Appendix I Hydrology Assessment

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Lake Taharoa

Hydrology Assessment

TAHAROA IRONSAND LIMITED

WWLA0546 | Rev. 5

5 September 2025

WWLA

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Contents

This report has been prepared for Taharoa Ironsands Limited (TIL) in respect of its application for all approvals under the Fast-track Approvals Act 2024 for the Central and Southern Blocks of the Taharoa Ironsand Mine. The Panel appointed to consider the application for the Central and Southern Blocks Mining Project may rely on this report for the purpose of making its decision under the Fast-track Approvals Act 2024.

This report has been prepared in accordance with the Environment Court's Code of Conduct for expert witnesses, contained in the Environment Court's Practice Note 2023. The authors of this report agree to comply with the Code of Conduct, and confirm that unless otherwise stated, the issues addressed in this report are within the area of expertise of the authors. No material facts have been omitted that might alter or detracted from the opinions expressed in this report.

Executive Summary

Taharoa Ironsands Limited (TIL) operates an ironsand mine at Taharoa on the west coast of the North Island, south of Kawhia Harbour. TIL is seeking new resource consents to continue the existing ironsand mining operation within the Central and Southern blocks of the mine and to enable the export of titanomagnetite from the Port of Taharoa. Mining activities include, among other activities, the abstraction of water - water used at the site for mine processing and ship loading activities is sourced from Wainui Stream which is the Lake Taharoa outlet stream.

Williamson Water & Land Advisory (WWLA) was commissioned by Taharoa Ironsands Limited (TIL) to undertake a hydrology assessment of the Taharoa Lakes and Wainui Stream in relation to the application to reconsent the existing dam and water takes from the Taharoa Lakes under the Fast-track Approvals Act 2024.

This report details the hydrological assessment of effects resulting from water abstractions from the lake and the presence of the dam. This assessment includes a high-level analysis of historic measured lake water levels, a lake water balance model, and an assessment of the potential effect of the water takes on lake levels, and their contribution to lake level fluctuation in comparison to natural inflows and outflows.

The lake water balance model provides insight into the hydrological functioning of the lake and characterises and quantifies the relative magnitude of key inputs (catchment inflow, and rainfall) and outputs (flow through the dam structure, evaporation, seepage loss, and TIL’s water takes) on fluctuations in lake level.

Four scenarios were assessed with the model, including one scenario that aligns with the concept of the “existing environment” and therefore assumes there were no water abstractions and no dam, and one extreme scenario where the maximum proposed processing water was taken 365 days of the year. Results of the scenarios showed:

- Water levels in Lake Taharoa are approximately 2.5 m higher as a result of the construction of the dam structure.
- Lake levels have remained relatively stable between ~9.6 m RL and ~10.4 m RL over the last 10-years (the period of available monitoring data).
- Lake level fluctuations are seasonal, with lower levels typically occurring in late summer, and higher levels throughout winter.
- While TIL’s water takes lower the lake levels, the reduction in lake level is transitory and temporary only. Lake levels recover as catchment inflows to the lake increase during winter and wetter periods.

Four water level trigger values and corresponding actions are recommended to maintain and protect the hydrological functioning of the Taharoa Lakes and downstream receiving environment.

On the basis these recommendations are implemented, the potential hydrological effects of TIL’s water takes on Lake Taharoa and the Wainui Stream are considered less than minor.

1. Introduction

Taharoa Ironsands Limited (TIL) operates an ironsand mine at Taharoa on the west coast of the North Island, south of Kawhia Harbour. TIL is seeking new resource consents to continue the existing ironsand mining operation within the Central and Southern blocks of the mine and to enable the export of titanomagnetite from the Port of Taharoa. Mining activities include, among other activities, the abstraction of water - water used at the site for mine processing and ship loading activities is sourced from Wainui Stream which is the Lake Taharoa outlet stream.

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1.1 Report Structure

The report comprises the following:

- Introduction (**Section 1**);
- Project description (**Section 2**);
- Available monitoring data (**Section 3**);
- Lake water balance assessment (**Section 4**);
- Scenario's assessment (**Section 5**);
- Additional Hydrological Considerations (**Section 6**);
- Recommendations (**Section 7**); and
- Conclusions (**Section 8**).

2. Project Description

2.1 Overview

The Taharoa mine is located approximately 8 km south of Kawhia Harbour and 45 km to the northwest of Te Kuiti. The site covers an area of 1,300 hectares (**Figure 1**).

TIL carries out iron sand mining activities at the site and associated ship loading activities. The mine has been in operation since 1972 (owned by New Zealand Steel until 2017). TIL is currently seeking new resource consents to continue the existing iron sand mining operation, concentration, and processing facilities.

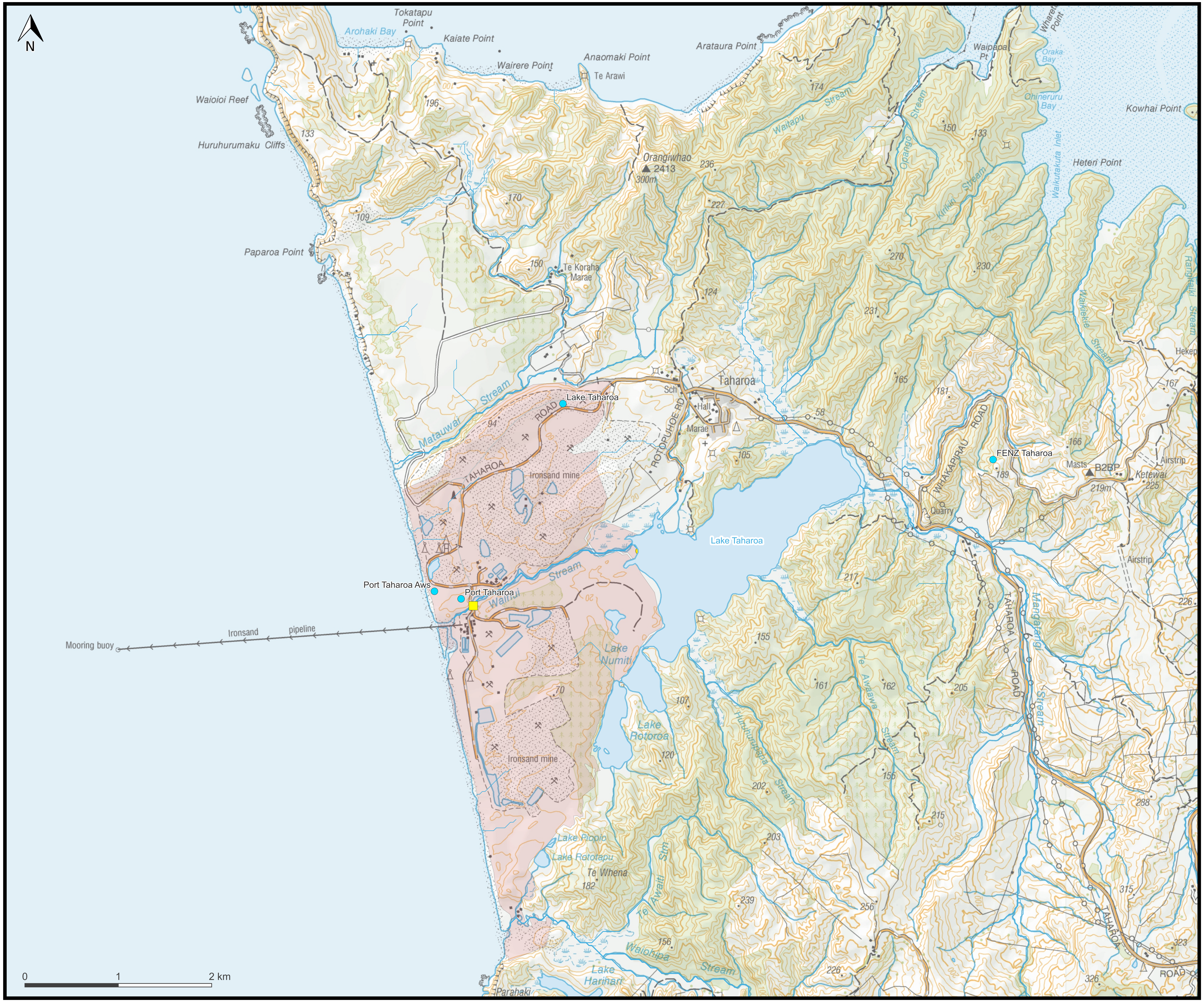
The mining process generally involves the following:

1. Removal of vegetation, topsoil and overburden;
2. Extraction via either dry mining (i.e., using dozers) or wet mining (dredging below the water table);
3. Mixing of iron sand with water to form a slurry for transport and processing;
4. Pumping of the slurry through a seabed pipeline to a bulk carrier ship moored offshore;
5. Ship loading and dewatering; and
6. Tailings disposal and rehabilitation of mined areas.

2.2 Environmental Setting

The Taharoa Lakes comprise three interconnected lakes, namely, Lake Taharoa, Lake Numiti, and Lake Rotoroa. Collectively, these lakes are known as the Taharoa Lakes and cover a combined surface area of approximately 2.55 km^2. The surface water catchments draining to the lakes covers an area of approximately 38 km^2.

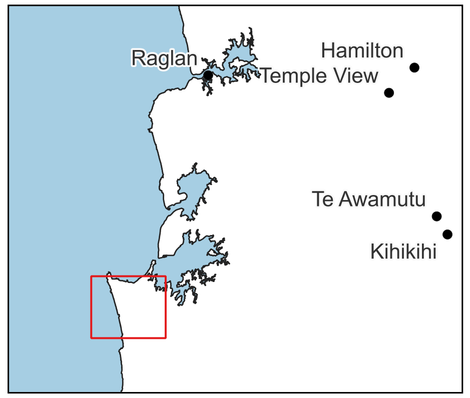
The natural outlet of the Taharoa Lakes is the Wainui Stream which runs from the north-western corner of Lake Taharoa, through the mine site, and discharges to the coast. Wainui Stream is approximately 2.5 km in length. A dam structure was established on the Wainui Stream in the 1970's to create a water supply reservoir for the mine. The dam structure impounds water in the stream behind the dam, raising the water level in the stream and lake. The reach of the Wainui Stream behind the dam is essentially an extension of the lake.



Map Title:
Location Overview

Project:
Lake Taharoa Hydrology Assessment

Client:
Taharoa Ironsand Limited



Legend

- Dam Structure
- Lake Water Level Logger
- Rain Guage
- Stream / River
- Mining Area

Data Provenance
Reference any 3rd party data sources here

Drawn by: Name Here
08/08/2025

Layout & Project File
A3 Landscape Template

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Figure 1.

2.3 Water Take

Water is required for day-to-day operational mining activities and to form a slurry to enable the iron sand to be pumped through pipelines for transport within the mine, processing and loading into bulk carrier ships moored offshore. A summary of TIL's consented water takes, historic and proposed future use of water is provided below.

Water is abstracted from the Wainui Stream (the outlet of Lake Taharoa to the sea) behind the reservoir dam structure. The Wainui Stream was dammed and diverted in the 1970's to create a water supply reservoir for iron sand mining operations. A box weir is located directly behind (i.e., upstream) the 4.6 m high dam, with two low level v-notches located on the western side to provide a low-level bypass and a flat, sharp crested weir around the remaining three sides. Water flows into the weir box, and into a culvert/outlet pipe through the dam structure, before discharging to the open channel of the Wainui Stream, downstream of the dam. A fish pass is also present, which discharges at a low rate to enable fish passage around the dam.

Water is abstracted from screened intakes adjacent to the box weir, just upstream from the dam.

2.3.1 Consented Water Takes

A summary of TIL's two currently consented water takes is presented in **Table 1**.

Table 1. Existing water take consents

Consent Number	Purpose	Daily Limit (m^3)	Annual Limit (m^3)
100905	Take water from a water supply reservoir created by the damming of the Wainui Stream, for the purpose of iron sand mining operations.	27,200	n/a
100906	Take water from a water supply reservoir created by the damming of the Wainui Stream, for the purpose of loading iron sand onto ships.	75,000	3,000,000

In addition to maximum abstraction volumes, both consents have restrictions on lake level drawdown. Both consents require the consent holder to notify Waikato Regional Council (WRC) in writing within 48 hours in the event the water level within the lake drops below RL 9 m. Consent 100905 requires TIL to cease the taking of water if water levels drop below RL 8.53 m as a result of exercising the consent.

Historic measured lake water levels for the period 2013 to March 2025 are presented in **Section 3.4**. At no point during this period have lake water levels dropped below the consented limits described above. In fact, the lowest operational level appears to be 9.5 m, which is significantly higher than the existing cease take level of 8.53 m and the WRC notification level of RL 9 m.

While we have been unable to identify any records which provide a basis for the 8.53 m RL trigger level, we believe it was likely based on the minimum lake level prior to construction of the dam.

