WILLIAMSON WATER ADVISORY

Adding value through sustainable & efficient use of a natural resource

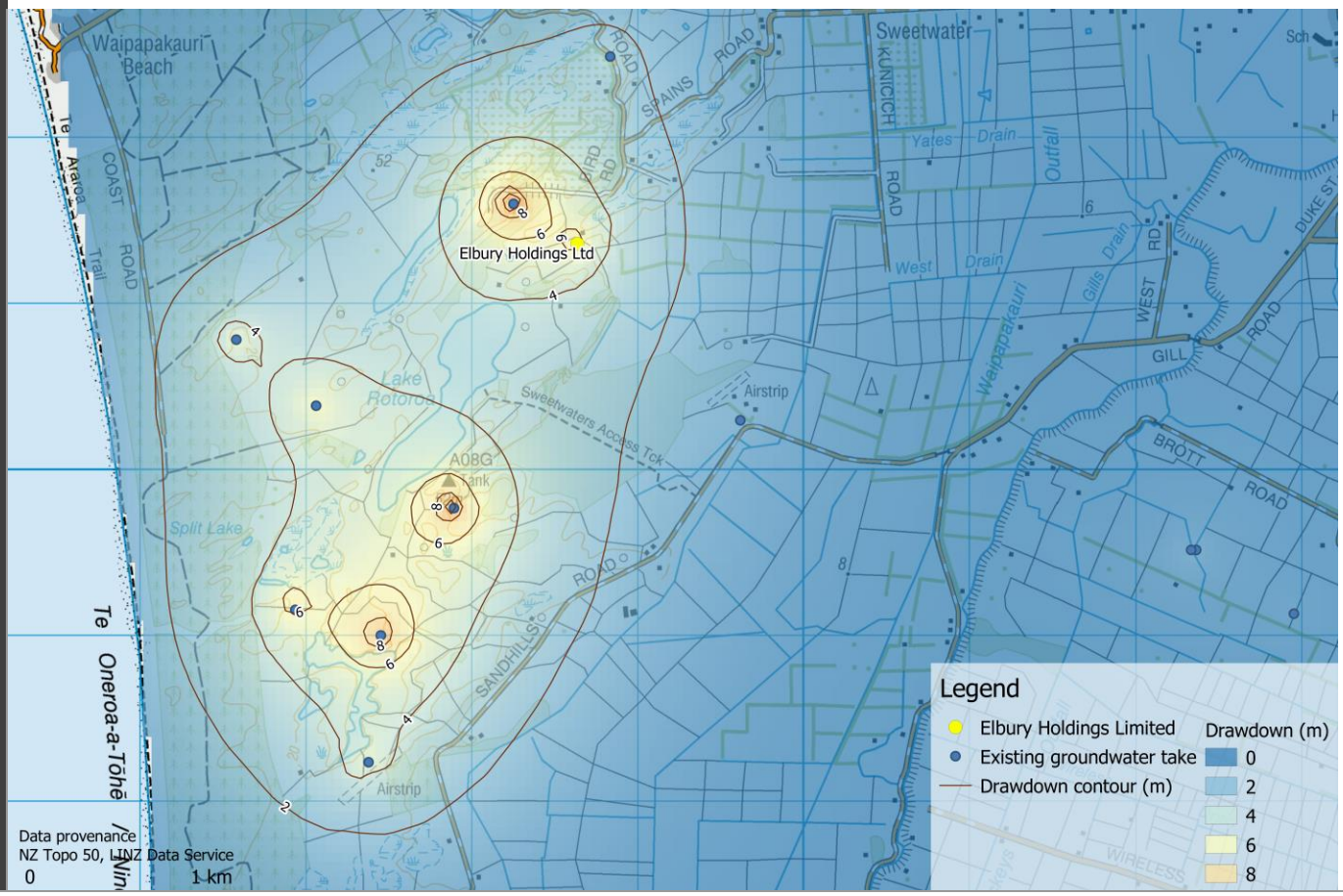
Irrigation Water Take Consent

Resource Consent Application & Assessment of Environmental Effects

ELBURY HOLDINGS LIMITED

WWA0046 | Rev. 3

3 August 2018



Irrigation Water Take Application

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Client name:	Elbury Holdings Limited
Project manager:	Jon Williamson
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Williamson Water Advisory

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Document history and status

Rev	Date	Description	By	Review	Approved
2	20 July 2018	Draft for client review			Jon Williamson
3	3 August 2018	Revised following client feedback			

Distribution of copies

Rev	Date issued	Issued to	Comments
2	20 July 2018	Elbury Holdings Ltd	Draft for client review
3	3 August 2018	Elbury Holdings Ltd	

Contents

1. Introduction

This document and attachments, prepared on behalf of Elbury Holdings Limited, comprise a Resource Consent Application and an Assessment of Environmental Effects report for irrigation of a 75-hectare Total Orchard Area[1] development. The development comprises two properties, both within the Awanui region of Northland. The larger of the two (92 hectares) is located at the terminus of Bird Road and the smaller (49 hectares) at Sandhill Road.

The background details of this application using Northland Regional Council's (NRC) "Application for Resource Consent" form is provided in **Appendix A**. Further details of various items where marked on the form are provided within **Section 2**.

1.1 Report Structure

The report comprises:

- **Section 2** – a description of the proposed activity and suggested consent conditions;
- **Section 3** - background information for the application area;
- **Section 4** – an assessment of environmental effects; and
- **Section 5** – summary and conclusions.

[1] Total Orchard Area was selected as the area metric for calculation of the irrigation water daily application volume by the Commissioners at the Hearing of 17 groundwater take applications for the Motutangi-Waiharara Water User Group in June 2017. The volume of water applied to this Total Orchard Area was 25 m^3/ha/day (see paragraphs 132 and 133 of the Commissioners Decision - June 2018). In the Commissioner's Decision they defined the Total Orchard Area as the area where the canopy occupies 80%.

2. Description of Proposed Activity

2.1 Location

Figure 1 provides a map of the project area. The properties occupy a total area of approximately 142 hectares, of which 75 hectares are to be devoted to orchard. As previously indicated, the properties are located at the end of Bird Road and Sandhill Road, respectively, in the Awanui region of Northland. The proposed production bore is located within the Bird road property.

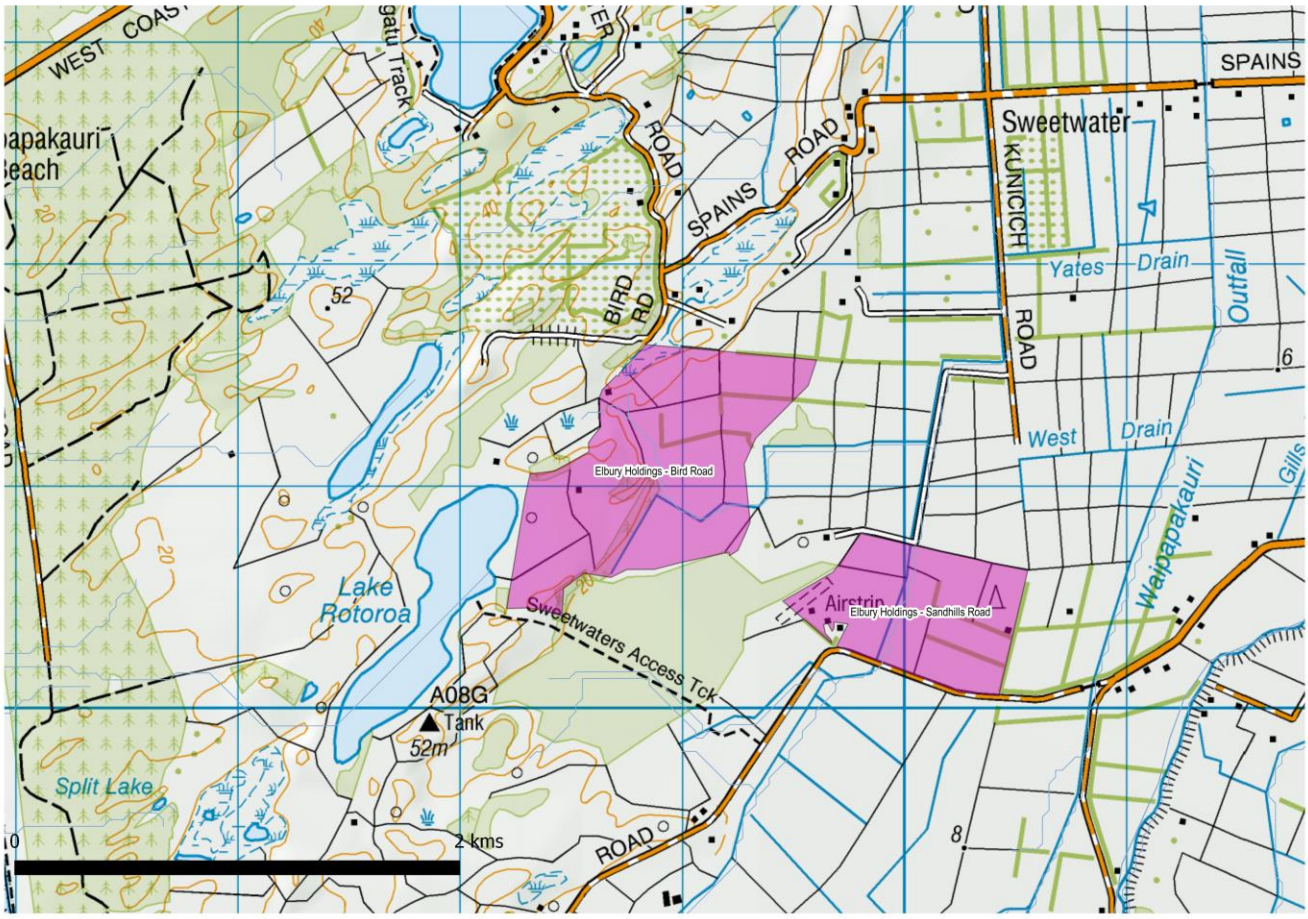


Figure 1. Project locality map.

2.2 Description of Proposed Activity

The resource consent application for Elbury Holdings Limited seeks to take and use groundwater from a new bore to develop and irrigate a new avocado orchard. The Total Orchard Area of the property is 75 ha.

This groundwater take is to irrigate the avocado orchard based on the assumption that 67% of the 75 ha Total Orchard Area will comprise the canopy of the crop. The take will be exercised from October to April, in accordance with the following conditions:

- Maximum daily volume of 1,875 m^3/day; and
- Maximum annual volume of 200,000 m^3/yr.

The maximum daily volume has been calculated at 25 m^3/ha/day over the Total Orchard Area, in accordance with the decision made in the Motutangi-Waiharara Water User Group (MWWUG) decision[2].

