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Ko te parehua o Te Reureu:

the Te Reureu terrace

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This thesis is dedicated to all my whānau, with a very special tribute to my grandparents Annette, Paranihi, Frank and Te Urikore. Although three of you cannot be here I hope I have made you proud with my achievements.

Gran you will have to be the judge, I hope you enjoy reading this and know I appreciate everything you have done for me. Thank you for your unconditional support, love and all you strength you have given to me.

Three other people need a special mention those are Dad, Mum and Narissa. I don’t think there is enough space to describe my gratitude for the love, support, hard word at times and perseverance you gave me, this is a testament to all of us.

Final note, “Don’t treat soil like dirt”.

Abstract

The Reureu Valley is distinctive with several enclaves from various iwi living there; Ngāti Raukawa, Ngāti Maniapoto, Ngāti Kahungunu and Tūwharetoa. The history of the valley shows several hapū migrating there due to broader land conflicts and to protect their land interests. The Reureu blocks lie within the rohe of Ngāti Pikiahu hapū o Ngāti Raukawa near Poupatate Marae.

Māori land development has the potential to contribute significantly to the agricultural sector. In a report conducted by the then Ministry of Agriculture and Fisheries in 2011, 40% of Māori freehold land was under-preforming with a further 40% under-utilised. The large number of Māori land blocks underdeveloped or underperforming means there is considerable room for development. Māori land development is not simple; many aspects from multiple ownership through to governance structures have inhibited growth. However, a recent dairy conversion has seen the collaboration of trusts, incorporations with land interests and government bodies to develop and accelerate a transformation of Māori land.

The Reureu blocks studied are currently under-developed and have owners wanting to look at possible land-use options. This includes research on what information is presently available; the quality of this information; and areas where information is lacking relative to make an informed decision about a change in land-use. Subsequently a determination of the information gaps was made.

A practical assessment of the resource was deemed necessary. Soil surveying was then conducted on the Reureu blocks. It was discovered that the soils previously mapped on these blocks were not found in this exercise, triggering the need for a full and extensive land evaluation approach.

Land evaluation tools were then used to assess the land, to ensure or aid the decision making in a type of land-use for the Reureu blocks. Land evaluation tools included LRI mapping, LUC mapping and suitability of six important features. Nutrient Management is a key issue when dealing with contemporary land-use, and the Reureu blocks lie within Horizons Regional Council region and regulations. Limits of leaching and consent conditions were therefore looked at for the potential of developing a dairy farm.

The conversion into dairy was preferred by the hapū therefore further investigation was carried out which is considered vital to a dairy platform. An assessment of FDE application, irrigation requirement (irrigation benefit), presence of stones, pugging susceptibility, potential use for cropping (presence of stones inhibiting crop growth), flood risk and nutrient budgets was made. Various computer models including Farmax and Overseer were used to gain realistic results to best represent the Reureu blocks as a dairy platform. The outcome is a body of knowledge the Reureu land owners can access for their due-diligence process.

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- Finally I wish to thank Lance Iwikau and the hapū of Te Reureu for the privilege of working with them on their whenua. I am confident this research will be of value to them into the future.

Whatungarongaro te tangata, toitu te whenua
As man disappears from sight, the land remains.

My interpretation of this whakataukī is with respect to the whenua and the decisions we make today impact on future decision made tomorrow. This thesis provides some support for those decisions made.

Nga mihi

Contents

List of Figures

List of Tables

Chapter 1 General Introduction

1.1 Background

1.1.1 Whakapapa

Whatungarongaro te tangata, toitū te whenua
As man disappears from sight, the land remains.

The Reureu valley in which the Reureu blocks are located are home to many enclaves from various iwi including Ngāti Raukawa, Tūwharetoa, Ngāti Kahungunu and Ngāti Maniapoto. The history behind the allocation of land for each iwi and their various hapū is therefore unique.

In New Zealand around the 1820s extensive and large scale migration of hapū and iwi was witnessed (Arapere, 1999). Migration was not only about exploring or the need to access food, but also due to war and famine as identified by Arapere. Arapere (1999) identifies other reasons for migration such as establishing relationships with Pākehā and migrating to those places that were less populated. Migrations were generally small iwi groups or the entire hapū such as Ngāti Toa, however in some hapū of iwi such as Ngāti Raukawa only a segment of the tribe migrated, with others preferring to remain in their original home place (Arapere, 1999).

Ngāti Raukawa experienced many changes between 1830 and 1872, often involving land confiscation and land sales and which were experienced by many other hapū in New Zealand at the same time (Arapere, 1999). The responses and experiences varied between hapū, and many were unique to each group. The migration during the 1820s and 1830s of Ngāti Pikiahu hapū of Ngāti Raukawa iwi was due to new desires and motivations, and had a substantial impact in terms of their iwi development in the future (Arapere, 1999). Ngāti Raukawa were consequently involved in the Kīngitanga and by the late 1850s most hapū of Ngāti Raukawa regardless of location, were Kīngitanga followers as well.

By 1860, Ngāti Pikiahu had lived in the Te Reureu Valley for over twenty years. Other Ngāti Raukawa hapū such as Ngāti Matakore and Ngāti Rangatahi were also based up the valley. A Tūwharetoa hapū Ngāti Waewae and some Ngāti Maniapoto also lived up the valley. The Reureu valley was home for many different hapū and iwi (Arapere, 1999).

Ngāti Waewae were also requested by Mananui Te Heuheu II to move to the Rangitikei area to protect Ngāti Tūwharetoa's land interests and prevent land sales (Waitangi Tribunal, n.d). Over time Ngāti Pikiahu and Ngāti Waewae merged to become Ngāti Pikiahu Waewae, a dual hapū representing both Ngāti Tūwharetoa and Ngāti Raukawa.

> "*Four wharenui exist at Te Reureu: Te Tikanga-ā-Tāwhiao (Tokorangi Marae); Poupatate (Onepuhi Marae); Te Hiri O Mahuta (Kakariki Marae) and Kotuku (Onepuhi Marae).*" (Waitangi Tribunal, Chapter 2)

The hapū Ngāti Pikiahu lived at many different papakāinga settlements along the Valley. In the year 1860 a wharenui was built with the purpose as a collective meeting place (Arapere, 1999). As Arapere (1999) states:

> *"Marae building to honour Kīngitanga alliance signified a subtle form of resistance to Pākehā encroachment into the Rangitikei Area."* (p. 124)

The wharenui was named '*Poupatate'* meaning the Post of patate (Seven-finger or *Schefflera digitata*) in honour of a whakataukī of the late Tawhiao (Arapere, 1999). The Ngāti Pikiahu people took a deeper approach to the whakataukī, binding the movement of Kīngitanga and their role with those similar to the building materials used to build the marae as well as being a sign of cultural resistance and political alignment with the Kīngitanga (Arapere, 1999). Poupatate was moved several times due to the ever changing Rangitikei River floods that occurred over time, however, its final place is now further up the Te Reureu Valley.

> *"Moreover, the embracing of Kīngitanga beliefs shaped and moulded Ngāti Pikiahu identity and strength as a hapū community. Indeed, the oral tradition relating the naming and building of Poupatate has remained a major focus of hapū collective identity into the 1990s and will continue and strengthen with the rededication of Poupatate for the new millennium."* (Arapere, 1999, p. 124)

Poupatate was one of a number of small hapū and whānau based meeting houses that stood along Te Reureu Valley; Te Kotuku Rerenga Tahi at Pariki was also similar in being a whānau based meeting house. In 1880 a hapū called Ngāti Waewae related closely to Ngāti Pikiahu built Te Tikanga marae. The difference between this Marae and Poupatate was, it was not only a small hapū , whānau based meeting house but one that could be utilised by various hapū from Ngāti Raukawa, Ngāti Maniapoto and Tūwharetoa from Tokorangi and Reureu area.

The sale of the Rangitikei-Manawatu block was a controversial one, initiated by the Crown forcing Māori to sell their land, supposedly a peaceful way to solve conflict between the three hapū (Arapere, 1999). Even though many did not agree nor want the land sales their voices were ignored. Many hapū from the Te Reureu Valley and Tokorangi opposed the sale of land, yet no response came from the Crown.

> *"Having had little response from letters to Crown agents, petitioned the Queen directly over the sale, in June 1867. Paranihi and Eruni Te Tau, representing Ngāti Pikiahu, Ngāti Waewae, Ngāti Maniapoto and Ngāti Hinewai, broached their concerns."* (Arapere, 1999, p. 130)

Māori have always had a strong connection with their land, being spiritual, cultural and historical, seeing themselves as kaitiaki or guardians of the land. For Māori the historical importance of their land leads back to past ancestors and a sense of belonging to the land is important to Māori. The most recent legislation covering Māori land is the Te Ture Whenua Māori Act (TTWMA) 1993 currently under review. Its main purpose is:

> *(a)The retention of Māori land and General land owned by Māori in the hands of the owners; and*
> *(b) The effective use, management, and development, by or on behalf of the owners, of Māori land and General land owned by Māori.*
> (Te Ture Whenua Māori Land Act 1993)

Land for Māori holds history; each area with its own history and whakapapa, linking whenua and whānau and a cultural sense of identity as Māori. A report prepared by Ministry of Justice (2001) titled *'He Hīnātore Ki te Ao Māori – A glimpse into the Māori World'* outlines the importance of land to Maori:

> *"Land provides us with a sense of identity, belonging and continuity. It is proof of our continued existence not only as a people, but also as tangata whenua of this country. It is proof of our tribal and kin group ties. Māori land represents tūrangawaewae. It is proof of our link with the ancestors of our past, and with generations to come. It is an assurance that we shall forever exist as a people, for as long as the land shall last." (As cited in Ministry of Justice, 2001, p.44)*

Māori identify themselves through their tūpuna and where they came from, identifying themselves as tangata whenua, literally people of the land. The connection Māori have with their land is not only physical but spiritual as well and expressed as whakapapa. Whakapapa allows Māori to identify themselves through the land, building a strong relationship with land and the natural resource. Māori identify themselves through pepeha referring to their maunga and awa, acknowledging parts of the environment that other Māori can recognise and build connections from there (Walker, 1989; Durie, 1994; Twotrees, 2000; Ministry of Justice 2001; Houkamau & Sibley, 2010). It is of the upmost importance when considering development on land to consider the aspirations, cultural values and implications for any land change as land is considered a taonga, a treasure (Roskruge, 2007). Kaitiakitanga, guardianship, is a Māori philosophy ‘key’ to help decision making, with the need to preserve, care for and nurture.

There are many other important values that are important to Maori when making land decisions some of these include arohatanga, wairuatanga, manaakitanga and mana whenua. (Roskruge, 2007; Te Puni Kokiri 2011; Harmsworth & Awatere, 2013)

1.1.2 Māori Land

Originally Māori land was owned communally by iwi, hapū and whānau rather than the Western concept of individual ownership. Māori owned land has developed a complex history. All land was originally commonly owned, however after the signing of the Treaty of Waitangi (Te Tiriti o Waitangi) in 1840 the Crown sought to obtain land from Māori (Controller and Auditor General, 2004). Royal instructions were given to develop a Land Court which would allow Māori land to be governed under English common law (Kingi, n.d). The Native Land Court is the key product developed from the Native Lands Acts of 1862 and 1865, (now the Māori Land Court [MLC]) with their main objective to as Kingi states:

> *“Encourage the extinction of (native) proprietary customs.”* (Kingi, n.d, p. 136)

The Native Land Act 1860-1862 also allowed land to be made available for sale, which saw Māori access to, retention and control of land compromised and effectively access to best soil resources in New Zealand was lost (Harmsworth & Roskruge, 2014).

Māori were resilient against land sales; however the Crown had brought in the New Zealand Settlement Act in 1863 which helped aid the confiscation of Māori land by declaring a district and all land within it *Crown* land. Over 526,000 hectares in the Taranaki region was confiscated during this period (Kingi, n.d). The Native Lands Act Section 23 employed the 10 owners rule, meaning Māori land with 10 or more owners were not issued a Certificate of Title (Kingi, n.d). Tribal land that was over 2000 hectares could be given a title. The process of preventing large numbers of owners to land meant land was fragmented into small unusable blocks. As cited in Kingi (n.d):

> *"Owners can have multiple interests in more than one block of land. This has resulted in owner-interests numbering more than two million and increasing by 185,000 a year with successions."* (p. 137)

Kingi introduces the term **individualised Māori land** whereby owners have an individual interest in the land, unfamiliar with Maori social structures and beliefs in terms of land ownership. The issues around confiscation and trying to fit Māori land into an individual ownership model have set many issues which Māori now face today. Māori land is now governed by the Te Ture Whenua Maori Act (TTWMA) 1993 which is discussed further in this chapter.

The Native Lands Act 1862 enabled Māori to establish ownership interests that were recognisable in English Law, allowing individuals to own this land leading to fragmentation of ownership. The Crown also during this time, confiscated large areas of Māori Land, some of which has since been returned, but the majority of the land still remains Crown owned (Controller and Auditor General, 2004). The Controller and Auditor General (2004) states:

> *"Māori Land tends to have characteristics not associated with other forms of privately owned land, and is subject to a range of unique restrictions and protections."* (Part 2.1)

Legislation has played an important role in the history of Māori land and the development of Māori land today and still does. In 1895 the Native Townships Act was passed which allowed Crown to build townships on Māori land (Woodley, 1996). Another act was the *Crown and Native Land Rating Act 1882* which allowed council/boards (rating bodies) to lease land due to unpaid rates. The act also saw excessive rates been placed on Māori land creating pressure on owners (Marr, 1999). Legislation from the 1950s to 1960s was shown to have an unfavourable effect on

Māori Society. For example, the Māori Affairs Act 1953 and Māori Trustee Act 1953 were in place to improve the economic and social situation for Māori (Butterworth & Butterworth, 1992: Controller and Auditor General, 2004; Te Tumu Paeroa, 2008). The Māori Affairs Amendment Act 1967 allowed the change in status of land which was owned by up to four owners to become general land, this process generally occurred without the knowledge of the owners and consent (Māori Multiple Owned Land Development Committee, 1998).

The most recent legislation TTWMA 1993 was put in place to help ensure Māori Land would be kept within Māori ownership:

> *"Section 2(2) of the Act states:…"it is the intention of Parliament that powers, duties and discretions conferred by this Act shall be exercise, as far as possible in a manner that facilitates and promotes the retention, use, development and control of Māori land as taonga tuko iho by Māori Owners, their Whānau , their hapū and their descendants."*[1]

The objectives of TTWMA 1993 are;

> *(1)In exercising its jurisdiction and powers under this Act, the primary objective of the court shall be to promote and assist in—*
> - *(a)the retention of Māori land and General land owned by Māori in the hands of the owners; and*
> - *(b) the effective use, management, and development, by or on behalf of the owners, of Māori land and General land owned by Māori.*
>
> *(2)In applying subsection (1), the court shall seek to achieve the following further objectives:*
> - *(a)to ascertain and give effect to the wishes of the owners of any land to which the proceedings relate:*
> - *(b)to provide a means whereby the owners may be kept informed of any proposals relating to any land, and a forum in which the owners might discuss any such proposal:*
> - *(c)to determine or facilitate the settlement of disputes and other matters among the owners of any land:*
> - *(d)to protect minority interests in any land against an oppressive majority, and to protect majority interests in the land against an unreasonable minority:*
> - *(e)to ensure fairness in dealings with the owners of any land in multiple ownership:*
> - *(f) to promote practical solutions to problems arising in the use or management of any land.*

[1] TTWMA 1993, section 2(2)

The TTWMA 1993 defines Māori land as having one of the following:

> *(1) For the purposes of this Act, all land in New Zealand shall have one of the following statuses:*
> *(a) Māori customary land*
> *(b) Māori freehold land*
> *(c) General land owned by Māori*
> *(d) General land*
> *(e) Crown land*
> *(f) Crown land reserved for Māori.*
> *(TTWMA 1993- section 129)*

The majority of Māori land falls under Māori Freehold Land status. Māori Freehold Land is land which has not been out of Māori ownership; this is determined by the Māori Land Court (MLC). Te Puni Kokiri (2011) state:

> *"1.4 million hectares of Māori Freehold land and a small portion of Māori Customary land, with 2 million ownership interests in 26,490 Māori freehold land titles*. (p. 8)"

The Ministry of Agriculture and Forestry (2011) report '*Māori Agribusiness in New Zealand. A study of the Māori Freehold Land Resource'* identified 1.5 million hectares as the total land area of Māori Freehold land.

> *"Māori today only have a fraction of the land and natural resources to which they once had rights or title and live in a more fragmented, modern, free-markets society."* (Harmsworth & Roskruge, 2013, p. 119).

Te Puni Kokiri (2011) outline that some of these blocks are only as small as 5 hectares, with large ownership interests. Māori land is inter-generational i.e. as one owner dies their descendants succeed their ownership, therefore increasing the total number of owners.

The history of Māori land is complex and for the purpose of this thesis a brief overview is useful. Currently the majority of Māori Land is not suitable for high productive agricultural use as represented in Table 1. As well as the blocks being deemed unsuitable for intensive or highly productive agricultural systems these blocks are also a lot smaller than those of a 'general rural land block' (Māori Multiple Owned Land Development Committee, 1998).

Landcare Research has developed a 'scoring' system to access land in terms of long term land management; this system is known as the Land-Use Capability (LUC). The land is rated from one to eight in terms of versatility for various land-uses from arable, pastoral and forestry; with class one being the most versatile and class eight being the least versatile. New Zealand consists of less than 1% of class one land and less than 15% is classed between classes one and three which are those classes capable for intensive land-use (Mackey et al., 2011). As discussed previously, Māori land generally lies in the higher land classes shown in Table 2.

The issues around land-use management and land-use come about from the disproportionate amount of land classed as highly versatile. With pressures to increase production, higher risk is inevitable when less versatile land is used for increased production and intensification (Mackey et al., 2011).

> *"Rated all Māori freehold land into classes, 34% as Class six, 31% as Class seven and 15% as Class eight. Only 3% of Māori free hold land was classed as Class one and two, with 16% classed as Class three or four."* (Ministry of Agriculture and Fisheries, 2001. P.7)

Table 1 Location of Māori Land held by the Māori Land Court District

Total Māori Land Area per Land Blocks by Māori Land Blocks and Average Land Area per Land Blocks by Māori Land Court District					
	Total Land Area per Māori Land District (ha)	Māori Land Area (ha)	% of Māori Land by Land District	Number of Land blocks	Average Land Area per Land Block (ha)
Tai Tokerau	1,732,192	139,873	8.07	4,889	29
Maniapoto	2,156,583	143,388	6.65	3,594	40
Waiariki	1,936,270	426,595	22.03	5,074	84
Tairawhiti	1,169,091	310,631	26.57	5,320	48
Tākitimu	1,936,492	88,608	4.58	1,254	71
Aotea	1,284,284	334,207	26.02	3,710	90
Te WaiPounamu	16,715,185	71,769	0.43	1,795	40
Total	**26,930,100**	**1,515,071**	**5.63**	**25,636**	**59**

Source: Māori Multiple Owned Land Development Committee Report 1998

With information provided in the Māori Multiple Owned Land Development Committee Report (1998) several key figures were brought to attention relative to Māori land. These are:

- 50% of Māori Land (25% of all land blocks) is vested in Ahu Whenua trusts
- 20% of land (64% of all land blocks) has no formalised administration structure
- 9% is managed by the Māori Trustee

The land blocks involved in this research are classified as class 2 land, according to Landcare Research's 'Visualising Māori Land Online' tool[2]. The land which is classed as class 2 accounts for 15% of the total land area, with potential for economic development due to versatility. The key for these blocks will be to identify the ideal land-use opportunity especially relative to the soils found on these blocks.

Table 2 Land-use Capability and Māori Land

Māori Land-use Capability			
Land-use Capability Class	% of Total Land	% of Māori Land	Description of Land-use Capability
1	0.71	0.40	Most versatile, multiple land-use – virtually no limitations to arable use
2	4.55	2.69	Good land with slight limitations to arable use
3	9.22	5.75	Moderate limitations to arable use restricting crops able to be grown
4	10.31	9.81	Severe limitations for arable use. More suited to pastoral or forestry
5	0.79	0.038	Unsuitable for cropping – pastoral/forestry
6	27.98	34.04	Non- arable land. Moderate limitations and hazards when under a perennial vegetation cover
7	21.45	32.19	With few exceptions can only support extensive grazing or erosion control forestry
8	22.10	13.28	Very severe limitations or hazards for any agricultural use.
Other	2.97	1.43	

Source: Māori Multiple Owned Land Development Committee Report 1998.

In summary, the potential of Māori land is somewhat limited as shown in Table 2. Only 8.8 % of all Maori land falls within classes 1-3 land with the majority of land (almost 80%) classed LUC 6–8. The LUC classification of Māori land is discussed further later.

[2]Tool can be found using the link: http://whenuaviz.landcareresearch.co.nz/

1.1.3 Current Issues/Models

Māori land falls under the jurisdiction of the MLC; therefore anyone wanting to administer their Māori land must apply to the court (Controller and Auditor General, 2004). A process is required by the MLC for anyone who wants to become an administrator of Māori Freehold land (Figure 1). Restrictions and protections under TTWMA 1993 are set to ensure these are met.

Before interests in Māori Land can be passed from a deceased person to their successor/s, a succession application must be made to the Māori Land Court. An application can be lodged at any MLC registry, but is sent to the registry that covers the area where the land interests are located. This registry is responsible for processing the application. The applicant completes a succession application form and supplies supporting documentation, such as a death certificate for the person whose interests they are succeeding to, as well as whakapapa links to that person and the block of land. Court staff check that the application is completed in full and that the supporting documentation and fee are included.
↓
Court staff then search the historical records held by the Court to see what interests the deceased person had in Māori Land and from where they were derived. Staff also check the *whakapapa* details attached to the application for consistency with the record, and then compile a report for the Judge in preparation for a hearing.
↓
If all details are confirmed, then the application is notified in a monthly Court publication that advises all interested parties about the time and place of hearings, and the applications to be heard. The applicant and interested parties are notified of these details at least two weeks before a hearing.
↓
The hearing is held at one of several centres within the areas covered by the seven registries. The purpose of the hearing is to confirm the report compiled by the Court staff; to receive evidence and comments from the applicant and other interested parties; and for the Court to make a decision on the case.
↓
After the hearing, Court staff produce minutes as a record of proceedings, which are then sent to the applicant and all interested parties. A Court order, which records the Judge's decision regarding the application, is subsequently sent to the applicant and, if necessary, to other interested parties.
↓
If no rehearing or appeal is applied for within the time limits set for each, then the process is completed by entering the Court order on the Māori Land Information System (which updates details about blocks of Māori Land) and, where applicable, registering a copy of the order with the Land Registry

Figure 1 Process for Succeeding to Interests in Māori Land through the Māori land Court
Source: Controller and Auditor General, 2004

Other restrictions exist when dealing with Māori Freehold Land as outlined by the Controller and Auditor General (2004):

- *No-one has the legal capacity to alienate any interest in Māori Freehold land, unless it is done in accordance with the Act*
- *No owner has the legal capacity to dispose of their interest in Māori Land through a will except in accordance with the Act*
- *No interest in Māori land is legally able to be taken for payment of an owner's debts or liabilities (an exception is in the case of bankruptcy) and*
- *Māori freehold Land cannot be charged, sold, or leased by local authorities for the non-payment of rates, except in accordance with the act.*

(Controller and Auditor General, 2004, section 2.20)

1.1.4 Ownership Structures

Various structures and governance models are implemented in the running of Māori freehold land. Trusts and Incorporations are some of the structures used to govern Māori Land. Trusts are the most common type of ownership structure used by Māori Landowners (Kingi, n.d).

> *"A trust is a group of people nominated by landowners/ shareholders to manage their land block or shares. In the Māori Land Court a trust is known as a management structure. Under TTWMA Māori Act 1993, there are five types of trusts."* (Māori Land Court 2011).[3]

Each trust requires as stated by the MLC (2011)

- Land vested in the trust to be trust property
- A trustee to have control of the property
- Beneficiaries

Trusts are a way to govern land. It aids in helping ensure land stays within the preferred owners, and ensures that each member of the trust is heard, and decisions are made as a collective, rather than individuals making decisions themselves. Under the TTWMA 1993 five types of trusts can be formed. These are:

1. Ahu whenua trust

> *This is the most common Māori land trust. The purpose of an Ahu whenua trust is to promote the use and administration of the land in the interest of the landowners. These trusts are often used for commercial purposes. This is a land management trust and involves whole blocks of land.*

2. Whenua topu trust

> *This is an iwi or hapū based trust. It is designed to facilitate the use and administration of the land in the interest of the iwi or hapū. This type of trust is used for receiving Crown land as part of any settlement. This is a land management trust and involves whole blocks of land.*

3. Whānau trust

> *This is a whānau oriented trust. It allows the whānau to bring together their Māori land interests for the benefit of the whānau and their descendants. This is a share management trust and relates primarily to specified shares in land.*

4. Putea trust

> *A putea trust allows the landowners of small and uneconomical interests to pool their interests together. This is a share management trust and relates primarily to specified shares in land.*

5. Kaitiaki trust

> *A Kaitiaki trust relates solely to an individual who is a minor or has a disability and is unable to manage their affairs. This trust can include all of an individual's assets.*

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[3] Retrieved from http://www.justice.govt.nz/courts/maori-land-court/make-an-application/maori-land-trusts-1/maori-land-trusts-hp

In the 'Māori Multiple Owned Land Development Committee' (1998) report it was identified that Ahu whenua trusts and Māori incorporations were best for economic development of Māori land. In order to formulate a trust, landowners need to hold a hui (meeting) and apply to the MLC. The trust must agree on the land blocks to be placed into that trust, the terms of the trust, nominate trustees and take minutes. To become a trustee you must have written consent, but there are certain criteria that can prohibit someone from becoming a trustee. Trustees are categorized in these ways:

- Responsible trustees
- Custodian trustees
- Advisory trustees

The Incorporation is another structure used to govern Māori land.

> *"A Māori incorporation is a structure similar to a company. Its purpose is to facilitate and promote the use and administration of Māori freehold land on behalf of the owners." (Māori Land Court, 2010, p. 2)*
>
> *"Māori incorporations are designed to manage whole blocks of land and are the most commercial of all Māori land management structures. Whānau, pūtea, and kaitiaki trusts can operate under the umbrella of a Māori incorporation."* (Māori Land Court, 2010, p. 2)

Incorporations were set up in the 1960s, whereby owners amalgamated individual titles of Māori land under a single administration; the process which the Reureu blocks are currently seeking. Incorporation is similar to a trust; however you can operate trusts underneath the incorporation as well. The main purpose is allowing Māori land owners and their trust to act as a business, which allows them the tools to develop land (Kingi, n.d). To establish an incorporation there are a few more requirements that owners must meet;. They need to:

> • *hold a meeting, in accordance with Part 9 of the Act, at which they pass a resolution to establish a Māori incorporation or*
>
> • *have 15 percent of the total shareholding consent and*
>
> • *send an application with a copy of the minutes of the meeting to the Māori Land Court.*
> *(Māori Land Court, 2010, p. 2)*

In summary, an incorporation needs several land blocks, a single administration and management structure and representatives elected by shareholders to be responsible for developing the land.

Māori incorporations can include one or more blocks of freehold land, as long as they have more than two owners. Once an incorporation has been formed it can purchase any land. One requirement is that each incorporation must have a constitution, which will have meetings of shareholders, voting, committees of management and shares. Incorporation has a chair person, secretary and other committee members. With incorporations, owners can gift land, invest, grant a lease or mortgage the land to help borrow funds. Incorporations generally have many shareholders thus calculating shares, and the transfer of shares are both important.

The issues that can arise from governance structures such as incorporations and trusts are firstly, to be on the committee you need to be voted on, therefore whānau political interests can sometimes influence reasons behind shareholders voting these members on status as against capability (Kingi, 2002), with some people driven by wanting to control a larger part of the committee rather than looking at the expertise of those who have put their hand forward. The committee membership often shows a lack of expertise across the board, and this can be reflected in the difference between performance of Māori land vs. that on non-Māori land (Kingi, 2002).

Another barrier which Māori land development faces is a lack of expertise in specialist areas. Kingi (2002) states:

> *"Large numbers of Māori Authorities function at a level well below their non-Māori counterparts. Decision-making for committees and trustees can be ponderous, reflecting the insufficient level of expertise on boards, and the costs of administering these organisations are disproportionately high. Māori are underrepresented in all aspects of the industry, with the exception of landowners and unskilled labourers, even though the aggregated contribution from Māori land in some industry is considerable."* (Kingi, 2002 p. 2)

The development of Māori land and its potential is not as clear cut as many would believe. Many obstacles have obscured the ability of Māori to reach the full potential with their land. These obstacles date from as far back as the Treaty of Waitangi in 1840 to more contemporary issues such as multiple ownership, access to decision making information and ability to access capital investment. Māori land ownership is complicated. The following list outlines some of the well-recognised traditional complications Māori owned land faces in terms of development:

- *Multiple ownership and succession*
- *Legislation*
- *Cultural Factors*
- *Governance*
- *Environmental Factors*
- *Economic Factors*
- *Political Factors*
- *Absentee Ownership*
  (Controller and Auditor General, 2004; Te Puni Kokiri, 2011).

Māori land owners face administrative issues such as the absence of owners or shareholders whose addresses are unknown leading to a lack in succession planning, as well as the difficulty of making a collective decision, not only due to the often large number of owners, but also differing ideas throughout the group (Māori Multiple Owned Land Committee, 1998). Another issue Māori land owners face is urbanisation (Rutledge, Price, Ross, Hewitt, Webb & Briggs, 2010), so having an active role in decision making is difficult. The ownership system now in place means owners do not have to live on the land to be considered an owner or have an interest in the block. Most Māori land owners today do not live on the land blocks or derive an livelihood from the land. The over-riding issue for Māori is the connection between the themselves and the land (Kingi, 2002) and this is primarily an element of whakapapa or identity.

The Māori land tenure system which was introduced by previous Governments was one that preferred individual ownership, a concept most Māori were unfamiliar with (Māori Multiple Owned Land Development Committee, 1998). Multiple ownership is a compounding issue as the number of owners is constantly increasing and some blocks, can have many hundreds of owners. Conversely most Māori own small interests in numerous land blocks. Small blocks face the issue of high owner-to-land-area ratio and administrative needs. Even trying to track down the actual owners of land can be an issue, due to lack of succession and outdated court records. Once contact has been made, it is often difficult to encourage those owners to participate actively in the decision involving their land. Multiple ownership has led to the term fragmented land and fragmentation with recent developments of amalgamating several Māori Land interests together (Māori Multiple Owned Land Development Committee, 1998). Amalgamating land blocks is a way in which the issue of multiple ownership could be overcome (Kingi, 20002). In the 'Māori Trustee Annual Report 2014' by Te Tumu Paeroa (previously the Māori Trustee) an example of a recent amalgamation

'*Rangihamama Dairy Limited Partnership*' saw Māori Trusts and governing bodies such as Ministry of Primary Industries (MPI) and Te Tumu Paeroa work together to start a Northland dairy venture. It has been said this scenario could be used as a model for other Māori Land Trusts. The Rangihamama Dairy Limited Partnership was established to overcome barriers Māori face in land development, from multiple ownership, developing economic scale and capacity to grow (MPI, 2014b; Te Tumu Paeroa 2014).

All Māori land has land court records so development issues can be located within that system. Information available to Māori trusts and incorporations is limited, and at times incorrect, this prohibits the progression towards further developed land. The primary issue around this is that it undermines the owner's ability to make informed decisions (Controller and Auditor, 2014).

Trying to formulate one joint idea around development can be a mission in itself when each owner has his/her own views, aspirations, goals, expectations and knowledge that they believe is the correct way to relate to the land. People can look at development in terms of what happens now, or what may occur in the future, this can also be the case when dealing with financial elements (Controller and Auditor General, 2004).

Access to finance has traditionally been extremely hard to gain for Māori land, due to the risk for lack of collateral. The risk is very high especially with so many owners. A key issue is that many Māori do not have the funds needed upfront to continue on with the development they hope to achieve. Reid (2011) describes:

> *"A constraint on Māori Land development is lack of access to development capital, this lack of access if often attributed to the inability of landowners to raise finance because communal land cannot be used as collateral."* (p. 247)

Kingi (n.d.) outlines several issues Māori land faces in terms of accessing development capital. These are:

- *multiple owners*
- *the sale of land being restricted to other members of the landowning group or to other Māori with affiliations to the titleholder*
- *owners and those involved in managing Māori land not having current and comprehensive knowledge of the requirements of financial institutions*
- *financial institutions not having full information about the opportunities and possibilities of the Māori land tenure and administration system*

- *the perception among financial institutions that lending risks are higher due to restrictions on trading land*
- *the costs of loan recovery.* (p. 145)

Banks and finance companies in the past have noted that the multiple ownership models did not guarantee ownership to individuals and hence the banks did not gain security. Some Incorporations have taken the approach of developing an asset base that includes assets that can be used as security such as land in general title, commercial property and other equities (Harmsworth, 2005).

A prominent visionary amongst Māori who remains within Māoridom today was Sir Apirana Ngata. Ngata had a vision for Māori:

> *"Land to apply best practice, aggregate small holding into larger economic units, nurture the environment and make final returns."* (as quoted in Keenan, 2013, p. 5)

The following section explores Maori aspirations for their land.

1.1.4 Potential for Māori Land

The primary industries of New Zealand rely heavily upon agricultural exports especially dairy, sheep and beef. Māori can play a pivotal role in the economy. Kingi (2013) estimates the Māori pastoral section contributes 8-10% of national milk solids and 10-15% of national sheep and beef stock units. MPI (2014a) estimated Māori assets in the primary industries sector at $10.6 billion ($NZ), with huge potential for future development.

The asset base which Māori contribute is significant so development in all areas including agriculture, horticulture, fisheries, energy and aquaculture is important. The opportunities and potential Māori contribution is huge, especially Māori freehold land which is governed under the TTWMA 1993 (Ministry of Agriculture and Fisheries, 2011).

Kingi (2013) outlines four key areas in terms of land development:

1. *significant potential for smaller affiliated entities to collaborate and leverage their collective scale*
2. *multiple layers of decision making within these entities that require input from expert consultants, thus providing reporting and monitoring disciplines not often found in typical family farms*

3. *conservation and risk aversion (because of intergenerational stewardship) that has led to low levels of debt and strong balance sheets*
4. *underlying influence of Mātauranga (traditional knowledge) and Tikanga (cultural constructs, values and protocols) that are captured within a unique cultural bastion.* (p. 1898).

In a report conducted by Ministry of Agriculture and Fisheries (MAF) in 2011 40% of Māori freehold land was deemed under performing with another 40% deemed underutilised. With these large numbers one can see the vast opportunity Māori have in terms of future development. Developments such as the Northland Dairy Conversion which MPI worked alongside Omapere Taraire E & Rangihamama X3A Ahu Whenua Trust (ORT) to help accelerate the Trust's transformation of 278 hectares from grazing to high-productivity dairy farming since 2012 (MPI, 2014b). The ORT model helps to get a number of stakeholders into a larger and more effective operation such as amalgamating several land blocks into one unit.

The Ministry for the Environment identified that in 2004, pastoral land-use was New Zealand's largest human land-use covering over 37% of the total land area of New Zealand (MFE, 2004). Although pastoral land has decreased, pastoral land-use for dairy has increased, increasing 24% in the period of twenty years (1994 – 2014). Conversions into dairy have become common practice among many dry stock farms and in some cases with detrimental effects towards water quality, soil health and greenhouse gas emissions (MFE, 2004).

With all the current opportunities for Māori land, careful planning must be undertaken to ensure land-use and development is environmentally sustainable and also economically suitable. As cited in Lynn et al. (2009):

> *"The importance of robust and objective evaluation of New Zealand's land resources in planning and the promotion of sustainable land managements can be emphasised in two important ways. Firstly, the value of New Zealand's annual agricultural and wood exports in 2007 totalled $13.45billion and $2.25 billion respectively."* (p. 7)

The ability of New Zealand to maintain and increase the profitability of its land resource requires sustainable land management. Land management requires an assessment to use for future planning that is based on a transparent robust assessment and good science (Lynn et al., 2009).

The Reureu blocks are an example of Māori owned land interests where owners want to work together at a larger scale, amalgamating these blocks to provide scale to work with for future land development.

When considering a change in land-use it is important to work through the steps that ensure effective decision making, as a change in land-use will usually require capital investment. With demonstrable restraints against Māori obtaining finance for capital investment, decisions need to be dealt with, taking into consideration both the economics and the environment. As kaitiaki it is important for Māori that information of the physical resource is gathered, with interpretations as to whether this information is accurate, accessible, scaled correctly and up-to-date.

> *"To achieve intergenerational sustainability and management of our precious natural resources, such as soil, it is essential to include a range of societal, community, and indigenous values and expectations in all aspects of decision making, planning and policy."* (Harmsworth & Roskruge, 2014, p. 266)

If not, then new information may need to be gathered. Land evaluation is a key component of land-use change, looking at the ability of the land to carry out its role under different uses such as dairy, sheep and beef.

Physical assessments of a natural resource such as land are important factors. Land evaluation is an important tool to help identify land for various uses. In simple terms land evaluation helps to estimate potential land for alternative land-uses (Dent & Young, 1981). Land evaluation needs information to be effective from three sources to make effective decisions these are; land, land-use and economics. Physical assessments are supported by specific data collection including soils tests.

Mackay et al., (2011) identified that 60% of New Zealand soils have some physical limitation to be used under pastoral agriculture. The importance of understanding the soil and all its qualities can be over-looked in ensuring a good land-use change decision is made. The importance of understanding the soil is paramount to a comprehensive fertiliser scheme to achieve high yields, as soil types vary not only within farms, but also within paddocks. Identifying these and the components such as Phosphorus retention of each will help to determine a good fertiliser scheme.

Soil tests are undertaken to give an overview of the nutrients available for plant uptake and therefore the necessary inputs for pastoral agriculture. Schipper (2010) identifies sources of nutrients in the soil can be derived from the clay fraction, organic matter, parent material, climate, organisms, topography, time and external nutrients. Dairy relies heavily on systems with external inputs to increase pasture production. Fertiliser programs are generally implemented to achieve this goal. As dairy is an important potential land use option for the Te Reureu blocks, further investigation into vital dairying aspects such as irrigation, farm dairy effluent (FDE) application and nutrient management will be undertaken. These will also be required by the owners or hapū when applying for resource consent. The uniqueness of any land blocks can indicate land-use change is possible if an economic argument based on physical assessment is undertaken.

The importance of this research will be outlined by identifying the small area of highly versatile land in New Zealand, the pressure to intensify current farm management and change of land-use from sheep and beef to dairy. The uniqueness of this study is the land is Māori Freehold land, has multiple owners and includes currently undeveloped land. Other issues around matters such governance, capital investment and a full economic analysis of this project are not covered in this research as the focus is on a physical assessment alone.

1.2 Research Question

How can an assessment of the physical resource with an emphasis on the soil of the Reureu blocks help to make informed decisions around potential land-use?

1.3 Research Objectives

The purpose of this research is to evaluate the land resource of the Reureu blocks. This includes research on what information is presently available, the quality of this information, and areas where information is lacking relative to making an informed decision about a change in land-use. The focus for this research will be on the physical resource, such as the soil resource.

The uniqueness of this research is in the context of several adjacent Māori land blocks looking at amalgamation to become more feasible for land and economic development at a larger scale than individual blocks.

The following research objectives are proposed:

- A full summary of background information currently available on the Reureu blocks:
    - soils
    - climate – rain, sunshine hours, wind, frost, temperature, flooding
    - geology
    - past and present land-use
- Determining if the information available is current, correct and of a correct scale for informing land-use changes.
- Reviewing land evaluation tools and their role in informing decisions on land-use change?
- Understanding soil and its role in land-use change relative to Māori interests:
    - soil mapping
    - soil fertility
    - nutrient management
- Evaluating land for dairy
    - identifying suitability based on key factors specific to dairy production unit

1.4 Chapters

The following breakdown of chapters is provided:

- *Chapter 1* examines the background information, research objectives and outlines chapters that are set forth in this thesis.
- *Chapter 2* provides an overview of the study area. Examining soil information conducted in regards to a national and regional scale. Examines the physical and

geological environment of the Reureu blocks and finally examines the past and current land-use.

- *Chapter 3* examines the methodologies used whilst carrying out this research
- *Chapter 4* examines the review on literature focusing on land evaluation tools and technology to be used for land development and making decisions around land-use. It also introduces the soil resource and its role in land development.
- *Chapter 5* examines the results of the study of soil mapping to land evaluation tools used to help make decisions about land-use.
- *Chapter 6* provides more information specific to dairying such as irrigation, effluent and nutrient budgeting.
- *Chapter 7* provides the discussion.
- *Chapter 8* provides the conclusion.

Chapter 2 Overview of Study Area

2.1 Introduction

The study area is located in the Manawatu Region specifically, in the Rangitikei River Valley. The land blocks involved are Māori freehold land, with some blocks leased for dairy support and other blocks for grazing. The majority of owners for some of these land blocks do not presently live there, with many living elsewhere in New Zealand or abroad (L. Iwikau, personal communication, June 2014). A majority of the owners want to amalgamate these blocks from small blocks of less than 1 ha to a total area of 204 ha dairy farm platform. For this idea to be accomplished a representative area of the blocks was investigated comprising of a total land area 74 ha. Information was gathered for the physical resource to contribute to an informed land change or development.

The objectives for this chapter are to provide:

- an overview of the land blocks involved;
- a review of previous soil studies relevant to these blocks both regionally and nationally;
- and, background to the study area and its location and physical environment.

2.2 Land blocks involved in study area

With Māori freehold land, complications arise from the number of owners and this collective is no exception with over 490 listed owners representing a wider beneficial interest for a total land area of 204 ha. The total area currently available for development will be around 74 ha with some land deemed too steep. For the purpose of this research the area of 0074 ha was focused on with a total land area of 204 ha potentially ready for development (Table 3).

The overall area for possible conversion is 204 ha; however as the total land area is still under debate from shareholders, this study focused on the 74 ha which had gained a consensus to look at development options.

Table 3 Outline of the land blocks involved

LINZ reference	Title Name	Land Area (ha)	Owners	Shares
424879	Reureu No 1 Section 12A	0.4705	21	186
426366	Reureu No 1 Section 12B	0.9409	72	372
426632	Reureu No 1 Section 12C	7.7733	20	3140
WN7B/655	Reureu 1, 16 Block	9.5	11	General land
437773	Reureu No 1 Section 13C	10.1323	39	4006
449554	Reureu 1 13A Block	0.8094	175	320
WN23C/199	Reureu 1 14A Block	2.6987	2	1067
WN25D/859	Reureu 1 14B Block	2.6987	1	1067
WN23C/200	Reureu 1 14C Block	2.6987	2	1067
WN502/260	Reureu 1 6B Block	7.1073	General	Rihi Iwikau
424344	Reureu 1 Section 6C No 3	1.1457	1	453
424345	Reureu 1 Section 6C 4A	0.8602	6	340.125
424503	Reureu 1 Sec 6C4B	1.4337	70	566.875
424186	Reureu 1 Sec 6C2	1	35	453
WN304/106	Reureu 1, 5A Block	13.1118	General	Rihi Iwikau
WNA2/581	Reureu 1, 5C Block	12.4365	General	Rihi Iwikau
424182	Reureu 1, 6C No.1	1	36	453

Currently all these blocks are independently managed and/or leased out for various uses such as dairy support, personal use, silage and hay. The majority of the blocks are leased out to a single local farmer. For the purpose of this study the blocks will be referred to collectively as the Reureu Blocks.

2.3 Location and General Description of the Study Area

The study area (40.4’52.254”S, 175.29’2.427”E) (Figure 2) is located within the Rangitikei river valley, bounded by Reureu Road, Kakariki and Makino Roads which lies approximately 10 km north of Halcombe. The land blocks are located in the Horizons Regional Council (HRC) Region within the Manawatu Area. Feilding is the closest town 21 km south and Palmerston North a further 15km west of Feilding. The total area of study is 74 ha.

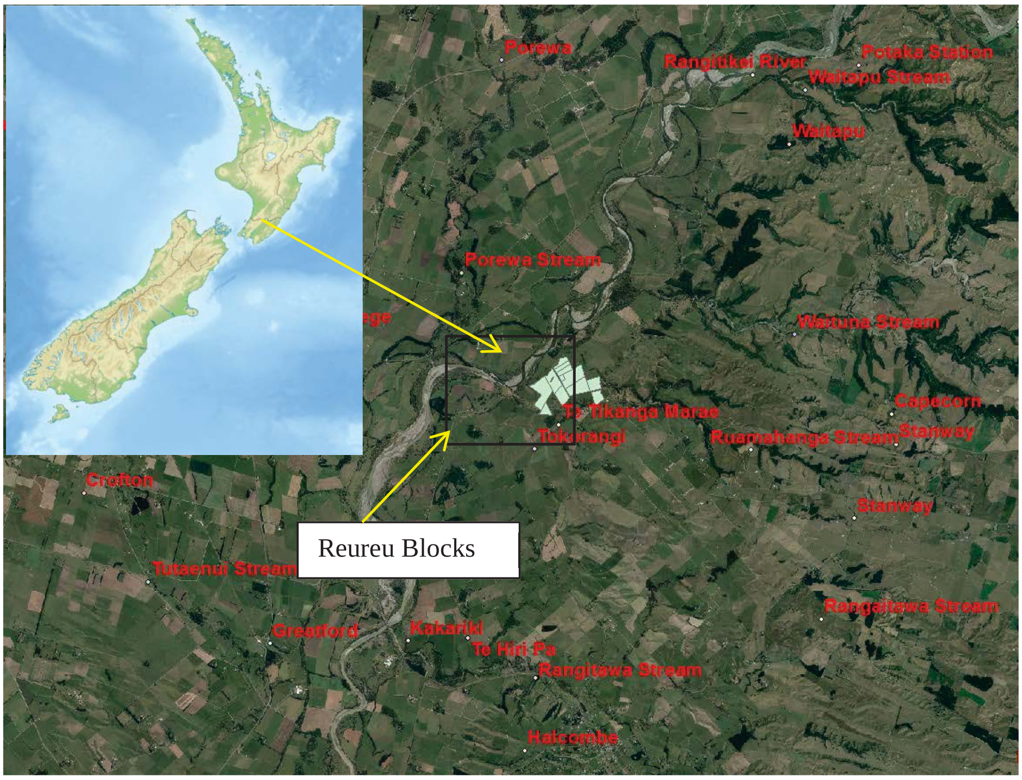

Figure 2 Locations of the Reureu Blocks

The landforms in this study site are mostly terrace lands and river flats. There are two terrace levels present; intermediate and lower. These terraces are covered with alluvium from the Rangitikei River, forming alluvial soils. The landscape is flat to slightly undulating where current and old streams cut through the blocks. These streams cut through the middle of the blocks and eventually drain into the Rangitikei River nearby. The soils found on the Reureu blocks are predominately those lying on frequently flooded terraces, with some soils on the slightly higher (intermediate) terrace rarely flooded and on the highest terrace soils are non-flooded. The soils on the intermediate terrace (i.e. soils experiencing rare flood events) are developed due to aggradation of gravels from nearby Rangitikei River and the Raumanga Stream. The soils on the Reureu blocks are derived from aggradation of gravels and alluvial deposits from the Raumanga Stream and Rangitikei River. Loess deposits were not common on the lower terrace and intermediate terrace, with some loess possibly present on the highest terrace.

2.4 Previous Soil Studies

2.4.1 National Scale

Various soil maps were researched to gain information on the possible soil types that might be encountered on these blocks.

The New Zealand Soil Bulletin 26(1) (1968) divides the country into various regions and provides more in-depth detail on the soils found in this region. The Reureu blocks in the Manawatu – Wellington region. The soils in this region are defined under five headings these are (Luke, 1968):

1. Central-yellow grey earths (and intergrades)
2. Central-yellow brown earths (and intergrades)
3. Steep land Soils
4. Central yellow-brown sands
5. Central recent, gley, recent and organic soils

The Reureu blocks lie are classified two main soils (Figure 3), these are;

- 14b – Halcombe-Raumai soils
- 22a – Takapau - Gwavas stony soils

Both the Halcombe-Raumai soil and Takapau – Gwavas soils are defined as a yellow grey earth soil. Yellow grey earths (YGE) [4] soils typically have a dark greyish brown top soil which is weakly developed with a crumb to nutty structure. YGE soils are prone to having a fragipan between 25cm – 60cm which is yellow in colour (Gibbs, 1980; Luke, 1968; Department of Scientific and Industrial Research (b), 1954). YGE are developed from windblown loess from river beds and coastal sand dunes, with the difference between the two soils measured by the rate of loess accumulation (Luke, 1968).

For more in-depth detail See chapter2 of the '*Soils of the North Island*' and '*Map found in the New Zealand Soil Bulletin No.26 (1)(1968)*'.

[4] The yellow grey earth's soils are not alluvial soils, this was discovered from soil mapping later.