2.3.2 The Proposed Activity

TIL is proposing to continue the abstraction of water from Wainui Stream as previously consented, with similar limits on the maximum rate of take, daily volume, 28-day rolling volume, and lake level triggers (as set out in **Table 2**).

The proposed limits are generally the same as those from the existing consents (**Section 2.3.1**), with a new lake level trigger that requires management steps to be implemented if the lake drops below 9.6 m RL.

Table 2. Proposed limits.

Description of limit
For water taken from the reservoir in the Wainui Stream, the instantaneous take rate must not exceed 868 L/s.
For water taken from the reservoir in the Wainui Stream, the daily take volume must not exceed 75,000 m^3.
For water taken from the reservoir in the Wainui Stream, for operating use, the daily volume must not exceed 27,200 m^3 as a 28-day rolling average, subject to the restrictions imposed by the condition below.
For water taken from the reservoir in the Wainui Stream, for ship loading use, the: • Daily volume of water taken must not exceed 75,000 m^3. • Annual volume of water taken must not exceed 3,000,000 m^3.
Water must not be taken when the Lake Taharoa water level is less than 8.53 m RL, relative to TIL's local vertical datum.
If Lake Taharoa water levels drop below 9.6 m RL, the consent holder must implement a management response to reduce the water being taken as far as practically possible and commission an ecologist to monitor the extent and health of wetland around the lake margin.
A residual flow through the dam outlet of no less than 10 L/s.
A residual flow through the fish pass of no less than 24 L/s.

2.3.3 Historic Operating Regime of the Water Take

Daily water abstraction data for the period March 2014 to December 2024 were provided by TIL (**Figure 2**). Abstracted water was categorised as day-to-day mine process water and ship loading water. Water for processing activities was abstracted almost every day, with an average daily volume of approximately 17,500 m^3, and an annual average volume of approximately 6,400,000 m^3.

Ship loading operations are currently undertaken approximately 18 times per year, requiring an average daily abstraction of approximately 37,000 m^3 and a maximum of 72,000 m^3 (or thereabouts) with an average annual volume of 3,830,000 m^3. To ensure the ship loading consented annual limit (**Table 1**) is complied with by TIL, approximately 1,200,000 m^3/year of processing water is recycled for use in the ship loading operations.

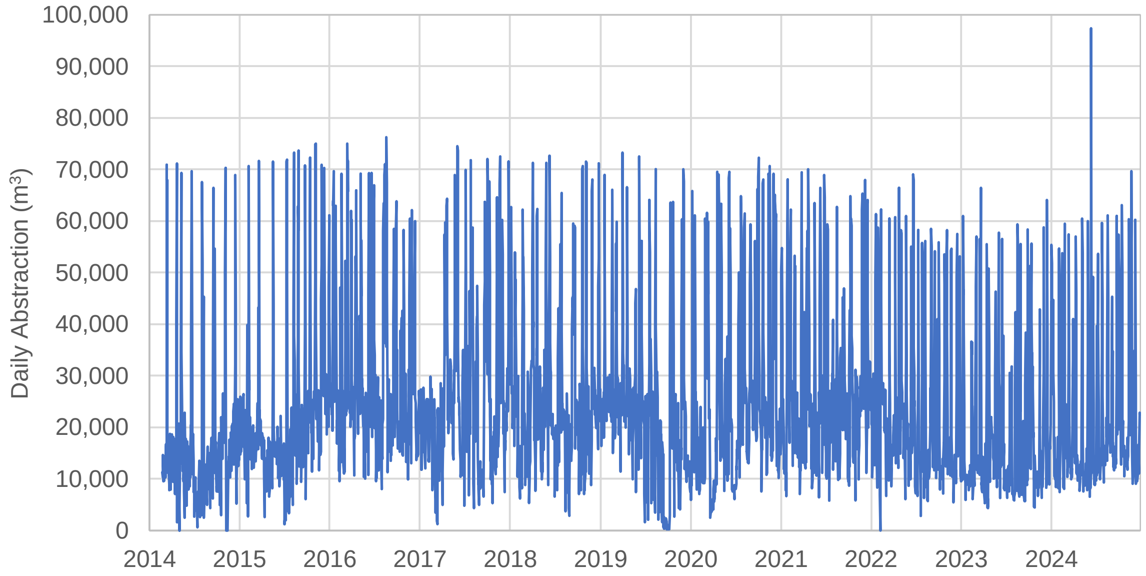


Figure 2. Measured historic water abstractions from Lake Taharoa.

3. Available Environmental Data

The following section details the available data that was utilised for the lake water balance modelling assessment. These datasets were used to inform parameterisation of the catchment flow and lake water balance models.

3.1 Climate Data

Evaporation and rainfall data were sourced from NIWA's Cliflo database and from the Fire and Emergency NZ (FENZ) rain gauge at Taharoa. The various datasets are summarised in **Table 3**.

The Port Taharoa rain gauge provided the longest duration record, however it had a number of periods of missing data. Prior to 1990, there were a number of prolonged periods of missing rainfall data. Therefore, the record from 1990 to present was used, as it was more complete. On average approximately 7% of the record was missing each year post 1990, with no alternative rainfall datasets available to infill missing data, until the start of the FENZ Taharoa rain gauge in 2018. Post 2018, the FENZ Taharoa rain gauge was used to infill periods of missing data.

Evaporation data from Te Kuiti covered the period from 2003 to 2024. The record was extended back to 1982 using calculated monthly median evaporation.

Table 3. Available climate data summary

Data type	Name (Source)	Location	Period
Rainfall	Port Taharoa (Cliflo)	2 km west of Lake Taharoa	1982 – 2024
Rainfall	Taharoa (FENZ)	3 km east of Lake Taharoa	2018 – 2024
Evaporation	Te Kuiti (Cliflo)	50 km south-east of Lake Taharoa	2003 – 2024

A summary of the annual rainfall and evaporation dataset used is presented in **Figure 3**.

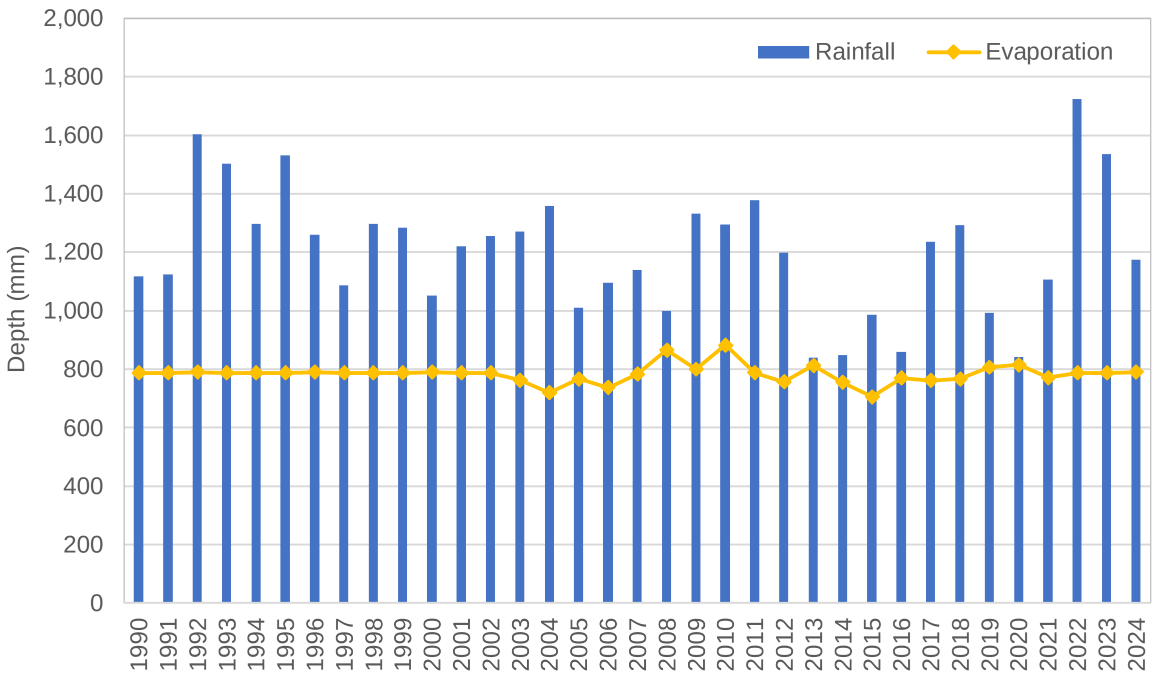


Figure 3. Climate data summary.

3.2 Soil and Geology

Inland of the mining operations, the GNS Fundamental Soils Layer (FSL) indicates two main soil types across the Lake Taharoa catchment; Marokopa Clay Loam and Pakau Silt Loam. Soil texture is predominantly classified as silt loam or clay loam. Soil depth on average is 0.75 m and permeability is classed as medium. New Zealand Geological Map (QMap) was used to provide an overview of the surface geology within the catchment, which is predominantly mudstone.

3.3 Lake Bathymetry and Surrounding Topography

A bathymetric survey of the Taharoa Lakes and Wainui Stream was undertaken by Discovery Marine Limited (DML) in November 2007[1]. The lakes were surveyed using a combination of a survey boat and small dinghy. A description of DML's survey methodology and key observations is provided below.

Wainui Stream was surveyed via a combination of cross-sections and a single longitudinal line down the middle of the stream. Lake Taharoa was surveyed via a regularly spaced grid pattern with lines and soundings at 50 m intervals.

The entire shoreline was surveyed from the boat. It was not possible to walk and survey the perimeter of the lake above lake level due to large swampy areas. Low lying areas beyond the lake edge were assigned height values based on visual observations in the field and also reference to topographic maps.

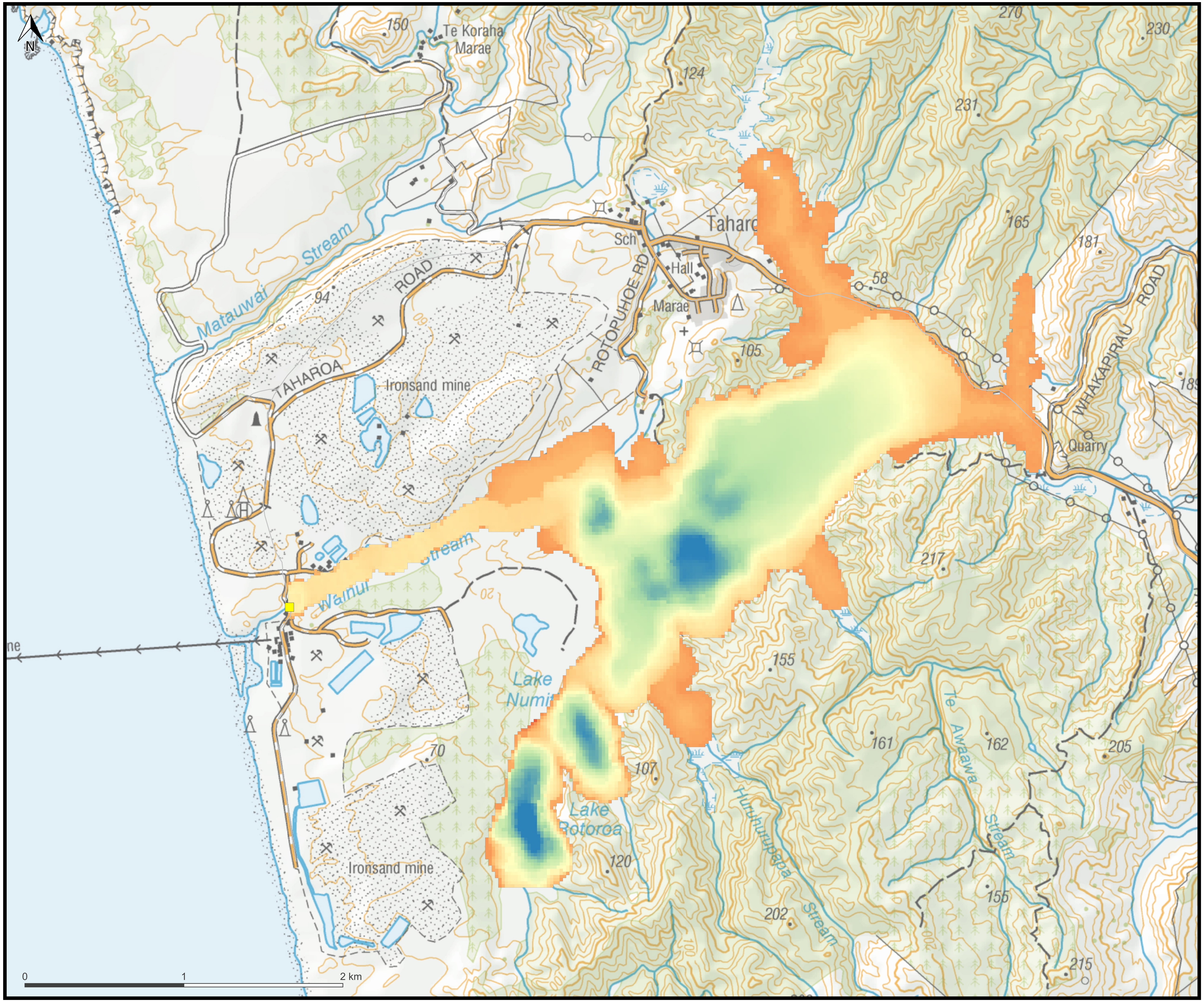
The bathymetric data was surveyed in terms of local datum, which is the same vertical datum used for historic lake level measurements (**Section 3.4**). It was previously understood that TIL's local datum was equivalent to mean sea level (MSL). As this project progressed and various datasets analysed, it became apparent the local datum was not equivalent to MSL.