The maximum annual volume has been calculated from the canopy area, which for this orchard (given the topographic and existing building constraints) is 67% of the Total Orchard Area or 50 ha[3]. The maximum annual volume has been calculated on the basis of 400 mm/annum, which is consistent with the Council Officers' recommendation in the MWWUG Hearing. This irrigation requirement is adequate to meet up to a 1 in 10 years drought requirement (**Section 3.1.4**).

[2] The maximum daily volume can also be calculated on the basis of 41.6 m^3/day per canopy hectare (4.16 mm irrigation system capacity) on the basis of a peak daily soil requirement of 3.74 mm/day per canopy hectare and allowing for 10% system losses in delivery and application.

[3] The maximum annual volume can also be calculated on the basis of approximately 96 days at full daily volume, which is equivalent to approximately 400 mm/year. In practice the maximum daily rate will only be required on consecutive days during the peak of summer and when this coincides with drought.

3. Background Information

3.1 Site Conditions

3.1.1 Soils

There is no Landcare Research S-map soil data available for this site, however there is pre S-map Fundamental Soil Layers information which describes the two main soil as sandy brown soils and acid mesic organic soils, with the following properties[4]:

- ***Physical properties*** – The brown soils have stable topsoil with well-developed polyhedral and spheroidal structure. The organic soil has a low bulk density, low bearing strength, and high total available water content.
- ***Chemical properties*** – The brown soils have low to moderate base saturation, and the clay minerals are dominantly mica and vermiculite. The organic soil has a high cation exchange capacity and are strongly acidic, with nutrient deficiencies.
- ***Biological properties*** – The brown soils contain large populations of active soil organisms, particularly earthworms. Whereas, soil organisms are restricted in the organic soil due to the anaerobic conditions. The high carbon to nitrogen ratios indicate slow decomposition.

3.1.2 Geology

The project site is underlain by the Aupouri Aquifer, consisting of an extensive sequence of fine sands, interspersed with sporadic iron pan, peat, and silt near the surface and shellbed in the deep layer. This consists of Pleistocene and Holocene unconsolidated sedimentary materials deposited in beach and dune (abandoned shorelines and marine terraces) and associated alluvial, intertidal estuarine, shallow marine, lakebed and wetland environments.

Towards the east coast, the sand becomes unconsolidated to poorly consolidated with sand, peat, mud, and shell deposits. Towards the west coast, the geology becomes primarily loose sand in mobile dune systems.

With increasing depth, the occurrence of shellbed layers increases. The shellbeds comprise layers that typically range in composition from 30-90% medium to coarse shell and 10-70% fine sand. The shellbed aquifer typically resides from approximately 70 to 120 mBGL. Underlying the shellbed aquifer are basement rocks of the Mount Camel Terrain, which typically comprise hard grey to dark green / black igneous rocks described in Isaac (1996) as intercalated basalt and basaltic andesite lava, pillow lava, rhyolitic tuff, tuff-breccia, conglomerate, sandstone and mudstone.

3.1.3 Hydrogeological Interpretation

The sands deposited on the east and west coast are generally younger and more permeable than the weathered sand in the central area. The shell content in the sand increases with depth, and the shell-rich sand layer is the most prolific water yielding aquifer in the region and hence the target for irrigation bores.

The aquifer system is unconfined at the surface but behaves in a manner that suggests a progressive degree of confinement with depth (leaky confinement). There is no well-defined regionally extensive confining layer but there are numerous low-permeability layers (e.g. iron pan, brown (organic) sand, silt, peat) that vary in depth and thickness, which over multiple occurrences collectively provide a degree of confinement that leads to the development of vertical pressure gradients.

3.1.4 Irrigation Requirements

The peak water requirement is 41.6 m^3/day per canopy hectare, which is equivalent to 4.16 mm per day. The irrigation requirement was simulated on a daily basis with the Soil Moisture Water Balance Model (SMWBM) using historical rainfall and evaporation data over a 59-year period from 1957 to 2016. The simulation results are

[4] All information is collected from the Landcare Research Soils Portal: https://soils.landcareresearch.co.nz/describing-soils/nzsc/soil-order

portrayed statistically on a monthly basis in **Figure 2**, which is a box and whisker plot showing the monthly median, lower quartile (25th percentile), upper quartile (75th percentile) and minimum and maximum recorded monthly values. The graph shows the seasonal irrigation profile and likelihood of water requirements each month.

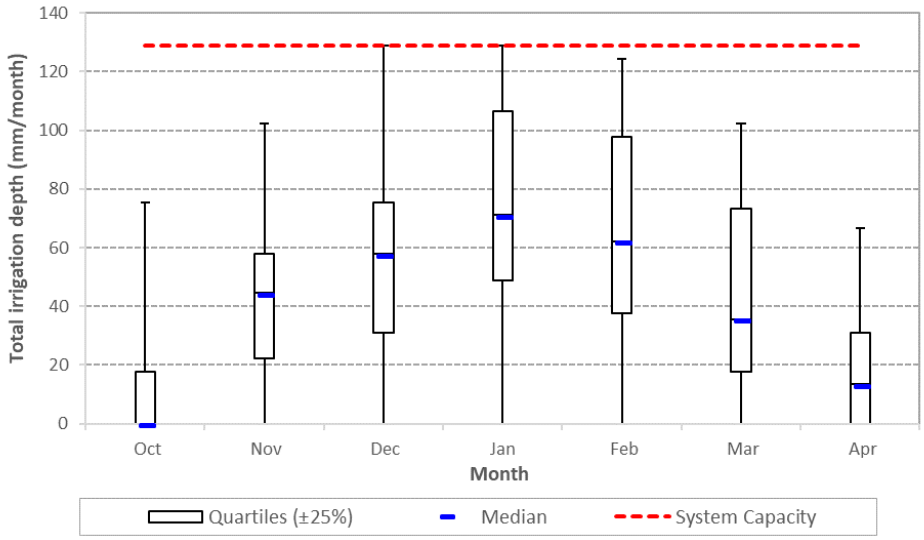


Figure 2. Simulated monthly statistical irrigation profile.

During the irrigation season, the rate of application will remain the same, but the number of days between irrigation events will increase during the shoulders of the season (i.e. typically in spring and autumn), which is exemplified in the monthly statistics shown in **Figure 2**.

Table 1 provides information on the frequency of monthly irrigation requirements and the number of days irrigation is likely required. The 1-year recurrence interval represents the typical monthly requirements and indicates that on average irrigation will not be required in October and April, and between November and March will vary from 18 mm to 47 mm per month with an annual total of 250 mm.

In a 10-year drought year, the irrigation requirement for the season is likely to be approximately 400 mm, with peak monthly totals up to approximately 120 mm, hence the amount of water being applied for is adequate to fully meet the requirements in the event of a 10-year drought.

Table 1. Frequency of monthly and annual irrigation requirements (mm) and days of irrigation [days].

Average Recurrence Interval	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Annual
1 yr	0 [0]	23 [6]	31 [7]	47 [11]	40 [10]	18 [4]	0 [0]	250 [60]
2 yr	0 [0]	44 [11]	58 [14]	69 [17]	62 [15]	36 [9]	16 [4]	307 [74]
4 yr	18 [4]	58 [14]	76 [18]	107 [26]	98 [24]	74 [18]	31 [7]	369 [89]
5 yr	18 [4]	62 [15]	76 [18]	107 [26]	98 [24]	80 [19]	40 [10]	382 [92]
10 yr	31 [7]	76 [18]	104 [25]	117 [28]	116 [28]	84 [20]	50 [12]	401 [96]
100 yr	53 [13]	102 [25]	124 [30]	129 [31]	124 [30]	100 [24]	64 [15]	545 [131]

Table 2 provides the orchard water balance under dryland and irrigated conditions and **Figure 3** shows the mean monthly seasonal breakdown of this data. The data represents the mean annual water balance components from the 59-year simulation. It is evident that under the irrigated orchard profile, soil moisture content is typically elevated during summer (as would be expected), and surface runoff, sub-soil drainage, soil evaporation and canopy interception all increase.

Avoidable losses due to surface runoff do not change appreciably, and the additional runoff that has occurred is due to excess rainfall rather than too much irrigation, demonstrating that the irrigation applications of 4.16 mm/day are efficient.

Table 2. Summary of average annual water balance components under irrigated and unirrigated profiles (mm/yr unless specified otherwise).

Annual Average	Dryland	Irrigated
Average Soil Moisture Content (mm)	92	104
Sub-Soil Drainage	452	522
Surface Runoff	93	105
Soil ET	467	547
Canopy Interception	179	284
TOTAL	1,191	1,458

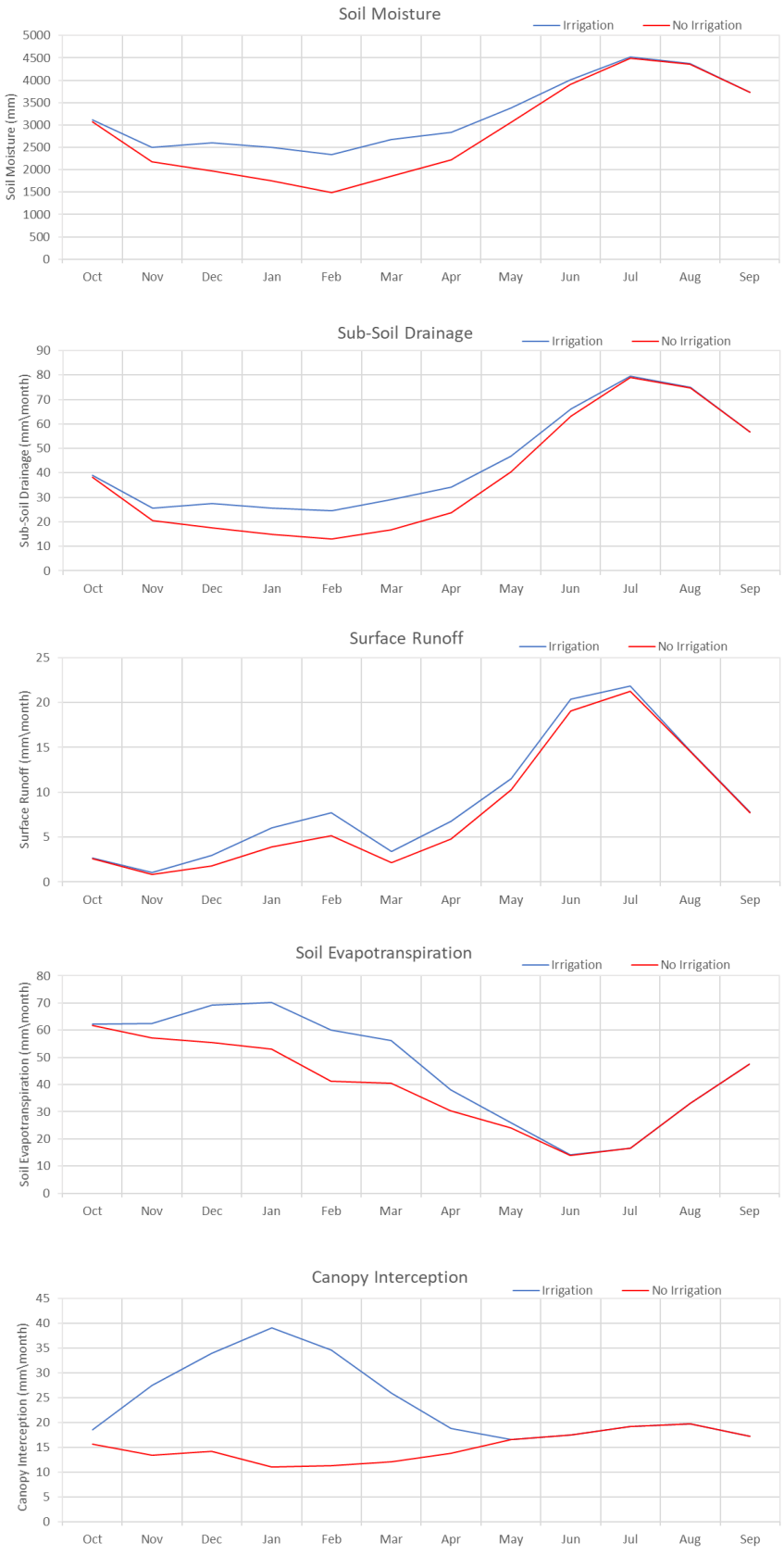


Figure 3. Comparison of water balance components.

