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21 September 2020

David Moore
Golf Strategy Group Ltd
By email

cc Ryan Brandenburg, Golf Strategy Group

Dear David

MURIWAI DOWNS GOLF COURSE: WATER SUPPLY OPTIONS ASSESSMENT

1.0 Introduction

Pattle Delamore Partners (PDP) has been engaged by Golf Strategy Group Ltd (GSGL) to carry out an options assessment of securing a reliable water supply for the planned future development of a golf resort facility at Muriwai. The site covers an area of about 500 hectares of farmlands located about 17 km southwest of Kumeu and 3 km north east of Muriwai Beach Township.

2.0 Scope

This options assessment has been based on a desktop study using the available geological and hydrogeological information.

The scope of the work is outlined below:

Water Demand

- Confirm annual water demand for irrigation and site ancillary uses.

Surface Water Sources

- Collate relevant data including streamflow, topographic, rainfall, etc
- Develop streamflow temporal statistics to use in the water take analysis
- Undertake a water take consent search
- Evaluate the current water allocation status and rules for the Okiritoto catchment
- Develop storage requirements for seasonal use over dry years
- Evaluate possible storage siting options
- Undertake broad planning of storage water take arrangements
- Undertake high level CAPEX and OPEX analysis to build and operate the take/storage system.

Groundwater Sources

- Review all available existing geological and hydrogeological data including undertake a bore search to identify existing users, well and usage details
- Develop a conceptual model of the groundwater systems in the area based on existing geological and hydrological information
- Determine the resource amounts and seasonal variability
- Check on water quality characteristics
- Undertake broad planning of well field options to tap into the resource
- Undertake high level CAPEX and OPEX analysis to build and operate the bore field for a nominal 20-year period.

3.0 Environmental Setting

3.1 Okiritoto Stream Catchment

The proposed golf course is located within the Okiritoto Stream catchment which has a total catchment area of approximately 23.5 km^2 as shown in Attachment 1. The stream borders the northern boundary of the proposed site where there is a waterfall which is significant to local iwi. The stream flows west toward Muriwai Beach where it discharges into the sea. It is understood some amount of surface stream flow is lost to groundwater as it passes through the sand dunes.

A stream hydrology report was completed in 1999 by Auckland Regional Council (TP102). This reports an extreme value analysis based on 19 stream gaugings completed at the waterfall site over summers between 1976-98. This analysis found the 1 in 5-year baseflow (Q_5) to be approximately 56 L/s at the Okiritoto Stream waterfall. An estimate for the 1 in 50-year (Q_{50}) baseflow at the same location was also obtained by applying a specific discharge rate of 2.6 L/s/km^2 (from TP102) to the catchment area to the waterfall (approx. 19 km^2). The resulting Q_{50} baseflow estimate is 48 L/s which was used for assessing potential of a baseflow take from the Okiritoto Stream for the proposed golf course.

There is also an estimate for $Q_{2.33}$ in TP102 for the waterfall site on the Okiritoto Stream. This is equivalent to mean annual low flow (MALF) and is reported to be approximately 58.6 L/s. However, TP102 states the method used to calculate this is "extremely uncertain" and recommends that further gauging should be undertaken. For the purposes of this assessment, MALF was assumed to be 60 L/s in the Okiritoto Stream.

There is already a consented Okiritoto Stream take at the existing Muriwai Links Golf Course. This is consented to take up to a maximum of 1,150 m^3/day and 130,000 m^3/year. It is estimated that during summer, this represents a Q_{50} baseflow take of approximately 20%.

There is one other consented Okiritoto Stream take but this is very small at 1,825 m^3/year and is for horticultural use.

4.0 Conceptual Groundwater Model

4.1 Geological Setting

According to the available third-party geological logs (Appendix 1), field observations and geological maps (Hayward, 1983), the study area consists of three major geological formations pertinent the hydrogeological flow regime at site (ordered youngest to oldest):

- Pillow Lava;
- Awhitu Formation; and

- Nihotupu/Piha Formations (Waitakere Group).

The regional geology is shown in Appendix 2.

4.1.1 Pillow Lava

A small isolated outcrop of Pillow Lava is identified on site (Figure 1). Consisting of stratified, andesitic breccia-conglomerate, this pillow lava is potentially connected to a more extensive volcanic unit (as seen exposed along the coastal cliffs south of Muriwai) unit extruded through the overlying Nihotuhu Formation.

4.1.2 Awhitu Formation

The Awhitu Formation has built up to about 200 mRL, overlying the older Nihotupu Formation (Waitakere and Waitemata Group, Hayward, 1983 & 1976).

Based on our previous investigations at Muriwai (PDP 2020), weathered outcrop of the Awhitu Formation consists of highly weathered, iron oxide stained, weak sandstones with interbedded layers of low permeability, highly weathered siltstone and mudstone with associated silts and clays.