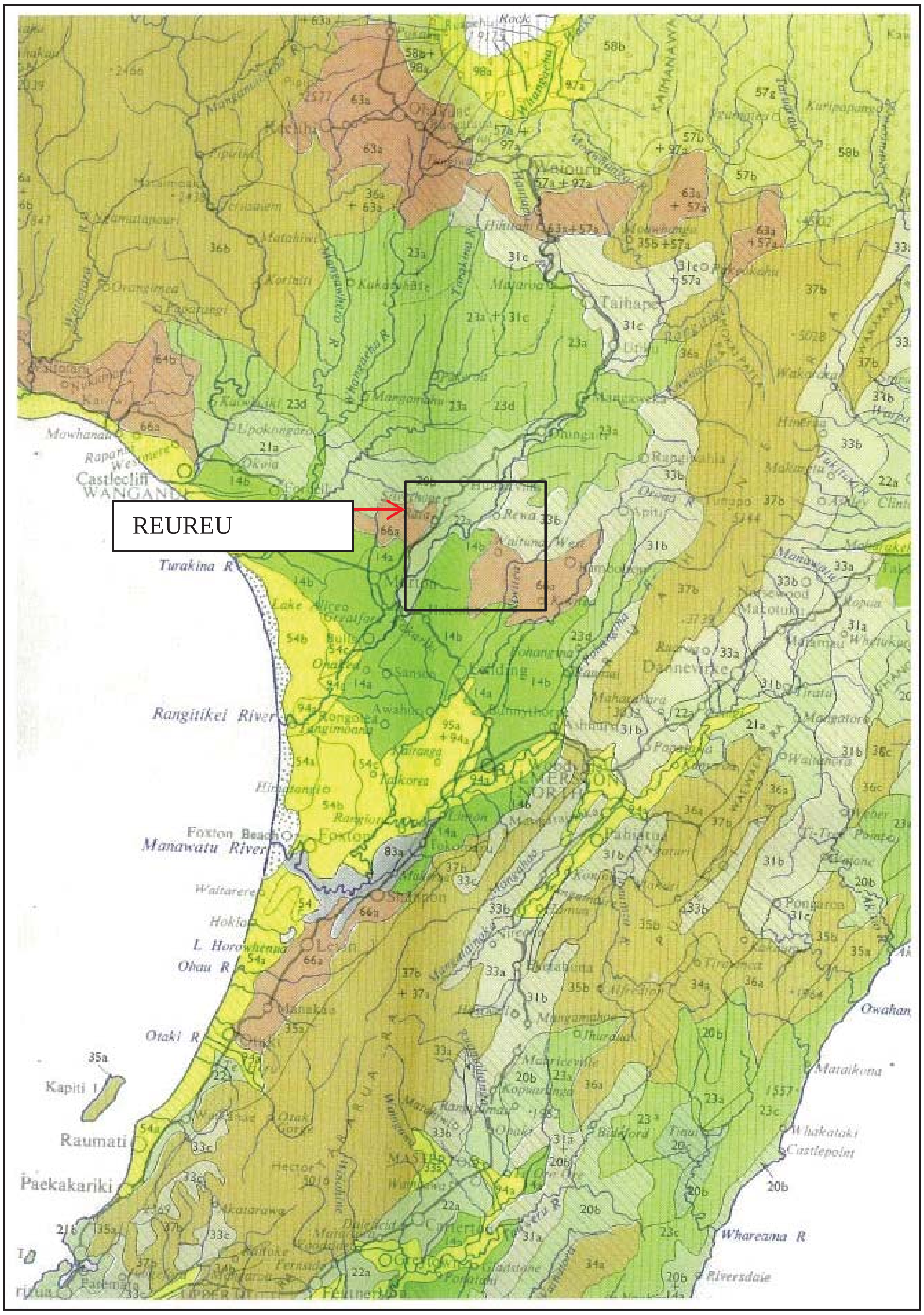

Figure 3 Soil Map of New Zealand

Source: NZSB 1968. Soils of New Zealand, Part 1 Luke, 1968, scale is 1:1,000,000

2.4.2 Regional Scale

There are only two soil maps publically available which are relevant to the Reureu Blocks these are '*Soils of New Zealand, part 1, 1954*' and the '*Oroua County Map*'[5].

[5] Oroua County Soil Map not published (Gibbs & Harris, 1956)

The Oroua County Map (see Appendix 2-1) was constructed by H.S Gibbs & C.S Harris in 1956. The map was compiled together from previous soil surveys undertaken by both Harris himself and also those by Gibbs and Harris jointly. The Reureu blocks are assigned the reference 1b (Figure 4 and Appendix 2-1). The reference 1b refers to Recent Soils, known as Esk Sands. A more detailed analysis of the physical and chemical properties of the Esk sands soils can be found in the Soil Bureau n.s (5) (DSIR, 1954) extended legend (Tables 4 and 5 for summaries).

Table 4 Physical Properties of Esk Sand (1b)

Reference	1b
Provisional Name	Esk Sand*
Parent Material	Alluvial sands
Native Vegetation	Totara, manuka, fern
Topography	Flat
Rainfall p.a (in)	30-70 (762 – 1778mm)
Soil Profile	6in (152.4mm) – greyish brown or blacks sand, on grey-brown sand
Natural Fertility**	Medium to low
Present Uses***	4,5,6,7
Carrying Capacity or Production	Average – 90-120lb (40.8-55kg) B fat**** 1-1.5 ewes Potential – 120-180lb[6] (55-81.6kg) Bfat**** 2-3 ewes
Adapted to***	5, 6
Response to Pasture top dressing	Phosphates – good Lime – slight to fair
Soil Erosion	Stream scouring and flooding, some wind

Source: Extended legend in Soil Survey, soil Bureau n.s (5) 1954 – summary from extended legend.

*- name used is one of several established soil types, which have been grouped together
** - natural vegetation – vegetation which is determined to cover soils pre-European times
***- Present use/Adapted to – 4 –semi intensive sheep farming (breeding ewes, most lambs fattened, beef cattle in parts, 5 – intensive sheep farming (fat lambs), 6 – dairying, 7 –market gardening
****- Bfat – butterfat per acre per annum

[6] Note the imperial scale i.e. inches, pounds and acres is a reflection of the time of the publication.

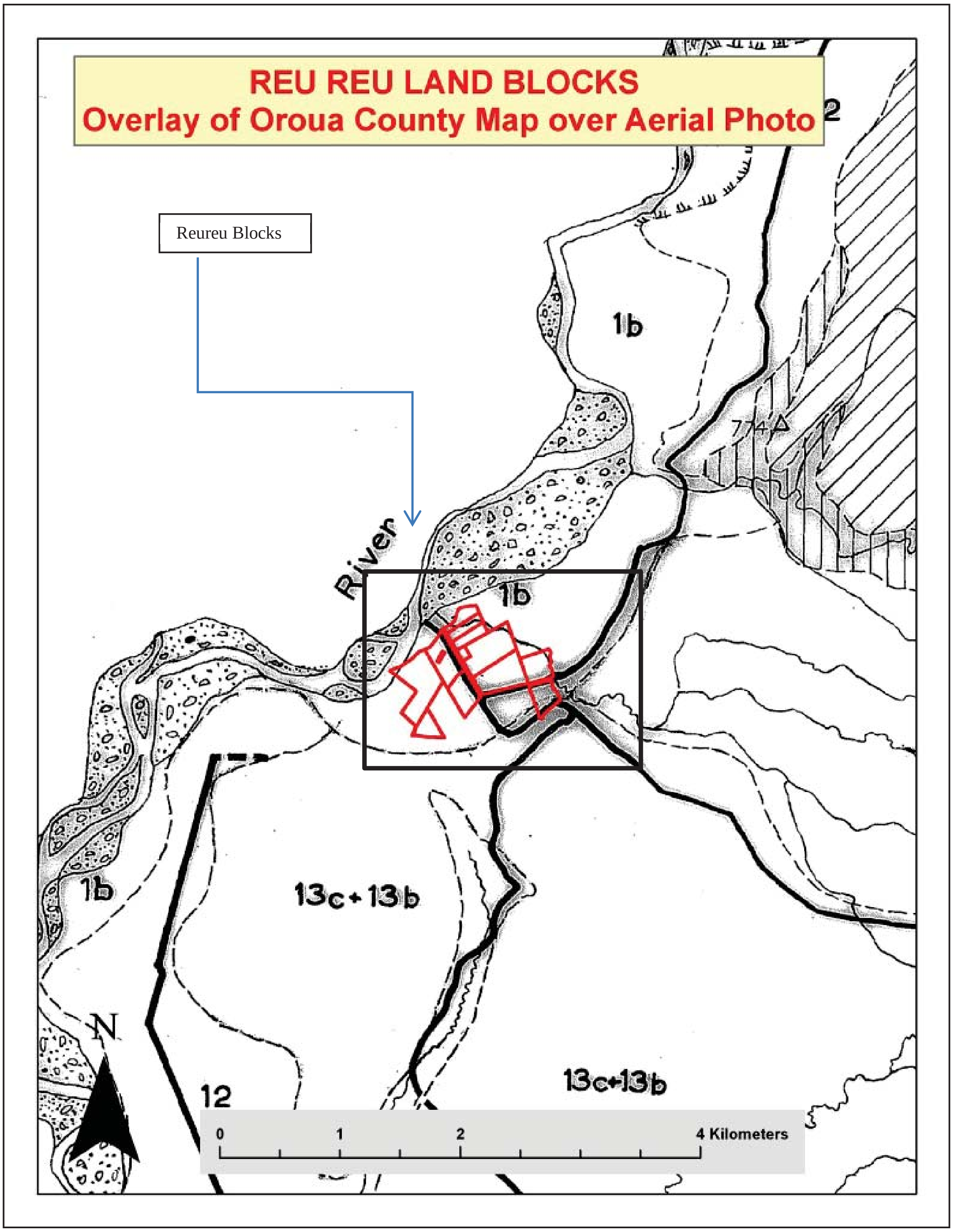

Figure 4 Oroua County Map Source (un-published).[7]

Source: Landcare Research

[7] Oroua County Soil Map not published (Gibbs & Harris, 1956)

Table 5 Chemical Properties of Esk Sands (1b)

Esk sands (1b)	Depth: 0-101.6mm	Depth: 304.8-457.2mm
1% Citric Acid Soluble: **P2O5%** **K2O%**	 0.019 0.058	 0.004 0.035
pH	5.6	5.8
Total N%	0.30	-
C/N	13	-
Base Exch. Capacity m.e%	15.2	10.0
Total Exch. Bases m.e%	6.1	5.1
% Base Sat.	34	51
Exch. Bases m.e% **Ca** **Mg**	 4.3 1.9	 2.9 1.2
Slope, Vegetation, Over sample etc.	Mixed grasses	

Source: Extended legend in Soil Survey, soil Bureau n.s (5) 1954 – summary from extended legend.

Scale of a soil map is important especially when considering the difference between regional and farm scale planning/mapping. A regional scale map would use a 1:50,000 map whereas a farm scale map would be 1:10,000 (Lynn et al., 2009). The Oroua County Map is produced at a scale of 1:63,360 which are too large when considering a change in land-use. It is therefore appropriate for a more detailed soil map of the Reureu blocks to be prepared to assist with any change in land-use decision.

2.5 Classification of Soils

The New Zealand Genetic Classification (NZGSC) of soils was developed by Norman Taylor in 1948. This style of classification system identified soil groups and how these were related to the environmental factors. The NZGSC enabled relationships to be drawn from soil forming properties to help identify soils at a broad scale (Taylor & Pohlen 1962). The difficulty with this classification system was the poorly defined definitions of each class. Land evaluations and modern day surveys require a far more in-depth classification of soils (McLaren & Cameron, 1996).

By the late 1980s the NZGSC soil classification become inundated and a new soil classification known as the New Zealand Soil Classification (NZSC) was developed by

Hewitt and released in 1992. The new system was NZSC classification, however it is important to be familiar with both the old system and new. The NZSC is a more detailed classification system which divides the soils in a hierarchical structure such as order, group and subgroup. A fourth level of classification of soils was soil forms added by Clayden & Webb (1993). The objectives of the new system as cited in McLaren & Cameron (1996) are to:

- *Provide better means of communication of NZ soils and their utilization*
- *Provide efficient vehicle for soil identification, soil series recognition and correlation and soil map legend establishment in soil surveys*
- *Enable efficient stratification of soil database information and*
- *Draw together knowledge of the properties of NZ soils and important similarities and differences amount them*

There are clear differences between the two classification systems. The NZGSC at its highest level is spilt into three orders (zonal, intrazonal and azonal). Whereas the NZSC are spilt into 15 soil orders (allophanic, anthropic, brown, gley, granular, melanic, organic, oxidic, pallic, podzals, pumice, raw, recent, semiarid, and ultic); Under the NZSC, once soil is assigned an order they are spilt into soil group and subgroup, then into soil series. Soil mapping requires even further information therefore soils are spilt into soil series (e.g. Manawatu Series).

Webb & Lilburne (2011) developed the soil classification system even further to contain order, group, subgroup, family, sibling, a concept used in classification of soils on S-Map. S-Map is a digital soils database of New Zealand, which can be used from regional to farm scale mapping, although not all of New Zealand is covered. A family is defined as combination of subgroup and soil form. The soil family name is commonly referred to as the soil series. Siblings are split off based on drainage, stoniness, texture and the depth of the soil series (Lilburne et al., 2004).

For land evaluation mapping (LRI) and land use capability mapping (LUC) soil information is classified in terms of the old NZGSC and NZSC classification. Soils may also be defined at a ‘regional’ level describing the series (Manawatu), soil type (Manawatu fine silt loam) and phase (Manawatu fine silt loam, mottled phase). S-Map is can also be used as it tries to get a consistent national soils database with a common legend.

2.5.1 Horizons Regional Council (HRC)

New Zealand is divided into sixteen regional councils, HRC being the regional council for the Manawatu-Wanganui region. Territorial authorities are the second tier of local government in New Zealand under regional councils. There are 12 city councils and 53 district councils. The purpose of regional councils is primarily to promote sustainable development.

The local regional authority for the Reureu blocks is HRC. HRC has assigned the Reureu blocks with a reference “12 GOT Ohakea Loam” (Appendix 2-2). The GOT represents Orthic Gley soils under the New Zealand Soil Classification (NZSC, Hewitt 2013) and 12 represents Ohakea Loam (Appendix 2-3) defined in the both the Kairanga County and Manawatu County soil reports.

Orthic Gley Soils are a group of Orthic Soils. Orthic Soils are found on stable land surfaces where groundwater does have an effect on these soils (McLaren & Cameron, 1996 ; Hewitt, 1998). According to Hewitt (1998);

> *“Orthic Gley soils are not strongly acidic, sandy or sulphuric with sedimentation during flooding uncommon”*. (p. 68)

The Classification of the Orthic Gley Soils can be found in the New Zealand Soil Classification Interim Reprint (2nd edition, 1998). Gley Soils are mineral soils on wetlands. These soils are classed as intrazonal order soils replacing the earlier name given in the *Soil Bureau Bulletin 5* as Meadow paddocks (Gibbs, 1980). The definition of an Intrazonal soil is a soil grouped due to soil forming processes which rely on parent material, topography and time (Gibbs, 1980). The uses for Gley soils generally support growing native forest, flax, flood reserve and wildlife; however this is diminishing under the intense pressures of dairy farming (Gibbs, 1980). The issues these particular soils have for intensive dairying are: slow drainage, high moisture content, low oxygen and cool soil temperatures (Gibbs, 1980). The New Zealand Soil Classification has 15 soil orders; one of these is Gley Soils. Gley Soils are most commonly affected by

waterlogging, are chemically reduced and have light grey subsoils with reddish/brown mottles present. The grey colour extends up to 90cm (Landcare Research, 2014). Gley soils are commonly found in areas which experience high groundwater tables. Large areas of these soils have been artificially developed to be used for agricultural use, possibly due to most of these soils being found on flat areas (Hewitt, 1998).

The Ohakea Loam is a soil type found on terrace land which soils are imperfectly to very poorly drained soils. The soils found on these terraces are mostly yellow-grey earths (Cowie & Rijkse, 1977). The Ohakea series is formed from loess, colluvium and alluvium which are generally found on the intermediate aggradational terrace. These soils are poorly drained Gley soils developed in colluvium derived from erosion of loess on adjacent hill side scarps or higher terraces (Cowie & Rijkse, 1977). Refer to Appendix 2-4 for other HRC GIS maps.

2.5.2 Fundamental Soil Layers from "Landcare Research"

The soil maps developed here are based on 1:63,360/1:50,000 scale soil maps which are based on information stored in the National Soils Database (NSD) or from pedologists who know the region's soils well. The Fundamental soil layers contain 16 key soil attributes which can be helpful in computer modelling and helping resource management decision making. The fundamental soil layers has information that has produced soil maps based on order, group, class and series for the Reureu Blocks. This can be achieved using the LRIS portal to import data into a GIS program.

The *fundamental soil layers* from Landcare Research has given the soil series on the Reureu blocks a code 12* which refers to Ohakea loam. Explanatory information on this series is discussed in the Soil Bureau bulletin (n.s) 5 1954, (Tables 6 and 7).

Table 6 Summary of extended legend information for Ohakea loam

Reference	12
Provisional Name	Ohakea loam
Parent Material	Alluvium
Native Vegetation	Broadleaf-podacarp forest
Topography	Flat to undulating
Rainfall p.a (in)	35-40 (889 – 1016mm)
Soil Profile	6in (152.4mm) – dark-grey loam 20in (508mm) – brownish-yellow clay 6-12in (152.4 – 304.8mm) sandy loam, on gravel
Natural Fertility*	Medium to high
Present Uses**	5,5a,6,4
Carrying Capacity or Production	Average – 135lb (61.2kg) B fat*** 2 – 3 ewes Potential – 5- 6 ewes
Adapted to**	5, 5a, 6
Response to Pasture top dressing	Phosphates – good Lime – fair
Soil Erosion	Nil

Source: Extended Legend in Soil Survey, Soil Bureau n.s (5) 1954.

*Natural Vegetation – vegetation which is determined to cover soils pre-European times
**Present Uses/Adapted – 5 Intensive sheep farming (fat lambs), 5a – intensive sheep farming (fat lambs plus cash crops, 6 – dairying, 4 – semi intensive sheep farming (breeding ewes, some lambs fattened, beef cattle.
***Bfat – butterfat per acre per annum

Table 7 Summary of the chemical analysis for Ohakea loam

Ohakea Loam (12)	**Depth: 0-152.4mm**	**Depth: 152.4 – 304.8mm**
1% Citric Acid Soluble: **P2O5%** **K2O%**	 0.013 0.031	 0.003
pH	6.1	6.6
Total N%	-	-
C/N	-	-
Base Exch. Capacity m.e%	22.8	18.4
Total Exch. Bases m.e%	8.5	6.6
% Base Sat.	38	46
Exch. Bases m.e% **Ca** **Mg**	 7.1 1.7	 4.1 2.8
Slope, Vegetation, Over sample etc.	Ryegrass, cocksfoot, browntop, clover	

Source: Extended Legend in Soil Survey, Soil Bureau n.s (5) 1954.

Appendix 2-5 shows GIS maps produced by Landcare *Fundamental Soil Layer*

2.6 Physical Environment

2.6.1 Climate

The Reureu blocks lie within the Manawatu /Rangitikei sub region, with a mild to sub humid climate (Cowie & Rijkse, 1977). The rainfall is relatively low compared with other western regions. The climate station used for the predictions of the following climate events was the Palmerston North Ews station (21963). Although this station is not in the exact location, climate events will be very similar, and this station was used as it has the most information collected to use one station for all events.

2.6.2 Rainfall

Rainfall data information was sourced from the CliFlo climate database, produced by NIWA. The total rainfall for the year 11th August 2013 to 11th August 2014 was 714 mm (Figure 5) (NIWA, 2014a). The average rainfall will be between 700-900 mm.

Rainfall data also collected from CliFlo over a 30 year period from 1981 to 2010 shows average total rainfall data was 969 mm (NIWA, 2014a). CliFlo is web based system that provides access to New Zealand's National Climate Database, found on NIWA website; to access CliFlo you need to register on the website.

> *"The climate database holds data from 6500 climate stations which have been operating for various periods since the earliest observations were made in the year 1850. CliFlo returns raw data and statistical summaries* (NIWA, 2014a)"

Another NIWA survey shows that average rainfall was 967 mm in Palmerston North, based on data from 1971 to 2000. Although there is a difference in rainfall from 2013-2014 as opposed to that over 30 year span, the average rainfall would comfortably, be 700–900 mm (NIWA, 2014a).

Rainfall data provided by HRC (P. Taylor personal communication, 14th May 2014), showed median annual rainfall to be 1027 mm and mean annual rainfall to be 1041 mm. These numbers fit well within the information provided by CliFlo.

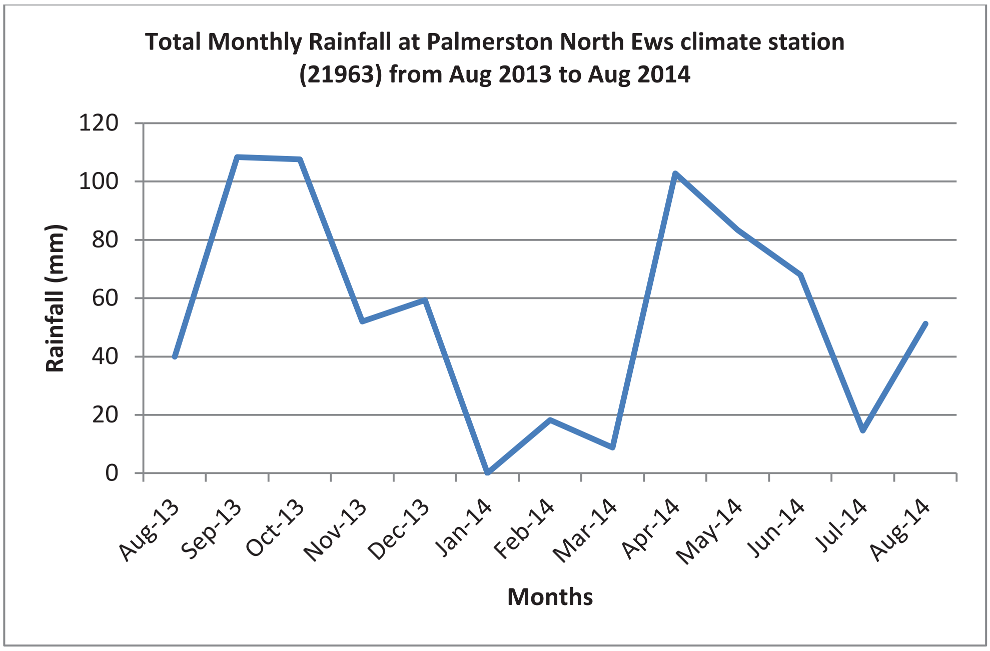

Figure 5 Total monthly rainfall from 11/08/2013 – 11/08/2014

Source: Data from CliFlo database, NIWA 2014.

The months from December through to March are the driest months of the year, with most of the rain falling between the months of April through to August. Evaporation data was available in three methods; open water, Penman PET and Priestley Taylor PET are measured in mm, as shown in Table 8 (PET = Potential Evapo Transpiration).

The Penman equation describes evaporation from an open water surface; variations of this equation are used to estimate evaporation from water and land. The Priestley Taylor equation estimates net evapotranspiration. The evapotranspiration shows that November experiences the highest rate of evapotranspiration, with the least amount experienced in June (NIWA, 2014a). The data was collected and summarised from CliFlo data on NIWA database, there was no data recorded between 17th December 2013 to 16th February 2014 (NIWA, 2014a). This was due to faulty equipment (S.Singh, personal communication, February 2015).

Table 8 Evaporation data from 11/08/2013 – 11/08/2014

	Open Water (mm)	**Penman PET (mm)**	**Priestley Taylor PET (mm)**
Aug-13	32.8	27.7	17.2
Sep-13	57.6	56.5	43.1
Oct-13	80.1	84.4	71.7
Nov-13	107.6	118.4	107.6
Dec-13	57.6	64.5	60.9
Jan-14			
Feb-14	70.1	66.6	56.3
Mar-14	113.4	98.1	73.5
Apr-14	75.2	56.2	35.4
May-14	48	31.5	12.7
Jun-14	45.3	23.9	3.2
Jul-14	43.3	24.3	4.1
Aug-14	14.7	10	4.4

Source: Data from CliFlo database, NIWA 2014.

Burgess (1985) explains that coastal lowland areas in the Manawatu are extremely dry, especially during the summer, with annual rainfall ranging from 900–1200 mm. Annual rainfall in the west of the Manawatu are lower than those in the east, possibly due to the hills. Extremely long periods of low rainfall are infrequent, with very dry spells defined as a period of 14 or more consecutive days without rain. If these periods are to occur in this region these are most frequent during January to March when anticyclones affect the North Island (Burgees, 1985).

2.6.3 Temperature

The mean air temperature over a 30 year period from 1981–2010 in the Palmerston North Climate Station (21963) was 13.3°C (NIWA, 2014b). Over the 30 year period a mean temperature of 17.6°C was recorded with a minimum temperature of 9°C (NIWA, 2014b).

The maximum temperature from the period of 11th August 2013 to 11th August 2014 was 26.15°C and the minimum temperature was 3.3°C. Temperatures tend to be higher from December through to April with the colder months experienced from May to September, shown in Figure 6 (NIWA, 2014b). Another NIWA report summary year 1971-2000 shows on average temperature 13.3°C, with a maximum of 33.0°C and a minimum of -6°C. The average between all the data shows that temperatures range between 12-18°C.

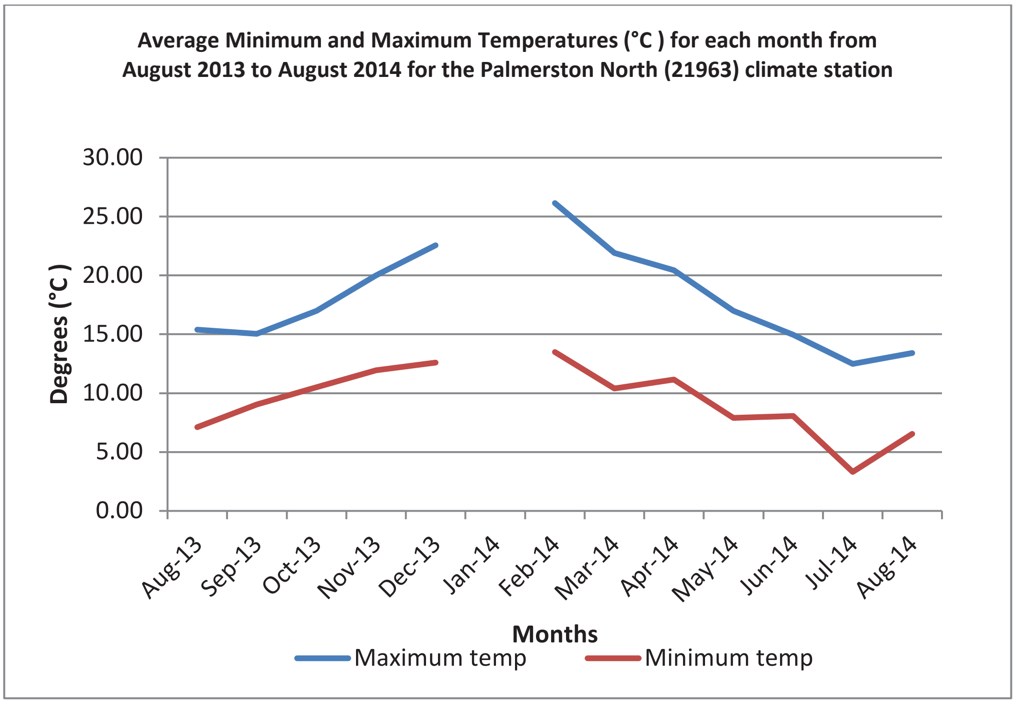

Figure 6 Minimum and Maximum temperatures from 11/08/2013 – 11/08/2014

Source: Data from CliFlo database, NIWA 2014.

2.6.4 Sunshine Hours

The total number of sunshine hours from the 11 August 2013 to the 11 August 2014 was 1953.5 hours, with the highest number of sunshine hours experienced through November to January. The lowest sunshine hours are experienced through May to September (Figure 7).

The 30 year period from 1981 through to 2010, shows that the average annual total sunshine hours were 1749.9. With the highest experienced in January and lowest in June. The pattern is very similar to the figures produced from the 2013 to 2014 data. Another NIWA (2014b) study conducted shows that average sunshine hours were 1733 hours annually, therefore the average and expected sunshine hours would be between 1700-1900 hours of sunshine a year.

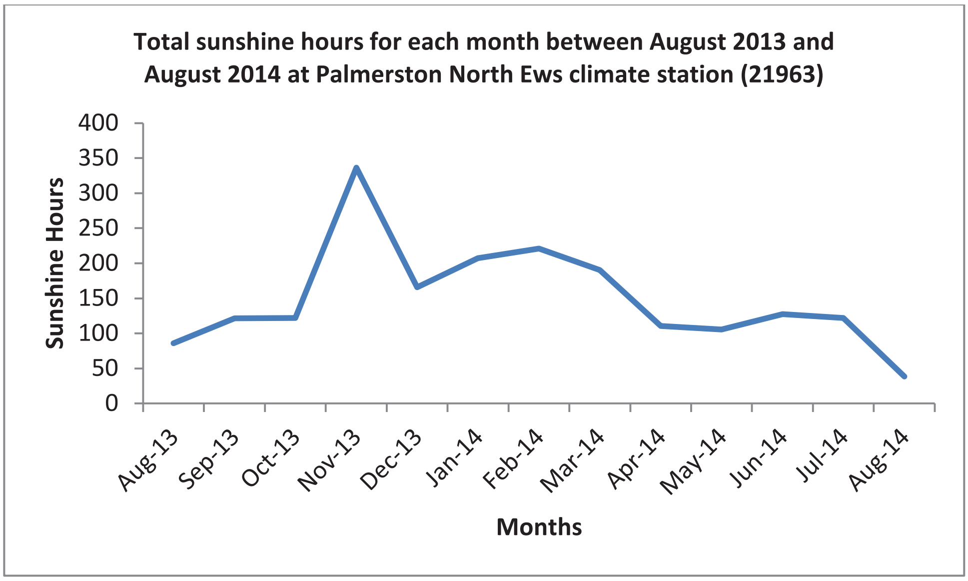

Figure 7 Total sunshine hours for each month between 11/08/2013 – 11/08/2014

Source: Data from CliFlo database, NIWA 2014.

2.6.5 Wind

The annual wind run from the 11 August 2013 to 11 August 2014 is 285.2 km, with the mean wind speed of 3.3 m/sec and a highest daily wind run of 718 km (Figure 8).

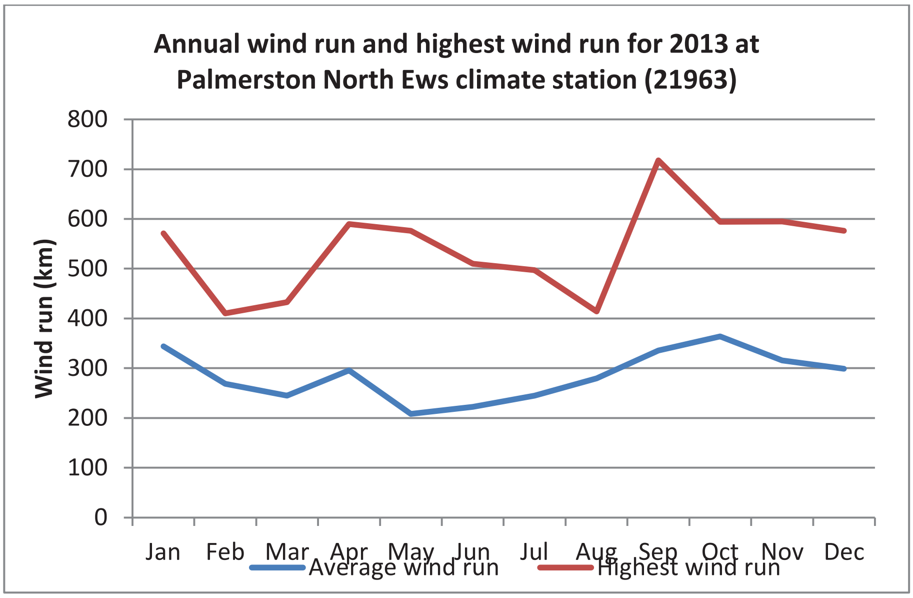

Figure 8 Average wind run and highest wind run for the year 2013

Source: Data from CliFlo database, NIWA 2014.

The NIWA study shows an average wind speed of 17 km/h with the expectancy of gale days, which require mean speeds of at least 63 km/h, as 3 per year. The predominant wind over New Zealand is a westerly wind, with the Manawatu region experiencing both northwest and southwest winds (Burgees, 1985).

Wind direction and speed in the Manawatu region are strongly modified by both the Tararua and Ruahine Ranges (Burgess, 1985). Burgess (1985) explains that the dominate wind west of the ranges are westerly to north westerly winds which occur quite frequently being 30 – 50% of the time. In Manawatu the most common winds are the south-west winds. Average wind speeds in this region tend to be around 15 -17 km/hr, with speeds increasing in the Manawatu George and surrounding hills (Burgess, 1985). Seasonal variation in the Manawatu Region is small, with lower wind speeds between March and August (Burgess, 1985).

2.6.6 Frost and Hail

A NIWA study conducted between the years of 1971-2000 shows an annual average of 38 ground frosts (NIWA, 2014b). Ground frosts are most commonly witnessed during the winter season, between May to August.

A 30 year study conducted from 1981-2010; shows the average number of days with frost per month over the study period (Table 9).

Table 9 Average frosts per month in days over 30 year study

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
0.1	0	0.2	1.5	4.8	8	10.3	9.2	4.1	2.3	0.7	0.2	40.3

Source: Data from CliFlo database, NIWA 2014.

Hailstorms are infrequent in the Manawatu Region, occurring less than five times a year on average, with most common experienced during spring and winter and mostly near the Tararua and Ruahine ranges (Burgees, 1985).

2.6.7 Flooding

In 2004 the Manawatu and the Rangitikei experienced a most severe flood; a flood recognised as a 1 in 50 year return period event. In February 2004 the large scale flooding followed a wet period of four weeks, were rainfall levels in several sites were 200% of the average (Environmental Services Limited & Thomas & Cowie, 2004). It was the third largest recorded flood in the Mangaweka locality, 80km from the Rangitikei river mouth in 108 years of records. The 2004 flooding event wasn't the only flooding event the Manawatu Region has experienced, in 1953 major flooding occurred, possibly the worst the region has seen (Burgees, 1985). Both events impacted on Reureu blocks with local informants describing the severity of the flooding. In the 2004 flood a local farmer who currently leases some of the blocks noted that half of the land he leases was under water, right up to the pump shed (Appendix 2-6 shows flood severity).

2.6.8 Ohakea Aerodrome Climate

The Ohakea Aerodrome report (1982) on climate is helpful as its proximity is closer to the Reureu blocks. However although this data is older, it will be used in conjunction with the information received from NIWA. The information from the Ohakea Climate station was not combined with NIWA data purely based on its age; however it is relevant to show trends prior to 1980.

2.6.8.1 Rainfall

The rainfall data was collected using a standard New Zealand Meteorological Service rain gauge. The following information is based on a period from 1940-1979. The average total rainfall for Ohakea Aerodrome was 914 mm per year, with the highest recording being 1148 mm and the lowest annual rainfall 665 mm. Figure 9 shows total monthly rainfall between 1940 and 1979.

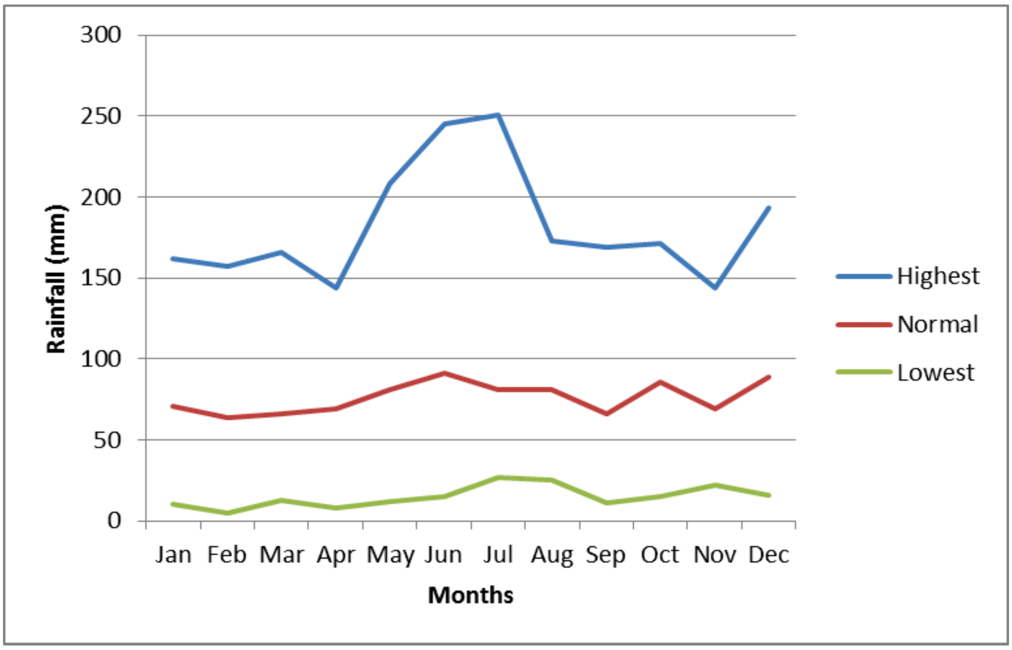

Figure 9 Rainfall at the Ohakea Aerodrome between 1940–1979

Source: Ministry of Transport, 1982.

2.6.8.2 Temperature

The temperature data is measured in degrees Celsius and was collected from 1940 – 1979. The mean yearly monthly maximum temperature was 28.4°C and the monthly minimum temperature was -0.9°C. On a normal day the temperature was around 13.2°C yearly (Ministry of Transport, 1982). Figure 10 shows the mean monthly maximum/minimum temperatures as well as daily maximum/minimum.

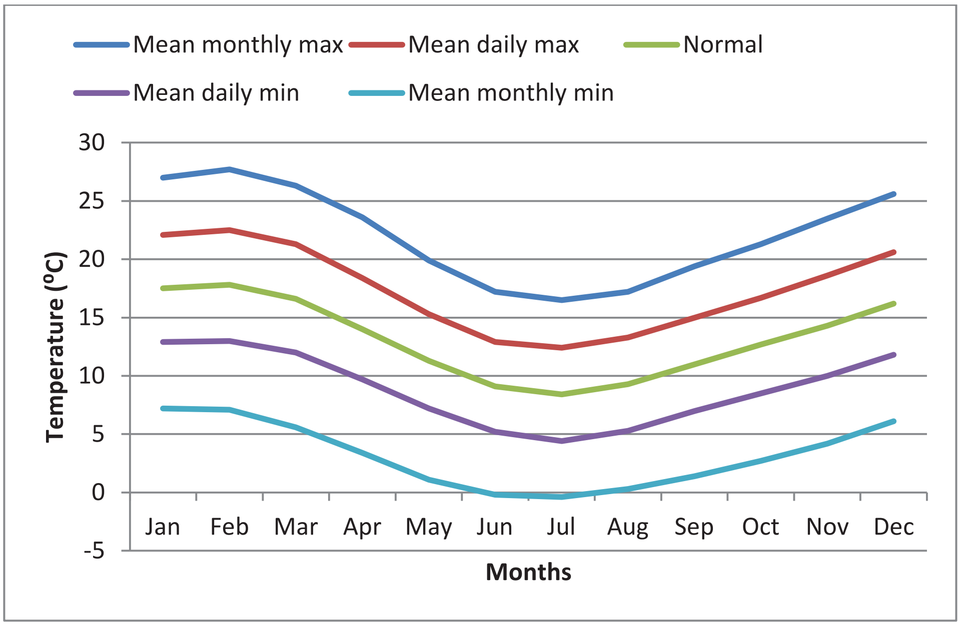

Figure 10 Temperature at the Ohakea Aerodrome from 1940 - 1979

Source: Ministry of Transport, 1982.

2.6.8.3 Wind

The wind was measured in knots; Figure 11 shows the average number of days with gusts over 34 knots and 52 knots. October and November seem to have the highest number of days with the most knots suggesting these are the windier periods of the year.

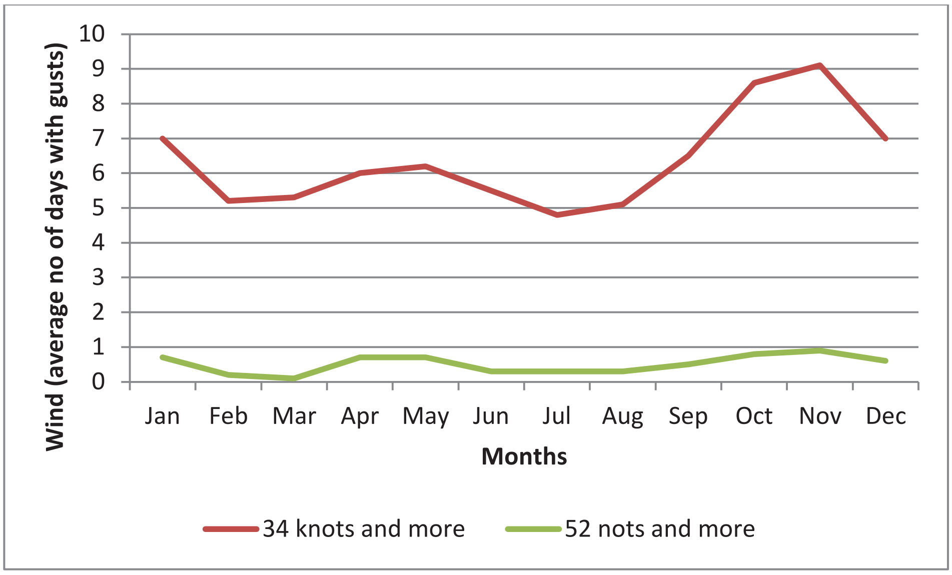

Figure 11 Wind speed at the Ohakea Aerodrome from 1940 – 1979.

Source: Ministry of Transport, 1982.

2.7 Geological History

Geological Information for the Reureu blocks can be found in the 'Geology of the Taranaki Area 2008', the 'Map 7' (Figure 13) for outline and labelled as 'Q1a' and 'Soils of the Kairanga County', The geological map of the Taranaki area is one of the national QMAP series produced by Geological & Nuclear Sciences (GNS). The scale of the map is 1:250,000 and should not be used alone for land-use planning, engineering projects, earthquake risk assessment and other work, more in depth information should be sourced (Townsend & Kamp, 2008). However for the purpose of this study, a brief overview of the geological units found is useful. Using Q-Map several GIS maps were produced to show geological units for the Reureu block (Appendix 2 -7).

The Reureu blocks lie within a mixture of river flats and terrace land. The river flats have been built up over many years though deposits of alluvium and flooding. The terrace land is a mixture of both river and marine terraces with the youngest river terrace as the Ohakea terrace (Cowie & Rijkse, 1977).

2.7.1 Geomorphology

The geomorphology summarised from the Geology of the Taranaki Area suggests the Reureu blocks are defined under Coastal lowlands. However the Rangitikei River does fall into the Matemateaonga range and dissected hill country. Through the processes of erosion and aggradation cycles this river has formed Quaternary alluvial terraces (Townsend, & Kamp, 2008). Quaternary refers to the time period of these alluvial terraces. Alluvial terraces are terraces made/formed by deposits of alluvium.

2.7.2 Stratigraphy

The Reureu blocks lie under the Quaternary Sediments (Q1a), with aggradational terraces along the major river and lie on valleys formed by fluvial processes combined and preserved by tectonic uplift (Townsend & Kamp, 2008).

> *"Aggradational terraces along the major river valleys have been formed by fluvial processes combined with regional tectonic uplift."* (p. 28)

The Reureu blocks are mapped Q1a which under the 'Geology of the Taranaki Area 2008' refers to:

- Alluvial terrace and floodplain deposits
- Alluvial fan and scree deposits
- Swamp deposits

2.7.2.1 Alluvial terrace and flood plain deposits

The gravel deposits which help to form the flood plains and alluvial terraces are dominated by rounded, poorly sorted to well-sorted gravels and silts. It is not uncommon to witness large boulder gravels throughout the gravels encountered yet most of these do not get larger than 0.3 m (Townsend & Kamp, 2008).

> *"Except on present flood plains the alluvial deposits form flights of aggradational terraces with older terraces preserved at progressively higher levels above the valley floors."* (Townsend, & Kamp, 2008, p. 30).

2.7.2.2 Alluvial fan and scree deposits

The alluvial fan deposits are widespread throughout the region. Many fans are too small to be mapped and are incorporated into alluvial terraces (Townsend, & Kamp, 2008).

2.7.2.3 Swamp Deposits

Holocene swamps are also common in the valleys but in this particular case the swamp was too small to map. Local knowledge have showed there was a swamp on the Reureu blocks in previous years, however over time this has been drained and converted into pasture. Although previous swamps are important due to their impact on nutrient losses, as the swamp has been drained for several years, was not considered important. A landform picture to show the landforms present on the Reureu blocks is seen in Figure 12.

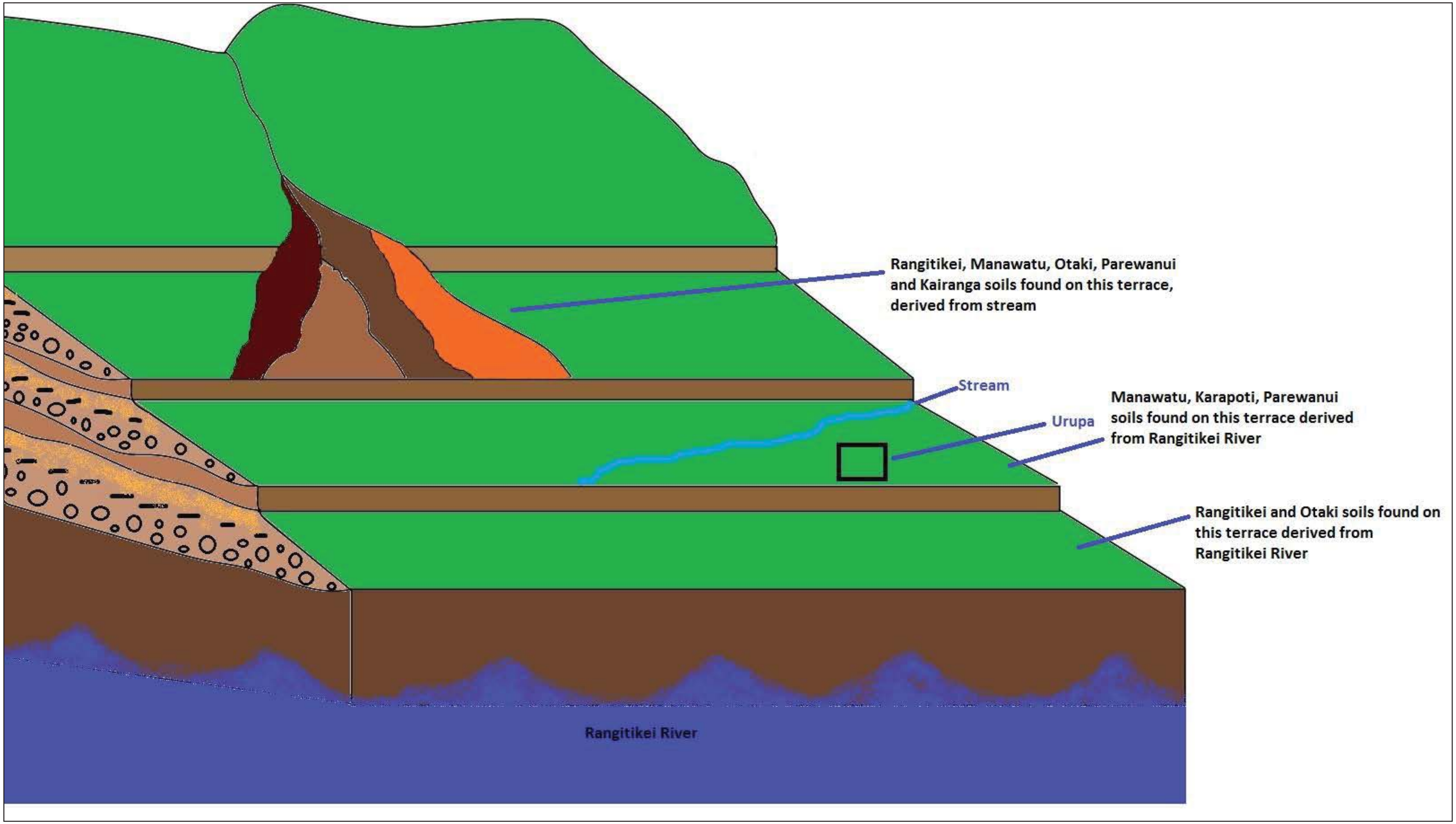

Figure 12 Typical Terrace landform seen on the Reureu block from the Rangitikei river

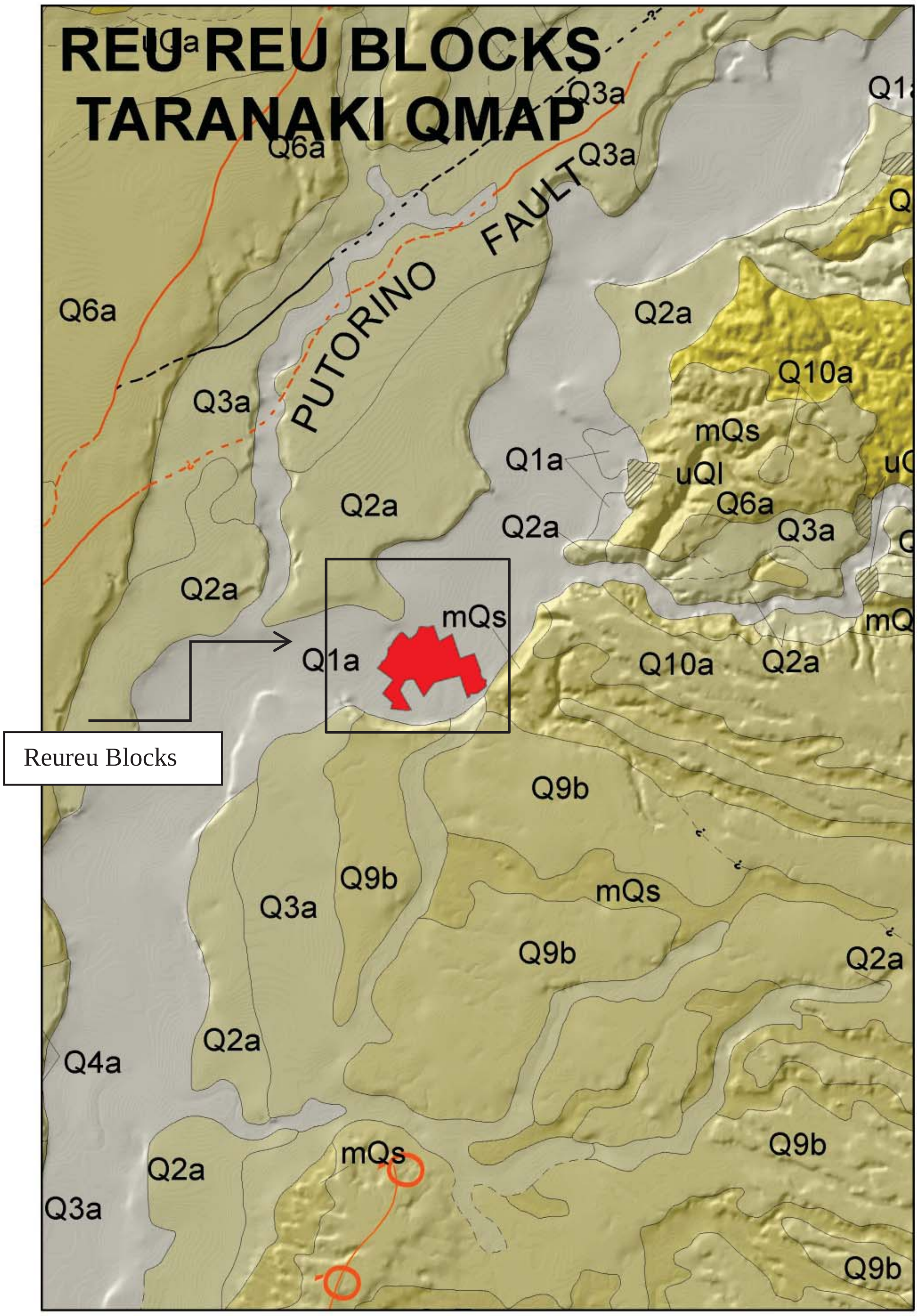

Figure 13 Geological Map of the Taranaki Region

Source: Geological Map 7, scale 1:250,000, Taranaki Region, Townsend & Kamp 2008.