3.2 Neighbouring Bore Information

There are 75 bores registered within the NRC database within a 2 km radius of the Elbury Holdings Limited site (**Figure 4**). Statistics on the 75 bores are as follows:

- 65 are active, 9 are inactive and 1 is pending.
- The bores range in depth from 0 m to 105.5 m with an average of 43.4 m.
- 51 bores have information attached in terms of the purpose of the bores:
  - one is for domestic and irrigation;
  - four are for domestic and stock;
  - four are for irrigation;
  - eight are for monitoring;
  - ten are for stock;
  - ten designated as exploration; and
  - 14 are for domestic purposes.

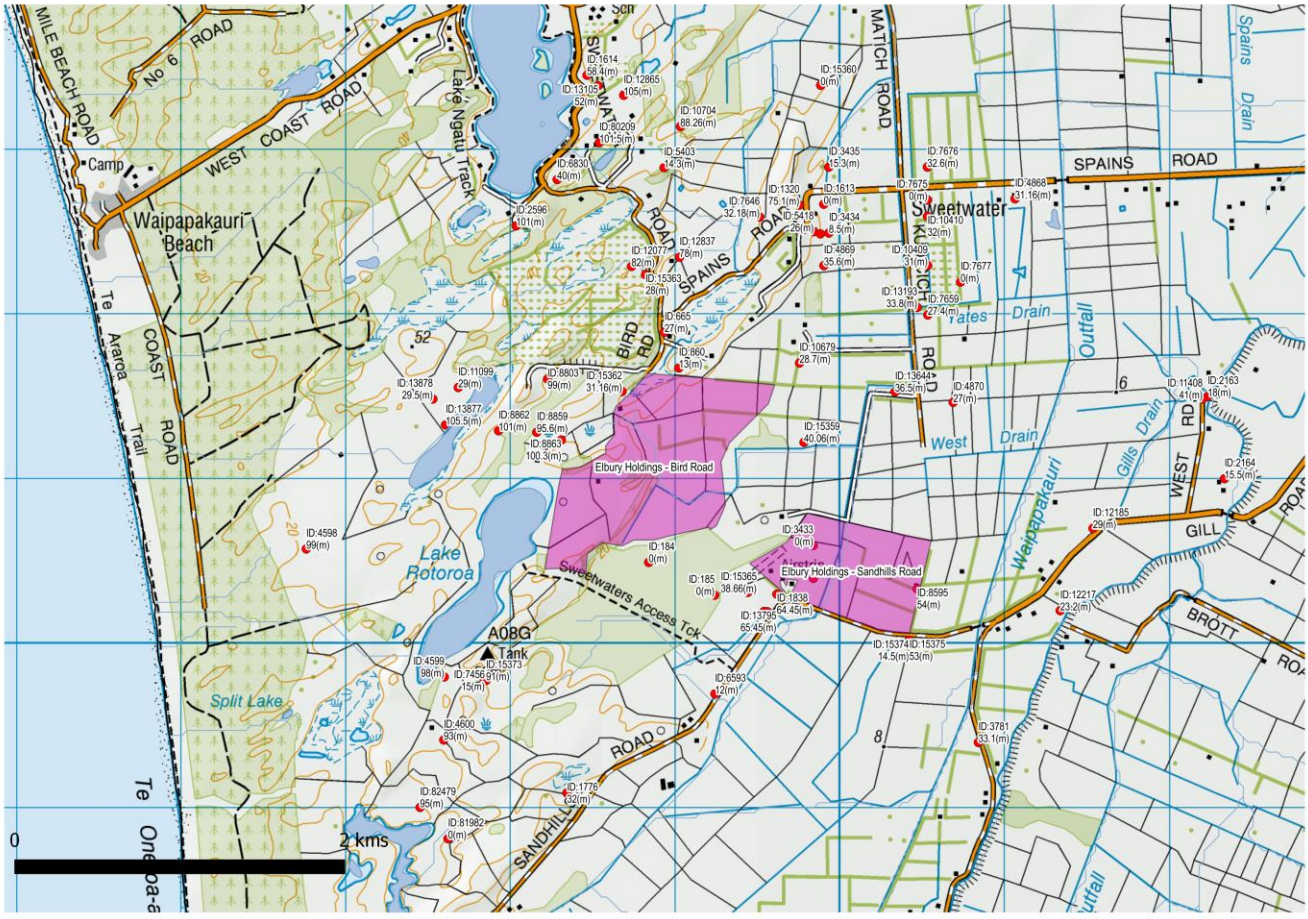


Figure 4. Neighbouring bores within a 2 km radius of Elbury Holdings Limited.

3.3 Allocation Zones

The Aupouri Peninsula Aquifer is divided into different allocation zones for management purposes. The proposed bore of Elbury Holdings Limited property is located within the Aupouri - Sweetwater allocation zone. The allocation limit, current level of allocation, and the level of allocation should this consent be granted are shown in **Table 3**.

Table 3 shows that the granting of the additional 200,000 m^3/yr for the Elbury Holdings Limited application will take the allocation status to 92% of the allocation limit, hence under the pNRP this consent maintains Discretionary Activity status.

Table 3. Aupouri Aquifer Limits[5] and Allocation Status.

Sub-aquifer	Allocation Limit		Allocation Status (Current)		Allocation Status (if Granted)	
	m^3/year	% Mean Annual Recharge	m^3/year	%	m^3/year	%
Aupouri - Sweetwater	4,675,000	35	4,124,480	88	4,324,480	92

[5] According to NRC's allocation maps at http://gis.nrc.govt.nz/LocalMaps-Viewer/?map=895e0785f7054d47b10a72edc38022dc

4. Assessment of Environmental Effects

The proposed take would draw water from the Aupouri – Sweetwater aquifer. The cumulative drawdown profiles at 150-days under current allocation, and with the proposed take included, were evaluated using analytical solutions described in the following sections. A proposed take of 1,875 m^3/day, an annual volume of 281,250 m^3/year was evaluated in the model, which is approximately 40% greater than the annual allocation sought in this application (200,000 m^3/year). Based on this assumption, the environmental effects discussed below can be considered extremely conservative.

The methodology and results of the groundwater and surface water impact analysis are detailed in **Appendix B.**

4.1 Pumping Interference Effects

Drawdown due to the proposed take was analysed using the Feather and Williamson Solutions (unpublished) and Theis (1935). The parameters in the model were calibrated against drawdown observed 250 m west of the first production bore (PB6) at the neighbouring Sweetwater Station. Data of which was obtained from the Sweetwater Station Farms Annual Monitoring Report (Jacobs, 2017).

A maximum drawdown ranging between of 10.6 m (Feather and Williamson) and 12.4 m (Theis) was estimated in the deep aquifer adjacent to the pumping bore. A drawdown of 0.14 m was estimated near the pumping bore in the shallow aquifer with the Feather and Williamson Solution.

The Theis solution (which does not consider aquifer and aquitard storage) was the more pessimistic estimate of the two drawdown solutions considered. Based on the Theis equation, the cumulative drawdown impact on neighbouring bores ranged from 0.4 m to 20.2 m in the deep aquifer.

The proposed take is unlikely to cause significant additional drawdown for majority of the existing bores. A maximum additional drawdown of 0.8 m (Feather and Williamson) and 1.9 m (Theis) was estimated at the FNDC bore location. This level of drawdown is insignificant in the context of the available drawdown of the aquifer, which is greater than100 m.

The interference effects on existing groundwater uses, considering the available drawdown of the aquifer, is considered less than minor.

4.2 Surface Water Effects

As discussed in **Appendix B**, there are four adjacent surface water features that may be impacted by this proposal:

- Unnamed swamp to northeast (0.2 km);
- Lake Rotoroa to southwest (0.6 km);
- Unnamed swamp to northwest (0.6 km); and
- Unnamed dune lake to northwest (0.7).

The predicted maximum cumulative drawdown in the shallow aquifer at the location of these water bodies is less than 0.35 m. A 0.35 m shallow aquifer drawdown impact would translate to approximately 0.105 m change in water level in a standing water body, assuming a shallow aquifer porosity of 0.3.

Lake Rotoroa is the most hydrologically and ecologically significant of the surface water bodies identified above. The Land Air Water Aotearoa (LAWA) website describes Lake Rotoroa[6] as:

- part of the Sweetwater group of lakes;
- fairly large (33.7 ha);

[6] https://www.lawa.org.nz/explore-data/northland-region/lakes/lake-rotoroa/

- relatively deep (7.3 m); with
- no defined inflows or outflows.

Lake Rotoroa (and we have assumed the same for the others) is classified as a shallow lake under the Prpn, given the depth being less than 10 m. Policy D.4.15 (Minimum levels for lakes and wetlands) of the pRPN states the following under point 2):

> "for shallow lakes (less than or equal to 10 metres in depth), median lake levels are not changed by more than 10 percent, and there is less than a 10 percent change in mean annual lake level fluctuation and patterns of lake level seasonality (relative summer versus winter) remain unchanged from the natural state."

On this basis, if we assume the average depth of the lake is half the maximum depth, 10% is equivalent to 0.365 m and therefore the maximum level of effect indicated (0.105 m) is well within the minimum level for the lake. The pattern of lake level fluctuation (high in winter and low in summer) will remain unchanged as irrigation ceases over winter.