In order to ensure the various datasets (e.g., measured water levels, topography etc) were analysed and interpreted correctly, TIL's surveyor surveyed a local LINZ geodetic benchmark of known elevation relative to New Zealand Vertical Datum (NZVD2016). A vertical offset correction of +2.38 m was determined necessary to convert NZVD to TIL local datum i.e. the local datum is 2.38 m higher than NZVD).

Please note, unless otherwise specified all elevation values presented in this report are relative to TIL's local datum to enable easy comparison to previous studies and data presented.

The lake survey bathymetry dataset is presented in **Figure 4**.

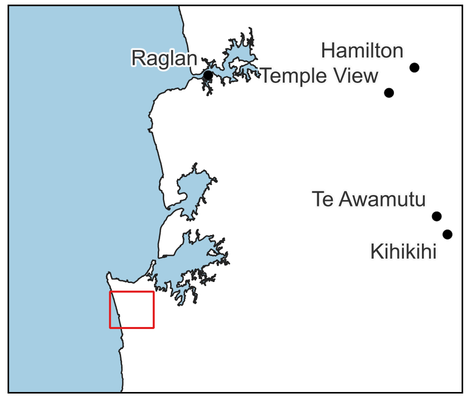
[1] DML 2007. Report of Survey. Taharoa Lakes and Wainui Stream. 6 December 2007.



Map Title:
Lake Bathymetry

Project:
Lake Taharoa Hydrology Assessment

Client:
Taharoa Ironsand Limited



Legend

Dam Structure

Elevation (m TIL Datum)

14 m

0 m

Data Provenance
Bathymetric survey data from DML (2007)

Drawn by: Josh Mawer
27/08/2025

Layout & Project File
A3 Landscape Template

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Figure 4.

The topography is generally steep around the north, east and southern sides of the lake. There are gentle sloping and low-lying wetland expanses along the north-west and south-west margins of the lake.

3.4 Historic Water Level Data

Measured lake water level data covering the period August 2013 to 2024 (inclusive) were provided by TIL (**Figure 5**). Lake levels appear to have remained relatively stable between ~9.6 m and 10.4 m, with a seasonal cycle of higher levels in winter, and lower levels in summer.

The two existing lake trigger levels (**Section 0**), are also indicated on the plot.

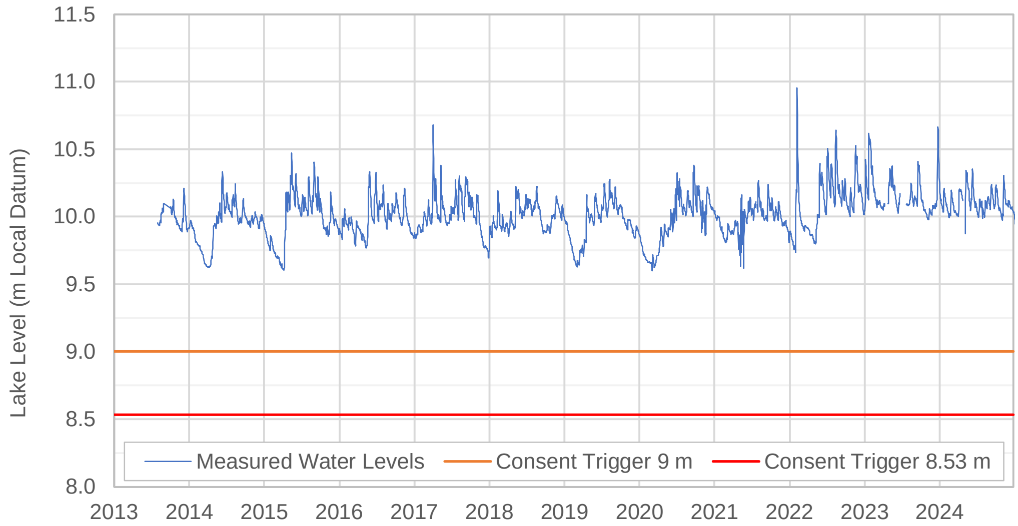


Figure 5. Historic measured lake water levels and existing consent trigger levels.

Water levels have also been measured in the Wainui Stream, immediately upstream of the dam structure. Available measured water level data from the dam are presented in **Figure 6**, and compared to those from the lake.

Water levels at the dam outlet are typically slightly lower than those in the main body of the lake (e.g., those presented in **Figure 5**) due to frictional headloss along the approximate 2 km long reach of the Wainui Stream, from the lake to the dam. On average, water levels at the dam are approximately 0.15 m lower (**Figure 6**). However, the exact difference appears to change with the lake level (i.e. there is a larger difference under high lake levels), and through time – likely reflecting changes in the stream morphology and/or fringing vegetation growth along the stream edges.

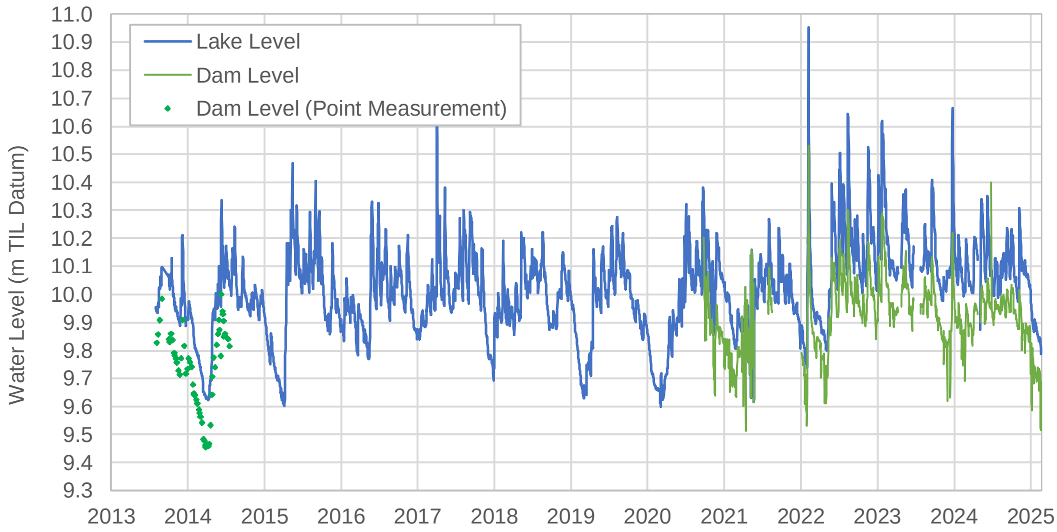


Figure 6. Comparison of measured water levels in the lake, and near the dam structure. (Raw data provided by TIL).

3.5 Measured Flow Data

A series of manual flow measurements (referred to as manual flow gaugings) were collected to inform various aspects of the wider project.

Manual flow gaugings were collected via standard wading measurements using a Sontek 2 Acoustic Doppler Velocimeter (ADV). Gaugings were undertake at the following locations:

- Wainui Stream: Downstream of the dam – to verify calculations of discharge through the dam structure and fish passage.
- Mitiwai Stream: Upstream of proposed mining areas – to verify catchment flow modelling and inform potential trigger limits.
- Mitiwai Stream: Near the mouth – to verify catchment flow modelling and inform potential trigger limits.

Table 4. Manual flow gaugings.

Date	Wainui Stream – d/s Dam		Mitiwai Upstream Site		Mitiwai Downstream Site	
	Dam Level (m RL)	Flow L/s)	Water Level (m RL)*	Flow (L/s)	Water Level (m RL)*	Flow (L/s)
27 May 2024	9.983	1,360	0.207	136	0.103	122
07 October 2024	9.970	802	0.459	566	0.365	627
14 February 2025	9.700	75	-	-	-	-
15 February 2025	-	-	0.132	28	-	-
18 February 2025	-	-	-	-	0.084	50
29 April 2025	9.890	309	-	-	-	-

Note: water levels relative to the stream bed at each sensor site.

This report details the hydrology assessment related to the Taharoa Lakes and Wainui Stream (i.e., the outlet of the lakes), and the potential effects on these water bodies associated with TIL's proposed water takes. The Mitiwai Stream is located approximately 1.6 km north of the mouth of the Wainui Stream and hence not covered in this hydrological assessment. An assessment of effects associated with TIL's proposed activities on flows in the Mitiwai Stream is documented in the Hydrogeological Assessment (WWLA, 2025)[2].

[2] WWLA, 2025. Taharoa Mine Expansion – Assessment of Groundwater Effects. Consultancy report prepared for Taharoa Ironsands Limited. WWLA1303. Rev 3. 5 August 2025.

4. Lake Water Balance Assessment

4.1 Overview

WWLA's Reservoir Storage Model (RSM) was used to undertake the lake water balance assessment. While the model is referred to as a reservoir storage model, conceptually, lakes are essentially a large reservoir. The RSM performs water balance calculations on an hourly timestep with outputs on a daily basis. The RSM accounts for inputs (rainfall and catchment inflows) and losses (evaporation, seepage (losses to groundwater), and abstractions) to determine the daily changes in storage volume and, by inference, water level.

The RSM provides a tool that enables rapid simulation and can therefore provide valuable insight into the hydrological functioning of a lake or storage reservoir through the simulation of exploratory scenarios involving trial and adjustment of key model inputs (e.g., the proportion of groundwater inflow or seepage loss).

4.2 Conceptual Lake Hydrological Functioning

In order to configure the RSM, a conceptual understanding of the lake's hydrological functioning is required, which is depicted in **Figure 7**.

The largest input of water to the lake will be catchment inflows from the streams that drain to the lake. Direct rainfall to the lake's surface will provide a smaller volume of water to the lake, due to the significantly smaller size of the lakes surface in comparison to the surrounding catchment.

Water will be lost from the lake primarily through the weir overflow through the dam structure, particularly during periods of higher lake level. Lower volumes of water will be lost from the lake through evaporation, the fish passage, and seepage to groundwater. However, it is noted these processes will become proportionally larger during periods of low lake levels.

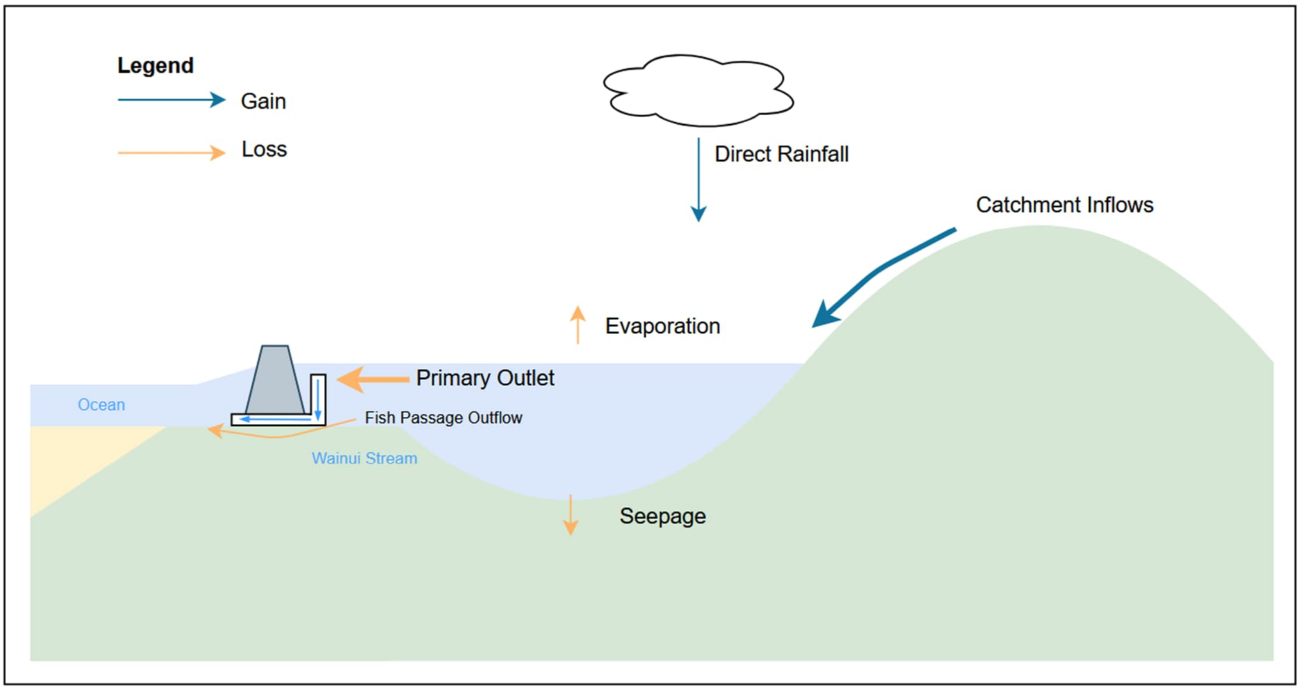


Figure 7. Conceptual lake water balance components.

