Appendix C. Hydrology Assessment Report

Consenting for Aratapu Water Storage Reservoir

Hydrology Assessment

TE TAI TOKERAU WATER TRUST

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01 September 2020

Aratapu Water Storage Reservoir Hydrology Study

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Contents

1. Introduction

Williamson Water & Land Advisory (WWLA) supported by a wider consortium of experts was commissioned by the Te Tai Tokerau Water Trust in July 2020 to prepare technical reports and documentation required for resource consent for a proposed 4 Mm^3 water storage reservoir in the upper catchment of a tributary to the Aratapu Creek. The reservoir is known as the Aratapu Water Storage Reservoir (AWSR).

1.1 Background

AWSR (previously referred to as K-13) was identified as a potential water storage reservoir site through the Northland Water Storage and Use Project (NWSUP) Pre-Feasibility Demand Assessment and Design Study, undertaken by WWLA and other technical experts for Northland Regional Council (NRC) in August 2019 (WWLA, 2020 a, b, c). In June 2020, the project was transferred to the Te Tai Tokerau Water Trust, who commissioned advancement of the AWSR scheme with detailed design and consenting programmes instigated.

The wider scope of works, undertaken to support consenting of the reservoir, includes the following by the indicated specialists:

- Ecological Assessment (Puhoi Stour);
- Archaeological Assessment (Geometria);
- Landscape Assessment (Simon Cocker Landscape Architecture);
- Hydrological Assessment (WWLA);
- Geotechnical Assessment and Reservoir Conceptual Design (Riley Consultants); and
- Preparation of consent documentation (WWLA).

This technical report presents the hydrological analysis, and details the assessment of environmental impacts and effects on downstream water users.

1.2 Report Structure

The report comprises descriptions of:

- A project overview (**Section 2**);
- A review of surface water allocation policy (**Section 3**);
- Catchment modelling overview (**Section 4**);
- Analysis of existing hydrological regimes and allocation (**Section 5**);
- Proposed storage reservoir and water takes (**Section 6**);
- Assessment of Environmental Effects (**Section 7**);
- Analysis of impacts on downstream water users (**Section 8**); and
- Summary and conclusions (**Section 9**).

2. Project Overview

2.1 Location

A location overview of the proposed 4 Mm^3 AWSR reservoir is displayed in **Figure 1**. The reservoir is positioned on an unnamed tributary in the upper catchment of the Aratapu Creek, and will be used to service and support local horticultural operations.

Full details of the conceptual design of the reservoir itself are presented in RILEY (2020) *Preliminary Geotechnical Concept Assessment Dam and Water Storage Reservoir.*

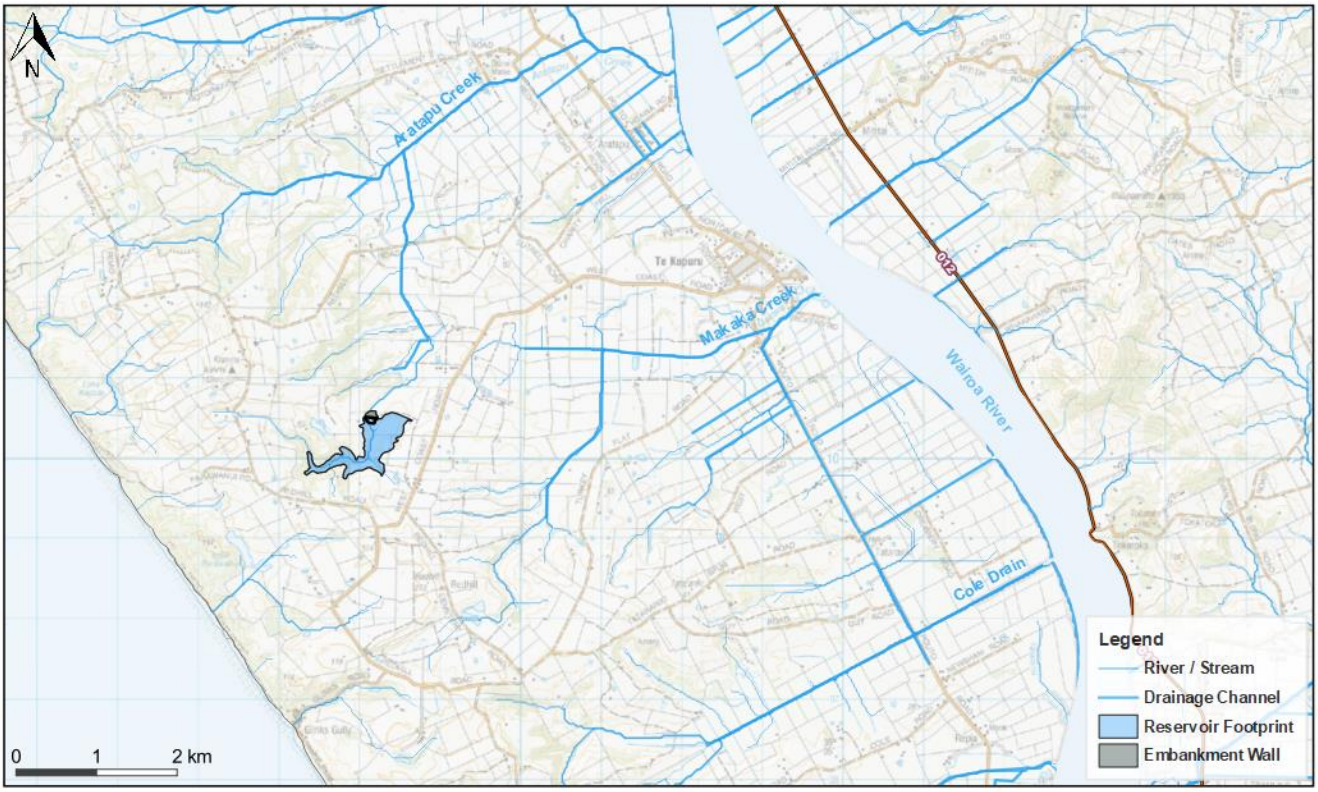

Figure 1. Project location overview map.

2.2 Water Resources

The reservoir will be filled through a combination of direct catchment inflows, three pumped takes, including high flow takes from Makaka Creek and Cole Drain, and a pumped core allocation (low-flow) take from the Kaihu River. The lower reaches of the Aratapu Creek are also a potential option if required. We are currently undertaking flow monitoring at these sites, as shown on **Figure 2**.

Figure 2. Proposed reservoir filling take locations. (Refer A3 attachment at rear).

For direct catchment inflows, it is currently proposed to harvest high-flows above the median, up to two times the standard deviation of flow at all times they are available (and the reservoir is not full), and low-flow core allocation outside of the irrigation season (i.e. winter months) only.

Details of the proposed takes are summarised in **Table 1**.

It should be noted, these are the currently proposed takes (including the damming and diversion of water by the reservoir embankment, which is referred to as a take), and may be revised in the future. However, given there are very few alternative water sources to fill AWSR, any changes would likely only be to the take rates currently proposed. It is also important to note that these water takes, and the taking and use of water from the proposed reservoir will be the subject of a separate resource consent application.

Table 1. Proposed water takes.

Take location and type	Rate (L/s) (Daily Mean)	Minimum flow criteria (L/s)	Note
Direct inflow – high-flow take	0 - 156	32	Gravity inflow from median to median plus 2x Std. Dev.
Direct inflow – low-flow take	1.9	3.8	Gravity inflow during winter only
Makaka Creek – high-flow take	250	69	Pumped take above the medium flow.
Cole Drain – high-flow take	200	67	Pumped take above the median flow.
Kaihu River – low-flow take	50	1,200	-

2.3 Water Use Requirements

The storage reservoir is proposed to service local community irrigation demands. Based on work undertaken as part of the NWSUP Pre-feasibility Design and Demand Study, the reservoir is expected to support up to approximately 1,070 hectares of horticultural development (WWLA, 2020d. in prep). However, the total area, and location of land serviced will ultimately depend on community uptake.

This hydrology assessment has been undertaken on the assumption of a maximum daily demand of 46,730 m^3/day during the irrigation season.

3. Regulatory Framework

This section provides an overview of key policies regarding surface water allocation and takes from the Proposed Regional Plan Northland (PRPN).

3.1 Allocation Limits

Allocation limits for streams are set to protect the health of aquatic ecosystems by capping the amount of water that can be taken from a water body above a minimum flow or level for lakes. This enables natural fluctuations in stream flow to occur, while providing somewhat for security of supply. An allocation limit along with a minimum flow criterion is defined, with restrictions applying when stream flow reduces below the minimum flow rate.

3.1.1 Core Allocation / Low-flow

NRC grouped networks of streams into freshwater management units based on common values of the water bodies and the sensitivity of the values to change in flow as follows:

- Large River;
- Small River;
- Coastal River; and
- Outstanding Value River.

All rivers and streams of interest to this study are classified as small rivers, which implies minimum flow of 80% MALF and an allocation limit of 40% of MALF are relevant (**Table 2**).

Policy H.4.3 of the Proposed Regional Plan for Northland states, the quantity of river flow available for abstraction below the median must not exceed the criteria outlined in **Table 2**, provided a minimum river flow is maintained (**Policy H.4.1**).

Table 2. Minimum flow criteria and allocation limits for Northland's rivers.

Management Unit	Minimum Flow (% of 7-day MALF)	Allocation Limit (% of 7-day MALF)
Outstanding rivers	100%	10%
Coastal rivers	90%	30%
Small rivers	80%	40%
Large river	80%	50%

3.1.2 High Flow

When river flow is above the median flow, **Policy C.5.1.10** states that the taking and use of water for a river that is not a permitted or controlled activity, is a restricted discretionary activity. Matters of discretion include:

1. The timing, rate and volume of the take to avoid or mitigate effects on existing authorised takes and aquatic ecosystem health.
2. Measures to ensure the reasonable and efficient use of water.
3. The positive effects of the activity.

4. Catchment Modelling

The following section details the catchment modelling undertaken to characterise the existing hydrological regime of the rivers and streams of interest.

The catchment model detailed in the sections below was based on the Kaipara Study Area model developed as part of the NWSUP: Pre-Feasibility assessment. Full details on the development of the original catchment model are provided WWLA (2020) NWSUP – Volume 2: Water Resources Analysis.

4.1 Available Data

The following sections summarise the available data used during the development of the catchment flow model relevant to the AWSR reservoir hydrology study.

4.1.1 Climate Data

The nearest rain gauge to AWSR from NRC's rain gauge network is the Wairoa at Turiwiri gauge, located approximately 10 kilometres to the north-north east. However, the rainfall record for this site only covers the period 1992-1997. The nearest ongoing rain gauge is Okoraka at Ngatawhiti Road (24 kilometres south-west), and covers the period 2015 to present. Therefore, in order to provide a consistent representation (both historically, and into the future), of local climate, rainfall and evaporation data were obtained from the National Institute of Water and Atmospheric Research (NIWA) virtual climate station network (VCSN).

The VCSN data provides estimates of daily rainfall and potential evapotranspiration on a 5 km regular grid, covering all of New Zealand. Estimates of climate parameters are produced for each VCSN point on a daily time-step based on spatial and temporal interpolation of recorded observation data at the nearest reliable meteorological sites.

Given the relatively small spatial scale of interest, a single VCSN point (Station ID: 30152), located approximately two kilometres northeast of AWSR, was used for the hydrology assessment. Average monthly rainfall and evaporation for this location are displayed in **Figure 3**.

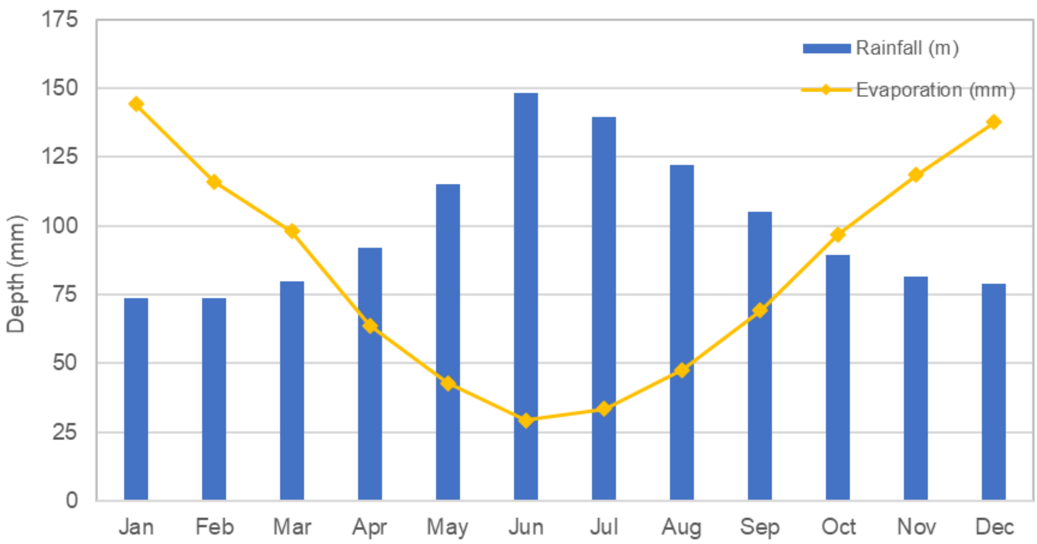

Figure 3. Average monthly rainfall and evaporation.