Therefore, the impact on surface water due to proposed abstraction in the deep aquifer is considered less than minor.

4.3 Saline Intrusion

Saltwater lateral migration along the base of the shellbed will be a more likely mechanism due to the low permeability bedrock underlying the deep shellbed aquifer.

The proposed take is located in the central sand area 2.9 km from the nearest coastline. Based on the Ghyben–Herzberg relation recent monitoring data from NRC Monitoring Piezometer MW1b, shown in **Figure B2** there is adequate pressure to prevent lateral inland migration of saltwater. Further details regarding the analysis of potential saline intrusion is provided in **Appendix B3.1**. The potential drawdown resulting from the groundwater take proposed in this application is unlikely to reverse the pressure gradient along the coast.

The impact on saltwater intrusion due to proposed take will be less than minor.

4.4 Ground Settlement

The potential maximum ground settlement was estimated from the cumulative drawdown in **Appendix B**.

Within 1.5 km of the proposed take, the estimated cumulative subsidence was 0.076 m, based on calculations assuming a maximum drawdown of 0.3 m and 20.2 m in the shallow and deep aquifers, respectively. In a rural setting, settlement effects of this magnitude are less than minor for the following reasons:

- there is no sensitive urban infrastructure such as water or wastewater mains or high-rise buildings to rupture or crack; and
- the changes in land surface due to farm machinery (e.g. rotary hoeing) would likely mask impacts of this magnitude (<0.3 m) if materialised.

In summary, the potential settlement effects are considered less than minor.

4.5 Water Quality

The potential risk to water quality from the leaching of fertilisers and pesticides that may be associated with horticulture is not a relevant consideration for a water take application under the current Northland Regional planning framework. With reference to the effects from horticultural sprays the Commissioners for the MWWUG water take applications stated in their Hearing Decision Report (June 2018) that:

"such are not matters that are directly engaged by the present applications for water abstraction. Accordingly, we have no present jurisdiction to consider those putative effects. If resource (or other) consent is subsequently required, then such will need to be applied for and considered at the appropriate time".

Nevertheless, there are a range of factors that make the leaching of fertiliser and pesticides unlikely to impact water quality:

- In practice orchardists in this area tend to apply fertiliser efficiently via fertigation as part of their irrigation water using a small dosage regularly, which is driven by both the soil conditions (i.e. high permeability and lacking in nutrients) and economic considerations.
- Inefficient irrigation practice will lead to root rot, thus because orchardists will actively avoid this, excessive leaching of nutrients is unlikely.
- Both fertiliser and approved pesticides are applied in accordance with permitted activity rules within the pRPN and rules needing to be met to become certified under the AvoGreen Assured program by the Avocado Industry Council Ltd. One of the key aims is "environmental sustainability by only using sprays when required".
- Due to the presence of significant amounts of organic matter within the shallow sand deposits, shallow groundwater is likely to be reducing. Under such conditions, nitrate concentrations are likely to be low in groundwater due to denitrification within the aquifer system. Available groundwater quality data from the Northland Regional Council confirms this assertion. The presence of organic matter is also likely to substantially decrease the mobility of any pesticide compounds prone to leaching.

4.6 Consideration of Alternatives

An AEE must include a description of alternative locations or methods for undertaking an activity, if it is likely that the activity will result in any significant adverse effect on the environment.

The effects of the proposed taking and using of groundwater were assessed above as being no more than minor on the environment and less than minor on other groundwater users. As such, no alternatives have been considered for this proposal.

5. Summary and Conclusions

Elbury Holdings Limited own a 142-hectare farm of which they are seeking consent to develop an orchard comprising 75-hectares of Total Orchard Area. The farm includes two separate properties at the end of Bird Road and adjacent to Sandhill Road, Awanui. This application seeks to establish a new groundwater take to facilitate the development of the orchard.

The groundwater take will be exercised from October to April, in accordance with the following volumes:

- Maximum daily volume of 1,875 m^3/day; and
- Maximum annual volume of 200,000 m^3/yr.

A consent duration of 30 years is sought, subject to a lapse period of 5 years.

If granted, this consent combined with the existing consents, will take the allocation status for the Aupouri-Sweetwater allocation zone to approximately 92% of full allocation. The activity status thus remains Discretionary.

The AEE has demonstrated that the potential adverse effects of the proposed water take and use on the environment will be less than minor, and the effects on persons will also be less than minor.

6. References

Feather and Williamson (currently unpublished). An Analytical Tool for Drawdown Analysis in Multi-Layered Aquifer Systems. (App soon to be publicly available on www.wwa.kiwi)

Hemker, C.J., and Maas, C., 1987. Unsteady flow to wells in layered and fissured aquifer systems. Journal of Hydrology, 90 (1987) 231-249.

Hunt, B. and Scott, D., 2007. Flow to a well in a two-aquifer system. Journal of Hydrologic Engineering, 12(2), 146-155.

HydroGeo Solutions, 2000. Aupouri Aquifer Sustainable Yield Groundwater Modelling Study. Consultancy report prepared for Northland Regional Council.

Lincoln AgriTech, 2015. Aupouri Aquifer Groundwater Model. Consultancy report prepared for Northland Regional Council.

SKM, 2007b. King Avocado Orchard Groundwater Take Consent Application (AEE Final). Consultancy report prepared for King Avocado Limited.

Williamson Water Advisory, 2017. Motutangi-Waiharara Groundwater Model Factual Technical Report – Modelling. Consultancy report prepared for Motutangi-Waiharara Water Users Group.

Jacobs, 2017. Sweetwater Farms Annual Monitoring Report. Consultancy report prepared for Landcorp Farming Limited (Landcorp) and Te Runanga O Te Rarawa.

Appendix A. Form A - Application For Resource Consent

APPLICATION FORM FOR RESOURCE CONSENT

NORTHLAND REGIONAL COUNCIL

Putting Northland first

Whāngārei Office	Phone:	(09) 470 1200
	Fax:	(09) 470 1202
Kaitāia Office	Phone:	(09) 408 6600
Ōpua Office	Phone:	(09) 402 7516
Dargaville Office	Phone:	(09) 439 3300
Free Phone		0800 002 004
E-mail		mailroom@nrc.govt.nz
Website		www.nrc.govt.nz

This application is made under Section 88/127 of the Resource Management Act 1991

To: Consents Department
Northland Regional Council
Private Bag 9021
Whāngārei Mail Centre
Whāngārei 0148

IMPORTANT NOTES TO APPLICANTS

(a) Please read fully the notes below and the Information Brochures and Explanatory Notes available from the Council, before preparing your application and any supporting information.

(b) The Resource Management Act 1991 sets out the information you must provide with your application for a resource consent. If you do not provide adequate information, your application cannot be received nor processed by the Council and will be returned to you. If you are unsure of what information should be included with your application, please contact the Council before submitting the application.

(c) Applications require notification (public advertising calling for submissions) unless the Council is satisfied that the adverse effects on the environment of the activity for which consent is sought will be minor; and written approval has been obtained from every person who the Council is satisfied may be adversely affected by the granting of the consent. The Council also has available a form "Form 8A – Affected Person's Written Approval", to help you record such approvals for applications that may be processed without public notification.

PART A – GENERAL

APPLICANT	Full Names
(1) Full Name of Applicant(s): (in full e.g. Albert William Jones and Mary Anne Jones. For Companies, Trusts and other Organisations, commonly used name)	Elbury Holdings Limited
	Attention: Fiona King
Phone Number – Business:	Fax:
Home:	09-406-7277 Mobile: 027-498-8133
E-mail:	elbury@xtra.co.nz

For applications by a company, private trusts or other entity/organisations, the Directors; Trustees and Officers' full names must be supplied and Section (12) completed and signed.

(2) Postal Address: (in full)	345 State Highway 1
	RD2
	Kaitaia 0482

(3) Residential Address: (if different from postal address)	

Application Form continued on next page

(4) Address for Service of Documents: (if different from postal address e.g. Consultant)	Jon Williamson (jon.williamson@wwa.kiwi) c/o Williamson Water Advisory PO Box 314 Kumeu, 0812 Auckland

(5) Owner/Occupier of Land/ Water Body: (if different from the Applicant)	

(6) Type(s) of Resource Consent sought from the Regional Council:

You will need to fill in a separate Assessment of Environmental Effects Form for each activity.
These forms can be obtained from the Northland Regional Council.

Coastal Permit

☐ Mooring ☐ Marine Farm ☐ Structure ☐ Pipeline/Cable

☐ Other (specify)_____

Land Use Consent

☐ Vegetation Clearance ☐ Quarry ☐ Structure in/over Watercourse

☐ Earthworks ☐ Construct/Alter a Bore ☐ Dam Structure

☐ Other (specify)_____

Water Permit

☐ Stream/Surface Take ☐ Damming ☒ Groundwater Take ☐ Diverting Water

☐ Other (specify)_____

Discharge Permit

☐ Domestic Effluent to Land ☐ General Discharge to Land ☐ Farm Dairy Effluent to Land/Water

☐ Air ☐ Water

☐ Other (specify)_____

(7) Other Resource Consents required from the District Council:

Where other Resource Consents are required for the same activity, they must be applied for at the same time.
Not doing so will delay the processing of this application.

What other Resource Consents are required from the District Council?

☒ None ☐ Land Use Consent ☐ Subdivision Consent

Have the applications been made? ☐ Yes ☐ No

(8) Description of the Activity:

Please briefly describe the activities and duration for which Consent(s) are being sought. It is important you fill this out correctly, as the Council cannot grant Consent for any activity you do not apply for.

Refer to Section 2.2 in Assessment of Environmental Effects

Application Form continued on next page

(9) Location of Property/Waterbody to which Application relates:

Describe the location in a manner which will allow it to be readily identified, e.g. street address, legal description, harbour, bay, map reference etc. Attach appropriate plans and/or diagrams.

Property Address: (see rate demand) Bird Road Locality: Awanui, Kaitaia

Legal Description: Lot 2 DP134738 / Lot 2 DP211844 Blk: _____ SD: _____

Other Location Information: _____

PART B – ASSESSMENT OF EFFECTS ON THE ENVIRONMENT

You must include an assessment of the effects of your activity on the environment as part of your application.

The Resource Management Act 1991 requires that each application include an assessment of the actual and potential effects of the activity on the environment in accordance with the Fourth Schedule.

To assist you to supply this assessment of effects, the Council has prepared specific forms for various consent activities. For minor activities, all that will be required is for you to complete the specific form. Where the potential effects of the activity are more significant, we recommend you undertake a full assessment of effects, with professional assistance if necessary.

If you are unsure of what information to include with you application and the assessment of effects, please contact the Council before submitting your application. A pre-lodgement meeting with relevant Consent Staff is recommended.