2.8 Vegetation and Land-use

In the past the Rangitikei landscape was mostly in native in forest, except for those areas close to the ocean (Gordan, 2009). The Manawatu region itself according to Osborne & Cowie:

> *"is an old-established area of fertile land giving high levels of production under dairy, sheep, beef cattle and cropping systems."* (p. 20)

As the region developed so did the varying changes in land-use. In the 1900 New Zealand set up its first co-operative dairy company, one of these was located on the banks of Rangitikei River at Kakariki, east of Marton. Today most of the original vegetation has been cleared and land sown into pasture for various types of pastoral farming (Cowie & Rijkse, 1977).

Natural vegetation today is very different than in the past. According to the 'Visualising Māori Land' online tool (Landcare Research & TPK, 2014) the current land cover is 'high producing exotic grassland' with the historical use most likely for all the blocks being 'Rimu (*Dacrydium cupressinum*) and Tawa (*Beilschmieda tawa)*'. The Reureu blocks also have some historical wetland areas, which have now been drained; this is evident when visiting the blocks. From 1962 until now (2014) there have been various uses for the blocks from grazing beef, maize silage and grass silage. Before 1962 dating back to end of the Second World War the land was used for two small dairy units (L. Iwikau, personal communication, 2014).

The Reureu blocks fall under the Taranaki-Manawatu Land Classification, with the dominant land-use in this area as pastoral farming. According the NZLUC Suits of the Taranaki – Manawatu Region (Fletcher, 1987) the region carries 20% of the nation's dairy cattle, 16% of beef cattle and 13.5% of sheep. Most of the barley and wheat crops are grown in the Rangitikei, Wanganui and Manawatu districts (Fletcher 1987). According to the New Zealand Land Resource Inventory (NZLRI) the vegetation on the Reureu blocks is denoted as 'P1/1'. This transcribes as grassland, high producing pasture, with the use of a capital letter this occupies over 40% of the total land area[8] (Newsome, Wilde & Willoughby, 2008).

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[8] Refer to this document for explanation of codes and for further explanation. https://lris.scinfo.org.nz/layer/76-nzlri-land-use-capability/

2.9 Previous Land-use Capability and Land Resource Inventory Maps

The Reureu blocks LUC and LRI maps are described in further detail in the book titled 'Land-use Capability Classification of the Taranaki-Manawatu Region' (Fletcher, 1987). The land-use capability system (LUC) is a system which splits land into classes from 1 – 8 based on rankings of versatility and suitability for different land uses (see sections 4.7 and 4.8).

The publication is one of a series that accompanies the NZLRI map, which is published at scale of 1:63,360. The North Island of New Zealand is divided into ten regions, the Taranaki-Manawatu is one of these ten and Table 10 outlines the area of LUC classes relative to the rest of New Zealand.

Table 10 Area of LUC Classes in Taranaki-Manawatu Region compared to New Zealand.

LUC Class	Area (ha)	% of Region		% of North Island	
1	64,300	2.7		1.3	
2	178,600	7.4	27.3 (Arable land)	6.3	27.8 (Arable land)
3	211,700	8.8		8.9	
4	201,500	8.4		11.3	
5	41,500	1.7		0.8	
6	733,800	30.5	62.0 (Non arable land)	35.2	61.1(Non-arable land)
7	717,050	29.8		25.1	
8	239,550	9.9	9.9 (protective land)	8.7	(Protective land)
Unmapped	20,090	2.4			

Source: Fletcher, 1987.

In the Taranaki-Manawatu region thirteen LUC suites can be identified as shown in Table 11, the factor which distinguishes between each LUC suite is soil parent material (Fletcher, 1987), with eight being subdivided further based on depth and texture of tephra, strength and hardness of rocks and climate and slope (Fletcher, 1987). An important note is that LUC suites were not defined at the time of the original mapping, therefore a number of LUC units do not fit exactly into one LUC suite or sub suite.

Table 11 LUC Suites and sub suites in the Taranaki-Manawatu Region.

LUC Suite/Sub suite number	LUC suite/subsuite
1.	Yellow brown loams
1a	Waimarino
1b	King Country
1c	Inland plateaux
1d	Taranaki
2	Lahars in Taranaki
3	Coastal sand country
4.	Alluvium
4a	Wide flood plains and river valleys
4b	Narrow river valleys
5.	Loess
5a	Low rainfall
5b	High rainfall
6.	Taupo airfall tephra
6a	Shallow Taupo airfall tephra
6b	Deep Taupo airfall tephra
7	Taupo flow tephra and water sorted tephra
8.	North-east uplands
8a	Shallow Taupo and/or Ngauruhoe tephra
8b	Deep Taupo and/or Ngauruhoe tephra
9.	Mudstone
9a	Jointed mudstone
9b	Banded mudstone
10	Siltstone
10a	Siltstone
10b	Uranui siltstone
11.	Sandstone
11a	Unconsolidated
11b	Moderately consolidated
11c	Moderately consolidated with slump and earthflow erosion
11d	Consolidated
11e	Hard consolidated
12	Deep-seated earthflow and slump erosion
13	Mountain lands

Source: Fletcher, 1987.

The Te Reureu block lies within LUC suite 5. Fletcher, (1987), describes this as;

> *"characterised as occurring on terraces with soils developed on quartzofeld-spathic loess from flood plains. There have also been intermittent additions of tephric loess and airfall tephra to the soil parent material."* (p. 88).

The suite occurs in the lower Rangitikei, Wanganui and Manawatu areas, consisting of 11 LUC units and approximately 6.3% of the region. The suite is further divided into low and high rainfall. High rainfall consists of 1150 mm to 1800 mm per year, occurring inland and soils are well drained, deep friable and no fragipan. Low rainfall consists of 800 mm and 1100 mm per year and has a distinct dry season which aligns to this region. Soils contain a compact fragipan and presence of gleying and mottles. These soils are dry during summer and extremely wet during winter, needing subsurface drainage if high production is required.

The Reureu blocks are defined under the LUC 5a sub suite with low rainfall (Fletcher, 1987). See '*Taranaki – Manawatu Region – Fletcher, 1987'* for specific information on physiography, climate, rock type, soils, erosion and land-use for suite 5a. The following brief summary outlines what can be found on the Reureu blocks:

> Annual rainfall of 900–1200 mm, soils identified on the block using 'Soils of the Kairanga County' (Cowie, 1972). The dominant parent material is alluvial gravels from both the Raumanga Stream and the Rangitikei River. Only slight erosion with stream bank being the most common. Land use is currently dry stock grazing.

With the current LUC shape files available by Landcare Research, the Reureu blocks are assigned the code '2s2' (Figure 14). Horizon Regional Council also maps the Reureu blocks as '2s2'. The Reureu blocks lie in Class 2 land in terms of versatility and soil factors are the dominant limitation, with a severity of 2. The extended explanation for the LUC class can be found in the '*Land-use Capability Classification of the Taranaki – Manawatu Region'*. A typical LUC 2s2 would be one that occurs on flat land, used for intensive pastoral production (sheep and beef) and some dairy. In order to achieve high production of this land subsurface drainage would need to be put in place as most of the soils found have poor drainage (Fletcher, 1987).

The assessment for pastoral and exotic forestry is an extension of the NZLRI. The purpose of which is to define land performance and potential levels for NZLRI. Table 12 provides the potential stock carrying capacity groupings and *Pinus radiata* side index groupings. The following information is to be used with caution, as it is considered out of date and dairy was not the intended use. However it can contribute alongside farm management programs such as Farmax help to benchmark farms by looking at relative stocking units to LUC classes.

Table 12 Overview of groupings for Potential stocking capacity and site index for *Pinus Radiata.*

Potential stock carrying capacity ranking	Potential stock carrying capacity (stock units/ha)	Exotic forest growth potential	Site index for *Pinus radiata*
Very high	>25	Very high	>35
High	21-25	High	30-35
Moderately high	16-20	Medium	25-29
Medium	11-15	Low	20-24
Low	6-10	Very Low	<20
Very low	1-5		
Sparse	<1		

Source: Fletcher, 1987.

Refer to Appendix 2-8 shows all GIS produced from LRIS portal.[9]

[9] Refer to this document for explanation on the meaning of the GIS maps https://lris.scinfo.org.nz/layer/76-nzlri-land-use-capability/

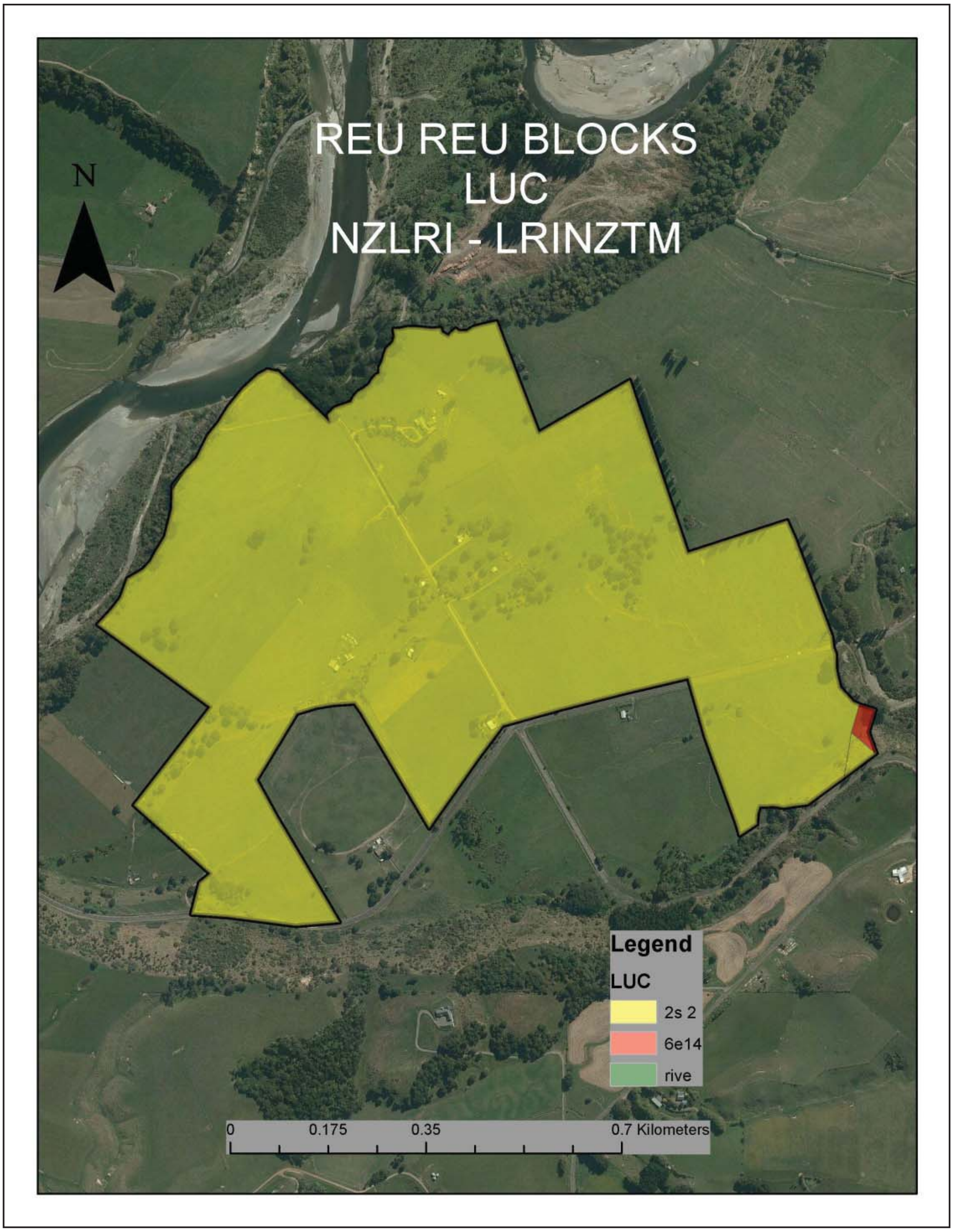

Figure 14 Land-use Capability Map of Reureu Blocks.

Source: Landcare Research LRIS portal, NZLRI.

Chapter 3 Methodology

3.1 Introduction

To ensure accountability, repeatability and unbiased results, researchers need to be held accountable for the process and procedures used throughout the research. It ensures information is gathered correctly and analysed using the correct procedures to ensure accurate account of the information. The methodology used in this thesis is drawn from a mix of:

- Kaupapa Māori Research Methodology (KMRM)
- Participatory Action Research (PAR)
- Accepted practice for soil mapping, sampling, testing and land evaluation maps
- Data Collection/Literature Review

As the research has an association to Te Ao Māori and involves Māori land, Kaupapa Māori Research Methodology (KMRM) was adopted at all times, to ensure the reason and outcome of the research were acceptable in a Māori context.

Participatory Action Research methodology (PAR) was used throughout the study with determining an issue and structuring the research around the question.

In order to clearly identify soils, collaboration from both Landcare Research Ltd and HRC was sought to determine which soils are found on the land blocks under survey. As soils are so diverse and can change regularly, identifying exact soils in detail is not always possible in a tight timeframe.

A literature review and data collection was conducted on past information and information already available to use was conducted, with an emphasis on maps available. The literature review also explored land evaluation, new technologies, soil (physical, morphological, chemical) nutrient management information and Māori development polices e.g. legislation.

3.2 Kaupapa Māori Research Methodology

Kaupapa Māori Research Methodology (KMRM) involves a 'collaborative' approach to research, with a belief that the benefits and outcomes of the research belong to the participants (Berryman, Soohoo & Nevin, 2013). The reasoning behind this type approach is;

> *"Māori do not think of himself or do anything for his own gain. He thought only of his people, and was absorbed in his Whānau just as the iwi absorbed in the hapū and the hapū in the Iwi."* (as cited in Berryman et al., 2013, p. 266)

KMRM allows relationships and patterns to be formed similar to that within extended Māori families and become part of the whānau (Berryman et al., 2013). Although 'western' methodologies may be implemented as well, Kaupapa Māori ensures Māori cultural perspectives help develop and contain the research carried out, especially within Māori Tikanga.

The development of KMRM is due to the issues faced around previous research conducted which largely was based on assumptions and no acknowledgement of the culture, values and beliefs in which research should be conducted. Questions started to be asked about who is researching, why are they which eventually lead to the development of KMRM (Duder, 2010). KMRM allows beliefs, values to be expressed and provides a guide of how to conduct research in a Māori way, so to ensure all researches and open, respectful and everyone benefits from the results.

Māori Tikanga is the cultural practices in the Māori culture. Manaakitanga is a key value of Tikanga as it describes appropriate ways of behaving and acting in everyday life, a key aspect of KMRM (Berryman et al., 2013). Kaupapa Māori researchers need to ensure work is completed benefiting those who are involved in the research, not just benefiting the researcher themselves, possibly a clear separation between a more western framework. The KMRM needs to ensure both parties benefit.

The challenges faced sometimes include contradicting views between Western and Māori worldviews (Berryman et al., 2013). Māori consider a collective research approach is best as opposed to an individualistic approach often preferred by a Western society and thus causing a gap in how research is understood and conducted amongst indigenous people (Berryman et al., 2013), however this is not always the case, but preferred in many cases. Another challenge faced is the unique ability of Māori to connect with other Māori involved in the research, relating to one another rather than being overbearing, a concept known as whakawhānaungatanga.

KMRM ensures appropriate cultural beliefs and practices and carried out effectively. It allows collaborative thinking, ensuring the end goal meets those needs/wants of those participating. Berryman et al., (2013) summarises the following five approaches which initially should be taken into consideration when dealing with Māori Research.

> *"Within Kaupapa Māori approach five research methods based on Māori metaphors were important to our work as a researcher"*
>
> - *Whakapapa (Genealogical Connection) – determines both individual and collective identity which helps determine the access to ancestral knowledge.*
> - *Whakawhānaungatanga (Process of building relationships and making connections) – establishing links, making connections through mihimihi referring to landscapes, rivers, mountains to gain a connection.*
> - *Kanohi ki te Kanohi (Face to Face) - Ensuring the importance of maintaining relationships, before, during and after the research has been completed.*
> - *Whakawhitiwhiti Korero – Conversations between researchers and participants ensuring the collaborative approach is upheld.*
> - *Mahi Tahi/Kotahitanga - Ensures not just the researcher is talking but sharing/debating ideas between the two, constructive dialogue flow between the two. Ensuring participants understand the research and if any upskilling can be achieved to carry out this.*
>
> (As cited in Berryman et al., 2013, p. 269)

Although many of the guidelines for conducting KMRM may be obscure to those outside of Māoridom, those who are vested to see Māori succeed and grow will not find these challenging. It is always the personal accountability that underpins KMRM, not doing for one's self but for others they feel accountable to (Berryman et al., 2013). KMRM may not be regarded as a scientific methodology however as under a wholly western framework Kaupapa Māori and mātauranga Māori values cannot be upheld. Kaupapa as a framework is still evolving incorporating Western and Māori ideas and values (Cragg, 2009). Therefore KMRM needs to be applied in conjunction with and ultimately adds accountability.

The most important aspect of Kaupapa Māori (Cragg, 2009) is that study Māori are involved in is initially guided by Māori and local Māori mana tangata will have some benefit. As cited in Cragg, (2009) there are ten factors (Figure 15) paramount in achieving KMRM.

1. Māori research must be conducted within a Māori cultural framework and incorporate Māori concepts of knowledge, skills, experiences, attitudes, processes, practices, customs, reo, values and beliefs.
2. Māori research must be conducted by people who have the necessary cultural, language, and research expertise. They must also possess a commitment to things Māori, the trust of the Māori community being researched, and an understanding of and commitment to the obligations, liabilities and responsibilities that are an integral part of Māori research.
3. Māori research should be focused on areas of importance and concern to Māori. It should arise out of their self-identified needs and aspirations.
4. Māori research should result in some positive outcome for Māori. This may be manifest in many different ways, e.g., improved services, increased knowledge, health gains, or more effective use of resources.
5. As much as possible, Māori research should involve the people being researched as active participants at all stages of the research process.
6. Māori research should empower those being researched. This empowerment should stem from both the research process and product.
7. Māori research should be controlled by Māori, particularly in relationship to ethical requirements, assessment, funding, intellectual property rights, and ownership and dissemination of knowledge.
8. People involved in conducting Māori research should be accountable to the research participants and to the Māori community in general.
9. Māori research should be of a high quality. It should be assessed by culturally appropriate methods and measured against Māori-relevant standards.
10. The methods, measures and procedures used in Māori research must take cognisance of Māori culture and preferences. They must take into account the previous nine requirements of Māori research.

Figure 15 Guidelines to be followed when conducting Kaupapa Māori Research.

Source: Cragg (2009).

Māori centred research and KMRM guidelines have been carried out for the Reureu blocks. The research topic and methodology was determined by Māori, carried out by Māori for the local Māori to benefit from.

3.2.1 Approach

The research topic has been determined by Māori, with myself being a Māori Researcher and the owners being Māori as well. The research will be undertaken in such a way that cultural values are upheld. The benefit will be for local hapū associated with the Reureu Blocks. KMRM is undertaken in a unique area of soil science under guidance of a Māori researcher and Māori supervisor.

3.3 Participatory Action Research Methodology (PAR)

PAR is a recurring process that involves outlining the question, reflecting upon and investigating the issues, developing a plan of action and refining the set plan (McIntyre, 2008).

The underlying principles specific to PAR are (McIntyre, 2008);

- *Collective commitment to investigate an issue or problem,*
- *Desire to engage in self- and collective reflection to gain clarity about the issue under investigation,*
- *Joint decision to engage in individual and/or collective action that leads to useful solution that benefits the people involved,*
- *Building of alliances between researchers and participants in the planning, implementation, and dissemination of the research process.*

PAR involves both researchers and participants working together to solve a problem which will be beneficial to both (Kindon, Pain, & Kesby, 2007). The PAR process involves researchers and participants to identify an issue or situation needing change, initiate research that will lead to action, with both the researcher and participants learning and developing. PAR can complement KMR or vice versa.

Kindon et al., (2007) define the "methods and techniques focus on dialogue, storytelling and collective action" suggesting a hands-on approach where the interaction with participants helps to develop information on their own terms. In this particular project, sharing knowledge or history of the land through myths and family history is a way in which knowledge is shared and passed down.

Wuest, McCool, Miller & Veseth (1999) suggest PAR as on-farm practice where the farmer is considered the ‘end user’ and ‘partner’ of the research. The farmer takes a role, in a sense, guiding the research by helping to set up goals and helping interpret the results. In terms of utilising Kaupapa Māori guidelines this is a key point, whereby the participation of the farmer/owners is important, this particular aspect of PAR methodology has been used. In these particular cases because the farmers were Māori this could be considered a double benefit.

As cited in Ryder (2003);

> *“WinklerPrins (1999) emphasizes the need to integrate local and scientific knowledge of the environment while Tabor (1992) recommends that soil surveyors communicate with farmers and herders to determine the relative productivity of soil types and their value for agriculture, forest and range”.* (p. 290)

As cited in Roskruge (2007);

> *“PAR methodology in which the community involved in the study actively participate with the research, throughout the process, from initial design to the presentation of results and discussion of their action implications.”* (p. 16)

In this project PAR and KMRM were collaborative and added considerable local input and understanding to the underlying soil resource.

Ethnopedology (People: Soil interaction) framework

Ethnopedology is part of ethnoecology which is the study of environmental knowledge and indigenous peoples. Ethnopedology is mixed structure (Figure 16) combining both natural and social sciences. It looks at covering all soil and knowledge systems from rural populations from those modern to most traditional rural populations, aiming to evaluate soil and land in the natural resource process. Ethnopedology outlines the importance of considering local knowledge of soils which till recently has not been reflected in soil science research. It also ensures land and soil information from old to new is recorded and used.

> *"Ethnopedology aims to document and understand the local approaches to soil perception, classification, appraisal, use and management"* (Bassols-Barrera & Zinck, 2003, p. 172).

Ethnopedological research covers as stated in Bareera-Bassols & Zinck (2003);

> *"(1) the formalization of local and land knowledge into classification schemes, (2) the compassion of local and technical soil classifications. (3) the analysis of local land evaluation systems, and (4) the assessment of agro-economical management practices."*

3.3.1 Approach

PAR research requires those people involved in the study to take part throughout the duration of the research. Frequent communication between the researcher and the owners will be sustained. Ethnopedological research was also used in this research as a guide for research conducted on soils.

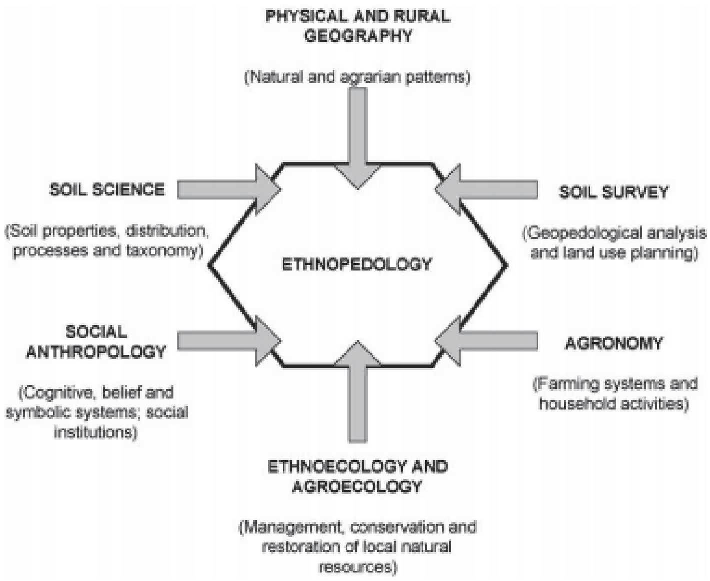

Figure 16 Ethnopedology as a hybrid.

Source: Bassols-Barrera & Zinck, 2003.

3.4 Literature Review of primary and secondary sources

A mixture of primary and secondary information sources were accessed for this research. Yin (2003, pg. 19) identified six sources of evidence usually presented in a case study; documentation, archival records, interviews, direct observations, participant observation and physical artefacts.

Primary source data present original and direct information, generally something that is created by someone with experience or expertise in that area. An example of a common source of primary data is interviews. Secondary data is data which has been collected by individuals/groups or agencies for purposes other than that of a particular research study. Secondary source data is information that is drawn on primary sources, giving expert analysis on the primary data.

A literature review is a source of secondary data, whereby information is checked from experts in that particular field. McMillan & Schumacher (1997) identify 5 purposes of a literature review;

- Define and limit a problem
- Allows your study to be put into perspective
- Helps to avoid unintentional replication of previous studies
- Helps define and set methods and measures
- Helps to relate findings to previous knowledge and suggest areas for further research.

3.4.1 Approach

Initially a review of the information current available on the Reureu blocks was sought. After the information was studied and gaps were drawn where more information was required, field work was carried out to fill the gaps. Background reading was conducted on land evaluation methods and soil and its role in making land-use decisions.

3.5 Data Collection

3.5.1 Soil Sampling

The greatest error or misrepresentation of soil tests is the natural variability of the soils themselves and obtaining a sample that is representative of the whole soil group (Taylor & Pohlen, 1968; Milne et al., 1995; McLaren & Cameron, 1996; Lynn et al., 2009), outlining the importance to ensure a representative sample is taken from the whole soil group which testing is conducted for (Peverill, Sparrow & Reuter, 1999). The variability can be reduced once the landscape is spilt and grouped according to the similarity (McLaren & Cameron, 1996). The area should be divided into uniform management units first, then consider different spatial variations which can contribute to soil forming factors.

Once the landscape units and land forms are clearly marked out, an ‘indicator’ paddock is chosen which should be representative of the whole farm. The indicator paddock is then sampled and tested. Testing is normally conducted on ‘management units’ so the farm is divided into land units of similar management needs. Overseer provides protocols that show how different factors other than soil and their influence on selecting management units such as fertiliser management (Overseer, 2007; L. Currie, personal communication, May 7 2014).

When sampling it is important that attention to the differences in both spatial variation and temporal variation are taken into account (FLRC, 2013). Timing of testing is also important, avoiding very wet and very dry periods.

McLaren and Cameron (1996) outline areas to avoid when soil sampling, these are:

- Stock Camps
- Gateways
- Dung and Urine Patches
- Raceways
- Under-trees
- Water troughs
- Fence Lines
- Hedges
- Headlands

McLaren and Cameron (1996) suggest 15-20 soil samples should be taken from each separate area or paddock to get a representative sample (see Table 13). Peverill et al., (1999) outlines the number of core samples and tests that can be carried out. According to Lance Currie (pers. comm. May 6 2014) soil testing should not be undertaken if paddocks have been recently grazed i.e. within two weeks of the soil sampling regime.

Table 13 Tests able to be conducted for certain core numbers taken.

Core Number	**Tests that can be carried out**
5-10	Suitable for total N and organic C only
10-20	Suitable for total N and organic C, pH and Al (no lime applied), EC(low salinity sites) and exchangeable cations (no amendments applied)
20-30	Suitable for total N and organic C, pH, EC and exchangeable and extractable K,P and S (virgin sites or no fertiliser applied for many years)
30-40	Suitable for all tests except where fertiliser, gypsum or lime recently applied, fertiliser is banded or stocking rates are high
40-60	Suitable for all tests (most situations)
>60	Suitable for all test but becoming impractical to collect(gains in accuracy with each extra core, decrease rapidly)

Source: Peverill et al., 1999.

In New Zealand, samples for Soil Fertility Service analysis by laboratories such as Hills Laboratory are taken from two different depths depending on the land-use from which the sample came from. For pasture soils sample is taken at 0-75 mm and for crops samples are taken at 0-150 mm (McLaren & Cameron, 1996). Peverill et al., (1999) outlines the standard sampling depths which are similar to those guidelines set out in New Zealand.

In order to collect a soil sample, usually only one sample is taken from each profile class represented in the survey, a pit is dug to the C horizon and soil profile and site characteristics recorded. Generally one sample is taken from each pedogenic horizon and from the face of the pit (McLaren & Cameron, 1996).

3.5.2 Approach

The Reureu blocks were divided into similar landscape/management units, giving four management units. A representative paddock was chosen for each management unit and samples taken in a diagonal line across the paddock to a depth of 7.5 cm. A total of 20 cores were collected for each management unit and sent away to Hills Laboratories for testing. For the purpose of time constraints soil samples were taken only for fertility testing so no sampling was taken within the profile. Appendix 3-1 shows common soil tests used in New Zealand. Refer also to field notes for common soil testing procedures.

3.6 Soil Surveying/Mapping

Soil surveying consists of geological/chemical or physical soil maps to show the parent material and underlying rocks. The first soil surveys in New Zealand conducted by Sir Theodore Rigg were of this nature (McLaren & Cameron, 1996). The issue with these maps is the lack of detail to incorporate all the soil forming factors, thus leaving out important soil characteristics.

The process that should be undertaken before attempting a soil survey should be;

- Identify the geology of the area or locality to be mapped
- Look for any existing soil maps
- Look for any LUC and LRI maps that may have been conducted (only relevant to New Zealand)
- Obtain or source rainfall isohyets for the locality
- Check for any peer reviewed scientific papers for the locality

A survey conducted on soil properties and their response to different management is necessary for land-use, especially in terms of land development and future planning. A soil survey is an in-depth representation of the soils found; making a more accurate overview of the physical resource when making land development decisions (Dent & Young, 1985). The main purpose of a soil survey for this project is to map the physical resource 'soil' to help determine possible land-uses, with a particular interest in dairy.

The soil survey is not easy to achieve, with soils changing rapidly from one area to another. The usefulness of any soil map depends largely on two things; the accuracy of which the soils are mapped and the relevance of the properties they possess (Dent & Young, 1985).

The first step in creating a soil map is to define the units to be mapped then, recording the soils according to their physical properties witnessed in the field. Dent & Young (1985) suggest two purposes for which soil surveys are conducted. A general purpose survey help provide basic information around the soil resource the main survey used for land evaluation. The other is special purpose soil surveys carried out where a particular purpose is known such as growing potatoes.

There are many users for soil surveys which are not limited to farmers, consultants, research workers, planning agencies, central and local governments and investors (Dent & Young, 1985).

> *"Soils can also warn flood risk, with a recent dairy conversion installed a new rotary shed at a site not consider a flood risk, in the very first season a 1-100 year flood caused several tens of thousands of dollars in damage."* (Manderson, Palmer, Mackay, Wilde & Rijkse, 2007, p. 50)

Manderson et al., (2007) also point out reasons to soil map which include, but are not limited to:

- High producing crops
- Environmental management
- Nutrient Management
- Water Management
- Strategic whole farm planning

The final produced map should be between 1:5,000 and 1:10,000 (Manderson et al., 2007). Field equipment needed (Nelson, 2003; Manderson et al., 2007):

- Work board
- Spade
- Base Map
- Pens
- Notebook
- Laminated instruction sheet (Soil description flow charts etc.)
- Water bottle

- Tape Measure
- Camera
- Soil Classification Handbooks (Milne et al., 1995 ; Hewitt 1993)
- Inclinometer
- Soil description templates
- Munsell Colour Chart

3.6.1 Approach

Previous soil maps and soil reports (see Chapter 2) for both the Manawatu Region and North Island were studied to become familiarized with parent materials, land-use and soil distribution for the Reureu location. The previous research provided information at a large scale not very useful in land-use decision making. Therefore a soil survey was undertaken at a more useful scale for land-use decision making (less than 1:10,000).

An aerial photograph (provided by Horizons) of the Reureu blocks was blown up onto A3 size paper to help identify features in the landscape and mark soil pits. The type of survey conducted was ‘free survey’, based primarily on changes in landform. A GPS was used for marking the soil pit locations. This helped to ensure accuracy and also allowed for the sites to be revisited.

At each pit a profile was described which described; horizon thickness, texture, colour, presence of stones/gravels, presence of mottling/gleying and other noticeable features (Refer to field notes disk). A photograph was also taken. The location and soils were then digitised later into GIS using ‘Arc GIS’.

The flow charts/descriptions used for soil profiling were standard soil profiling guidelines by Palmer (2014). (Refer to field notes disk for more information).

3.7 Classification of Soils

3.7.1 New Zealand Soil Classification

The New Zealand Soil Classification (NZSC) has many layers from broad to more detailed as shown below; as you move down the scale the observations and descriptions become more detailed.

- Order
    - Group
        - Subgroup
            - Soil form
                - Series
                    - Type
                        - Subtypes
                            - Phase

Recent soil classification systems do not include the soil series, type, subtype and phase instead using families and siblings. The soils at Reureu were classified based on the more traditional classification using soil series.

Soils were classified based on the drainage abilities of the soils. Soil series were discussed further with a professional with local knowledge of these soils[10]. The classification and survey method is based on traditional soil survey methods and the older style of soil classification not the current soil classification system used in S-Map.

3.7.2 Regional Soil Classification – Soil Series

Soils on the Reureu blocks were named in this exercise using familiar regional soil series.

The following Soil Series were identified:

- Manawatu Soil Series
- Parewanui Soil Series

[10] Dr Alan Palmer, Senior Lecturer in Soil Science, Massey University

- Otaki Soil Series
- Rangitikei Soil Series
- Karapoti Soil Series
- Kairanga Soil Series

3.7.3 Horizon Notation

Soils contain soil horizons, layers within the soil. Each soil horizon has properties which influence soil-forming, not called a layer and develop under surface and are genetically related to one another. The Master Horizons include four organic horizons O, L, F, H and five mineral horizons A, E, B, C, and R. Initially inspection of the profile needs attention and care to determine horizon notation[11].

The capital letters A, E, B, C, O and R represent the master horizons and layers of the soils. In the case of two capital letters presented together, the horizon properties are dominated by the first letter with features of the second AB. If the horizon is mixed then the dominant is given over secondary such as A/B. Lowercase letters are used as suffixes to describe specific kinds of the master horizon[12]. (Refer to the disk for soil description guidelines used).

3.7.4 Approach

The Reureu Block Soils are classified based on common regional soil series such as the Manawatu Soil Series. The soils are than categorized and distinguished on both pedalogical and physiographic features. The features are parent material, profile form (horizons present, structure and development) and depth. The Reureu blocks are in the Manawatu region, soil series such as the Otaki Series (which is unfamiliar) was named with the help of Dr Alan Palmer with his knowledge in local soils (Table 14).

Soils were classified based on soil classifications used by Cowie, a published soils expert (A. Palmer, personal communication, July 2014) and a new classification given for a frequently flooded soil which is moderately drained and imperfectly drained.

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[11] Horizon Notation for New Zealand Soils (Clayden & Hewitt, 1994).
[12] Horizon Notation for New Zealand Soils (Clayden & Hewitt, 1994).

Table 14 Classification of Soils[13]

	Stony	Well-drained	Moderately drained	Imperfectly drained	Poorly drained
Frequently Flooded	Otaki**	Rangitikei*			Parewanui*
Occasionally Flooded	Otaki**	Manawatu*	Hokowhitu** Manawatu Mottled*	Cloverlea** Kairanga fine sandy loam*	Kairanga** Kairanga silt loam*
Non-flooded	-	Karapoti*	Konini**	Marima**	Te Arakura**

* - Names used by Cowie

** - Names used by Dr Alan Palmer

Key features in the soil profile that helped to determine the soil series were; drainage, depth of profile to gravels and texture. All of these features will greatly impact the land-use and management (Nelson, 2003). The drainage class of the soil was determined based on low Chroma (grey) mottles. Depth to gravel also helped to name the soil profiles, due to limitations on land-uses and management.

3.8 Presentation of Soil Map

The soil map produced for the Reureu blocks needs to be less than 1:10,000 to be effective for land-use decision making. The Soil Map will be presented using a GIS programme called Arc Map[14].

3.8.1 Approach

The information gathered in the field was put into a GIS programme Arc Map and polygons were made based upon differences in soil. Those polygons which were similar where grouped together. These polygons where then assigned attributes such as soil name, soil code, LUC, LRI etc.). The background image used was the Horizons Mosaic (2012).

A soil mapping legend helps identify the corresponding soil code. There are two mapping legends presented; a pedalogical legend and a physiographic legend.

---

[13] Personal Communication A. Palmer

[14] GIS maps produced were created using ArcGIS® software by Esri. ArcGIS® and ArcMap™ are the intellectual property of Esri and are used herein under license. Copyright © Esri. All rights reserved. For more information about Esri® software, please visit www.esri.com.

3.9 Land Evaluation Maps

In order to map LUC and LRI components, the Landcare *Manual 3rd Edition on Land-use Survey Handbook* (2009) was used for correct procedures to be used when carrying out the survey.

Landcare Research Ltd provides a *Manual 3rd Edition on Land-use Survey Handbook* (2009) that should be followed to assign LRI and LUC components (Lynn et al., 2009).

Land suitability maps for the Reureu Blocks were also produced based on the guidelines[15] by Webb & Wilson (1995) and DairyNZ (n.d). The features chosen were those most significant for a dairy land-use:

- Suitability for Effluent
- Irrigation requirement
- Flood risk
- Suitability for arable crops
- Presence of stones
- Susceptibility to pugging

The explanation of each suitability map is explained in Chapter 6.

3.9.1 Approach

Each soil polygon from the soil map produced was given the four (erosion, slope, vegetation and rock type) remaining features required for LRI mapping. These were then put onto the map using codes identified in the *Manual 3rd Edition on Land-use Survey Handbook* (2009) (see Chapter 6 for more detail). In order to complete the LUC classification mapping an LRI map must be completed first.[16]

The farm boundaries were digitised which than had the assigned LRI units. An attribute table was mapped with several fields needed such as:

- The LRI five physical factors (Rock, Soil, Slope, Erosion and Vegetation)
- LUC class (Class, subclass and unit)

[15] A Manual of Land Characteristics for Evaluation of Rural Land (Webb & Wilson, 1995)
[16] Landcare Manual 3rd Edition on Land Use Survey Handbook (Lynn et al., 2009)

- Soil name (soil code)
- Ratings for suitability (effluent, irrigation, presence of stones, arable crops, flood risk).

The colours used to present the LUC map were those in guidelines in the '*Manual on land-use Survey Handbook' (Lynn et al., 2009).* Assigning each LUC class was done with reference to the Manual on land-use survey handbook and reference to the '*Taranaki and Manawatu LUC book' (Lynn et al., 2009).*

Chapter 4 Literature Review

4.1 Soil

The soils found of the Reureu blocks on river flats. There are six soil series that are found of the blocks;

- Rangitikei Soil Series
- Parewanui Soil Series
- Otaki Soil Series
- Manawatu Soil Series
- Karapoti Soil Series
- Kairanga Soil Series

As the ‘Soils of the Kairanga County Soil Bulletin’ has the best descriptions of the soil series listed above (A. Palmer, personal communication, July 2014) it was used for generic soil descriptions for the following soil series, except where indicated otherwise.

4.2 Soil Physical Properties

The following section describes the physical properties of those soils found on the Reureu blocks, with reference to both Cowie (1978) and S-Map. Soils are divided into three sections rapidly accumulating soils, slowly accumulating soils and non-accumulating soils.

4.2.1 Rapid Accumulating Soils - Floodplains

Soils which are rapid accumulating are those soils which are prone to frequent flooding. These soils are found on river flats, back plains and back basins. These soils have been formed on alluvium laid down by rivers close by, in this case the Rangitikei (Cowie, 1978). The presence of flooding has affected the soil-forming process which in turn means these soils properties are determined by the alluvium deposited on the river flats (Cowie, 1978).

The soils on the Reureu block which were classified as rapid accumulating soils according to Cowie (1978) are listed below:

- Rangitikei Soil Series (well drained)
- Parewanui Soil Series (imperfectly drained)
- Otaki Soil Series (well drained)

Each of the soil series will be described in detail with reference to Cowie (1978) and S-Map. Cowie (1978) has based his soil series classification on the drainage ability of the soil.

4.2.1.1 Rangitikei Soil Series – Recent Soil

The Rangitikei soils are classified as *recent soils* according to the NZSC system. A recent soil is a weakly developed soil with distinct topsoil and the B horizon is virtually non-existent or only weakly expressed. Recent soils vary in age depending on the accumulation and occurrence of flood levees and alluvium. Spatial variability of these soils is high due to the differences in materials they are formed on. These soils tend to have low plant-available water and a naturally high fertility level.

The Rangitikei Soil Series are soils which are moderately to excessively drained soils, occurring on river flats and streams. These soils are sandy textured soils with little development, due to the rapid accumulation of alluvium (Cowie, 1978). The rapid accumulation of alluvium means flood deposits are hard to differentiate (Cowie, 1978). Lack of development means that these soils are prone to compaction under heavily stocked pastures. These soils also tend to have low P-retention levels, are prone to drought during summer and due to poor structure erosion risk is high. However with irrigation and careful management of these soils they can be used for more intensive grazing and dairy.

The following three Rangitikei soils are described below to give brief overviews of the soil series:

- Rangitikei loamy sand
- Rangitikei sandy loam
- Rangitikei fine sandy loam

4.2.1.1.1 Rangitikei loamy sand (recent soil)

The Rangitikei loamy sand (Table 15) is an excessively drained, rapidly accumulating soil. This soil series overlies gravels which normally lie 60 to 120 cm from the surface, if these gravels are found shallower than 45 cm; the soil is referred to as the *Rangitikei loamy sand, shallow phase* (Cowie, 1978). A typical profile shows darkish grey brown topsoil which overlies a grey fine sandy layer with little to no development (poor structure). The B horizon in this soil is barely visible or does not occur due to insufficient time for soil development (Cowie, 1978). This soil tends to have a low P-retention, needs to be irrigated during summer (drought vulnerability) and is not farmed intensively due to flood risk (S-Map). However some good pastures can occur on this soil because of its free draining characteristics and locality to the river which means that it tends not to dry out as much in summer as expected.

Table 15 Summary of Rangitikei loamy sand.

Parent Material	Alluvium
Topography and Physiography	Flat to hummocky. Berm areas frequently flooded.
Mean Annual Rainfall	890 – 1270 mm
Distinguishing features of the Soil and environment	On low frequently flooded river flats. Well to excessively drained, sandy and shallow soils with flood banding. Differs from the slowly accumulating Manawatu series in having shallower and more poorly defined A horizon and no B horizon.
Overall Drainage	Well to excessively
Internal Drainage	Very rapid
Natural Nutrient Status	Moderate to low; low P, high K, medium Ca
Present Land-use	Rough grazing
Potential Land-use	Grazing
Limitations for intensive Soil Use	Frequent flooding; dries out in summer
Soil Classification **Common Name**	Weakly leached rapidly accumulating recent soils

Source: Extended Legend for Soil Map of Kairanga County (Cowie, 1978).

4.2.1.1.2 Rangitikei sandy loam (recent soil)

The Rangitikei sandy loam (Table 16) soil is deeper and finer textured than the loamy soil, and occurs on slightly higher flats than the loamy sand (Cowie, 1978). Where mottles are distinct, the soil is referred to as *Rangitikei mottled sandy loam.* The presence of mottles according to Cowie (1978) refers to the natural drainage which prevents the soil from drying out in the summer.

Table 16 Summary of a Rangitikei sandy loam

Parent Material	Alluvium
Topography and Physiography	Flat. Berm areas and low river flats, frequently flooded
Mean Annual Rainfall	890 – 1270 mm
Distinguishing features of the Soil and environment	Same as the Rangitikei loamy sand except heavier in texture
Overall Drainage	Slowly excessively drained
Internal Drainage	Rapid
Natural Nutrient Status	Moderate to low; low P, high K, medium Ca
Present Land-use	Rough grazing
Potential Land-use	Flattening, winter grazing
Limitations for intensive Soil Use	Frequent flooding; dries out in summer
Soil Classification **Common Name**	Weakly leached rapidly accumulating recent soils

Source: Extended Legend for Soil Map of Kairanga County (Cowie, 1978)

4.2.1.1.3 Rangitikei fine sandy loam (recent soil)

The Rangitikei fine sandy loam (Table 17) is well drained and differs from the other Rangitikei soils as it becomes finer and browner. Cowie (1978) states this soil represents the change between the Rangitikei Soil Series and the Manawatu Soil Series. Gravels generally appear 60 cm from the surface, however if these gravels are found higher than 45 cm, the soil is referred to as the *Rangitikei fine sandy loam, shallow phase.* If mottles are present the soil is referred to as the *Rangitikei mottled fine sandy loam* (Cowie, 1978).

> *"A profile shows 76 cm, of dark greyish brown fine sandy loam with weakly developed nut structure overlying light olive brown fine sandy loam. In some profiles olive fine sands occur below 60 cm from the surface."* (Cowie, 1978, p. 29)

Table 17 Summary of a Rangitikei fine sandy loam

Parent Material	Alluvium
Topography and Physiography	Flat. Low river flats, frequently flooded
Mean Annual Rainfall	890 – 1270 mm
Distinguishing features of the Soil and environment	On frequently flooded river flats. Well drained with fine sandy loam textures and ill-defined but thick A horizons. Transitional to Manawatu soils
Overall Drainage	Well drained
Internal Drainage	Medium
Natural Nutrient Status	High; high P, K and Ca
Present Land-use	Fattening, dairying, grazing
Potential Land-use	Fattening, dairying and cropping if protected from flooding
Limitations for intensive Soil Use	Frequent flooding; shallow phase dries out in summer
Soil Classification **Common Name**	Weakly leached rapidly accumulating recent soils

Source: Extended Legend for Soil Map of Kairanga County (Cowie, 1978)

4.2.1.3 Otaki Soil Series (Recent Soil)

The Otaki soil series are also classified as a *recent soil* under the NZSC classification system. Although there is no information in the Kairanga County Bulletin about the Otaki Soil Series, this soil is very similar to that of a Rangitikei shallow silt loam and Rangitikei shallow sandy loam (A. Palmer, personal communication, January 2015). The Otaki Soil is a stony soil, with gravels appearing at very shallow depths. For more detailed information the Rangitikei soil series descriptions.

> *"The Otaki soils are developed in coarse sandy river gravels and their characteristics are 5 – 15 cm of topsoil overlying unaltered gravels often with stones to the surface of the profile."* (Blair, 2003, p. 12)

4.2.1.2 Parewanui Soil Series (Gley soil)

The Parewanui soil series are defined as a *Gley Soil* under the NZSC system. A Gley soil is affected by water logging and in some cases can correspond to past wetland areas. Gley soils have light grey subsoil's, BG horizons and the presence of mottles. Gley soils are most common where there is a high water table. The Parewanui Series includes soils formed on frequently flooded low-lying areas where natural drainage is poor to very poor (Cowie, 1978). The soils are finer textured alluvium further away from the river than the Rangitikei Soils. The flood waters where these soils are found lie for longer (Cowie, 1978). The Parewanui Soil Series have a naturally high nutrient status due to the alluvium deposited during flooding. These soils suffer from poor drainage (i.e. high water table and shallow rooting depth) and flooding potential which hinder intensive land use (Cowie, 1978).

4.2.1.2.1 Parewanui silt loam (gley soil)

The Parewanui silt loam (Table 18) is the most common of the soil series. The drainage of this soil is poor and heavy stocking rates can cause pugging. With the addition of new drainage systems such as mole and tile drains, greater pasture production can be achieved (Cowie, 1978). A typical profile shows a heavy topsoil (clay) or silt loam with many brown/red mottles present. The topsoil is moderately developed and aggregates in both the top and subsoil horizons dry are hard when dry (Cowie, 1978).

