Waiau Arm water quality monitoring 2026

Prepared for Meridian Energy Limited

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Executive summary

Meridian Energy Limited (Meridian) is required to undertake water quality monitoring in the Lower Waiau River upstream of the Manapōuri Lake Control (MLC; hereafter referred to as the Waiau Arm[1]) during summer as a condition of resource consents granted by Environment Southland for the operation of the Manapōuri Power Scheme (MPS). Water quality monitoring was established prior to the Manapōuri Tailrace Amended Discharge (MTAD) consents that were approved in 2010. MTAD was predicted to alter the flow regime in the Waiau Arm, with the potential for consequent changes in habitat condition. In particular, these flow changes were anticipated to increase the risk of summer phytoplankton blooms in the Waiau Arm.

Since 2013[2], aspects of water quality and clarity have been monitored under the monitoring programme as required by the 1996 and 2010 MTAD consent conditions. Surveys are conducted fortnightly (flow permitting) between 1 January and 31 March at three sites in the Waiau Arm and one site in Lake Manapōuri. Water quality data are collected by an independent contractor and assessed by Earth Sciences New Zealand (Earth Sciences NZ) against established water quality criteria for dissolved oxygen, pH, water clarity (as Secchi disk depth) and chlorophyll *a*[3] to determine if any outcomes require management action (e.g., additional surveys[4], need for flushing). Sampling methods, trigger criteria and the flow management action plan follow a protocol that was updated in 2025[5] as approved by Environment Southland. This report presents the results of water quality monitoring for the 2026 summer monitoring period.

Six scheduled surveys were completed in 2026, from 5 January to 26 March. No additional surveys were required. The sampling methods and procedures used were the same as in previous years. Water temperature, dissolved oxygen (reported as %DO), pH and turbidity were measured at the surface and 1 m intervals down depth profiles (maximum depth 15 m) at the four sites, and water clarity as Secchi disk depth was measured at each site. The pH probe was calibrated prior to each field survey. Flow in the Waiau Arm, weather conditions, and rainfall events prior to the surveys were considered in the interpretation of the monitoring results.

MTAD was exercised (i.e., discharge of fresh water into Doubtful Sound between 510–550 m^3/s when conditions permit) during the monitoring period. Mean daily flow in the Waiau Arm was 28.7 m^3/s and flow was towards the MLC for 84% of the time (from 1 January to 31 March). Positive flows (i.e., flows towards MLC) were maintained, in part and at times, due to consent requirements for the Manapōuri Lake Control Improvement Project (MLC:IP).

Water quality and clarity were generally good to very good at all sites over the monitoring period. Based on chlorophyll *a*, sites in the Waiau Arm were typically classified as microtrophic to oligotrophic, except on 8 February when elevated concentrations resulted in those sites being classified as mestrophic or eutrophic. Water clarity (as Secchi depth) also declined at the Waiau Arm sites on this date.

On 8 February, the Secchi disk clarity criterion was triggered at all Waiau Arm sites and the chlorophyll *a* criterion was triggered at Site 3. The observed decline in water clarity was likely

[1] See Glossary (Section 6) for further details.
[2] The first summer following when the MTAD regime was exercised (23 October 2012).
[3] The chlorophyll *a* criterion was added to the protocol in 2025 (see Section 1).
[4] Additional surveys are undertaken at an increased frequency (usually within a week) to follow-up on a trigger or declining trend in water quality (e.g., declining clarity or dissolved oxygen).
[5] The protocol is referred to as Sutherland (2010, updated 2025). (See Section 1 and Appendix D for further details).

due to increased phytoplankton biomass during a period of parked and negative flows in the Waiau Arm. In response, a flow release was undertaken between 13–15 February to replace water in the Waiau Arm (35 m^3/s for 48 hours). In accordance with the protocol (specifically the flow management action plan), after such a flow release, scheduled surveys are to resume. In the subsequent survey on 24 February, water clarity had improved and chlorophyll *a* concentrations had declined, with no criteria triggered. The brief duration of these triggers and the timely and effective management response suggest that water quality conditions were unlikely to have resulted in any measurable adverse effects on aquatic ecology or habitat in the Waiau Arm.

No other criteria for action were triggered or management actions were required.

1 Introduction

Since the early 2000s, Meridian Energy Limited (Meridian) has undertaken water quality monitoring in the Lower Waiau River upstream of the Manapōuri Lake Control (MLC; referred to as the Waiau Arm[6]). This is required under monitoring requirements set out in Appendix 1 of the operating consents granted for the Manapōuri Power Scheme (MPS) in 1996. In 2010, Meridian was granted resource consent for the Manapōuri Tailrace Amended Discharge (MTAD), which allowed for an increase in maximum discharge from 510 m^3/s to 550 m^3/s from the tailrace of the existing Manapōuri Power Station to Deep Cove in Doubtful Sound, when conditions permit. As a result of MTAD, it was predicted the hydrological regime of the Waiau Arm would be altered, with the degree of alteration dependent on the frequency of MTAD operation. The MTAD regime was first exercised on 23 October 2012 and has been implemented periodically since then. Water quality monitoring requirements for the Waiau Arm were refined under the MTAD consents and subsequently updated in Appendix 1 of the 1996 MPS operating consents (see Appendix A).

The Waiau Arm comprises the outlet of Lake Manapōuri, just upstream of Pearl Harbour, to the Manapōuri Lake Control (MLC). Depending on lake levels and river conditions, water in the Waiau Arm either flows from the lake to the MLC (positive flow), from the Mararoa River (upstream of the MLC) to the lake (negative flow) or is 'parked'[7], with little to no flow moving through the Arm. It was predicted that under the MTAD regime there would be some changes in hydrology in the Waiau Arm, including: a slight increase in the amount of water flowing to the lake from the Mararoa River under certain lake levels; an increase in the number of days the Waiau Arm is 'parked' in a year; and a reduction of peak flows during flood events (Mabin 2008). The hydrology of the Waiau Arm shapes its aquatic habitat; therefore, hydrological changes from the MTAD regime have the potential to affect the habitat both positively and negatively.

An assessment of the potential effects of the MTAD on the biological communities of the Waiau Arm suggested that during dry years under the MTAD hydrological regime, as the age of the water in the Waiau Arm increases due to lower flows and increased 'parked' events, there is an increased potential for effects on the biological communities due to high phytoplankton biomass forming when the water column becomes thermally stratified in summer (Sutherland and Graynoth 2009). Under these conditions, phytoplankton growth could be further enhanced by nutrient inputs from point and non-point sources, which could accumulate in the upper layer of the water column.

To help ensure timely detection of any potential water quality issues, to allow for efficient management of the Waiau Arm, and to meet resource consent requirements, Meridian conducts water quality and clarity sampling in the Waiau Arm annually during the summer months (1 January–31 March). The sampling methods and trigger criteria for the management action plan follow the protocol in Sutherland (2010, updated 2025[8]). The Sutherland (2010) protocol superseded the version established by Biggs et al. (2006). In summary, the protocol now incorporates updated Secchi depth criteria (including a numeric threshold and revised method for calculating percentage change in January surveys), the introduction of a chlorophyll

[6] See Glossary (Section 6) for further details.
[7] The term "parked" refers to times of little to no flow moving through the Waiau Arm (i.e., when flow is ± 8 m^3/s; Spigel et al. 2006)
[8] The protocol in Sutherland (2010) was updated in 2025 following Environment Southland's approval of recommendations made in Hogsden and Kilroy (2025). See Appendix D.

a trigger criterion with requirement for fortnightly chlorophyll *a* sampling to assess compliance, and an updated flow management action plan (Sutherland 2010, updated 2025).

This report presents the results of the 14th season of summer monitoring.

2 Methods

2.1 Monitoring sites

Water quality surveys were conducted at four monitoring sites, three in the Waiau Arm (Sites 1, 2 and 3) and a control site in Lake Manapōuri (Site 4; Figure 2-1). The site in Lake Manapōuri is located offshore from Frasers Beach, in water approximately 80 m deep. This site is not affected by waters entering the lake from the Waiau Arm or nearshore influences from the beach.



Figure 2-1: Location of four monitoring sites in the Waiau Arm (Sites 1 to 3) and in Lake Manapōuri (Site 4). Sites were surveyed in the following order: Site 4, 1, 2, and 3.

2.2 Water quality monitoring

The Waiau Arm monitoring protocol, including methods and rationale for the water quality parameters used are described in more detail in Sutherland (2010, updated 2025; Appendix D).

In brief, on each monitoring survey, depth profiles of temperature, dissolved oxygen (DO), pH and turbidity were recorded using an EXO Sonde 1 water quality meter calibrated against laboratory standards. This was the sixth monitoring season using the EXO Sonde, which replaced the TROLL 9500 meter in 2021. Measurements were taken along a depth profile from just below the surface, 0.5 m below the surface, and then at 1 m intervals until just above the bottom of the Waiau Arm. In the site on Lake Manapōuri (Site 4) measurements were made in the same way, but to a maximum depth of 15 m, which is the maximum length of the water quality meter cable. The pH probe was calibrated before each survey.

Turbidity is a measure of the scattering of light particles by particles suspended in the water and is measured in formazin nephelometric units (FNU). Low turbidity values are indicative of clearer water, whereas higher values indicate more suspended particles are present, which make the water increasingly cloudy or turbid. This water quality parameter is not required as

part of the protocol but is measured as the additional data it provides may be helpful in explaining Secchi disk clarity patterns.

Water clarity was measured at each site using a Secchi disk, following Davies-Colley et al. (1993). The black and white Secchi disk, attached to a graduated line, was lowered through the water column until it could no longer be seen by the observer (step 1). Then the Secchi disk was raised until it just reappeared (step 2). The average depth (m) for step 1 and step 2 was recorded as the Secchi depth measurement.

The protocol now requires the collection of replicate surface-water samples (from the upper 20 cm of the water column) for subsequent measurement of water-column chlorophyll *a* (Sutherland 2010, updated 2025). During surveys, samples were collected at each site, stored on ice, and couriered to Hill Laboratories (Christchurch) for analysis within 48 hours of collection. This was the first season in which chlorophyll *a* sampling was required by the protocol; however, Meridian had voluntarily introduced chlorophyll *a* to the monitoring programme in summer 2020. Chlorophyll *a* sampling was added to provide an indication of phytoplankton biomass and to support interpretation of water quality patterns and results.

2.3 Timing of surveys

Six scheduled water quality monitoring surveys were undertaken from 5 January to 26 March 2026 within the summer monitoring period (Table 2-1). The monitoring protocol states that all surveys should be undertaken in the morning, between 0900 and 1000 NZT, so that DO and pH values, which vary during the day, are standardised where possible at the four sites. However, sampling all four sites typically takes 3–4 hours. Therefore, some variation in DO and pH values due to time of day may be expected. The sites are always surveyed in the following order: Sites 4 (Lake Manapōuri), followed by Sites 1, 2 and 3 in the Waiau Arm. Survey dates, times and weather conditions are provided in Table 2-1.

MTAD was exercised during the year beginning 1 April 2025 and during the summer monitoring period (1 January–31 March) in 2026 (Appendix B).

Table 2-1: Details on water quality monitoring surveys undertaken in the Waiau Arm from January to March 2026. Notes on weather conditions were made by the field team.