PART C – GENERAL

(10) Renewal of an Existing Resource Consent:

☐ Yes ☒ No ☐ A change in conditions of a current Resource Consent

(11) Fee/Deposit Enclosed with Application(s):

Application to be processed as: ☐ Notified ☐ Limited Notified ☐ Non-notified

☐ Coastal Permit: $ _____ ☐ Land Use Consent: $ _____

☒ Water Permit: $ _____ ☐ Discharge Permit: $ _____

☒ Bore Permit: $ 3296 ☐ Change Conditions: $ _____

(12) Signature of Applicant(s) or Persons authorised to sign on behalf of Applicant(s):

IMPORTANT NOTES TO APPLICANTS

(a) Your application must be accompanied by the minimum fee (deposit) as determined by the Council. A schedule of the fee/deposits for different consent applications is annexed. Please note that applications by private trusts and other group entities require the personal guarantees of the Trustees and/or Officers for the payment of costs to be submitted with the application.

- For complex applications, the Council may require an additional deposit pursuant to Section 36(3) of the Act, based on the estimated costs for processing such complex applications and may require progressive monthly payments during consent processing.
- The final fee is based on actual and reasonable costs including disbursements and where this fee exceeds the fee/deposit, the additional fee is subject to objection and appeal.

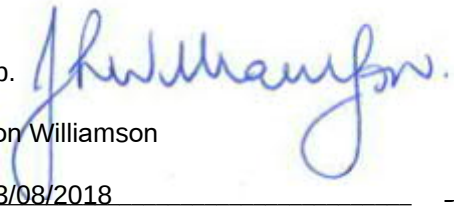
(b) All accounts are payable by the 20th of the month following the date of invoice. Any actual and reasonable costs, including but not limited to legal costs, debt collection fees or disbursements incurred as a result of any default in payment, shall be recoverable from the Applicant and is so notified in compliance with the Credit Contracts and Finance Act 2003. Submitting this Application authorises the Council to, if necessary, provide your personal information to a Credit Reporter in order to employ in its debt collection services in compliance with the Credit Reporting Privacy Code 2004, should payment default occur.

(c) Resource Consents usually attract an annual fee to recover the reasonable costs of the Council's monitoring, supervision and administration of the Consent during its term.

(d) The information you provide is official information. It will be used to process the application and, together with other official information, assist the management of the region's natural and physical resources. Access to information held by the Northland Regional Council is administered in accordance with the Local Government Official Information and Meetings Act 1987 and the Privacy Act 1993.

Application Form continued on next page

I/we declare that, to the best of my/our knowledge and belief, the information given in this Application and attached Assessment of Environmental Effects is true and correct. I/we unconditionally guarantee jointly and severally to pay the actual and reasonable costs of processing this Application as and when charges become due and payable. I/we acknowledge that I/we understand the consequences of sig

Signature: pp.  **ignature:** _____

Full Name (print): Jon Williamson **ull Name** (print): _____

Date: 03/08/2018 **ate:** _____

Continue with Trustees' and Authorised Officers' signatures below, as necessary.

Personal details and signatures of Trustees*, or Officers authorised to sign on behalf of and to bind Trusts, Societies and Unincorporated Entities.	*** Private and Family Trusts only**
Full Name and Status: (Trustee, Officer etc)	
Full Residential Address:	
Signature:	

Full Name and Status: (Trustee, Officer etc)	
Full Residential Address:	
Signature:	

Full Name and Status: (Trustee, Officer etc)	
Full Residential Address:	
Signature:	

Full Name and Status: (Trustee, Officer etc)	
Full Residential Address:	
Signature:	

CHECKLIST – Have you remembered to…

- ☐ Complete all details set out in this Application Form
- ☐ Include an Assessment of Effects of the activity on the environment, set out in the attached form
- ☐ Sign and date the Application Form
- ☐ Include a Site Plan
- ☐ Include the appropriate fee as set out in the *"Schedule of Minimum Estimated Initial Fees"*
- ☐ Complete details of Trustees and/or Authorised Officers on this page

Appendix B. Environmental Impact Analysis

B.1 Drawdown analysis

The drawdown analysis was conducted based on the peak daily groundwater take of 1,875 m^3/day, which will be applied to Total Orchard Area development of 75 ha. The drawdown was evaluated after 150-days of pumping at the maximum rate, which equates to a total take of 281,250 m^3/year. The drawdown impact was analysed using:

- **Theis Solution**: Analytical solution to compute drawdown in abstraction layer with a confined non-leaky condition.
- **Feather & Williamson Solution**: Analytical solution to compute drawdown in a multi-layer aquifer system considering elastic storage within layers.

In order to assess the potential drawdown, realistic and appropriate permeability values of the sediments need to be estimated. The hydrogeological parameters of shellbed from historical pumping tests conducted at neighbouring property (Sweetwater Station) is summarised in **Table B1.**

Table B1. Summary of hydrogeological parameters of shellbed analysed from pumping test data.

Bore	Screen depth	Depth	Lithology	Transmissivity	Thickness	Specific storage	Analysis method	Source
	mBGL	mBGL		m^2/day	m	m^{-1}	-	
Sweetwater PB6	72-89	89	Shell	292	17	-	Driscoll	Sweetwater Station 2012/13 Drilling report (SKM,2013)
				144*		$5.0x10^{-1}$*	Theis step test	
				249		$6.0x10^{-3}$	Theis constant rate	
				234		$1.8x10^{-3}$	Agarwal+Theis	
Sweetwater MW1b	88-94	94	Shell	522	6	$3.1x10^{-4}$	Theis constant rate	
				469		$2.7x10^{-4}$	Agarwal+Theis	
Sweetwater PB2	73-75,76-85,87.5-93.5	96	Shell	430	17	-	Constant pumping	Sweetwater Farms PB2 Test Pumping report (WWA,2018)
				354		-	Theis recovery	
			Minimum	234	6	$2.7 x10^{-4}$		
			Median	354	17	$1.1x10^{-3}$		
			Average	364	13	$2.1x10^{-3}$		
			Maximum	522	17	$6.0x10^{-3}$		

*Outlier data were excluded in descriptive statistics.

A useful summary of regional test pumping results was presented in the Section 92 response to the Resource Consent Application RM20995 for Sweetwater Station (SKM, 2010), with the derived hydraulic conductivity results reproduced in **Figure B1**.

Bore Owner	WellARCNo	Easting (NZMG)	Northing (NZMG)	Test Type	Test Length (hrs)	Abstraction Rate (m^3/day)	Observation Bores	Screened Geology	Hydraulic Conductivity (m/sec)	Information Source
King	201374	2533400	6681500	Constant Rate	24	576	Yes (1)	Sand	1.8×10^{-5}	HydroGeo Solutions (2000)
Sweetwater Orchards	201424	2529558	6684434	Constant Rate	72	1,176	Yes (1)	Shell	1.9×10^{-4}	Woodward Clyde (1998)
Kaurex Corporation	200230	2530331	6697328	Constant Rate	9.5	273	No (PB only)	Shell	$4.3 - 3.3 \times 10^{-5}$	HydroGeo Solutions (2000)
Matai Orchards	201507	2529399	6691299	Constant Rate	88.5	497	Yes (1)	Shell	$4.0 - 2.0 \times 10^{-4}$	SKM (2007)
Hopkins	200184	2520300	6706800	Constant Rate	24	260	No (PB only)	Shell	$4.2 - 1.7 \times 10^{-5}$	HydroGeo Solutions (2000)
Fitzwater	200229	2529743	6690648	Constant Rate	24	864	Yes (4)	Shell	$2.1 - 1.4 \times 10^{-4}$	HydroGeo Solutions (2000) and SKM (2007)
Brown	200060	2521699	6706300	Constant Rate	22	708	Yes (3)	Sand	$5.6 \times 10^{-6} - 1.3 \times 10^{-4}$	HydroGeo Solutions (2000)
Hogg	201007	2528300	6685799	Constant Rate	20.9	160	No (PB only)	Sand	$2.1 - 1.9 \times 10^{-4}$	HydroGeo Solutions (2000)
Waiharara	209499	2528580	6690100	Constant Rate	91	1,113	Yes (2)	Shell	2.0×10^{-4}	SKM (2007)
King Avocado Ltd	209606	2527482	6690562	Constant Rate	168	2,393	Yes (3)	Shell	$4.3 - 1.5 \times 10^{-4}$	SKM (2007)
Hamilton Nurseries	201025	2531401	6684155	Constant Rate	6	300	Yes (2)	Sand	1.2×10^{-4}	SKM (2001)
Stanisich Orchard	200192	2528600	6695799	Constant Rate	1	1,442	No (PB only)	Shell	5.0×10^{-5}	SKM (2002a)
Terra Nova Orchard	200335	2521199	6706499	Constant Rat	39	674	Yes (6)	Shell	$4.0 - 3.0 \times 10^{-4}$	SKM (2002b)
Northland Catchment Commission	200048	2519855	6701857	N/A	N/A	N/A	N/A	Sand	$7.1 - 6.1 \times 10^{-5}$	HydroGeo Solutions (2000)
Northland Catchment Commission	200081	2528583	6689795	N/A	N/A	N/A	N/A	Sand	$2.9 - 1.25 \times 10^{-5}$	HydroGeo Solutions (2000)
Colville	200059	2521792	6705887	Step (4)	22.3	63 - 233	No (PB only)	Sand	5.3×10^{-5}	HydroGeo Solutions (2000)
Fraser	201002	2525552	6671053	Step (3)	22	88.6 - 163	No (PB only)	Sand	3.0×10^{-4}	NRC database
Rechards Enterprises	200043	2522513	6708792	Step (4)	19	149 - 333	No (PB only)	Sand	$7.1 - 6.0 \times 10^{-5}$	HydroGeo Solutions (2000)
Herbert	200152	2528178	6688977	Step (4)	20	127 - 319	No (PB only)	Sand	8.4×10^{-5}	HydroGeo Solutions (2000)

Figure B1. Aquifer pumping tests in the region and summarised hydraulic conductivities. (Appendix B from Section 92 response for Resource Consent Application No. RM20995, SKM 2010)

B.1.1 Feather & Williamson Solution and calibration

Feather and Williamson (unpublished) developed a solution for drawdown calculation in a multi-layer aquifer system considering elastic storage, which by coincidence was an extension of the solution by Hemker and Maas (1987) for unsteady flow to wells within a layered aquifer system, and an extension of the solution by Hunt and Scott (2007) for two-layered systems. By assigning the hydrogeologic parameters and thicknesses of individual layers, drawdown is calculated for each individual layer using an inversion of Laplace transformation of the groundwater flow equation.

A 6-layer single well pumping model was setup, and the model structure is sourced from the MWWUG groundwater model (WWA, 2017). The recent monitoring data of MW1b from Sweetwater Farms Annual Monitoring Report (Jacobs, 2017) were used to calibrate the model, shown in **Table B2**.