Table 18 Summary of a Parewanui silt loam

Parent Material	Alluvium
Topography and Physiography	Flat. Low river basins, frequently flooded
Mean Annual Rainfall	890 – 1140 mm
Distinguishing features of the Soil and environment	On low, frequently flooded river basins and flats. Poorly drained with poorly defined A horizon on grey clay loam to clay with iron mottles. More frequent flooding occurs than on Kairanga soils, and they have less well defined topsoils.
Overall Drainage	Poorly drained
Internal Drainage	Slow
Natural Nutrient Status	High; very high P, high K and Ca
Present Land-use	Dairying, fattening, grazing and cropping
Potential Land-use	Cropping, dairying, fattening
Limitations for intensive Soil Use	Poor drainage; frequent flooding
Soil Classification **Common Name**	Weakly leached rapidly accumulating gley recent soils

Source: Extended Legend for Soil Map of Kairanga County (Cowie, 1978)

4.2.2 Slowly Accumulating Soils – Rarely flooded

Soils which are slowly accumulating have had more time to develop than those which are rapidly accumulating. These soils are found on slightly higher terraces and not flooded as frequently as those located on lower terraces boarding the river.

> *"The rate of accumulation of alluvium is therefore less than in the Rangitikei soils so that there is generally sufficient time between floods for the accumulation of organic matter to darken each flood layer, and for worms to incorporate it into the soil. Thus flood layering is not as evident in the profile as in the Rangitikei soils."* (Cowie, 1978, p. 30)

The soils on the Reureu block which were classified as slowly accumulating soils according to Cowie (1978) are listed below:

- Manawatu Soil Series (well drained)
- Kairanga Soil Series (imperfectly drained)

Each of the soil series will be described in detail with reference to Cowie (1978) and S-Map. Cowie (1978) has based his soil series classification on the drainage ability of the soil.

4.2.2.1 Manawatu Soil Series – Recent Soil

The Manawatu Soils are defined as *Recent Soils* under the NZSC system (refer to section 4.2.1.1 for more detail on recent soils). The Manawatu Soil Series are located on higher terraces than those of the Rangitikei Series. The Manawatu Soils are generally well to excessively drained soils, where flooding has occurred in the past (Cowie, 1978). The Manawatu Soils have less accumulation of alluvium compared to that of the Rangitikei Series, showing more development in the topsoil and subsoil (Cowie, 1978). The Manawatu Soils have low P retention, good internal drainage, low drought vulnerability and small susceptibility to pugging. These soils are very versatile and can be used for a variety of uses. The Manawatu Soils topsoil is broken down by continuous cultivation or intensive stocking. An example by Cowie:

> *"Thus in market gardens or nurseries which have been cropped continuously for 10 to 20 years, the topsoil becomes almost structure less and very compact. As a result, a downward percolation of rain water is slowed considerably, giving poor aeration in the root zone."* (Cowie, 1978 p. 30).

4.2.2.1.1 Manawatu silt loam (recent soil)

The Manawatu silt loam (Table 19) lies on well drained alluvial flats which receive fine alluvial material.

> *"Profiles show 23 cm of friable brown silt loam with moderately developed nut structure, overlying 50cm of light olive brown firm silt loam, with moderately developed blocky structure."* (Cowie, 1978, p. 30)

Table 19 Summary of a Manawatu silt loam

Parent Material	Alluvium
Topography and Physiography	Flat. River levees, occasionally flooded
Mean Annual Rainfall	890 – 1270 mm
Distinguishing features of the Soil and environment	On very occasionally flooded river flats and levees. Well to moderately well drained with silty textures. Less frequent flooding than Rangitikei soils with browner and deeper A; on olive brown B; and less flood banding. Better drained and browner subsoil's than those of slowly accumulating Kairanga soils.
Overall Drainage	Well and moderate drained
Internal Drainage	Medium
Natural Nutrient Status	High; high P and Ca, medium K
Present Land-use	Dairying, fattening, market gardening, cropping
Potential Land-use	Market gardening, cropping, dairying, fattening
Limitations for intensive Soil Use	Parts liable to flooding
Soil Classification Common Name	Weakly leached rapidly accumulating recent soils

Source: Extended Legend for Soil Map of Kairanga County (Cowie, 1978)

4.2.2.1.2 Manawatu mottled silt loam (recent soil)

The mottled silt loam (Table 20) has poorer drainage than the silt loam and is transitional to Kairanga Soils. The Manawatu mottled silt loam soil has good natural nutrient status, drains well in winter and doesn't dry out in summer (Cowie, 1978).

4.2.2.1.3 Manawatu fine sandy loam (recent soil)

The Manawatu fine sandy loam (Table 20) is the most common soil type in this group. It is formed on slightly sandier textures, drainage is somewhat better and the soil tends to does not dry out during the summer (Cowie, 1978).

> *"Profiles show 25cm of dark greyish brown friable fine sandy loam or silt loam with moderately developed nut structure overlying 10cm of live brown firm fine sandy loam with weakly developed nut structure "* (Cowie, 1978, p. 31).

Table 20 Summary of a Manawatu fine sandy loam.

Parent Material	Alluvium
Topography and Physiography	Flat. River levees, occasionally flooded
Mean Annual Rainfall	890 – 1270 mm
Distinguishing features of the Soil and environment	On occasionally flooded river flats and levees. Well to moderately well drained with fine sandy textures. Differ from Manawatu silt loam in having sandier textures.
Overall Drainage	Well drained
Internal Drainage	Medium
Natural Nutrient Status	High; high P and Ca, medium K
Present Land-use	Dairying, fattening, market gardening, nurseries, cropping
Potential Land-use	Market gardening, nurseries, cropping, dairying, fattening
Limitations for intensive Soil Use	Dries out slightly in summer; parts liable to infrequent flooding
Soil Classification Common Name	Weakly leached rapidly accumulating recent soils

Source: Extended Legend for Soil Map of Kairanga County (Cowie, 1978)

The Manawatu fine sandy loam is referred to as *Manawatu fine sandy loam, stony phase* where shallow stones are found. If brown/grey mottles are present in the subsoil the soil, becomes the *Manawatu mottled fine sandy loam* (Cowie, 1978). The presence of mottles shows the water table rises during winter affecting soil drainage (Cowie, 1978).

4.2.2.1.4 Manawatu sandy loam

The Manawatu sandy loam (Table 21) soils are located on higher terraces where there are sandier textures, which overlie gravels which are located 60 – 90 cm from the surface. If gravels are present within 30 cm of the surface than the soil is referred to as '*Manawatu sandy loam, gravelly phase*' (Cowie, 1978). The sandy loam soil is more freely drained than either the fine sandy loam or silt loam. However the Manawatu sandy loam soil does dry out during the summer, so irrigation may be necessary (Cowie, 1978).

> *"Profiles show 20 to 25 cm of very dark greyish brown friable sandy loam topsoil overlying 28 to 45 cm light olive brown friable sandy loam which passes down to an olive loose sand. The topsoil has moderately developed fine to medium nut structure, and the underlying sand is single grained"* (Cowie, 1978, p. 31)

Table 21 Summary of a Manawatu Sandy Loam.

Parent Material	Alluvium
Topography and Physiography	Flat. River levees, occasionally flooded
Mean Annual Rainfall	890 – 1270 mm
Distinguishing features of the Soil and environment	On occasionally flooded levees. Well to somewhat excessively drained with sandy profiles on sand and gravel. Sandier textured and shallower over sand or gravel than Manawatu fine sandy loam.
Overall Drainage	Somewhat excessively and well drained
Internal Drainage	Rapid
Natural Nutrient Status	High; high P and Ca, medium K
Present Land-use	Dairying, fattening, market gardening, nurseries
Potential Land-use	Market gardening, nurseries, cropping, dairying, fattening
Limitations for intensive Soil Use	Dries out slightly in summer; parts liable to infrequent flooding
Soil Classification Common Name	Weakly leached rapidly accumulating recent soils

Source: Extended Legend for Soil Map of Kairanga County (Cowie, 1978)

If mottles are present, than the soil is referred to as the *Manawatu mottled sandy loam.* The presence of mottles suggests drainage will be impeded to a degree: these soils do not dry out as much in summer.

4.2.2.2 Kairanga Soil Series (Gley soil)

The Kairanga soil is classified as a *'Gley Soil'* under the NZSC system (refer to section 4.2.1.2 for more in depth information of Gley soils). The Kairanga soils are those soils which are imperfectly, poorly and very poorly drained and are located in those areas which historical flood (Cowie, 1978). These soils have a high natural level of fertility however intensive land use is restricted by poor drainage. The 'Kairanga County Bulletin' does not describe the Kairanga clay loam soil, therefore generalised points were used.

> *"Kairanga soils have a distinct, dark greyish brown topsoil's which overlie grey to olive grey subsoils with distinct yellowish brown mottles"* (Cowie, 1978, p. 32)
>
> *"The main feature distinguishing thee soils from those of the Parewanui series is the presence of a more distinct, darker-coloured topsoil. This results from the greater length of time between floods enabling plant remains to darken the top soils"* (Cowie, 1978, p. 32)

4.2.3 Non Accumulating Soils – No longer flooded

The Karapoti Soils are mapped on higher, better, drained river terraces, which usually experience less to no flooding and therefore do not receive any alluvium (Cowie, 1978). Non accumulating soils are those which do not experience addition of alluvium via a fluvial process and are located on the oldest river terrace.

4.2.3.1 Karapoti Soil Series

The Karapoti Soil Series are those soils found on higher terraces which no longer experience flooding anymore. These soils have black or dark brown topsoil. The 'Kairanga County Bulletin' (Cowie, 1978) does not describe a Karapoti sandy loam therefore a Karapoti brown sandy loam is used to best describe the series closest to those found on the Reureu blocks (see Table 22 for a summary of a Karapoti brown sandy loam soil).

Table 22 Summary of a Karapoti brown sandy loam, gravelly phase.

Parent Material	Alluvium
Topography and Physiography	Flat to undulating. Ridges and river flats
Mean Annual Rainfall	890 – 1140 mm
Distinguishing features of the Soil and environment	Higher parts of levees and river flats now free of flooding. Well to somewhat excessively drained with very dark greyish brown A horizon, on light olive brown horizon with faint mottles, and olive sand C horizon. Its high position and mottled B horizon separate it from Manawatu Series
Overall Drainage	Well to somewhat excessively drained
Internal Drainage	Medium to rapid
Natural Nutrient Status	Moderate to high; low P, medium Ca, and high K
Present Land-use	Fattening, dairying
Potential Land-use	Cropping, dairying, fattening
Limitations for intensive Soil Use	Gravelly phase dries out in summer
Soil Classification Common Name	Weakly leached rapidly accumulating recent soils

Source: Extended Legend for Soil Map of Kairanga County (Cowie, 1978)

4.3 Soil Chemical Properties

Soil chemistry is important as it helps to determine natural nutrient levels and current fertility levels. Once this is established fertility requirements can be identified to enable the soil fertility levels to be sufficient for production levels.

The soil chemistry factors taken into account were:

- Soil pH
- Cation exchange Capacity (CEC)
- Phosphorus (Olsen P)
- Nitrogen
- Potassium
- Sulphur
- Magnesium
- Calcium
- Sodium

A procedure was followed as defined in Blakemore, Searle & Daly, (1978), McLaren & Cameron (1996); Morton & Roberts, 1999, Dairy Research Corporation et al., (2003) and FLRC, (2013).

4.4 Soil Water

Soil water is derived from the hydrological cycle where inputs and outputs determine soil water storage (McLaren & Cameron, 1996; FLRC, 2013). The soil water balance helps give information of available water holding capacity (AWC) as well as help determine the impact of irrigation and effluent absorption capacity (Coulter, J.D, 1973).

The soil water balance can be managed by using the following equation:

$$\Delta W = P + I - R - D - S - E$$

where

ΔW is change in water storage (mm)

P is rainfall (mm)

I is irrigated water (mm)

R is deep drainage (mm)

D is discharge from drains and/or interflow (mm)

S is surface runoff (mm)

E is evaporation

4.5 Nutrient Budgeting

Nutrient management is a fundamental; aspect of a farming system. Monitoring nutrient levels helps, not only maximise yields, but also reduces the risk of leaching and surface runoff. As stricter resource consent conditions are applied and nutrient caps become more frequently used the need to monitor nutrient levels will be crucial. The two most commonly known sources of nutrient pollution are nitrogen and phosphorous.

The goal of nutrient management is to maximise the efficiency of fertiliser and effluent use when applied rather than ensuring it is utilised by the plant or lost from the farming system. Nutrients brought onto the farm and used on the farm should be applied in such a way that they help to achieve maximum yield of crop/pasture growth. The soil's ability to provide nutrients naturally will always be limited and the addition of fertiliser is to provide key nutrients phosphorous (P), sulphur (S), nitrogen (N), potassium (K), calcium (Ca) and magnesium (Mg). This can be achieved by;

- Raising plant available nutrients in the soil
- Replacing losses of nutrients from the farming system

Nutrient budgets can be constructed using the Overseer[17] programme. However an understanding of the nutrient cycles and the movement of nutrients in a plant-animal system is important.

> **"***OVERSEER® Nutrient Budgets is an agricultural management tool which assists farmers and their advisers to examine nutrient use and movements within a farm to optimize production and environmental outcomes.*
>
> *The computer model calculates and estimates the nutrient flows in a productive farming system and identifies risk for environmental impacts through nutrient loss, including run off and leaching, and greenhouse gas emissions.*[18]

The following areas affect nutrient management strategies, plans and budgets:

- Fertiliser use
    - Timing
    - Form
    - Application rate
    - Application strategy

(Gregg, Hedley, Cooper & Cooke, 1993; McLaren & Cameron, 1996; Legard, Crush & Penno, 1998; McDowell, Monaghan & Carey, 2003; FLRC, 2013).

- Artificial drainage (Collins et al., 2007)
- Soil Characteristics
    - Bypass flow
    - Soil Type
    - Soil Structure
    - Soil drainage

(McLaren & Cameron, 1996; Journeaux, 2005; McLeod et al., 2008; Webb, Hewitt, Lilburne & McLeod, 2010; FLRC, 2013)

[17] OVERSEER ® Nutrient Budgeting - © 2015 OVERSEER
[18] Definition retrieved from http://www.overseer.org.nz/

4.5.1 Farm Dairy Effluent (FDE)

Farm dairy effluent contains many nutrients which plants use for growth such as nitrogen, phosphorus and potassium.

> *"Biological treatment of these effluents using pond systems achieves a high degree of removal of the chemical oxygen demand (COD), the biochemical oxygen demand (BOD) and the suspended solids of the waste. The pond system are not designed to remove nutrients that become pollutants when the effluents are discharged directly to streams."* (FLRC, 2013 p. 4-43)

The application of FDE to land is a way to mitigate nutrient loss, by maximising the removal of nutrient from FDE before it enters water ways (FLRC, 2013). FDE is generally applied to a small section of the farm, not the entire farm. With FDE only applied in a small area, the concentrations of nutrients are higher and therefore the risk of leaching in winter and spring is high (Journeaux, 2005; FLRC, 2013).

For an efficient and effective FDE system three main requirements are needed. These are having management guidelines (related to soil and landscape risk factors), farm specific design (storage capacity, irrigation and effluent block) and daily management (irrigation timing and depth, monitoring) (FLRC, 2013; Dr D. Horne, personal communication, October 2014).

Monitoring FDE by way of pond level readings, correct application timing (rainfall rates, soil water deficit which needs to be accurate) and reliable equipment. Pond readings help to ensure management of FDE is efficient. Accurate information to inform when scheduling application of FDE is important. This can be achieved by soil moisture sensor readings and weather predictions taken from local climate stations. Soil water balances are also an effective tool to ensure soil can tolerate FDE application, decreasing the risk of runoff and leaching.

FDE is stored in various pond systems, enabling application of FDE to be applied when ideal conditions are present 'deferred irrigation'. The type of irrigation system used can also increase the rate at which contaminants are lost to waterways (Collins et al., 2007).

Farm specific information is also important, as the amount of FDE varies from farm to farm. In each regional council regulations/standards are set to limit the amount of effluent (N amount) to be applied to land.

Irrigation rate, soils information and concentration of FDE can be useful when determining the storage requirements specific to that farm. Tools such as the '*Storage Calculator*' can also be used to help determine the pond requirements.

4.6 Land Evaluation

The FAO (United Nations Food and Agriculture Organisation) as cited in Costantini (2009) define land evaluation as;

> *"The process of assessment of land performance when used for specific purposes, involving the execution and interpretation of surveys and studies of land forms, soils, vegetation, climate and other aspects of land in order to identify and make a comparison of promising kinds of land-use in terms of applicable to the objectives of the evaluation."* (Costantini, 2009 p. 4)

McRae and Burnham (1981) identify land evaluation as;

> *"Almost every activity of man uses land and, as human numbers and activities have multiplied, land has become a scarce resource. Decision making about land-use is a political activity, often rising strong emotions and much influenced by the social and economic situation. Land varies greatly in topography, climate, geology, soil and vegetation cover. A clear understanding of the opportunities and limitations presented by these relatively permanent factors of the environmental is an essential part of the rational discussion of changes in land-use."* (p. 1)

Webb and Wilson (1995) define land evaluation as;

> *"Land evaluation aims to rate the quality of land for a particular use relative to other land in an area. It provides and objective foundation upon which to base decisions and land management, land purchase and land-use planning."* (Webb & Wilson 1995, p. 6)

Landon (1991) defines land evaluation as;

> *"A general term embracing all forms of interpretation, and not implying any particular method of evaluation, or classification or final land-use. There is regrettable but inevitable ambiguity because of the 'monitoring and evaluation' concept emplyed by econmists, fincal analysts and planner, restricted to their post hoc assessments and reviews."* (p. 41)

A single definition for Land Evaluation might therefore be 'an assessment of the physical features of the land for specific purpose so as to ensure the land is used in a sustainable way'.

Evaluation is carried out at various scales from farm scale to a more general scale. Evaluation carried out at the farm level is to provide information to the farmers, who then use the land according to economic, social and cultural considerations. A larger scale evaluation is, used for regional and national planning.
Dent and Young (1981) state;

> *"The demand for a process such as land evaluation was developed when mapping natural resources alone was not enough to provide guidance on how land should be used and what the consequences might be for that land-use."* (p. 115)

An example of this can be seen by soil maps outlining the soil found or vegetation maps outlining plants you will encounter, however neither map specifies whether or not a certain land-use such as dairying can exist. The step further which takes all the physical elements as well as specific requirements for a certain land-use is land evaluation. Dent and Young (1981) show that soil surveying is often the main basis for land evaluation.

Land evaluation helps to identify resources offered by land and requirements of a new land-use (Dent & Young, 1981). Land information can be sourced using existing surveys such as soil surveys, making sure the scale is appropriate for land change. Dent and Young (1985) separate two types of land evaluation. These are;

- *Major land improvement substantial and reasonably permanent improvement in the qualities of land, and which requires large capital expenditure.*
- *Minor land improvement small effect, less permanent, does not require large capital investment.*
  (pp. 117 – 118)

Land evaluation may also be separated into 'qualitative evaluation' and 'quantitative evaluation'. Qualitative evaluation is expressed in terms such as highly, moderately and marginally or not suitable, whereas quantitative provides estimates of production of that particular land-use (Dent & Young, 1985). An economic evaluation of land needs to include results in terms of profit and loss (often expressed as Gross margins etc.) mostly used if investment is required or during a project appraisal.

Land evaluation according to Dent & Young (1985) can also be distinguished by 'current land suitability' referring to present condition of land without major improvements and 'potential land suitability', referring to value of land after improvements.

The scale at which land evaluation is useful varies from regional and national planning to on-farm management and decision making in terms of land-use and versatility.
The main principles behind land evaluation according to Dent & Young (1985) are:

- *Land evaluation involves comparison between the requirements of land-use and the qualities of the land.*
- *Evaluation requires a comparison of benefits obtained with inputs needed.*
- *Evaluation is made in terms relevant to the conditions of the country or region concerned.*
- *Evaluation involves comparison between alternatives.*

(Dent & Young 1985 pp. 124 -126)

Land evaluation does not make the final decision for decision makers, if merely introduces options for future land-use.

Land evaluation can then help in weighing the decisions in terms of land suitability and also the social and economic benefits. Land evaluation does not specify the best land-use, it helps by suggesting alternatives. Land evaluation can be used for various uses from land resource planning, land purchasing to a change in land-use.

4.6.1 Applications of land evaluation

There are several uses for land evaluation the following are major areas where land evaluation has a direct applicaiton (Webb & Wilson, 1995 ; George, nd ; FAO, nd):

- *Land Resource Planning:*

> *"Whenever planners need to evaulation land for alternative uses, an objective classification to rank the relative sutiability of land for these purposes is needed. Land evaluation can identify regional constrants to*

> *land-use and food production and guide regional policy making."* (Webb & Wilson, 1995 p. 6)

- *Guiding Land Purchase*

> *"Where the vaule of land is related to its productive capacity, land evaulation helps determine a suitable purchase price or rental value of land by providing an objective description or land quality and potential and the likely management units required under particluar land-uses. Land evaluation is particlary useful when comparing the relative value of different areas of land."* (Webb & Wilson, 1995 p. 6)

- *Determining suitability of land for a change in land-use*

> *"Land evaluation can help protect investment and to increase profits wherever land improvement or a change in mangement is being considered."* (Webb & Wilson, 1995 p. 6)

- *Assessment of suitability and environmental impacts of land-use*

> *"Land evaluation can form a basis for assessment of the environmental impacts or social consequences of land-use practices."* (Webb & Wilson, 1995 p. 6)

- *Assessment of land suitability for effluent disposal*

> *"Soils differ in their inheret ability to store and assimilate effluents. Land evaluation can assess the ability of land to assimilate effluents and the risk of ponding, runoff or leaching of contaminants to groundwaters."* (Webb & Wilson, 1995 p. 7)

- *Economic assesemnt for land-use*

> *"Land evaulation can include economic analyses to estimate the econmoic suitability of each land unit for different land-uses."* (Webb & Wilson, 1995, p. 7)

Landon (1991) further defines land suitability as;

> *"Term which relates to specific use. The USBR system is an example. If classifies land by its economic suitability for irrigated agricultural development. These systems are usually more detailed, more specific quantitative limits to the class."* (p. 41).

4.7 Land Capability Classification/Systems

The main purpose of land capability classification is it maps land into capability classes ranging 1- best to 8-worst. Two concepts form the basis of this system. These are:

- Capability – This outlines the potential for land to be used in a specific way. A class is assigned to land meaning this land is versatile for that class and those below it (Dent & Young, 1985, pg. 129).
- Limitations – These have an adverse effect on capability, preventing certain land-uses. Limitations can be spilt into permanent which cannot be easily changed and those which are temporary and can be changed such as soil nutrient levels (Dent & Young, 1985, pg. 129).

Land will generally be classed based on permanent limitations and these become the deciding factor for the future. Landon (1991) defines land capability as;

> *"A rather more specific term derived from the USDA and used for a ranked system based on the severity of land limitations for general agricultural use."* (p. 41)

The usefulness of these Land Capability Classification Maps is vast however farm planning is the main reason as to why this system was developed (Dent & Young, 1985). The Land Use Capability (LUC) is method used for classification of land by more or less wide range of agro-pastoral systems. Original methodology was elaborated by the Soil Conservation Service of the U.S Department of Agriculture (1961) on the basis of detailed soil surveys. The methodology developed in the US is still the most common used (Costantini, 1999).

4.7.1 New Zealand Land-use Capability (LUC) System

The LUC classification is a qualitative land evaluation system developed to assess land based on its overall capability rather than specific land-use types. The major issue with this type of classification system is that it has broad classes with low precision. Furthermore there is a difference in interpretation from one region to another, so developing a national standard of capability has been challenging. (Webb et al., n.d.). Webb and his colleagues mapped LUC classes 1 and 2 at a 1:50,000 scale of the whole of New Zealand, providing an overall picture of where these classes are found (Auckland City Council, 2013).

The LUC classification system is used to provide an index of versatility (Table 23) for an overview of this system provided by Webb (Landcare Research, n.d.);

> *"There are eight land-use capability classes, four arable and four non-arable, arranged in order of increasing degree of limitation or hazard to use and in decreasing order of versatility of use, from one to eight."* (Soil Conservation and Rivers Control Council, 1971, p. 21; as cited in Webb, n.d.)

The LUC classification system has been used in New Zealand to help land development and management of individual farms in whole catchments at a district and regional level since 1952 (Lynn et al., 2009). The LUC classification system is defined as;

> *"A systematic arrangement of different kinds of land according to those properties that determine its capacity for long-term sustained production."* (Lynn et al., 2009, p. 8)

The LUC classification groups land to show suitability for farming; however as Webb & Wilson (1995) point out there is a bias towards arable cropping and soil conservation. The NZLUC Classification system assesses land based on its ability to be used for arable/pastoral/forestry and conservation land-use, rather than its ability for a particular land-use and crops.

Table 23 Standard ranges of physical factors for LUC Classes

Physical factor	**LUC classes 1 and 2**	**LUC class 3**	**LUC classes 4 to 8**
Slope	up to slope 7^o	up to slope 15^o	no maximum
Altitude	up to 400 m asl	up to 600 m asl	no maximum
Mean annual rainfall	up to 1400 mm	up to 2400 mm	no maximum
Erosion	no more than a negligible to slight risk of erosion under cultivation	no more than a moderate risk of erosion under cultivation	erosion risk may extend to being extreme
Soil depth and texture[1]	>90 cm of clay loam to sandy loam, which is stone free to stony. *or* >45 cm of clay loam to sandy loam, which is stone free or slightly stony	>90 cm of clay loam to silt loam which is very stony *or* 45-90 cm clay loam to silt loam which is stony *or* 30-45 cm of clay loam to silt loam, which is stone free to stony *or* 30-45 cm of sandy loam which is stone free to slightly stony *or* >30 cm of clay soil	may include any other soil depths and textures
Soil drainage[1]	must be well drained, or moderately well drained, or imperfectly drained	may be poorly drained	may be very poorly drained

Source: Webb, n.d.

*NB Land classified as LUC classes 1 and 2 must also comprise soils which are well supplied with plant nutrients, and/or have nutrient deficiencies that are easy to correct, and which have sufficiently low levels of toxic chemicals, and salinity, that these do not significantly impair crop selection or performance.

Webb & Wilson (1995) identify the following limitations that the LUC system suffers:

- *General rating of land capability provided by LUC can be inappropriate for specific land-uses. Two example of inappropriate LUC ratings in relation to the suitability of land for intensive food production are;*
    - *Sandy soils that possess excellent drainage, aeration and root growth conditions have high value for horticulture under irrigation. However, within the LUC system, sandy soils are downgraded because of the risk of erosion and low soil-water storage under dry land conditions. Neither limitation is significant under intensive irrigation management.*
    - *On the other land, land areas with drainage limitations which present a major risk for orchard and berry fruit production are sometimes given high LUC ratings because of their relatively favourable productivity for pasture and for some crops under dry land conditions.*
- *Criteria used in the classification of soil are poorly defined, and classification are frequently made on subjective assessments of defining criteria*
- *Limited number of attributes used to determine the classification of flat land. Soil attributes are limited to drainage, depth, texture and stoniness. Other attributes of importance to crop growth or management, such as root penetrability within the root zone, aeration and compactability of soil materials under wheeled traffic, are not considered.*

  (Webb & Wilson, 1995 p. 8 – 9)

The LUC classification system has two vital components. The first is compiled of five physical factors which need to be considered for long term planning as follows. This is known as the Land Resource Inventory (LRI);

Rock Type – Soil Unit – Slope Group

Erosion severity and type – Vegetation Cover

The second component of the LUC classification system is whereby land is categorised into eight classes (see Figure 17).

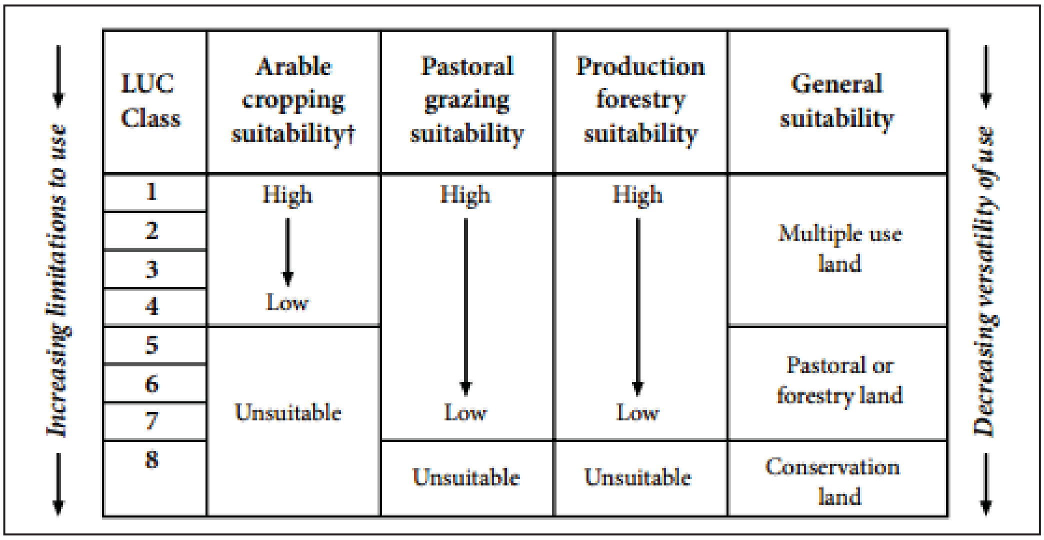

Figure 17 LUC Classes related to versatility and limitations
Source: Lynn et al., 2009.

According to Lynn et al., (2009):

> *"National and international experience has shown that classification of land according to its capability for long-term production, based on its physical limitations and site-specific management needs, provides the most reliable basis on which to promote sustainable land management."* (p.7)

The LUC classification system defines the word capability as used in the sense of suitability for productive use or uses after taking into account the physical limitations of the land (Lynn et al., 2009). Productive capacity will be dependent of physical qualities of the land, soil and environment in question. The physical qualities are not always ideal; these can be referred as a physical limitation. The physical qualities will have an effect on the intensity of the land-use and the land-use itself (Lynn et al., 2009).

The scale in which these LRI and LUC maps are produced is important, especially if the previous maps are used for decision making. The mapping scale should be based on the smallest area of interest which translates to farm mapping scale as shown in Figure 18.

Smallest area of interest	Corresponding scale*	Common applications
10 m^2	1:500	Horticulture, viticulture, localised riparian studies
0.1 ha	1:5,000	Horticulture, viticulture, arable, intensive pastoral
0.4 ha	1:10,000	Arable, pastoral
1 ha	1:15,000	Pastoral, catchment studies
5 ha	1: 35,000	Extensive pastoral, catchment studies, forestry surveys
10 ha	1:50,000	District and regional studies

Figure 18 Suggested Mapping Scale for LRI and LUC mapping.
Source: Lynn et al., 2009.

For farm scale land-use decisions, a farm scale map 1:5000 or 1:10,000 is needed. Regional planning may require less detail so scale over 1:50,000 are often used.

> *"Scale is important when using LRI and LUC map information in Geographic Information Systems (GIS). Such systems can readily rescale the information beyond its original scale of collection. Significantly enlarging the scale can produce unreliable and misleading results, or result in information that is at best nonsense."* (Lynn et al., (2009) p. 11).

The LUC classification has three components the LUC class, LUC subclass and LUC unit as shown in Figure 19.

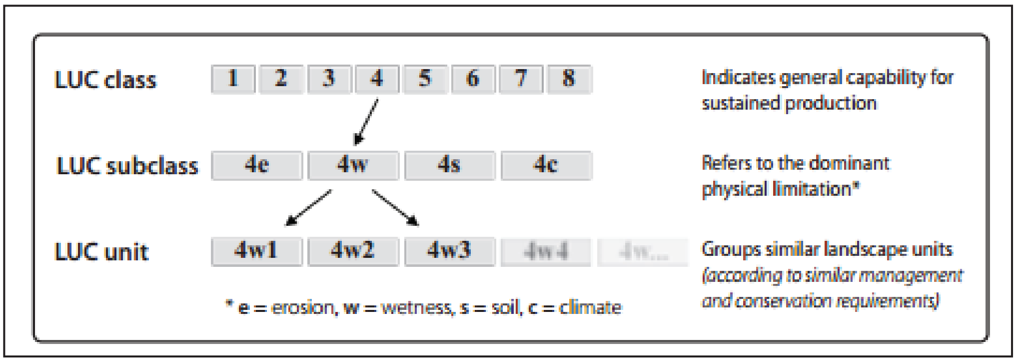

Figure 19 Components of the Land-use Capability Classification System.
Source: Lynn et al., 2009.

The LUC class is the broadest grouping with eight classes in total, limitations increase and versatility decrease from LUC class 1 to LUC class 8. The LUC classes 1 to 4 is considered suitable for arable cropping, horticulture, pastoral grazing, tree crop or production forestry (Lynn et al., 2009). The land which is classed into LUC classes is applied without amendments such as drainage; it is the natural state of the land which is categorized. Classes 5 to 7 are generally not suitable for arable, but are suitable for pastoral grazing, tree crop or production forestry use. Class 8 is land is unsuitable for grazing and production and is best managed as a 'conservation block' planted and left, however some land can already be covered in vegetation such as scrub and be left (Lynn et al., 2009).

The LUC subclass identifies the main kind of physical limitation of which there are four (see Figure 20).

'e'	**erodibility** – where susceptibility to erosion is the dominant limitation.
'w'	**wetness** – where a high water table, slow internal drainage, and/or flooding constitutes the dominant limitation.
's'	**soil** – where the dominant limitation is within the rooting zone. This can be due to shallow soil profiles, subsurface pans, stoniness, rock outcrops, low soil water holding capacity, low fertility (where this is difficult to correct), salinity or toxicity.
'c'	**climate** – where the climate is the dominant limitation. This can be summer drought, excessive rainfall, unseasonal or frequent frost and/or snow, and exposure to strong winds or salt spray.

Figure 20 LUC sub-classes
Source: Lynn et al., 2009.

The final category is the LUC unit which is considered the most detailed component, located at the end of the LUC code. The LUC subclasses are subdivided into LUC units. These are grouped based on similar land inventories being mapped; which will require the same management, same intensity of conversion suitable for same crops, pasture of forestry species and have similar potential yields (Lynn et al., 2009).
Fletcher (1987) defines the LUC unit as

> *"A group of LUC unit which, although differing in land-use capability, share a definitive physical characteristic which units them in the landscape"* (p., 24).

The purpose of introducing a LUC suite helps to relate the landscape and LUC unit.
An example of the LUC format *LUC '6e1'* would be broken down into Class '6', subclass erodability *'e'* and '*1*' as the unit. If one or more limitations exist there is a 'priority' of allocation of limiting factors in this order;

Erodability ⟶ **Wetness** ⟶ **Soil** ⟶ **Climate**

Refer to the '*Land-use Capability Survey Handbook, 3rd Edition (Lynn et al., 2009).*

4.7.2 New Zealand Land Resource Inventory (LRI)

The Land Resource Inventory (LRI) evaluates five physical factors which are considered to be fundamental for long-term sustainable land-use (Lynn et al., 2009):

1. Rock type
2. Soil
3. Slope angle
4. Erosion type of severity
5. Vegetation cover

The importance of each of these differs by location, all having some influence, either individually or in combination, for potential land-use (Lynn et al., 2009). The LRI factors are mapped at the same time, with a different map being produced if one factor changes (Lynn et al., 2009). Detailed information around classification codes can be found in the ‘*Land-use Capability Survey Handbook*’.[19]

4.7.2.1 Rock

Rock type has a major influence on the slope, natural fertility and stability of New Zealand soils, such as the effect of tephra and loess on soil fertility. This classification was developed by Lynn & Crippen (1991) and is used as standard practice in the LRI classification. The classification was based on four objectives as cited in Lynn et al., (2009). These are;

- *To group rock types that have similar erosion susceptibilities and characteristics*
- *Concentrate on those rock types that directly influence land surface morphology and therefore land-use*
- *To distinguish rock types that can be recognised and mapped by soil conservators, land managers and earth scientists, with limited formal geological training*
- *To provide information of rock types that can be easily readily understood and applied by planners and land managers.*
  (p. 14)

The definition and use of some terms are not standard geological usage. Background research into the rock types and geology of the area should be identified though geological maps and the NZLRI maps to help identify rock type. The codes can be found in the ‘*3rd Edition Land-use Survey Handbook*’.[20]

4.8.2.2 Soil

Identifying the soil can be very difficult with most of the New Zealand soil maps published at a large scale, not at the farm scale needed for LRI. The accuracy of the larger New Zealand soil maps should be taken with caution (Lynn et al., 2009; pers. comm. A. Palmer, November 2014). The Crown Research Institute, Landcare Research New Zealand Ltd is the primary source for New Zealand soil maps, with regional/

[19] 3rd Edition Land Use Capability Survey Handbook – A New Zealand Handbook for the Classification of Land (Lynn et al., 2009)
[20] 3rd Edition Land Use Capability Survey Handbook – A New Zealand Handbook for the Classification of Land (Lynn et al., 2009)

district councils and universities often having produced their own soil maps. The New Zealand Soil Bureau also developed many of the older soil maps which have now been re-mapped or re-classified with developing technology.

New Zealand soils use the NZ Soil Classification by Hewitt (1998). Regional soil series may be used to describe soils, grouping soils by location, type and phase. New Zealand soils have been categorised using Hewitt (2013) and Webb & Lilburne (2011). Historically the use of soil series names was used; an example of this is the '*Manawatu fine sandy loam, mottled phase*'. Regional soil series are now limited to series and phases where the phase includes texture. This is to ensure consistency throughout New Zealand. New initiatives such as Landcare Research's S-Map names soils by 'Families' and 'Siblings' (Lynn et al., 2009). Recording soil codes is complex with three methods recommended for recording the code (Figure 21). Some researchers develop their own codes whilst out in the field, changing these when they are back in the office. A Soil Code is essentially a symbol to represent a specific soil so that it may be identified from others.

1. Use codes from an existing published source, such as a local soil map (Figure 4).

   Af – Cl – A
   Ø – gI

   Figure 4: Soil code from an existing soil map. In this case the Cl represents the Clutha soil series as used in Beecroft et al. (1991).

2. Use the NZ Soil Classification, ideally classifying soils down to the most detailed *soilform* category (Figure 5).

   Af – RFW, Md, z, m – A
   Ø – gI

   Figure 5: Soil code from the NZ Soil Classification. The code translates to a Weathered Fluvial Recent, (deep) stoneless, silty, moderate permeability soil.

3. Use S-map *families* and *siblings* when they become available (Figure 6).

   Af – Waim_9 – A
   Ø – gI

   *Figure 6: Soil code from S-map. Waim_9 refers to the 9th **Sibling** of the **Waimakariri Family** of soils.*

Figure 21 Recording Soil codes for LRI.
Source: Lynn et al., 2009.

4.8.2.3 Slope

Slope is measured in degrees from the horizontal (Figure 22). In the field the slopes is measured using a clinometer or estimated by the eye. Slopes can also be calculated from Digital Elevation Models (DEM) where accuracy and precision is available.

Slope Group	Slope angle (degrees)	Description	Typical examples
A	0–3°	Flat to gently undulating	Flats, terraces
B	4–7°	Undulating	Terraces, fans
C	8–15°	Rolling	Downlands, fans
D	16–20°	Strongly rolling	Downlands, hill country
E	21–25°	Moderately steep	Hill country
F	26–35°	Steep	Hill country and steeplands
G	>35°	Very steep	Steeplands, cliffs

Additional symbols that can be used	
+	Compound slopes. This is used where more than one major slope group occurs in a unit. For example, D+E slopes means that slopes are mainly strongly rolling but the unit contains a significant area of land with moderately steep slopes.
/	Slopes which are borderline between two slope groupings are recorded in the form D/E, i.e. most slopes are 20–21 degrees.
'	A dash to the top right of a slope symbol indicates the slopes are dissected. For example A' indicates that the land is flat to gently undulating but is dissected by narrow entrenched gullies or drainage lines.
$^{+}$ or $^{-}$	Superscripts $^{+}$ and $^{-}$ are optional symbols to indicate to which end of the slope group the slope actually lies. For example, the symbol F^{-} indicates that the measured slope is closer to 26°, while F^{+} would indicate that the slope is closer to 35°.

Figure 22 Slope codes for LRI classification
Source: Lynn et al., 2009.

4.8.2.4 Erosion

Erosion is a major factor to consider, with both environmental and economic considerations. The definitions and classifications used in the LRI system have been developed from over 50 years of surveys, farm plan mapping and meeting the needs of the NZ conservation community (Lynn et al., 2009). Figure 23 outlines erosion types and symbols. The erosion severity rankings follow a six-part system, with present erosion assessed on each map unit and potential erosion assessed for whole LUC unit (Lynn et al., 2009). There are thirteen erosion types and one deposition recognised split into four major groups which are described by Lynn et al., (2009):

- *Surface erosion involves the movement of a thin layer of particles across the ground by water, wind or gravity*
- *Mass movement erosion includes a wide range of erosion types where material moves down slope as a more-or-less coherent mass under the influence of gravity*

- *Fluvial erosion involves the removal of material by channelized running water*
- *Deposition is a special category concerning the accumulation of waterborne material across large areas.* (p. 23).

Category	Erosion types	Symbol	Optional prefixes (examples)
1. Surface erosion	Sheet	Sh	
	Wind	W	
	Scree	Sc	
2. Mass movement	Soil slip	Ss	s = shallow, d = deep, r = riparian
	Earthflow	Ef	s = shallow, d = deep, r = riparian
	Slump	Su	s = shallow, d = deep, r = riparian
	Rock fall	Rf	
	Debris avalanche	Da	
	Debris flow	Df	
3. Fluvial erosion	Rill	R	
	Gully	G	s = shallow, d = deep
	Tunnel gully	T	
	Streambank	Sb	
4. Deposition	Deposition	D	

Figure 23 Erosion types and codes for LRI classification

Source: Lynn et al., 2009.

		Sheet, wind & scree	Soil slip	Debris avalanche	Debris flow	Rock fall
Symbol	**Severity**	*Area (%)*	*Area (%)*	*Area (%)*	*Area (%)*	*Area (%)*
0	negligible	<1	<0.5	<0.5	<0.5	<1
1	slight	1–10	0.5–2	0.5–2	0.5–2	1–5
2	moderate	10–20	2–5	2–5	2–5	5–10
3	severe	20–40	5–10	5–10	5–10	10–20
4	very severe	40–60	10–20	10–20	10–20	20–30
5	extreme	>60	>20	>20	>20	>30

Earthflow & Slump †	Rill	Gully †	Tunnel gully	Stream bank *		Deposition
Size (ha)	*Area (%)*	*Size (ha)*	*Area (%)*	*Reach (%)*	*Lateral (m)*	*Area (%)*
0	<0.5	0	<0.5	<1	<0.5	<1
<0.5	0.5–2	<0.05	0.5–2	1–5	0.5–1	1–10
0.5–1	2–5	0.05–0.5	2–5	5–10	1–2	10–20
1–5	5–15	0.5–1	5–10	10–25	2–3	20–40
5–10	15–30	1–5	10–20	25–40	3–5	40–60
>10	>30	>5	>20	>40	>5	>60

Figure 24 Codes for Erosion Severity for Surface Erosion

Source: Lynn et al., 2009.

Erosion severity is denoted by a symbol to describe the severity of that type of erosion, Figure 24 shows the severity of surface erosion. The LRI erosion code sometimes requires additional information around *soil profile loss and track severity*, further information on this can be found in *'3rd Edition Land-use Capability Survey Handbook'*[21]. Soil profile loss is the loss of soil from the profile which helps describe the residual soil environment. Tracks can also affect erosion as they act as a 'point source' for water sediment and nutrient input (Lynn et al., 2009).

4.8.2.5 Vegetation

The Vegetation classification has been developed by Hunter & Blaschke (1986) and was published in the 1st Edition of the LUC Survey Handbook (Lynn et al., 2009) with codes changed to better match the vegetation class. The classification contains 52 classes[22] . The classes are spilt into five groups. Each map unit should have one class of vegetation, if this is not possible up to four classes can be used. If more than one is used this is referred to as clumped vegetation and given an '*' to represent this (Lynn et al., 2009).

4.8 Land Characteristics for evaluation of rural land

A manual of '*Land Characteristics for evaluation of Rural Land'* (Webb & Wilson, 1995) was useful when identifying a particular land-use and particular area of land. Land is rated based on land characteristics (Table 24) were selected for their influence of productivity, crop quality and suitability to land management (Webb & Wilson, 1995). Land characteristics are identified based on their direct impact on suitability or versatility. Each land quality i.e. root penetrability are then ranked according to suitability or versatility. The manual produced by Webb & Wilson (1995) has the ability to aid in interpretations related to land suitability, land versatility and integrative classifications.

> *"Land suitability classifications used to determine the ability of land to grow a particular crop (e.g. wheat, grapes) or specific crop type (e.g. cereals) or for*

[21] *3rd Edition Land Use Capability Survey Handbook – A New Zealand Handbook for the Classification of Land (Lynn et al., 2009)*
[22] *3rd Edition Land Use Capability Survey Handbook – A New Zealand Handbook for the Classification of Land (Lynn et al., 2009)*

particular land treatment (land suitability for irrigation or septic tank absorption fields." (Webb & Wilson, 1995 p. 11)

"Land Versatility – A versatility classification rates land according to its ability to support production and management of a specified range of crops on a sustained yield basis." (Webb & Wilson, 1995 p. 11)

Table 24 Land Characteristics and related land qualities from 'Manual of Land Characteristics for Evaluation of Rural Land

Land Characteristics	Related land qualities
Topographic characteristics: Slope angle	Trafficability, workability, erosion hazard, harvesting efficiency irrigability
Soil Physical characteristics:	
Effective rooting depth	Water and nutrient availability, root penetrability
Penetrability	Root penetrability
Profile available water	Water availability, droughtiness
Soil Wetness	Supply of oxygen to root zone, risk of waterlogging, water availability
Air-filled porosity	Supply of oxygen to root zone, risk of water logging, ease of drainage
Stoniness	Workability, root penetrability
Rock outcrop	Hindrance to machinery and related management constraints
Permeability profile	Ease of drainage, risk of waterlogging, effluent absorption potential, leaching and water loss hazards
Penetration resistance in topsoils	Soil Trafficability
Days with water content below plastic limit	Soil workability
Clay content and mineralogy of top soils	Topsoil structural stability, arable sustainability, susceptibility to compaction and crusting
Soil chemical characteristics:	
Nutrients (P,K and S)	Nutrient supply
pH	Aluminium toxicity, nutrient availability
Salinity	Crop growth, slaking*
Cation-exchange capacity (CEC)	Buffering capacity, effluent absorption capacity
Organic matter	Structural stability, workability
Phosphorous retention	Structural stability, P fertiliser requirement
Environmental characteristics:	
Flood return interval	Flood hazard
Erosion severity	Erosion hazard
Climate characteristics:	
Soil temperature	Crop suitability, yield
Frost severity	Frost damage
Frost-free period	Frost hazard, crop suitability, yield
Growing degree days	Crop suitability, yield, ripening
Chill period	Vernalisation, crop suitability, yield
Sunshine hours	Crop suitability, yield, ripening
Soil water balance	Water deficit, irrigation requirement, effluent absorption capacity.

Source: Webb & Wilson 1995.

** - Slaking – refers to the breakdown of large air-dry soil aggregates into smaller micro aggregates when in water.*

The following outlines and describes a few of the characteristics from Webb & Wilson in more detail which are specifically important to the Reureu blocks and a dairy production unit.

4.8.1 Topographic Characteristics

Topography refers to earth's surface features. It considers the land in a broader context taking into account relief, landforms, catchments and both natural and artificial features.

4.8.1.1 Slope

Topography affects management and production costs by influencing the cost to access the land (Webb & Wilson, 1995). Slope can also affect workability and also increase the risk of erosion. If the slope is too steep access becomes an issue.

4.8.2 Soil Physical Characteristics

The physical characteristics of soil can determine its' ability to aid plant growth, inhibit plant growth and inhibit plant growth. Even if the soils chemical characteristics are suited to a specific requirements, if the physical condition is unfavourable then plant growth will stop or be inhibited (McLaren & Hewitt, 1996).

4.8.2.1 Effective rooting depth

The effective rooting depth is the depth of soil that can be used by rooting systems of crops/plants. It also helps to promote root development, therefore water and nutrient uptake (Webb & Wilson, 1995).

4.8.2.2 Profile available water (PAW)

The amount of water a plant of crop has available for uptake is important especially in those areas with low rainfall or where rainfall varies. The PAW is also important in determining the land's ability to withstand the application of effluent (Webb & Wilson, 1995).

> *"The amount of available water which can be stored in the soil is a function of six main factors: texture, structure, organic matter, soil depth, profile layering and stone content"* (McLaren & Cameron, 1996, p. 84).

4.8.2.3 Stoniness

Stoniness is the measure of stones in number, size, shape and lithology. In some crops stoney soils can be beneficial especially as they can facilitate spring warming of soils so rating this land quality will be dependent on land-use or particular crop (Webb & Wilson, 1995). The presence of stones in the soil in terms of soil drainage means the soil's ability to store water is reduced. The degree of reduction is related to the percentage of stones found (McLaren & Hewitt, 1996).

4.8.2.4 Permeability Profile

The permeability profile determines hazards of waterlogging and water loss (Webb & Wilson, 1995). A soil which is said to be saturated is one where all the pores are full of water and no air present. Saturated soils can differ between the drainage ability of soils such as a poorly drained soil after heavy rainfall having a saturated top soil and an unsaturated subsoil (McLaren & Hewitt, 1996).

> *"Permeability is the quality of the soil that enables water or air to move through it. Permeability is estimated through assessment of 'saturated hydraulic conductivity', i.e. rate at which soil transmits water when saturated."* (Webb & Wilson, 1995, p. 20)

Permeability of the soil is of importance when considering timing and application of irrigation, managing dairy farm effluent and the drainage requirements of the soil.