4.1.2 Flow Data

Observed flow data from NRC were available for two locations downstream of AWSR, which are summarised in **Table 3** and displayed in **Figure 4**. These two monitoring sites were used to provide a degree of verification to the accuracy of simulated flows from the catchment flow model (**Section 4.3**).

Table 3. Summary of available flow monitoring data

Dataset	Location Relative to AWSR	Description	Source
Aratapu Creek Tributary at Guy Ropes	Approx. 4 km to the north / downstream.	Three spot gaugings between 1995 and 2004	NRC
Aratapu Creek Tributary at Plaisted	Approx. 3 km to the north / downstream.	One spot gauging in 2003	NRC

Figure 4. Location of available gauged flow data. (Refer A3 attachment at rear).

4.1.3 Consented Water Takes

Consented water take data were provided by NRC, and takes in the local area surrounding AWSR are summarised in **Table 4**, and displayed in **Figure 5**. Of the surrounding takes, only AUT.007743.01.04 (highlighted in red) is located in the catchment downstream of AWSR. All other takes occur in neighbouring catchments.

Table 4. Consented water takes downstream of AWSR.

IRIS ID	Source	Purpose	Annual Take (m^3)
AUT.007792.01.02	Dam	Irrigation - Horticulture	8,766
AUT.009413.01.02	Ground water	Stock - Dairy	34,675
AUT.008188.01.02	Dam	Irrigation - Horticulture	30,000
AUT.007772.01.03	Surface water	Irrigation - Pasture	340,000
AUT.007442.01.04	Surface water	Irrigation - Pasture	300,000
AUT.007944.01.03	Surface water	Drinking - Public Water Supply	36,525
AUT.007743.01.04	Surface water	Irrigation - Pasture	69,000
AUT.039301.01.02	Surface water	Irrigation - Vegetables/Market Garden	55,782
AUT.007944.02.03	Ground water	Drinking - Public Water Supply	36,525

Figure 5. Consented water takes downstream, or in close proximity to AWSR. (Refer A3 attachment at rear).

4.2 Soil Moisture Water Balance Model

In order to quantify the volume of water available for harvesting and storage, catchment models were developed for the Aratapu Creek and its tributaries using the Soil Moisture Water Balance Model (SMWBM).

4.2.1 Overview

The Soil Moisture Water Balance Model was utilised as the rainfall runoff model for this project. The SMWBM is a semi-deterministic model that is parameterised via relationships to catchment physical characteristics. Model functionality incorporates daily rainfall disaggregation and computation on an hourly timestep during rain events, interception storage, surface runoff, surface ponding, soil infiltration, soil moisture storage, sub-soil drainage, vadose zone flow and groundwater discharges for differing land physical characteristics and use types. The model also contains an irrigation demand module. The vadose zone and irrigation demand modules were not used in this assessment.

The SMWBM incorporates parameters characterising the catchment in relation to the following characteristics, with a conceptual diagram of the SMWBM structure and functionality described in more detail in **Appendix A**.

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

4.3 Model Verification

The catchment models developed for NWSUP – Volume 2: Water Resources Assessment were utilised for this assessment. Full details of the catchment model development and initial calibration are provided in the NWSUP – Volume 2: Water Resources report (WWLA, 2020b).

The subsections below detail the model calibration to available spot gauge data within the catchment of the AWSR. It should be noted, flow monitoring is currently being undertaken at the location of the reservoir wall and proposed high-flow take site downstream. The catchment models will be further verified against this data prior to submission of the water take consents associated with the reservoir.

4.3.1 Aratapu Creek Tributary at Guy Ropes

A comparison of modelled and observed flow at the Aratapu Creek Tributary at Guy Ropes monitoring site is presented in **Figure 6**. In general, there is good agreement to the three low-flow spot gauging’s. However, the limited number of data points and absence of high flow measurements prevents firm conclusions on model calibration at this location.

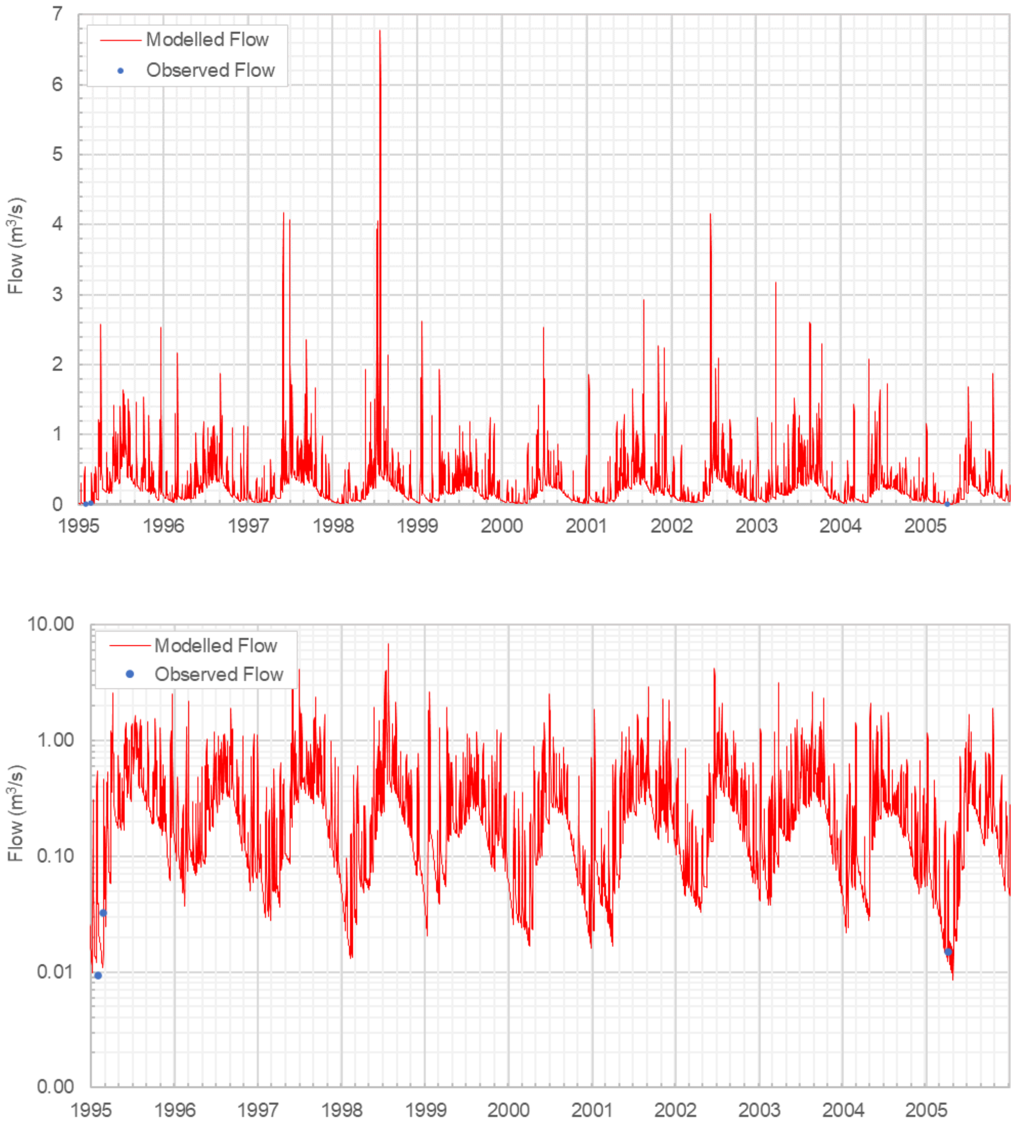

Figure 6. Comparison of modelled and observed flow at Aratapu Creek Trib at Guy Ropes (top = linear y-axis, bottom = log y-axis).

4.3.2 Aratapu Creek Tributary at Plaisted

A comparison of modelled and observed flow at the Aratapu Creek Tributary at Plaisted monitoring site is presented in **Figure 7**. There is good agreement to the single low-flow gauging. However, similar to above, no firm conclusions on model calibration can be drawn due to the paucity of available flow data at this location.

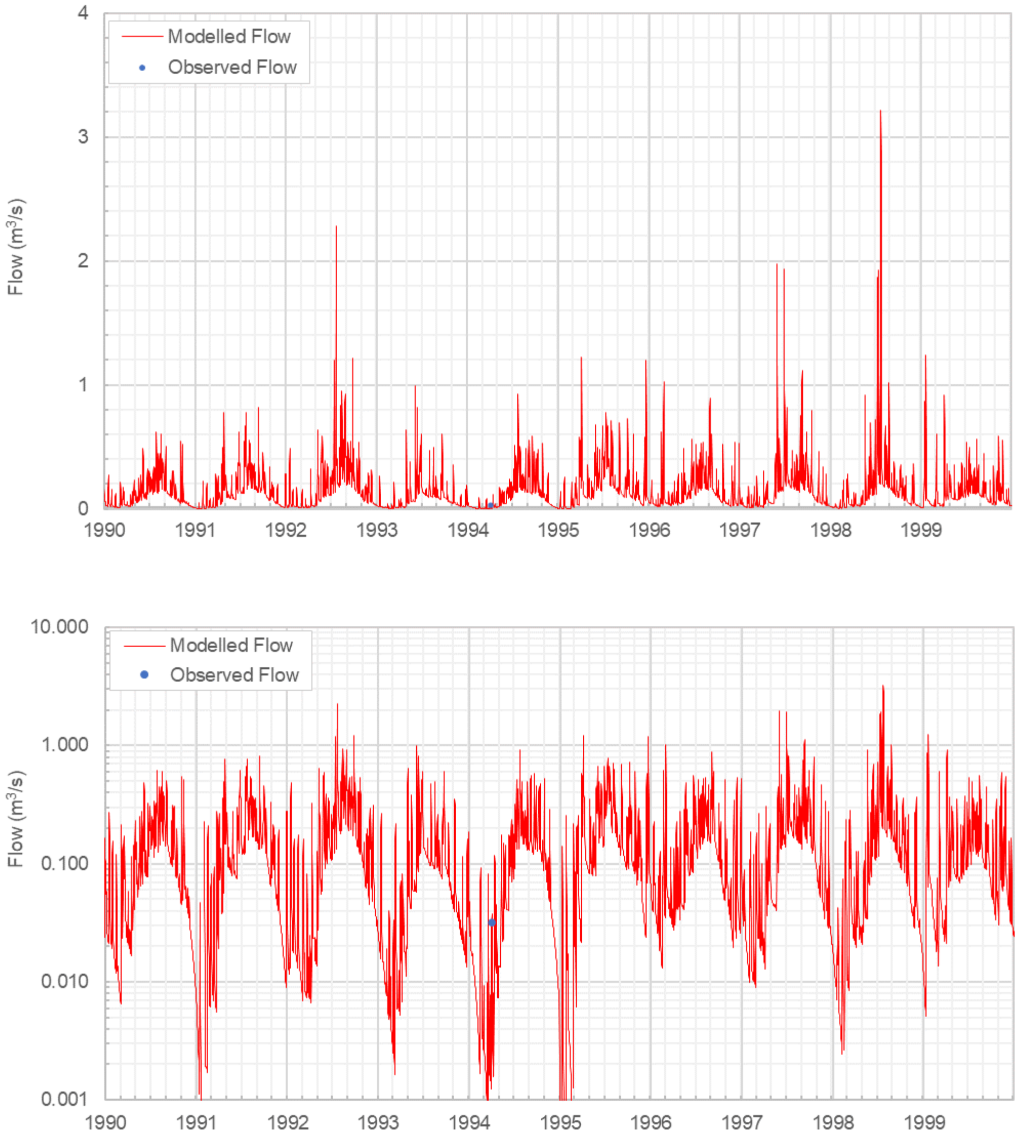

Figure 7. Comparison of modelled and observed flow at Aratapu Creek Tributary at Plaisted (top = linear y-axis, bottom = log y-axis).