Table B2. Monitoring data of MW1b for irrigation season 2016 (Jacobs, 2017)

Name	Depth (mBGL)	Lithology	Abstraction Start	Abstraction End	Flow rate (m^3/day)	Total volume (m^3)	Max drawdown (m)*	Average flow rate (m^3/day)	Average drawdown (m)
MW1b	94	Shell	03/11/2016	15/02/2017	3,000-10,729	404,099	5.17	3,886	2.3

* 5.17 m drawdown occurred with a pumping rate of 10,729 m^3/day exercised for one day. The flow rate ranged between 3,000 and 6,500 m^3/day for most of the irrigation season.

Based on total volume of 404,099 m^3 (3,886 m^3/day for 104 days), the model was calibrated to simulate an average drawdown of 2.6 m at approximate 250 m radius location from pumping bore (250 m is the distance between pumping bore PB6 and monitoring bore MW1b in Sweetwater Farms Annual Monitoring Report, shown in **Figure B2**). The hydrogeological parameters used in the model are summarised in **Table B3**.

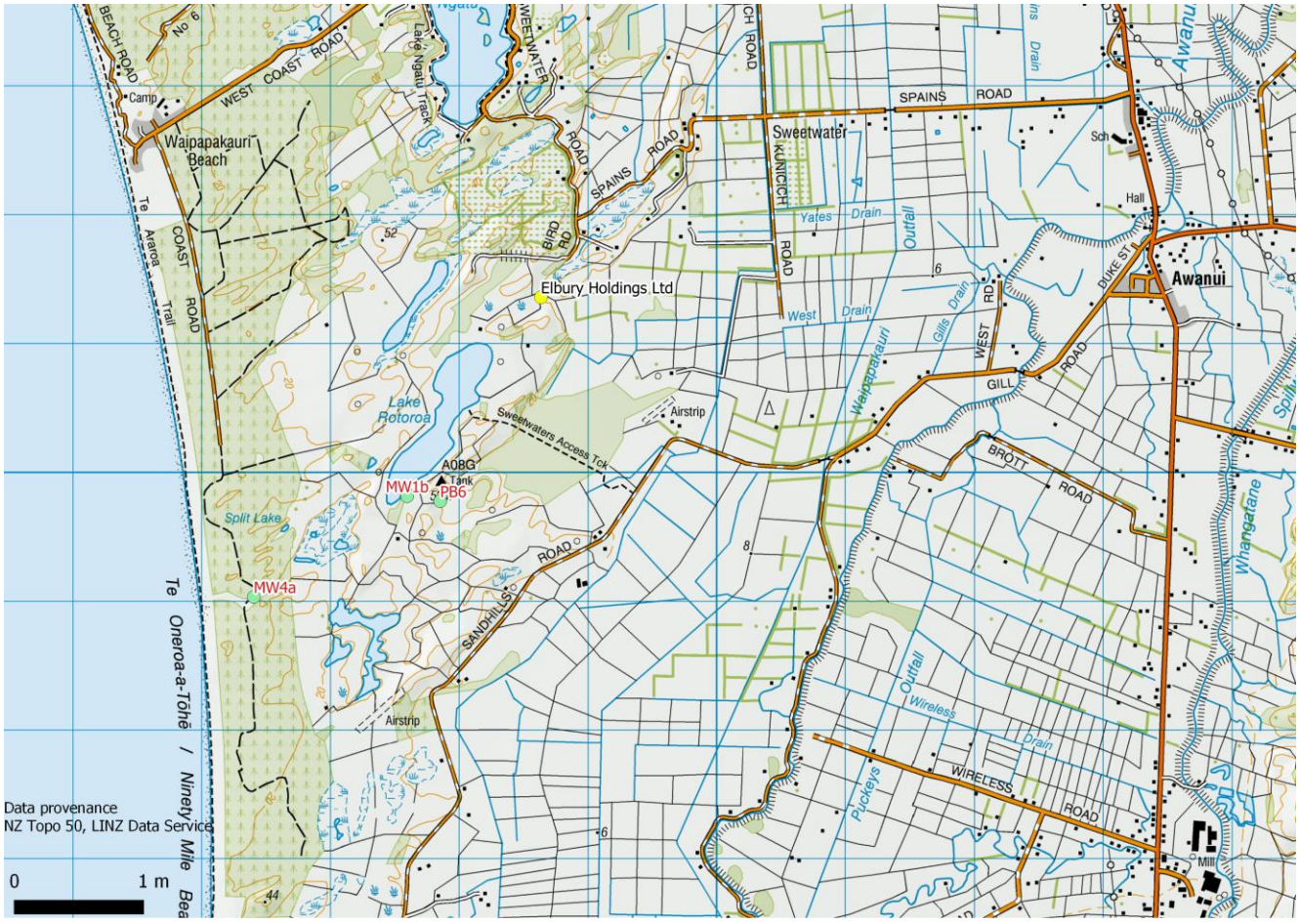


Figure B2. Location of pumping bore PB6 and monitoring bore MW1b and MW4a at Sweetwater Station.

Table B3. Hydrogeologic parameterisation in the Feather and Williamson model.

Layer	Transmissivity (m^2/day)	Horizontal hydraulic conductivity (m/s)	Vertical anisotropy (-)	Storativity (-)	Layer thickness (m)
1	45	1.74E-05	100	2.50E-01	30
2	30	1.74E-05	100	1.25E-02	20
3	25	1.93E-05	100	1.00E-02	15
4	80	1.54E-04	1	1.12E-02	6
5	10	3.86E-05	100	1.50E-03	3
6	240	1.63E-04	1	1.81E-02	17

Using the same model, the drawdown of proposed Elbury Holdings Limited bores was simulated and is shown in **Figure B3.** In the proximity of the pumping bore, maximum drawdown of 10.6 m and 0.14 m were simulated for the deep and shallow aquifer, respectively.

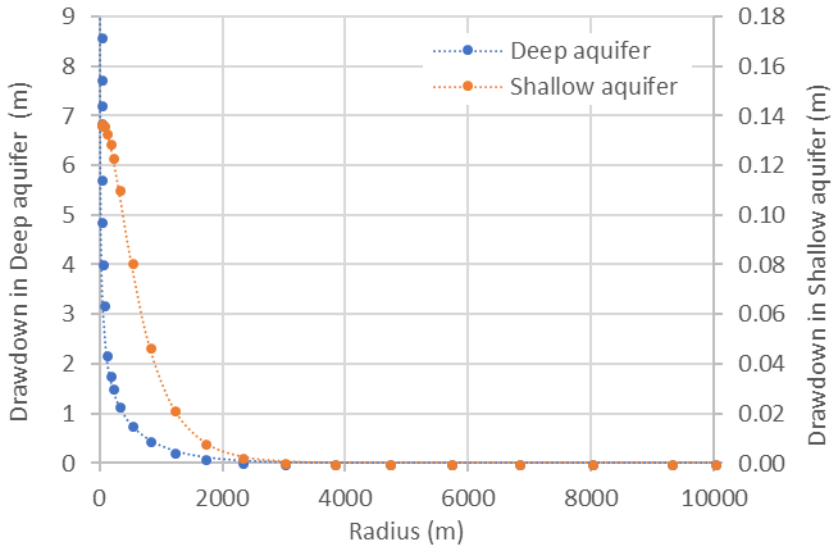


Figure B3. Estimated drawdown in deep aquifer and shallow aquifer (Feather & Williamson).

B.1.2 Theis Drawdown Solution

The hydrogeological parameters of Layer 6 in the model discussed above were used to represent the deep shellbed aquifer. The estimated drawdown after 150-days of pumping at various distance from pumping bore is shown in **Figure B4**. Near the pumping location, a maximum drawdown of 12.4 m was simulated.

Due to geological conditions featuring discrete layers of low-permeability materials (e.g. iron pan, silt, peat), the regional aquifer is a leaky confined system, showing a progressive confinement with depth. The confined (non-leaky) condition of the Theis solution will lead to an appropriately conservative overestimation of drawdown in the deep shellbed.

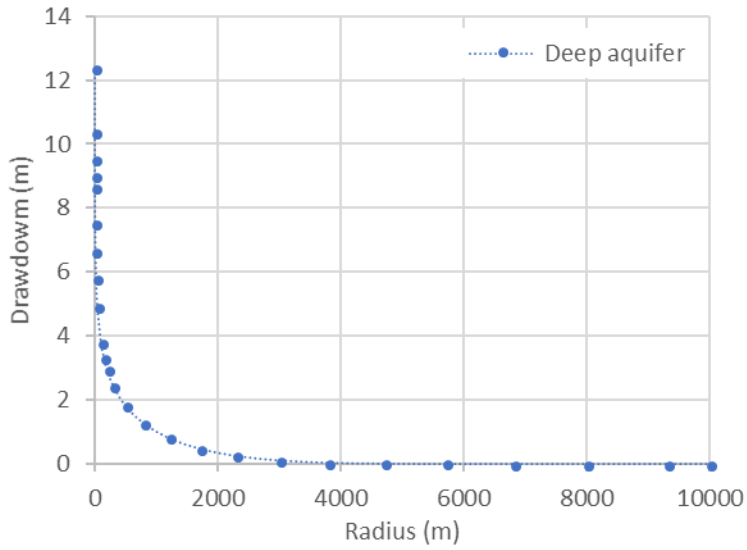


Figure B4. Calculated drawdown of abstraction layer (Theis).

The calculated drawdown extent and magnitude from Feather and Williamson Solution is less than from the Theis Solution, due to the vertical leakance simulated in the model. The drawdown estimated from Feather and Williamson Solution is considered a more realistic solution for leaky-confined aquifer systems, nevertheless the Theis Solution has value as an upper range estimate and therefore conservative approximation.

B.2 Cumulative Impact

The cumulative impact was assessed based on all existing consents and the proposed take of Elbury Holdings Limited, using Theis and Feather and Williamson analytical solutions. The current existing groundwater take consents are summarised in **Table B4**.

Table B4. Existing groundwater take consents in the project region.