Bedding strike and dip recordings at each outcrop indicate a generally uniform, 5 degrees (sub-horizontal) dip with strata generally dipping towards the north / north-west.

A clay dominant weathered zone, approximately 2 m in thick, is recorded at the surface. It is considered likely that this low permeability weathered zone is present extensively across the Awhitu Formation at the surface.

4.1.3 Nihotupu Formation/Piha Formation (Waitakere Group)

Consisting of well-bedded volcanic grit, sandstone and minor siltstone (Hayward, 1976), the Nihotupu Formation forms part of the upper Waitemata Group (Waitakere Sub-group) which underlies the Awhitu Formation and Mitiwai Dune Sands.

Interpretation of two available drillers' logs situated at 82 and 130 Oaia Rd (Bores IDs: 21261 and 22794 respectively, Appendix 1) drilled through Awhitu Sand Formation indicate the depth of underlying Nihotupu Formation sandstones greater than 100 m (<40 m RL). Based on the field observation, the thickness of this formation is reduced towards the Okiritoto Stream and is exposed at some reaches of the stream and the main tributary through the site.

4.2 Groundwater Resource Potential

In terms of the potential for groundwater supply, there are three aquifer units beneath site; the shallow Awhitu formation, underlying Nihotupu Formation and extruding Pillow Lava (Figure 2). Potential groundwater supply for each of these aquifer units is discussed below.

Based on feasible reservoir storage and surface water baseflow contribution, the required groundwater yield is estimated to be approximately 200 m^3/day. This is likely to be achievable at the site, however a number of bores will be required. Pilot drilling is recommended in order to accurately determine the groundwater resource potential.

There are currently no existing consented groundwater takes within the Okiritoto catchment. There are currently five permitted bores within the catchment all of which target the Nihotupu formation for domestic supply (up to 20 m^3/day). The location of these permitted bores is shown in Appendix 1.

4.2.1 Awhitu Formation Aquifer Resource

The interbedded structure of the Awhitu Formation forms a series of multiple shallow, perched groundwater layers. These perched groundwater layers are typically non-uniform; with variable thickness and lateral extent. As a result, the Awhitu formation is unlikely to yield a suitable groundwater supply at site. The shallow, perched groundwater layers within the Awhitu Formation also provide the predominant source of baseflow to the Okiritoto stream (and upper sub-catchments across site). As a result, any targeted groundwater abstraction from the Awhitu would deplete the Okiritoto stream base-flow.

4.2.2 Nihotupu Formation Aquifer Resource

The Nihotupu formation is typically at >100 m depth below ground level to the south of site, shallowing to the north of site, with evidence of Nihotupu exposure along the Okiritoto Stream (Appendix 2).

The groundwater resource is likely to be largely separated from the overlying perched groundwater with the Awhitu formation at site.

The Nihotupu formation has been targeted by a number of small domestic groundwater supplies. Available air-lift pump testing results from neighbouring bores (Bores IDs: 21261 and 22794) have been reviewed. Calculated transmissivity ranges between 1 to 3 m^2/day (Geometric mean of ~2 m^2/day). Assuming 100 m of effective drawdown, a bore yield of approximately 20 to 50 m^3/d is anticipated. As a result, multiple deep groundwater bores will be required across site to achieve the desired yield from this aquifer.

4.2.3 Pillow Lava Aquifer Resource

There is a small outcrop of Pillow Lava present at site. Depending on the wider connection of the unit and the degree of fracturing, this volcanic formation is potentially of significantly higher permeability than the surrounding Nihotupu, and may be a significant groundwater resource at site. There are no available bores in the area to support this theory at this stage. It is recommended that a pilot bore be drilled through the basalt outcrop at site and pump testing be performed to establish the groundwater resource.

4.3 Groundwater Quality

PDP has previously undertaken water quality sampling for groundwater supplies sourced from both the shallow Awhitu and deeper Nihotupu aquifers (PDP, 2020). Both aquifer resources are generally considered to be of potable quality, within the Drinking Quality Standards of New Zealand (DWSNZ, 2008; revised 2018).

5.0 Irrigation Demand

Irrigation demand for the proposed golf course was provided in an email from R Brandenburg on 29 July 2020. This outlined the expected irrigation demand for the Muriwai Downs location during the grow-in period and during regular operation. The grow-in period is typically the first 18 months of golf course establishment and spans two summers.

Peak demand during the grow-in period was estimated to be 1,500 m^3/day during summer. Towards the end of the grow-in period, the demand will decrease to regular levels with an estimated peak demand of 1,200 m^3/day. Winter demand during the grow-in period was the same as normal operation at an estimated 100 m^3/day.