4.3.3 Overall Statement on Model Verification

The catchment flow model is considered to have demonstrated good agreement to the limited available spot gauge data at two locations downstream of AWSR. In addition, as the SMWBM simulates a closed water balance system, and there is good confidence in the rainfall input data (as described previously in WWLA, 2020b), additional confidence in the overall volume of water simulated (groundwater + surface water) is held by the modelling team.

Overall, the model is considered to provide appropriate representation of daily streamflow dynamics for the purpose of this consent application. Flow monitoring data currently being collected will be used to further verify the catchment models prior to submitting the water take consent application associated with the reservoir.

5. Existing Hydrological Regimes

The catchment model described in **Section 4** were used to simulate streamflow from 1972 to present at three representative reference locations in order to characterise the existing flow regimes of the Aratapu Creek and unnamed tributaries.

A similar analysis is presented and compared in **Section 7.1** on flows simulated representing post construction of the reservoir.

The analysis includes the following components for each assessment location:

- **Flow hydrographs and flow duration curves:** used to visually demonstrate change, along with standard statistics such as the 7-day mean annual low-flow (7-day MALF), and FRE3 (annual average number of flow events exceeding 3x the median flow).
- **The 7-Day MALF statistic:** is important as it forms the basis of low-flow allocation regulations under the PRPN, with the minimum flow criteria and allocable flow being defined as a proportion on the 7-Day MALF.
- **The FRE3 statistics:** is the number of floods per period of interest (year or season) greater than three times the relevant median flow. FRE3 provides an index of flow variability that is ecologically relevant i.e. the frequency of eco-system disturbance that is needed for a balanced ecosystem composition (periphyton, macro-invertebrates and other biota to co-habitat). Larger values of FRE3 are more desirable than smaller values.

5.1 Flow Assessment Locations

Three representative flow assessment locations were selected to compare the existing streamflow regime (this section) and post reservoir construction (**Section 7.1**). The locations were selected to demonstrate the impacts of harvesting direct catchment inflows during high-flow periods (i.e. above median), and harvesting of the core-allocation take during winter. These locations are displayed in **Figure 8**, and are described as follows:

- **Downstream AWSR Embankment:** This assessment site represents the location immediately downstream of the AWSR embankment wall and therefore represents the location of maximum impact;
- **Redhill Road:** This assessment site is approximately 2.5 kilometres downstream of AWSR, and includes the addition of three small tributaries which enter downstream of AWSR; and
- **Downstream Aratapu Confluence:** This assessment site is located immediately downstream of the confluence with Aratapu Creek, approximately 3.6 km downstream of AWSR.

Figure 8. Representative assessment locations and their upstream catchments. (Refer A3 attachment at rear).

The existing flow regimes of these assessment locations are summarised in the sections below.

5.1.1 Downstream AWSR Embankment

The hydrograph and flow duration curves for the Downstream AWSR Embankment assessment location are presented in **Figure 9** and **Figure 10**, and summary statistics presented in **Table 5**.

Simulated historic streamflow at this location ranges from approximately 0.5 L/s to a maximum of 1,150 L/s, with a median of 31.8 L/s.

High flow events occur in response to rainfall events, while stream baseflow exhibits a seasonal pattern, with higher baseflow occurring during winter, and low-flows during summer.

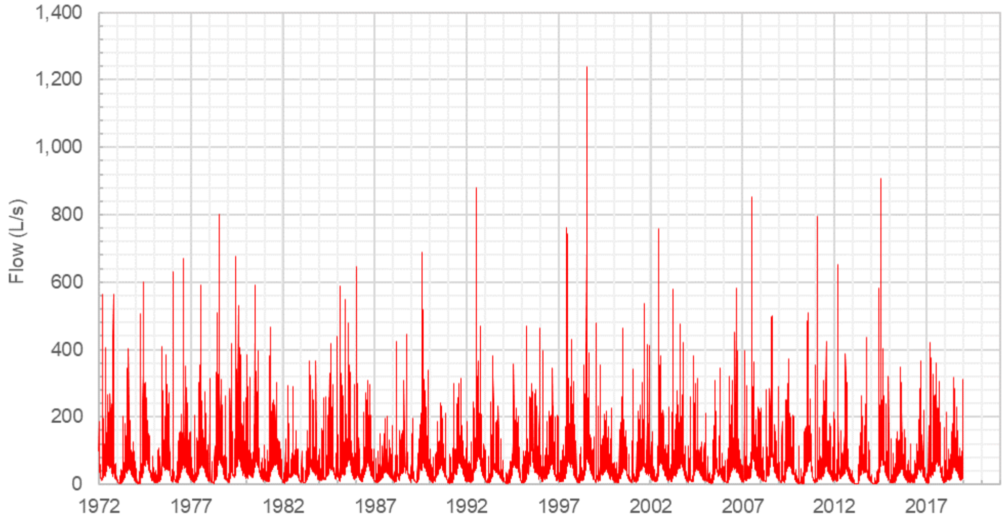

Figure 9. Simulated flow hydrograph for Downstream AWSR Embankment assessment location.

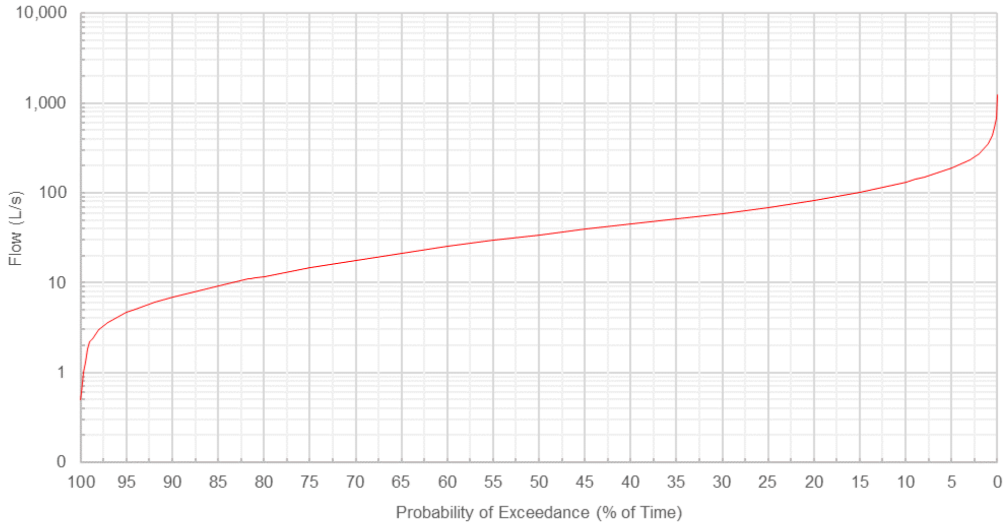

Figure 10. Simulated flow duration curve for Downstream AWSR Embankment assessment location.

Table 5. Flow statistics for Downstream AWSR Embankment assessment location.

Statistic	Value
Minimum (L/s)	0.5
Median (L/s)	31.8
Maximum (L/s)	1,149
7-Day MALF (L/s)	4.6
FRE3 (count)	18.2

5.1.2 Redhill Road

The hydrograph and flow duration curves for the Redhill Road assessment location are presented in **Figure 11** and **Figure 12**, and summary statistics presented in **Table 11**.

Simulated historic streamflow at this location ranges from approximately 1.1 L/s to a maximum of 2,755 L/s, with a median of 76.2 L/s. As demonstrated in the assessment location above, high flow events occur in response to rainfall events, while stream baseflow exhibits a seasonal pattern, with higher baseflow occurring during winter, and low-flows during summer.

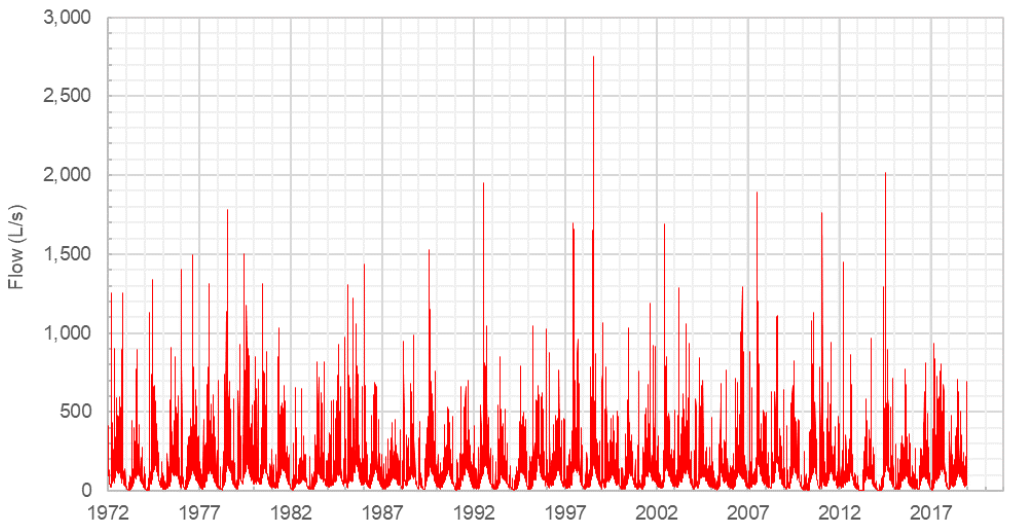

Figure 11. Simulated flow hydrograph for Redhill Road assessment location.

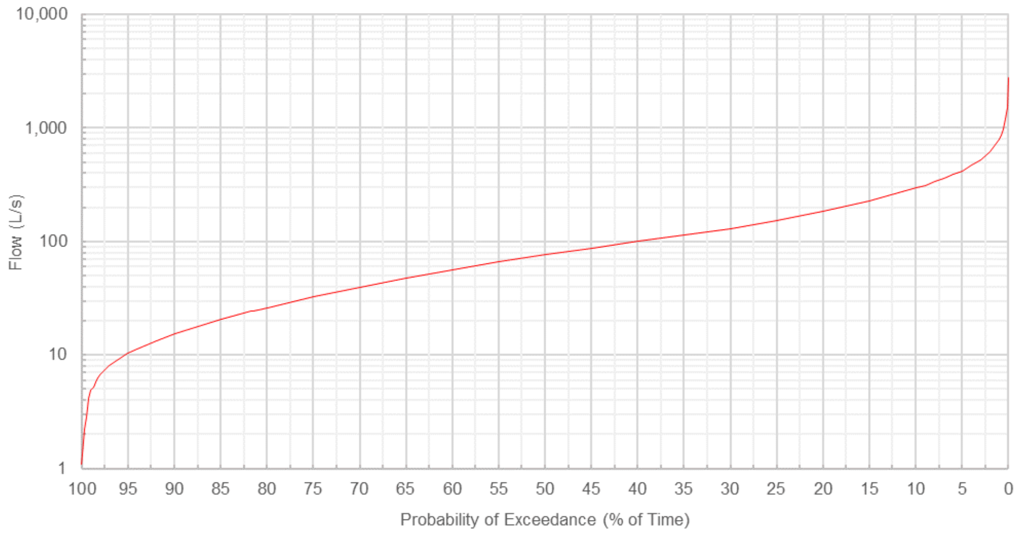

Figure 12. Simulated flow duration curve for Redhill Road assessment location.

Table 6. Flow statistics for Redhill Road assessment location.

Statistic	Value
Minimum (L/s)	1.1
Median (L/s)	76.2
Maximum (L/s)	2,755
7-Day MALF (L/s)	11.0
FRE3 (count)	18.2

5.1.3 Downstream Aratapu Confluence

The hydrograph and flow duration curves for the Aratapu Confluence assessment location are presented in **Figure 13** and **Figure 14**, and summary statistics presented in **Table 7**.

Simulated historic streamflow at this location ranges from approximately 2.3 L/s to a maximum of 7,995 L/s, with a median of 159.3 L/s.

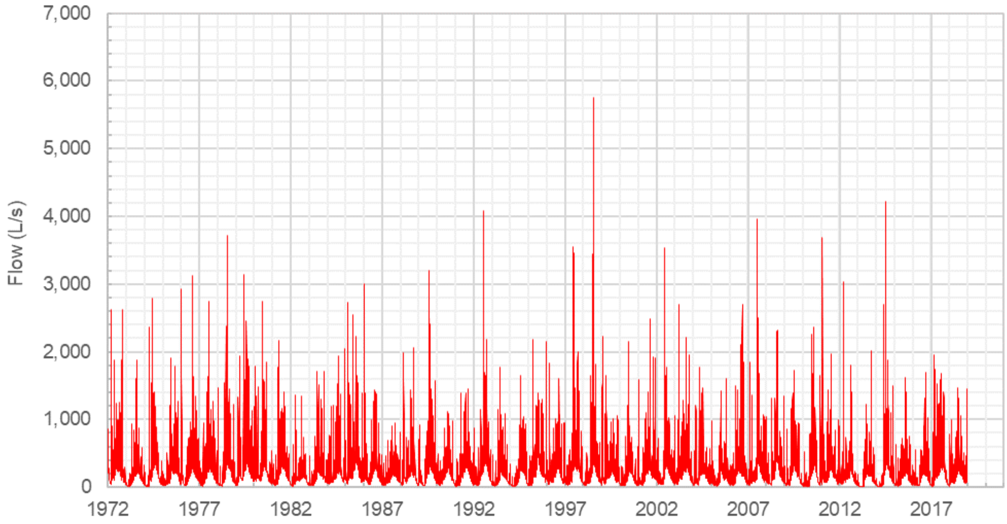

Figure 13. Simulated flow hydrograph for Downstream Aratapu Confluence assessment location.