Survey date	Start time (h)	Time at Site 3 (h)	Notes on weather conditions
5-Jan-26	9:56	12:45	Warm, sunny conditions with light westerly breezes down the Waiau Arm.
21-Jan-26	11:00	14:06	Calm, warm conditions with high overcast cloud and occasional light rain at Site 3.
8-Feb-26	14:00	16:43	Warm, mostly calm conditions with light southerly to westerly winds and clear skies. Drier spell of weather with a few warmer days over recent weeks.
24-Feb-26	10:00	13:20	Calm, warm conditions with mostly clear skies and little wind. Small amount of localised rain since last survey but generally drier conditions.
11-Mar-26	10:20	13:09	Calm conditions with overcast cloud and cool on the lake (Site 4) to partly cloudy then clear sunny, warm conditions with little wind along the Waiau Arm.

Survey date	Start time (h)	Time at Site 3 (h)	Notes on weather conditions
26-Mar-26	14:15	16:15	Calm, settled conditions with high overcast cloud and little to no wind. Fog delayed start of survey. Lake surface like glass.

2.4 Post-survey assessment

Survey results were sent from the field team to Earth Sciences NZ on the day of the survey and data were entered within 24 hours. Based on the data, an assessment was made whether any criteria for action had been triggered and this information was reported to Meridian. The criteria for action are defined by Sutherland (2010, updated 2025) and are as follows:

- Dissolved oxygen (% saturation; %DO) <85% at any site;
- pH >9 at any site;
- Secchi disk clarity[9] (depth, in m) >33% less than the mean of the three previous sampling occasions at any site AND / OR less than 3.5 m (except that the calculation will use the long-term mean Secchi depth for the month of January[10] for comparison for the first three surveys each year); and
- Chlorophyll *a* ≥5 mg/m^3 at any site[11].

The %DO and pH variables were assessed on average water column depth (up to 15 m). Any action required following the trigger of one or more criteria is summarised in the flow management plan (Appendix C[12]). Flow in the Waiau Arm, weather conditions, and the occurrence of significant rainfall events just prior to the survey were considered in the interpretation of the monitoring results. Turbidity and chlorophyll *a* data collected during the survey are also considered in interpretation of results, noting that chlorophyll *a* results are not usually received for 4–5 days following a survey.

Flow records at two hydrological recordings sites (Waiau @ MLC Tailwater (site 79719) and Mararoa @ Cliffs (site 79737)) were accessed to calculate flow in the Waiau Arm (i.e., flow at Waiau @MCL Tailwater minus flow at Mararoa @ Cliffs). All references to flows are mean daily flow unless stated otherwise.

[9] Secchi disk clarity criterion updated in 2025.
[10] Long-term mean for January is calculated from Waiau Arm water quality monitoring data from January 2011.
[11] Chlorophyll *a* criterion added to the programme and flow management plan in 2025.
[12] The flow management plan was updated in Sutherland (2010, updated 2025). See Appendix D for further details.

3 Results and discussion

3.1 Waiau Arm flow

Flow in the Waiau Arm was towards the MLC for 84% of the time (shown as positive flows on Figure 3-1) during the summer monitoring period in 2026 (1 January–31 March). Mean daily flow in the Waiau Arm was 28.7 m^3/s, with a peak flow of 323.9 m^3/s recorded on 11 January. The peak flow was recorded during a lake spill event that began on 10 January. Flow was low (i.e., ± 8 m^3/s or "parked") in the Waiau Arm for 61% of the time during the summer monitoring period.

Monthly recreational flows were released on 25 January, 22 February and 23 March during the summer monitoring period (Figure 3-1). In addition, a flow release to replace water in the Waiau Arm occurred on 13–15 February (35 m^3/s for 48 hours) in response to a chlorophyll *a* trigger recorded on 8 February (see Section 3.2.5 for details). A 24-hour supplementary flow was also released during the summer monitoring period for nuisance periphyton management in the Lower Waiau River (below MLC) on 19–20 March with a peak flow of 110 m^3/s followed by a return to minimum flows at MLC.

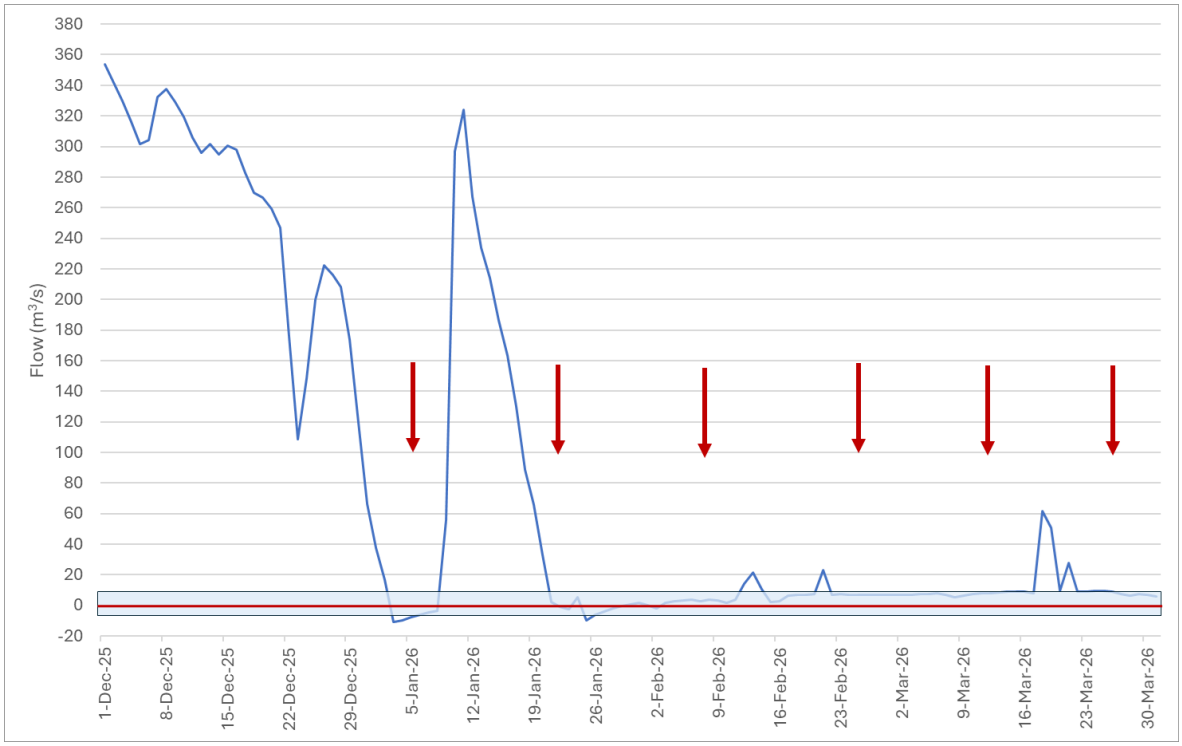


Figure 3-1: Mean daily flow in the Waiau Arm from 1 December 2025 to 31 March 2026. The red line indicates zero flow. Positive flow is towards the Manapōuri Lake Control (MLC), whereas negative flow is towards Lake Manapōuri. The blue shaded area indicates when flow is ± 8 m^3/s, which is termed "parked" and shows times of little to no flow moving through the Waiau Arm (Spigel et al. 2006). Red arrows indicate dates of scheduled fortnightly surveys.

3.2 Water quality parameters

A summary of water temperature, %DO, pH, Secchi disk clarity, turbidity and chlorophyll *a* data collected on the six scheduled surveys between 5 January and 26 March 2026 is provided below.

3.2.1 Water temperature

Across all four sites, water temperature profiles showed gradual declines with depth, with no distinct thermocline evident over the monitoring period, indicating predominately well-mixed conditions (Figure 3-2). Surface water temperatures at all sites in the Waiau Arm (Sites 1 to 3) were highest on the 8 February survey, which corresponded to a trigger of the chlorophyll *a* criterion (Section 3.2.5).

3.2.2 Dissolved oxygen

Dissolved oxygen (DO%) was relatively high at all sites throughout the monitoring period, ranging from 85 to 110% through most of the water column. The only exception was a single low measurement of 64.1% recorded at 12 m depth at Site 1 on 24 February (Figure 3-3). Occasional low DO% values at depth have been previously reported at Site 1, including isolated events in 2024 and 2025 (Hogsden and Key 2025), but such occurrences are rare at other sites and have not been recorded in Lake Manapōuri (Hogsden et al. 2024). Dissolved oxygen was stable over time and with depth throughout the monitoring season at Site 4 in the lake. Mean DO% was well above the DO% criterion for action (<85%, averaged down the water column) at all sites in every survey in 2026; therefore, the DO% criterion was not triggered.

3.2.3 pH

pH ranged from 6.9 to 8.6 across Sites 1–3 in the Waiau Arm and from 6.9 to 7.8 at Site 4 in Lake Manapōuri (Figure 3-4). pH was relatively stable at each site, over time and with depth, with more variability recorded on 8 February survey at the Waiau Arm sites. Data are not reported on 21 January due to a fault with the pH probe.

The pH criterion for action was not triggered during the summer monitoring period in 2026.

3.2.4 Turbidity and Secchi disk clarity

Turbidity was consistently low (almost always less than 2 FNU) at all four sites throughout the water column in 2026. Vertical profiles showed little variation with depth or time, indicating minimal influence of suspended material at all sites (Figure 3-5). The highest turbidity at Site 3 on 8 February coincided with a chlorophyll *a* criterion trigger (see Section 3.2.5) but other sites in the Waiau Arm do not reflect this result, particularly at Site 1 where turbidity was very low (<0.5 FNU).

Secchi disk clarity in the Waiau Arm (Sites 1–3) ranged from 3.3 to 8.3 m over the monitoring period. The lowest and highest clarity values were recorded on 8 February (Sites 1 and 3) and 21 January (Sites 1 and 3), respectively (Figure 3-6). Water clarity varied at Sites 1 to 3 across summer but was generally high (i.e., ≥5 m) and consistently greater than values observed in previous monitoring periods (Hogsden et al. 2024). High water clarity in early to mid-January coincided with periods of high flows associated with lake spill events (Figure 3-1).

Water clarity declined at all sites in the Waiau Arm on 8 February, with shallower Secchi depths resulting in the Secchi disk criterion being triggered at all sites. As flows had been ‘parked’ and negative (i.e., towards the lake) for 60% of the time since the previous survey, this reduction in clarity likely reflected a combination of increased phytoplankton (see Section 3.2.5) during a period of parked and negative flows (Figure 3-1). A flow was released from MLC to flush water in the Waiau Arm in response to a trigger of the chlorophyll *a* criterion (≥ 5 mg/m^3) and by the next survey on 24 February, water clarity had improved.). The Secchi disk criterion was no longer

triggered at any site, and water clarity remained high for the rest of the monitoring season, reflecting the positive flows maintained for the Manapōuri Lake Control Improvement Project (MLC:IP)[13].