X	Y	IRISID	Name	Purpose	Daily volume*	Annual Allocation	Peak rate*	Type
					m^3/day	m^3/year	(m^3/day)	
1622365	6119515	AUT.007148.01.02	K J & F G King 1	Irrigation - Arable/Crop	49	12,754	85	Irrigation take
1622954	6119131	AUT.007148.01.02	K J & F G King 2	Irrigation - Arable/Crop	70	25,000	167	
1618833	6122488	AUT.008391.01.02	J A Trussler	Irrigation - Horticulture	800	148,800	992	
1623509	6117021	AUT.007429.01.03	R F & M H	Irrigation - Horticulture	200	23,760	158	
1622335	6119515	AUT.007148.01.02	K J & F G King 3	Irrigation - Arable/Crop	550	55,000	367	
1617060	6120384	AUT.020995.01.03	Sweetwater PB1	Irrigation Crop	-	2,317,000**	1,862	
1617450	6119000	AUT.020995.01.03	Sweetwater PB2				4,000	
1616579	6120782	AUT.020995.01.03	Sweetwater PB3		-		1,862	
1616934	6119154	AUT.020995.01.03	Sweetwater PB4		-		1,862	
1617891	6119767	AUT.020995.01.03	Sweetwater PB6		-		4,000	
1617376	6118236	AUT.020995.01.03	Sweetwater PB11				1,862	
1623319	6122860	AUT.007618.01.03	Te Urungi O Ngati Kuri Limited	Industrial - Other	50	18,250	50	Water supply and industrial take
1615677	6122797	AUT.003606.01.04	Far North Holiday Park Ltd	Drinking - Commercial	30	-	30	
1619617	6120296	AUT.010649.01.03	Landcorp Farming Limited	Stock - Dairy	183	66,667	183	
1618250	6121600	AUT.025683.01.03	FNDC	Drinking - Public Water Supply	5,000	1,460,000	5,000	

*Peak rate is calculated based on the total allocation, assuming 150-days pumping during irrigation season for irrigation takes. For water supply and industrial take, peak rate is assumed to be equal to daily volume.

**There are two bores (PB2 and PB6) been constructed. Peak rate is determined based on the sustainable yield from pumping tests. Additional bore locations are selected based on the likelihood location of the future development and locations specified in the resources consent.

The cumulative drawdown in the deep aquifer from Feather and Williamson and Theis solution is shown in **Figure B5** and **Figure B6**, respectively.

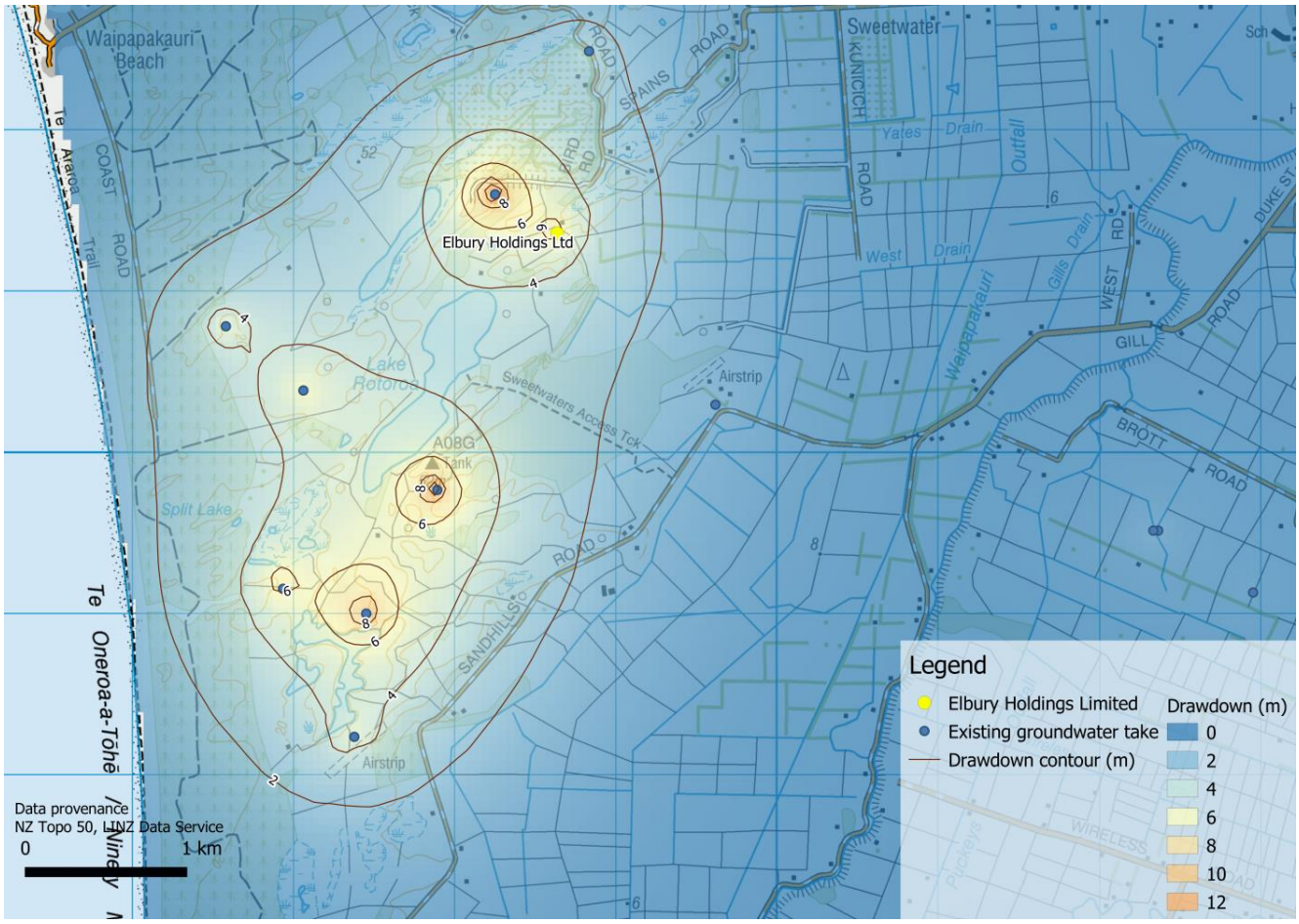


Figure B5. Cumulative drawdown in deep aquifer Feather and Williamson Analysis.

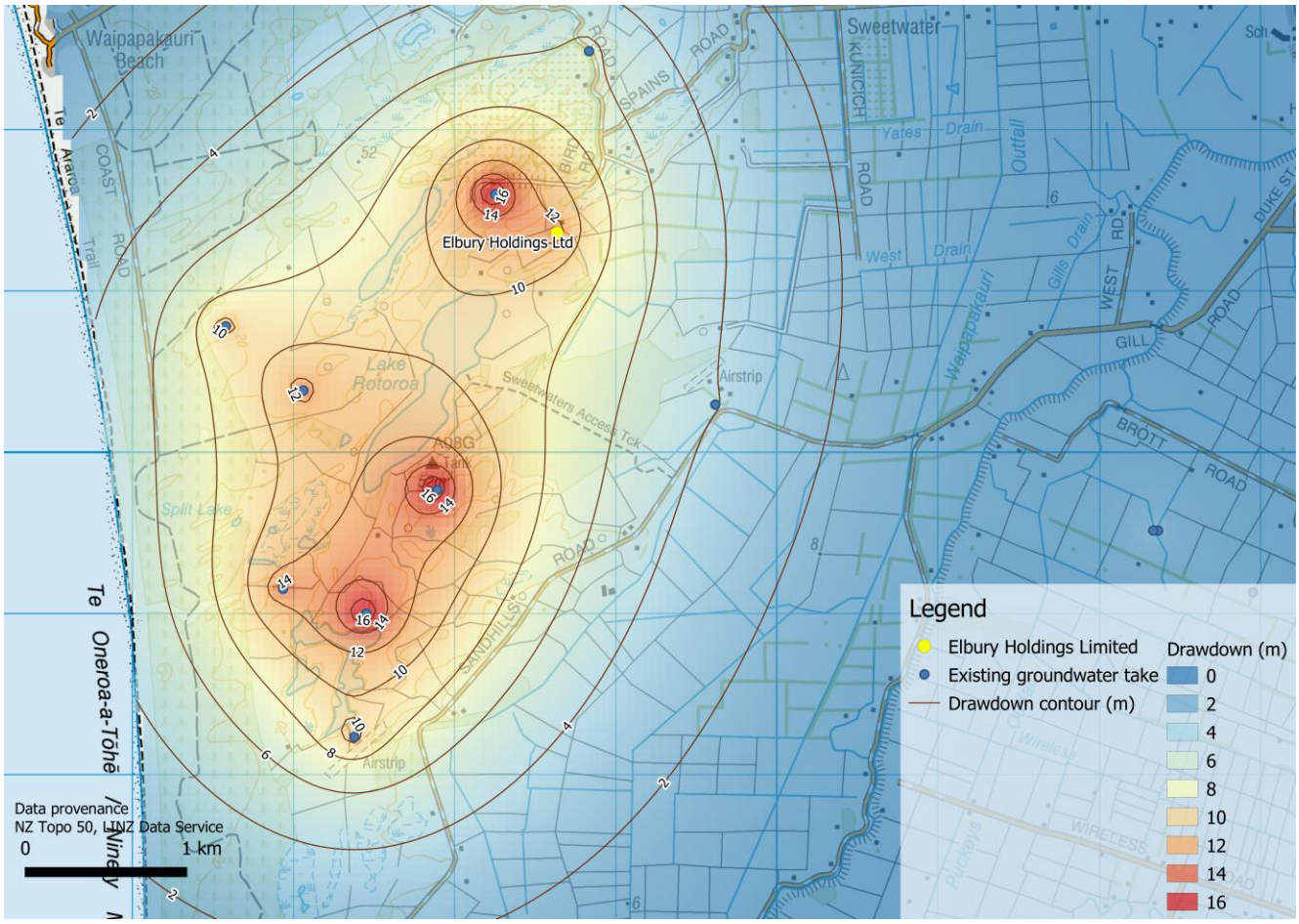


Figure B6. Cumulative drawdown in deep aquifer Theis Analysis.

Table B5. Drawdown estimated for existing groundwater take locations.

Neighbouring bore	Distance from Elbury Holdings Limited Bore (km)	Current drawdown (m)		Cumulative drawdown (m)		Additional drawdown (m)	
		Feather and Williamson	Theis	Feather and Williamson	Theis	Feather and Williamson	Theis
FNDC	0.5	11.1	18.3	11.9	20.2	0.8	1.9
J A Trussler	1.1	3.1	6.2	3.3	7.0	0.3	0.9
Landcorp Farming Limited	1.4	1.1	3.5	1.2	4.1	0.2	0.6
Sweetwater PB6	1.8	11.5	18.0	11.6	18.4	0.1	0.5
Sweetwater PB1	1.9	5.5	12.3	5.6	12.7	0.1	0.4
Sweetwater PB3	2.1	5.1	11.4	5.1	11.7	0.1	0.3
Sweetwater PB2	2.6	9.2	18.8	9.2	18.9	0.0	0.2
Sweetwater PB4	2.8	6.3	14.6	6.3	14.8	0.0	0.1
Far North Holiday Park Ltd	3.3	0.2	1.1	0.3	1.2	0.0	0.1
Sweetwater PB11	3.4	5.0	10.8	5.0	10.9	0.0	0.1
K J & F G King 3	4.1	0.7	1.5	0.7	1.5	0.0	0.0
K J & F G King 1	4.2	0.7	1.5	0.7	1.5	0.0	0.0
K J & F G King 2	4.9	0.4	0.9	0.4	0.9	0.0	0.0
Te Urungi O Ngati Kuri Limited	4.9	0.1	0.2	0.1	0.2	0.0	0.0
R F & M H Barber	6.5	0.2	0.4	0.2	0.4	0.0	0.0

Table B5 indicates, that the proposed take is unlikely to cause additional drawdown in the deep aquifer for some of the existing bores shown from both of analytical solutions.