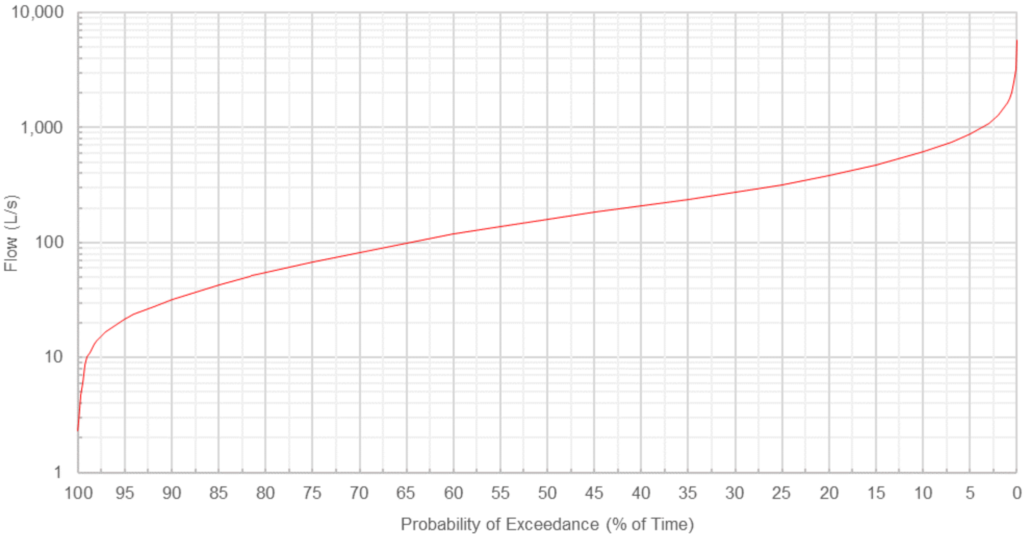

Figure 14. Simulated flow duration curve for Downstream Aratapu Confluence assessment location.

Table 7. Flow statistics for Downstream Aratapu Confluence assessment location.

Statistic	Value
Minimum (L/s)	2.3
Median (L/s)	159.3
Maximum (L/s)	7,995
7-Day MALF (L/s)	23.0
FRE3 (count)	18.2

5.2 Flow Regime Summary

A summary of daily average flow statistics along with key water take consenting metrics for each of the assessment sites are presented in **Table 8**.

Table 8. Summary of existing daily average flow regime statistics for key assessment locations.

Statistic	Downstream AWSR Embankment	Redhill Road	Downstream Aratapu Confluence
Catchment area (km^2) [ha]	3.2 [320]	7.2 [720]	15.0 [1,500]
Minimum (L/s)	0.5	1.1	2.3
Median (L/s)	34.3	76.2	159.3
Maximum (L/s)	1,240	2,755	7,995
7-Day MALF (L/s)	5.0	11.0	23.0
Minimum Flow (80% MALF)	4.0	8.9	18.4
Run of River Allocation Limit (40% MALF)	2.0	4.4	9.2
FRE3 (count)	18	18	18

6. Proposed Storage Reservoir

6.1 Reservoir Design

Full details of the conceptual design of the reservoir itself is provided in RILEY (2020) *Preliminary Geotechnical Concept Assessment Dam and Water Storage Reservoir.* The design of reservoir is shown in **Figure 15**, with key physical dimensions summarised in **Table 9**.

Figure 15. Reservoir design drawing. (Refer A3 attachment at rear).

Table 9. Reservoir characteristics.

Property	Value
Dam crest Level (m)	29 m RL
Fully supply level (m)	27 m RL
Storage at full supply level (m^3)	4,000,000
Max. water depth at full supply (m)	20
Emergency spillway width (m)	20 (at base)

6.2 Water Takes

As described in **Section 2**, the exact water take locations and rates have not yet been finalised and will be consented separately from the reservoir itself. As was shown on **Figure 2**, there are three currently proposed water takes (excluding direct catchment inflows), which are summarised in **Table 10** and are not expected to change significantly.

For the purposes of simulating “historic” reservoir operation to quantify potential downstream effects, the takes outlined in **Table 10** were configured in the reservoir storage model (**Appendix B**).

Table 10. Proposed water takes.

Take location and type	Rate (L/s)	Minimum flow criteria (L/s)	Note
Makaka Creek – high-flow take	250	69	Pumped Above Median Take
Cole Drain – high-flow take	200	67	Pumped Above Median Take
Kaihu River – core allocation / low-flow	50	1,200	-

7. Assessment of Environmental Effects

The following sections detail the assessment of hydrological environmental impacts associated with operation of the proposed AWSR water storage reservoir on downstream surface water flow regimes only. This section does not detail flow regime effects associated with proposed pumped water takes, as these are to be consented separately.

7.1 Impacts on Surface Water Flow Regimes

The impacts on surface water flow regimes were characterised by comparing simulated flow of the existing flow regime (**Section 5**) to the flow regime associated with the proposed reservoir at the three representative assessment location, which were described in **Section 5.1**.

7.1.1 Reservoir Operation

The conceptualised historic operation of the storage reservoir is presented in **Figure 16**, in regards to key inflow and outflow volumes, and changes in reservoir storage. The impact of these takes and release on the downstream flow regime at the three representative locations are then discussed in the sections below.

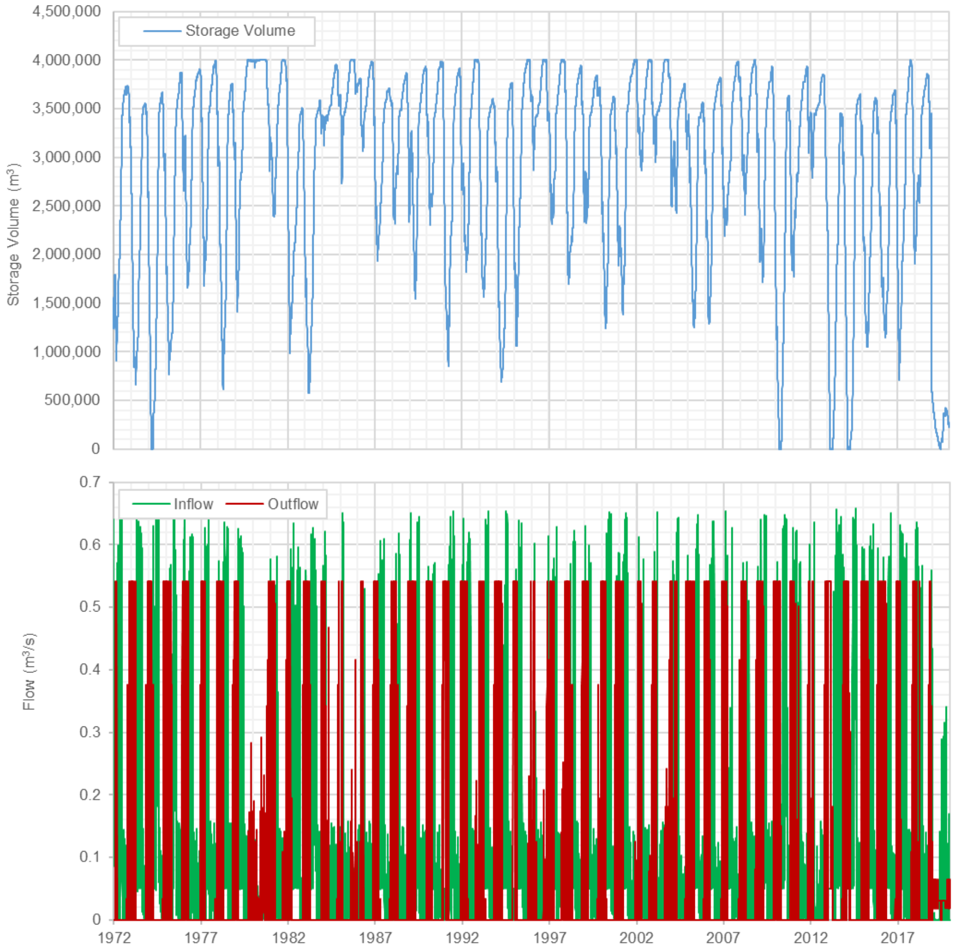

Figure 16. Reservoir operation – change in storage volume (top), and storage inflows and releases (bottom).

7.1.2 Downstream AWSR Embankment

The hydrograph and flow duration curve for the Downstream of the AWSR Embankment assessment location are presented in **Figure 17** and **Figure 18**, respectively and summary flow statistics are presented in **Table 11**. As this location is immediately downstream of the reservoir, it represents the location of largest impact due to the storage of above median direct catchment inflows.

As indicated in **Figure 17**, a proportion of above median flow is captured (harvested) by the reservoir. This has the effect of reducing high flow variability and frequency of flushing flows immediately downstream of the reservoir to some extent, although it is noted that flows above approximately 200 L/s remain largely unaffected. This is an important point as these larger flows are the most important for flushing the stream system.

The frequency of spills, or flushing flows from the reservoir will largely depend on the management regime and weather systems (i.e. back to back high flows during winter when the reservoir is full).

As demonstrated by the next downstream representative assessment location (**Section 7.1.3**), the proportional change in flow regime quickly diminishes with increasing distance downstream, as lateral catchment inflows increase and additional tributaries join.

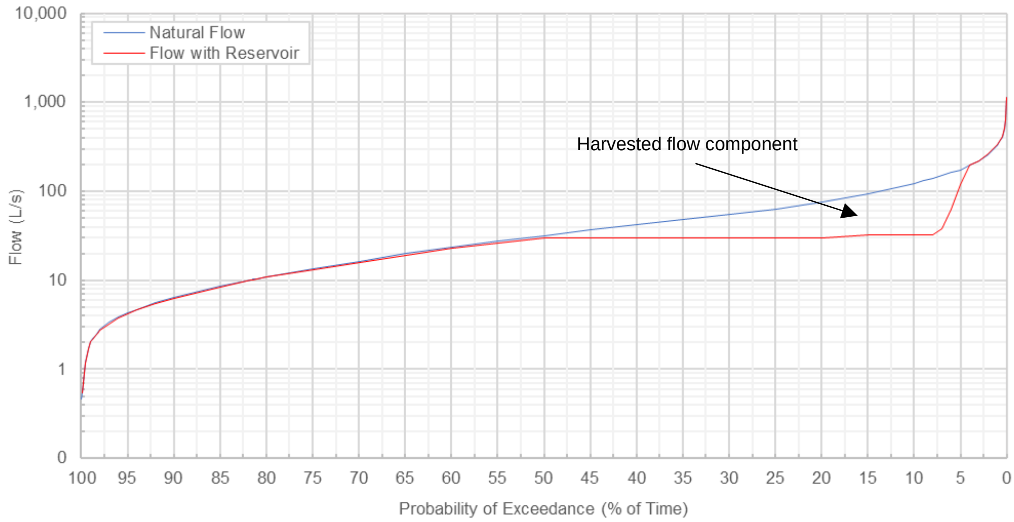

Figure 17. Comparison flow duration curve at the Downstream AWSR Embankment assessment location.