4.3 Model Inputs

The following sub-sections describe the configuration of each key RSM input.

4.3.1 Stage, Area, and Volume Curves

The stage (water level), area, and volume curves represent the fundamental geometry of the lake. The curves characterise the change in surface area and change in volume with change in lake water level.

The maximum lake surface area was estimated from aerial imagery in GIS, and the stage, area and volume curve, calculated from the lake bathymetric survey (**Section 3.3**) and Waikato LiDAR Digital Elevation Model (DEM), is presented in **Figure 8**.

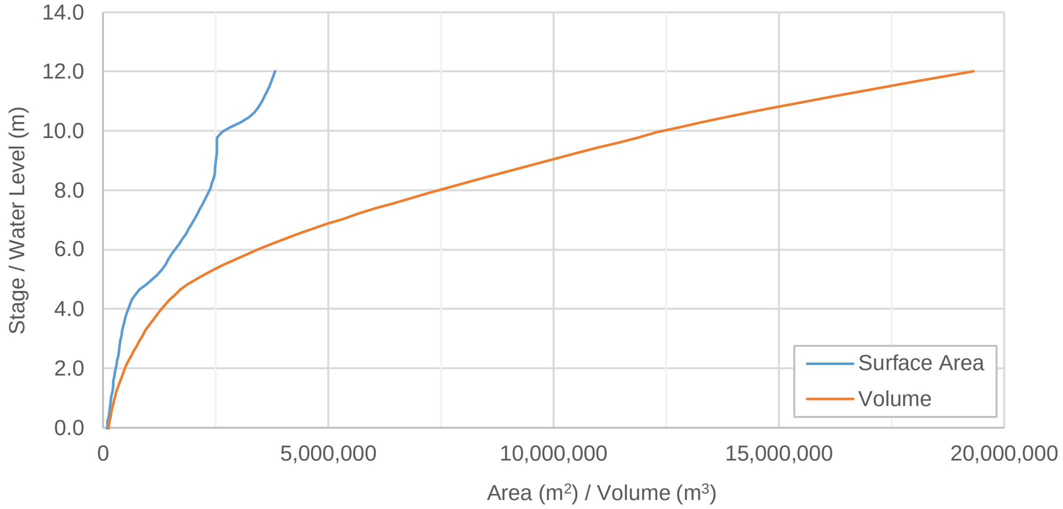


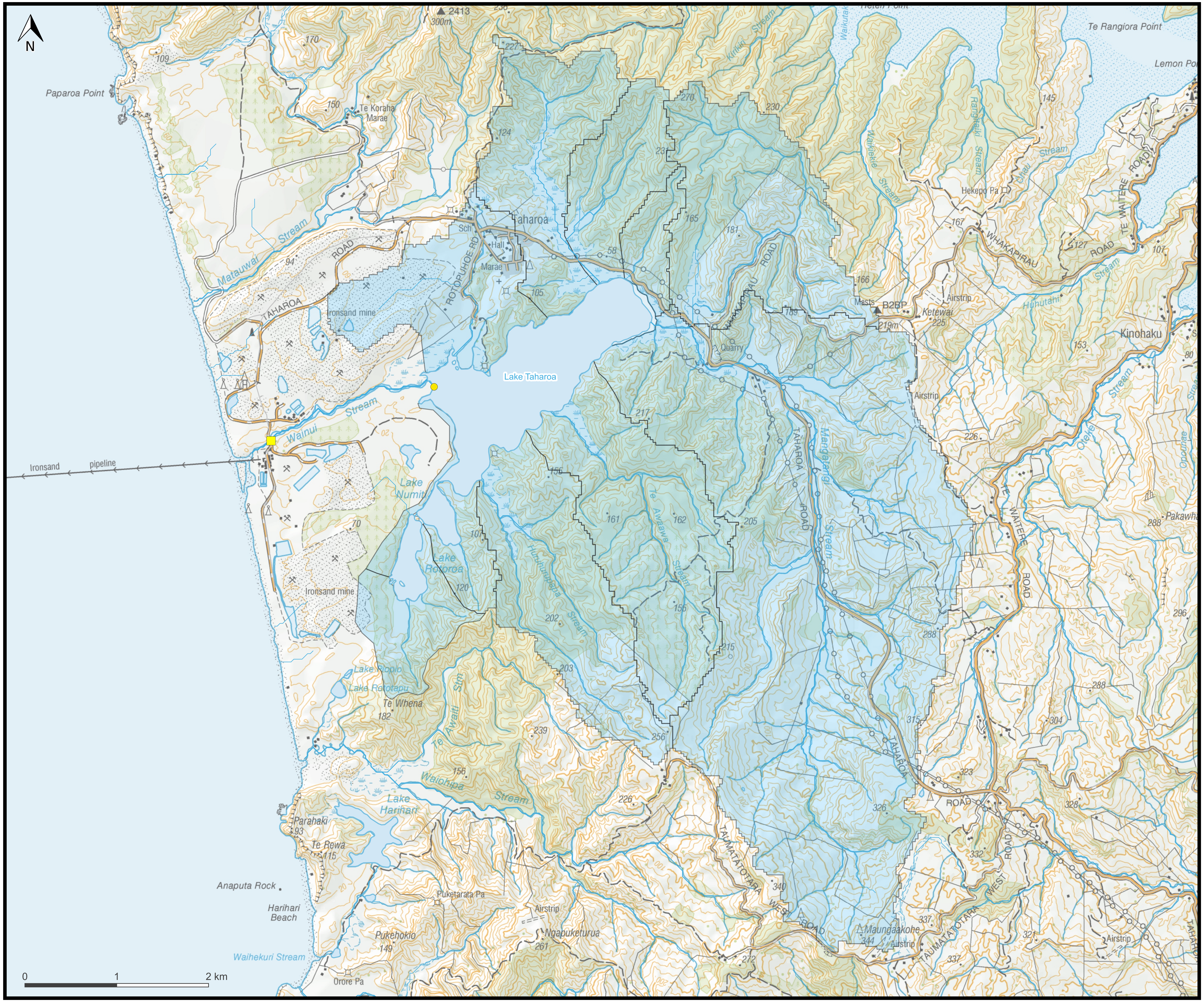
Figure 8. Stage, area, volume curve.

4.3.2 Rainfall and Evaporation

Rainfall and evaporation were configured using the datasets as described in **Section 3.1**.

4.3.3 Catchment Inflows

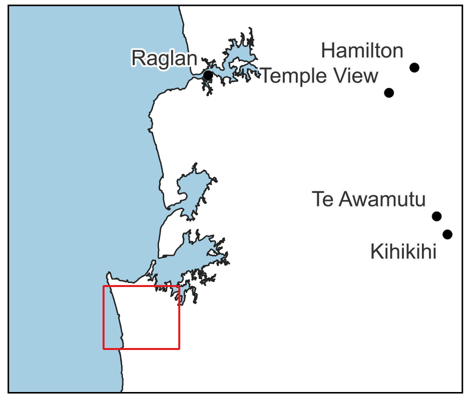
The surface water catchments flowing into Lake Taharoa are displayed in **Figure 9**, and cover an area of approximately 37 km^2. The catchments predominantly consist of forest and pasture. No measured stream flow data exists within the catchments that flow into the lake, hence an uncalibrated model was used to estimate stream flow.



Map Title:
Lake Surface Water Catchments

Project:
Lake Taharoa Hydrology Assessment

Client:
Taharoa Ironsand Limited



Legend

- Dam Structure
- Lake Water Level Logger
- Stream / River
- Lake Surface Water Catchments

Data Provenance
Topographic basemap from LINZ

Drawn by: Josh Mawer
27/08/2025

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Figure 9.

A catchment rainfall runoff model was developed to provide an estimate of catchment inflows to the lake in the absence of measured flow data. The model developed utilised WWLA's Soil Moisture Water Balance Model (SMWBM).

The SMWBM is a semi-deterministic rainfall-runoff model. The model utilises daily rainfall and evaporation input data to calculate the soil moisture conditions under natural rainfall conditions. The model operates on a daily time step during dry days, however when rain days occur, a finer hourly calculation step is implemented to enable peak flows to be assessed more accurately than a daily time step model.

Model parameters were set based on our understanding of the catchment physical characteristics (i.e. soils, geology, topography, and land use), and the climate data described in **Section 3.1**. The resulting simulated catchment inflow hydrograph, representative of all catchments draining into the lake collectively, is presented in **Figure 10**, and tabulated summary statistics presented **Table 5**.

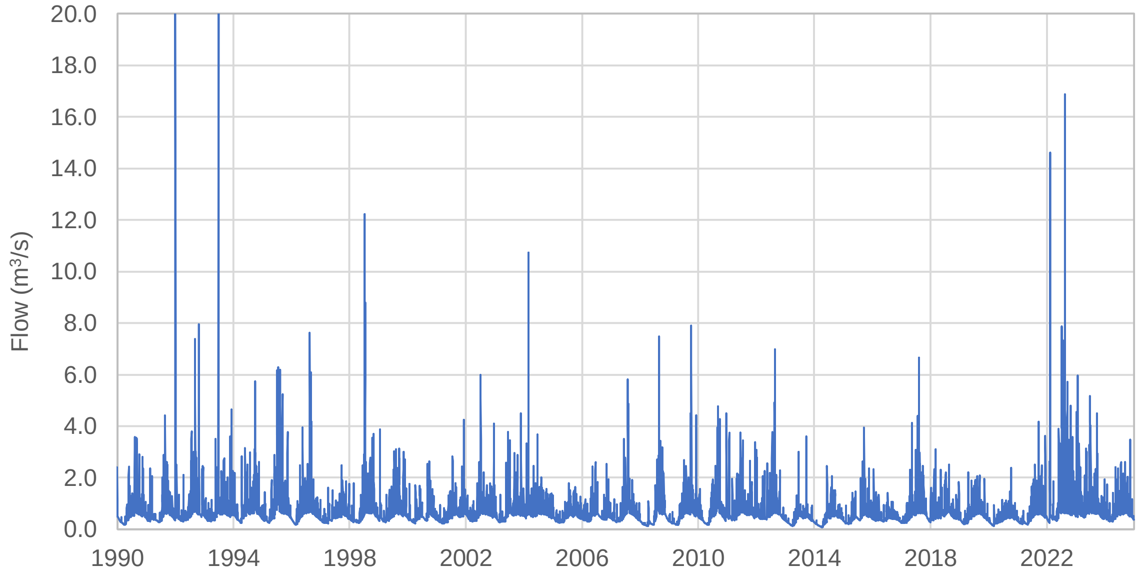


Figure 10. Simulated catchment inflows to Lake Taharoa.

Table 5. Summary statistics of simulated catchment inflows to Lake Taharoa.

Statistic	Flow (m^3/s)	Flow (m^3/d)
Minimum	0.08	6,985
5th Percentile	0.22	19,433
25th Percentile	0.38	32,665
Median	0.53	45,690
Mean	0.73	62,678
75th Percentile	0.75	65,009
95th Percentile	1.32	114,369
Maximum	29.88	2,581,317

The long-term water balance for the catchment is summarised in **Table 6**. This indicates the hydrological characteristics of the catchment are dominated by groundwater flows (31%), with surface runoff contributing a smaller total (19%) on a long-term average. Interception loss and soil evaporation collectively account for 50% of the water balance.

Table 6. Catchment water balance summary (% of mean annual rainfall).

Interception Loss	Soil Evaporation	Groundwater Recharge	Surface Runoff	Change in Soil Storage	Total
20%	30%	31%	19%	0%	100%

Full details of the SMWBM along with model parameters applied is presented in **Appendix A**.

4.3.4 Abstractions

TIL's abstractions from the lake were configured based on their daily measured abstraction dataset (**Figure 2**).

4.3.5 Discharges Through Outlet Dam Structure

As alluded to in **Section 2.3**, the dam structure on the Wainui Stream (the outlet of Lake Taharoa) consists of a box weir with twin v-notch low-level bypass, a higher rectangular, sharp-crested weir bypass and fish passage structure The discharge rate over the weir into the culvert is controlled by the water level behind the dam structure. Therefore, the discharge rate is passively controlled, and cannot be actively controlled.

A photograph of the western wall of the box weir intake is provided in **Figure 11**, and shows the twin low-level v-notches. At higher lake levels, water also discharges over the three remaining sides.