A graphical representation of irrigation demand over the first 2 years of operation is shown in Figure 1 below. The rainfall data used for this water supply assessment is also shown in Figure 2. Data was obtained from Auckland Council's Muriwai Golf Course rainfall gauge (ID 648411). For the storage simulation discussed in Section 6, rainfall recorded between July 2019 and June 2020 was used to represent conservative 'drought' conditions with lower than average rainfall across most of the year and minimal rainfall recorded between mid-November to mid-January.

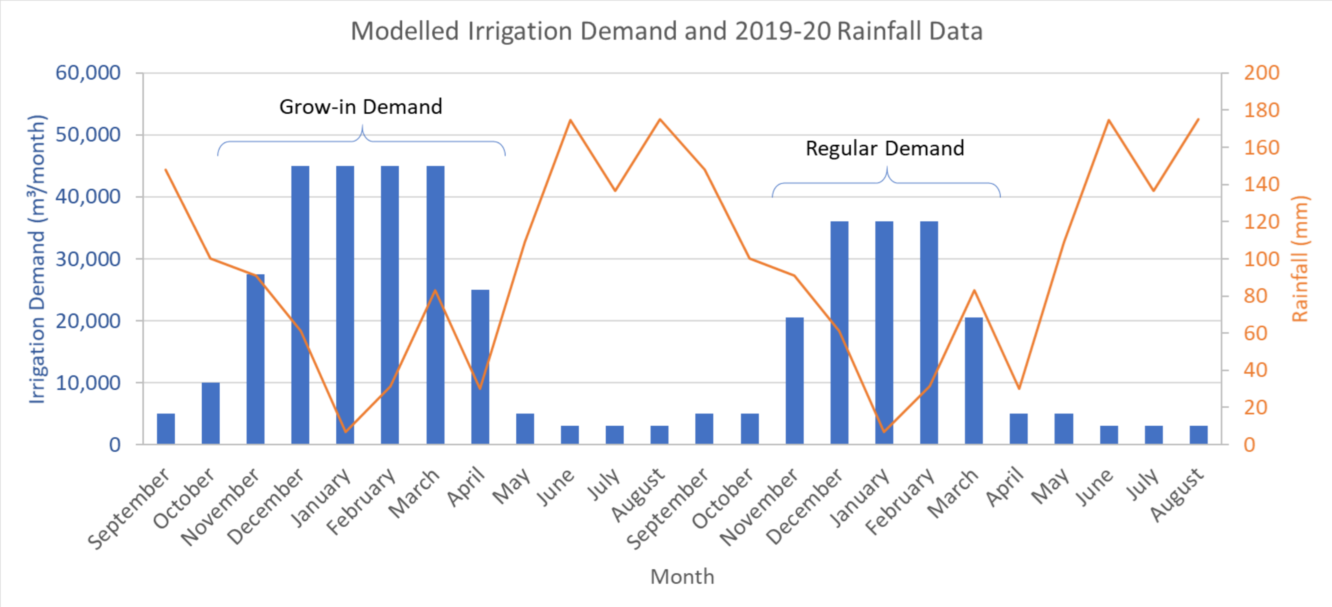

Figure 1: Irrigation Demand and Rainfall Graph

5.1 Water Supply Modelling Assumptions

The following assumptions were made for surface water supply modelling:

1. Okiritoto Stream 1 in 50-year (Q_{50}) baseflow of 48 L/s at the waterfall was used for this assessment.
2. Okiritoto Stream tributary Q_{50} baseflow was assumed to be approximately 6.3 L/s (13% of Okiritoto Stream Q_{50} baseflow as a proportion of catchment area).
3. For the purposes of this assessment, mean annual low flow (MALF) in Okiritoto Stream (at the waterfall) was assumed to be approximately 60 L/s based on TP102.
4. Rainfall runoff coefficient of 0.5 (50%) used for Okiritoto Stream tributary.
5. Evaporation losses of 5 mm per day on average from surface water bodies during summer.
6. Available groundwater supply of 200 m^3/day was assumed.

6.0 Water Supply Storage Options

Several potential water storage locations were identified by desktop investigation as shown in Figure 2 below. Most of these storage locations are on-stream although many of the smaller streams would be considered intermittent (seasonal flows) or ephemeral (only flow as a direct result of rainfall). The exception to this would be Location J which is considered off-stream with minimal contributing catchment.

Locations H, F and G are located on the path of an Okiritoto Stream tributary with a catchment area of approximately 2.4 km^2 with an estimated Q_{50} baseflow of 6.3 L/s. This is the largest catchment area in which storage dams could be positioned within the site.

Location J is considered an off-stream storage location on flat ground with a minimal catchment area but a very large storage volume of approximately 100,000 m^3. This option will rely completely on pumping from the Okiritoto Stream to fill the storage pond.