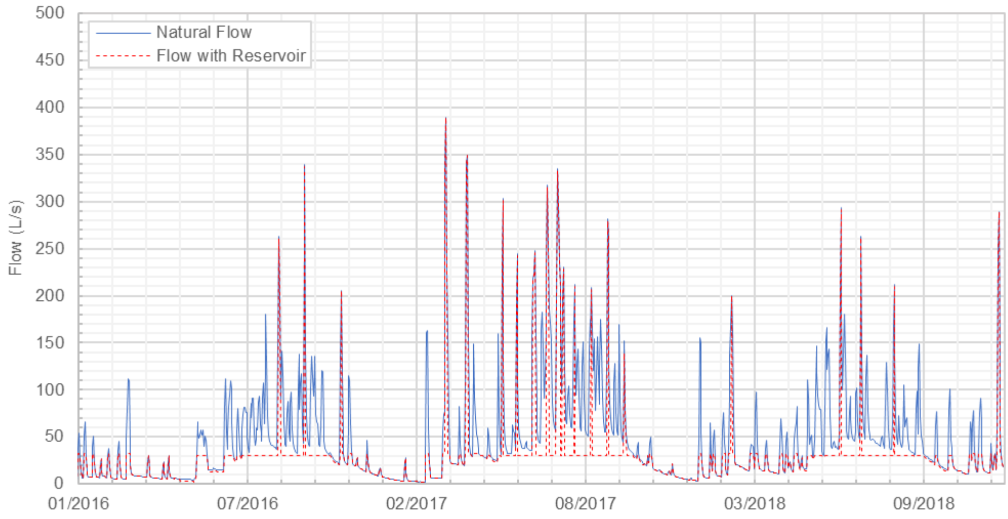

Figure 18. Example comparison of flow hydrograph sub-set at the Downstream AWSR Embankment assessment location.

A comparison of the flow statistics between the two scenarios is presented in **Table 11**.

Table 11. Downstream AWSR Embankment assessment location flow statistics.

Statistic	Natural Flow	Flow with Reservoir
Minimum (L/s)	0.5	0.5
Median (L/s)	31.8	30.0
Maximum (L/s)	1,149	1,147
7-Day MALF (L/s)	4.6	4.5
FRE3 (count)	18	9

7.1.3 Redhill Road

The hydrograph and flow duration curve for the Redhill Road assessment location are presented in **Figure 19** and **Figure 20**, respectively and summary flow statistics are presented in **Table 12**.

Both plots and the summary statistics show the impact of capturing above median flows in the reservoir has significantly decreased, and the flow regime is largely similar to the natural flow (i.e. without the reservoir).

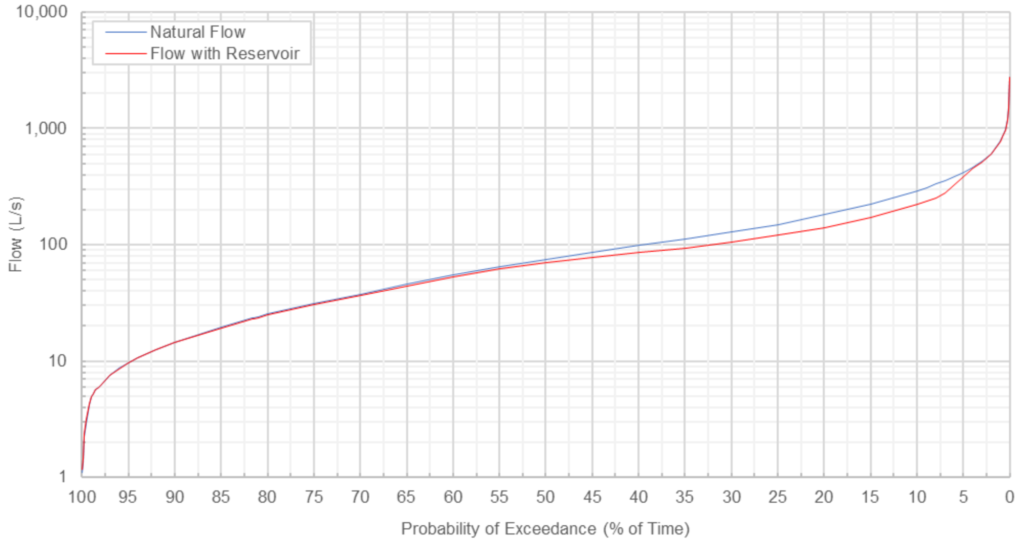

Figure 19. Comparison flow duration curve at the Redhill Road assessment location.

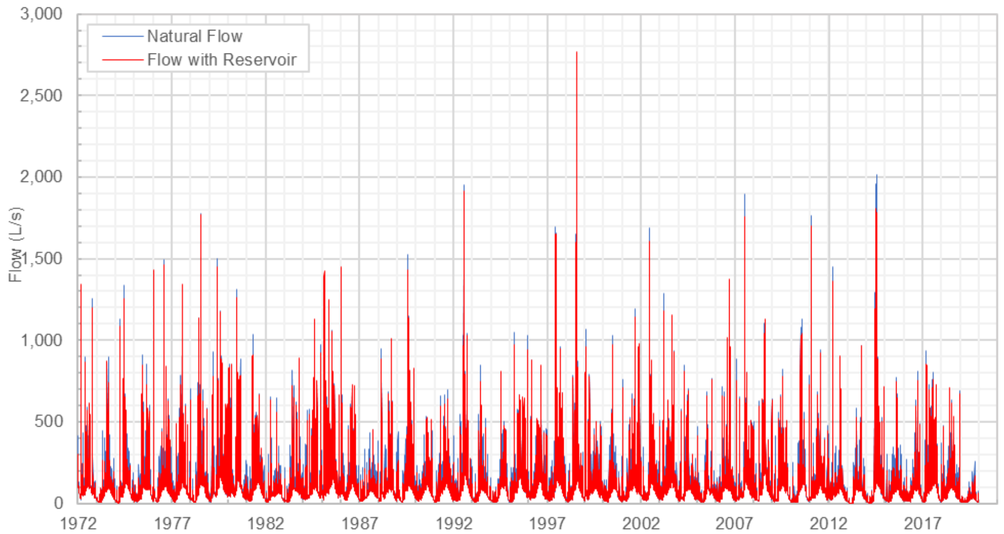

Figure 20. Comparison of flow hydrographs at the Redhill Road assessment location.

A comparison of the flow statistics between the two scenarios is presented in **Table 11**.

Table 12. Redhill Road assessment location flow statistics.

Statistic	Natural Flow	Flow with Reservoir
Minimum (L/s)	1.1	1.1
Median (L/s)	76.2	72.6
Maximum (L/s)	2,755	2,753
7-Day MALF (L/s)	11.0	10.9
FRE3 (count)	18	14

7.1.4 Downstream Aratapu Confluence

The hydrograph and flow duration curve for the Downstream of Aratapu Confluence assessment location are presented in **Figure 21** and **Figure 22**, respectively and summary flow statistics are presented in

Table 13.

The impact of capturing above median flow into the AWSR reservoir is considered minimal at this location.

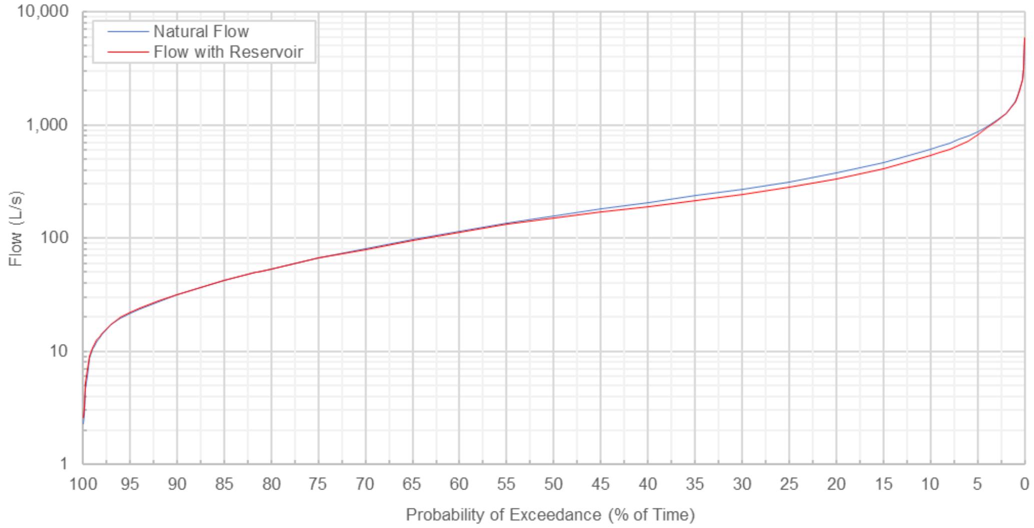

Figure 21. Comparison flow duration curve at the Downstream Aratapu Confluence assessment location.

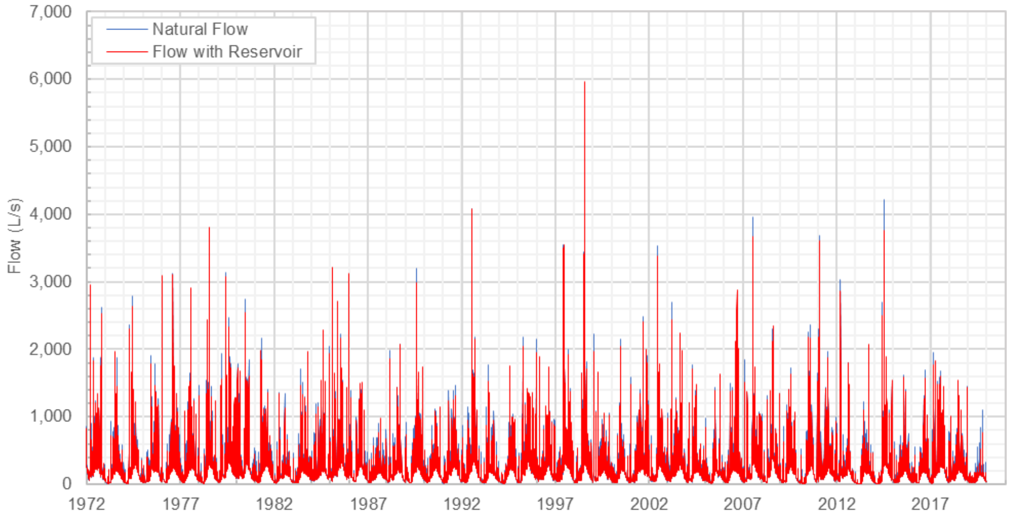

Figure 22. Comparison of flow hydrographs at the Downstream Aratapu Confluence assessment location.

A comparison of the flow statistics between the two scenarios is presented in **Table 11**.

Table 13. Downstream Aratapu Confluence assessment location flow statistics.

Statistic	Natural Flow	Flow with Reservoir
Minimum (L/s)	2.3	2.3
Median (L/s)	159.3	155.6
Maximum (L/s)	5,961	5,959
7-Day MALF (L/s)	23.0	22.8
FRE3 (count)	18.2	16.6

7.2 Impacts on Interactions with Groundwater

The reservoir may cause a small localised rise in groundwater levels due to reservoir seepage. If so, this would be considered to have a positive environmental impact, as it would act to increase stream baseflow. While this positive environmental impact is identified, such impacts are still considered to be minor.

8. Impact on Downstream Water Users

The following sections provide detail on the potential effect on downstream water users associated with operation of the proposed AWSR reservoir only, and does not detail those associated with proposed pumped water takes, as these are to be consented separately.

There is only one currently consented surface water take downstream of the proposed AWSR reservoir (**Figure 5**), AUT.007743.01.04. The purpose of this consent is listed as "to take water for pasture irrigation". The consent allows for a maximum daily allocation limit of 3.99 L/s, and a maximum annual take of 69,000 m^3/year.

8.1 Impact of Core Allocation Takes

The proposed core allocation take for direct inflows to the AWSR will only occur during winter. As the downstream consented take (AUT.007743.01.04) is for irrigation of pasture, the consent would only be utilised during summer. Therefore, it is considered there will be no effect on this downstream consented water take associated with a winter core allocation take for direct inflows to AWSR.

8.2 Impact of High-Flow Take

The harvesting of high flows will not negatively affect the downstream consented water take. The reservoir high flow take will only occur during times of above median flow at the reservoir (> 34.5 L/s), thus there will be at least 30.5 L/s in excess of the consented take rate passing downstream of the reservoir during periods of high flow harvesting. In addition, the consented irrigation take is not likely to be operational during times of high-flow taking (i.e. wet periods).

In terms of takes permitted under a Regional Plan or by Section 14(3)(b) of the Resource Management Act 1991, total daily take per property downstream of the lowest point of proposed taking is estimated at:

a) 10 cubic meters (equivalent to 0.116 L/s), or

b) 30 cubic metres (equivalent to 0.347 L/s) for the purposes of dairy shed wash down and milk cooling water.

There are estimated to be 14 properties downstream of the reservoir, immediately adjacent to the Aratapu Creek or its upper tributary, that would require Section 14(3)(b) water. However, the median flow of 34.5 L/s (which will not be harvested) at the location immediately downstream of the AWSR embankment is equivalent to 297 permitted takes at 0.116 L/s, or 99 permitted takes at 0.347 L/s. In addition, catchment flow increases with increasing distance downstream as additional lateral inflows occur and tributaries join.

Based on the above, there are no potential negative impacts anticipated on downstream water users.