Figure 11. Outlet weir. (Photograph provided by TIL)

The outlet weir has reportedly been upgraded and modified on a number of occasions since construction in the late 1970's. There do not appear to be any current as-built or design drawings that reflect the current state of the structure which is shown in **Figure 11**. TIL provided measurements collected from the platform above the weir, and these are illustrated on the schematic in **Figure 12** - which illustrates an "unfolded" form of the box weir (i.e., the unfolded to represent a straight line). This shows the invert of the two v-notches at 9.36 m, that are 1.3 m wide at the top. The remaining three sides are approximately at 9.8 m.

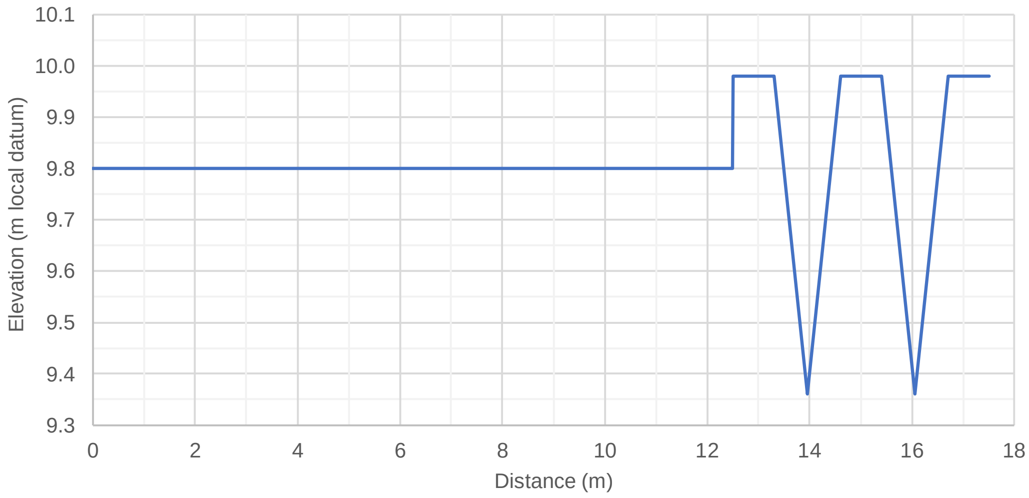


Figure 12. Schematic of the outlet weir.

A stage (water level) vs outflow curve was initially developed by applying a weir equation to calculate the discharge at frequent increments above the invert of the v-notches (i.e., 9.36 m). A constant discharge of 34 L/s was assigned for all levels below the invert of the v-notch – representing the combined rate required for downstream residual flow and fish passage flow (**Table 2**).

There is uncertainty in the exact lake topography and bathymetry behind the dam structure, and the amount of head loss (i.e., decrease in water level) along the length of the Wainui Stream behind the dam. Therefore, ultimately the stage vs outflow curve was adjusted as a calibration parameter, while maintaining the general shape determined from the hydraulic equations (i.e., increasing outflow volume with increasing water levels).

The final stage vs outflow curve from the calibration scenario (**Section 5.1**) is presented in **Figure 13**.

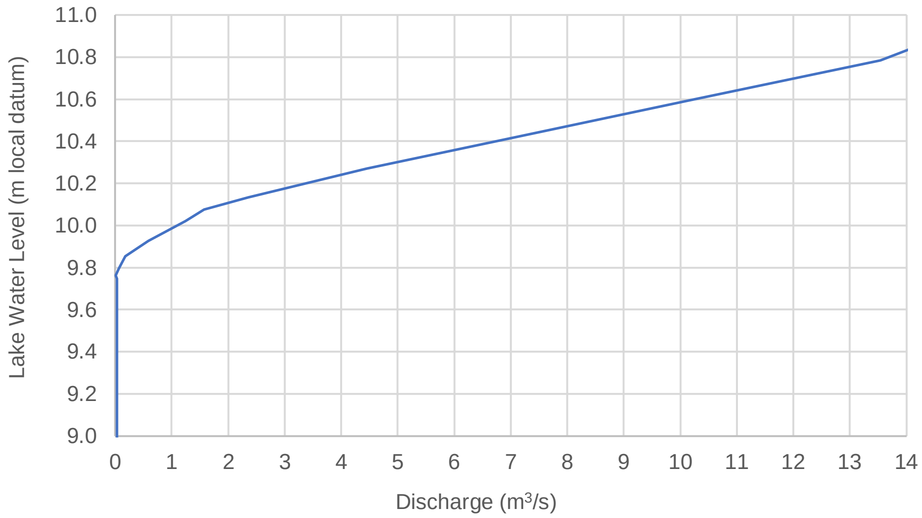


Figure 13. Stage vs outflow curve.

4.3.6 Groundwater Seepage from Lake

Due to uncertainties in the exact configuration of the outlet structure, vertical datum offsets, and frictional headloss along the Wainui Stream, the discharge through the outlet dam structure curve was adjusted as a model calibration parameter to provide the best match to measured water levels. Therefore, lake seepage to groundwater was implicitly accounted for as part of discharge losses described in **Section 4.3.5**.

4.4 Calibration Simulation

4.4.1 Lake Levels

A comparison of measured lake water levels and simulated lake water levels based on historic measured water take data is presented in **Figure 14**. The historic measured water take data (**Section 0**) were included in the assessment as an abstraction from the lake. This simulation is referred to as Scenario 1 (S1). The primary calibration mechanism was adjustments to the stage overflow curve (**Section 4.3.5**). Particular attention was provided to achieving a good match to periods of low lake level, as these are the times of greater concern from a wider project assessment of effects perspective.

The good degree of alignment between simulated and measured water levels demonstrates the lake water balance model was able to successfully simulate the general magnitude, timing and periodicity observed in the measured lake water levels.

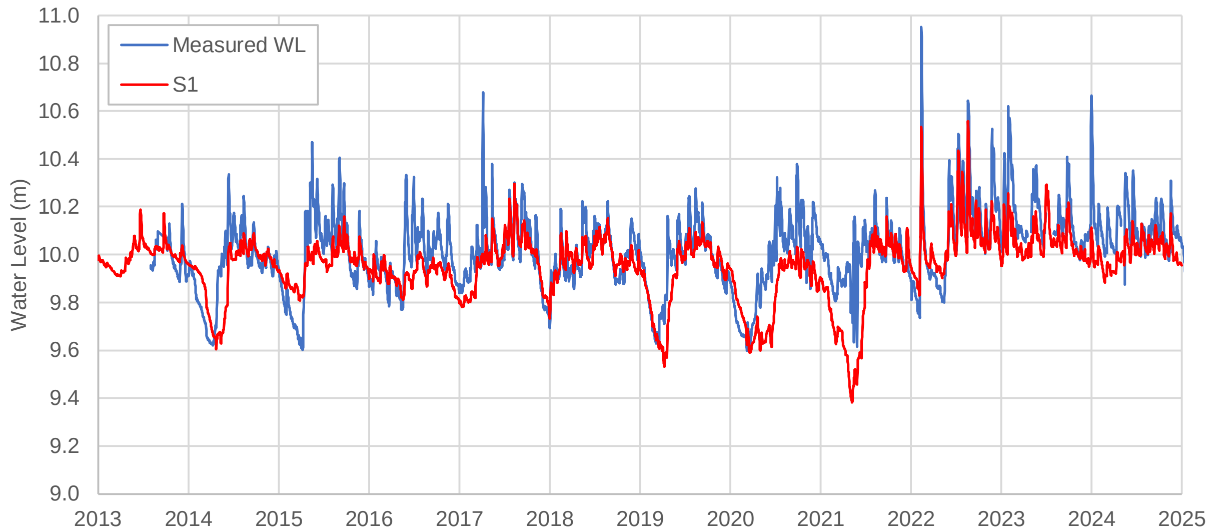


Figure 14. Comparison of measured lake water level and simulated S1 lake water level.

4.4.2 Water Balance

A summary of the proportional contribution of each component to the overall lake water balance is presented in **Table 7** for the calibration period. This demonstrates, over a long-term average, catchment inflows are the largest inflow (gain) to the lake, making up 88% of the total inflow volume.

Combined flows through the dam outlet structure are the largest loss (57%), closely followed by abstractions (35%). Evaporation from the lakes surface accounts for approximately 8% of the total losses.

Table 7. Lake water balance summary.

Component		Percentage (%)
Gains	Rainfall	12%
	Catchment inflows	88%
Losses	Evaporation	8%
	Abstractions (water takes)	35%
	Flow through outlet and seepage	57%

5. Water Take Scenarios

Four exploratory water take scenarios, in addition to the calibration scenario, were simulated to assess the effect of TIL's proposed water takes on water levels in Lake Taharoa. The scenarios and resulting effect on water levels are detailed below.

5.1 Scenario Descriptions

The five scenarios are summarised in **Table 8**.

Table 8. Exploratory scenarios.

#	Name	Description
S1	Calibration / Historic Water Takes (presented in **Section 4.4**)	Historic measured water takes (as described in **Section 3.4**). Note: measured water level data were only available for the period August 2013 to present.
S2	No Water Takes	No water takes, but assuming the dam outlet structure is still present
S3	Maximum Future Water Take	Maximum consented (and proposed) processing water take (27,200 m^3/day) each day, and 35 ship loading events per year (21,428 m^3/day x 4 days per ship loading event)
S4	Increased Ship Loading Take and Average Processing Water Take	Average current processing water take (17,500 m^3/day) each day, and 35 ship loading events per year (21,428 m^3/day x 4 days per ship loading event)
S5	Naturalised – No Dam and No Water Takes	Assumed removal of the dam structure, and no water takes (i.e. the existing environment for the purpose of the resource consenting process).

Scenarios 2 to 4 represent exploratory scenarios to provide an indication of the potential effects resulting from various water take regimes on lake water levels.

Ship loading operations at the offshore port are expected to increase in frequency to a projected maximum of 35 times per year (up from a maximum of 20 per year at present). Each ship loading event takes approximately 90 hours.

The volume and duration of ship loading events will vary each year, depending on available supply, demand, and weather conditions. Therefore, to develop a representative water take time series, a Monte Carlo approach[3] was used to randomly select 35 four-day ship loading periods each year within the simulation period. The processing water take was assumed to occur every day of the year.

To assess the potential future operating regime of Lake Taharoa under the proposed water take limits, it was assumed the ship loading take would operate at 21,428 m^3/day (3,000,000 m^3/year ÷ 35 ship loadings/year ÷ 4 days per ship loading event). It was assumed that recycled processing water will supply the additional water requirements for ship loading over and above the proposed take from Wainui Stream, as currently occurs.

The scenarios simulated are considered conservative, as they do not include any active management of the takes (i.e., reducing take volumes as lake levels become low), but did include a cease take trigger when simulated lake levels dropped below 8.53 m RL. In reality, TIL proposes to review abstraction rates when lake levels drop below 9.6 m RL in order to assess and avoid any potential adverse effects on wetlands around the margins of the lake (**Section 2.3.2**). The model presented here does not make an assumption around operational reductions in take, and thus conservatively assumes the continued abstraction as specified for each scenario.

Scenario 5 represents a hypothetical scenario for assessment purposes only. In this scenario, it was assumed the existing dam structure was removed in its entirety, and no water take abstractions occur. This reflects a

[3] Ship loading events were randomly distributed throughout the year, for each year of the simulation.

naturalised scenario. Removal of the dam structure was approximated assuming the Wainui Stream would function as a fully contracted broad crested weir based on the stream geometry at the upstream lake side (elevation of 8.5 m, and rectangular channel width of 10 m). In reality, if the dam structure was removed, the morphology of the Wainui Stream would change to reach a new dynamic equilibrium with lake discharges.

Projected climate change is fairly neutral for the Taharoa area, with only a 2% decrease in annual rainfall projected for the period 2041-2060[4]. Summer rainfall is projected to decrease by ~5%, while winter rainfall is projected to increase by ~2%. Overall, the number of wet days (>1 mm of rainfall) is projected to increase slightly. Given the fairly neutral changes in projected rainfall, potential effects of climate changes were not included in the exploratory scenarios.

5.2 Scenario Results

5.2.1 Scenarios 1 to 4

A comparison of simulated water levels through time for Scenarios 1 to 4 are presented in **Figure 15**. It should be noted, as measured water take data were not available prior to 2013, Scenario 1 and Scenario 2 are identical (i.e., no water takes) for the period 1990 to 2013.

The primary difference between scenarios is the magnitude of drawdown in lake water levels during late summer and into autumn periods. Peak lake water levels, that typically occur in late winter, are largely similar between all scenarios. This is because natural catchment inflows are comparatively larger than the water takes (for Scenarios 1 to 4) during these times, and thus water levels are predominantly controlled by outflows through the dam structure, rather than the water takes. If no water was taken at all (i.e., Scenario 2), there would still be natural fluctuations in the water level of Lake Taharoa between approximately 9.8 m and 10.9 m RL.