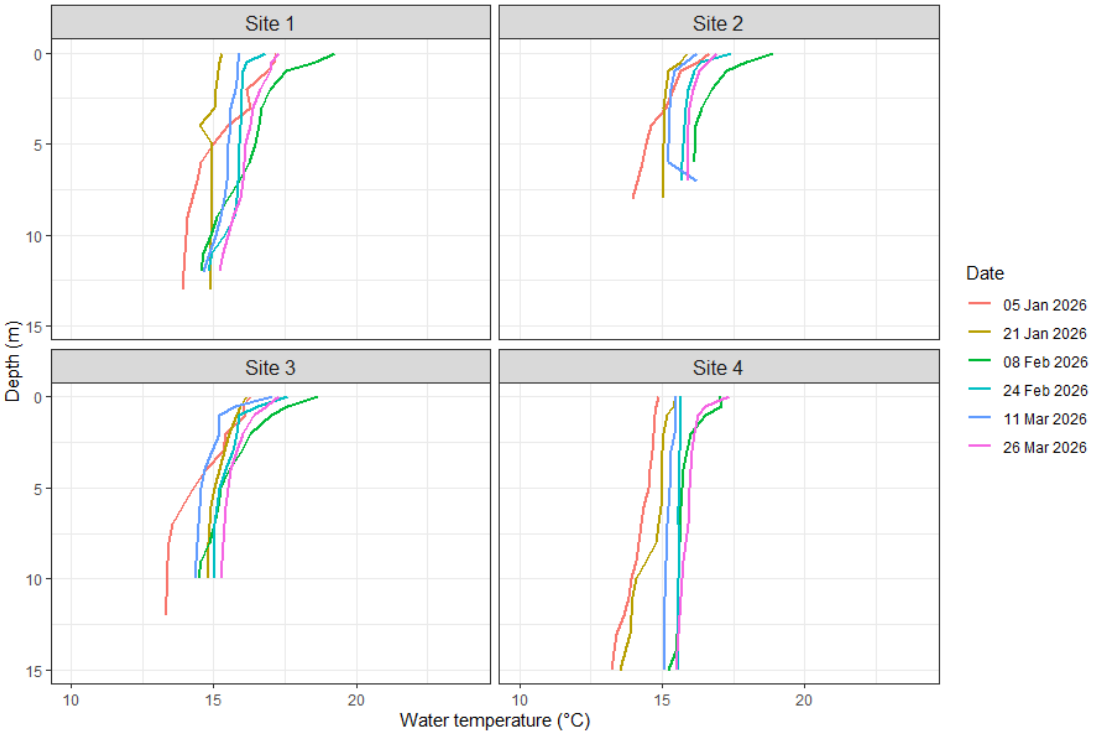


Figure 3-2: Vertical temperature (°C) profiles measured at three sites in the Waiau Arm (Sites 1–3) and a control site in Lake Manapōuri (Site 4) in 2026. Dissolved oxygen profiles for each of the six scheduled surveys are shown on the same plot for each site. Colour coding as per key.

[13] The resource consents for this project require positive flows to be maintained for the duration of the initial parallel channel excavation, and during any future maintenance of the channel.

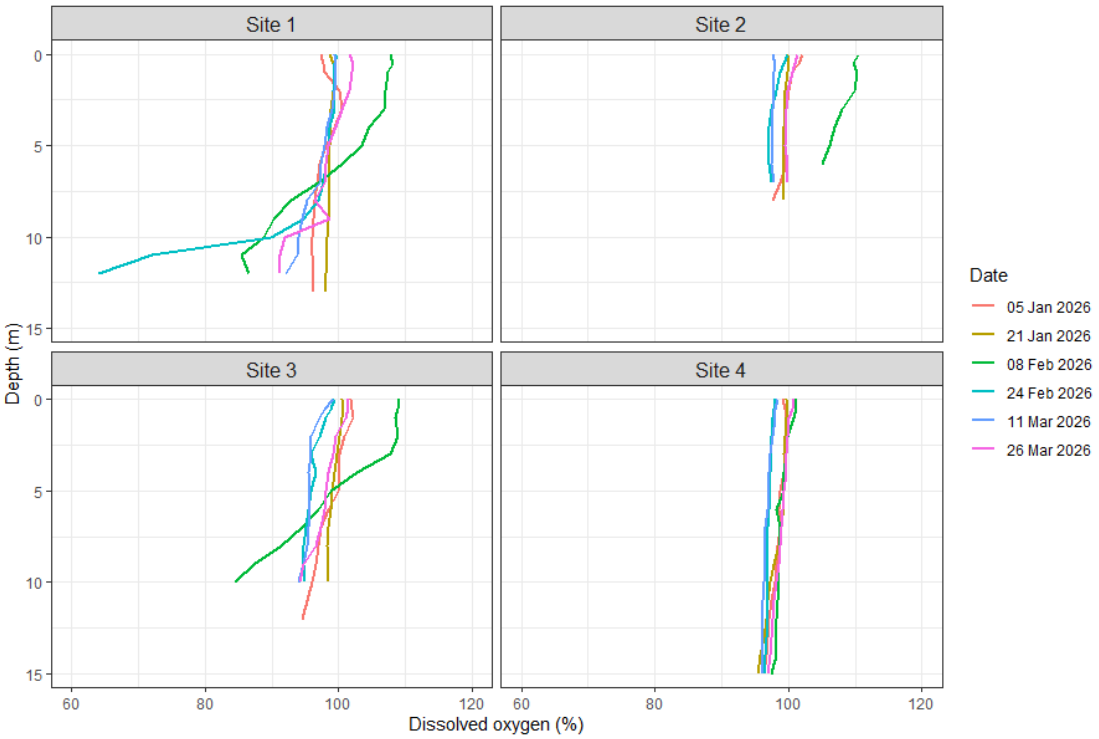


Figure 3-3: Vertical dissolved oxygen (%) profiles measured at three sites in the Waiau Arm (Sites 1–3) and a control site in Lake Manapōuri (Site 4) in 2026. Dissolved oxygen profiles for each of the six scheduled surveys are shown on the same plot for each site. Colour coding as per key.

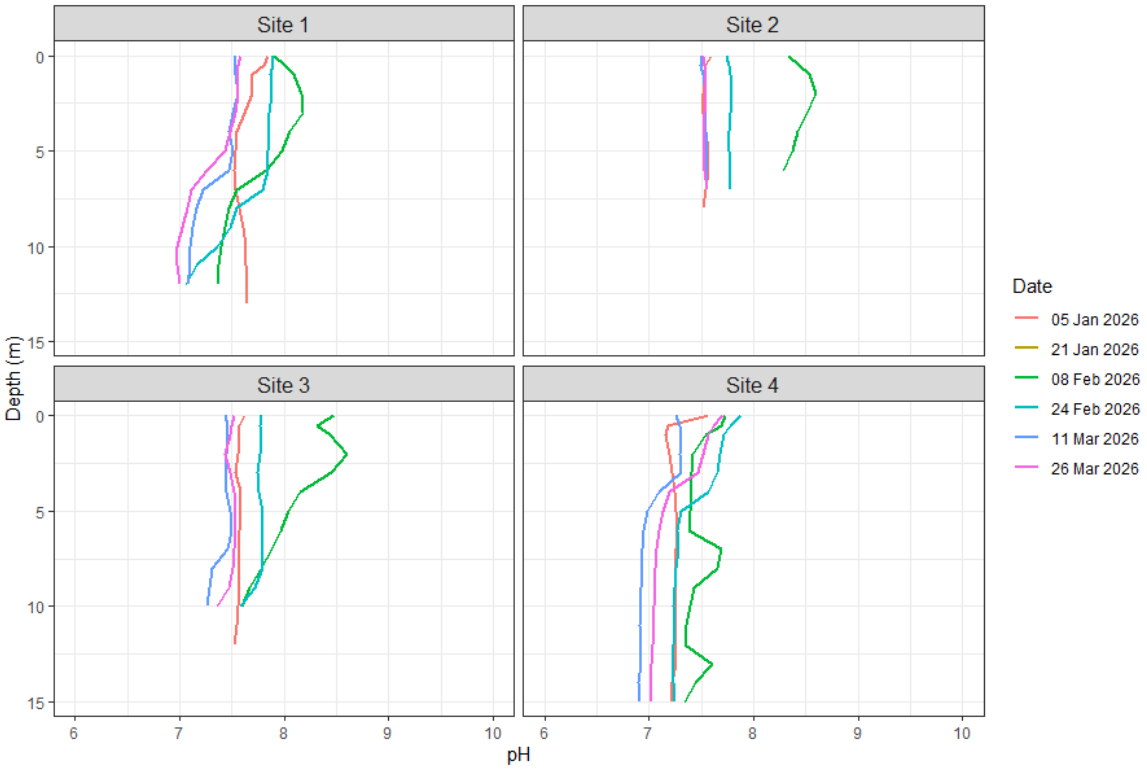


Figure 3-4: Vertical pH profiles measured at three sites in the Waiau Arm (Sites 1–3) and a control site in Lake Manapōuri (Site 4) in 2026. pH profiles for each of the six scheduled surveys are shown on the same plot for each site. Colour coding as per key.

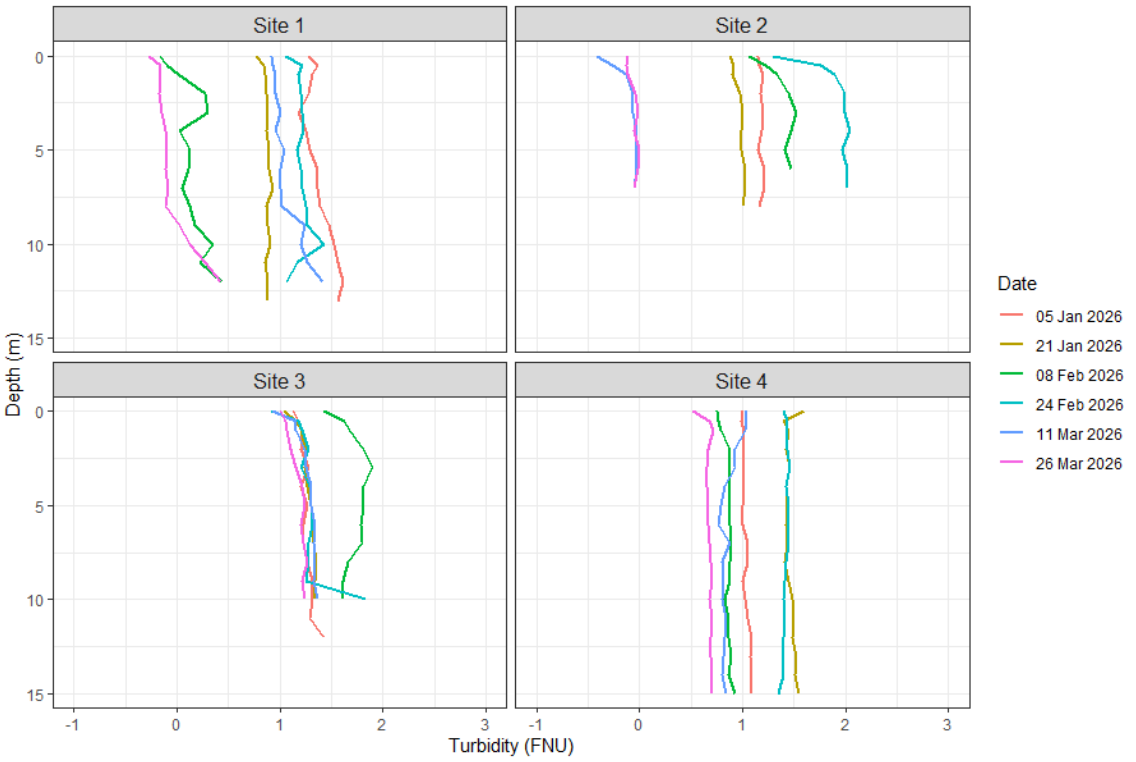


Figure 3-5: Vertical turbidity profiles measured at three sites in the Waiau Arm (Sites 1–3) and a control site in Lake Manapōuri (Site 4) in 2026. Turbidity profiles for each of the six scheduled surveys are shown on the same plot for each site. Colour coding as per key.