9. Summary

This hydrology study considered the hydrological impacts of:

- operation of the proposed AWSR water storage reservoir;
- harvesting of high flow direct catchment inflows into the reservoir, from the median up to two times the standard deviation of flow;
- a core allocation take of direct catchment inflows, during winter only.

The following key conclusions were drawn from the hydrology study:

- The largest impact on streamflow in the unnamed tributary in the upper catchment of the Aratapu Creek of occurs directly downstream of the reservoir due to the capture of above median flows within the reservoir upstream. As all below median flow is bypassed, there is no change in streamflow during periods of below median flow (50% of the time). During winter there will be a small reduction (1.9 L/s) due to the core allocation take.
- The change in streamflow as a proportion of the total flow, due to the harvesting of above median flows, decreases with increasing distance downstream of the reservoir, as lateral catchment inflows occur and additional tributaries join. The general variation in streamflow is largely similar to the natural situation approximately 2.5 kilometre downstream at the Redhill Road assessment location.
- There is only one consented water take downstream of AWSR, and as it is for pasture irrigation, it will not be negatively impacted by the proposed winter core allocation take, or the high flow.

10. References

Clausen, B., Biggs, B.J.F. 1997. Relationships between benthic biota and hydrological indices in New Zealand streams. Freshwater Biology 38, 327-342

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WWLA. 2020b. Northland Water Storage and Use Project – Volume 2: Water Resources Assessment. Consultancy Report prepared for Northland Regional Council by Williamson Water & Land Advisory and RILEY Consultants.

WWLA. 2020c. Northland Water Storage and Use Project – Volume 3: Conceptual Design and Costing. Consultancy Report prepared for Northland Regional Council by Williamson Water & Land Advisory and RILEY Consultants.

WWLA. 2020d. Northland Water Storage and Use Project – Kaipara Optimisation Study. Consultancy Report prepared for Te Tai Tokerau Water by Williamson Water & Land Advisory and RILEY Consultants.

Appendix A. Soil Moisture Water Balance Model

Parameter	Name	Description	Calibrated Value
ST (mm)	Maximum soil water content	ST defines the size of the soil moisture store in terms of a depth of water.	247
SL (mm)	Soil moisture content where drainage ceases.	Soil moisture storage capacity below which sub-soil drainage ceases due to soil moisture retention.	0
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.	2.2
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.	4.4
ZMIN (mm/hr)	Minimum infiltration rate		0
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.	2
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.	2
AI (-)	Impervious portion of catchment	AI represents the proportion of the catchment that is impervious and directly linked to surface water drainage pathways.	0
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 daily pan evaporation rate, and as the soil moisture capacity decreases, evaporation decreases according to the predefined function.	0
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.	0.9
TL (days)	Routing coefficient for surface runoff	TL defines the attenuation and time delay of surface water runoff.	1
GL (days)	Groundwater recession parameter	GL governs the attenuation in groundwater discharge or baseflow from a catchment.	1

Parameter	Name	Description	Calibrated Value
QOBS (m^3/day)	Initial stream volume	QOBS defines the initial volume of water in the stream at the model start period and is used to precondition the soil moisture status.	126,900
AA, BB	Coefficients for rainfall disaggregation.	Used to determine the rainfall event duration and pattern.	0.22, 0.216

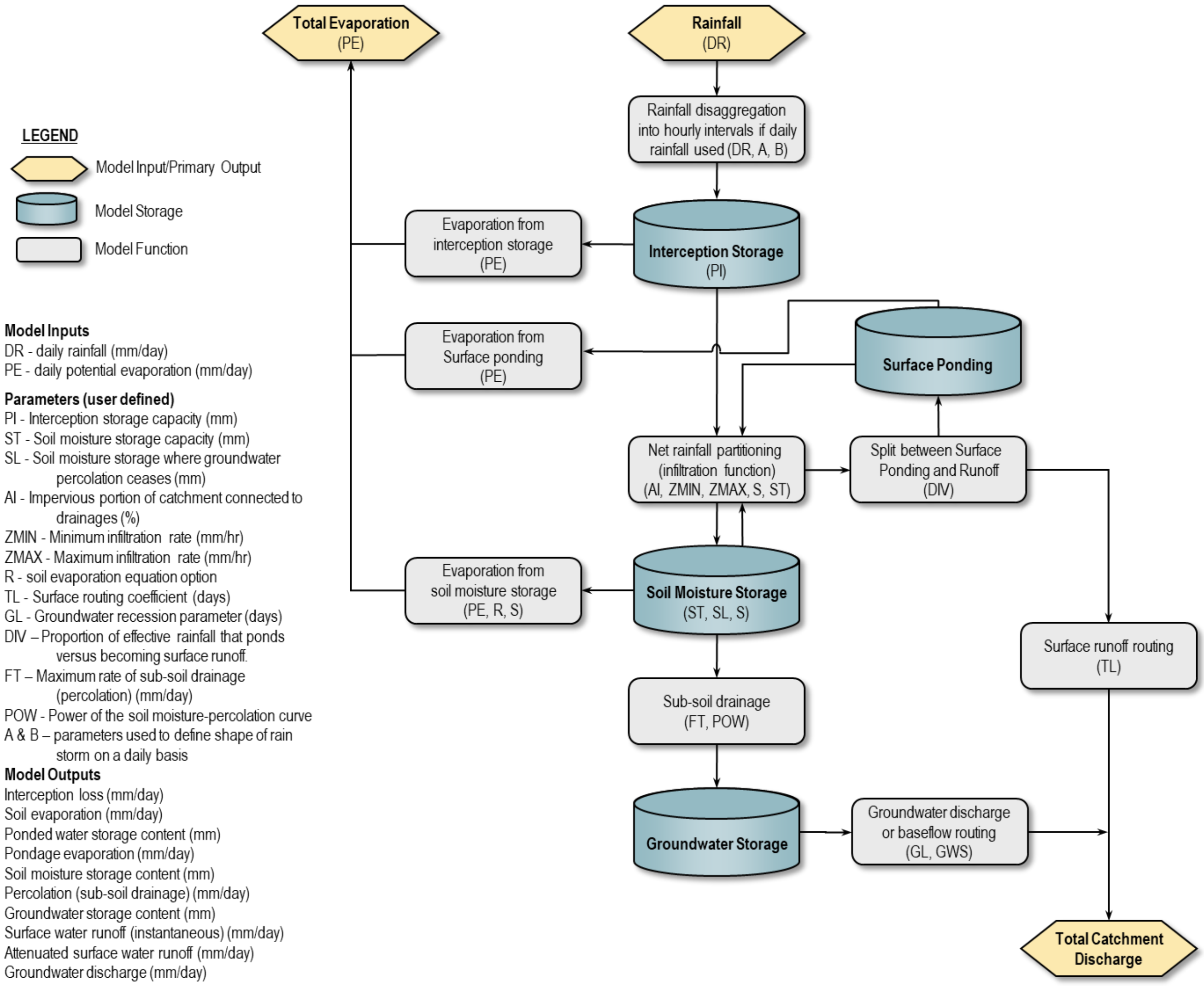


Figure 23. Schematic overview of the SMWBM.

Appendix B. SOURCE Modelling

The SOURCE modelling framework was utilised to model the conceptual operation of the storage reservoir and effects on the downstream flow regime. SOURCE is a hydrological modelling platform developed by the Australian research and not for profit organisation eWater. The platform is comprised of an interface integrating various models (as plugins) and internal tools designed to simulate and extract results for all aspects of water resource systems at a range of spatial and temporal scales.

The schematic modelling component of SOURCE was used to model the conceptual storage operation. The schematic model comprises of a series of linked nodes, representing individual components of the scheme, and rules and constraints on the transfer of water between nodes.

A schematic of the SOURCE model setup is shown in **Figure 24**.

The key node types used in the scheme storage optimisation modelling included:

- **Storage Nodes –** are used to represent storages such as dams, reservoirs, weirs and ponds. Storage Nodes calculate the daily water balance and are governed and constrained by inflows, physical limits on discharges (i.e. outflow pipe or pump capacities), downstream demands and gains (direct rainfall on reservoirs) and losses (evaporation for the reservoir surface). The storage node was configured based on the current conceptual design of the reservoir (WWLA, 2020c).
- **Inflow Nodes –** provide a source (inflow) of water to Storage Nodes. Inflow Nodes were configured with time series extracted from the catchment models**,** representing direct catchment inflows to the reservoir and take locations.
- **Supply Point Nodes –** define a location where water can be extracted to meet a demand required by Water User Nodes. Supply Point Nodes provide a means of constraining extractions (takes) based on physical constraints such a maximum pumping capacity, or when reservoir storage volumes are above or below a specified level.
- **Water User Nodes –** define a water take demand profile, and are always located immediately downstream of a Supply Point Node. Water user nodes simply represent a water take (demand) from a Storage Node, on the condition that sufficient volume of water is available within the storage, and the take is within the constraints of the upstream Supply Point Node. A water user node was configured for the irrigation take. The irrigation take was defined based on the outputs of the SMWBM_Irr model (WWLA, 2020a), for a 1,070hectare irrigable area, and a peak application rate of 4.4 mm/day.
- **Pipe Junction Nodes –** are used to transfer water between locations, and to represent pump stations in a water supply system. They operate using a rules-based ordering system. Pipe junction nodes were configured to represent the harvesting of water to storage in the reservoir. Pipe junctions were used to simulate the harvesting of high flows from the Aratapu Stream, upstream of the reservoir, for the high-flow take at Makaka Stream and Cole Drain, and the run of river take from the Kaihu River. The takes were configured with maximum pumping rates and a management criterion to only transfer (pump) water when the reservoir storage volume was less than 85% of full supply capacity.