4.8.2.5 Clay content and mineralogy

Clay is important to both the physical and chemical properties of a soil. The mineral makeup of the topsoil can have an effect on the soil's structure stability. In New Zealand short range order aluminosilicates are described as having random or no crystalline structure (McLaren & Cameron, 1996). Aluminosilicates are silicates in which aluminium replaces some of the silicon, especially in rock forming minerals.

> *"Goldberg (1989) reports that sesquioxides and aluminosilicates with short range order increase aggregate stability, permeability, friability and porosity."* (Webb & Wilson, 1995, p. 22)

Clay has a large surface area and is negatively charged, which enables the soil to exchange cations and anions, affecting the CEC ability of the soil. The higher the clay content of the soil, the higher the CEC of the soil (NCDA & CS Agronomic Division, 1999).

4.8.3 Soil chemical characteristics

The chemical component of soil affects its ability to uptake, hold and provide plants with nutrients. The chemical properties of a soil are in a basic sense derived from the weathering of parent material. The characteristics described below have been described previously in this Chapter (4.3).

4.8.3.1 Nutrient Content

The nutrient content refers to the soils inherent (i.e. natural) fertility, and the soils ability to provide nutrients to meet the need of the crop (Webb & Wilson, 1995). It is the natural state without fertiliser inputs of the current status of the soil.

4.8.3.2 pH

The pH of the soil will have major implications on particular crops and land-use (Webb & Wilson, 1995) also nutrient availability. For more detailed information on pH see the previous section 4.3.

4.8.3.3 Organic Matter

Organic matter in soils promotes aggregation in top soils, which in turn helps to increase water holding capacity, porosity and infiltration of the soil (Webb & Wilson, 1995) and helps in soil structure.

4.8.3.4 Phosphorous retention

The phosphorus retention in soil aids in understanding the phosphorus requirement of the crop and the soil’s ability to release and retain this nutrient (Webb & Wilson, 1995).

4.8.4 Environmental Characteristics

The environmental characteristics specifically important to the Reureu blocks are erosion and flood return interval (flood severity). This is because the blocks are low lying and the bordering Rangitikei River has previously caused major flooding. The erosion issues are not only subject to hill slips but also stream bank erosion.

4.8.4.1 Erosion severity

Soil erosion is a potential risk factor, which needs to be rated on the possibility of all types of erosion occurring which are ranked using the LUC classification system (Webb & Wilson, 1995).

4.8.4.2 Flood return interval

Flooding is a major environmental factor with the ability to completely destroy crops in severe floods. Rating the risk of flood is important (Webb & Wilson, 1995).

4.8.5 Climatic Characteristics[23]

The climatic characteristics of most importance to the Reureu blocks will be the associated soil water deficit or surplus. This in turn will help determine irrigation requirements and managing of blocks in winter and summer.

4.8.5.1 Soil water deficit/surplus

Soil water deficit/surplus takes into account rainfall and evaporation levels; this in turn can lead to irrigation requirements (Webb & Wilson, 1995). The soil water deficit can also help to determine the best soils to apply dairy effluent on as well and also help manage stock (i.e. paddocks to avoid during winter – pugging).

4.8.6 Specific Characteristics to be assessed for the Reureu Blocks

The following list outlines the six most important issues specific to the development of the Reureu blocks for dairy platform. The following characteristics were chosen due to their benefit for the hapū if they are to develop a dairy platform. These characteristics will help give an overview as how to manage certain dairy farming aspects effectively. These were determined by conversations with experts such as Associate Professor Dave Horne and Dr Alan Palmer. These are those characteristics that would be most significant to land owners as they make a decision for land-use, in particular dairy.

[23] Summarising table 30, further detail the Webb & Wilson (1995) '*Manual of Rural Land Characteristics*'.

The characteristics are based on the soil's ability to manage the following:

- Suitability for Effluent:
    - Which soils are best for effluent disposal? Which should be avoided?
- Irrigation requirement:
    - During summer months which soils are prone to drying out?
- Flood risk:
    - The risk of a severe flood (1 – 10 ten year floods).
- Cultivation (suitability):
    - Are there any barriers preventing workability of the soil for cultivation for a summer/winter crop?
- Presence of stones:
    - What is the percentage of stones present in the profile?
- Susceptibility to pugging:
    - In the winter months or after heavy rainfall, which soils are most likely to pug? (Pugging is basically compaction of soils).

Each of these characteristics is discussed in Chapter 6 relative to the Reureu blocks.

4.9 Soil Suitability

Many issues exist where current land-use is unsuitable leading to soil erosion, coastal erosion, land slips, water quality deterioration and much more. The importance of ensuring land is suited to its current use ensures it will be available for future uses and mitigate any long-term damage.

New Zealand has many Land-use Capability Surveys completed which are at a scale of 1:63,360, which can be used at regional, national and district planning levels and large catchment planning areas. However there should be 'window of error' as the precision and accuracy of these maps is unknown at this scale. More comprehensive maps should be conducted at a lower scale and required for food decision making.

4.10 All Paddock Sampling

The benefits of all paddock sampling rather than the usual practice of dividing the farm into management units and landscapes and using an indicator paddock to generate fertilizer requirements are vast. The use of all paddock sampling helps to apply fertiliser more effectively ensuring those paddocks low in fertility are able to increase productivity and financial savings are gained (Roberts, White, Lawerence, & Manning, 2011). Another benefit of all paddock sampling is it can help to bring both the pH and phosphorus status in all paddocks the same. The study conducted on Niaruo Farm a 96.4 ha dairy farm in South Taranaki, showed that all paddock sampling and altering amounts and types of fertiliser has shown a 20% drop fertiliser expenditure of the cost of the 'one rate fits all' used previously. The benefits here did not compromise pasture production or milk production (Roberts, White, Lawerence, & Manning, 2011).

4.11 Policy Drivers

4.11.1 Resource Management Act 1991 (RMA)

The Resource Management Act 1991 (RMA) purpose is to[24];

> *5- Purpose*
> *(1)The purpose of this Act is to promote the sustainable management of natural and physical resources.*
> *(2)In this Act,* **sustainable management** *means managing the use, development, and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic, and cultural well-being and for their health and safety while—*
> *(a) sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations; and*
> *(b) safeguarding the life-supporting capacity of air, water, soil, and ecosystems; and*
> *(c) avoiding, remedying, or mitigating any adverse effects of activities on the environment*
>
> *8- Treaty of Waitangi*
> *In achieving the purpose of this Act, all persons exercising functions and powers under it, in relation to managing the use, development, and protection of natural and physical resources, shall take into account the principles of the Treaty of Waitangi (Te Tiriti o Waitangi).*

The RMA promotes sustainable management of our natural and physical resources. Under the RMA local government bodies are able to enforce rules to promote and

[24] Resource Management Act 1991.
http://www.legislation.govt.nz/act/public/1991/0069/latest/DLM231905.html

protect our physical and natural resources by way of regulations and policies in their region which align with national guidelines.

4.11.2 Te Ture Whenua Māori 1993 (TTWM)

The roles of the TTWM are ownership structures and to facilitate development of Māori land.

2- Interpretation of Act generally[25]

> *(1)It is the intention of Parliament that the provisions of this Act shall be interpreted in a manner that best furthers the principles set out in the Preamble.*
> *(2)Without limiting the generality of subsection (1), it is the intention of Parliament that powers, duties, and discretions conferred by this Act shall be exercised, as far as possible, in a manner that facilitates and promotes the retention, use, development, and control of Māori land as taonga tuku iho by Māori owners, their Whānau , their hapū , and their descendants, and that protects wahi tapu.*
> *(3)In the event of any conflict in meaning between the Māori and the English versions of the Preamble, the Māori version shall prevail.*
> *(TTWMA Māori Lands Act 1993).*

The role of Māori Land Court as given in this act is as follows;

17- General objectives[26]

- *(1)In exercising its jurisdiction and powers under this Act, the primary objective of the court shall be to promote and assist in—*
    - *(a)the retention of Māori land and General land owned by Māori in the hands of the owners; and*
    - *(b)the effective use, management, and development, by or on behalf of the owners, of Māori land and General land owned by Māori.*

  (2)In applying subsection (1), the court shall seek to achieve the following further objectives:
    - *(a)to ascertain and give effect to the wishes of the owners of any land to which the proceedings relate:*
    - *(b)to provide a means whereby the owners may be kept informed of any proposals relating to any land, and a forum in which the owners might discuss any such proposal:*
    - *(c)to determine or facilitate the settlement of disputes and other matters among the owners of any land:*

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[25] Retrieved from http://www.legislation.govt.nz/act/public/1993/0004/latest/DLM289882.html#DLM289893

[26] Retrieved from http://www.legislation.govt.nz/act/public/1993/0004/latest/DLM289882.html#DLM289893

- *(d)to protect minority interests in any land against an oppressive majority, and to protect majority interests in the land against an unreasonable minority:*
- *(e)to ensure fairness in dealings with the owners of any land in multiple ownership:*
- *(f) to promote practical solutions to problems arising in the use or management of any land.*

More in-depth information of the purpose and role of the TTWM and role of the Māori Land Court is explained in Chapter 1.

4.11.3 Local Government Act 2002

The purpose of the Local Government Act 2002 is;

3- Purpose[27]

> *The purpose of this Act is to provide for democratic and effective local government that recognises the diversity of New Zealand communities; and, to that end, this Act—*
> - *(a)states the purpose of local government; and*
> - *(b)provides a framework and powers for local authorities to decide which activities they undertake and the manner in which they will undertake them; and*
> - *(c)promotes the accountability of local authorities to their communities; and*
> - *(d) provides for local authorities to play a broad role in meeting the current and future needs of their communities for good-quality local infrastructure, local public services, and performance of regulatory functions.*

The role of the Local Government Act 2002 is to help meet needs for current and future communities by way of development, infrastructure and to regulate rules and regulations set out by central government.

4.11.4 Horizons Regional Council [Syn. Horizons] (HRC)

The Reureu blocks fall under the jurisdiction of HRC (formerly Manawatu-Wanganui Regional Council); therefore a careful look into the rules and regulations set out by this territorial authority is needed. Under the Resource Management Act 1991 (RMA), it deals with the effects on the environment of economic activity including farming. Under

[27] Retrieved from
http://www.legislation.govt.nz/act/public/2002/0084/latest/DLM170873.html#DLM170878

the RMA, councils such as HRC can manage these effects (Dairying and Environment Committee, 2006). HRC have developed a 'One Plan', which was prepared by them in accordance with its function as a regional government under the Resource Management Act 1991 (RMA) and this was a ground breaking approach which Local Government is watching carefully. HRC states in the One Plan;

> *"The challenge for the Manawatu-Wanganui Region is to strike the ideal balance between using natural resources for economic and social wellbeing, while keeping the environment in good health"*.(Chapter 1, p.1-1)

> *"The One Plan has been prepared by Regional Council in accordance with its functions under the Resource Management Act 1991 (RMA). The One Plan can be described as a "one-stop shop" regional planning document that defines how the natural and physical resources of the Region (including fresh air, clean water, productive land and natural ecosystems) will be cared for and managed by the Regional Council in partnership with Territorial Authorities and the Community"* (Horizons, 2014, p. 1-1).

Section 5 of the One Plan (Horizons (a), 2013) deals with land, highlighting that the adverse effects on the environment come about due to capability of land and soil to support a particular land-use and the effect this land-use has on land and soil. Mismanagement of land and soil can lead to major implications such as degradation of water resource from nutrients and sediment (Horizons, 2013b).

The Reureu block will need to apply for consent for a new land-use. The proposed idea around conversion to dairy production will require new consent.

The application for consent for change of land-use activity to dairy farm section 13-1B a controlled activity of the One Plan (Horizons, 2011) requires the following[28]:

- Nutrient Management Plan – prepared by a qualified consultant with a nutrient budget
- Soil Map
- Dairy Effluent Storage calculation (how managed – cannot leak more than 0.09 mm/day)

[28] More information can be found https://www.horizons.govt.nz/assets/one-plan-publications-and-reports/SWQ-Planning-Rebuttal-Evidence-Chris-Hansen-attachment-20120416.pdf

- Farm features showing waterways, culverts and irrigation block
- Overseer outputs and inputs
- Farm Description (comprehensive)
- Calculations of nitrogen leaching
- Description on how farm will be managed (Phosphorous, Nitrogen, Sediment loss, fodder cropping and use of supplementary feed)
- How fertiliser will be managed
- Identify water uptakes

The consent term is aligned to the common catchment with an expiry in 2017 which is set out in Policy 12A-5 of the One Plan (Horizons (a), 2014). The Reureu blocks currently lie under the Onepuhi catchment which has its expiry is 2017 and thereafter in subsequent ten yearly intervals.

If granted consent the term would be date from now (2014 – 2017 = 3) +10 years = 13 year consent (pers. comm. Peter Taylor, 16th September 2014) (see Appendix 4-1 draft consent conditions). After the consent has expired a new consent application will need to be made. The new consent will reflect any new rules set out in the One Plan.

In terms of the dairy sector, the One Plan tries to ensure;

- *Improving effluent treatment/disposal management;*
- *The adoption of best practice methods, e.g. deferred effluent irrigation*
- *systems;*
- *The adoption of nutrient management plans, and*
- *Making dairy farming (and other intensive rural land-uses) a consented*

(Horizons, 2012)

HRC (2014) have set out leaching limits for nitrogen based on the LUC classification of land (Table 25).

Table 25 Environment Court One Plan Leaching Limits (KgN/ha/yr)[29]

Environment Court One Plan numbers								
	LUC 1	LUC 2	LUC 3	LUC 4	LUC 5	LUC 6	LUC 7	LUC 8
Year 1	30	27	24	18	16	15	8	2
5	27	25	21	16	13	10	6	2
10	26	22	19	14	13	10	6	2
20	25	21	18	13	12	10	6	2

Source: Horizons, 2014 (pers. comm. Peter Taylor)

[29] Table provided by Peter Taylor, Horizons Regional Council.

4.11.5 Clean Streams Accord

The Clean Streams Accord is an agreement signed in 2003 by Fonterra, Ministry for the Environment, (the then) Ministry of Agriculture and Forestry and regional councils. The accord was set up to combat the 'dirty dairying' image on New Zealand's Dairy Farm Industry.

The purpose of the accord is to promote sustainable dairy farming in New Zealand, by reducing the impact of dairying on waterways. There are six priorities set out by the Accord:

1. *The exclusion of dairy cattle from streams, rivers and lakes, and their banks*
2. *Farm races to include bridges or culverts where stock regularly cross a water course*
3. *That farm dairy effluent is appropriately treated and discharged*
4. *That nutrients be managed effectively to minimise losses to ground and surface waters*
5. *Regionally significant wetlands be fenced and their natural water regimes are protected and;*
6. *Fonterra and regional councils develop regional action plans to implement the Accord by June 2004.*
(HRC, 2012).

The Reureu blocks will need to follow these and other guidelines when deciding on a land-use, and especially dairy production.

4.12 Land-use Dairy

The Reureu block owners have expressed interest in amalgamating their interests converting to a dairy production unit. DairyNZ (industry representative body) highlight some key steps or aspects to consider when looking at conversion, these are[30];

- Gathering information – regional and district requirements, dairy company requirements, irrigation schemes.
    - The gathering stage is where district, local and regional regulations should be considered. If a new conversion how long will the consent be, conditions, becoming a sensitive catchment etc.

[30] More information can be found on http://www.dairynz.co.nz/farm/farm-construction/responsible-dairy-conversions/where-to-start/

- Planning stage – need to ensure environmental considerations such as developing and creating farm plans (goals, policies), determining layout of farm (raceways, location of shed and effluent pond), nutrient budgets, effluent plans, water use and allocation, soil health.
    - Utilise expert advice where possible, have clear layout of the farm, ensure policies and procedures are developed, utilise technological developments to make the farm 'more efficient'. Dairy NZ also highlight the key areas to take note of such as;
        - Soil health, Irrigation, Effluent, Nutrient Management and many more
- Implementation – All earthworks, construction can go ahead.

(DairyNZ, 2015a)

Physical suitability of land for dairying requires consideration, identifying if the land is suitable is key. Other suitability considerations would be to locate areas prone to leaching or areas of concern and the economic cost involved. Converting is a costly exercise thus ensuring feasibility of the venture is paramount.

There are many considerations when converting to a dairy farm as outlined the requirements to gain consent from the regional council as well as those guidelines set out by DairyNZ. In chapter five a scenario farm has been developed to identify some of the requirements by Horizons that are required for consent. As this thesis has focused on the physical features, an economic analysis has not been carried out and should be, undertaken if the owners are to continue with a dairy production unit.

> *"A Responsible Conversion Plan is about striving to be good dairy industry ambassadors, while setting up a successful and sustainable business"*
>
> DairyNZ, 2015a.

Chapter 5 Results

5.1 Soil Mapping

Soil mapping of the Reureu blocks were carried out at a scale less than 1:10,000 to produce a quality soil map for farm scale decision making. The current 74 ha was mapped, with pits dug based upon changes in the landscape, terrace levels and areas that differed from others. Most of the holes were dug to a depth of 1 m except for those with gravels present in the top 40 cm. At each hole a soil profile was described based on standard description methods (Milne et al., 1995).

5.1.1 Soil Descriptions

Each soil profile was described using guidelines from Palmer (2013) and Lowe (2008). Each profile was described according to the following;

- Site description - location
- Horizon notation including horizon boundary and horizon thickness
- Soil morphological features including soil colour, soil texture, stoniness, soil consistence

Refer to field notes disk provided for guidelines used to describe soils. Only a selection of the soils found on the Reureu blocks are described below (Refer to Appendix 5-1 for all soil profiles).

5.1.2 Soil Identification

The soils were identified based on the well-known soil series names and defined by stoniness and the texture of top layer. Soils were also classified with assistance from Dr Alan Palmer, Soils Department, Massey University a local expert, and reference to Cowie (1978).

5.1.3 Rapidly Accumulating Soils

Rapidly accumulating soils are those soils that are prone to frequent flooding, which can occur every year. These soils have little time to develop strong soil structure and with the frequent deposition of alluvium flood events are hard to distinguish between. The rapidly accumulating soils are most typically found on lower river terraces. The following soil series are classified as rapidly accumulating.

5.1.3.1 Rangitikei Soil Series

Soils of the Rangitikei Series are formed on low lying river flats, prone to flooding and suffer from frequent deposition of alluvium from the nearby Rangitikei River. The Rangitikei soil series cover 35.6 ha of the total block. The Reureu blocks had several different Rangitikei soil types named (A. Palmer, personal communication, October, 2014) these were:

- Rangitikei deep silt loam over sand (RdSL/Ss)
- Rangitikei deep sandy loam (RdSsL)
- Rangitikei deep silt loam (RdSL)
- Rangitikei moderately deep sandy loam (RmdSsL)
- Rangitikei shallow sandy loam (RsSsL)
- Rangitikei shallow silt loam (RsSL)

Rangitikei deep sandy loam (7 ha)

Profile Description:

Ap 0-12 cm Dark brown (7.5YR 3/3) sandy loam; slightly firm; some hemic material (plant material); brittle; slightly plastic; moderately sticky; moderate development; fine to medium blocky structure; medium many roots; distinct boundary.

Bw 12-35 cm Brown (10YR 5/3) sandy silt; very weak to weak; very friable; slightly plastic; slightly sticky; weakly developed; fine to very fine crumb structure; extremely fine few roots; distinct boundary.

Cu1 35-60 cm Brown (7.5YR 4/3) sand; friable; slightly plastic; slightly sticky; apedal single grain; distinct boundary.

Figure 25 Rangitikei deep sandy loam[31]

Cu2 60-100 cm Pinkish grey (7.5YR 6/2) sand; very friable; non plastic; non sticky; sand is fine grained; apedal single grain.

[31] Profile found on the Reureu Blocks

Rangitikei deep silt loam over sand (3 ha)

Profile Description:

Ap **0-15 cm** Dark brown (7.5YR 3/3) silt loam; slightly firm; some humic material (plant material); brittle; slightly plastic; moderately sticky; moderate development; very fine blocky structure; medium many roots; distinct boundary.

Bu **15-40 cm** Brown (10YR 5/3) silt loam; very weak to weak; very friable; slightly plastic; slightly sticky; weakly developed; fine to very fine crumb structure; extremely fine few roots; distinct boundary.

Cu1 **40-60 cm** Pinkish grey (7.5YR 6/2) sandy loam; friable; slightly plastic; slightly sticky; apedal single grain; distinct boundary.

Cu **60-100 cm** Light grey (7.5YR 7/1) sand; very friable; non plastic; non sticky; sand is fine grained; apedal single grain.

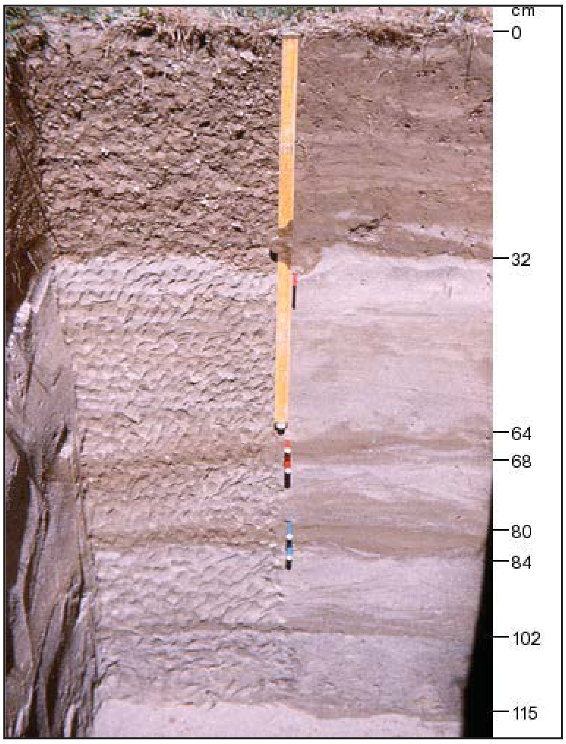


Figure 26 Typical profile of a Rangitikei silt loam over sand[32]

[32] Profile of Rangitikei silt loam over sand provided by Massey University (Soil Map) retrieved from http://atlas.massey.ac.nz/soils/legend/legend.html. (Not profile described).

Rangitikei deep silt loam (9.2 ha)

Profile Description

Apg. 0-10 cm Reddish brown (5YR 4/3) silty clay loam; firm; faint (<5%) fine mottles present, red in colour; brittle; slightly plastic; slightly sticky; moderate development; fine few blocky structure; medium few roots present; wavy boundary.

Bg 10-70 cm Brown (7.5YR 5/2) silt; weak; faint (<5%) fine mottles present red in colour; friable; non plastic; non sticky; weakly developed; fine to very fine crumb structure; distinct boundary.

Cw 70-100 cm Brown (7.5 5/2) sand; weak; apedal single grain; no mottles present; very friable; non plastic; non sticky; fine grained sand.

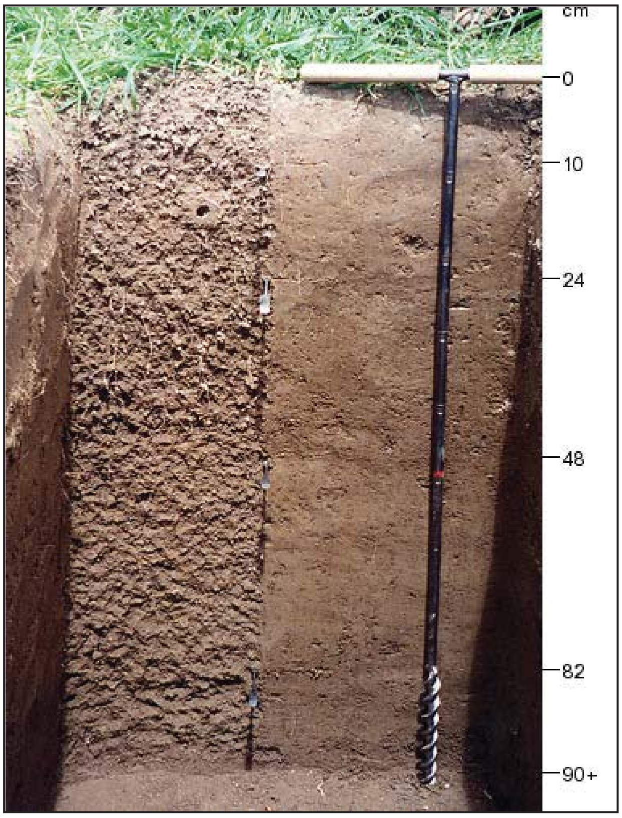


Figure 27 Typical Profile of a Rangitikei silt loam[33]

[33] Profile of Rangitikei silt loam provided by Massey University Soil Map. Retrieved form http://atlas.massey.ac.nz/soils/profiles/profile.html?P24. (Not profile described).

Rangitikei moderately deep sandy loam (5.3 ha)

Profile Description:

Apg.	**0-5 cm**	Brown (10YR 4/3) sandy loam; weak; faint (5%) fine mottles present red in colour; friable; non plastic; non sticky; weakly developed; fine crumb structure; fine sized sand; wavy boundary.
Bg	**5-25 cm**	Dark grey (10YR 4/1) sandy loam; weak; friable to very friable; non plastic; non sticky; weakly developed; fine crumb structure; medium sized sand; distinct boundary.
Cg	**25-55 cm**	Brown/grey (10YR 4/1) sand; very weak; very friable; non plastic; non sticky; fine sized sand; apedal singe grain. At 55 cm soil becomes extremely gravelly with gravels ranging from coarse to boulders.
2Cu	**55 cm on**	On un-weathered sandy gravels

Rangitikei shallow sandy loam (3.3 ha)

Profile Description:

Ap **0-5 cm** Brown/yellowish (7.5YR 4/4) sandy loam; slightly firm to weak; faint (5-10%) fine mottles present; friable; slightly plastic; slightly sticky; weakly developed; fine crumb structure; very fine to medium common roots present; wavy boundary.

Cu **5-40 cm** Brown (7.5YR 5/3) sand; weak; weak; friable; non plastic; non sticky; apedal single grain; extremely fine few root present.

2Cu **40 cm on** Becoming extremely gravelly (60 – 80%) at 40 cm, gravels ranging between 2mm – 10 mm in size, rounded in shape.

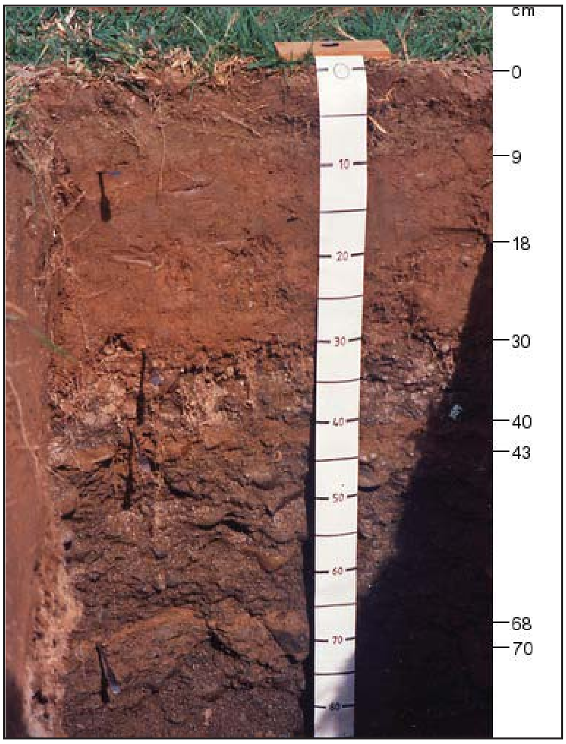


Figure 28 Typical Profile of a Rangitikei shallow fine sandy loam[34]

[34] Profile of Rangitikei Shallow Fine Sandy Loam provided by Massey University, Soil Map. Retrieved from http://atlas.massey.ac.nz/soils/profiles/profile.html?P36. (Not profile described).

Rangitikei shallow silt loam (8 ha)

Profile Description:

Ap **0-5 cm** Brown (10YR 4/3) silt loam; slightly firm to weak; faint fine (5%) few mottles present; friable; slightly plastic; slightly sticky; weakly developed; fine nut structure; very fine to medium common roots present; wavy boundary.

Cu **5-40 cm** Brown (10YR 5/3) silt; weak; friable; non plastic; non sticky; apedal single grain; extremely fine few root present. Becoming extremely gravelly at 40 cm.

2Cu **40 cm on** On un-weathered sandy gravels

5.1.3.2 Parewanui Soil Series

The Parewanui Soil Series are those soils that are rapidly accumulating soils found on lower river flats. These soils experience frequent applications of alluvium from nearby river ways which are the Rangitikei River and the Raumanga Stream. The total area for the Parewanui Series mapped was 9.9 ha. The Reureu blocks were given the following names (A. Palmer, personal communication, October, 2014):

- Parewanui deep silt loam (PdSL)
- Parewanui deep sandy loam (PdSsL)

Parewanui deep silt loam (3.1 ha)

Profile Description:

Apg. 0-10 cm Brown (7.5YR 5/2) silt loam; firm to very firm; distinct medium many mottles present (red/yellow in colour 20%); brittle; moderately plastic; moderately sticky; weakly developed; fine to very fine crumb structure; distinct boundary.

Bg 10-45 cm Brown (7.5YR 5/2) clayey silt; slightly firm; faint (<5%) fine mottles present; friable; slightly plastic; slightly sticky; weakly developed; fine to very fine crumb structure.

Cu 45-100 cm Pinkish grey (7.5YR 6/2) clayey silt; weak to slightly firm; faint (<5%) fine mottles present; friable; slightly plastic; slightly sticky; apedal single grain.

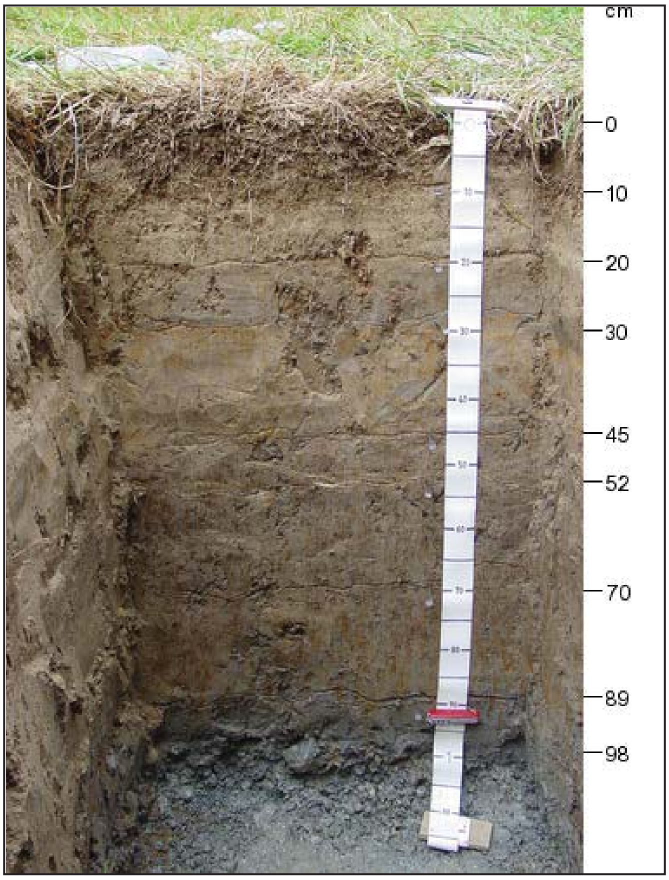


Figure 29 Typical Profile of a Parewanui silt loam[35]

[35] Profile of a Parewanui silt loam provided by Massey University, Soil Map. Retrieved from http://atlas.massey.ac.nz/soils/profiles/profile.html?P72. (Not the profile described).

Parewanui deep sandy loam (6.8 ha)

Profile description:

Ap 0-20 cm Brown (7.5YR 4/4) sandy loam; weak; faint (<5%) fine many mottles present; slightly gravelly ranging from 5- 15 mm; friable; non plastic; non sticky; weakly to moderately developed; nutty structure fine to very fine; sand is medium sized; very fine few roots present; wavy boundary.

Bg 20-40 cm Brown (7.5YR 4/3) loamy sand; distinct (25%) fine mottles present, red/orange in colour; very slightly gravelly less than 5 mm; friable; non plastic; non sticky; weak development; apedal single grain; extremely fine few roots present; wavy boundary.

Cg1 40-80 cm Dark yellowish brown (10YR 4/6) loamy sand; distinct medium many mottles present; friable; non plastic; non sticky; weak development; apedal single grain; sand is fine sized; wavy boundary.

Cg2 80-94 cm Pale brown (10YR 8/4) sand; distinct (25- 30%) medium mottles present, orange/red in colour; very friable; non plastic; non sticky; very weak development; apedal single grain; sand is coarse sized. At 94 cm extremely gravelly (river gravels).

2Cu 94 cm on On un-weathered gravels present

5.1.3.2 Otaki Soil Series

The Otaki Soil Series are rapidly accumulating soils, similar to those of a shallow Rangitikei Soil (A.Palmer, personal communication, January 2015). These soils are shallow stony soils and cover a total land area of 8.8 ha of the Reureu blocks. The Reureu blocks were given the following names (A, Palmer, personal communication, October, 2014):

- Otaki silt loam (OSL)
- Otaki sandy loam (OSsL)

Otaki silt loam (5.4 ha)

Profile Description:

Ap	**0-15 cm**	Brown (7.5YR 4/3) silt loam; weak; slightly plastic; slightly sticky; weakly developed; fine to very fine nut structure; extremely gravelly at 5 cm with gravels ranging from 10 mm to 100 mm in size.
2Cu	**15 cm on**	On un-weathered sandy gravels

Figure 30 Typical Profile of a Otaki silt loam[36]

[36] Profile provided by Dr. Alan Palmer (2015). (Not the profile described).

Otaki sandy loam (3.4 ha)

Profile Description:

Ap	**0-20 cm**	Brown (7.5YR 5/2) sandy clay loam; weak; distinct (20%) medium mottles present red/orange in colour; very friable; non plastic; non sticky; weakly developed; fine to medium nut structure. At 20 cm soil becomes extremely gravelly (60 – 80%) ranging from pebbles to 200 mm gravels in size some as large as boulders, rounded to sub rounded in shape.
2Cu	**20 cm on**	On unweathered sandy gravels

5.1.4 Slowly Accumulating

5.1.4.1 Manawatu Soil Series

The Manawatu Soils that were found on the Reureu blocks are soils that are lie on higher terraces and suffer from occasional flooding, therefore less time for soil development. Manawatu Soils generally have a more defined A horizon due to the longer gap with alluvium deposits. The Manawatu Soils covered a total land area of 14.2 ha. The following Manawatu Soils were found on the Reureu block:

- Manawatu deep sandy loam (MdSsL)
- Manawatu deep silt loam over sand (MdSL/Ss)
- Manawatu deep silt loam (MdSL)
- Manawatu shallow silt loam (MsSL)
- Manawatu moderately deep silt loam (MmdSL)

Manawatu deep silt loam (9.3 ha)

Profile Description:

Ap	**0-10 cm**	Brown (7.5YR 4/2) silt loam; very firm; faint (5%) fine few mottles present; brittle; moderately plastic; moderately sticky; weakly developed; very fine crumb structure; very fine abundant roots; wavy boundary.
Bw	**10-50 cm**	Brown (7.5YR 4/3) silt loam; firm; distinct (25%) fine mottles present; brittle; moderate plastic; moderately sticky; weakly developed; fine nutty structure; distinct boundary.
BC	**50-70 cm**	Pinkish grey (7.5YR 6/2) clayey sand; weak; distinct (25%) medium mottles red in colour; friable; slightly plastic; non sticky; weakly developed; fine nut structure; distinct boundary.
Cg	**70-100 cm**	Light grey (7.5YR 7/1) sand; very weak; distinct (25%) fine mottles present red/orange in colour; very friable; non plastic; non sticky; apedal single grain; sand is medium to fine sized; at 70 cm woody/pumice material found.

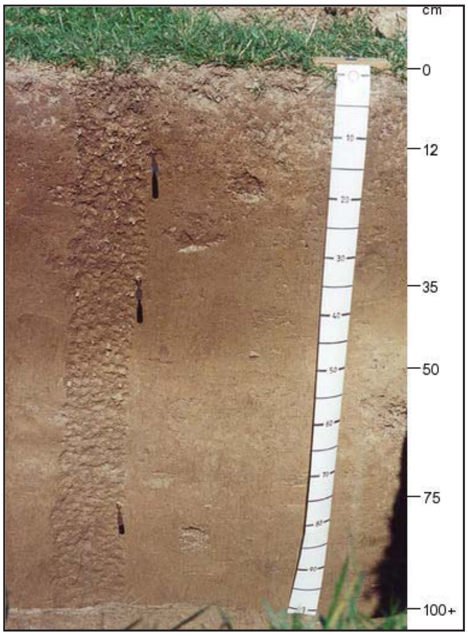


Figure 31 Typical Profile of a Manawatu silt loam[37]

[37] Profile of Manawatu silt loam provided by Massey University, Soil Map. Retrieved from http://atlas.massey.ac.nz/soils/profiles/profile.html?P33. (Not profile described).

Manawatu deep sandy loam (0.6 ha)

Profile Description:

Ap	**0-4 cm**	Brown (7.5YR 4/2) loamy sand; weak; friable; slightly plastic to non-plastic; non sticky; weakly developed; fine crumb structure; fine many roots present; sand is medium to fine sized; distinct boundary.
Bg	**4-25 cm**	Brown (7.5YR 5/3) loamy sand; weak; distinct (25%) fine red mottles present; friable; slightly plastic; slightly sticky; weakly developed; fine crumb structure; few very fine roots present; sand is medium to fine sized; distinct boundary.
BCg	**25-80 cm**	Brown (7.5YR 5/3) loamy sand; weak; distinct (25%) fine red mottles present; friable; slightly plastic; slightly sticky; weakly developed; fine crumb structure; sand is coarse sized; distinct boundary.
Cg	**80-100 cm**	Light grey brown (7.5YR 6/1) silt; weak; prominent fine to medium many mottles present 50% red in colour; friable; slightly plastic; slightly sticky; apedal single grain.

Manawatu deep silt loam over sand (0.3 ha)

Profile Description:

Ap **0-30 cm** Dark brown (10YR 3/3) silt loam; friable; non sticky; moderate plasticity; weak development, fine to very fine crumb structure; fine few roots present; smooth boundary.

Bw **30-60 cm** Brown (7.5YR 5/3) sandy loam; fine sized sand; very friable; non sticky; non plastic; weak development; fine crumb structure; no roots present, occluded horizon.

Cu **60-100 cm** Light brown (7.5YR 6/4) sandy loam; very friable; non sticky; non plastic; weak to extremely weak; no roots present.

Figure 32 Typical Profile of a Manawatu deep silt loam over sand[38]

[38] Soil Profile of a Manawatu Deep Silt Loam over Sand found on the Reureu Blocks.

Manawatu shallow silt loam (0.3 ha)

Profile Description:

Ap **0-10cm** Dark brown yellowish (10YR 4/6) silt loam; weak; slightly sticky; slightly plastic; fine blocky structure; coarse many roots; indistinct boundary.

Bg **10-30 cm** Light brown to grey (10YR 6/2) silt clay loam; very fine few mottles 1 – 5%; firm; friable; slightly sticky; slightly plastic; moderate development; fine blocky structure; wavy boundary.

2Cu **30cm on** On un-weathered gravels present

Manawatu moderately deep silt loam (2.5 ha)

Ap **0-10 cm** Brown (7.5YR 4/3) silt loam; firm; moderately sticky; moderately plastic; moderate development blocky; brittle to semi-deformable; fine few roots present; distinct boundary.

Bw **10-40 cm** Brown (7.5YR 4/2) sandy clay; firm; moderately sticky, moderately plastic; moderate development blocky; brittle; distinct boundary.

Cu **40-100 cm** Brown (7.5YR 4/4) sand; friable; non sticky; non plastic; weak development; apedal single grain; sand is fine textured.

Figure 33 Typical Profile of a Manawatu moderately deep silt loam[39]

[39] Profile of a Manawatu moderately deep silt loam found on the Reureu blocks. (Not profile described).

5.1.4.2 Kairanga Soil Series

The Kairanga Soil Series is a slowly accumulating soil, with additions of alluvium as frequent as the Manawatu Soil Series. The Kairanga Soil found on the Reureu blocks is a clay loam soil which seems to have poor drainage due to the mottles found in the profile description. The Kairanga Soil Series covers 1.4 ha of the total area mapped on the Reureu blocks.

Kairanga Clay Loam (1.4 ha)

Profile Description:

Ap	**0-2 cm**	Brown (7.5YR 4/3) clay loam; firm; gleying is present (1 6/n); prominent (>50%) medium mottles present red/orange in colour; brittle; moderately plastic; moderately sticky; weakly developed; many polyhedral peds; coarse many roots; distinct boundary.
Bg	**2-25 cm**	Grey (10YR 6/1) clay loam; firm; prominent (>50%) fine mottles present red/orange in colour; very slightly gravely; brittle; very plastic; moderately sticky; weakly developed; few nutty peds; wavy boundary.
Cg	**25-27 cm**	Grey (10YR 6/1) sand; weak; prominent (>50%) fine mottles present red/orange in colour; extremely gravelly (60% - 80%) ranging from 1 mm to 100 mm in size, sub-rounded to rounded shape; friable; very plastic; moderately sticky; apedal single grain.
2Cg	**27 cm on**	On unweathered sandy gravels

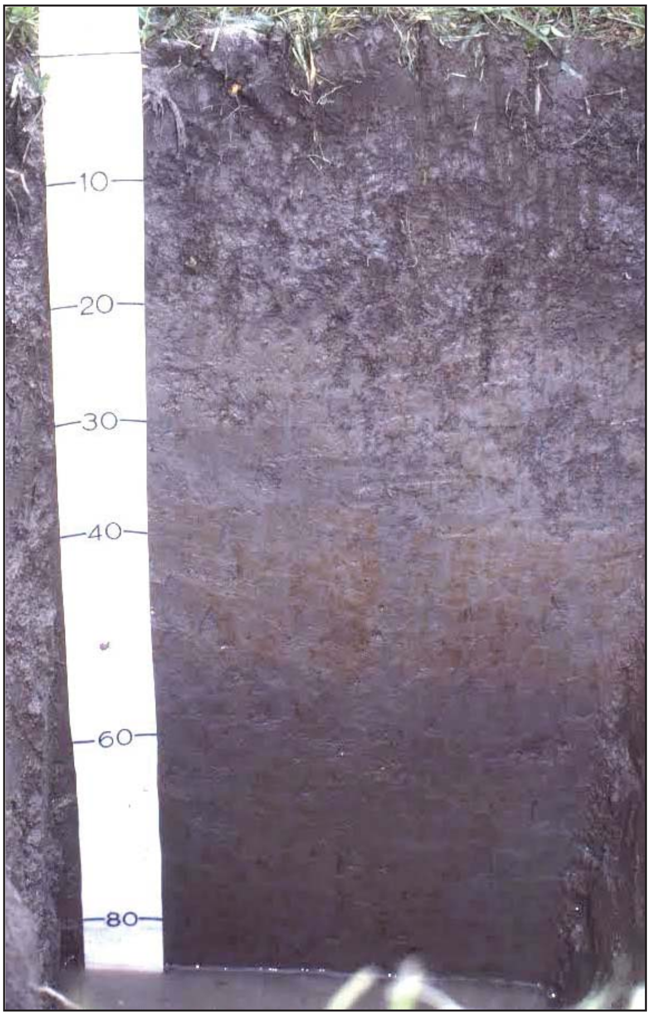


Figure 34 Typical Profile of a Kairanga clay loam[40]

5.1.5 Non Accumulating

5.1.5.1 Karapoti Soil Series

The Karapoti Soil Series lies on a higher terrace than all of the other soil series and is generally not prone to flooding. As this soil isn't prone to flooding it has much more time to develop with more defined A and B horizons. The Karapoti Soil covers a total area of 2 ha of the total area mapped on the Reureu blocks. One only sub-series was identified here.

[40] Profile provided by Dr. Alan Palmer (2015). (Not profile described).

Karapoti silt loam (3.1 ha)

Profile Description:

Ap 0-20 cm Brown (7.5YR 5/2) silt loam; slightly firm; brittle; slightly plastic; slightly sticky; weakly developed; fine to medium nutty crumb structure; extremely fine common roots present; distinct boundary.

Bw 20-37 cm Light yellowish brown (2.5YR 6/3) silt loam; slightly firm; brittle; slightly plastic; slightly sticky; weakly to moderately developed; fine to very fine crumb structure; fine common roots present, wavy boundary.

Figure 35 Profile found on the Reureu block Karapoti silt loam.

Bw/Cw 37-57 cm Olive yellow (2.5YR 6/6) sandy silt loam; firm; brittle; moderately plastic; moderately sticky; weakly to moderately developed; fine nut structure; distinct boundary.

Cw 57-90 cm Olive brown (2.5YR 5/3) fine sand; weak; brittle; non plastic; non sticky; sand is fine sized; apedal single grain. At 70 cm 20 cm band of gravels ranging from small gravels 5 mm to boulders.

5.1.6 Total Area

Table 26 outlines the total area measured in hectares for each soil type encountered on the Reureu blocks.

Table 26 Total area of each Soil Series found on the Reureu Blocks

Soil Series	Total Area (ha)
Rangitikei Soil Series	35.8
Otaki Soil Series	8.8
Parewanui Soil Series	9.9
Manawatu Soil Series	13
Kairanga Soil Series	1.4
Karapoti Soil Series	3.1
Total	72.0

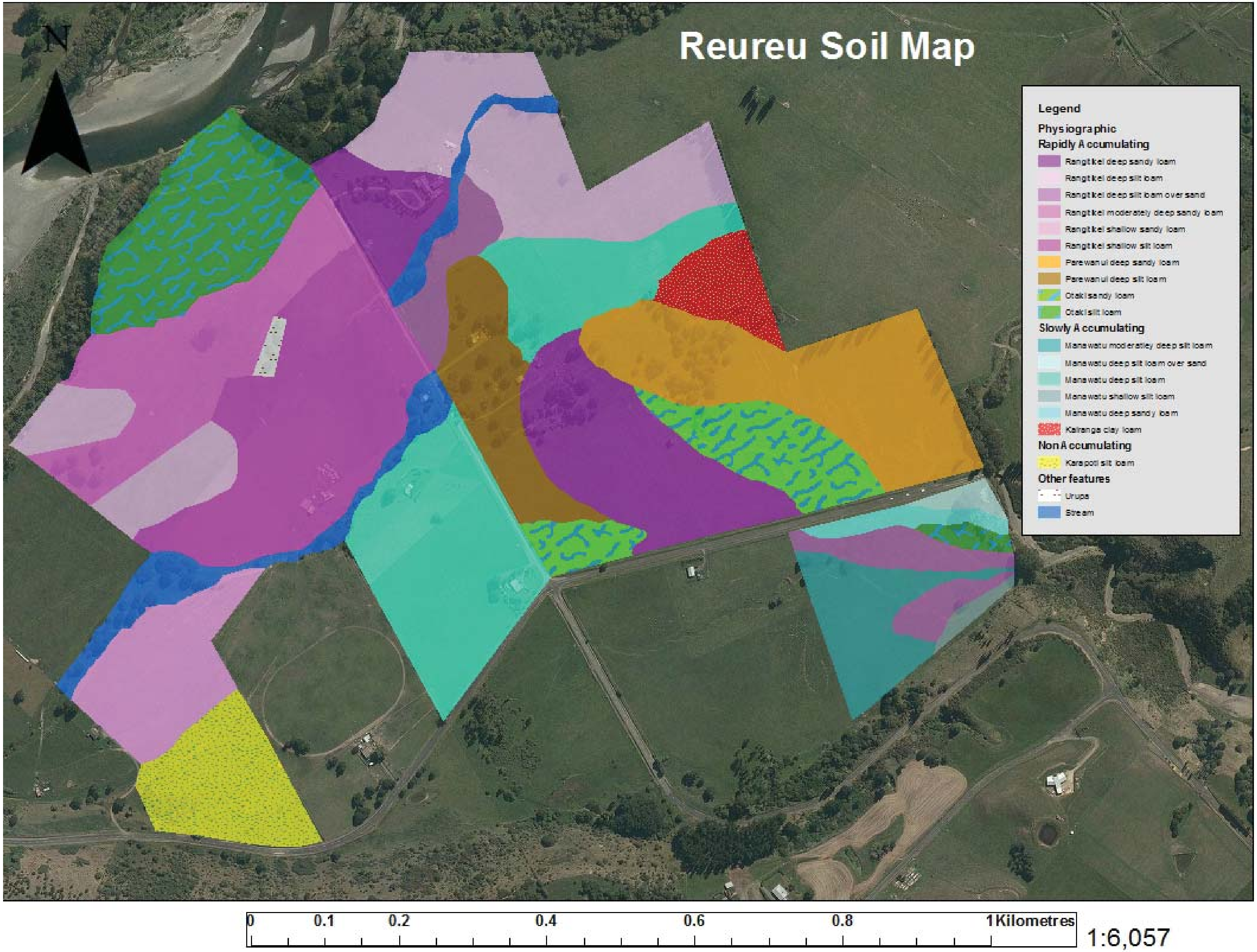
The total area mapped was 74 ha; the remaining 2 ha is either stream, houses or stream running through farm.