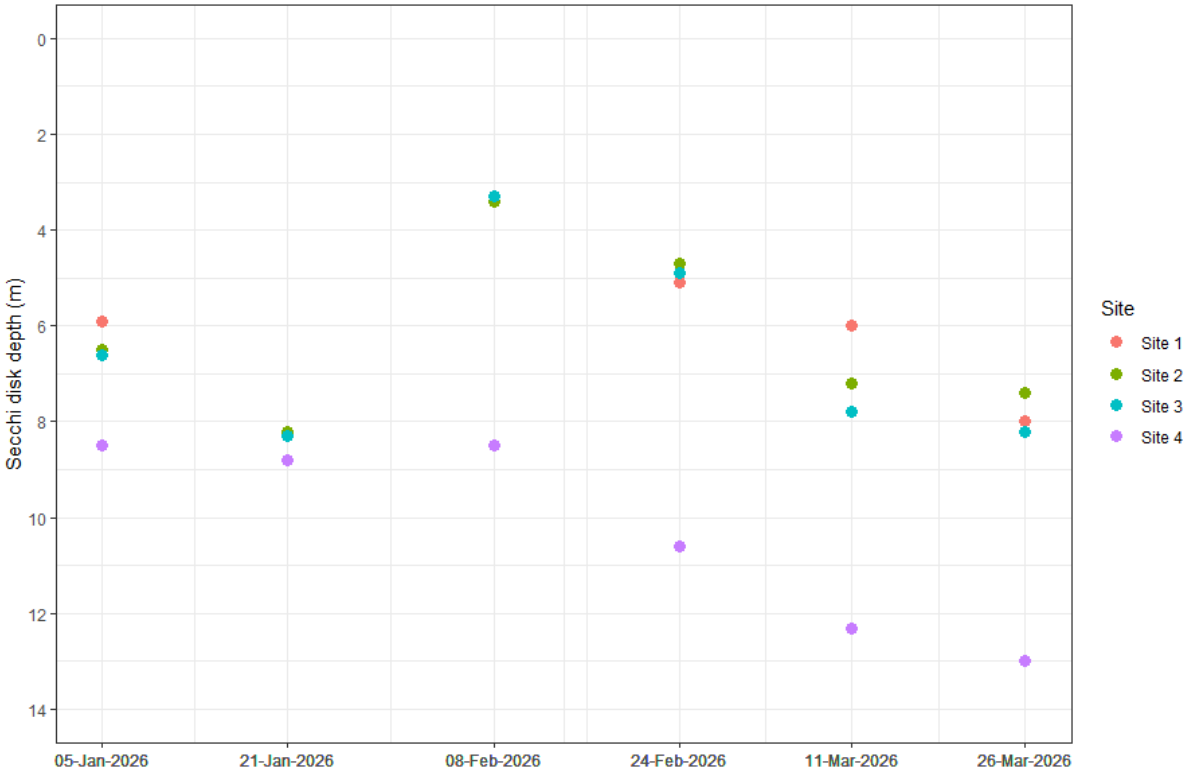


Figure 3-6: Mean Secchi disk depth (m) measured at three sites in in the Waiau Arm (Sites 1–3) and at the control site in Lake Manapōuri (Site 4) in 2026. Higher Secchi depths indicate higher water clarity. Equal mean Secchi depth was recorded at Sites 1 and 3 on 21 January (8.3 m) and 8 February (3.3 m).

3.2.5 Chlorophyll *a*

Chlorophyll *a* concentrations ranged from 0.4 to 5.3 mg/m^3 across Sites 1 to 3 in the Waiau Arm and from 0.2 to 0.8 mg/m^3 at Site 4 in Lake Manapōuri during the summer monitoring in 2026. The highest chlorophyll *a* concentrations at all three Waiau Arm sites were recorded on 8 February, and the chlorophyll *a* criterion (≥ 5 mg/m^3) was triggered at Site 3 (Figure 3-7). Following the flow management plan (Appendix C), the stakeholder group was advised of the chlorophyll *a* trigger and the management response in emails from Meridian sent on 13 February. In response to the trigger, a flow release was undertaken between 13-15 February (see Section 3.1). By the next survey on 24 February, chlorophyll *a* concentrations had declined to below the trigger threshold and water clarity had also increased (see Figure 3-6).

Chlorophyll *a* is one indicator of the trophic status of a lake (or other relatively slow-moving waterbody), which can range from ultra-microtrophic to hypertrophic, indicating progressively more phytoplankton (algal) biomass[14]. For most of the monitoring season, sites in the Waiau Arm were classified as microtrophic to oligotrophic based on chlorophyll *a*, except for all sites on 8 February when chlorophyll *a* concentrations were elevated and the sites were classified as mestrophic to eutrophic (Figure 3-7). The lake site was classified as ultra-microtrophic or microtrophic for all surveys, which indicates very good water quality. This result is consistent

[14]Ranges of chlorophyll *a* concentrations for lakes of different trophic states in New Zealand, which indicate progressively more algal biomass: ultra-microtrophic (0.13–0.33 mg/m^3), microtrophic (0.33–0.82 mg/m^3), oligotrophic (0.82–2.0 mg/m^3), mesotrophic (2.0–5.0 mg/m^3), eutrophic (5.0–12.0 mg/m^3), supertrophic (12–31 mg/m^3), and hypertrophic (>31 mg/m^3; Burns et al. 2000).

with longer-term water quality patterns in Lake Manapōuri based on the Trophic Lake Index (score based on nutrient, chlorophyll *a* and water clarity measurements) from 2010 to 2024[15].

Median chlorophyll *a* concentrations at all sites in 2026 (Table 3-1) were well below the National Policy Statement for Freshwater Management (NPS-FM) national bottom line of 12 mg/m^3 and would indicatively place all sites in Band A, noting the attribute statistic is annual median value and results reported here are over a 3-month period (New Zealand Government 2024). Median concentrations were generally lower in the Waiau Arm sites in 2026 than reported in previous seasons (Table 3-1).

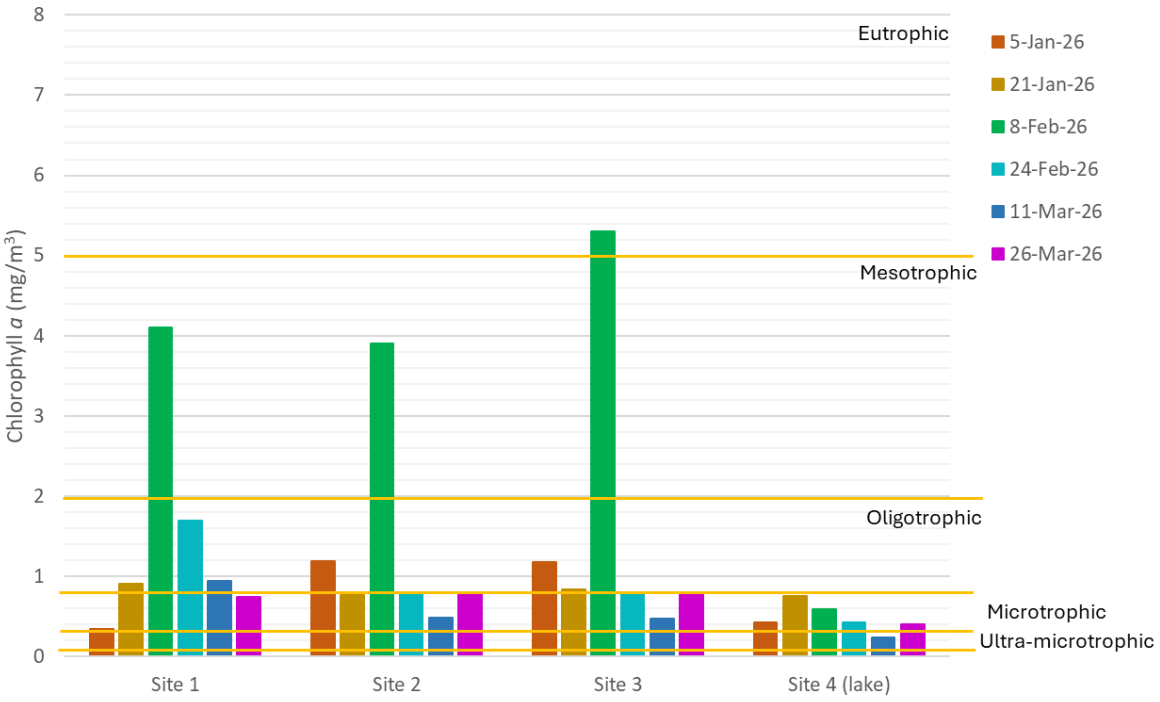


Figure 3-7: Phytoplankton biomass (measured as chlorophyll *a*) collected in the surface waters of each site during the six scheduled surveys in the summer monitoring period in 2026. Values are means of duplicate samples collected at each site. Ranges shown for lake trophic state classification following Burns et al. (2000).

[15] Land, Air, Water Aotearoa (LAWA) - Lake Manapouri

Table 3-1: Summary phytoplankton biomass as measured by chlorophyll *a* samples collected in the surface waters at each site during the scheduled surveys (1 January–31 March) in monitoring seasons from 2020–2026.

	Chlorophyll *a* (mg/m^3)											
	Site 1			Site 2			Site 3			Site 4		
Year	Median	Range	N	Median	Range	N	Median	Range	N	Median	Range	N
2020	0.7	0.1 – 1.2	4	1.0	0.6 – 1.4	4	1.0	0.6 – 1.3	4	0.6	0.4 – 0.7	4
2021	2.0	0.5 – 5.1	8	2.0	0.8 – 2.9	8	2.5	0.8 – 6.0	8	0.8	0.3 – 0.9	8
2022	1.3	0.9 – 2.8	7	1.0	0.4 – 4.4	7	1.1	0.8 – 6.7	7	0.8	0.5 – 1.4	7
2023	1.5	0.8 – 2.6	7	1.3	0.9 – 2.5	7	1.4	0.9 – 2.4	7	0.9	0.5 – 1.6	7
2024	3.3	0.79 – 4.0	5	1.5	0.7 – 4.3	5	1.9	0.8 – 5.6	5	0.8	0.4 – 0.9	5
2025	1.5	0.8 – 2.5	6	1.7	0.9 –2.7	6	1.5	0.8 –2.8	6	1.0	0.7 – 1.2	6
2026	0.9	0.4 – 4.1	6	0.8	0.5 – 3.9	6	0.8	0.5 – 5.3	6	0.4	0.2 – 0.8	6

4 Summary and conclusions

Six scheduled surveys (from 5 January to 26 March) were completed in the summer monitoring period in 2026. No additional surveys were required.

During the monitoring period, mean daily flow in the Waiau Arm was 28.7 m^3/s and flow was towards the MLC for 84% of the time. Flows were 'parked' (± 8 m^3/s) for 61% of the monitoring period. The peak flow (359 m^3/s) on 11 January was part of a lake spill event that began on 10 January. Three monthly recreational flow releases occurred during the monitoring period (25 January, 22 February, 23 March) along with an additional flow release (35 m^3/s for 48 h) undertaken between 13–15 February in response to a chlorophyll *a* trigger recorded on 8 February and a supplementary flow release on 19–20 March for nuisance periphyton management in the Lower Waiau River.