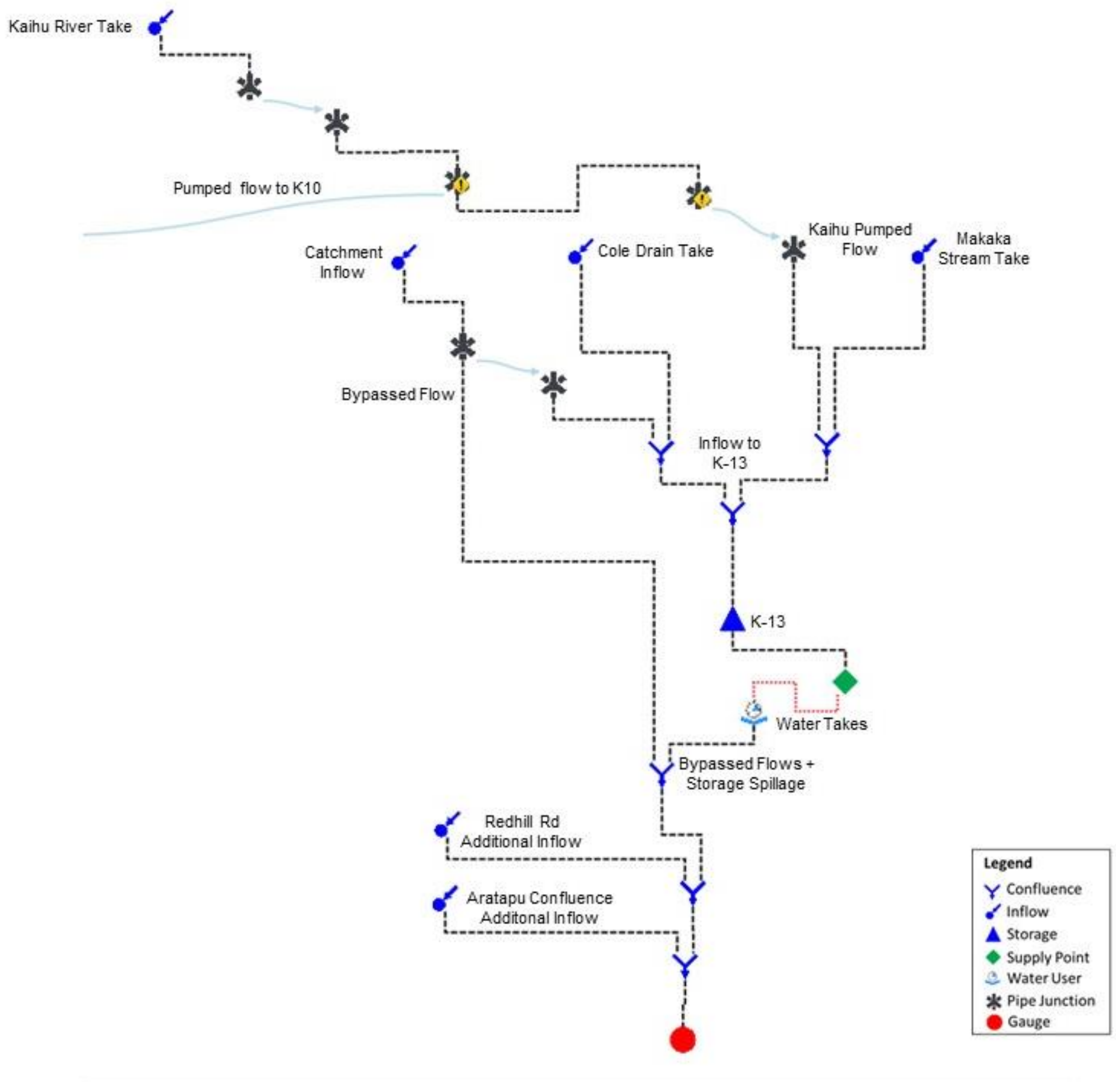
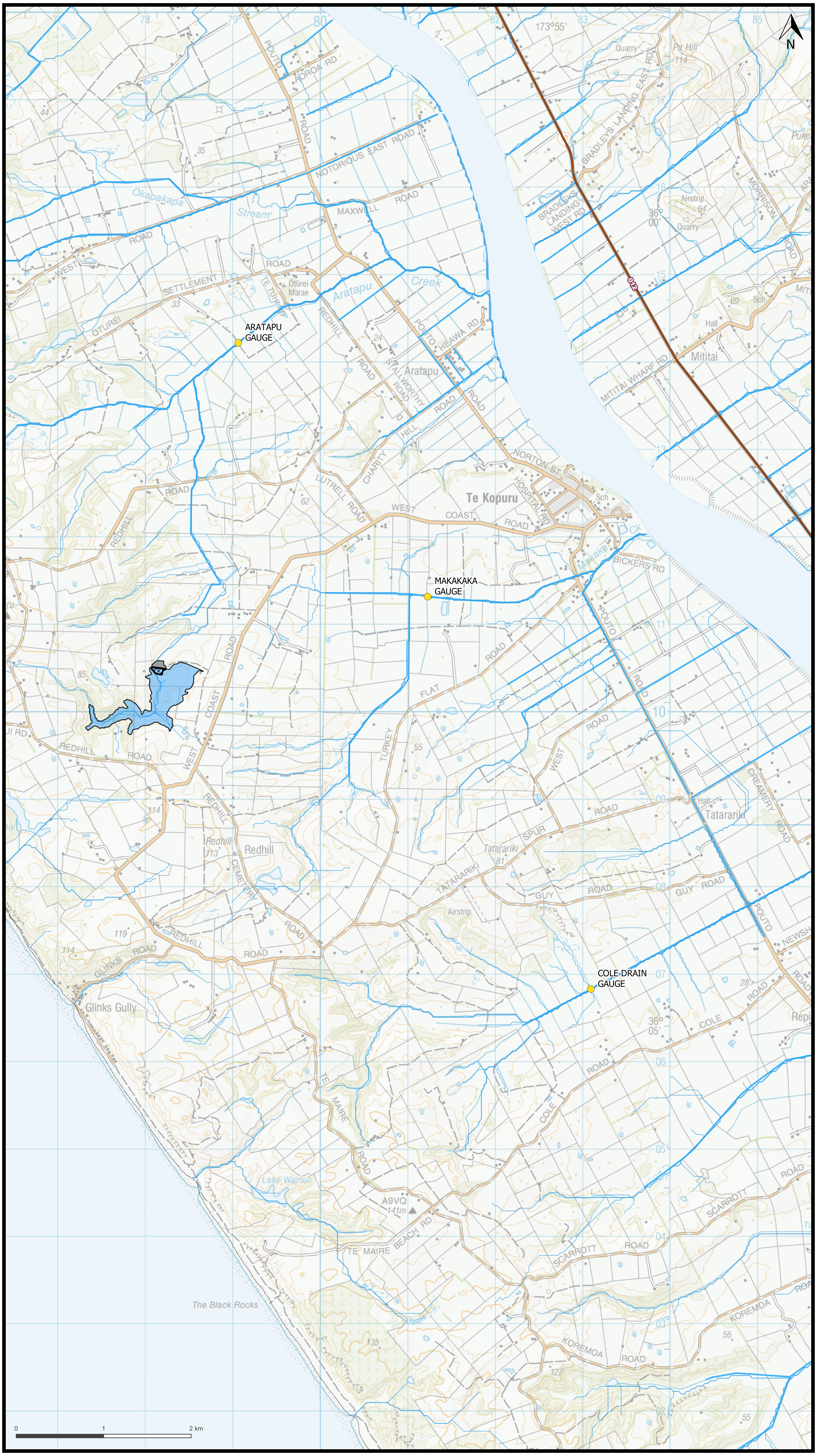


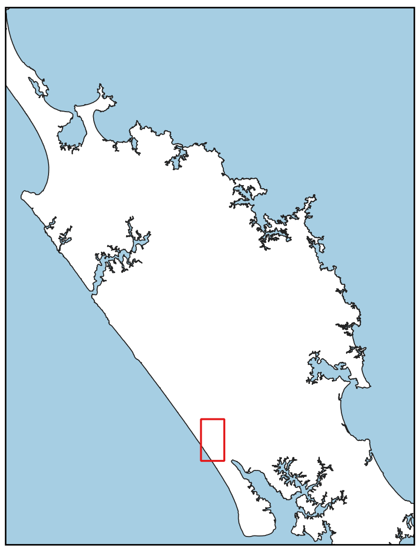
Figure 24. SOURCE model schematic.



Map Title:
Current Flow Monitoring Locations

Project:
Aratapu Water Storage Reservoir Hydrology Study

Client:
Te Tai Tokerau Water Trust



Legend

- Monitoring Site
- River / Stream
- State Highway
- Reservoir Footprint

Data Provenance
Topographic Data derived from Land Information New Zealand

Layout & Project File
Flow Gauge Locations Report Figure
K-13_Hydrology_Study_Report.qgz

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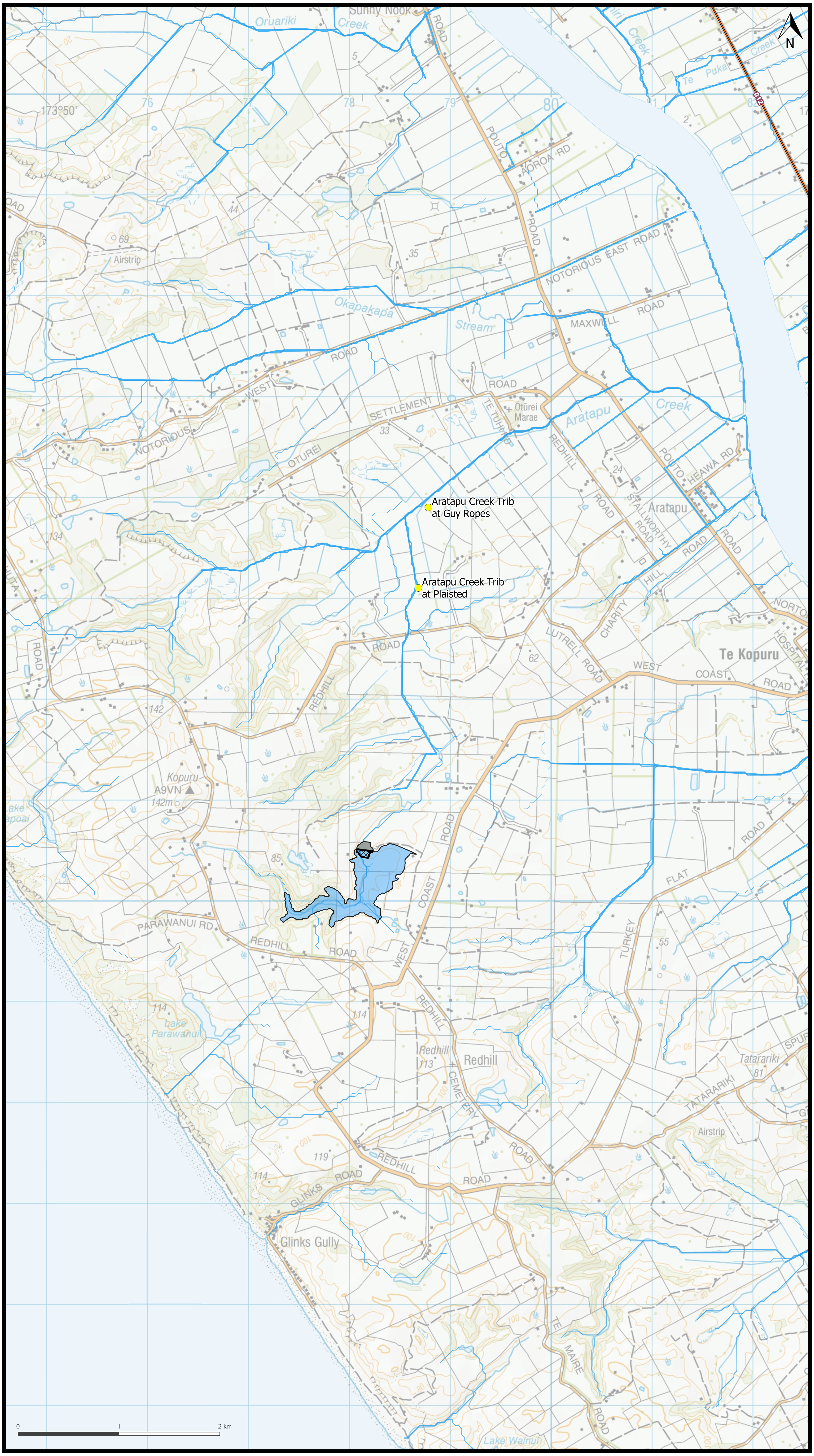
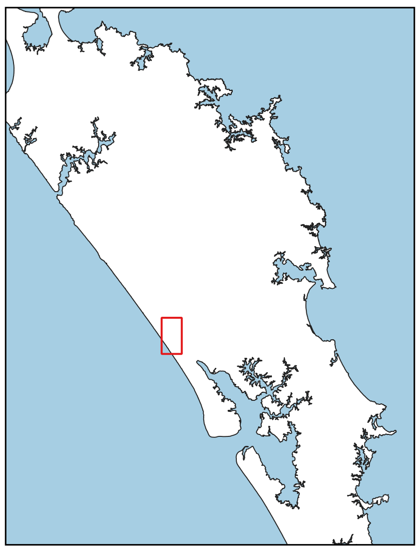
Figure 02.





Map Title:
Flow Gauging Locations

Project:
Aratapu Water Storage Reservoir Hydrology Study

Client:
Te Tai Tokerau Water Trust

Legend

- **Flow Gauging Site**
- **State Highway**
- **River / Stream**
- **Drainage Channel**
- **Reservoir Footprint**