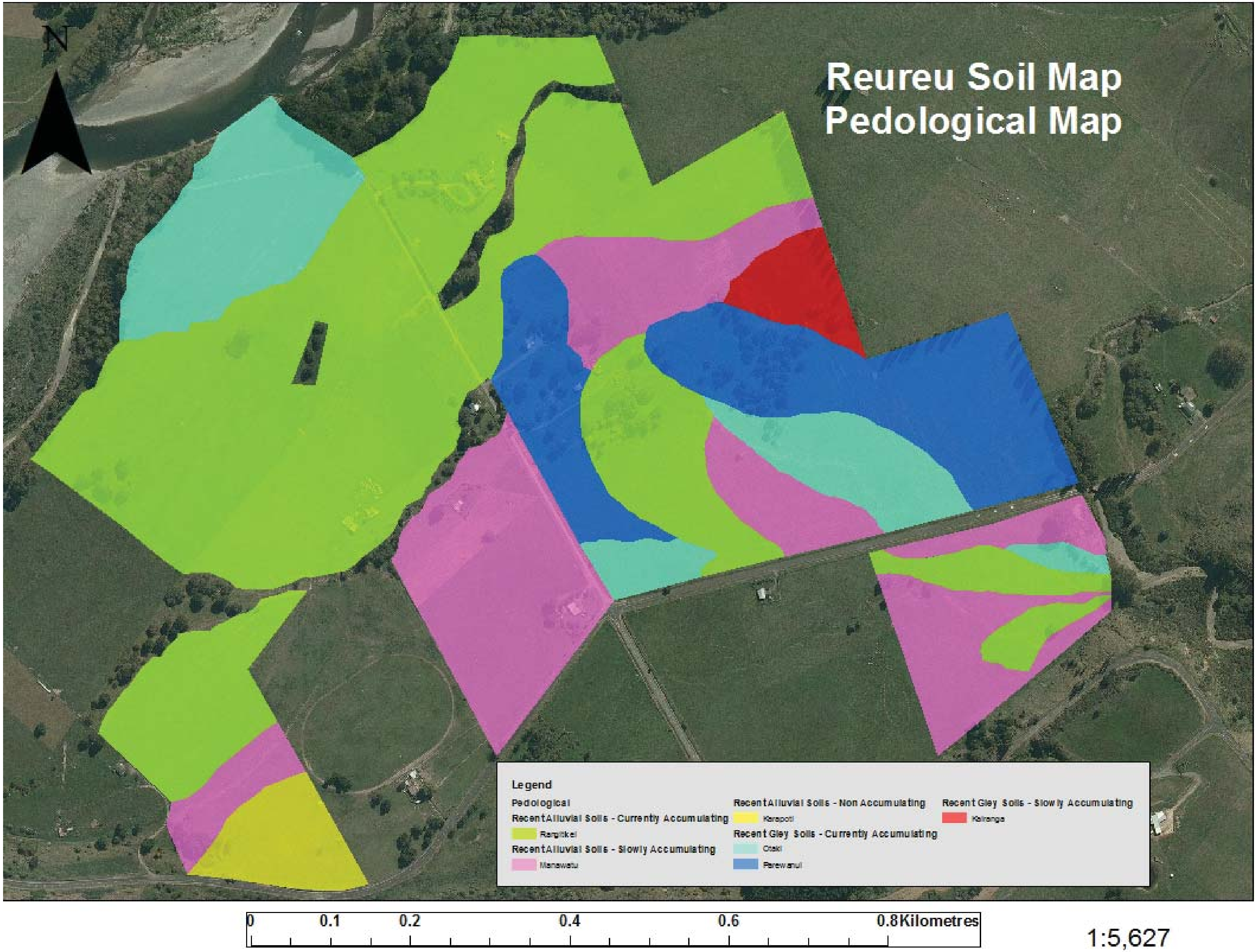
5.1.7 GIS compilation

The soil and land boundaries were digitized and captured using the GIS programme 'Arc Map'. A topographic map of the HRC boundary was used as a base for the map. The soil pits dug were then placed onto the map and soil polygons were drawn based on the information received from field trials. After each polygon was made, soil codes and full soil names were given to each polygon.

The Soil map was compiled together by information retrieved from field work. There may be a variation between the completed map and actual map of soils. The Reureu blocks were complicated to map, due to the nature of the Rangitikei River and a nearby stream which has determined the soils on the eastern side of the farm.

Two legends were produced for the Reureu Blocks; a Physiographic Legend and a Pedological Legend. The Physiographic Map separated the soils based on drainage and where located on the blocks. The Pedological Map separated the soils based on pedology i.e. recent soils. The Urupa which lies on the Reureu blocks does not carry a name as such, but aligns to the old Pa which was there known as Onepuehu Pa.


Reureu Soil Map
N
Legend
Physiographic
Rapidly Accumulating
Rangitikei deep sandy loam
Rangitikei deep silt loam
Rangitikei deep silt loam over sand
Rangitikei moderately deep sandy loam
Rangitikei shallow sandy loam
Rangitikei shallow silt loam
Parewanui deep sandy loam
Parewanui deep silt loam
Otaki sandy loam
Otaki silt loam
Slowly Accumulating
Manawatu moderatley deep silt loam
Manawatu deep silt loam over sand
Manawatu deep silt loam
Manawatu shallow silt loam
Manawatu deep sandy loam
Kairanga clay loam
Non Accumulating
Karapoti silt loam
Other features
Urupa
Stream
0 0.1 0.2 0.4 0.6 0.8 1 Kilometres
1:6,057


Reureu Soil Map
Pedological Map
N
Legend
Pedological
RecentAlluvial Soils - Currently Accumulating
Rangitikei
RecentAlluvial Soils - Slowly Accumulating
Manawatu
RecentAlluvial Soils - Non Accumulating
Karapoti
Recent Gley Soils - Currently Accumulating
Otaki
Parewanui
Recent Gley Soils - Slowly Accumulating
Kairanga
0 0.1 0.2 0.4 0.6 0.8Kilometres
1:5,627

5.2 Land Resource Inventory Mapping

During the mapping excersize each polygon was labelled with its correct five LRI features. These were:

- Rock Type
- Erosion
- Vegetation
- Soil
- Slope

The codes choosen for each of physical features except soil were chosen using the *'Land-use Capability Survey Handbook' (Lynn et al., 2009)*. The soil codes used were those codes used on the soil map – codes determined during the data collection process. The polygons were mapped out where there was a significant change in any one of the five physical factors.

The polygons were than each given an equation;

Rock Type – Soil Unit – Slope Group

Erosion severity and type – Vegetation Cover

The codes for each of the polygons can be found in the *'Land-use Capability Survey Handbook (Lynn et al., 2009)'*.

The following list outlines the symbols used on the Reureu LRI map.

5.2.1 Symbols used for the Reureu block

Rock type

Gr - refers to alluvial gravels

Cl – refers to coarse slope deposits

Soil Unit

RdSL – refers to Rangitikei deep silt loam

RdSL/Ss – refers to Rangitikei deep silt loam over sand

RdSsL – refers to Rangitikei deep sandy loam

RmdSsL – refers to Rangitikei moderatley deep sandy loam

RhSsL – refers to Rangitikei shallow sandy loam

RhSL – refers to Rangitikei shallow silt loam

OSL – refers to Otaki silt loam

OssL – refers to Otaki sandy loam

PSsL – refers to Parewanui deep sandy loam

PdSL – refers to Parewanui deep silt loam

MdSL – refers to Manawatu deep silt loam

MdSsL – refers to Manawatu deep sandy loam

MdSL/Ss – refers to Manwatu deep silt loam over sand

MmdSL – refers to Manawatu Moderatley deep silt loam

MhSL – refers to Manawatu shallow silt loam

KCL – refers to Kairanga clay loam

KpSL – refers to Karapoti silt loam

Slope

A – refers to flat to gently undulating

B/C – refers to undultaing to rolling (4-15º)

Erosion severity and type

DØ – refers to Deposition Negligible

D1 – refers to deposition Slight

Sb3 – refers to Streambank Severe

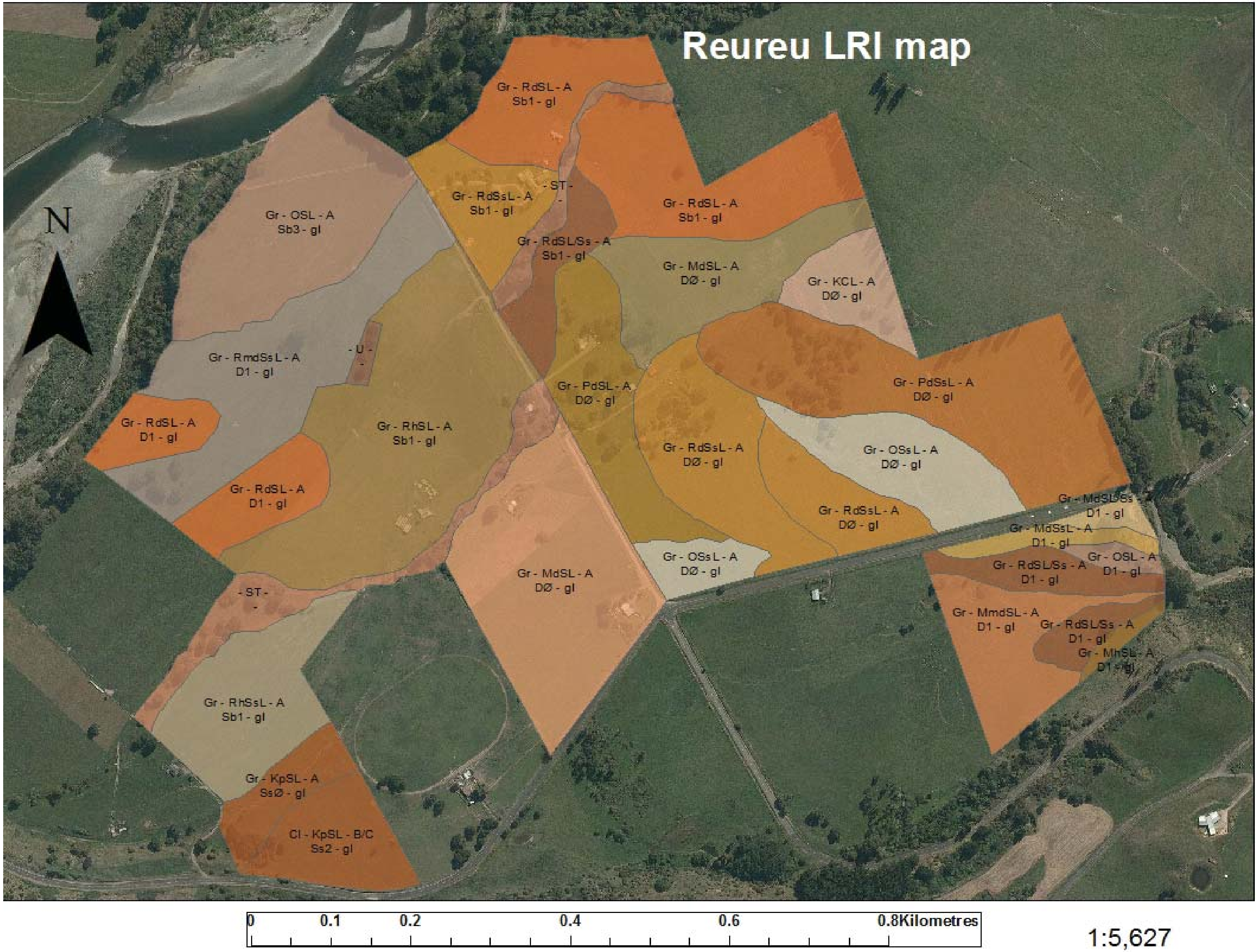
Sb1 – refers to Streambank Slight

Ss2 – refers to Soil Slip Moderate

Vegetation Cover

gI – refers to improved pasture

After the LRI component of the land evaluation was completed, the LUC units for each polygon was assigned, with reference for guidelines as stated in the '*Land-use Capability Handbook' (Lynn et al., 2009).*


Reureu LRI map
N
Gr - RdSL - A
Sb1 - gl
Gr - OSL - A
Sb3 - gl
Gr - RdSsL - A
Sb1 - gl
- ST -
Gr - RdSL - A
Sb1 - gl
Gr - RdSL/Ss - A
Sb1 - gl
Gr - MdSL - A
DØ - gl
Gr - KCL - A
DØ - gl
Gr - RmdSsL - A
D1 - gl
- U -
Gr - PdSL - A
DØ - gl
Gr - PdSsL - A
DØ - gl
Gr - RdSL - A
D1 - gl
Gr - RhSL - A
Sb1 - gl
Gr - RdSsL - A
DØ - gl
Gr - OSsL - A
DØ - gl
Gr - RdSL - A
D1 - gl
Gr - RdSsL - A
DØ - gl
Gr - MdSL/Ss
D1 - gl
Gr - MdSsL - A
D1 - gl
Gr - OSsL - A
DØ - gl
Gr - RdSL/Ss - A
D1 - gl
Gr - OSL - A
D1 - gl
Gr - MdSL - A
DØ - gl
- ST -
Gr - MmdSL - A
D1 - gl
Gr - RdSL/Ss - A
D1 - gl
Gr - MhSL - A
D1 - gl
Gr - RhSsL - A
Sb1 - gl
Gr - KpSL - A
SsØ - gl
Cl - KpSL - B/C
Ss2 - gl
0 0.1 0.2 0.4 0.6 0.8Kilometres
1:5,627

5.3 Land-use Capability Mapping

Each of the LRI polygons was assigned a Class, Subclass and Unit, wherever possible regional LUC are used to help classify the Reureu LUC. The Reureu blocks lie within the '*Taranaki – Wanganui Region LUC classification*' (Fletcher, 1987), which was therefore used to help assign an LUC to each polygon.

The class of each polygon was chosen based on the '*Land-use Capability Survey Handbook' (Lynn et al., 2009)* and the *'Taranaki – Wanganui LUC classification' (Fletcher, 1987)*. The subclass chosen was based on the dominant limiting factor, if two were present than as stated in the *'Land-use Capability Survey Handbook' (Lynn et al., 2009) the* priority allocation was given. The unit (i.e. severity of limitation) for each polygon was assigned based on similar regional units.

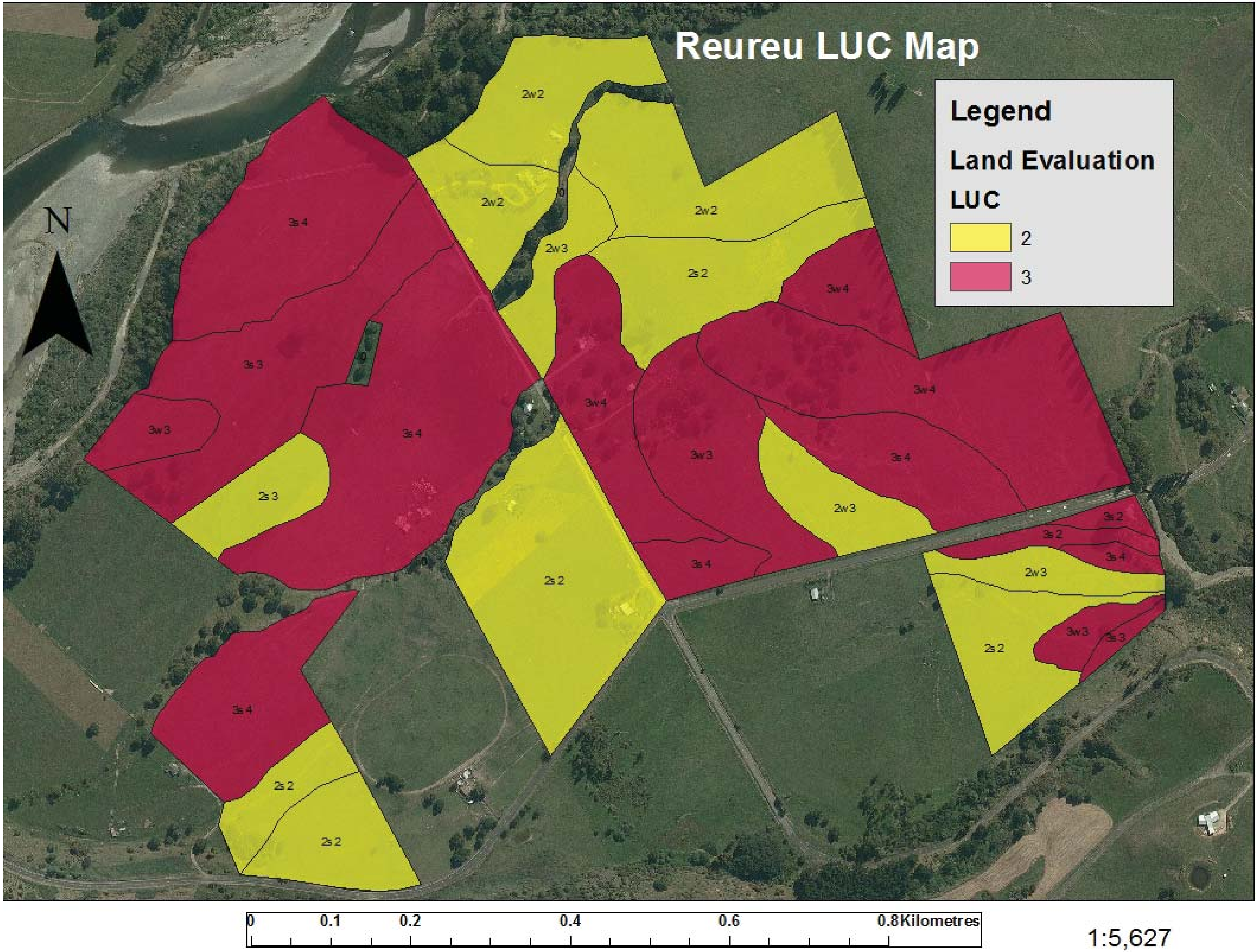
Each of the LUC units is explained in further detail below. The LUC suite and sub-suite used are those which are referred to in the '*Taranaki – Manawatu Region Land-use Capability Handbook' (Fletcher, 1987).*[41]

The LUC classes are explained as an extended legend to help identify blocks and differentiate between different management types. The *Pinus radiata* site index is based on the *Taranaki – Manawatu Region Extended Legend' (Fletcher, 1987)* information. The following outlines site index based on height in metres of *Pinus Radiata* at 20 years old:

- Very high >35, High 30-35, Medium 25-29, low, 20-24 and Very low <20

The Reureu blocks have a total area of LUC Class 2 land of 29ha and LUC Class 3 land of 43ha.

[41] Used as these were the original LUC suite and sub suite for the Reureu blocks


Reureu LUC Map
Legend
Land Evaluation
LUC
2
3
N
2w2
2w2
2w2
2w3
2s2
3w4
3w4
3w4
3s4
3s4
3s4
3s4
3s4
3s3
3w3
3w3
3w3
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2w3
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2s2
2s2
2s2
2s2
2s2
3s2
3s2
3s3
0
0
0
0 0.1 0.2 0.4 0.6 0.8 Kilometres
1:5,627

LUC unit: IIs2 (8.6 ha)

LUC suite:		5. Loess
LUC sub suite:		5a
Description:		Flats located on slightly higher terrace away from frequent flooding formed from alluvial deposits. Flat to gently undulating terraces.
Slope:		0 - 3° (A)
Rock Type:		Alluvial Gravels (Gr)
Soil:		Manawatu deep silt loam Manawatu moderately deep silt loam Karapoti silt loam
Erosion:	*Present:*	Negligible to slight (mostly negligible) deposition, slight soil slip
	Potential:	Slight deposition, slight to moderate soil slip
Vegetation:		Improved Pasture (gI)
Land-use:	*Present:*	Undeveloped, pastoral grazing
	Agriculture Potential:	Intensive pastoral grazing, dairying cropping, root and green fodder crops.
	Forestry Potential:	Production (site index P. radiate 29- 34)
Management:		Apply fertiliser to achieve higher production levels. Possible addition of subsurface drainage to achieve high levels of cropping and pastoral production might be required. Those soils which lie close to the stream should have stream bank protection. Limitation poor soil structure and poor internal soil drainage. Shelter belts required for horticulture.
Comments:		Slight limitation due to soil conditions. These soils can still be flooded, therefore protection from nearby waterways would be recommended.

LUC unit: IIw2		(14.9 ha)
LUC suite:		5. Loess
LUC sub suite:		5a
Description:		Flats located on slightly higher terrace away from frequent flooding formed from alluvial deposits.
Slope:		0 - 3° (A)
Rock Type:		Alluvial Gravels (Gr)
Soil:		Rangitikei deep silt loam Manawatu deep silt loam
Erosion:	*Present:*	Negligible Stream bank, negligible deposition
	Potential:	Slight Stream bank, negligible to slight deposition
Vegetation:		Improved Pasture (gI)
Land-use:	*Present:*	Undeveloped, pastoral farming
	Agriculture Potential:	Intensive pastoral grazing, dairying cropping, cereal cropping, root and green fodder cropping, horticulture.
	Forestry Potential:	Production (site index P. radiate 33-35)
Management:		The stream banks will need to be protected to ensure soil loss is minimal, planting along the stream may be beneficial. These soils suffer from soil wetness, from occasional flooding, gleying and presence of mottles. However these soils have a good soil depth 45-90 cm. Shelter belts required for horticulture.
Comments:		Soils close to streams need to be protected. Soils in this category have continued wetness limitation after drainage.

LUC unit: IIw3 (5.5 ha)

LUC suite:		5. Loess
LUC sub suite:		5a
Description:		Flats located on slightly higher terrace away from frequent flooding formed from alluvial deposits
Slope:		0 - 3° (A)
Rock Type:		Alluvial Gravels (Gr)
Soil:		Rangitikei deep silt loam over sand Rangitikei deep silt loam over sand Rangitikei deep sandy loam
Erosion:	*Present:*	Negligible to slight (mostly negligible) deposition
	Potential:	Slight deposition
Vegetation:		Improved Pasture (gI)
Land-use:	*Present:*	Undeveloped, pastoral grazing
	Agriculture Potential:	Intensive pastoral grazing, dairying cropping, root and green fodder cropping
	Forestry Potential:	Production (site index P. radiate 23-26)

Management: The soils are quite free draining soils, therefore may need to be irrigated during the summer months. These soils suffer from the possibility of frequent flooding.

Comments: To achieve maximum production, fertiliser application and irrigation will be required. Soils have a slight limitation due to the wetness of the soils and poor internal drainage. Drainage systems will need to be in place to maximise production values.

LUC unit: IIIs2 (0.9ha)

LUC suite: 5. Loess

LUC sub suite: 5a

Description: Flats located on lower terrace formed by alluvial deposits, close to stream.

Slope: 0 - 3° (A)

Rock Type: Alluvial Gravels (Gr)

Soil: Manawatu deep silt loam over sand
Manawatu deep sandy loam

Erosion: *Present:* Negligible to slight deposition
Potential: Slight to moderate deposition

Vegetation: Improved Pasture (gI)

Land-use: *Present:* Undeveloped, pastoral grazing
Agriculture Potential: Intensive pastoral grazing, cropping, dairying, horticulture, cereals, root and green fodder crops.
Forestry Potential: Production (site index P. radiate 29-32)

Management: The soils have moderate soil depths, with the presence of stones above 45 cm, but below 20 cm, limiting their versatility. The nearby stream has also the possibility of depositing alluvial deposits across these soils.

Comments: Subsurface drainage may be required and protection from the nearby stream to avoid alluvial deposits. Seasonal soil moisture deficits limit versatility. Shelterbelts required for horticultural use.

LUC unit: IIIs3 (0.3ha)

LUC suite:		5. Loess
LUC sub suite:		5a
Description:		Flats located on lower terrace formed by alluvial deposits, close to stream.
Slope:		0 - 3° (A)
Rock Type:		Alluvial Gravels (Gr)
Soil:		Rangitikei moderately deep sandy loam Manawatu shallow silt loam
Erosion:	*Present:*	Negligible to slight deposition
	Potential:	Slight to moderate deposition
Vegetation:		Improved Pasture (gI)
Land-use:	*Present:*	Undeveloped, pastoral grazing
	Agriculture Potential:	Intensive pastoral grazing, cropping, dairying horticulture, cereals, root and green fodder crops.
	Forestry Potential:	Production (site index P. radiate 23-26)
Management:		The soils have moderate soil depths, with the presence of stones above 30 cm, limiting their versatility. The nearby stream has also the possibility of depositing alluvial deposits across these soils. The presence of stones is 15-35% between 20–45 cm.
Comments:		Subsurface drainage may be required and protection from the nearby stream to avoid alluvial deposits. Also the nearby South hill may need to be stabilised in the future.

LUC unit: IIIs4		(3.8 ha)
LUC suite:		5. Loess
LUC sub suite:		5a
Description:		Flats located on lower terrace formed by alluvial deposits, close to Rangitikei River.
Slope:		0 - 3° (A)
Rock Type:		Alluvial Gravels (Gr)
Soil:		Otaki silt loam Rangitikei shallow silt loam Rangitikei shallow sandy loam Otaki sandy loam
Erosion:	*Present:*	Negligible to slight deposition, Moderate Stream bank erosion
	Potential:	Slight to moderate deposition, Moderate stream bank erosion
Vegetation:		Improved Pasture (gI)
Land-use:	*Present:*	Undeveloped, pastoral grazing
	Agriculture Potential:	Pastoral Grazing (intensive with careful management), intensive grazing, dairying
	Forestry Potential:	Production (site index P. radiate 27-29)
Management:		The soils here have 40-70% stones present in the top 20 cm, which limits their ability to be cultivated. The Otaki soils will also drain excessively, so management of nutrient loss will need to be monitored.
Comments:		Irrigation for these soils during the summer months will be required to achieve maximum production.

LUC unit: IIIw3 (10.4 ha)

LUC suite:		5. Loess
LUC sub suite:		5a
Description:		Flats located on lower terrace formed by alluvial deposits, close to Rangitikei River and stream.
Slope:		0 - 3° (A)
Rock Type:		Alluvial Gravels (Gr)
Soil:		Rangitikei deep silt loam Rangitikei deep sandy loam Rangitikei deep silt loam over sand
Erosion:	*Present:*	Negligible to slight deposition
	Potential:	Slight to moderate deposition
Vegetation:		Improved Pasture (gI)
Land-use:	*Present:*	Undeveloped, pastoral grazing
	Agriculture Potential:	Pastoral Grazing (intensive with careful management), intensive dairying, vegetable cropping, root and green fodder cropping.
	Forestry Potential:	Unsuitable
Management:		The soils have frequent flooding events which can occur, slow internal drainage and low water holding capacities. Cropping can be affected if frequent flooding and excessive rainfall in some areas.
Comments:		Irrigation for these soils during the summer months will be required to achieve maximum production. Cropping versatility is restricted by wetness of soils.

LUC unit: IIIw4 (29 ha)

LUC suite:		5. Loess
LUC sub suite:		5a
Description:		Flats located on lower terrace formed by alluvial deposits, close to Rangitikei River and stream.
Slope:		0 - 3°
Rock Type:		Alluvial Gravels (Gr)
Soil:		Parewanui deep silt loam Parewanui deep sandy loam Kairanga clay loam
Erosion:	*Present:*	Negligible to slight deposition
	Potential:	Slight to moderate deposition
Vegetation:		Improved Pasture (gI)
Land-use:	*Present:*	Undeveloped, pastoral grazing
	Agriculture Potential:	Pastoral Grazing (intensive with careful management) intensive dairying.
	Forestry Potential:	Production (site index P. radiate 30 -33)
Management:		The soils have frequent flooding events which can occur, slow internal drainage and low water holding capacities. The Parewanui Soil has very poor drainage; careful management of these soils in terms of nutrient loss will need to be managed. Control water table.
Comments:		Irrigation for these soils during the summer months will be required to achieve maximum production. High water table during winter and spring limits cropping production.

5.3.1 LUC Leaching Limits

Horizons Regional Council has set limits on the amount of nitrogen leaching allowed and is measured in kgN/ha/yr.

The Nitrogen leaching allowance is as follows:

- Year 1 – 25 kgN/ha/yr
- Year 5 – 22 kgN/ha/yr
- Year 10 – 20 kgN/ha/yr
- Year 20 – 19 kgN/ha/yr

(HRC, P. Taylor, personal communication, 2014).

The total leaching allowance for the Reureu blocks are given (Table 27). (HRC, P. Taylor, personal communication, 2014).

The Reureu blocks show that overall the biggest limitation over the 74 ha, is a soil factor with 43 ha of the total area having a presence of stones within the top 20 cm of the soil profile which limit the versatility. The only other limitation on the Reureu blocks is soil wetness. Wetness in the Reureu case is due to the frequent flooding events, slow internal drainage, presence of mottles and gleying. Management of these two limitations will need to be taken into account to determine the best possible land-use, taking into account the nitrogen leaching amounts.

Table 27 Leaching Limits for Reureu blocks as per LUC class

Year	**LUC 2**	**LUC 3**	**Total**
Ha	29	43	72
1	783	1080	1863
5	725	945	1670
10	638	855	1493
20	609	810	1419

5.4 Suitability Mapping

The suitability maps were based on those characteristics important for land to be used as a dairy farm. Those were:

- Suitability for Effluent
- Irrigation requirement
- Flood risk
- Cultivation (suitability)
- Presence of stones
- Susceptibility to pugging

Each of the above characteristics is now explained as to how they were rated and applied to the Reureu blocks, based on the soil profiles throughout the farm.

5.4.1 Suitability for Effluent

Effluent applied to the land will contain high concentrations of nutrients, therefore soils which are excessively drained or poorly drained need to be avoided. The scale was from 1 – 5 (Table 28), with 1 being the most suitable and 5 being least suitable for effluent application. As the rating gets higher so does the risk of leaching or surface runoff potential (Table 29 for summary of total land area relative to suitability for effluent disposal).

Table 28 Suitability Rating for Effluent Application

Rating	**Suitability**
1	*Most Suitable*
2	*Suitable*
3	*Moderately Suitable*
4	*Least Suitable*
5	*Not Suitable*

Table 29 Summary of Total land area relative to suitability for effluent disposal

Rating	Total Land Area (ha)
1	2
2	10.2
2.5	1.2
3	24.4
3.5	14
4.5	9.9
5	10.6

5.4.2 Irrigation Requirement

The irrigation characteristic is based on the soils requirement for irrigation, which can be related to the drainage ability of the soil and the soil texture. Irrigation was scaled (Table 30) from 1 being requires the most irrigation to 5 which requires no irrigation. This is based on irrigation used for production purposes of crops and pasture. As the rating increases the need for irrigation to maximise production levels are less. This can be a consequence of soil texture, drainage ability of soil and whether or not the soil dries out fast (Table 31 for summary of total land area relative to requirement for irrigation).

Table 30 Irrigation Requirement

Rating	Irrigation Requirement
1	*Requires irrigation the most*
2	*Needs irrigation*
3	*Moderately requires to be irrigated*
4	*Rarely requires irrigation*
5	*Does not require irrigation*

Table 31 Summary of Total land area relative to irrigation requirement

Rating	Total Land Area (ha)
1.5	26.2
2	18.4
2.5	9.9
3	1.4
3.5	4
4	10.2
5	2

5.4.3 Flood Susceptibility

Flood susceptibility was based on whether or not the soil would be prone to flooding. Flood severity was based on 1 – 5 (Table 32), with one being the 1 being the most frequently flooded and 5 being the least susceptible to flooding (Table 33 for summary of total land area relative to flood severity).

Table 32 Flood Susceptibility

Rating	Flood Susceptibility
1	*Very Susceptible*
2	*Susceptible*
3	*Moderate susceptibility*
4	*Slight susceptibility*
5	*Nil*

Table 33 Summary of Total land relative to flood susceptibility

Rating	Total Land Area (ha)
1.5	8.8
2	45.6
3	15.5
5	2

5.4.4 Suitability for arable crops

The suitability for arable cropping is based on the top 10 cm of the soil for agricultural and pastoral uses and the presence of stones which may impair cultivation for some crops. Suitability for arable crops was based on a scale from 1 to 5 (Table 34). With 1 being the most suitable to cultivation for crops and 5 being the most least suitable, this is based on presence of stones between 0 -10 cm. The cultivation is based on crop planting and use of machinery that is used for cultivation (Table 35 for summary of total land area relative suitability of land for arable cropping).

Table 34 Suitability for Cultivation

Rating	**Suitability for Cultivation**
5	*Presence of stones in found between 0 -10 cm (80-100%)*
4	*Presence of stones in found between 0 -10 cm (60-80%)*
3	*Presence of stones in found between 0 -10 cm (40-60%)*
2	*Presence of stones in found between 0 -10 cm (20-40%)*
1	*Presence of stones in found between 0 -10 cm (0%)*

Table 35 Total land relative to suitability for cultivation of land

Rating	**Total Land Area (ha)**
1	14.6
2	30.6
2.5	8
3.5	0.3
4.5	12.7
5	6.2

5.4.5 Presence of Stones

Stoniness is based on soil texture. Although the presence of stones in soil can be mitigated, there are huge costs involved. The presence of stones in soils can affect soil texture, potential rooting depth, soil drainage and soil moisture holding capacity. Stoniness is soils on the Reureu block was scaled form 1 to 5, 1 being least stony, to 5 being most stony (Table 36). This was throughout the soil profile which is up to 1m (Table 37 for total land area relative to presence of stones in profile).

Table 36 Presence of Stones up a 1m soil profile

Rating	Presence of stones
1	*Non stony (0 – 2%)*
2	*Slightly stony (2 – 5%)*
3	*Moderately stony (5 – 10%)*
4	*Very stony (10 – 15%)*
5	*Extremely stony (> 15%)*

Table 37 Total area relative to presence of stones in soil profile

Rating	Total Land Area (ha)
1	25.7
1.5	6.5
2	7.9
2.5	3.1
3	18.3
3.5	1.4
4.5	8.8

5.4.6 Susceptibility to pugging

Pugging is whereby soil aggregates are broken down and spaces in the soil are reduced. Pugging is important as it may negatively affect drainage, plant growth, more topsoil runoff and require higher fertiliser inputs. In terms of the Reureu blocks, susceptibility to pugging is important to avoid those soils that will prone to pugging more than others.

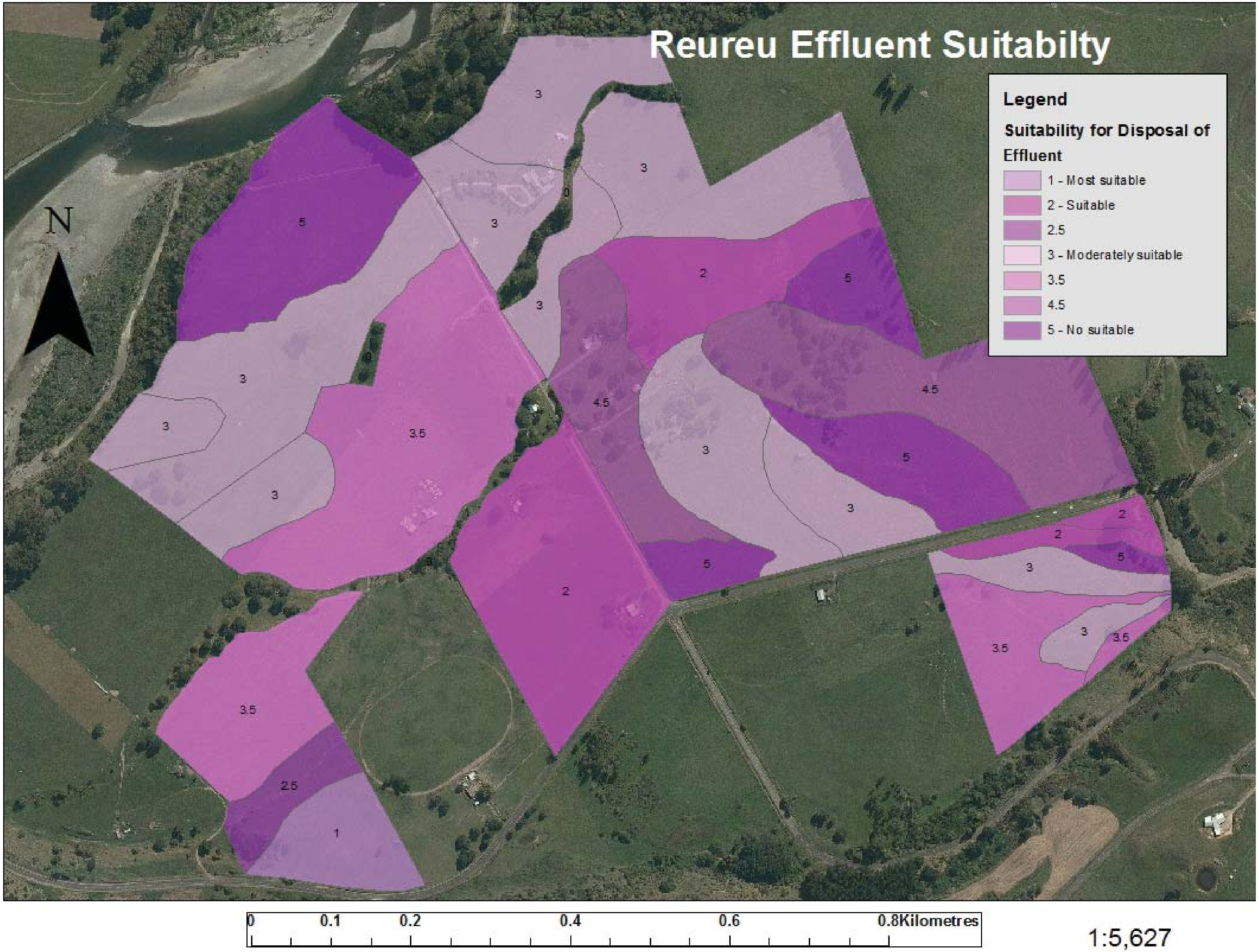
Pugging susceptibility was rated based on those soils most prone to pugging given 1 and those least prone to pugging given 5 (Table 38) (Table 39 for total area relative to susceptibility of soil to pug).

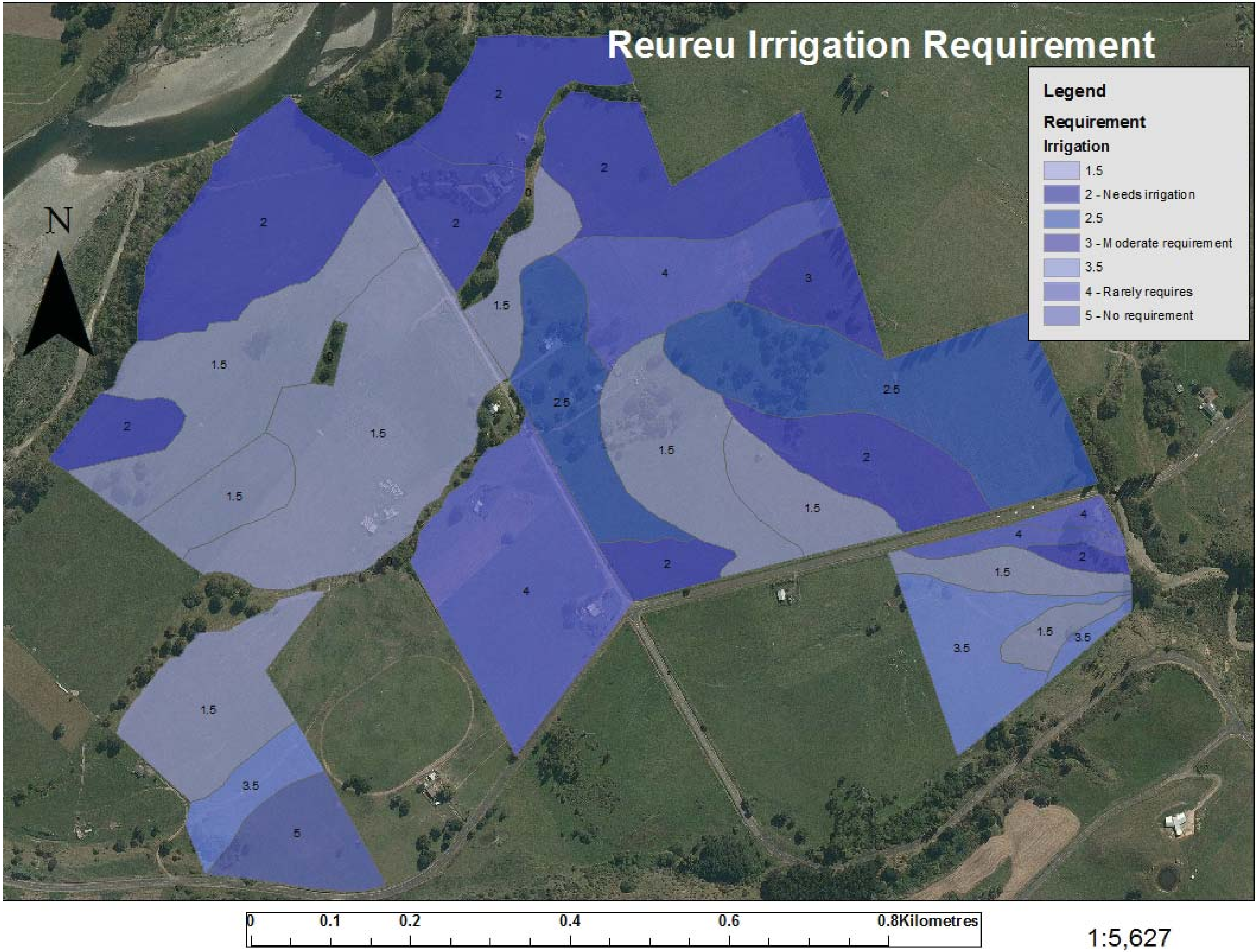
Table 38 Susceptibility to pugging

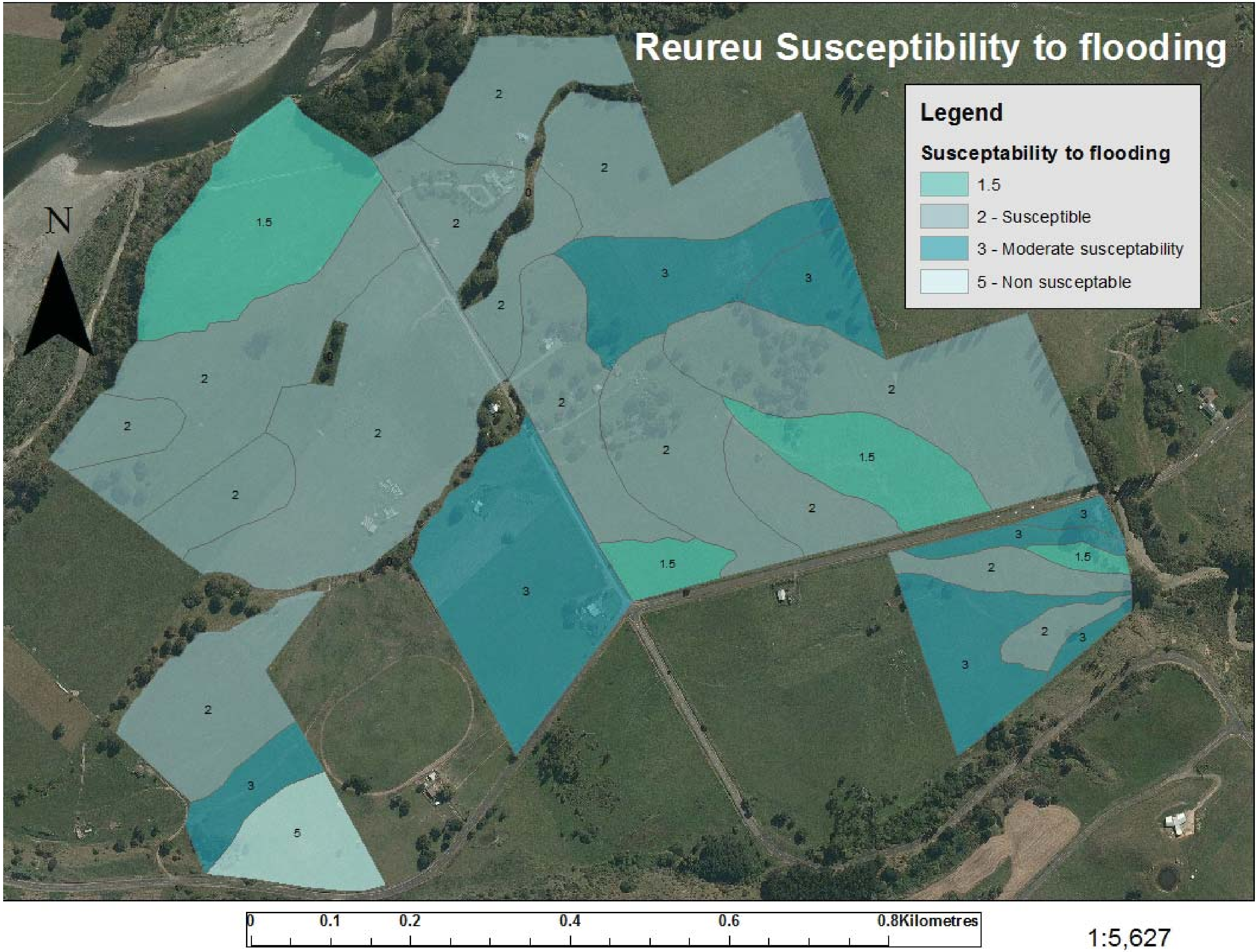
Rating	Susceptibility to pugging
1	*Very susceptible to pugging*
2	*Susceptible to pug*
3	*Moderate susceptibility to pug*
4	*Slight susceptibility*
5	*Extremely rare to pug*

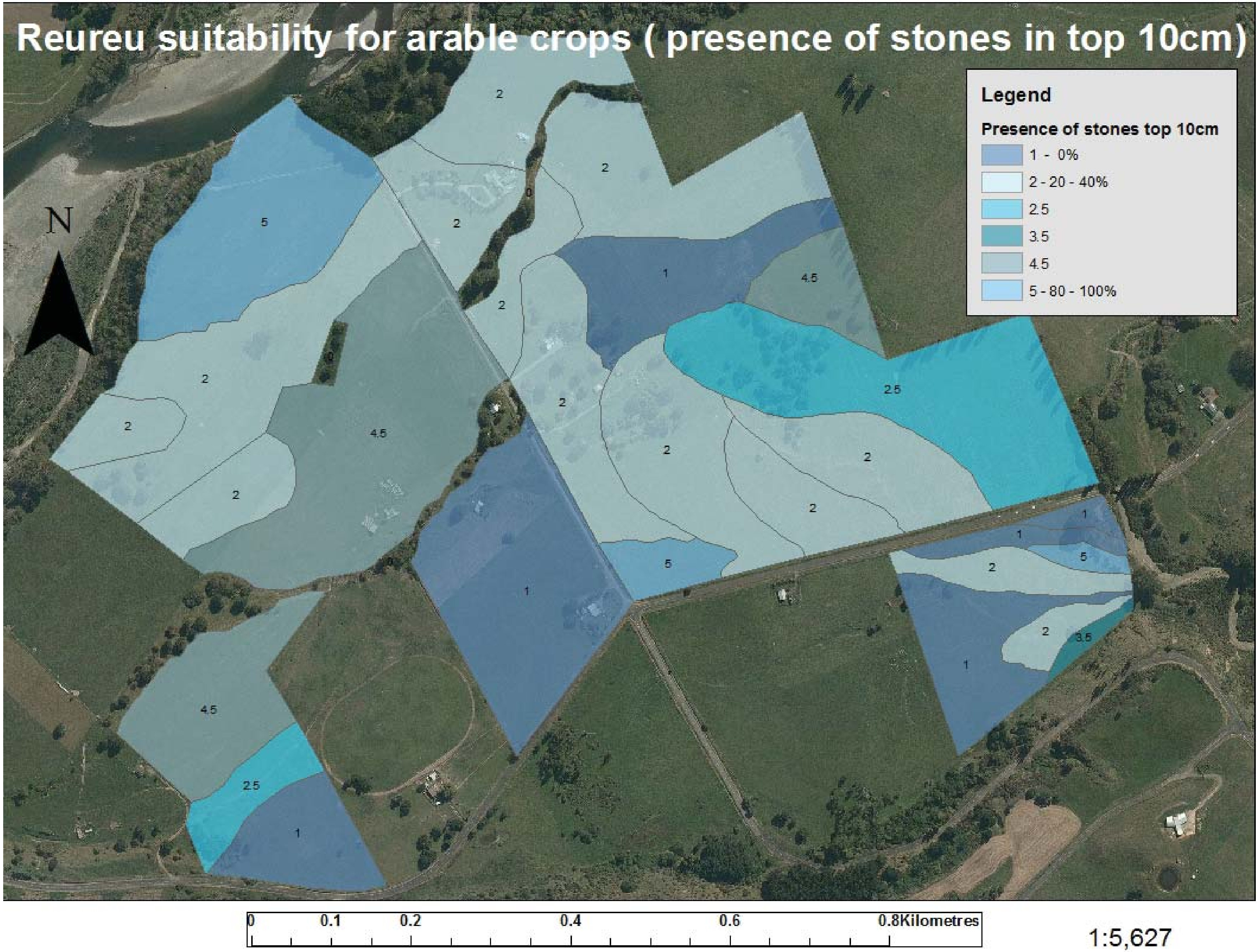
Table 39 Total area relative to susceptibility of soil to pug