Across all four sites, vertical temperature profiles showed gradual changes with depth and no distinct thermoclines, indicating predominantly well-mixed conditions throughout the monitoring period. Surface water temperatures were highest on 8 February, coinciding with elevated chlorophyll *a*. Dissolved oxygen was generally high at all sites (85–110%) through most of the water column, with a single low bottom measurement (64.1%) recorded at Site 1 on 24 February. Dissolved oxygen remained stable over time and depth at the lake site. pH ranged from 6.9 to 8.6 in the Waiau Arm and from 6.9 to 7.8 in Lake Manapōuri and was generally stable over time and with depth.

Turbidity was consistently low (almost always <2 FNU) at all sites during all surveys. Secchi disk clarity in the Waiau Arm ranged from 3.3 to 8.3 m and, although variable across the season, was generally high (≥5 m). Water clarity declined in the Waiau Arm on 8 February, triggering the Secchi disk criterion at all sites, likely due to increased phytoplankton biomass during a period of parked and negative flows. Water clarity improved by the 24 February survey following a targeted flow release to replace water in the Waiau Arm, and the Secchi disk criterion was not triggered again for the remainder of the season. In Lake Manapōuri, water clarity remained high throughout the monitoring period.

Chlorophyll *a* concentrations ranged from 0.4 to 5.3 mg/m^3 at Waiau Arm sites and from 0.2 to 0.8 mg/m^3 at the lake site. The highest concentrations at all Waiau Arm sites were recorded on 8 February, when the chlorophyll *a* criterion was triggered at Site 3. Concentrations declined by the subsequent survey on 24 February following the mid-February flow release, coinciding with improved water clarity. Based on chlorophyll *a*, Waiau Arm sites were generally classified as microtrophic to oligotrophic, with a temporary shift to mesotrophic to eutrophic conditions on 8 February. The lake site remained ultra-microtrophic to microtrophic throughout the season, indicating very good water quality.

No criteria for action for dissolved oxygen or pH were triggered during the monitoring period in 2026. The Secchi disk clarity criterion was triggered at all Waiau Arm sites on 8 February only, while the chlorophyll *a* criterion was triggered at Site 3 only on the same date. Following the flow release on 13–15 February to replace water in the Waiau Arm, water clarity had improved and chlorophyll *a* concentrations declined, with no criteria triggered on the subsequent survey on 24 February. The short duration of the triggers suggests the water quality conditions were unlikely to have resulted in any measurable effects on aquatic ecology or habitat within the Waiau Arm.

5 Acknowledgments

This report was funded by Meridian Energy Ltd. Thanks to Maree Key and Bailey Key for field assistance during the surveys and to Eddie Stead (Meridian) for providing the MTAD hydrograph. We also thank Andy Wang (Instrument Systems, Earth Sciences NZ) for calibrating the water quality instrument prior to the monitoring season and Michelle Greenwood (Earth Sciences NZ) for reviewing this report.

6 Glossary of abbreviations and terms

MLC:IP	Manapōuri Lake Control Improvement Project
Lower Waiau River upstream of the Manapōuri Lake Control (MLC)	Meridian acknowledges the Toitū Te Whenua Land Information New Zealand gazetted official and recorded place names and Appendix 1 of the proposed Southland Water and Land Plan that refer to the water between the outlet of Lake Manapōuri, just upstream of Pearl Harbour, to the Manapōuri Lake Control structure (MLC) as the Waiau River. Meridian notes the MPS 1996 and MTAD 2010 resource consents reference this reach of the river as the Waiau Arm. Meridian, while acknowledging the official and recorded name, and that the Waiau Arm is part of the Waiau River, refers to the Waiau Arm for compliance and compliance reporting matters, such as this report.
Lower Waiau River	The reach of the Waiau River between the MLC and Te WaeWae Bay.
NPS-FM	National Policy Statement for Freshwater Management
Parked	“Parked” events refers to times of little to no flow moving through the Waiau Arm (i.e., when flow is ± 8 m^3/s; Spigel et al. 2006). Parked water in the Waiau Arm may comprise Lake Manapōuri water and Mararoa River water. The term refers to water that remains in the Waiau Arm with limited net transport toward the MLC.
Positive flow	Flow recorded in the Waiau Arm of Lake Manapōuri water moving downstream through the MLC and into the Lower Waiau River.

7 References

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Appendix A MTAD and MPS consent conditions related to water quality monitoring

The water quality monitoring requirements in the MTAD consent 206156 are set out in Condition 6 and Appendix A, as below:

Waiau Arm Water Quality

> Condition 6: *Prior to exercising this consent, the consent holder shall prepare and implement a protocol for monitoring changes in water quality and for subsequent flow management in the Waiau Arm, in accordance with the details set out in Appendix A of this consent. The purpose of the protocol will be to establish a monitoring programme and a management plan specifying the actions to occur should declining water quality and/or a phytoplankton bloom be detected. The aim of the protocol will be to ensure that the flushing of the affected water in the Waiau Arm, with water in Lake Manapouri, occurs in an effective manner in response to the actual measured effect and until the affected water is removed. The protocol shall be forwarded to Environment Southland for its approval prior to exercise of this consent.*
>
> Appendix A, B (ii), clauses 10 and 11:
>
> 10. *The consent holder shall undertake water quality and clarity monitoring in accordance with the protocol set out in Biggs et al. (2006) and as currently undertaken in the Waiau Arm. The consent holder will keep Environment Southland and stakeholders informed on the implementation and ongoing development of the protocol.*
>
> 11. *Fortnightly water quality samples shall be collected by appropriately trained personnel from 1 January to 31 March.*

Note: As per these requirements, Meridian submitted an updated water quality protocol to Environment Southland prior to exercising the MTAD consent. The updated protocol was referred to as Sutherland (2010)[16] and is also referenced as NIWA (2010) in the revised Appendix 1 monitoring requirements under Meridian's 1996 operating consents (consent number 96020, Appendix 1, A 4 Waiau Arm) as below:

Objective: To enable the implementation of a protocol for monitoring changes in water quality and for subsequent flow management in the Waiau Arm. The purpose of the protocol is to establish a monitoring programme and a management plan specifying the actions to occur should declining water quality and/or phytoplankton bloom be detected in response to more than minor effects arising from the operation of the MPS.

> *Method: Monitoring of water quality and subsequent flow management in the Waiau Arm shall be undertaken in accordance with the details set out in NIWA, 2010. Any changes to the monitoring from that set out in NIWA, 2010, shall require approval from Environment Southland prior to implementation.*

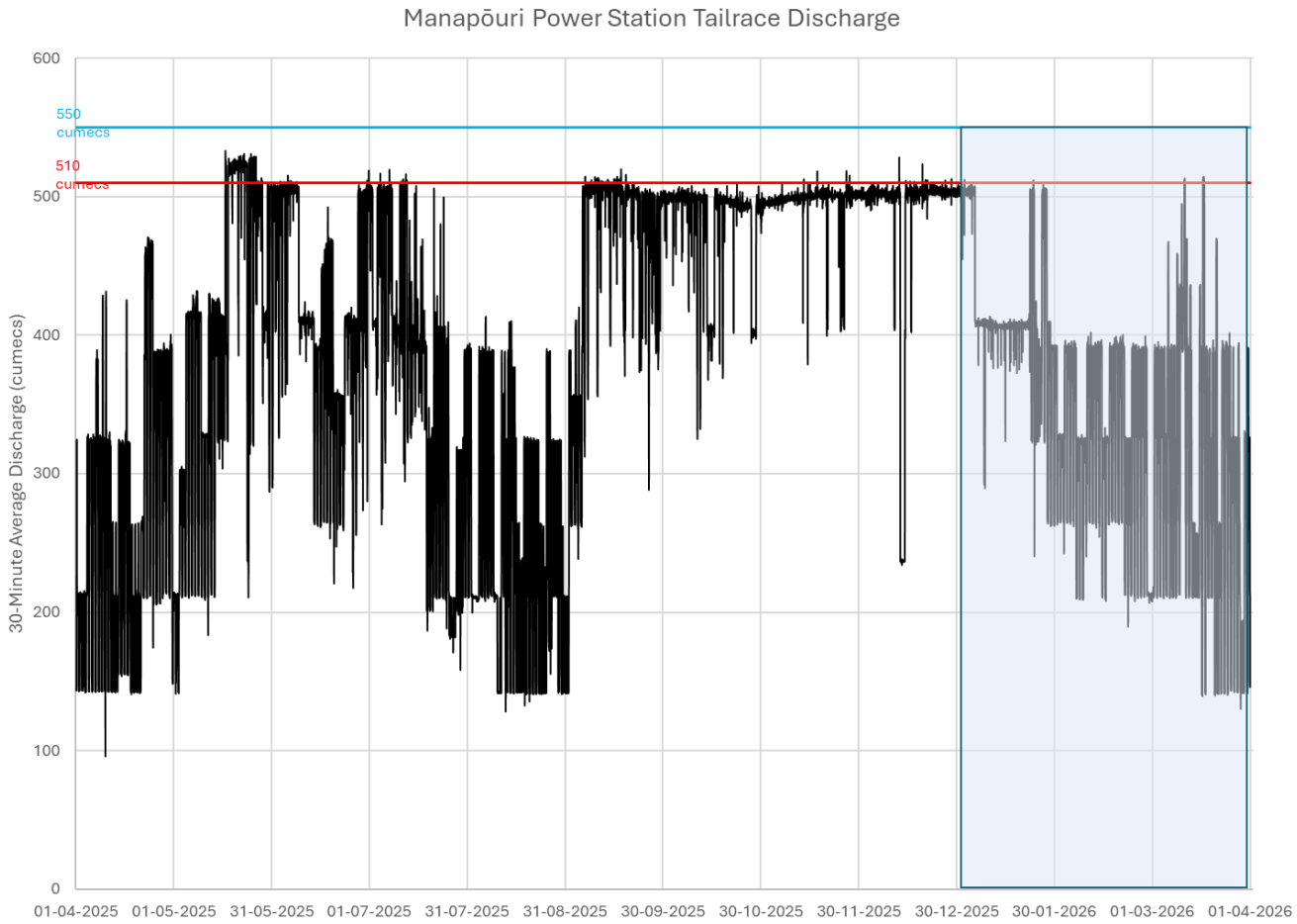
Reference: NIWA. 2010. Water quality monitoring protocol for Waiau Arm.

[16] The same four sites and three of the water quality criteria parameters proposed by Biggs et al. (2006) were adopted under Sutherland (2010). A fourth water quality parameter (water colour/appearance) was dropped. In addition, there were changes to the timing of sampling periods.

The protocol was updated again in 2025 following approval by Environment Southland as confirmed in an emailed letter dated 5 December 2025. The updated version is referred to as Sutherland (2010, updated 2025); see Appendix D.