Under Scenario 3, the consented (and proposed) cease take trigger level of 8.53 m RL (**Section 2.3.1**) was encountered on four occasions throughout the 34-year simulation period. Under Scenario 4, the cease take level was not triggered at any point throughout the simulated period.

Scenario 3 represents an exploratory scenario only. TIL is unlikely to abstract processing water at the maximum consented take rate every day (given that its current average daily volume is approximately 10,000 m^3 less than the daily limit). In reality, the future abstraction rate will likely more align with Scenario 4 or conservatively, somewhere between those represented for Scenario 3 and Scenario 4. We note, these scenarios are also conservative in that they do not include any demand management (i.e., lowering abstraction volumes as lake levels decrease).

As shown in **Figure 2**, processing water is abstracted each day, and ship loading events occur throughout the year, with no particular strong seasonal pattern or trend. Therefore, the temporal variation in lake water levels (timing and periodicity of rise and fall in water levels) is due to seasonal variation in natural catchment inflows. This will not change with any future increase in the frequency of water abstraction associated with an increased number of ship loading events.

[4] Based on climate change scenario SSP2-4.5. https://map.climatedata.environment.govt.nz/

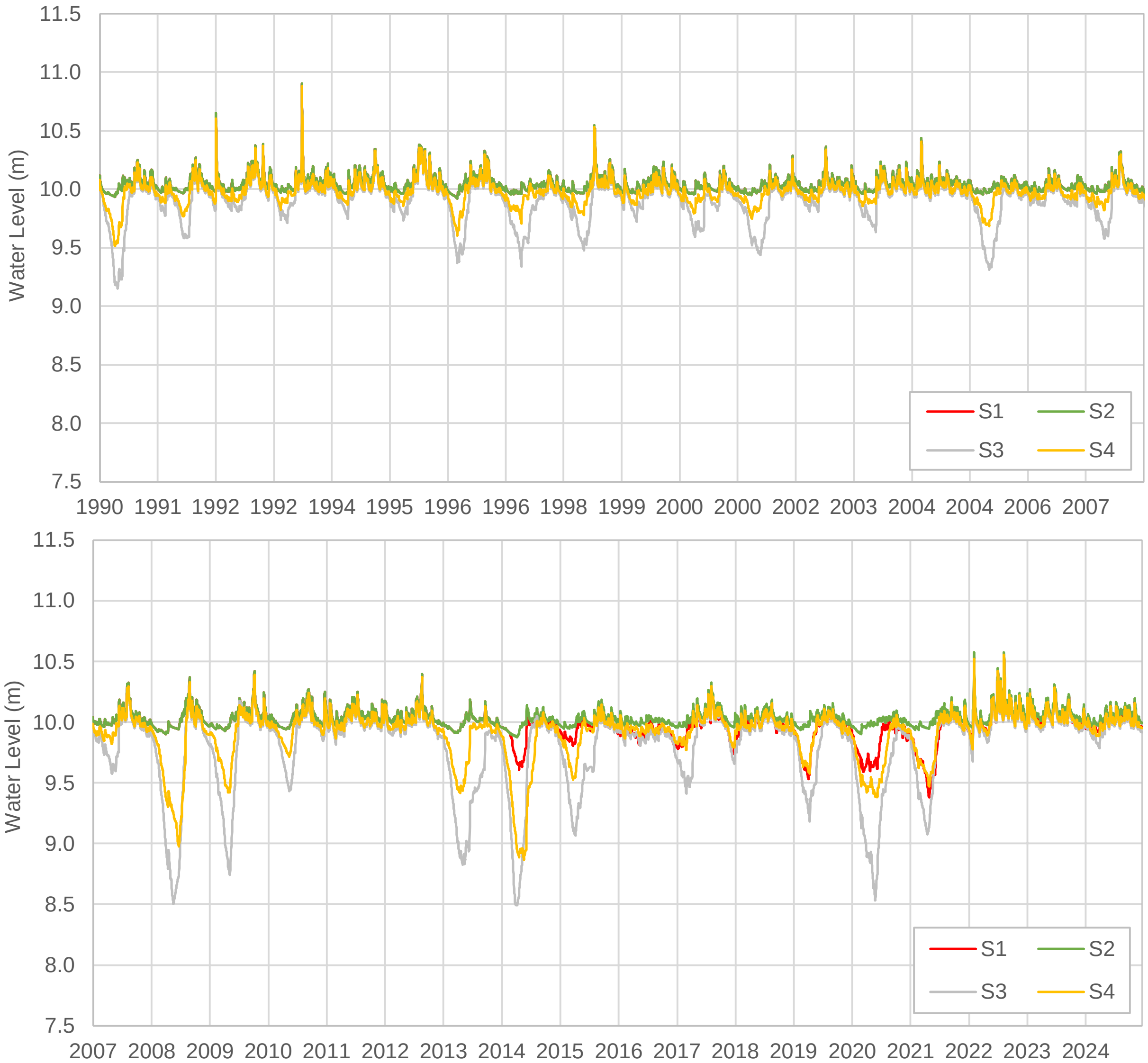


Figure 15. Simulated lake water levels 1990 – 2007 (top), and 2007 – 2024 (bottom).

The proportion of time lake water levels are exceeded for each scenario is presented in **Figure 16**. This further shows that simulated lake water levels for Scenarios 1, 2, and 4, remained above the lake level cease take trigger (8.53 m) 100% of the time. Simulated lake levels for Scenario 3 were only at 8.53 m for approximately <1% of the time.

The water level probability exceedance plot also shows under median conditions (i.e., 50th percentile) lake water levels only differ by 0.11 m between scenarios. Under lower lake levels (i.e., higher probabilities of exceedance), the difference in lake water levels between scenarios increases.

The scenarios show that lake water levels during periods of low lake levels (i.e., typically late summer) are sensitive to lake abstraction take rates. This is because the simulated water take abstraction rates are greater than typical summer natural catchment inflows. Conversely, during winter natural catchment inflows are greater than the simulated abstraction rates, and thus water levels are largely controlled by flow over/through the dam structure during these periods.

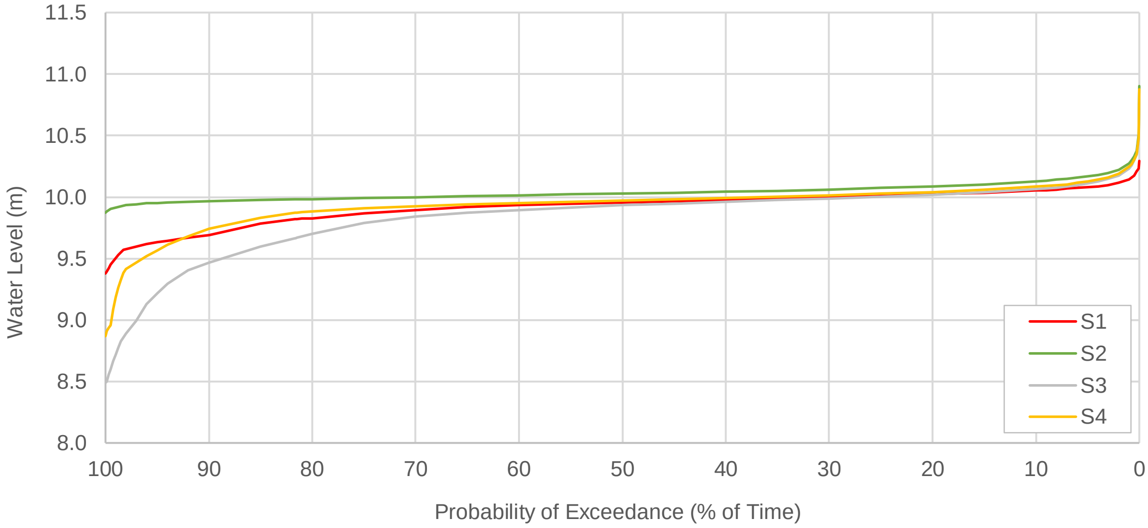


Figure 16. Lake water level probability of exceedance plot.

The proportional contribution of the individual lake water balance comments for Scenarios 2 to 4 are tabulated in **Table 9**. The proportional split of gains (rainfall and catchment inflows) remains the same between scenarios. The proportional split of losses depends on the abstraction scenario considered. In general, the two exploratory scenarios assessed with hypothetical future abstraction regimes indicate abstractions account for approximately 35-50% of losses from the lake. Approximately 8% is lost through evaporation, and the remainder through discharge via the outlet structure.

Table 9. Scenarios – lake water balance summary.

Component		S2	S3	S4
Gains	Rainfall	12%	12%	12%
	Catchment inflows	88%	88%	88%
Losses	Evaporation	8%	8%	8%
	Abstractions (water takes)	0%	49%	36%
	Flow through outlet and seepage	92%	44%	56%

5.2.2 Scenario 5

Scenario 5 was simulated to provide a hypothetical indication of lake level regime <u>if</u> the dam structure on Wainui Stream was removed in its entirety, and no water take abstractions occurred (i.e., a naturalised scenario). Simulated lake levels are presented in **Figure 17**, and compared with those from Scenario 2 (the same water abstraction scenario, but with the dam structure remaining in place). This showed that prior to the construction of the dam (or if it was to be removed) lake levels would have been significantly lower (~2.5 m lower). Fluctuations in levels would have exhibited a similar temporal pattern with lower levels in late summer due to low inflows, and increased levels in late winter in response to higher winter inflows and storm events.

It is evident that in both the potential future water take scenarios analysed (i.e., Scenarios 3 and 4) that lake levels would be considerably higher than under the baseline/naturalised Scenario 5. The only exception to this, was under Scenario 3 during which four short periods of similar lake level (i.e., ~8.53 m RL) occurred and triggered the cease take limit.

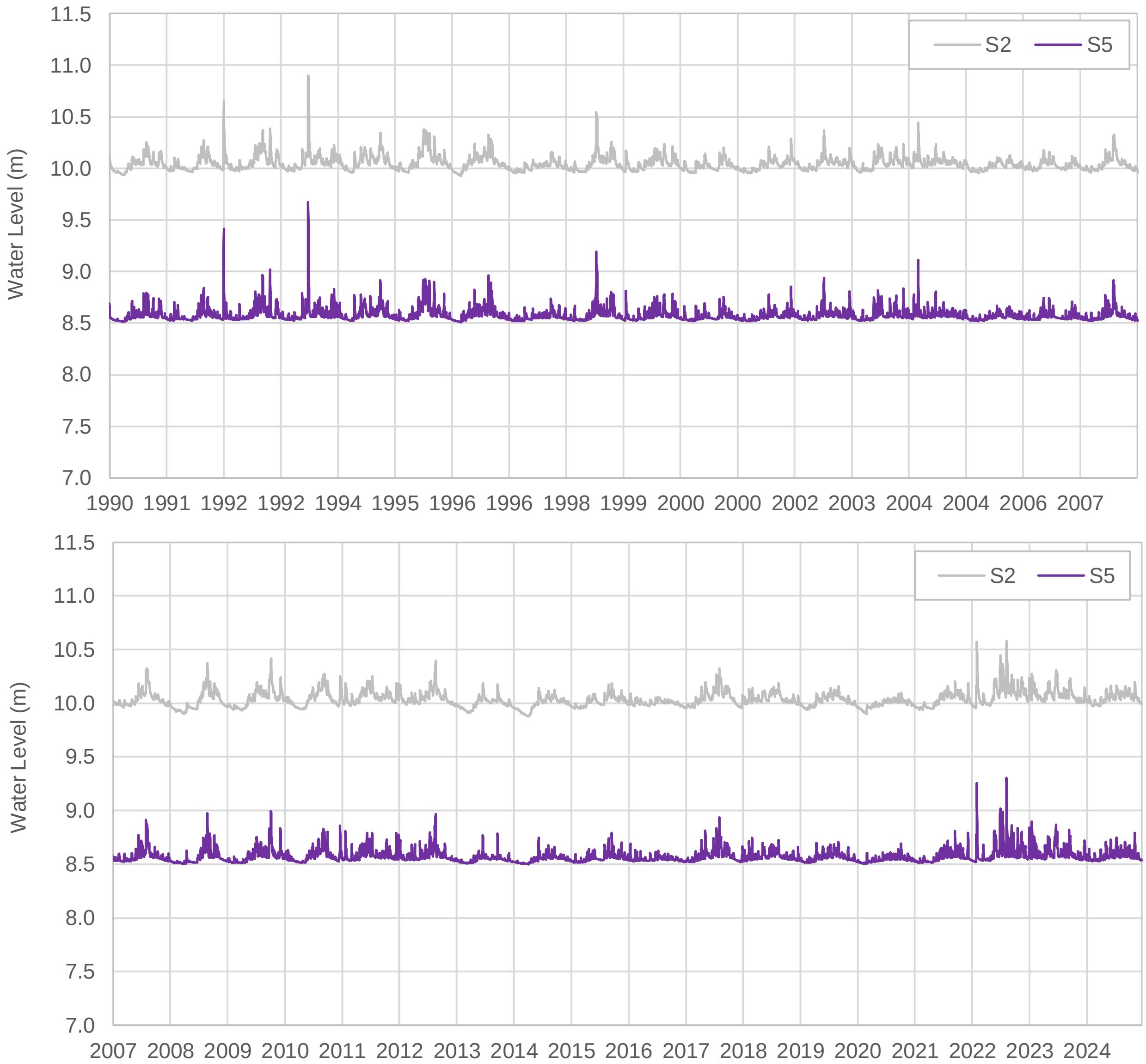


Figure 17. Comparison of simulated Scenario 2 and Scenario 5 lake water levels.