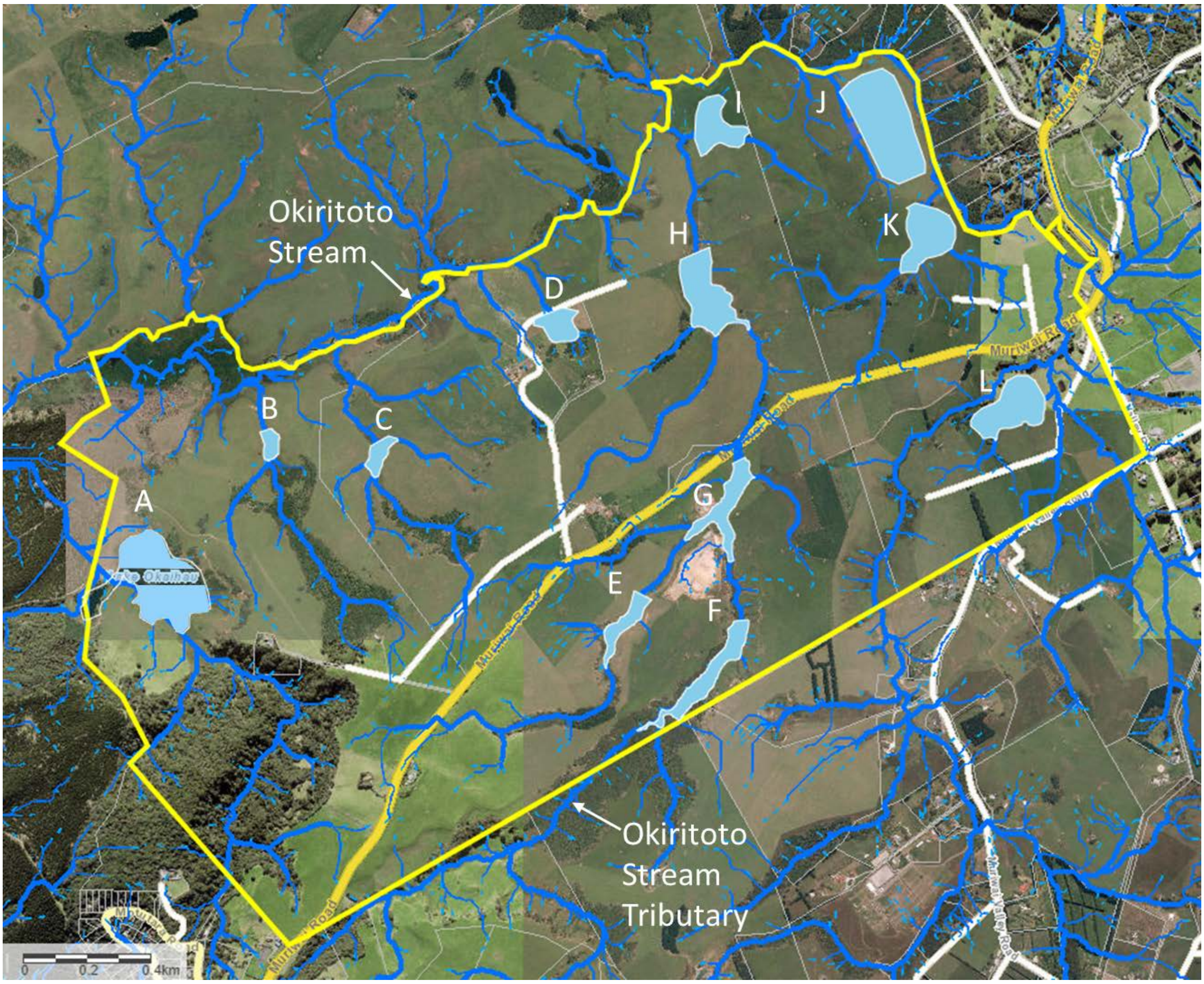

Figure 2: Potential Storage Locations Identified

6.1 Storage Option Comparison

An initial comparison was made between the storage options shown in Figure 2 to determine which options merited further assessment. This comparison is shown in Table 1 below

Table 1: Storage Location Option Comparison

Location	Description	Catchment Area (km^2)	Storage Volume (m^3)	Surface Area (m^2)	Dam Height (m)	Comment	Further Investigation
A	Existing Natural Lake (Lake Okaihau)	1.6	Unknown	63,000	-	Small inflow and waterbody is a significant ecological/cultural feature	Not recommended
B	Stream Channel	0.3	9,000	4,000	5.0	Minimal storage volume and small contributing catchment	Not recommended
C	Stream Channel	0.3	13,000	6,000	5.0	Minimal storage volume and small contributing catchment	Not recommended
D	Stream/Wetland Area	0.1	20,000	10,000	5.0	Small storage volume, small contributing catchment and ecological effects of flooding wetland	Not recommended
E	Stream Channel	0.4	20,000	10,000	5.0	Small storage volume and small contributing catchment	Not recommended
F	Stream Channel	1.2	25,000	20,000	4.5	Good storage volume and location for supplementary storage in conjunction with Location H	Recommended
G	Stream Channel	2.0	20,000	18,000	4.0	Site constraints due to adjacent quarry limit expansion of storage volume and dam height	Not recommended
H	Stream Channel	2.4	70,000	29,000	6.0	Large storage volume for footprint and good catchment size	Recommended
I	Stream Channel	0.1	20,000	18,000	4.0	Small storage volume, extensive earthworks required and small contributing catchment	Not recommended