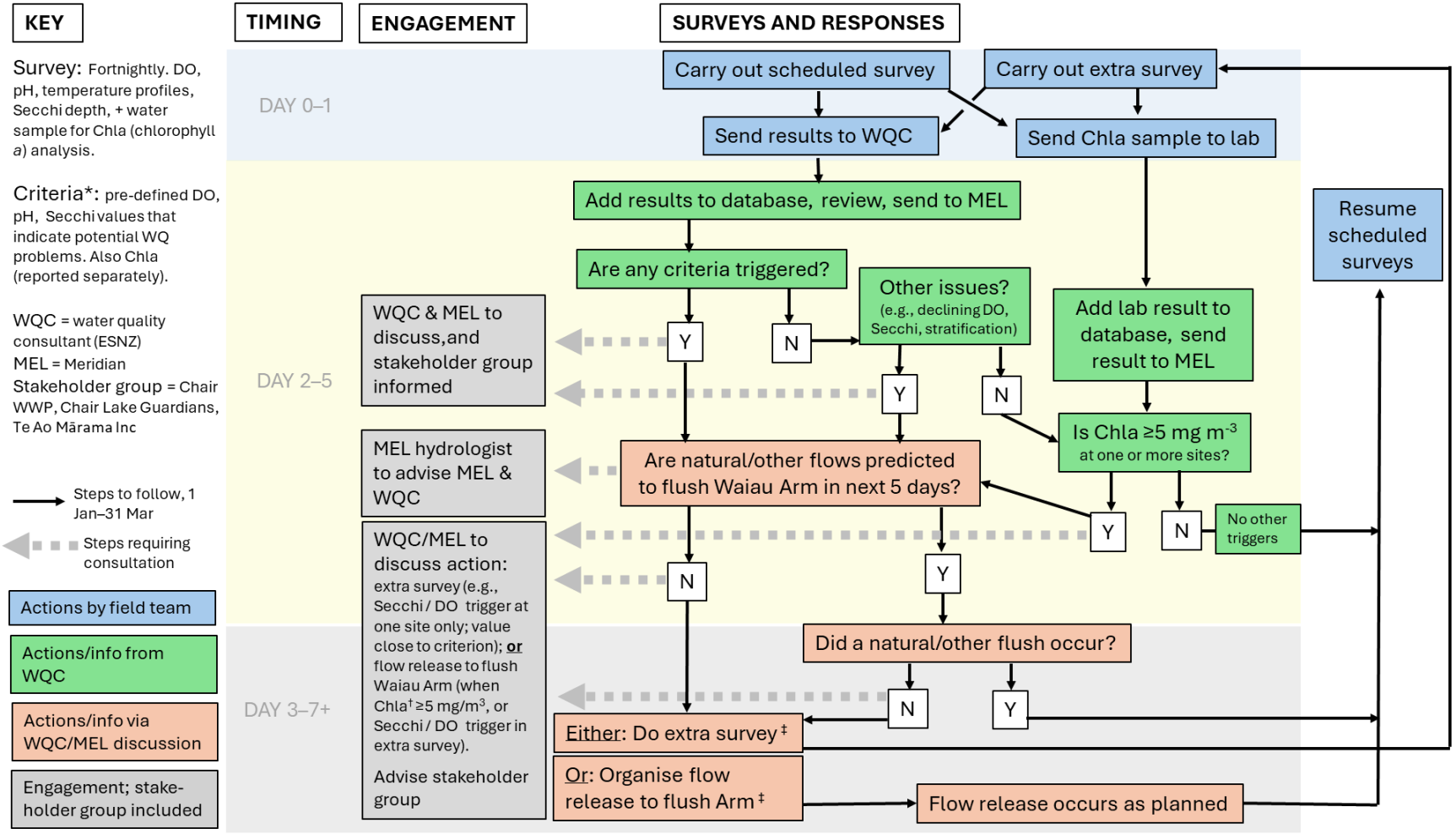
Appendix B Manapōuri Power Station tailrace discharge, 1 April 2025 to 31 March 2026

The blue-shaded section highlights the 2026 summer monitoring period (1 January–31 March) in the Waiau Arm. MTAD was exercised (indicated by an excursion over 510 m^3/s (the red line) during this period. Figure provided by Eddie Stead, Meridian.



Appendix C Flow management action plan for the Waiau Arm

Flow diagram representing the flow management plan on the need for flushing of the Waiau Arm based on water quality monitoring results following each survey. For further details, refer to Sutherland (2010, updated 2025) or see Appendix D.



*Dissolved oxygen (DO,% saturation) <85% at any site; pH >9 at any site; Secchi disk clarity (depth, m) >33% less than the mean of the three previous sampling occasions at any site AND / OR less than 3.5 m (except that the calculation will use the long-term mean Secchi depth for the month of January1 for comparison of the first three surveys each year, with long-term mean calculated from January 2011).

† Chla (mg/m^3) ≥ 5 at any site (source: MLC:IP resource consent 20233670-01, condition 15(e)).

‡ A flushing flow should always follow if the first action (extra survey) indicates that the trigger is continuing.

Appendix D Protocol, Sutherland (2010, updated 2025)

The protocol (Sutherland 2010, updated 2025) is appended, which documents the changes made to Sutherland (2010) and approval from Environment Southland.

Earth Sciences New Zealand

Water quality monitoring protocol for the Waiau Arm

Sutherland 2010, updated 2025

Prepared for Meridian Energy

May 2026

Prepared by:
Kristy Hogsden

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Client Report No: 2026111CH
Report date: May 2026
Project No: MEL25507

Revision	Description	Date
Version 1.0	Final version sent to client	15 May 2026
Version	Final report after client review	19 August 2026

Quality Assurance Statement		
	Reviewed by:	Jo Hoyle
	Formatting checked by:	Rachel Wright
	Approved for release by:	Charles Pearson

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Executive summary

Water quality monitoring in the in the Lower Waiau River upstream of the Manapōuri Lake Control (hereafter referred to as the Waiau Arm[1]) during summer (January to March) is a condition of the resource consents issued to Meridian Energy Ltd (Meridian) for the operation of the Manapōuri Tailrace Amended Discharge (MTAD) as part of the Manapōuri Power Scheme (MPS). Since the consent was granted in 2010, water quality monitoring in the Waiau Arm has followed a consistent format based on a protocol and flow management action plan developed at that time (Sutherland 2010).

The Sutherland (2010) protocol was updated in 2025 following approval by Environment Southland of recommendations set out in Hogsden and Kilroy (2025). The updated protocol is hereafter referred to as *Sutherland (2010, updated 2025)*. The updates, which are intended to improve the effectiveness of the monitoring programme in terms of timely detection of potential water quality issues and efficiency of water management actions in the future, include:

- Addition of a numeric threshold and revised method for calculating percentage change in January surveys for the Secchi disk clarity criterion;
- Introduction of a chlorophyll *a* trigger criterion with requirement for fortnightly chlorophyll *a* sampling for assessment of the criterion; and
- An updated flow management action plan with clearer focus on timing, decision points and action responsibilities.

This report documents the changes made to the sampling methods, trigger criteria and flow management action plan. The original Sutherland (2010) report is also appended to this report, so that the full protocol (with some aspects retained and others updated) can be found in one place.

[1] Meridian acknowledges the Toitū Te Whenua Land Information New Zealand gazetted official and recorded place names and Appendix 1 of the proposed Southland Water and Land Plan that refer to the water between the outlet of Lake Manapōuri, just upstream of Pearl Harbour, to the Manapōuri Lake Control structure (MLC) as the Waiau River. Meridian notes the MPS 1996 and MTAD 2010 resource consents reference this reach of the river as the Waiau Arm. Meridian, while acknowledging the official and recorded name, and that the Waiau Arm is part of the Waiau River, refers to the Waiau Arm for compliance and compliance reporting matters, such as this report.

1 Updates to the Sutherland (2010) protocol

Water quality monitoring in the Waiau Arm[1] in summer (January to March) is a condition of the resource consents held by Meridian Energy Ltd (Meridian) for operation of the Manapōuri Tailrace Amended Discharge (MTAD) as part of the Manapōuri Power Scheme (MPS). Since the consent was granted in 2010, monitoring has been undertaken using a consistent framework based on an established protocol and associated flow management action plan (Sutherland 2010, see Appendix A). The Sutherland (2010) protocol was updated in 2025 following approval by Environment Southland of recommendations set out in Hogsden and Kilroy (2025). The updated protocol is hereafter referred to as *Sutherland (2010, updated 2025)*.

The updates to the Sutherland (2010) protocol include two updates to the Secchi disk clarity criterion, requirement for fortnightly chlorophyll *a* sampling and incorporation of a chlorophyll *a* criterion, and an updated flow management action plan. These changes were approved by Environment Southland in December 2025 (see Section 2). The approved changes to the Sutherland (2010) protocol for Secchi disk clarity, chlorophyll *a*, and the flow management action plan are documented below:

A. **Secchi disk clarity**, original text from Section 3, point 3, pg 5 of Sutherland (2010):

> 3. Secchi disk clarity: if Secchi clarity declines by more than 33% of the average of the previous 3 sampling occasions, then a water sample should be taken to quantify the water composition to determine possible causes (analyses to include ammonia, dissolved reactive phosphorus, suspended solids (total and volatile), spectral absorbance, chlorophyll *a*).

Secchi disk clarity, approved changes to original text (tracked changes):

> 3. Secchi disk clarity: if Secchi clarity declines by more than 33% ~~of the average~~ less than the mean of the previous ~~3~~ three sampling occasions at any sites AND / OR less than 3.5 m (except that the calculation will use the long-term mean Secchi depth for the month of January[1] for comparison of the first three surveys each year)~~, then a water sample should be taken to quantify the water composition to determine possible causes (analyses to include ammonia, dissolved reactive phosphorus, suspended solids (total and volatile), spectral absorbance, chlorophyll *a*)~~.
>
> [1] Long-term mean for January calculated from Waiau Arm water quality monitoring data from January 2011.

Secchi disk clarity, approved text for updated protocol (in full):

> Secchi disk clarity: if Secchi clarity declines by more than 33% less than the mean of the three previous sampling occasions at any site AND / OR less than 3.5 m (except that the calculation will use the long-term mean Secchi depth for the month of January[1] for comparison of the first three surveys each year).
>
> [1]Long-term mean for January calculated from Waiau Arm water quality monitoring data from January 2011.

B. B. **Chlorophyll *a***, approved text for Section 2.7, pg 4 (a new section added to the Sutherland (2010) protocol):

Two replicate chlorophyll *a* samples will be collected at each site. The samples will be taken from within 20 cm of the surface water. Samples will be kept chilled (not frozen) and sent for laboratory analysis the following day. Chlorophyll *a* results will be advised to Meridian's representative upon receipt to allow the flow management plan to be initiated in a timely manner, if required.