Six bores within 2 km of the Elbury Holdings Ltd bore will potentially have an additional drawdown of up to 0.8 m based on Feather and Williamson Solution. The largest additional drawdown will occur at FNDC bore, due to its adjacency to the proposed take.

Based on Theis Solution, the maximum additional drawdown of 1.9 m will occur at FNDC bore location. The fully confined condition implied in the Theis Solution leads to a more pervasive outcome, which is considered unlikely to be realistic because the aquifer is leaky.

B.3 Surface Water Impact

The cumulative drawdown in the shallow aquifer is shown in **Figure B7**, which shows the shallow aquifer is less affected by the proposed abstraction. The maximum drawdown in shallow aquifer was 0.33 m, which was simulated around the FNDC bore location.

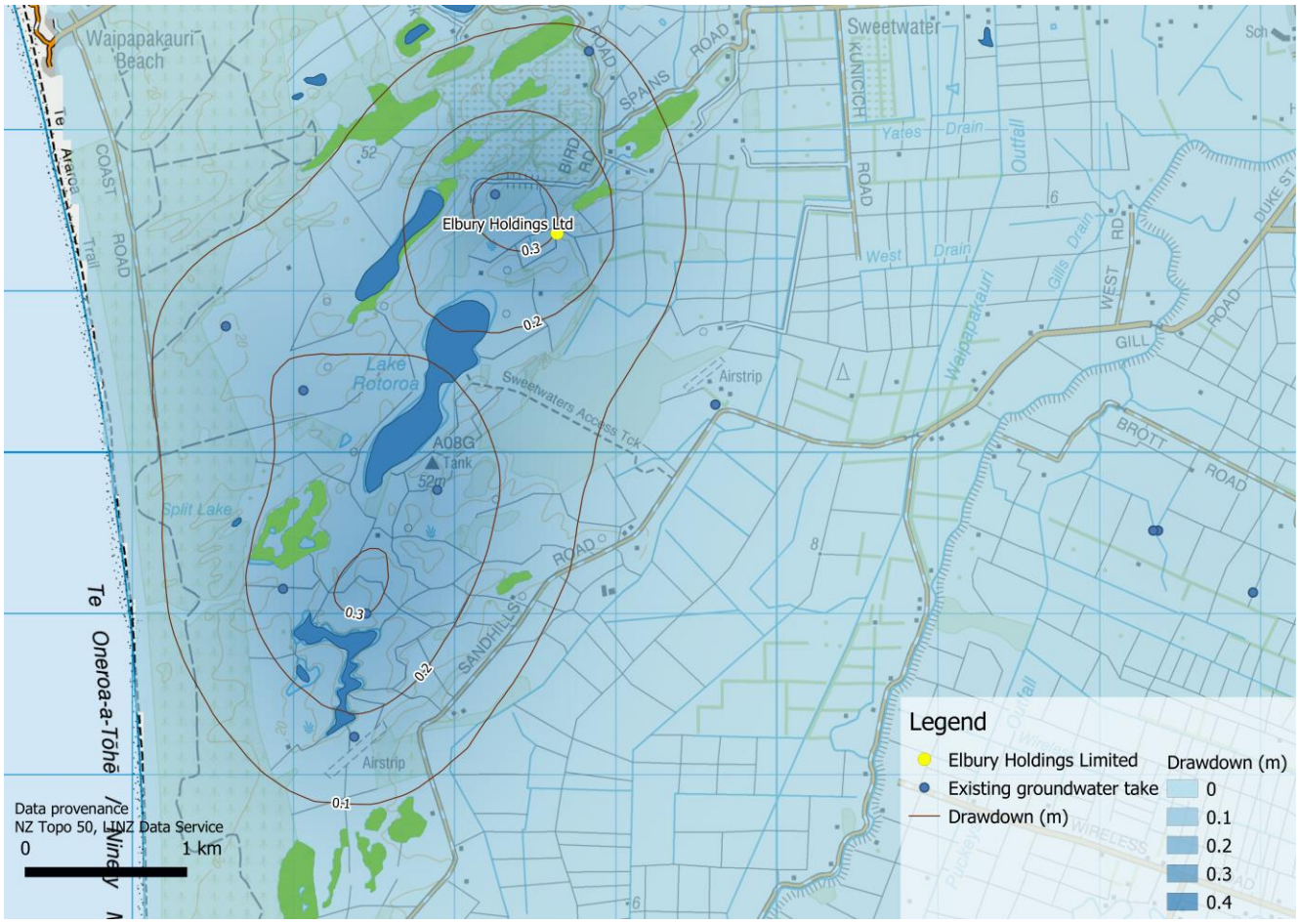


Figure B7. Cumulative drawdown in shallow aquifer Feather and Williamson.

The surface water features in the area adjacent to Elbury Holdings Limited are shown on **Figure B5** and include:

- Unnamed swamp to northeast (0.2 km);
- Lake Rotoroa to southwest (0.6 km)
- Unnamed swamp to northwest (0.6 km)
- Unnamed Dune Lake to northwest (0.7 km)

The maximum additional drawdown in shallow aquifer due to the proposed take will be less than 0.14 m, which would translate to an unmeasurable impact within a standing or flowing water body.

Therefore, the proposed take for the deep aquifer is unlikely to pose significant impact on the surficial hydrological features.

B.3.1 Saltwater intrusion

The deep shellbed aquifer is underlain by low permeability bedrock. Due to the low permeability of this material, saltwater will be more likely to migrate inland along the base of the shellbed aquifer, instead of up-conning from the sediments below.

The Elbury Holdings Limited bore will be located in the central area, and approximately 3 km away from the west coast. From Aupouri Aquifer Sustainable Yield Groundwater Modelling Study (HydroGeo Solutions,2000),

the Aupouri aquifer base is located around -70 - -60 mAMSL along the west coastline in this area , based on the interpolation from available borelogs. Following the Ghyben-Herzberg analytical solution[7], this equates to a minimum fresh water pressure of 1.5 – 1.75 mAMSL that will prevent the saltwater from migrating inland along the base of the deep shellbed aquifer.

NRC monitoring bore MW1b, shown in **Figure B2** is screened in the deep shellbed aquifer from 88 mBGL to 94 mBGL and is located approximately 420 m away from the west coastline. The groundwater level ranged between 7.3 mAMSL and 7.6 mAMSL from 07/06/2017 to 24/01/2018. The potential cumulative drawdown at this location shown in **Figure B5** will be approximately 2m, with the active pumping of FNDC bore and maximum allocation usage of Sweetwater Station. The predicted groundwater level of 5 mAMSL at this location will still be adequate to maintain the pressure along the coastline to prevent saltwater migration inland along the base of the deep shellbed aquifer.

B.3.2 Ground Settlement

Groundwater settlement was calculated using the Bouwer (1977)[8] equation:

$$S_u = (P_{i2} - P_{i1})\frac{Z_1}{E}$$

where S_u = vertical subsidence (m)
$P_{i2} – P_{i1}$ = Increase in intergranular pressure due to drop of the water table
Z_1 = layer thickness
E = modulus of elasticity of the soil

The following characteristics were assumed for the aquifer:

- Porosity = 0.25
- Unsaturated water content = 0.08
- Specific weight of aquifer material (consolidated silty sand) = 20 kN/m^3 (Silty sand density ranges between 1,410 kg/m^3 and 2,275 kg/m^3[9], corresponding to specific weight of 14 kN/m^3 and 22 kN/m^3)
- Specific weight of water = 9.81 kN/m^3.

The deep shellbed material is denser and less compressible compared to the mixture of sand, silt and peat overlying above. The subsidence analysis was conducted using three separate layers representing the conceptual hydrogeological units of the sub-surface environment, and the parameter values used are shown in **Table B5**, which were selected from the elasticity values referenced in **Table B6**.

Table B5. Elasticity and depth of each zone for subsidence estimate.

Stratigraphy	Total depth**	Modulus of elasticity (kPa)*
Silty sand (unsaturated zone)	8**	10,000
Silty sand (saturated zone)	70	20,000
Shellbed (saturated zone)	20	50,000

* Modulus of elasticity (E) was sourced from Bouwer,1977

**Depth was estimated from monitoring data of Sweetwater Farms PB2 Test Pumping Report (WWA,2018)

[7] Ghyben-Herzberg analytical solution states for every one meter water pressure above sea level, there will be forty meters fresh water pressure below sea level in the aquifer.
[8] Bouwer, H., 1977. Land Subsidence and Cracking Due to Ground-Water Depletion. Ground Water 15, 358–364. doi:10.1111/j.1745-6584.1977.tb03180.
[9] Density ranges for different soil types: http://structx.com/Soil_Properties_002.html

Table B6. Modulus of elasticity [E] for unconsolidated materials (Bouwer, 1977).

Material	E (kg/cm^2)	E (kPa)
Peat	1 – 5	98 – 490
Loose clay	10 – 50	981 – 4,903
Medium clay and silt	50 – 100	4,903 – 9,807
Dense clay and silt	100 – 1,000	9,807 – 98,067
Loose sand	100 – 200	9,808 – 19,613
Dense sand	500 – 2,000	49,033 – 196,133
Dense gravel and sand	2,000 – 10,000	196,133 – 980,665

The cumulative drawdown profile is an overlap of cone of depressions from the proposed take and existing groundwater takes. The drawdown magnitude around the proposed take will not attenuate as a circular pattern. Therefore, maximum cumulative drawdown was extracted within a 1.5 km radius of the proposed take, and the estimated maximum subsidence was calculated by combining the Feather and Williamson analysis for the shallow aquifer with the Theis analysis for the deep aquifer, as shown in **Table B7**.

Table B7. Calculated subsidence (m) within 1.5 km of the pumping bore.

Scenario	Feather and Williamson	Theis
Drawdown (m)	0.3	20.2
Unit 1. Sand (unsatured)	0.0001	-
Unit 2. Sand (saturated)	0.0094	-
Unit 3. Shellbed (saturated)	-	0.066
Maximum Cumulative	0.076	

Within 1.5 km of proposed take, the estimated cumulative subsidence is 0.08 m, with a maximum drawdown of 0.3 m and 20.2 m in shallow and deep aquifer, respectively. In a rural setting, settlement effects of this magnitude (or less as would be more realistic) are less than minor for the following reasons:

- There is no sensitive urban infrastructure like water or wastewater mains or high-rise buildings to rupture or crack; and
- The changes in land surface due to farm machinery (e.g. rotary hoeing) would likely mask impacts of this magnitude (<0.3 m) if materialised.

In summary, the potential settlement effects are considered less than minor.