Table 1: Storage Location Option Comparison

Location	Description	Catchment Area (km^2)	Storage Volume (m^3)	Surface Area (m^2)	Dam Height (m)	Comment	Further Investigation
J	Off-stream Pond adjacent to Okiritoto Stream	0.1	100,000	40,000	NA	Large storage volume which requires pumping and extensive earthworks although off-stream location reduces ecological effects	Recommended
K	Stream Channel	0.4	25,000	22,000	4.0	Extensive earthworks required and small contributing catchment	Not recommended
L	Stream Channel	0.2	30,000	23,000	2.0	Extensive earthworks required and small contributing catchment	Not recommended

Notes:

1. *All values in this table are approximate and based on Auckland Council GeoMaps information.*

6.2 Summer Storage Simulation Parameters

From the above Table 1, three storage locations: H, F and J were selected for further assessment. Their catchment areas and simulated inflows are shown in Table 2. The assumptions used for the modelling are outlined in Section 5.1.

Option 1 was the only option where any baseflow take was assumed. The baseflow take was assumed to be a maximum of 200 m^3/day during summer which represents approximately 5 % of the Okiritoto Stream Q_{50} baseflow. 5% was taken as a nominally small amount to reduce potential consenting challenges.

Option 3 relies almost completely on a pumped stream take which can only occur above the Okiritoto Stream MALF (estimated at approximately 60 L/s from historical stream gauging data). The take regime would be graduated according to increasing stream flow up to the assumed maximum take of 12 L/s (1,000 m^3/day). Further modelling and investigation will be required to refine the regime needed.

Table 2: Storage Simulation Options and Inputs

Option Description	Storage Location(s)	Rainfall Catchment Area (km^2)	Groundwater Take (m^3/day)	Baseflow Take (m^3/day)	Max Stream Take (m^3/day)
Option 1- Single Storage Dam & Groundwater	On-stream (H)	2.4	200	200[1]	0
Option 2- Two Storage Dams & Groundwater	On-stream (H + F)	2.4	200	0	0
Option 3- Off Stream Reservoir & Groundwater	Off-stream (J)	0.1	200	0	1,000[2]

Notes:

1. *Approximately 5% of Q_{50} baseflow within the Okiritoto Stream.*
2. *It was assumed that pumping would only occur above Okiritoto Stream MALF, with no pumping during the summer months of December and January.*

6.3 Option 1 (Single Dam & Groundwater) Storage Simulation

Option 1 proposes to use a single 6 m high dam at storage location H with approximately 75,000 m^3 of storage volume and assumes 200 m^3/day of baseflow, as well as 200 m^3/day of pumped groundwater inflow.

It should be noted that this storage volume has been sized based on the grow-in period demand of 1,500 m^3/day. The 2019/20 rainfall data includes a period of 2 months with no rainfall over a summer which produced drought conditions. For any prolonged period without rainfall, this option shows a continuous reduction in storage volume as it is reliant on rainfall to replenish storage. During regular golf course summer irrigation demand of 1,200 m^3/day, the storage would extend for a 3-month period of no rainfall.

To better understand this option, further investigation should be undertaken into the hydrology of the Okiritoto Stream tributary to confirm the baseflow that is available during summer months. A detailed assessment into the ecological effects and consenting requirements for this option should also be undertaken. Minimising the effects on fish passage and any stream ecology will be required.

6.4 Option 2 (Two Dams & Groundwater) Storage Simulation

Option 2 proposes to construct a dam at Location H (as with Option 1) and to provide supplementary storage within a second 4.5 m high storage dam at Location F. This eliminates the need to take stream baseflow. Pumping of 200 m^3/day groundwater is expected to still be available when required.

The resulting simulation indicates approximately 70,000 m^3 of storage is required within the main dam as well as a further 25,000 m^3 of storage within the supplementary dam. The main benefit of this option is that both storage dams are on the same tributary which is able to capture a larger runoff volume from the large catchment area. The two dams bring the total storage volume to approximately 95,000 m^3 which means that no baseflow take was required based on the 2019/20 summer rainfall simulation.