Chlorophyll *a*, approved text for Section 3, point 4, pg 5 (a new point added to the Sutherland (2010) flow management action plan):

4. Chlorophyll *a*: if chlorophyll *a* is greater than or equal to 5 mg/m^3 at any site.

C. C**. Flow management action plan**, original flow diagram from Section 3, Figure 2, pg 5 of Sutherland (2010):

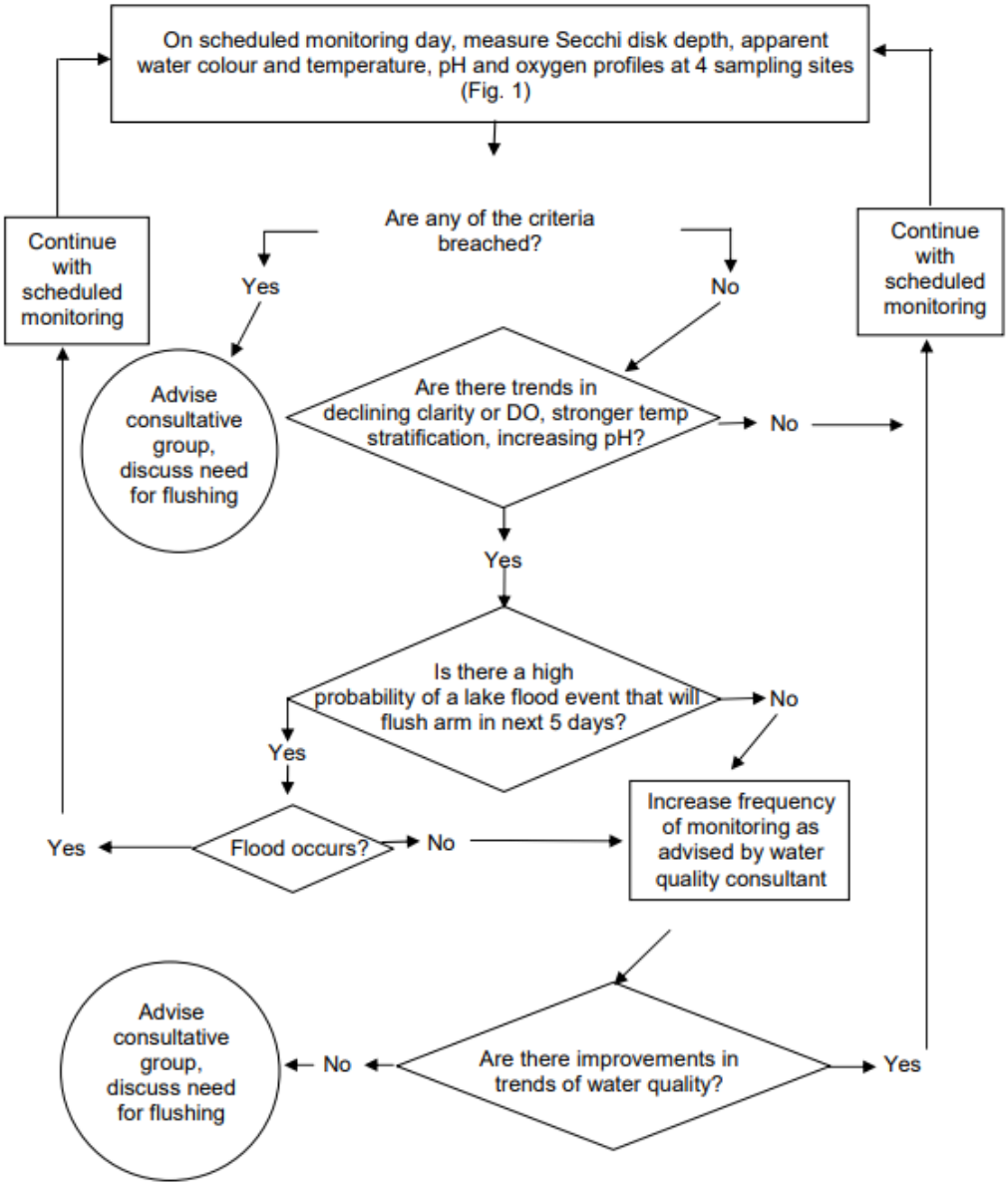
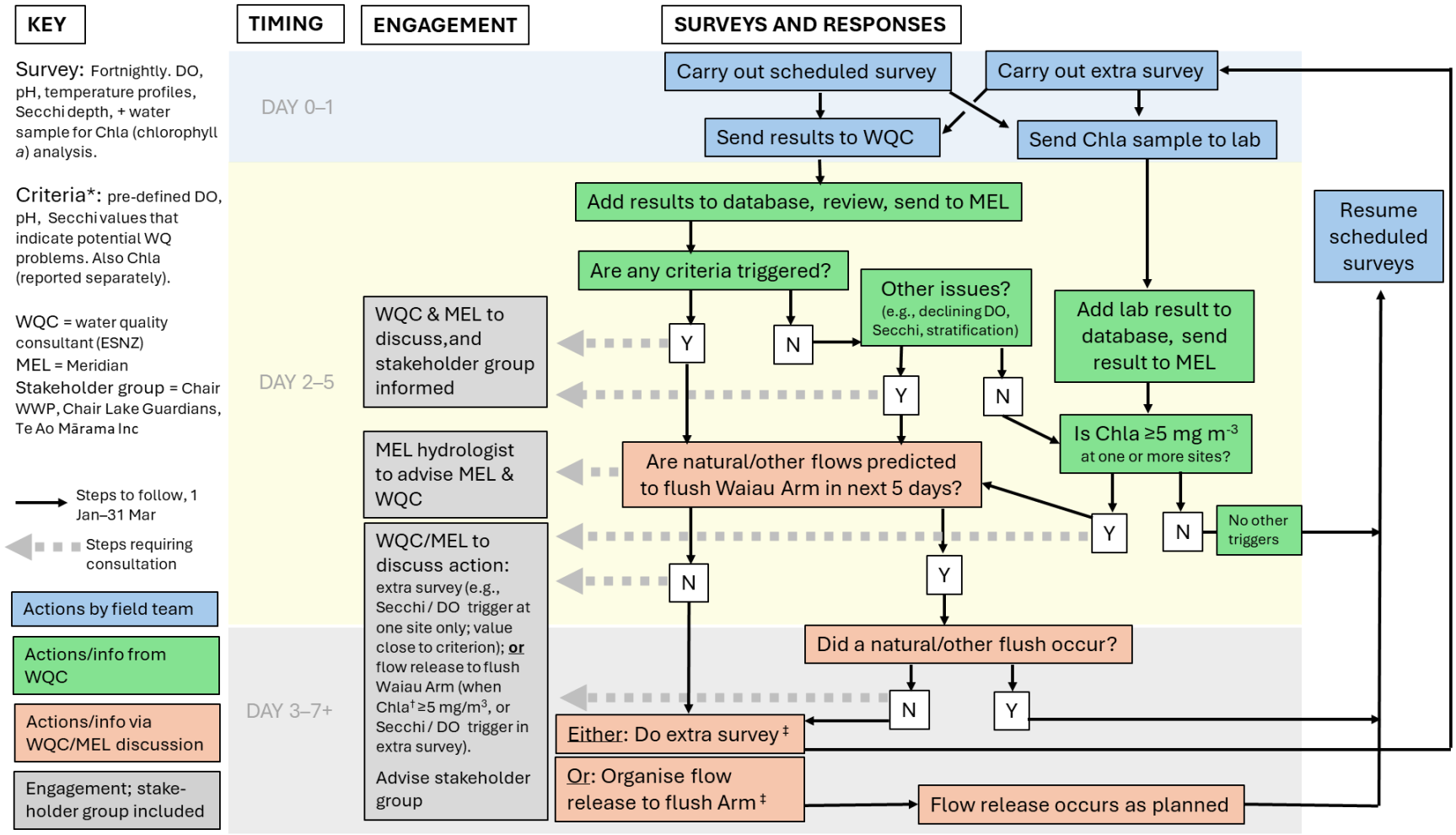


Figure 2: **Flow diagram representing the flow management plan on the need for flushing of the Waiau Arm, based on the water quality monitoring results.**

Flow management action plan, approved updated flow diagram: see following page



*Dissolved oxygen (DO,% saturation) <85% at any site; pH >9 at any site; Secchi disk clarity (depth, m) >33% less than the mean of the three previous sampling occasions at any site AND / OR less than 3.5 m (except that the calculation will use the long-term mean Secchi depth for the month of January1 for comparison of the first three surveys each year, with long-term mean calculated from January 2011).

† Chla (mg/m^3) ≥ 5 at any site (source: MLC:IP resource consent 20233670-01, condition 15(e)).

‡ A flushing flow should always follow if the first action (extra survey) indicates that the trigger is continuing.

2 Environment Southland approval letter

Our Reference: REQ-25264651
Enquiries to: Ciaran Thayer
Email: Ciaran.Thayer@es.govt.nz

5 December 2025

Meridian Energy Limited
C/- Jason Holland
PO Box 2146
Christchurch 8140

Dear Jason

Waiau Arm Water Quality Monitoring Programme change approval – Resource Consent AUTH-206156-V4

As per condition 7 of resource consent AUTH-206156-V4 Environment Southland approves the changes to the Waiau Arm Water Quality Monitoring Programme outlined in Appendix B of ESNZs amended memo dated 3 December 2025.

Yours sincerely

Hayley Fitchett
General Manager Strategy and Regulation

For **now** & **our future**

Cnr North Rd & Price St, Invercargill | DX No. YX20175 | Private Bag 90116, Invercargill 9840 | 03 211 5115 or 0800 76 88 45 | service@es.govt.nz | www.es.govt.nz

3 References

Hogsden, K., Kilroy, C. (2025) Waiau Arm water quality monitoring programme review – final recommendations – Amended 3 December 2025. Earth Sciences NZ Client Report 2025305. Prepared for Meridian Energy Ltd.

Sutherland, D.L. (2010) Water quality monitoring protocol for the Waiau Arm. NIWA Client Report CH2010-112. Prepared for Meridian Energy Ltd.

Appendix A Sutherland (2010) report

NIWA
Taihoro Nukurangi

Water quality monitoring Waiau Arm

NIWA Client Report: CHC2010-112
September 2010

NIWA Project:

NIWA
Taihoro Nukurangi

Water quality monitoring Waiau Arm

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Prepared for

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Reviewed by:

Marty Bonnett

Approved for release by:

Ned Norton

1. Introduction

1.1. Background

In May 2003, following a relatively dry summer and autumn a major water quality / algal bloom issue was observed in the lower section of the Waiau Arm (Ms Jan Riddell, witness for the Waiau Working Party, 7 September 2009). A number of stakeholders raised concerns over this 'bloom' and the health of the Waiau Arm. In response to these concerns, Meridian commissioned a water quality study of the Waiau Arm (Spigel et al 2006). This study showed that water quality and clarity in the Waiau Arm are determined by a number of factors, including flow, residence time, phytoplankton biomass and run-off during rainfall. The relationship between flow, residence time and phytoplankton biomass and ultimately water quality was not straightforward. Spigel et al. (2006) found that there was a strong seasonal temperature and light effect, with low algal biomass maintained during winter even with long residence times, but moderate levels of chlorophyll *a* (a measure of algal biomass) could develop in summer months even at short residence times.

In addition to this study, Meridian instigated a water quality monitoring programme in the Waiau Arm in December 2006 which continues to present day. The purpose of this monitoring programme was to ensure timely detection of any potential water quality issues to allow for efficient management of the Waiau Arm.

1.2. Manapouri Tailrace Amended Discharge (MTAD)

In 2010, Meridian was granted a resource consent to increase the maximum allowable discharge from the tailrace of the existing Manapouri Power Station. This would result in changes in the discharge of water down the Waiau Arm, in particular an increase in the number of days minimum flows will be discharged down the Arm. This could lead to an increased risk of phytoplankton biomass developing to a point where it begins to negatively impact the water quality and clarity in the Waiau Arm during summer months (Sutherland and Graynoth 2009).

In the evidence of Sutherland (2009) monitoring of water quality and clarity was recommended during summer months to detect early changes as a result of phytoplankton growth. Mitigation of declining water quality, by means of a managed 'flush' of affected water out of the Waiau Arm, was also recommended. In the hearing decision by the consents committee the consent conditions state:

Waiau Arm Water Quality

Prior to exercising this consent, the consent holder shall prepare and implement a protocol for monitoring changes in water quality and for subsequent flow management in the Waiau Arm, in accordance with the details set out in Appendix A of this consent. The purpose of the protocol will be to establish a monitoring programme and a management plan specifying the actions to occur should declining water quality and/or a phytoplankton bloom be detected. The aim of the protocol will be to ensure that the flushing of the affected water in the Waiau Arm, with water derived from Lake Manapouri, occurs in an effective manner in response to the actual measured effect and until the affected water is removed. The protocol shall be forwarded to Environment Southland for its approval prior to the exercise of this consent.