Data Provenance
Topographic Data derived from Land Information New Zealand

Layout & Project File
Flow Gauge Locations
K-13_Hydrology_Study_Report_EL.qgz

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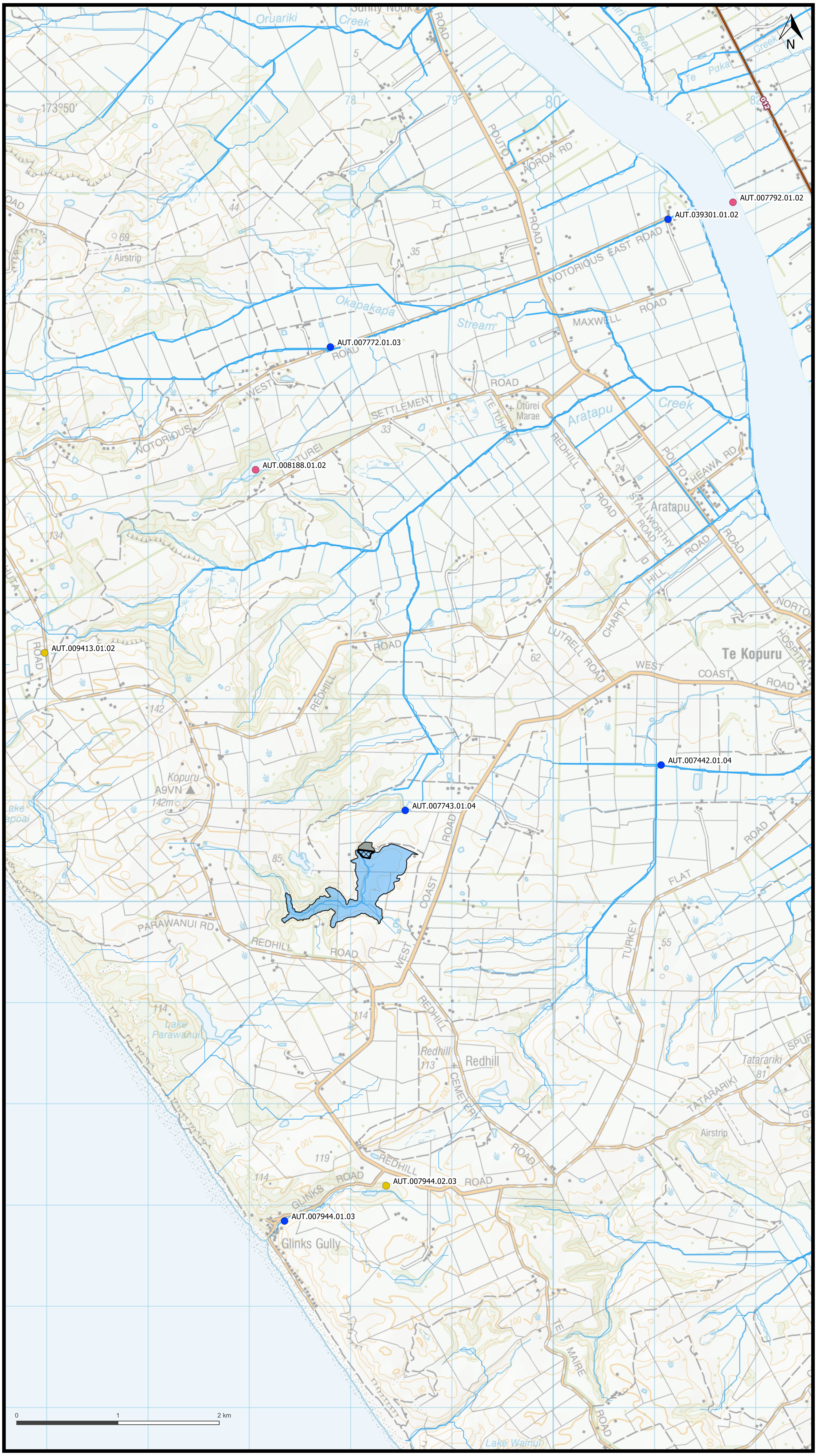
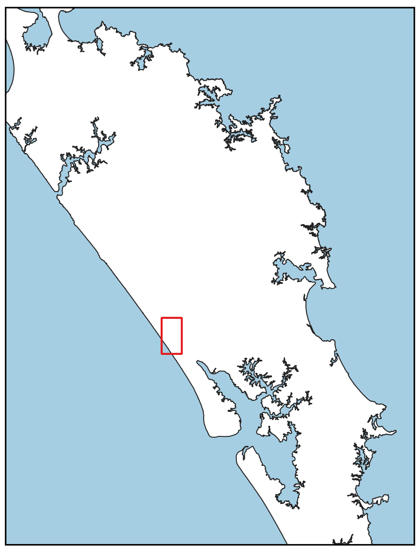
Figure 04.



Map Title:
Consented Water Takes

Project:
Aratapu Water Storage Reservoir Hydrology Study

Client:
Te Tai Tokerau Water Trust



Legend

- Dam Water Take
- Ground Water Take
- Surface Water Take
- River / Stream
- Drainage Channel
- State Highway
- Reservoir Footprint

Data Provenance
Topographic Data derived from Land Information New Zealand

Layout & Project File
Consented water takes
K-13_Hydrology_Study_Report_EL.qgz

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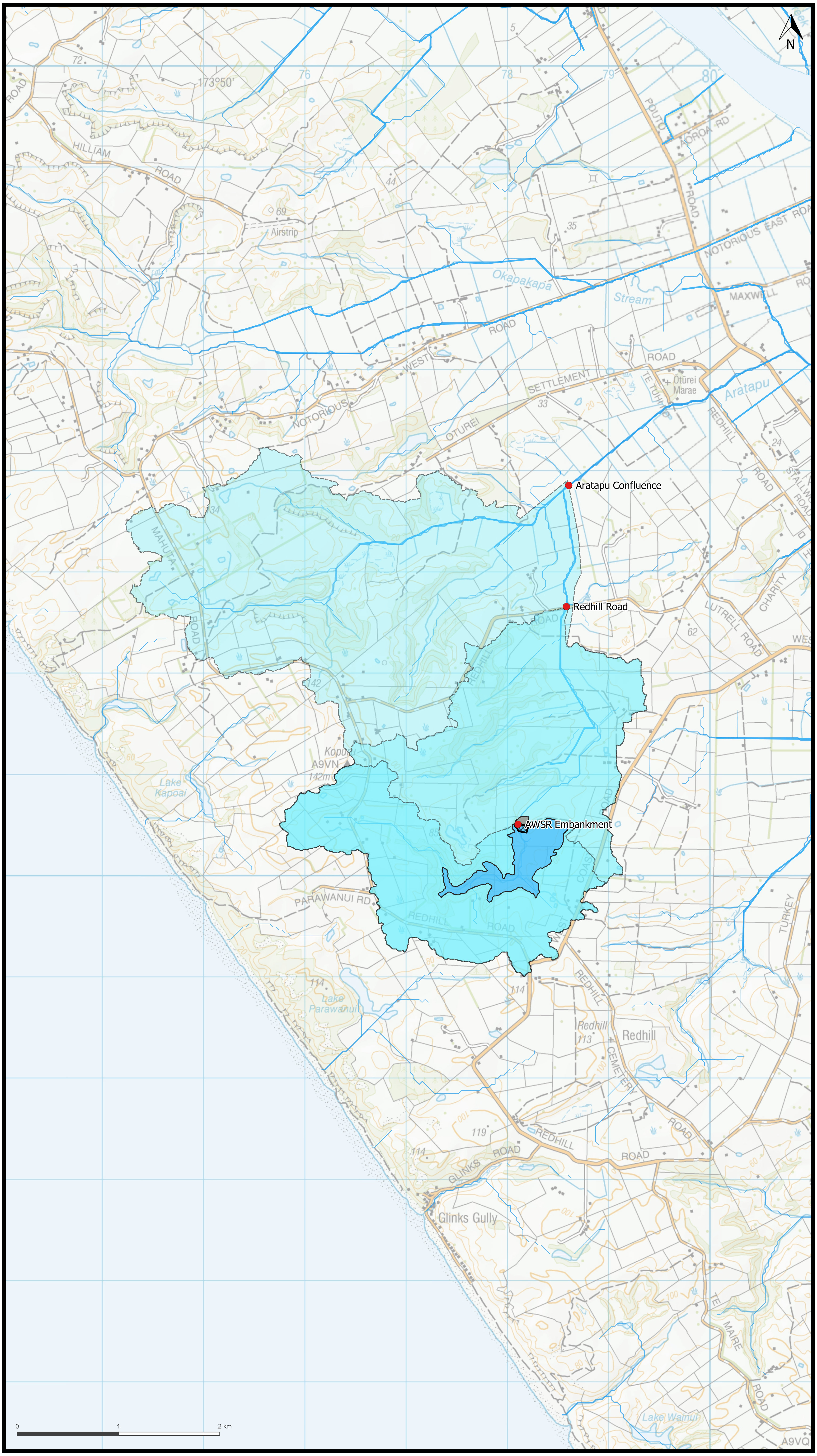
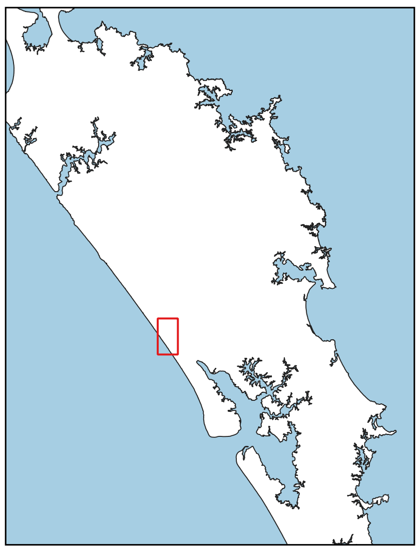
Figure 05.



Map Title:
Representative Assessment Locations

Project:
Aratapu Water Storage Reservoir Hydrology Study

Client:
Te Tai Tokerau Water Trust



Legend

- K13 Assessment Location
- River / Stream
- Drainage Channel
- Assessment Location Catchment
- Reservoir Footprint

Data Provenance
Topographic Data derived from Land Information New Zealand

Layout & Project File
Assessment Locations
K-13_Hydrology_Study_Report_EL.qgz

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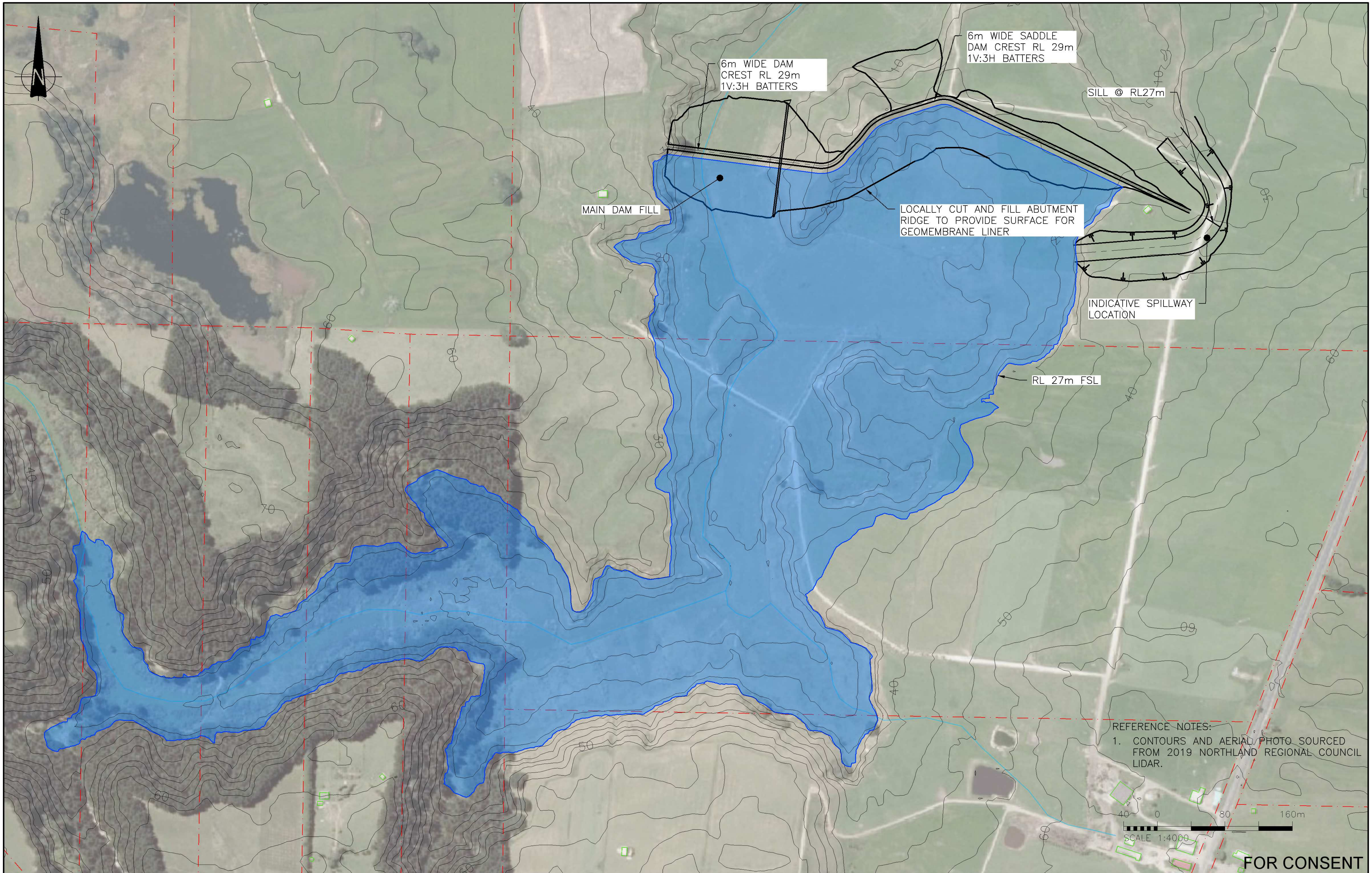
Figure 06.



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DRAWN	CAD CHECK	
MP		
DATE DRAWN		ISSUE DATE
AUG. 2020		24 / 03 / 20

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Nga Puna Wai He Koha Oranga Tangata He Koha Oranga Whenua
The Springs of Water A gift of life to our people A gift of life to our land

CLIENT	TE TAI TOKERAU WATER TRUST
ADDRESS	NORTHLAND
PROJECT	K13 WATER STORAGE AND USE PROJECT
SHEET TITLE	DAM & RESERVIOR LAYOUT - 3.8 Mm3 OPTION

ACENZ

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