	20	80%	57%	44%	36%	31%	25%	21%	17%	12%	9%
	25	83%	62%	50%	42%	36%	29%	25%	20%	14%	11%
	30	86%	67%	55%	46%	40%	33%	29%	23%	17%	13%
	35	88%	70%	58%	50%	44%	37%	32%	26%	19%	15%
	40	89%	73%	62%	53%	47%	40%	35%	29%	21%	17%
	45	90%	75%	64%	56%	50%	43%	38%	31%	23%	18%
	50	91%	77%	67%	59%	53%	45%	40%	33%	25%	20%
	120	96%	89%	83%	77%	73%	67%	62%	55%	44%	38%