Table 10. Lake water balance summary.

Component		S2 Percentage (%)	S5 Percentage (%)
Gains	Rainfall	12%	10%
	Catchment inflows	88%	90%
Losses	Evaporation	8%	6%
	Abstractions (water takes)	0%	0
	Flow through outlet and seepage	92%	94%

6. Additional Hydrological Considerations

This section provides details on additional hydrological considerations that are not specifically analysed as part of the lake water balance assessment (**Sections 4** and **5**).

6.1 Minimum Flows in the Wainui Stream, Downstream of the Dam

Residual flow conditions (i.e., minimum flow requirement) are often specified for streams, rivers, and reservoirs to maintain and protect ecological habitats during low flow conditions.

There are two components that make up the flow in the Wainui Stream, downstream of the dam, as illustrated in **Figure 7**. These are:

- Flow through the fish passage around the dam structure, which joins into the Wainui Stream a short distance downstream of the dam; and
- Flows through the outlet weir/dam structure.

The residual flow requirements for these two components are discussed below.

The residual flow from the lakes downstream to the Wainui Stream is not actively controlled and is a function of lake level and flow through the low level fish passage. TIL's current Taharoa Mine Water Management Plan[5] states that it was agreed with Environment Waikato that TIL will implement temporary pumping of water into the fish pass when water levels drop to a level where fish are at risk of being stranded in the pass. The Water Management Plan states the pumping system requires a flow rate of between 24 to 34 L/s to be maintained. Therefore, currently a minimum flow of at least 24 L/s must be maintained from the lake, to the Wainui Stream downstream of the dam, through the fish pass.

Flows through the outlet weir are controlled based on the water level directly behind the dam structure. Historically, there does not appear to have been a residual flow requirement for flows through the outlet weir. Through discussions with TIL's project ecologist, it was agreed that a minimum flow requirement could be set at the minimum flow from available monitoring records, on the basis that habitat downstream had remained when this level (and consequent downstream flow rate) had occurred, provided flows were not reduced to this level for extended periods of time.

As seen in **Figure 6** the lowest water level measured behind the dam structure was 9.45 m RL in early 2014. This is equivalent to 0.09 m head above the invert of the two v-notches in the weir structure (**Figure 12**). Applying a standard weir flow calculation, the flow through the outlet weir at this level would have been 10 L/s.

It is acknowledged this condition has previously only occurred temporarily, and as such it is not intended that flow be maintained at this level for extended periods of time. TIL proposes a condition that requires it to engage a suitably qualified and experienced ecologist to monitor and report in-stream ecological values if the minimum flow is maintained at that level for more than 14 consecutive days.

The proposed lake trigger level which requires TIL to reduce its water takes from the lake as far as practicable when lake levels drop below 9.6 m RL, will also provide protection against extended periods of minimum flow.

6.2 Flooding / High Lake Levels

The lake water balance assessment detailed in **Sections 4** and **5** of this report primarily considered low and moderate/normal lake levels. However, as shown by Scenario 5, the presence of the dam has increased average lake levels by approximately 2.5 m so the remaining consideration is high/flood lake levels. The resulting associated potential effect of this is inundation of land surrounding the lake margins.

[5] Taharoa Ironsands Ltd, 2019. TIL – Water Management Plan. Appendix E Taharoa Compliance Management Plan. Revision 3. October 2019.

As seen in **Figure 5**, the highest daily average lake level that has occurred in the last eleven years was 10.9 m RL, which is approximately 1 m higher than the median lake level. This occurred on 13 February 2022 – and was the result of ex-Tropical Cyclone Dovi[6].

It is understood based on a review of road elevations that the primary area of concern regarding flooding during high lake levels is the section of Taharoa Road, approximately 500 metres south-west of Taharoa community. This section of road is located along a topographic low (~10.5 m RL) and is close to current normal lake water levels, as illustrated in **Figure 18**.

Given the low elevation of the road relative to the natural land upgradient of the lake (i.e., northward, and the left-hand side on **Figure 18**) this section would be prone to flooding during high catchment flows even if the dam was not present.

Figure 18. Taharoa Road – Screenshot from Google Streetview January 2010.

As noted in **Section 4.3.5**, the box weir outlet behind the dam is the primary outlet to the downstream reach of the Wainui Stream. The box weir is a 'passive' structure, and cannot be actively operated or modified to increase (or decrease) outflow rates for a given water level. As such, it is not possible for TIL to "control" or affect high lake water levels based on the current weir design.

Beyond the practical considerations to setting an upper lake level condition (which would require physical modifications to the outlet weir), high water levels are uncommon and of short duration when they do occur. Hence in our view, it is not necessary to introduce a maximum lake level condition.

[6] https://niwa.co.nz/sites/default/files/Climate_Summary_February_2022_FINAL.pdf

7. Recommendations

This section details our recommendations in order to protect and maintain the hydrological functioning of the Taharoa Lakes and downstream receiving environment.

7.1 Lake and Dam Trigger Levels

As detailed in **Section 3.4**, water levels immediately behind the dam are typically lower than those measured in the main body of the lake. Consequently, consent trigger levels should be set with respect to a specified location, depending on their objective. Recommended dam and lake trigger levels are detailed in **Table 11**.

Table 11. Recommended trigger water levels.

No.	Level (m RL)	Location	Objective / Purpose
1	8.53	Lake	Minimum allowable lake level. No abstractions shall occur below this level. As noted in Section 2.3.1, it is believed this is equal to the minimum lake level prior to construction of the dam.
2	9.6	Lake	Minimum lake level over the last 10-years. TIL shall: • Implement management responses to reduce their water takes from the lake as far as practicable. • Engage a suitably qualified and experienced ecologist to monitor and report on the extent and health of the raupo and flax wetland on the margins of Lake Taharoa. This trigger provides an alert that lake levels are dropping below what has occurred over recent times (the last 10-years), and as such signals a requirement to monitoring ecological health.
3	9.36	Dam	Invert level of the v-notch. Natural flows through the outlet weir will cease if water levels behind the dam drop below this level. As such, TIL shall implement temporary manual pumping into the box weir at a rate of not less than 10 L/s in order to maintain the residual flow immediately downstream of the dam.
4	9.3	Dam	Invert level of the fish pass. Natural flows through the outlet weir will cease if water levels behind the dam drop below this level. TIL shall implement temporary manual pumping of water into the fish pass at a rate of at least 24 L/s.

7.2 Residual Flow in the Wainui Stream

As detailed in **Section 6.1**, the minimum historical flow (based on available dam water level measurement data) would have been 10 L/s. It was agreed with TIL's project freshwater ecologist that the residual flow requirement could be set at this rate on the basis that habitat downstream had remained, despite this level previously occurring. Hence a minimum flow requirement of 10 L/s immediately downstream of the dam structure is recommended.

8. Conclusion

Taharoa Ironsands Limited (TIL) operates an ironsand mine at Taharoa on the west coast of the North Island, south of Kawhia Harbour. TIL is seeking new resource consents to continue the existing ironsand mining operation within the Central and Southern blocks of the mine. As part of the mining process, TIL abstracts water from the lake formed behind the dam structure on the Wainui Stream. This water is used for both general processing activities and ship loadings.

Annual ship loading events at the port are currently undertaken approximately 18 times per year and will increase to around 35 per year as future production increases. This will likely require an increase in the regularity and volume of water to be abstracted from Lake Taharoa. However, any such increases will remain within TIL's currently consented water take limits which are proposed to continue to apply to the new consents.

A lake water balance model of Lake Taharoa was developed to provide insight into the hydrological functioning of the lake, the proportional contribution of inputs (i.e., rainfall and catchment inflows) and losses (evaporation, abstractions, and discharges through the outlet), and potential impacts of increasing TIL's abstraction frequency on lake water levels. The lake water balance model was calibrated to historic measured lake water levels.

Four scenarios were assessed with the model, including one scenario that aligns with the concept of the "existing environment" and therefore assuming there were no water abstractions and no dam, and one extreme scenario where the maximum processing water was taken 365 days of the year. Results of the scenarios showed:

- Water levels in Lake Taharoa are approximately 2.5 m higher as a result of the construction of the dam structure.
- Lake levels have remained relatively stable between ~9.6 m RL and ~10.4 m RL over the last 10-years (the period of available monitoring data).
- Lake level fluctuations are seasonal, with lower levels typically occurring in late summer, and higher levels throughout winter.
- While TIL's water takes can result in lower lake levels, the reduction in lake levels is transitory/temporary only. Lake levels recover as catchment inflows to the lake increase during winter and wetter periods.
- Four water lever trigger values and corresponding actions are recommended to maintain and protect the hydrological functioning of the Taharoa Lakes and downstream receiving environment.

On the basis these recommendations are implemented, the potential hydrological effects of TIL's water takes on Lake Taharoa and the Wainui Stream are considered less than minor. The change in the hydrologic regime created by the dam can be managed by conditions to an appropriate level.

Appendix A. Soil Moisture Water Balance Model

The Soil Moisture Water Balance Model (SMWBM) is a semi-deterministic rainfall runoff model. Model functionality incorporates a surface ponding function and evaporation functions for differing land cover.

The model can operate using either daily or hourly rainfall and daily evaporation input data to calculate the soil moisture conditions under natural rainfall conditions. The model operates on a daily time step during dry days, however when rain days occur, a finer hourly calculation step is implemented to enable peak flows to be assessed more accurately than a daily time step model.

The SMWBM version utilised in this project incorporates parameters characterising the catchment in relation to:

- Interception storage;
- Evaporation losses;
- Soil moisture storage;
- Surface runoff;
- Soil infiltration;
- Sub-soil drainage;
- Flow in the unsaturated zone;
- Stream base flows; and
- The recession and/or attenuation of ground and surface water flow components.

Table 12. SMWBM parameter description.

Parameter	Name	Description
ST (mm)	Maximum soil water content	ST defines the size of the soil moisture store in terms of a depth of water
SL (mm)	Soil moisture content where drainage ceases.	Soil moisture storage capacity below which sub-soil drainage ceases due to soil moisture retention.
FT (mm/day)	Sub-soil drainage rate from soil moisture storage at full capacity	Together with POW, FT (mm/day) controls the rate of percolation to the underlying aquifer system from the soil moisture storage zone. FT is the maximum rate of percolation through the soil zone.
ZMAX (mm/hr)	Maximum infiltration rate	ZMAX and ZMIN are nominal maximum and minimum infiltration rates in mm/hr used by the model to calculate the actual infiltration rate ZACT. ZMAX and ZMIN regulate the volume of water entering soil moisture storage and the resulting surface runoff. ZACT may be greater than ZMAX at the start of a rainfall event. ZACT is usually nearest to ZMAX when soil moisture is nearing maximum capacity.
ZMIN (mm/hr)	Minimum infiltration rate	
POW (>0)	Power of the soil moisture-percolation equation	POW determines the rate at which sub-soil drainage diminishes as the soil moisture content is decreased. POW therefore has significant effect on the seasonal distribution and reliability of drainage and hence baseflow, as well as the total yield from a catchment.
PI (mm)	Interception storage capacity	PI defines the storage capacity of rainfall that that is intercepted by the overhead canopy or vegetation and does not reach the soil zone.
AI (-)	Impervious portion of catchment	AI represents the proportion of the catchment that is impervious and directly linked to drainage pathways.

Parameter	Name	Description
R (0,1)	Evaporation – soil moisture relationship	Together with the soil moisture storage parameters ST and SL, R governs the evaporative process within the model. Two different relationships are available. The rate of evapotranspiration is estimated using either a linear (0) or power-curve (1) relationship relating evaporation to the soil moisture status of the soil. As the soil moisture capacity approaches, full, evaporation occurs at a near maximum rate based on the mean monthly pan evaporation rate, and as the soil moisture capacity decreases, evaporation decreases according to the predefined function.
DIV (-)	Fraction of excess rainfall allocated directly to pond storage	DIV has values between 0 and 1 and defines the proportion of excess rainfall ponded at the surface due to saturation of the soil zone or rainfall exceeding the soils infiltration capacity to eventually infiltrate the soil, with the remainder (and typically majority) as direct runoff.
TL (days)	Routing coefficient for surface runoff	TL defines the lag of surface water runoff.
GL (days)	Groundwater recession parameter	GL governs the lag in groundwater discharge or baseflow from a catchment.
QOBS (m^3/s)	Initial observed streamflow	QOBS defines the initial volume of water in the stream at the model start period and is used to precondition the soil moisture status.
AA, BB	Coefficients for rainfall disaggregation.	Used to determine the rainfall event duration and pattern when daily rainfall is used. These parameters are turned off when hourly rainfall data are used.