The consent holder shall undertake water quality and clarity monitoring in accordance with the protocol set out in Biggs et al (2006) and as currently undertaken in Waiau Arm. The consent holder will submit the protocol to Environment Southland prior to the exercise of the consent. The consent holder will keep Environment Southland and stakeholders informed on the implementation and ongoing development of the protocol.

Fortnightly water quality samples shall be collected by appropriately trained personnel from 1 January to 31 March.

This report outlines the protocols for undertaking water quality and clarity monitoring in the Waiau Arm in accordance to Biggs et al. (2006). Biggs et al. (2006) chose the water quality parameters dissolved oxygen, pH, temperature and the clarity parameter Secchi depth for monitoring following consultation with the Waiau Working Party, Guardians of the lakes, Department of Conservation and Meridian. The main rationale for these parameters over others, such as nutrients and chlorophyll *a*, was that these instantaneous results allows for a quick response to declining conditions.

2. Field procedures

2.1. Sampling sites

The water quality sampling sites shall be the same sites that have been monitored by Meridian since December 2006. There are three monitoring sites spaced down the length of the Waiau Arm and one control site, offshore from Frasers Beach, Lake Manapouri (Figure 1).

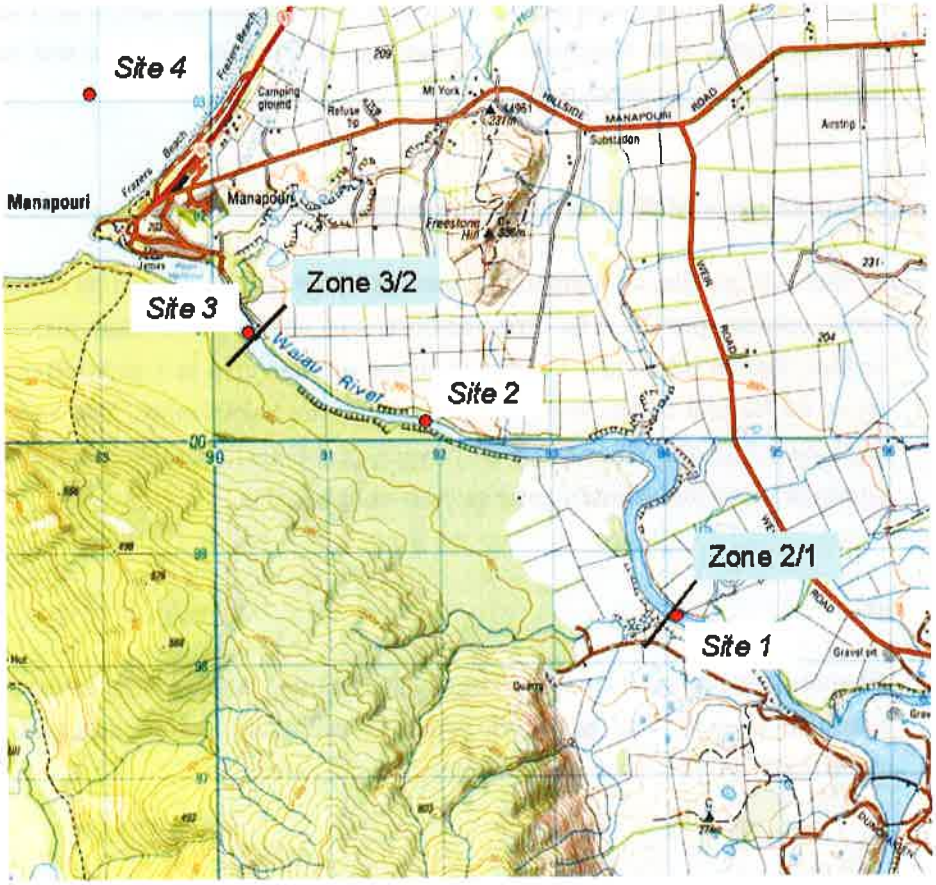


Figure 1: **Locations of water quality sampling sites within the Waiau Arm (Sites 1-3) and Lake control site (Site 4). Sites are based on water quality monitoring sites that have been sampled by Meridian since 2006.**

2.2. Timing of sampling

Water quality parameters that are influenced by factors such as biological activity (e.g. dissolved oxygen) or sunlight (e.g. temperature) vary over the course of the day. In order to compare parameters between sampling occasions in a meaningful way, it is important to ensure that sampling occurs at the same time of day each occasion. Measurements should be made between 9.00 and 10:00 am NZST since, for most variables, morning water quality values are typically similar to the diurnal median value (Oswald, 1991).

2.3. Secchi Disk Depth

Secchi disk depth should be measured in accordance with methodology in Davies-Colley (1994) and Burns et al. (2000) and described below. Secchi disk should be viewed on the sunny side of the boat to avoid distortion of the view by the shadow of the boat. The Secchi disk, attached to a graduated line, is simply lowered into the

water until the image disappears. This depth is noted and the disk is then raised slowly until the image just reappears. The average of the disappearance and reappearance depths is the Secchi depth (m).

2.4. Temperature and dissolved oxygen profiles

At each site profiles of temperature and dissolved oxygen should be recorded down a water column profile. The first measurement shall be recorded just below water surface, then at 0.5 m and 1 m below water surface, then in 1 m increments until just above the bottom of the Arm (or in the case of the Lake Control Site 4 to a maximum depth of 12-15 m). The dissolved oxygen probe shall be calibrated with 100% air saturated water immediately prior to each sampling day.

2.5. pH

pH should be recorded along the same water column depth profile as temperature and dissolved oxygen. The pH probe shall be calibrated against standard pH buffers immediately prior to each sampling day.

2.6. Data handling

To ensure timely detection of any potential water quality problems, it is important that monitoring results are received by the designated water quality consultant within 24 hours. Results should then be analysed and advised to Meridian's representative within the following 24 hours. This will allow for the flow management plan to be initiated by Meridian in a timely manner, if deemed necessary. The flow management plan, which includes early consultation with representatives from the stakeholders, is detailed in Figure 2.

Flow management action plan

To ensure a timely response to any potential water quality problem, it is recommended that the following criteria are used as trigger points for discussion on the necessity of implementing remedial action. These criteria are:

1. Dissolved oxygen: average water column dissolved oxygen falls below 85% at any site;

2. pH: average water column mid-day pH exceeds 9 at any site;

3. Secchi disk clarity: if Secchi clarity declines by more than 33% of the average of the previous 3 sampling occasions, then a water sample should be taken to quantify the water composition to determine possible causes (analyses to include ammonia, dissolved reactive phosphorus, suspended solids (total and volatile), spectral absorbance, chlorophyll *a*).

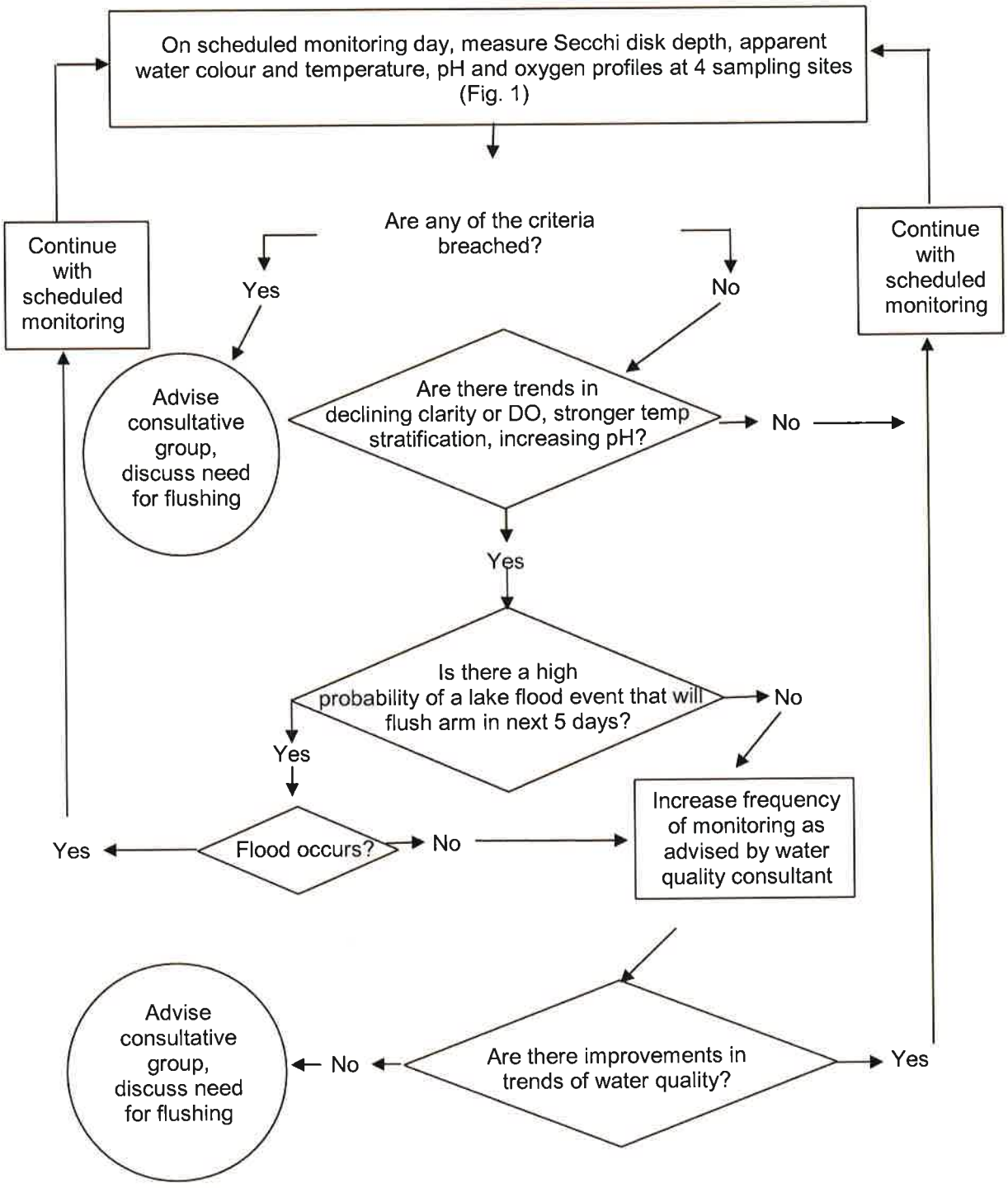


Figure 2: **Flow diagram representing the flow management plan on the need for flushing of the Waiau Arm, based on the water quality monitoring results.**

The first two parameters can have absolute values assigned as the trigger point as they are a direct measure of chemical quality that affect biota. On the other hand, Secchi is an apparent optical property that is a reflection of a number of interacting physical and biological processes.

The conservative trigger values set for each criteria have been used to allow for any potential problems to be identified well in advance. This ensures that if remedial action is required, the management action guideline for the Waiau Arm (Figure 2) can be implemented in a timely manner before any decline in water quality becomes an ecological problem.

4. References

Burns, N.; Bryers, G.; Bowman, E. (2000). Protocol for monitoring trophic levels of New Zealand lakes and reservoirs. *Lake Consulting Client Report 99/2*.

Davies-Colley, R.J. (1994). Water Quality guidelines No. 2. Guidelines for the management of water colour and clarity. *Ministry for the Environment, Wellington.*

Oswald, W.J. (1991) 'Introduction to advanced integrated wastewater ponding systems.' *Water Science and Technology 24(5),*:1-7.

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