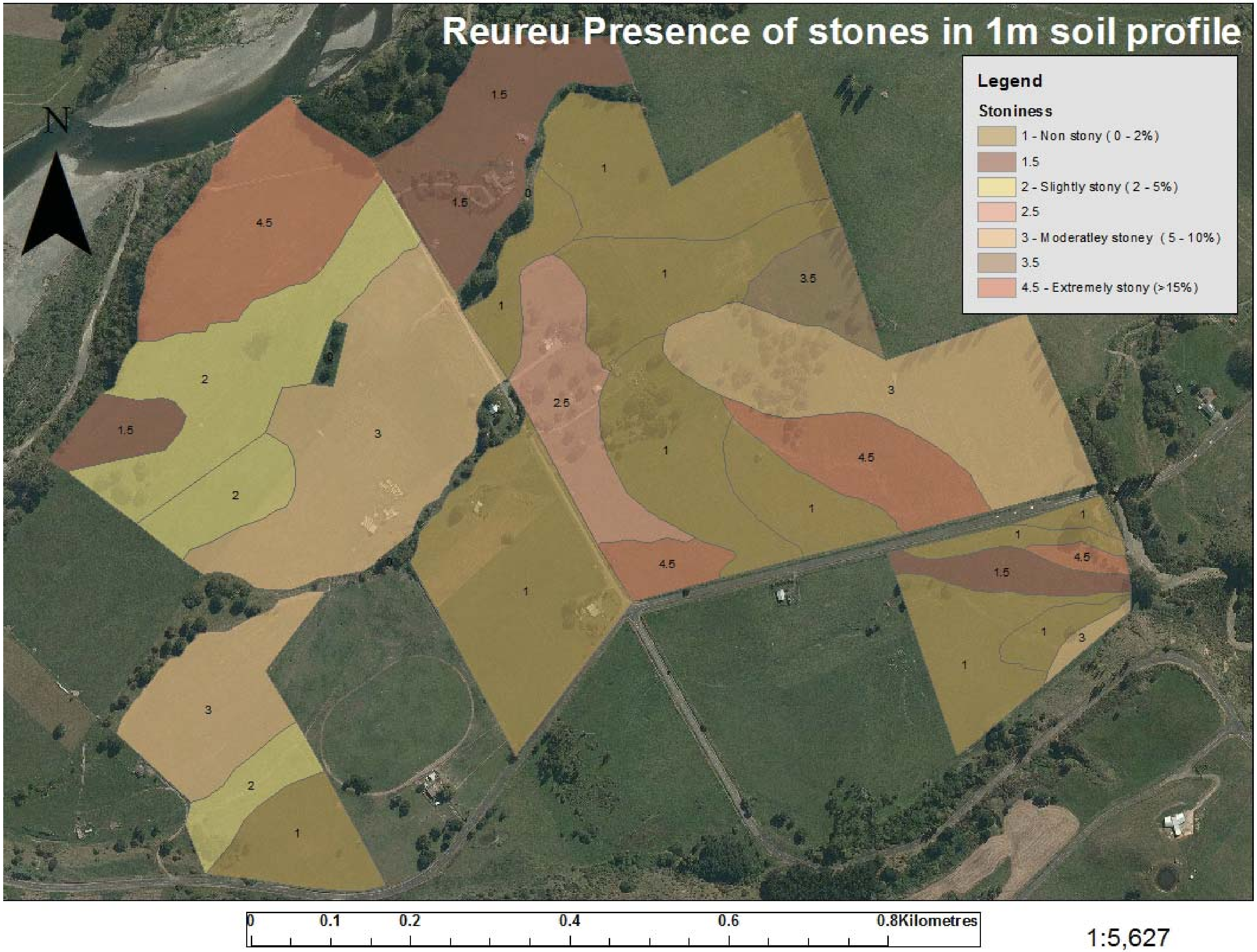
Rating	Total Land Area (ha)
1	1.4
1.5	11.3
2	43.1
3.5	0.3
4	13.9
5	2

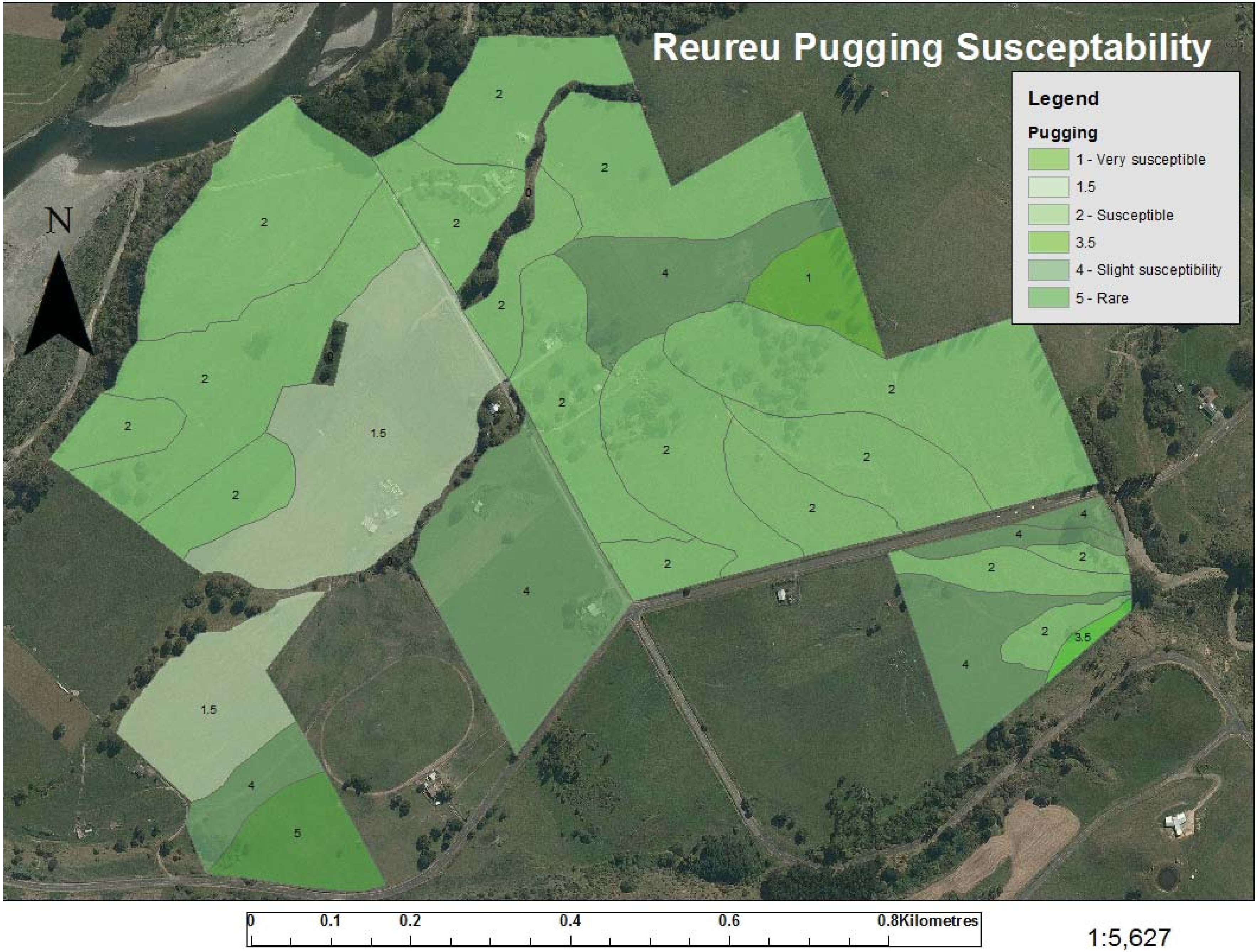

Reureu Effluent Suitabilty
Legend
Suitability for Disposal of Effluent
1 - Most suitable
2 - Suitable
2.5
3 - Moderately suitable
3.5
4.5
5 - No suitable
N
0
0.1
0.2
0.4
0.6
0.8Kilometres
1:5,627


Reureu Irrigation Requirement
Legend
Requirement
Irrigation
1.5
2 - Needs irrigation
2.5
3 - Moderate requirement
3.5
4 - Rarely requires
5 - No requirement
N
0 0.1 0.2 0.4 0.6 0.8Kilometres
1:5,627


Reureu Susceptibility to flooding
Legend
Susceptability to flooding
1.5
2 - Susceptible
3 - Moderate susceptability
5 - Non susceptable
N
0
0.1
0.2
0.4
0.6
0.8Kilometres
1:5,627


Reureu suitability for arable crops (presence of stones in top 10cm)
Legend
Presence of stones top 10cm
1 - 0%
2 - 20 - 40%
2.5
3.5
4.5
5 - 80 - 100%
N
0
0.1
0.2
0.4
0.6
0.8Kilometres
1:5,627


Reureu Presence of stones in 1m soil profile
Legend
Stoniness
1 - Non stony (0 - 2%)
1.5
2 - Slightly stony (2 - 5%)
2.5
3 - Moderatley stoney (5 - 10%)
3.5
4.5 - Extremely stony (>15%)
N
0
0.1
0.2
0.4
0.6
0.8Kilometres
1:5,627


Reureu Pugging Susceptability
Legend
Pugging
1 - Very susceptible
1.5
2 - Susceptible
3.5
4 - Slight susceptibility
5 - Rare
N
0
0.1
0.2
0.4
0.6
0.8Kilometres
1:5,627

5.5 Soil Fertility

Soil samples collected in the field were sent to Hills Laboratory in Hamilton and analysed (see Appendix 5-2). Due to time and cost constraints, the samples were selected based on management units which are split according to landscape units and land forms. Once blocks were spilt into landscape units an 'indicator' paddock was chosen for sampling. This paddock was than representative for the whole block.

A total of 20 core samples were taken to a depth of 7.5 cm, the standard depth for agricultural samples. Soil nutrient status is an important indicator of the potential for production and crop growth.

The Reureu blocks were spilt up into four Management Blocks and summary of results are found in Table 40 (see Appendix 5-3 for Map of management units and location of soil samples).

Table 40 Summary of Fertility Results for the Reureu Blocks

Fertility Results	*Management A*	*Management B*	*Management C*	*Management D*
pH (pH units)	5.4	5.8	5.9	5.5
Olsen P (mg/L)	19	12	8	11
Potassium (me/100g)	0.31	0.32	0.37	0.26
Calcium (me/100g)	3.2	5.4	6.8	4.4
Magnesium (me/100g)	1.22	1.21	1.38	1.65
CEC (me/100g)	12	12	13	14
Organic Matter (%)	4.2	4.2	4.1	4.9
MAF	K 6 Ca 4 Mg 25 Na 5	K 6 Ca 6 Mg 24 Na 5	K 7 Ca 7 Mg 27 Na 6	K 4 Ca 5 Mg 31 Na 7

5.5.1 pH

The ideal or optimum pH value should be around 5.8 - 6.0. All of the Reureu blocks except block C have low pH values. The pH levels are not ideal however they are not significantly low and can be mitigated through the addition of lime products.

5.5.2 Olsen P

The Olsen P values for all of the Reureu blocks fall below the optimum level which is 20-30. Blocks B, C and D have extremely low Olsen P levels. All of the blocks need the addition of phosphate fertiliser to raise the levels to optimum values. Superphosphate should be applied gradually rather than as a single application. Smaller frequent applications would be beneficial and also lessen the risk of loss of P in surface runoff into the nearby waterways.

5.5.3 Potassium

The MAF quick test results show that all of the samples except sample 'C' have levels ranging from 4-7 which is slightly lower than optimum K levels. Potassium fertilisers will need to be added to the soil to increase these levels. Common fertilisers available are potassium chloride and potassium sulphate. The addition of K fertiliser needs to be managed so as to avoid the risks associated with cows which are ready to calve or in early lactation grazing pasture with high K concentrations. There is no great variation between the levels of potassium between the blocks due primarily to similarities in parent material.

5.5.4 Magnesium

The optimum magnesium Quick test value has two levels: 8 -10 for pasture and 25-30 for animal health (FLRC, 2013). The Reureu blocks fall into the lower end of the range, for animal health. Therefore magnesium will need to be added.

5.5.5 CEC

The medium range for CEC values is 12-25. Each of the blocks sampled lies within in this range; however they all lie at the lower end of these medium CEC values. The values of the CEC reflect the sandy, silty and low organic matter nature of the soils.

5.5.6 Organic Matter

The Organic Matter of a soil is important as a source for nutrients in particular nitrogen. The Reureu blocks all have lower to average organic matter levels with medium levels should be 5 to 10%. Soils with medium to high levels of organic matter are more likely to have good structure, moisture retention and water infiltration.

Chapter 6 Scenario Dairy Platform

The owners of the Reureu blocks are investigating the potential to convert these blocks into a dairy farm. As this is a conversion to dairy farming in the Horizon's region, this new land-use will have to comply with Nitrogen leaching limits as set in the Council's 'One Plan'. This thesis explores the key issues related to soil water management and nutrient management associated with such a change in land-use. Numerous aspects of a farm's performance must be inputted into Overseer before it can generate a nutrient budget. In order to identify this information, the farm systems model '*Farmax*' was used to model a typical farm for Reureu block. Values from Farmax were then imported into Overseer in order to produce nutrient budgets for the proposed dairy farm (hereafter simply called the dairy farm). The main issue explored with Overseer was the likelihood than any future dairy farm would comply with Reureu block's N leaching allocation as awarded under Horizon Regional Council's 'One Plan'.

The following chapter identifies dairy as a specific land-use and focuses on key elements that will be necessary for the owners to consider.

The land evaluation investigation up to now has been in terms of general land-use, potentially looking at a range of options. This chapter now focuses on contemporary dairy issues related to soil. Two farm scale simulation models were used those are Farmax and Overseer. Farmax provides the farm setting, financial and physical figures whilst Overseer gives the environmental figures needed.

6.1 Farmax[42]

Farmax was developed AgResearch in the late 1980s to help sheep and beef farmers make better business decisions. Nowadays however it has the ability to forecast dairy farm requirements to assess effects of management practices on overall profitability. Essentially Farmax is a tool that helps farmers get the most out of their farm.

Ronaldo Vibart a scientist from AgResearch identifies the following top four benefits of Farmax:

---

[42] Farmax Limited

1. *The model captures the biophysical essence of a pastoral farm or farm system*
2. *It assesses farm viability by matching feed supply with feed demand;*
3. *You can create blocks that are different from other land blocks. Although these blocks cannot be managed independently this is still good feature of the software*
4. *The financial data is updated regularly and provides a good compassion tool (across scenarios or farm practices tested).*
   (Farmax, 2014, p 3).

Farmax enables people to run a 'scenario' to ensure they have the right management structures in place and to see the economic benefit or cost associated with some decision making. One downfall of the programme is it does not produce environmental indicators.

The values used in Farmax can be found in the Appendices for Chapter 5. The values used were those for a typical system 3/4 dairy farm. A farm system is as follows (DairyNZ, 2015b);[43]

> *The Five Production Systems are a way to group farm production systems by allocation of imported feed.*
>
> *As New Zealand pastoral farming is about profitably balancing feed supply and demand, five production systems have been described by DairyNZ primarily on the basis of when imported feed is fed to dry or lactating cows during the season and secondly by the amount of imported feed and/or off farm grazing. The definitions do not include grazing or feed for young stock.*
>
> ***System 1 - All grass self-contained, all stock on the dairy platform***
>
> *No feed is imported. No supplement fed to the herd except supplement harvested off the effective milking area and dry cows are not grazed off the effective milking area.*
>
> ***System 2 - Feed imported, either supplement or grazing off, fed to dry cows***
>
> *Approx. 4 - 14% of total feed is imported. Large variation in % as in high rainfall areas and cold climates such as Southland, most of the cows are wintered off.*
>
> ***System 3 - Feed imported to extend lactation (typically autumn feed) and for dry cows***
>
> *Approx. 10-20% of total feed is imported. Westland - feed to extend lactation may be imported in spring rather than autumn.*

---

[43] Retrieved from http://www.dairynz.co.nz/farm/farm-systems/the-5-production-systems/

System 4 - Feed imported and used at both ends of lactation and for dry cows

Approx. 20 - 30% of total feed is imported onto the farm.

System 5 - Imported feed used all year, throughout lactation & for dry cows

Approx. 25 - 40% (but can be up to 55%) of total feed is imported.

**Note: Farms feeding 1-2kg of meal or grain per cow per day for most of the season will best fit in System 3.*

Typical values for a system 3/4 dairy farm along with proposed Reureu Block information (land area, regional pasture growth rates etc.) were entered into Farmax (see Appendix 6-1). The model was used to help simulate a dairy farm on the Reureu block and produce the data required for Overseer to produce the nutrient budgets which would be needed for a resource consent application.

A brief breakdown of the Reureu Dairy Platform:

- 210 Cows (F x J), 160 bobby calves, 50 replacement heifer calves
- Turnips producing 92 t, with 12 t of new pasture produced after crop rotation
- Nitrogen applied 4 times at a rate of 40 kgN/ha over the total 74 ha.
- Supplements brought onto the farm
    - Maize silage 180 t
    - Pasture silage 30 t

Farmax produced some values for the Reureu Platform such as the milk solids produced per hectare (kg/ha) which is 1113 kg/ha, herd size per hectare which is 2.9 (cows/ha) and average milk production per cow of 381. In a report written by DairyNZ and LIC (2013) *"New Zealand Dairy Statistics 2012-2013"*, for the year 2012/2013 the average cows per hectare was 2.85, milk solids per cow were 346 and milk solids per hectare was 988. The Reureu dairy platform aligns very closely with these numbers, these numbers will vary in the actual dairy platform. However taking into account the physical variables and putting aside the model, these figures are 'realistic' .

6.2 Overseer[44]

Version 6.1 of Overseer was released in September 2013. This is the current version and the version that was used to generate the Reureu block nutrient budgets.

Overseer is regarded as the programme for determine nutrient budgets. However there are some issues with Overseer that need to be acknowledged to ensure fair and accurate information:

- Assumes best practice
  - This is a key issue; those who do not understand how to use the programme should not. Ensuring all information entered is correct. An example is the soils aspect using soil series, rather than orders is better. There is a guideline that you can use[45]
- Estimates annual average nutrient budgeting inputs (management, climate) are constant
- Not 100% accurate – set on calculations
- Underlying assumptions

Although there are some issues with Overseer the programme is still very helpful in that it:

- Helps monitor nutrients
- Produces a nutrient budget
- Helps to regulate nutrient loss – both for farmers and regional councils

The information used in the Overseer program for the Reureu blocks is as follows;

- 210 cows (F x J cows) producing 80,000 kg/yr
- The blocks were spilt based on soil types and area. The soils are;
  - Kairanga
  - Karapoti
  - Parewanui
  - Otaki
  - Manawatu Deep
  - Manawatu Mod. –deep
  - Manawatu Shallow
  - Rangitikei Shallow

[44] OVERSEER® - MPI, FANZ, AgResearch
[45] Manual - **overseer**.org.nz/files/download/119b106220ef304

    - Effluent block (includes the areas of Rangitikei Deep and Rangitikei Mod deep)

  Note: Overseer suggest using soil series for soil description, this was followed.

- Soil fertility for each block was set at 'typical values' for a developed dairy farm
    - Olsen P – 30, QT K – 7, QT Ca – 9, QT Mg – 21, QT Na – 8, Organic S - 9
- Fodder crop rotation – 11 ha rotating through all blocks, re-sown to grass in March
- Supplements Imported – 184 t of maize silage and 108 t pasture silage
- Effluent system
    - Holding pond, emptied every 5 years, application <12 mm
- Fertiliser inputs were;
    - May, June, July, August – 87 N kg/ha/month of N-rich Urea
    - October – 450 kg/ha/month of Superten 10K 20% Potash Super

See Appendix 6 –2 for Overseer Data

6.2.1 Nutrient Budgets

The aim of a nutrient budget is to quantify the cycling of nutrients into, around and from a farm, in this case the nutrients applied to the Reureu blocks. Nutrient budgets help monitor compliance of consent conditions as well as assuring correct and efficient application and use of nutrients in fertiliser and imported supplements.

Overseer is well regarded for nutrient management plans, a major requirement for farming. Monitoring nutrient levels helps not only maximise yields but also reduces the risk of leaching and surface runoff. As stricter consent conditions are applied and nutrient caps start to become more frequently used the need to monitor nutrient levels will be crucial. The two most commonly known sources of nutrient pollution are nitrogen and phosphorous.

The goal of nutrient management is to maximise the efficiency of fertiliser use and effluent use when applied rather to ensure it can be utilised to the plant rather than been lost from the farming system. Nutrients that are brought onto the farm and used on the farm should be applied in such a way that they help to achieve maximum yield of crop/pasture growth.

FLRC (2013) identify the following aspects to help minimise nutrient losses in an ‘environmentally acceptable’ manner as;

- *The current soil fertility status is known and further nutrient addition is judged appropriate on the basis of the relationships between soil fertility status and desired plant or animal productivity and potential environmental risk.*

- *The form, amounts and pathways of the nutrient loss is known, which means that the nutrient cycles within farming systems and between farming systems and the wider environment must be understood.*
  (FLRC, 2013, pg. 5-2)

The soil’s ability to provide nutrients naturally will be limited, the addition of fertiliser to provide nutrients such as phosphorous (P), sulphur (S), nitrogen (N), potassium (K), calcium (Ca) and magnesium (Mg). This can be achieved by;

- Raising plant available nutrients in the soil
- Replacing losses of nutrients from the farming system

The application of additional fertilisers to increase productivity comes at an environmental risk, so management practices need to be in order to minimise the adverse impacts on water bodies.,

Nutrient budgets can be constructed using the Overseer programme. However an understanding of the nutrient cycles and the movement of nutrients in a plant-animal system is important.

The overall nutrient budget for the Reureu blocks show a loss to water of 42 kgN/ha/yr (Figure 36). A typical dairy farm leach’s between 24 – 42 kgN/ha/yr through leaching (Figure 39).

Horizons consent conditions for nitrogen leaching are based on the LUC classification of the land. Class 2 land is able to leach up to 27 kgN/ha/yr and Class 3 land up to 24 kgN/ha/yr in their first year of consent. The dairy farm will leach 15 kgN/ha/yr more on

Class 2 land than allowed and 18 kgN/ha/yr on Class 3 land. The Parewanui soil is classified as a Class 3 soil therefore would not be compliant if leaching 28 kgN/ha/yr (Figure 37). The only block that would be compliant is the Kairanga block leaching 20 kgN/ha/yr. At 55 kgN/ha/yr, the effluent block is leaching the greatest quantity of nitrogen. The concentration of nitrogen in drainage water from the effluent block is well above that of a *'standard drinking concentration of 11.3ppm'*. All the blocks with concentrations in bold (Figure 37) show concentration levels of nitrogen above that of standard drinking water concentration. All of blocks show a surplus of nitrogen added as well.

Phosphorus loss (Figure 38) for the blocks does not seem to be an issue, however the fertiliser application of phosphorus to the Manawatu-Mod. deep and Manawatu shallow block poses a 'medium' risk of loss. The phosphorus loss associated with fertiliser application to both these soils is higher due to the increased chance of runoff from these soils i.e. as they have a slight drainage impediment. Furthermore, Manawatu soils tend to have low to medium P retention which is the soils ability to fix phosphate.

(kg/ha/yr)	N	P	K	S	Ca	Mg	Na
Nutrients added							
Fertiliser, lime & other	79	16	22	19	40	0	0
Rain/clover N fixation	7	0	2	3	2	4	14
Irrigation	0	0	0	0	0	0	0
Supplements	62	8	52	5	10	5	5
Nutrients removed							
As products	122	19	50	10	41	4	8
Exported effluent	0	0	0	0	0	0	0
As supplements and crop residues	0	0	0	0	0	0	0
To atmosphere	59	0	0	0	0	0	0
To water	42	0.7	10	23	53	5	17
Change in farm pools							
Plant Material	-12	-2	-19	-1	-2	-2	-1
Organic pool	-71	5	0	-6	-9	-4	0
Inorganic mineral	0	2	-13	0	-10	-16	-18
Inorganic soil pool	7	-1	49	0	-21	21	13

Figure 36 Reureu Nutrient Budget for Whole Farm

Block name	Total N lost	N lost to water	N in drainage *	N surplus	Added N **
	kg N/yr	kg N/ha/yr	ppm	kg N/ha/yr	kg N/ha/yr
Kairanga	22	20	5.9	69	160
Karapoti	64	40	**11.5**	69	160
Otaki	271	40	11.3	69	160
Parewanui	199	26	8.2	69	160
Effluent (Rangitikei deep and mod deep	1333	55	**13.9**	74	165
Manawatu Deep	306	39	**11.5**	69	160
Manawatu Mod-deep	114	41	**11.8**	69	160
Manawatu Shallow	8	41	**11.8**	69	160
Rangitikei Shallow	367	42	**12.0**	69	160
Fodder Crop 1	361	33	5.4	-16	0
Other sources	79				
Whole farm	3123	42			
Less N removed in wetland	0				
Farm output	3123	42			

Figure 37 Reureu Nitrogen Overview

Block name	Total P lost	P lost to water	P loss categories		
	kg P/yr	kg P/ha/yr	Soil	Fertiliser	Effluent
Kairanga	1	0.7	Low	Low	N/A
Karapoti	1	0.4	Low	Low	N/A
Otaki	4	0.6	Low	Low	N/A
Parewanui	5	0.7	Low	Low	N/A
Effluent (Rangitikei deep and mod deep	10	0.4	Low	N/A	Low
Manawatu Deep	4	0.5	Low	Low	N/A
Manawatu Mod-deep	2	0.6	Low	Medium	N/A
Manawatu Shallow	0	0.6	Low	Medium	N/A
Rangitikei Shallow	4	0.4	Low	Low	N/A
Fodder Crop 1	6	0.5	N/A	N/A	N/A
Other sources	17				
Whole farm	52	0.7			

Figure 38 Reureu Dairy Platform Phosphorus Loss

Whole farm report		Benchmark farm	Current farm
Inputs (farm average)			
Clover N	kg N/ha/yr		5
Fertiliser N	kg N/ha/yr		79
Other N added	kg N/ha/yr		64
Indices			
Average N loss to water	kg N/ha/yr	24-42	42
N_20 emissions	kg N/ha/yr		14.8
Farm N surplus	kg N/ha/yr	123-191	27
N conversion efficiency	%	27-35	82

Figure 39 Nitrogen Overview Reureu Dairy Platform

Recommendations for the whole block will appear at the end of this chapter, once each block's nutrient budget has been discussed. In presenting these nutrient budgets, the focus is on meeting consent conditions as imposed by Horizons for nitrogen leaching, and considering phosphorus losses.

6.2.1.1 Kairanga Block

The Kairanga Block is leaching 20 kg/ha/yr of nitrogen (Figure 40) which falls under the nitrogen leaching allocation for this class of land. The concentration of N in drainage water (5.9 ppm) is less than that of the drinking water standard. There is also minimal risk in terms of phosphorus loss.

Nutrient budget

(kg/ha/yr)	N	P	K	S	Ca	Mg	Na	H+*
Nutrients added								
Fertiliser, lime & other	160	32	45	38	81	0	0	0.0
Rain/clover N fixation	2	0	2	3	2	4	14	0.0
Irrigation	0	0	0	0	0	0	0	0.0
Nutrients removed								
As animal products	93	16	21	6	23	2	6	0.0
As supplements	0	0	0	0	0	0	0	0.0
Net transfer by animals	13	-1	10	-1	1	0	-3	0.0
To atmosphere	109	0	0	0	0	0	0	0.0
To water	20	0.4	12	29	42	5	18	-1.2
Change in block pools								
Organic pool	-73	12	0	7	0	0	0	-0.1
Inorganic mineral	0	6	-7	0	-4	-6	-7	0.0
Inorganic soil pool	0	-1	11	0	21	3	0	1.3

Figure 40 Kairanga Nutrient Budget

6.2.1.2 Karapoti Block

The Karapoti block leaches 40 kgN/ha/yr (Figure 41) this is over the leaching rates set out by Horizons and is also at the higher end of '*typical dairy farm nitrogen loss*'. The concentration of N in drainage water (11.5 ppm) is just over that of the drinking water standard. The phosphorus risk loss is low in the Karapoti block.

Nutrient budget

(kg/ha/yr)	N	P	K	S	Ca	Mg	Na	H+*
Nutrients added								
Fertiliser, lime & other	160	32	45	38	81	0	0	0.0
Rain/clover N fixation	2	0	2	3	2	4	14	0.0
Irrigation	0	0	0	0	0	0	0	0.0
Nutrients removed								
As animal products	93	16	21	6	23	2	6	0.0
As supplements	0	0	0	0	0	0	0	0.0
Net transfer by animals	13	-1	10	-1	1	0	-3	0.0
To atmosphere	41	0	0	0	0	0	0	0.0
To water	40	0.4	12	29	53	4	13	-2.4
Change in block pools								
Organic pool	-25	11	0	7	0	0	0	-0.1
Inorganic mineral	0	6	-7	0	-11	-18	-20	0.0
Inorganic soil pool	0	-1	11	0	18	16	18	2.5

Figure 41 Karapoti Nutrient Block

6.2.1.3 Otaki Block

The Otaki Block leaches 40 kgN/ha/yr, (Figure 42); this is above the consent conditions for Horizons and in the higher end of *'typical dairy farm nitrogen loss'*. The concentration of N in drainage water (11.3 ppm) matches the drinking water standard. The phosphorus loss in the Otaki is rated as low.

Nutrient budget

(kg/ha/yr)	N	P	K	S	Ca	Mg	Na	H+*
Nutrients added								
Fertiliser, lime & other	160	32	45	38	81	0	0	0.0
Rain/clover N fixation	2	0	2	3	2	4	14	0.0
Irrigation	0	0	0	0	0	0	0	0.0
Nutrients removed								
As animal products	93	16	21	6	23	2	6	0.0
As supplements	0	0	0	0	0	0	0	0.0
Net transfer by animals	13	-1	10	-1	1	0	-3	0.0
To atmosphere	55	0	0	0	0	0	0	0.0
To water	40	0.6	12	29	60	6	20	-2.4
Change in block pools								
Organic pool	-39	14	0	7	0	0	0	-0.1
Inorganic mineral	0	4	-7	0	-11	-18	-20	0.0
Inorganic soil pool	0	-1	11	0	11	14	11	2.5

Figure 42 Otaki Nutrient Budget

6.2.1.4 Parewanui Block

The Parewanui Block leaches 26 kgN/ha/yr (Figure 43) this just falls under the consent conditions from Horizons and also falls at the lower end of *'typical dairy farm nitrogen loss'*. The concentration of N in drainage water (8.2 ppm) is less than that of the drinking water standard. The phosphorus risk loss is low.

Nutrient budget

(kg/ha/yr)	N	P	K	S	Ca	Mg	Na	H+*
Nutrients added								
Fertiliser, lime & other	160	32	45	38	81	0	0	0.0
Rain/clover N fixation	2	0	2	3	2	4	14	0.0
Irrigation	0	0	0	0	0	0	0	0.0
Nutrients removed								
As animal products	93	16	21	6	23	2	6	0.0
As supplements	0	0	0	0	0	0	0	0.0
Net transfer by animals	13	-1	10	-1	1	0	-3	0.0
To atmosphere	90	0	0	0	0	0	0	0.0
To water	26	0.5	12	29	42	3	12	-1.4
Change in block pools								
Organic pool	-60	11	0	7	0	0	0	-0.1
Inorganic mineral	0	7	-7	0	-4	-6	-7	0.0
Inorganic soil pool	0	-1	11	0	21	5	6	1.5

Figure 43 Parewanui Nutrient Budget

6.2.1.5 Effluent Block

It is recommended practise to irrigate farm dairy effluent to low risk soils i.e. free draining soils. Therefore, in these intial Overseer simulations, effluent was irrigated to the permeable Rangitikei soils. In Overseer, effluent irrigation is "actively managed". However, the Effluent block leaches 55 kgN/ha/yr, (Figure 44). This is well above the consent conditions for Horizons and at the higher end of *'typical dairy farm nitrogen loss'*. The effluent block has the largest nitrogen leaching rate of the whole dairy platform. The concentration of nitrogen in drainage water (13.9 ppm) is much higher than the drinking water standard and phosphorus loss risk from this blocks is classified as low.

The major issues for the effluent block will be the loss of nitrogen from the block which is not a major issue currently for Horizons. Effluent management will need to be re-assessed to try and mitigate problems (see section 6.2.2).

Nutrient budget

(kg/ha/yr)	N	P	K	S	Ca	Mg	Na	H+*
Nutrients added								
Fertiliser, lime & other	0	0	0	0	0	0	0	0.0
Rain/clover N fixation	2	0	2	3	2	4	14	0.0
Irrigation	0	0	0	0	0	0	0	0.0
Effluent added	165	33	161	15	57	25	7	-8.6
Nutrients removed								
As animal products	93	16	21	6	23	2	6	0.0
As supplements	0	0	0	0	0	0	0	0.0
Net transfer by animals	13	-1	10	-1	1	0	-3	0.0
To atmosphere	36	0	0	0	0	0	0	0.0
To water	55	0.4	9	20	65	5	16	-3.7
Change in block pools								
Organic pool	-30	17	0	-7	0	0	0	-0.6
Inorganic mineral	0	-1	-3	0	-11	-18	-20	0.0
Inorganic soil pool	0	1	124	0	-18	39	22	-4.2

Figure 44 Effluent Block Nutrient Budget

6.2.1.6 Manawatu Deep Block

The Manawatu Deep block leaches 39 kgN/ha/yr, (Figure 45) this is well above the consent conditions for Horizons and at the higher end of *'typical dairy farm nitrogen loss'*. The concentration of Nitrogen loss (11.5 ppm) from this block does not quite meet the standard drinking conditions. The major issues for this block are the loss of nitrogen and concentration lost.

Nutrient budget

(kg/ha/yr)	N	P	K	S	Ca	Mg	Na	H+*
Nutrients added								
Fertiliser, lime & other	160	32	45	38	81	0	0	0.0
Rain/clover N fixation	2	0	2	3	2	4	14	0.0
Irrigation	0	0	0	0	0	0	0	0.0
Nutrients removed								
As animal products	93	16	21	6	23	2	6	0.0
As supplements	0	0	0	0	0	0	0	0.0
Net transfer by animals	13	-1	10	-1	1	0	-3	0.0
To atmosphere	41	0	0	0	0	0	0	0.0
To water	39	0.5	12	29	52	4	13	-2.4
Change in block pools								
Organic pool	-24	16	0	7	0	0	0	-0.1
Inorganic mineral	0	2	-7	0	-11	-18	-20	0.0
Inorganic soil pool	0	-1	11	0	19	16	18	2.5

Figure 45 – Manawatu Deep Block Nutrient Budget

6.2.1.7 Manawatu Moderately Deep Block & Manawatu Shallow Block

The Manawatu Mod. Deep block leaches 41 kgN/ha/yr, (Figure 46) this is well above the consent conditions for Horizons and in the higher end of '*typical dairy farm nitrogen loss*'. The concentration of Nitrogen in drainage water (11.8 ppm) from this block does not meet the standard drinking conditions. Phosphorus loss from this block is 0.6 kg/ha/yr. In the phosphorus loss catergory, this block falls under the medium risk, this may be due to the soil itself having a low P retention or the slow mineralisation of parent material.

The major issues for this block are the loss of nitrogen and phoshours risk. Phosphate fertilisers will need to be added to the block when uptake is at its highest. The Manawatu Shallow Block nutrient budget is exactly the same as the Manawatu Moderatley Deep Block, therefore refer to that budget and notes on this block.

Nutrient budget

(kg/ha/yr)	N	P	K	S	Ca	Mg	Na	H+*
Nutrients added								
Fertiliser, lime & other	160	32	45	38	81	0	0	0.0
Rain/clover N fixation	2	0	2	3	2	4	14	0.0
Irrigation	0	0	0	0	0	0	0	0.0
Nutrients removed								
As animal products	93	16	21	6	23	2	6	0.0
As supplements	0	0	0	0	0	0	0	0.0
Net transfer by animals	13	-1	10	-1	1	0	-3	0.0
To atmosphere	41	0	0	0	0	0	0	0.0
To water	41	0.6	12	29	53	4	13	-2.5
Change in block pools								
Organic pool	-26	16	0	7	0	0	0	-0.1
Inorganic mineral	0	2	-7	0	-11	-18	-20	0.0
Inorganic soil pool	0	-1	11	0	17	16	18	2.6

Figure 46 Manawatu Mod Deep Nutrient Budget

6.2.1.8 Rangitikei Shallow Block

The Rangitikei Shallow block leaches 42 kgN/ha/yr, (Figure 47) this is well above the consent conditions for Horizons and in the higher end of '*typical dairy farm nitrogen loss*'. The concentration of Nitrogen in drainage water (12 ppm) does meet the drinking standard.

The major issue for this block is the loss of nitrogen.

Nutrient budget

(kg/ha/yr)	N	P	K	S	Ca	Mg	Na	H+*
Nutrients added								
Fertiliser, lime & other	160	32	45	38	81	0	0	0.0
Rain/clover N fixation	2	0	2	3	2	4	14	0.0
Irrigation	0	0	0	0	0	0	0	0.0
Nutrients removed								
As animal products	93	16	21	6	23	2	6	0.0
As supplements	0	0	0	0	0	0	0	0.0
Net transfer by animals	13	-1	10	-1	1	0	-3	0.0
To atmosphere	44	0	0	0	0	0	0	0.0
To water	42	0.4	12	29	58	5	16	-2.6
Change in block pools								
Organic pool	-30	18	0	7	0	0	0	-0.1
Inorganic mineral	0	0	-7	0	-11	-18	-20	0.0
Inorganic soil pool	0	-1	11	0	13	15	15	2.7

Figure 47 Rangitikei Shallow Nutrient Block

6.2.1.9 Fodder Crop

The Fodder Crop leaches 33 kgN/ha/yr, (Figure 48) this is above the consent conditions for Horizons. The concentration of Nitrogen loss from this block does meet the standard drinking conditions of 11.3 ppm as it is only 5.4 ppm.

The standard plant material is the difference between the nutrient amount at the beginning to the end of the standing crop. Figure 48 shows that all nutrients (N, P, K, S, Ca, Mg and Na) have higher nutrient levels at the beginning rather than the end. The root stover and residues show Ca levels are higher at the beginning of the crop than at the end of the crop cycle. The organic pool shows mineralisation of N, P and S.

Nutrient budget

(kg/ha/yr)	N	P	K	S	Ca	Mg	Na
Nutrients added							
Fertiliser, lime & other	0	0	0	0	0	0	0
Rain/clover N fixation	35	0	2	3	2	4	14
Irrigation	0	0	0	0	0	0	0
Nutrients removed							
As product	305	38	222	38	153	15	18
As supplements and crop residues	0	0	0	0	0	0	0
Net transfer by animals	8	0	6	-1	1	0	-1
To atmosphere	37	0	0	0	0	0	0
To water	33	0.5	4	10	39	9	31
Change in block pools							
Standing plant material	-193	-16	-132	-9	-14	-11	-7
Root and stover residuals	115	4	3	4	-2	0	0
Organic pool	-321	-25	0	-39	0	0	0
Inorganic mineral	0	3	-60	0	-11	-18	-20
Inorganic plant available	50	-4	-42	0	-163	9	-6

Figure 48 Fodder Crop Nutrient Budget

6.2.2 Overall Recommendations for the Dairy Platform

The block reports show that nitrogen leaching levels for the majority of the farm are not meeting consent conditions in both kgN/ha/yr and concentration. To meet the conditions established by the Horizons consent:

- Smaller, more frequent applications of nitrogen fertiliser more frequently and applications made at 'low risk' periods of the year.
- Decreasing the amount of nitrogen fertiliser used and/or replacement with supplement (e.g. maize) with a low crude protein concentration.
- Consider looking at cow numbers and possibly lowering cow numbers and increasing per cow performance
- Grazing winter stock off the farm
- More supplement feed (with low crude protein concentration) brought in
- Expanding the effluent area applied – looking at more efficient tools to apply effluent this could be by use of Precision Agricultural tools available
    - o Considering a different soil type to apply effluent as currently on the Rangitikei Deep and Mod. deep (see section 6.3)
      (FLRC, 2013a ; FLRC, 2013b)

Note: The soil test values as explained are based on 'typical' soil values, the actual fertility of the Reureu blocks are discussed in Chapter 5. These tests show that capital fertiliser applications will be needed to raise levels to the optimum; further information and discussion around the current fertility and levels needed are discussed in Chapter 5.

Phosphorus loss from the dairy platform is only an issue on the Manawatu Mod-deep and Manawatu shallow blocks. To mitigate these losses, the application, and timing of phosphate fertiliser should be considered. Smaller more frequent applications may help minimise these losses.

6.3 Farm Dairy Effluent

6.3.1 Storage Calculator

Where there is a selection of soil types, it is standard practise to choose to irrigate farm dairy effluent (FDE) to 'low risk' soils. Accordingly, the effluent block discussed above comprised the free draining Rangitikei soils. One reason for this preference for low risk over high risk soils is that a much smaller storage volume is required.

The Dairy Effluent Storage Calculator is a software tool[46] which helps to determine the storage requirements for farm effluent. Each dairy farm has a unique storage requirement that depends on a number of factors including soil type. The following are results of utilising the storage calculator on both a high risk soil and low risk soil for the Reureu dairy platform.

Two different scenarios were run through the storage calculator one of a low risk soil and the other on a high risk and the results are discussed below. However these are not an economic assessment and quotes are based on 2014 data.

6.3.1 High Risk Soil

A high risk soil is one with an increased risk of effluent loss to waterways. Waikato Regional Council (2014) describes a risk soil as;

[46] Dairy Effleunt Storage Calculator (DESC) – Current Version 1.44, Expries: 01/10/2015. http://www.massey.ac.nz/~flrc/required/FDE%20Calculator/Obtain_DESC.html

> *"High risk soils have an increased risk of effluent loss to water ways. This is because the preferential or overland flow water transport mechanism that reduces contact time with the soil within the root zone where nutrient utilisation takes place. Careful management of effluent through deferred and low application rates will minimise the risk."*[47]

The high risk soils on the Reureu block that could be irrigated with FDE include the Parewanui, Manawatu Deep and Manawatu Mod-deep. The total area of the effluent block of a high risk soil was 24 ha and the Storage Calculator suggests that a pond that can hold 4845 cubic meters would need to be installed. This pond would have a pumpable volume of 3606 cubic metres (Figure 49).

Refer to Appendix 6-3 for storage calculator information.

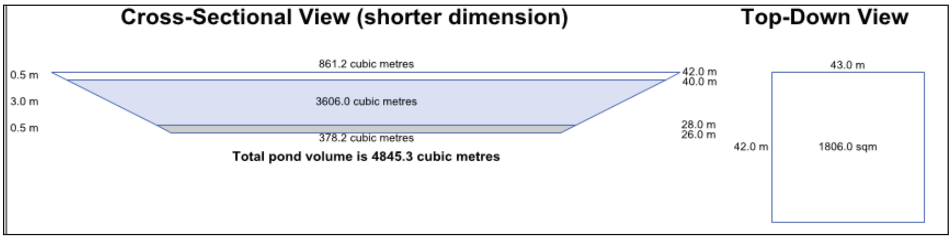


Figure 49 Cross sectional view of storage pond for high risk soil

6.3.2 Low Risk Soil

A low risk soil is one that will allow liquid to drain more evenly through the profile. The Waikato Regional Council (2014) describes a low risk soil as;

> *"Low risk soils drain liquid more evenly though the soil profile as a result of their porosity and fine soil structure. Therefore these soils have a greater frequency of when effluent can be applied, with very small or zero water deficits, because the liquid runoffs, ponds or moves preferentially through the soil when draining. They cannot however receive effluent when they are already saturated. Most of these soils also have a large water holding capacity that slows greater volumes to be applied; however, shallow and stony variants can only handle small volumes of liquid safely in one event".*[48]

The total area of the effluent block of a low soil was also 24 ha and the Storage Calculator suggests that a pond that can hold 1453 cubic meters would need to be

[47] Definition retrieved from http://www.waikatoregion.govt.nz/soilsmapinfo/
[48] Definition retrieved from http://www.waikatoregion.govt.nz/soilsmapinfo/

installed. This pond would have a pumpable volume of 1062 cubic metres (Figure 50). A summary report of this scenario can be found in Appendix 6-3.

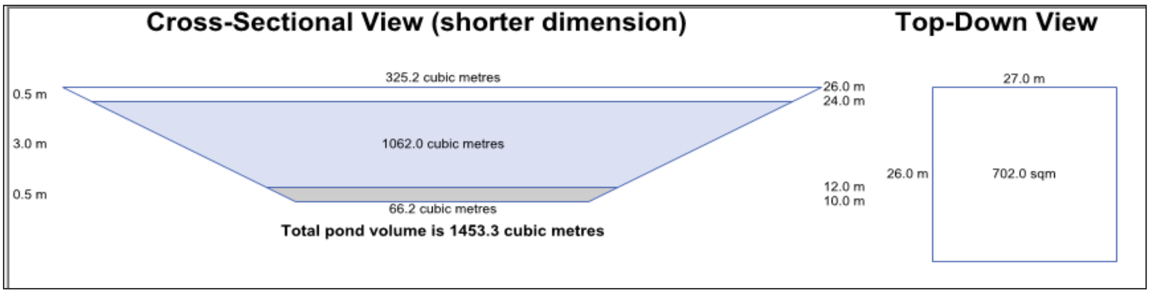


Figure 50 Cross section view of storage pond for low risk soil

6.3.3 Comparing the differences between applying to a low risk and high risk soil.

At first glance, applying FDE to low risk soils on the Reureu block would seem the most logical choice. However, given the need to reduce nitrogen leaching under FDE irrigation to the Rangitikei soils, there are other considerations to be made.

Comparisons between applying FDE (Table 41) to high risk and low risk soils were carried out for a total area of 24 ha. This comparison was based on the cost of the pond, total nitrogen lost from both areas, and the cost of mitigating nitrogen leaching. In this exercise, FDE was applied to approximately 24 ha of either low risk soil or high risk soil or a combination of low (5 ha) and high risk soil (19 ha). No nitrogen fertiliser was applied to areas irrigated with FDE. Approximately 120 kg of N as urea (46.0.0) was applied to paddocks that did not receive urea (46.0.0).

The application of FDE to a low risk soil (Rangitikei mod deep/deep) saw a total farm leaching loss to water of 3316 kgN/yr under effluent added at a rate of 174 kg N/ha/yr. The total cost of a pond (1453 m^3) for the application of FDE to low risk soils was calculated to be $46,354.

In comparison, the total nitrogen leaching loss for the whole farm under FDE irrigation to high risk soils was 3077 kgN/yr. The annual rate of nitrogen application as effluent was 178 kgN/ha/yr. The total cost of the pond for the high risk soil scenario was

$105,697. The difference in cost for the storage facilities required for irrigation to low and high risk soils is $59,342.

This is an interesting dilemma. On the one hand, irrigating FDE to the low risk soil incurs a much smaller storage cost. On the other hand, irrigating FDE to the high risk soil reduces nitrogen leaching by approximately 239 kg N/yr (Table 41). A basic cost comparison will be undertaken in an effort to identify the best soil to irrigate with FDE.

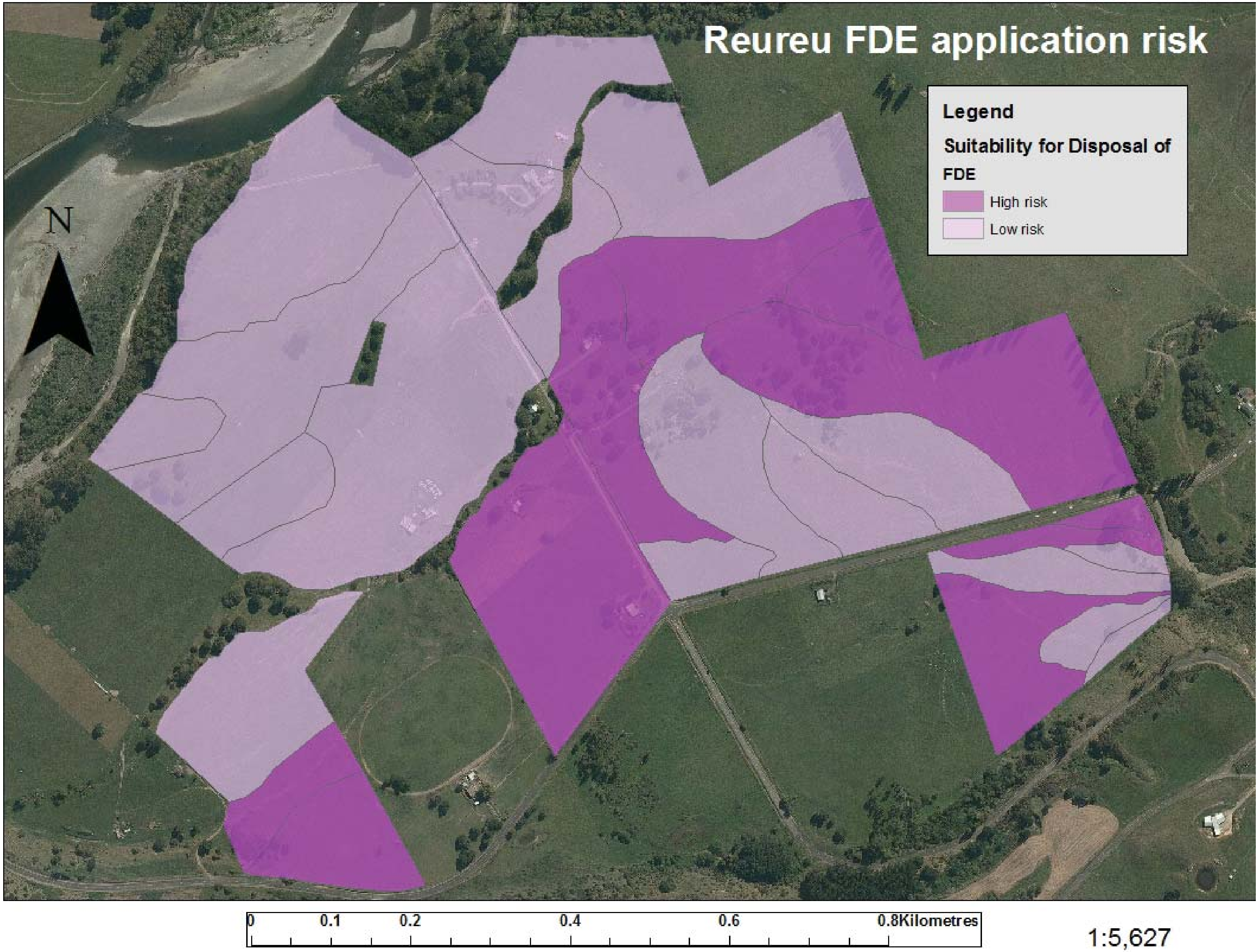
Accounting for the annualised cost shows that approximately $5940/yr would be required to meet the cost associated with this larger storage volume or, in other words, to pay for FDE application to the high risk soil. One of the cheapest measures for reducing nitrogen leaching is to replace urea boosted pasture with imported maize silage. The cost of this measure is $57 kg N/ha (J. Hanly, personal communication, 2014). If the owners of the Reureu farm had to reduce nitrogen leaching by 239 kg at a cost of $57 kg N, it would cost $13,623 a year. Therefore although the initial set up cost of the effluent pond seems cheaper, over time and taking into consideration the cost of nitrogen lost, the answer as to whether effluent should be applied to a low risk or high risk soil isn't as clear cut as one might have thought.