As the supplementary storage dam is upstream of the main dam, it is not expected that pumping infrastructure would be required between the dams. The dam at Location F would release flow downstream to be captured within the main dam at Location H.

As with Option 1, further investigation into the hydrology of Okiritoto Stream tributary should be undertaken along with more detailed storage simulation over a longer period. The ecological effects on this option will be similar to Option 1 although there will now be two barriers to fish passage within the tributary. The ability to meet the irrigation demands without any baseflow take is a significant advantage.

6.5 Option 3 (Off-Stream Reservoir & Groundwater) Storage Simulation

Option 3 proposes to utilise a large off-stream storage (Location J) which relies entirely on pumped inflow from the Okiritoto Stream and groundwater take. To provide inflow to this storage, pumped flow from the Okiritoto Stream will be required. To avoid ecological effects, only flow above a determined MALF will be taken.

It is estimated that a minimum average pumping rate of 1,000 m^3/day (12 L/s) will be required assuming pumping is possible at least 50% of the time (6 months of the year). A further 200 m^3/day of pumped groundwater flow will also be required to meet demand during the grow-in period (up to 250,000 m^3/year).

Based on available information (ARC TP102, 1999), it can be assumed that winter flow will be in excess of MALF which is 60 L/s (5000 m^3/day). It is proposed that only flow above 60 L/s will be pumped from the Okiritoto Stream. Therefore, the average pumped stream take during winter of 1000 m^3/day is considered reasonable. Further modelling and stream gauging will need to be completed to confirm what stream MALF and pumping rates should be used to achieve the required volumes and minimise any effects.

Using the 2019/20 rainfall simulation results in a storage volume of approximately 100,000 m^3 is required within the off-stream storage location. This assumes that no pumping from the Okiritoto Stream was possible during the 2 months of no rainfall during summer.

The main benefit of this option is that the off-stream storage location has minimal ecological effects on the Okiritoto Stream. However, a large pump intake structure will need to be constructed within the stream. Also, the volume of earthworks and costs associated with this option will be much larger than the more passive on-stream storage dams.

7.0 Very Rough Order of Costs

A very rough order of CAPEX and OPEX (per annum) costs have been estimated and are shown in Table 3. The range of Capex costs indicate such things as whether earthworks materials can be sourced from site or are imported, whether soils require conditioning, whether slope stability improvements on reservoir faces are required and whether an estimated number of 2 to 4 groundwater bores is required. The irrigation pumping and reticulation around the course is assumed the same for all options. Unit rates are rough order indications based on indicative areas, volumes and percentages, and applying general engineering construction rates from QV costbuilder (www.qvcostbuilder.co.nz) and from engineering experience. Rates have not been verified by suppliers or contractors as this would be done later on once a scope of works is better defined and a preliminary design completed. Capex includes consenting, design, investigation, preliminary and general and MSQA costs. A contingency of 40% is added to cover unforeseen project costs that may arise.

Table 3: Very Rough Order CAPEX and OPEX Cost Estimates

	OPTION 1	OPTION 2	OPTION 3
CAPEX[1]	**\$(M)**	**\$(M)**	**\$(M)**
Storage and Streamworks	3.6 - 4.7	5.0 - 6.7	5.1 - 7.8
Groundwater	0.25 - 0.5	0.25 - 0.5	0.25 – 0.5
Irrigation	2.0	2.0	2.0
Contingency (40%)	2.3 - 2.9	2.9 - 3,7	2.9 - 4.1
TOTAL (ex GST)	**\$8M - \$10M**	**\$10M - \$13M**	**\$10M - \$15M**
OPEX[1,2]	\$300K pa	\$400K pa	\$430K pa

Notes:

1. *All CAPEX and OPEX costs are ex GST.*
2. *Based on 5% of CAPEX cost per year for maintenance.*

8.0 Conclusions

The following conclusions can be made:

1. We can conclude there is good potential for sufficient water supply to meet the proposed golf course irrigation demands using a combination of surface water and groundwater supplies within the site.
2. The three water supply options proposed in this report are not exhaustive but are expected to provide a good representation of the water supply options available.
3. Groundwater supply is expected to be available although pilot bore drilling/aquifer testing will confirm its yield and whether a flow of 200 m^3/day is available.
4. The Okiritoto Stream tributary is the largest catchment within the site on which on-stream storage dams can be constructed. Further investigation into the hydrology of this catchment is required to develop a long-term dam storage simulation.
5. Water supply storage volumes between an estimated 75,000 - 100,000 m^3 are required to meet the golf course irrigation demand based on 2019/20 rainfall simulation.