A conceptual diagram of the key components of SMWBM model structure and functionality is shown in **Figure 19**.

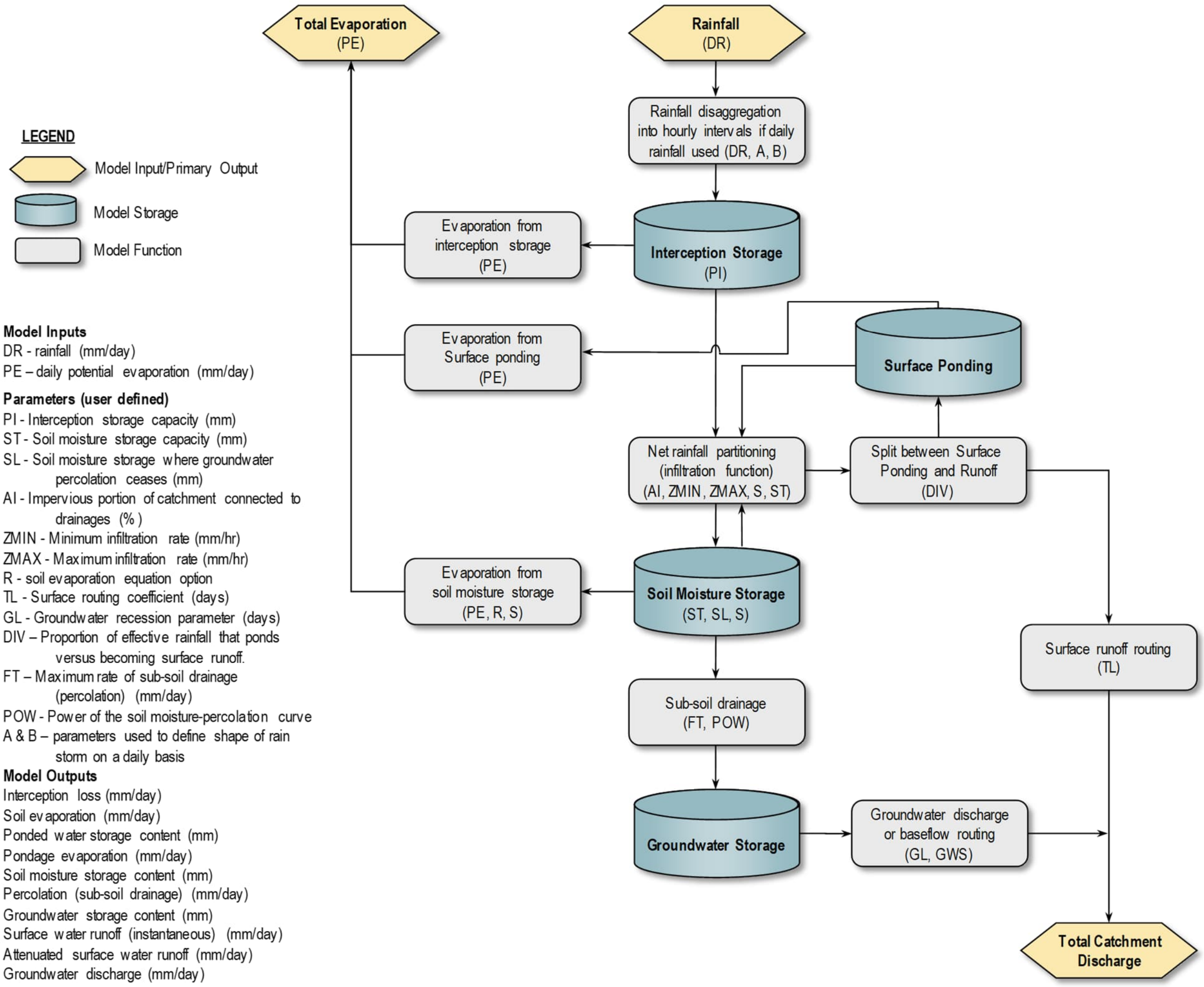
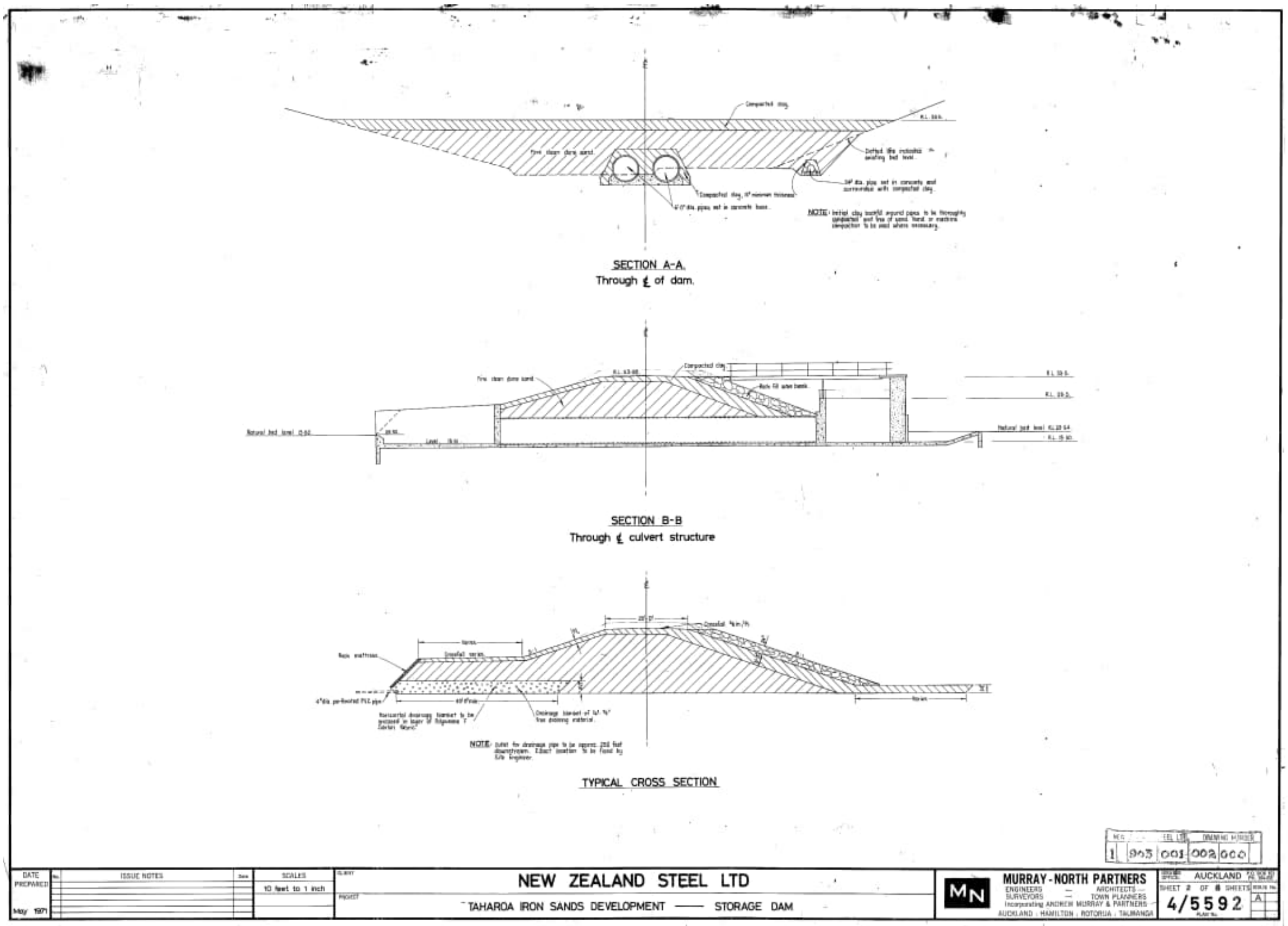
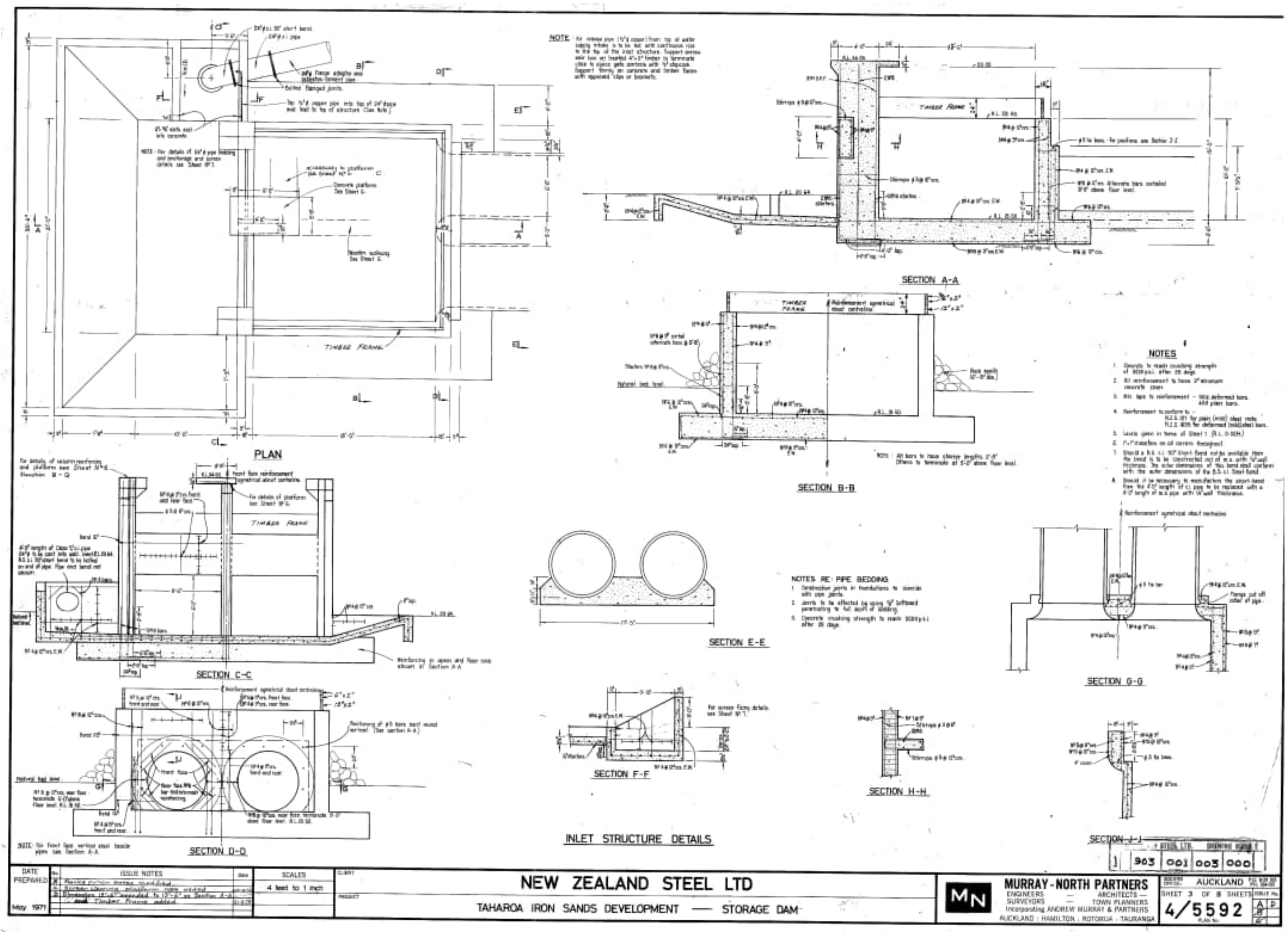


Figure 19. Flow diagram of the SMWBM structure and parameters.


SECTION A-A.
Through ℄ of dam.
SECTION B-B
Through ℄ culvert structure
TYPICAL CROSS SECTION
NEW ZEALAND STEEL LTD
TAHAROA IRON SANDS DEVELOPMENT —— STORAGE DAM
MURRAY-NORTH PARTNERS
10 feet to 1 inch
May 1971
4/5592


PLAN
SECTION A-A
SECTION B-B
SECTION C-C
SECTION D-D
SECTION E-E
SECTION F-F
SECTION G-G
SECTION H-H
NOTES
NOTES RE: PIPE BEDDING
INLET STRUCTURE DETAILS
NEW ZEALAND STEEL LTD
TAHAROA IRON SANDS DEVELOPMENT — STORAGE DAM
MURRAY-NORTH PARTNERS
AUCKLAND
4 feet to 1 inch
4/5592