6. Option 1 proposes a single dam storage on the Okiritoto tributary with maximum take of up to 5% of the Okiritoto Stream Q_{50} baseflow during summer to meet irrigation demand.
7. Option 2 proposes a supplementary storage dam upstream of the Option 1 storage dam on the Okiritoto tributary to eliminate the need for baseflow take.
8. Option 3 proposes an off-stream storage location which requires 100% pumped inflow from the Okiritoto Stream. This option avoids the ecological effects of damming natural waterways but further investigation into the hydrology of the Okiritoto Stream is required to determine if the pumping volumes required can be realistically achieved above MALF. This investigation is expected to include detailed catchment modelling and continuous flow gauging to confirm Q_{50} baseflow and MALF.
9. Further assessment into the consenting requirements and ecological effects of each option would assist in selection of a preferred option.

9.0 References

Auckland Regional Council (1999) Okiritoto Catchment Water Resource Study. Technical Publication No. 102. Prepared by David T Bowden, March 1999.

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10.0 Limitations

This letter report has been prepared by Pattle Delamore Partners Limited (PDP) on the basis of information provided by Golf Strategy Group and Auckland Council. PDP has not independently verified the provided information and has relied upon it being accurate and sufficient for use by PDP in preparing the letter report. PDP accepts no responsibility for errors or omissions in, or the currency or sufficiency of, the provided information.

This letter report has been prepared by PDP on the specific instructions of Golf Strategy Group for the limited purposes described in the letter report. PDP accepts no liability if the letter report is used for a different purpose or if it is used or relied on by any other person. Any such use or reliance will be solely at their own risk.

Yours faithfully

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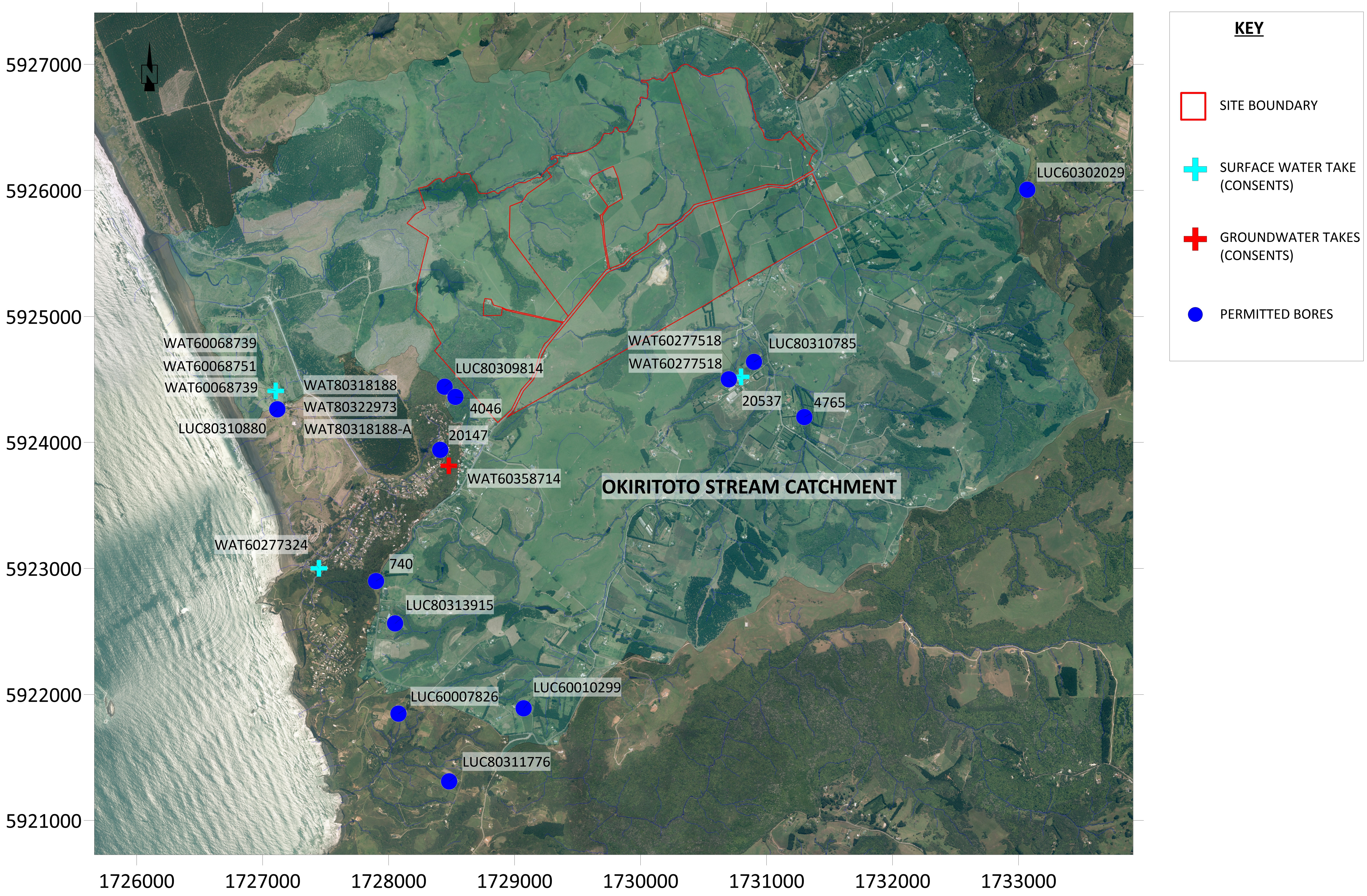

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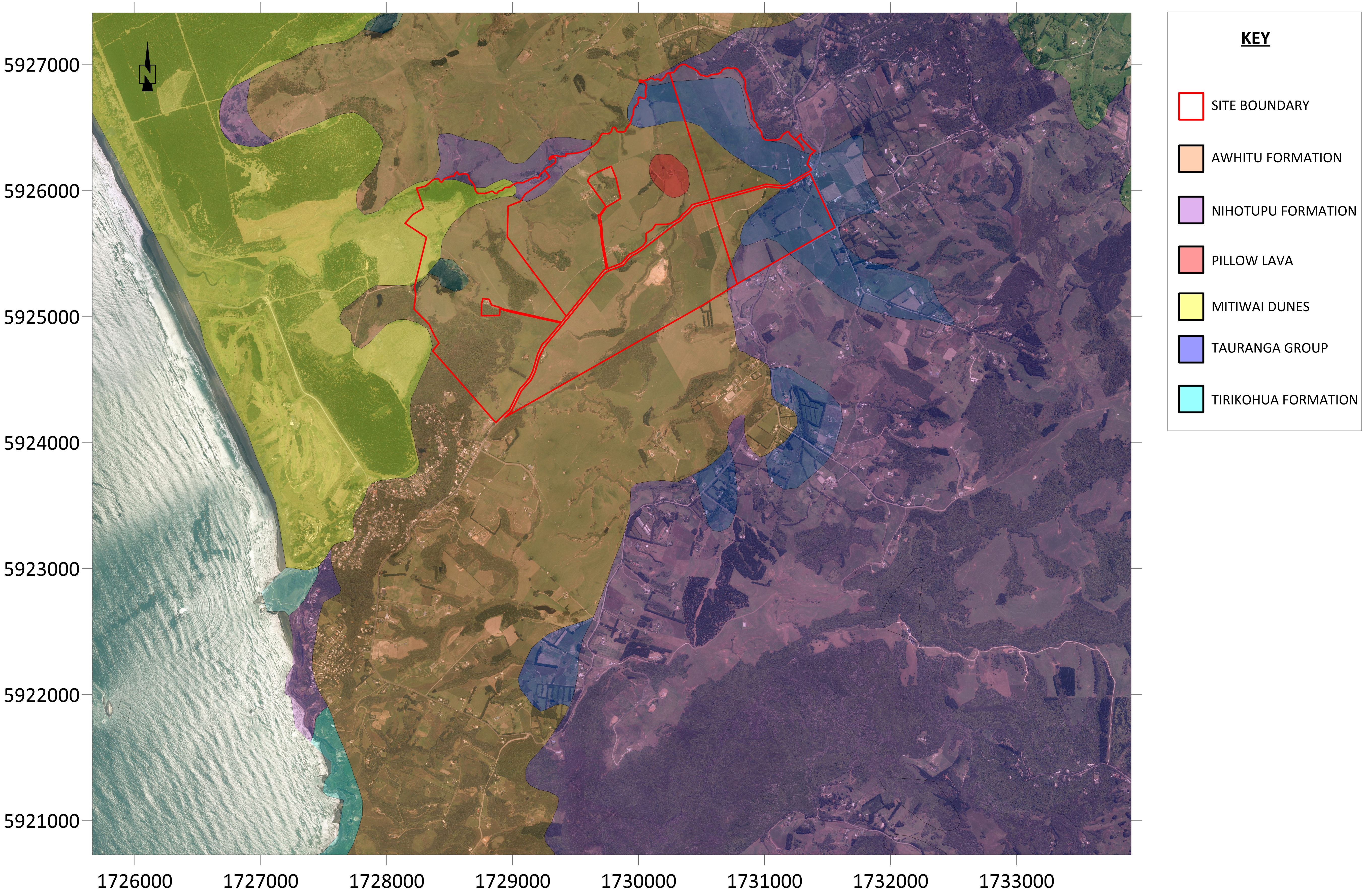
2. CADASTRAL AND TOPOGRAPHICAL INFORMATION DERIVED FROM LINZ DATA.

APPENDIX 1: OKIRITOTO STREAM CATCHMENT, CONSENTED WATER TAKES AND PERMITTED BORE LOCATIONS



APPENDIX 2: REGIONAL GEOLOGY

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