Table 41 Summary of the Comparisons between applying FDE to a low risk soil and high risk soil.

	Cost of pond	**Difference in N leached whole farm (kg N/yr)**
Low risk soil	$46354	3316 kgN/yr
High risk soil	$105697	3077 kgN/yr
	Difference in pond cost	**Difference in N leached**
	$59342	239 kgN/yr
	Annualised Cost of difference in pond	**Cost of mitigation**
Depreciation (over 50 yrs)	$1186	$57 kg/N
Opportunity cost 8%	$4747	
Total cost	$5934	$13623

By irrigating FDE to the Parewanui soil, the quantity of leaching under effluent irrigation is decreased. When FDE irrigation is removed from the Rangitikei soils and replaced with timely urea applications leaching from this block is reduced to 49 kgN/ha/yr.

There is potential to realise the benefits of both the high and low risk soils by applying FDE to both. In this case, irrigating FDE to a small area of low risk soils will markedly reduce the required storage volume. An investigation of the difference in pond size required if we applied FDE to 5 ha of low risk soil and left the rest on the high risk soil saw a huge difference in pond size i.e. the pond size is much smaller than that required if only the high risk soil is irrigated with FDE. The new pond size would be 2021 cubic metres and cost $54,800. In terms of nitrogen leaching there is little difference between this scenario and the high risk case. It must be highlighted that these figures are based on 2014 data and this is not an economic assessment.


Reureu FDE application risk
Legend
Suitability for Disposal of FDE
High risk
Low risk
N
0
0.1
0.2
0.4
0.6
0.8Kilometres
1:5,627

6.4 Irrigation

The purpose of irrigation is to apply water to plants that dry out to keep production levels up. Dairy NZ (2011) identified the following four factors that influence irrigation needs;

- Soil type
- Plant type
- Climate
- Irrigation system capability

An irrigation scenario was run for two soil types on the Reureu Dairy platform; the Rangitikei and Parewanui Soils. Soil specific data was not available so S-Map soil water data was used. The pasture response to irrigation was modelled using a water balance as described by Scotter et al., (1979). Climate data for the period 1981 to 2013 was accessed from NIWA‘s Cliflo site.

6.4.1 Rangitikei Soil

S-map suggested values of 30 mm and 60 mm for the readily and totally available water holding capacity of the Rangitikei soil, respectively. The soil water balance produced the following values were produced for the Rangitikei soil;

- Average irrigation yearly applied 319 mm
- Average production was 16920 kg/ha
- Production with no irrigation 12846 kg/ha
- Pasture response with irrigation 4074 (kg/ha)

The pasture response was 4 t more with irrigation than without (Figure 51). This is quite a substantial response to irrigation and therefore serious consideration should be given to installing an irrigation system on this soil.

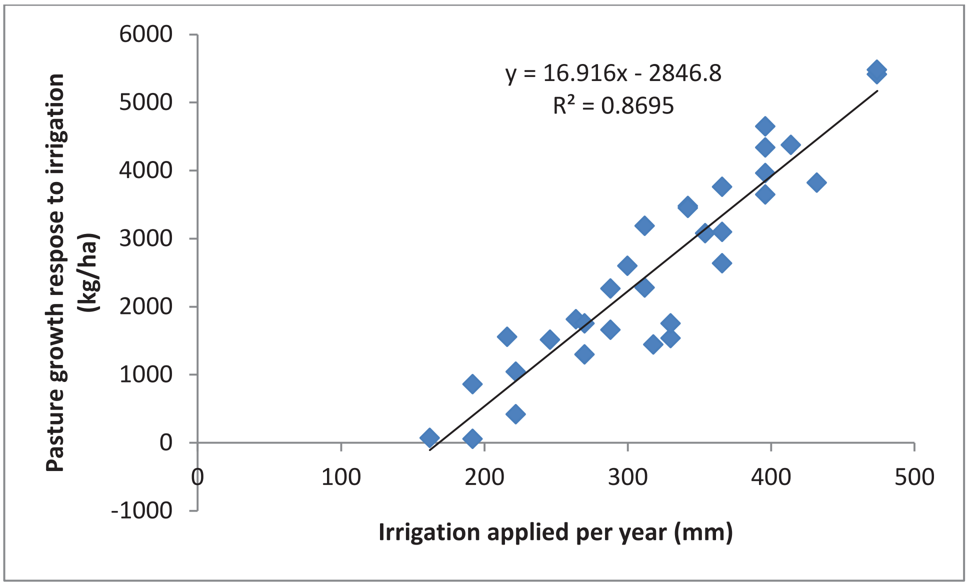


Figure 51 Pasture Response to irrigation applied in the Rangitikei Soil

6.4.2 Parewanui Soil

S-map suggested values of 70 mm and 140 mm for the readily and totally available water holding capacity of the Parewanui soil, respectively. The irrigation values were averages of yearly data collected from 1981 – 2013 for irrigation (mm) applied and production (kg/ha). The following values were produced;

- Average irrigation yearly applied 320 mm
- Average production was 16979 kg/ha
- Production with no irrigation 14408 kg/ha
- Pasture response with irrigation 2570 (kg/ha)

The pasture response (pasture production kg/ha) was 2.5 t more with irrigation than without (Figure 52). This response from irrigation on the Parewanui soil is not as great as the Rangitikei soil and is unlikely to be economically feasible on this fine textured soil.

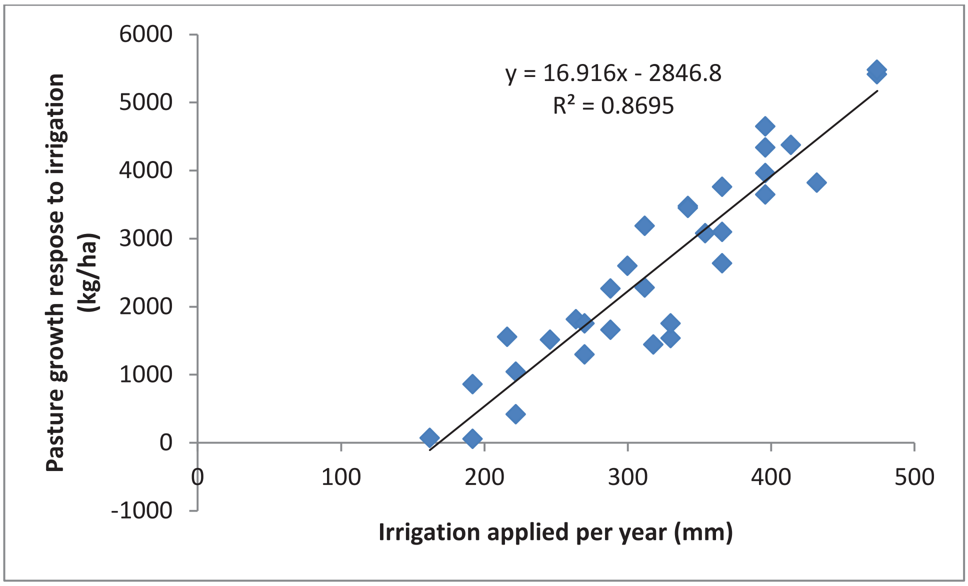


Figure 52 Pasture Response to irrigation applied in the Parewanui Soil

Irrigation will almost certainly result in an increase in nutrient (nitrogen and phosphorus) losses to the aquatic environment. Although the size of the pasture response to irrigation of the Rangitikei suggests that irrigation of this soil would be profitable, this would need to be weighed against the magnitude of any increase in nutrient losses, particularly nitrogen leaching. This further analysis was considered to be beyond the scope of the present study.

Chapter 7 Discussion

7.1 Evaluating Soil Information Available

The Reureu blocks are a clear example of the importance of obtaining the appropriate information, particularly soil mapping and an analysis of soil management issues, before implementing a change in land-use. The information available from different sources often varies. An example of this can be found in the difference in past and present soil names. It is important to keep 'up to date' information available. It is also noted that soil maps are never 100% accurate and the maps presented in this thesis are no exception.

The soil information available for the Reureu blocks (Chapter 2) revealed that the Oroua County Map has not been published and that it is the only soil map at a reasonable scale for this particular area. The other soil maps available are old soil maps such as those found in the New Zealand Soil Bulletin 26(1) (1968) and are at a large scale. The soil survey of the North Island does provide soil maps even though these are out of date, and the fundamental soil layer is provided in GIS format. However these too are at a large scale; too large to inform decisions around a land-use change. HRC also provides soil maps for the Reureu blocks. The scale of these maps is 1:50,000 and these maps contain errors. The assumption these maps are totally correct can be costly for farmers and the environment. A scaled map of 1:10,000 is sufficient for farm scale mapping.

The Oroua County Map identifies the soils of the Reureu blocks as Esk Sands, while Landcare Research Ltd and Horizons identify them as Ohakea Loam. The difference between these soils is vast and is highlighted in Chapter 2. The field work conducted on the Reureu blocks found very different soils. A full list and description of the soils found on the Reureu block can be seen in Chapter 6. The differences between the descriptions given in Chapter 6 and the aforementioned maps highlights the importance of ensuring the scale of the soil map and accuracy of maps. Maps provided at a larger scale are not helpful at a farm planning level.

The main objective of the soil survey was to determine if the information already available was correct, and to help identify and to evaluate the soils for various land-uses. The research has shown the importance of ensuring soil maps are at a reasonable scale (i.e. 1:10,000) for farm planning and taking note of the year these were produced. As some soils are relatively dynamic, up-to-date information is imperative. This is particularly the case for rapidly accumulating soils which need to be monitored more regularly due to the frequency of alluvial deposits and changing soil dynamics.

Once the soils of the Reureu block had been correctly identified, they were assessed using the 'suitability' framework (Chapter 5.4). This assessment demonstrated that the soils of the Reureu block lend themselves to dairy farming as a land-use. The owners of the Reureu block are interested in converting the land to a dairy system. Furthermore, accurate soils information is important to detailed assessment of the impacts of land-use on the environment and strategic soil management. This point was demonstrated with reference to nitrogen leaching, the management of farm dairy effluent, and the response to irrigation. The tools used to model these issues – Overseer, The FDE Storage Calculator and the soil water balance – were all very sensitive to soil inputs data.

Producing a soil map allows clear, concise decision making regarding land-use and management. Soils often change across a landscape and the physical, morphological and chemical components of soil change from series to series and within the same series. Identifying each soil can enable decision making that suits, and is unique to, particular soils. The soils were difficult to map at times due to the variation between paddocks and the stream on the eastern edge of the farm being a dominant factor in the soil pattern found on the eastern side. The soil pattern closer to the Rangitikei River was dominated by alluvial deposits from the river itself. The soil names used were based on drainage ability of the soils; therefore their correlation with those soils in S-map is not apparent.

7.1.1 Recommendations

When considering a change in land-use it is important that information of soils is as up to date as possible, the map scale is correct and that the soils have been correctly identified. The Reureu blocks are a clear example of the pitfalls of assuming that the soil maps provided by various organisations such as Landcare Research Ltd and HRC are correct. This study illustrates the importance of ensuring that soil spatial information is of an appropriate scale for the resolution of management issues. Overall a detailed, accurate soil map was extremely important to an analysis of suitable land-use, environmental impacts and selection of soil management practices. The soil map produced here will now be able to be used to ensure the correct land-use and that the decision support tools for irrigation and effluent management are used correctly.

7.2 Physical Environment

Identifying the physical environment (Chapter 2) of the Reureu blocks is important for a potential change in land-use. The climate data used in the soil water balance was accessed from the virtual Climate Station Network administered by NIWA. The area is characterized as warm, dry summers and wet mild winters, with rainfall ranging between 900 – 1200m on rainfall, with temperatures ranging between 15° - 17°C.

The geology of the area can be found in the 'Taranaki – Wanganui' Q-Map (Chapter 2). The terraces which the Reureu blocks lie on are formed by alluvial deposits from the Rangitikei River and a nearby stream. The Reureu blocks are in a low lying position close to the nearby Rangitikei River and Raumanga stream flowing through the land area which, as stated above, have determined the soil pattern found here.

7.3 Land Evaluation

Information sourced from literature was gathered on land evaluation frameworks, tools and strategies to help in a general evaluation of the Reureu blocks (Chapter 4). Land evaluation was a key component to help evaluate the land's suitability to land-uses. Land Resource Inventory was the first step in land evaluation leading onto Land-use Capability. PAR was used when looking in more detail to the nutrient caps and restrictions the owners may face.

The Land Resource Inventory Map produced shows the five physical factors which have determined each polygon in the LRI map. The combination of these five factors in turn reflects on what LUC class they are assigned. It was important to ensure the Reureu blocks were correctly assigned LUC as this is able to help, not only determine potential land-uses, but also in terms of leaching limits given by HRC in their regulations in the

One Plan. As New Zealand and global markets become more environmentally conscious, stricter regulations of leaching limits will be imposed on farmers. An example of this is the Waikato Regional Council and the limits on farming activities around Lake Taupo which are in place to try and ameliorate a decline in lake health. Although the Reureu farms are not in a sensitive catchment currently, this could change at any moment. Therefore the importance behind assigning the correct LUC classes and ensuring correct or most suitable land-uses are used on these blocks. It will be imperative that the correct land-use and management tools are used to ensure the Reureu lands keep within these boundaries.

Initially the literature from both Landcare Research Ltd and HRC identified all the land in the Reureu blocks as LUC 2s2 (discussed in Chapter 2). However throughout the fieldwork it was evident that in fact some of the land blocks were not class 2, with the majority of the blocks being class 3. This was due to either soil limitations (stoniness in top 20 cm) or wetness (poor internal drainage). The difference in terms of capability between class 2 and 3 is quite marked as shown in the '*Land-use Capability Handbook*'. This handbook was key to identifying the different classes as well as discussions with soils expert Dr Alan Palmer (personal communication, 2014). The difference between the soil limitations is quite significant with class 2 land having stones between 45-60 cm and class 3 land having stones from 20 cm – 45 cm affecting depth. The presence of stones also would impact on drainage of the soil, in some cases causing the soil to be excessively drained thus impacting on nutrient loss, especially nitrogen.

Suitability maps were conducted on several aspects (i.e. effluent, irrigation) identified as significant for change in land-use in particular dairying (see Chapter 5.5). These maps were rated as shown in tables 29-37 from worst to best, to identify areas of concern or any potential issues the owners may face. Not all of this information is required for consent; however the impact factors may have is important when considering differing land use options. These maps add to the knowledge base for these owners. The tables in section 5.4 and scale used were drawn from those used Webb & Wilson 1995.

In summary, the land evaluation is a tool to help assess land choice decisions in terms of land development and help employ best practice in terms of nutrient management. The importance of assigning the correct LUC class was evident with nitrogen leaching allocations being affected as well as choice of land-use.

Other aspects of land evaluation such as the use of remote sensing were considered, however expert advice was that here remote sensing would not add any extra information to this research (M. Tuohy, personal communication, 16th September 2014). Other land evaluation tools or technological developments that could be classed as precision agriculture were all also reviewed to see if these developing technologies could be used but time constraints meant that this was not possible. Electromagnetic (EM) mapping is a new technology that can be used to map soils: EM mapping identifies differences in soil texture. Although this technologies show promising signs of reducing cost and time associated with mapping soils, it does not add additional value if a soil map has been conducted.

Proximal soil sensing and wireless sensor network are new technologies developed to aid in real time data processing and precision application. Real time soil moisture information would be useful in terms of identifying irrigation requirements. Precision application of fertiliser and irrigation can also be used to maximise the efficient use of these resources.

Land evaluation tools such as LRI and LUC mapping are imperative in terms of ensuring a correct land-use is chosen for the particular soil parameters and environmental conditions present. Land evaluation frameworks assess the physical requirements of the land. An aspect to land evaluation which was not discussed in the thesis is the economic impact of changes to land-use. As the thesis was focused on the physical resources with particular emphasis on the soil resource, financial matters were not generally taken into account here.

7.3.1 Recommendations

Land evaluation tools such as LRI and LUC mapping are imperative in terms of ensuring a correct land-use is chosen for the particular soil parameters and environmental conditions present. Land evaluation promotes the assessment of the physical requirements of the land. An aspect to land evaluation which was not discussed in this thesis is the economic impact. As the thesis was focused on the physical resources with particular emphasis on the soil resource, this was not taken into account. Beyond the physical evaluation of the resource the next imperative is to assess the economic impacts with the chosen land-use to ensure it is feasible. The environmental impacts will be discussed under the nutrient management heading further on in this chapter.

The other management tools and technologies developed to help ensure their maximum precision and application are useful and should be utilised where possible. An example of new technologies which could be used in the future would be Electromagnetic Mapping (EM). Technologies such as these would be helpful to ensure best practice and the most efficient use of resources.

7.4 Soil Fertility

Soil fertility is an important factor in land-use; it not only helps to determine the current nutrient status of the blocks but also to determine fertiliser requirements to ensure maximum production. Soil fertility testing helps to achieve and maintain appropriate levels of soil fertility especially plant nutrient availability. Testing is the first step; the second is the interpretation of the results and third is the recommendations to add fertiliser either as capital or maintenance. Chapter 5 discusses soil fertility with the results specific to the Reureu blocks in Chapter 6. Recommendations on fertiliser have been discussed in Chapter 6 – the scenario dairy farm. Soil fertility tests help to ensure fertiliser is optimised and used efficiently to get maximum production.

An issue with many Māori leased farms is the lack of nutrient management, thus affecting the whole fertiliser regime in the future. Such is the case for this block which has seen little fertiliser application throughout the lease period (L. Iwikau, personal communication, 2014).

Soil tests were conducted based on Management Units that were selected at the beginning of this project. The fertility status of the Reureu blocks currently suggests little to no fertiliser has been added and additional applications will be required to get levels to the 'optimum range' for dairy land-use. The soil fertility samples were taken at a depth of 7.5 cm, as this is the depth needed for pastoral testing, however if the land-use is cropping new tests will need to be conducted to a minimum depth of 15 cm.

The optimum ranges for nutrient requirements for a typical dairy production are discussed in Chapter 5. As the Reureu block owners are considering dairy as a land-use the fertiliser requirements for dairy production was used. This would vary if a cropping or intensive sheep and beef farm was the chosen land-use instead.

7.4.1 Recommendations

Throughout the project, it would have been ideal to undertake a 'whole paddock' sample, whereby an understanding of the nutrient status of each paddock could be gained. On the potential change in land-use, paddock boundaries may also change, hence the reason for dividing the land into management units instead. Once a specific land-use has been chosen it is recommended that all paddocks tested again. This will give an overall view of all the paddocks and make fertiliser applications more effective. It is also suggested pin-pointing, either by marker or GPS, the points used for fertility testing to ensure the same locations are tested next time to monitor the progress of soil fertility over a period of time.

7.5 Scenario Dairy Platform

7.5.1 Differences between Farmax and Overseer

Whilst entering the data into both of the modelling programs Overseer and Farmax there was a clear difference in the amount of grass produced. The difference between these programs is not to be used as definitive results but help model the possibilities. Farmax dealt with the farm setting, financial and biophysical aspects whilst Overseer dealt with the environmental causes. It must be noted that these programmes help model a scenario or current situation and variation can be apparent. The use of one of these programmes alone would not be beneficial, as some aspect would be left out, so using these together gives a better understanding of the ‘farm scenario’. Farmax does require training as it can be quite complicated to use. So does Overseer; anyone who does not have experience in these programmes should seek advice from those who do.

Farmax data entered showed 13.3 t of grass produced and 474 of milk solids produced per cow with a total of 99,540 milk solids produced. Using that same information Overseer predicted over 15 t of grass produced, which is unrealistic, therefore data was subsequently changed to match or simulate a typical system 3/4 dairy farm in the Manawatu. There were clearly some issues with transferring data from Farmax into Overseer and producing the same scenarios and therefore caution is needed when using these models in tandem.

7.5.2 Overseer

The soil profile data inputted into Overseer has a marked effect on the outputs particularly nitrogen leaching. An example of this was seen with the large difference between nitrogen leaching from the Effluent Block (Rangitikei soil) when the lower soil profile texture was changed from ‘light’ to ‘medium’. Overseer predicts that a soil with a ‘medium’ lower texture will leach 30 kgN/ha/yr (with a nitrogen concentration of 8.6 ppm) whereas a soil with a ‘light’ lower texture will leach 55 kg/N/yr (with a nitrogen concentration of 13.9 ppm).

Accurate and comprehensive information about the soil profile is required if Overseer is to reliably model soil and water processes. Block specific data should be used when looking at soil texture, especially if the soil is coarse as this will directly impact on the AWC of the soil and thus increase or decrease the risk of nitrogen leaching.

The Overseer program can help manage nutrients efficiently. New Zealand soils are generally low in natural fertility, therefore fertiliser costs are a major expense. Nutrient management is a key aspect to a sustainable dairy unit for the Reureu blocks. There are concerns around the data input into Overseer. Overseer is not a tool to be used by someone unfamiliar with the input system. As shown previously, differences between leaching rates can be vastly different with only a slight change is soil characteristics. It is also important to remember that Overseer is concerned with the environmental impacts only.

7.5.3 Dairy Effluent Storage Calculator

The dairy effluent storage calculator was used to explore two scenarios: one with a low risk soil and the other a high risk soil. For the first time, this study discovered that selecting the most appropriate soil for FDE irrigation is not as straightforward as has commonly been claimed. The initial cost of storage for low risk application of FDE will be cheaper. However this decrease in storage capacity for irrigation to the low risk soil must be weighed against the increase in nitrogen leaching when FDE is applied to the low risk soil. A cost analysis showed, in actual fact, if Reureu had to reduce nitrogen leaching, the overall cost per year is less when FDE is applied to a high risk soil despite the greater storage expense. In other words, contrary to received wisdom, the results in Chapter 5 showed significant cost benefit in applying FDE to high risk soil.

7.5.4 Irrigation

The modelling of the response to irrigation again revealed the importance of reliable soil information. Approximately 4 t more grass production can be expected under irrigation on the Rangitikei soils: a response of this magnitude is likely to warrant the investment in irrigation (Howe, 2014). In comparison, irrigation of the Parewanui soil resulted in an increase of 2.5 t; irrigation of this soil is unlikely to be economic.

7.6 Overall

The thesis has highlighted many issues associated with the use of large scaled maps (Soil, LUC) when making decisions about changes in land-use. It has shown that in fact tools such as S-Map can be helpful, however the whole of New Zealand is not covered, therefore other maps need to be sourced. A key point has been the differences in soil types found on the Reureu blocks and the complexity of the soil pattern. There are vast differences between the soils identified on existing maps e.g. Oroua County, *cf*

Horizons maps as opposed to soils discovered by the soil survey described in this study. This shows the significance of understanding that soil spatial differences are important and need to be considered. It is also suggested that some of the soils on the Reureu block also vary in a temporal manner.

An important issue to point out is the opportunity these owners now have which has been to gather information which is valuable in making a decision for future land-use. The power of knowledge will be critical for the owners to move forward especially for those owners who are in a 'risk-sensitive' environment. For most Māori land the ability of owners to access such information is out of reach for various reasons which have been introduced in Chapter 1.

Frameworks that assess landforms/soil resources can be employed to identify the potential for land-use change in a general sense. These frameworks include both advantageous attributes and constraints. Good soil information is the basis of such frameworks. The frameworks applied suggest dairying is an appropriate land-use for the Reureu block. If the owners of the block had only access to the existing maps then they would have likely made a different land-use and environmental constraints, the cost of a detailed soil map is very small.

Once a land-use has been selected more detailed analyses of strategic aspects of soil management is required including the environmental impacts of the land-use. This was demonstrated in the current study by considering nitrogen leaching, the selection of the most appropriate soil to irrigate with FDE and, the likely response of two contrasting soils to water irrigation. Again good soils information was the key input in the models employed to conduct these analyses.

The environmental factors need acknowledgement outside soil factors, these can weigh heavily on the decision made and should be considered before a decision is finalised. These include weather (rain, climate, wind) as well as ecological impacts (cleanliness of streams, wildlife). Although currently the blocks do not lie in a 'sensitive catchment' this could change which would impact the decision of land-use, so consideration and acknowledgement of these is also important.

The issue of compliance and how this can determine land-use decision making needs to be emphasised. The role HRC play in the decision making of the Reureu blocks is crucial, as they have set requirements for a change in land-use and if these are not met the consequences are huge. Compliance is not just local government but central government as well, with adjustments to RMA which essentially control land-use decision making and land-use choices. It is imperative that the hapū carry out a detailed economic analysis before deciding on the final land-use option.

The table below (see Table 42) outlines some key disadvantages and advantages for dairying. Key points to note are for that other dairy alternatives such as sheep dairying and goat dairying have not be assessed, therefore considering alternative dairying as a land-use option should not be ruled out based on this information. The disadvantages for these different options (sheep and goat dairying) could well change the overall decision and some disadvantages may not be relevant to a different dairying option.

Table 42 Advantages and Disadvantages for Dairying

Advantages	Disadvantages
• Kairanga soil block under leaching consent conditions • Nearby hills for grazing • The cost for initial set up of pond for application of effluent to high risk soil is less than if you were to pay a cost for nitrogen lost. • Increase in DM production of irrigation used • Flat land • Future potential for larger land size • Economic benefit as opposed to current situation	• Leaching • Runoff • Effluent management • Climate (rain, wind) • Flood severity (susceptibility high) • Soil type (stoniness, presence of stones and effect for farming i.e. cultivation) • Arable ability of soils (difficult) • Pugging • Fertility levels are low (large input cost involved into upgrading these) • Leaching rates for class 2 and 3 higher than consent conditions

Chapter 8 – Conclusion

A detailed soil survey is the foundation of any informed decision about land-use change and strategic soil management, including environmental impacts. Information is generally the basis of frameworks that are commonly employed to explore the potential for land-use in a general sense. This soil information is then used to help make strategic decisions about soil management for any given land-use. The information gathered is helpful in ensuring consent conditions are met and ensuring the have accurate, up-to-date information on hand when dealing with compliance and consents.

Māori land owners are often disadvantaged when it comes to accessing this information, because of varying factors around accessibility and affordability. The information owners have is either dated or in this case incomplete e.g. soil maps. It is more challenging to develop land without the correct and up-to-date information. Key points have been highlighted as to why the ‘power of knowledge’ is important when making land-use decision making (i.e. soil map – scale, accuracy). It can be even harder for Māori as so many obstacles have been in place over time to hinder development that having information is even more important to overcome these obstacles.

These processes were demonstrated for the Reureu block on the banks of the Rangitikei River. The soil survey conducted in this study revealed a complex soil pattern comprising a wide range of soil types. This soil information was collected and placed in land evaluation frameworks which in turn supported a land-use change to dairying based on soil physical factors. The Rangitikei River also plays an important role in determining land-use showing how this river can influence decision making. The Rangitikei River is dynamic in that it changes (i.e. floods, transports debris, drought) constantly and the influencing factors are dynamic within themselves.

Furthermore, in the context of a dairy land-use, this soil information was used to explore a range of more specific soil management and environmental issues. The tools and models used to explore nitrogen leaching, FDE management and the response to irrigation were all highly sensitive to soil type and characteristics. Perhaps the best example of the usefulness of detailed soil information was the finding that in some circumstances it may be more cost effective to irrigate FDE to high risk soils than low risk soils. Armed with accurate soil information, the owners of the Reureu blocks are empowered to think through the challenges to resource management associated with a land-use change to dairying. The logical next step is to undertake a wider analysis such as economic factors to support the decision process even further.

Glossary of Māori Terms

Awa – river

Hapū – one's sub-tribe

Iwi – one's tribe

Kaitiaki – guardian

Kaitiakitanga – guardianship

Kanohi ki te kanohi – face to face

Manaakitanga – process of showing respect/generosity for others

Marae – meeting place

Maunga – mountain

Mihimihi – greet

Papa-kainga – village or home base, especially on communal owned land

Pākehā – European or non-Māori

Parehua – terrace

Pepeha – tribal saying/motto

Tangata whenua – people of the land

Taonga – treasure

Tupuna or *tipuna* – ancestor

Tūpuna or *tīpuna* – ancestors

Whakawhānaungatanga – Process of establishing relationships, relating well to others

Whakataukī – saying a proverb (significant saying)

Whakapapa – a recitation, especially of descent or genealogy

Whānau – family

Wharenui – meeting house

Whenua – land

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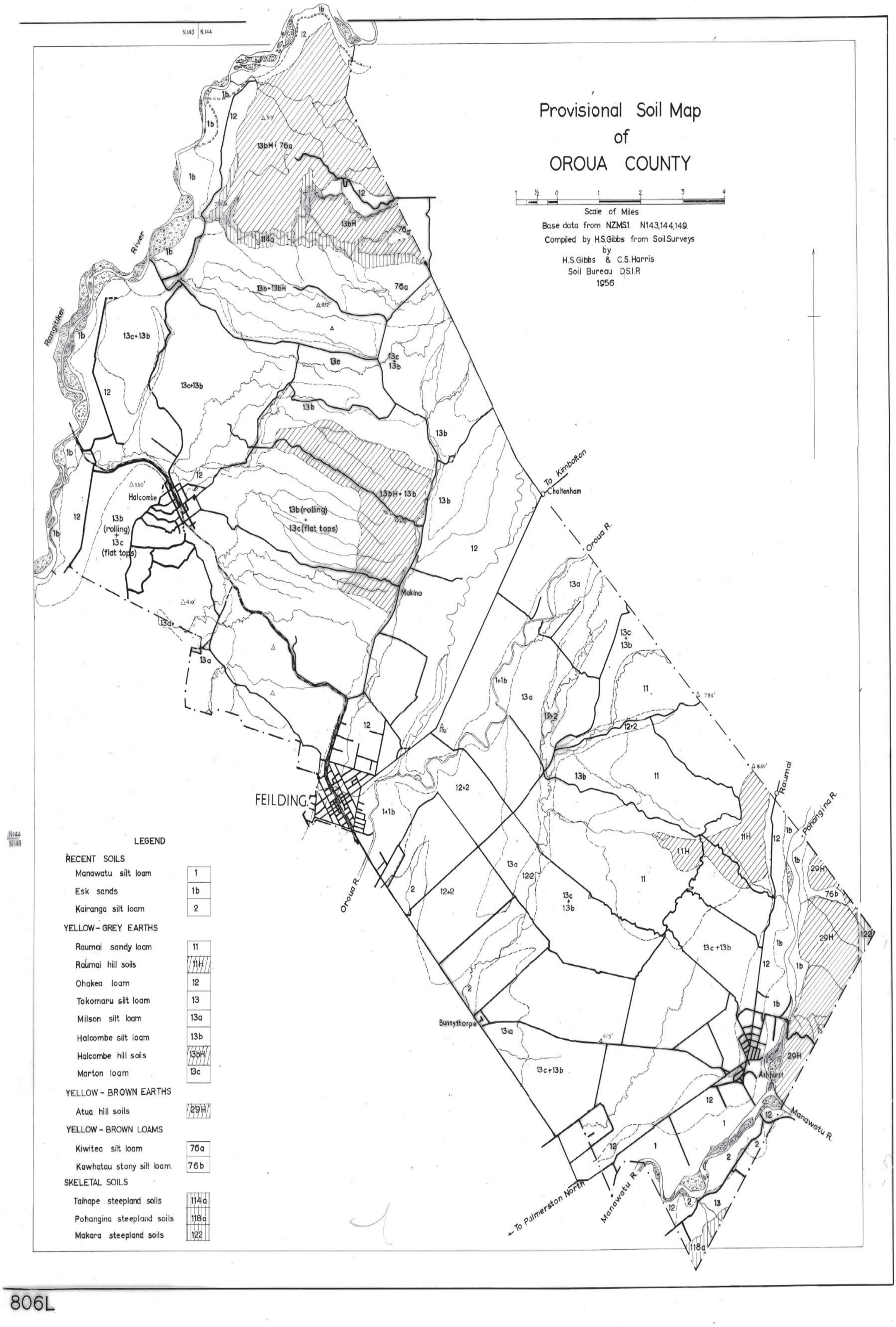
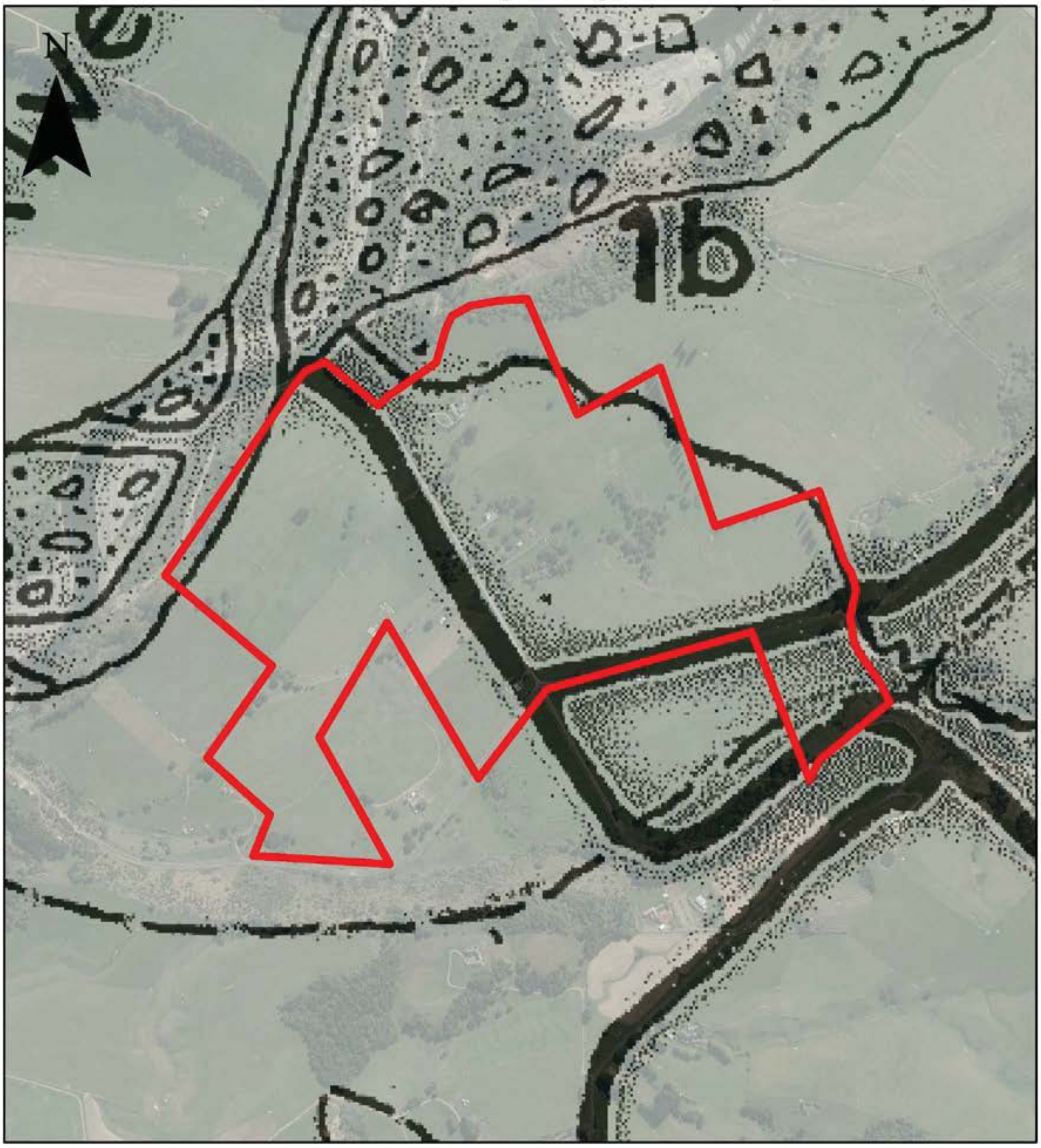
- Associate Professor Dave Horne – Associate Professor in Soil Science, Massey University
- Lance Iwikau – Senior Implementation Advisor - MPI
- Peter Taylor – Manager Rural Advice – Horizons
- Seema Singh – Climate Technician - NIWA
- Mike Tuohy – Senior Lecturer in Earth Science, Massey University

Appendices


Provisional Soil Map
of
OROUA COUNTY
Scale of Miles
Base data from NZMS1 N143,144,149
Compiled by H.S.Gibbs from Soil Surveys
by
H.S.Gibbs & C.S.Harris
Soil Bureau D.S.I.R
1956
LEGEND
RECENT SOILS
Manawatu silt loam 1
Esk sands 1b
Kairanga silt loam 2
YELLOW - GREY EARTHS
Raumai sandy loam 11
Raumai hill soils 11H
Ohakea loam 12
Tokomaru silt loam 13
Milson silt loam 13a
Halcombe silt loam 13b
Halcombe hill soils 13bH
Marton loam 13c
YELLOW - BROWN EARTHS
Atua hill soils 29H
YELLOW - BROWN LOAMS
Kiwitea silt loam 76a
Kawhatau stony silt loam 76b
SKELETAL SOILS
Taihape steepland soils 114a
Pohangina steepland soils 118a
Makara steepland soils 122
FEILDING
Halcombe
Bunnythorpe
Ashhurst
Cheltenham
Makino
To Kimbolton
To Palmerston North
Oroua R.
Manawatu R.
Pohangina R.
Raumai
Rangitikei River
806L

Reureu
Oroua County Map Overlay



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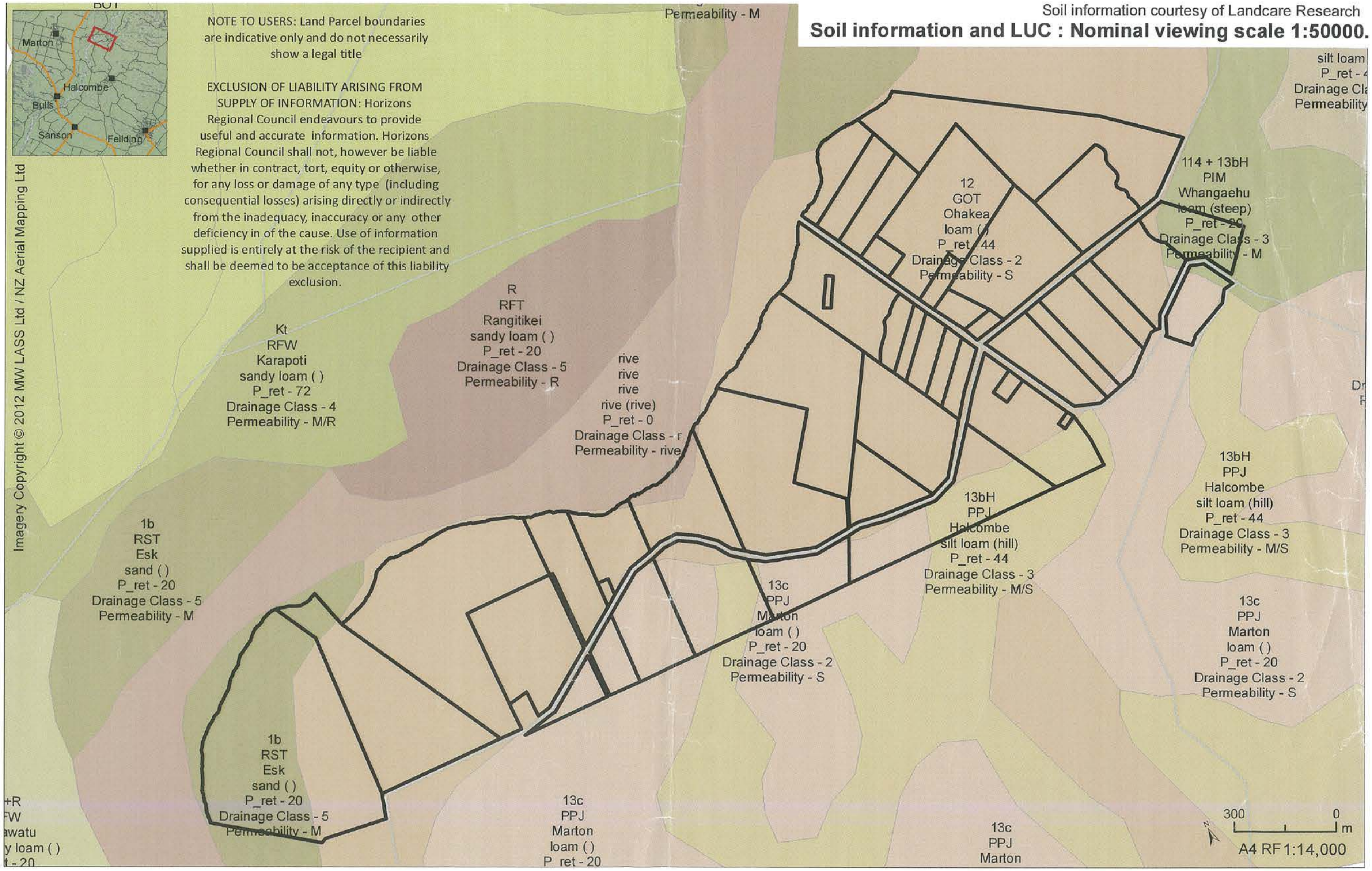

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Onepuhi Rd

Soil Map

Prepared by Catchment Information
Feb 2014
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Landcare Research
Manaaki Whenua

SOIL REPORT

Horizons Regional Council

Report generated: 25-Jan-2015 from http://smap.landcareresearch.co.nz

This information sheet describes the typical average properties of the specified soil to a depth of 1 metre, and should not be the primary source of data when making land use decisions on individual farms and paddocks.

Family: Flaxton*f*

Smap ref: Flax_87a.1

Ohakea (Flaxton_87a.1)

Key physical properties

Depth class (diggability)		Deep (> 1 m)
Texture profile		Silty Loam
Potential rooting depth		50 - 75 (cm)
Rooting barrier		Anoxic conditions
Topsoil stoniness		Stoneless
Topsoil clay range		20 - 30 %
Drainage class		Poorly drained
Aeration in root zone		Limited
Permeability profile		Moderate Over Slow
Depth to slowly permeable horizon		60 - 80 (cm)
Permeability of slowest horizon		Slow (< 4 mm/h)
Profile available water	(0 - 100cm or root barrier)	Very high (233.4 mm)
	(0 - 60cm or root barrier)	Very high (149.6 mm)
	(0 - 30cm or root barrier)	Moderate (86.5 mm)
Dry bulk density, topsoil		0.94 (g/cm3)
Dry bulk density, subsoil		1.22 (g/cm3)
Depth to hard rock		No hard rock within 1 m
Depth to soft rock		No soft rock within 1 m
Depth to stony layer class		No significant stony layer within 1 m

Key chemical properties

Topsoil P retention	Medium (38%)

About this publication

- This information sheet describes the *typical average properties* of the specified soil.
- For further information on individual soils, contact Landcare Research New Zealand Ltd: www.landcareresearch.co.nz
- Advice should be sought from soil and land use experts before making decisions on individual farms and paddocks.
- The information has been derived from numerous sources. It may not be complete, correct or up to date.
- This information sheet is licensed by Landcare Research on an "as is" and "as available" basis and without any warranty of any kind, either express or implied.
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Family: Flaxton*f*

Smap ref: Flax_87a.1

Ohakea (Flaxton_87a.1)

Additional factors to consider in choice of crop and irrigation management practices

Vulnerability classes relate to soil properties only and do not take into account climate or management

Soil structure integrity

Erodibility of soil material	Slight
Structural vulnerability	High (0.62)
Pugging vulnerability	not available yet

Water management

Water logging vulnerability	High
Drought vulnerability - if not irrigated	Low
Bypass flow	High
Hydrological soil group	B/D

Contaminant management

N leaching vulnerability	Very low
P leaching vulnerability	Medium
Bypass flow	High
Dairy effluent (FDE) risk category	C if slope > 7 deg otherwise B

Relative Runoff Potential

Slope	0-3°	4-7°	8-15°	16-25°	>25°
Risk	L	M	M	H	H

Additional information

Soil classification	Typic Orthic Gley Soils
Family	Flaxton*f*
Sibling number	87
Profile texture group	Silty
Soil profile material	Stoneless soil
Rock class of stones/rocks	Not Applicable
Rock origin of fine earth	From Hard Sandstone Rock
Parent material origin	Alluvium

Characteristics of functional horizons in order from top to base of profile:

Functional Horizon	Thickness	Stones	Clay*	Sand*
Loamy Weak	22 - 35 cm	0 %	20 - 30 %	15 - 25 %
Loamy Coarse Slightly Firm	10 - 15 cm	0 %	20 - 33 %	40 - 60 %
Loamy Coarse Firm	53 - 68 cm	0 %	25 - 34 %	40 - 60 %

* clay and sand percent values are for the mineral fines (excludes stones). Silt = 100 - (clay + sand)

Family: Flaxton*f*

Smap ref: Flax_87a.1

Ohakea (Flaxton_87a.1)

Soil information for Overseer ™

The following information can be entered in Overseer Nutrient Budget model v6.1. This information is derived from the S-map soil properties which are matched to the most appropriate Overseer categories.

Soil description page

Click the 'Select soil by order' option. From the 'Order' dropdown box select: Gley

Soil profile page

Top soil (0 - 10 cm)

Top soil texture: Silt loam

Is stony: False

Is compacted (this depends on management so cannot be obtained from S-map)

Lower profile

Maximum rooting depth: 63 (cm)

Depth to impeded drainage layer: Leave as 0

Soil texture group:

Non-standard layer (depth in brackets): leave blank

Drainage/runoff page

Profile drainage class (in natural state): Poorly drained

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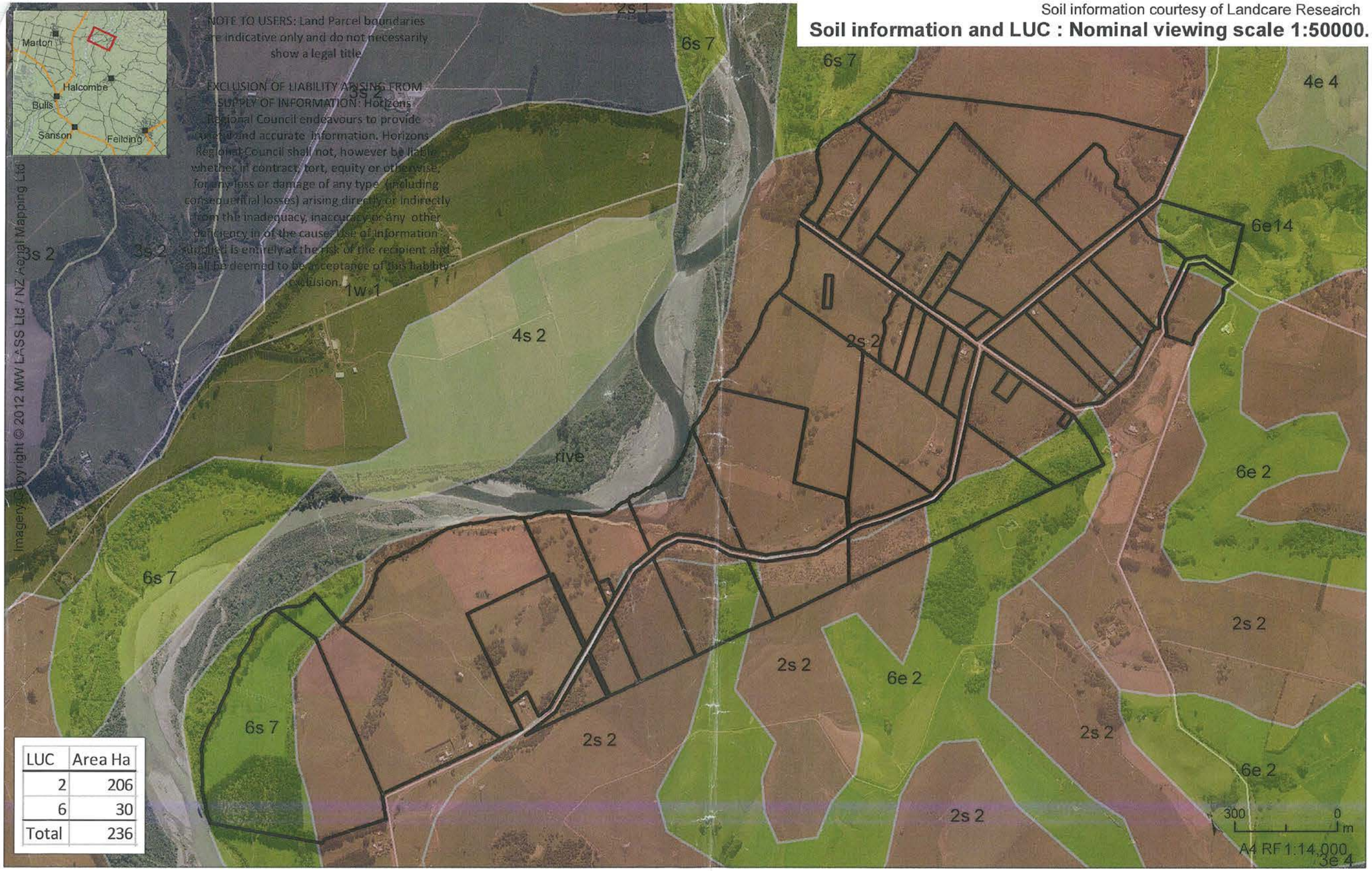
Soil information courtesy of Landcare Research

Soil information and LUC : Nominal viewing scale 1:50000.



LUC	Area Ha
2	206
6	30
Total	236

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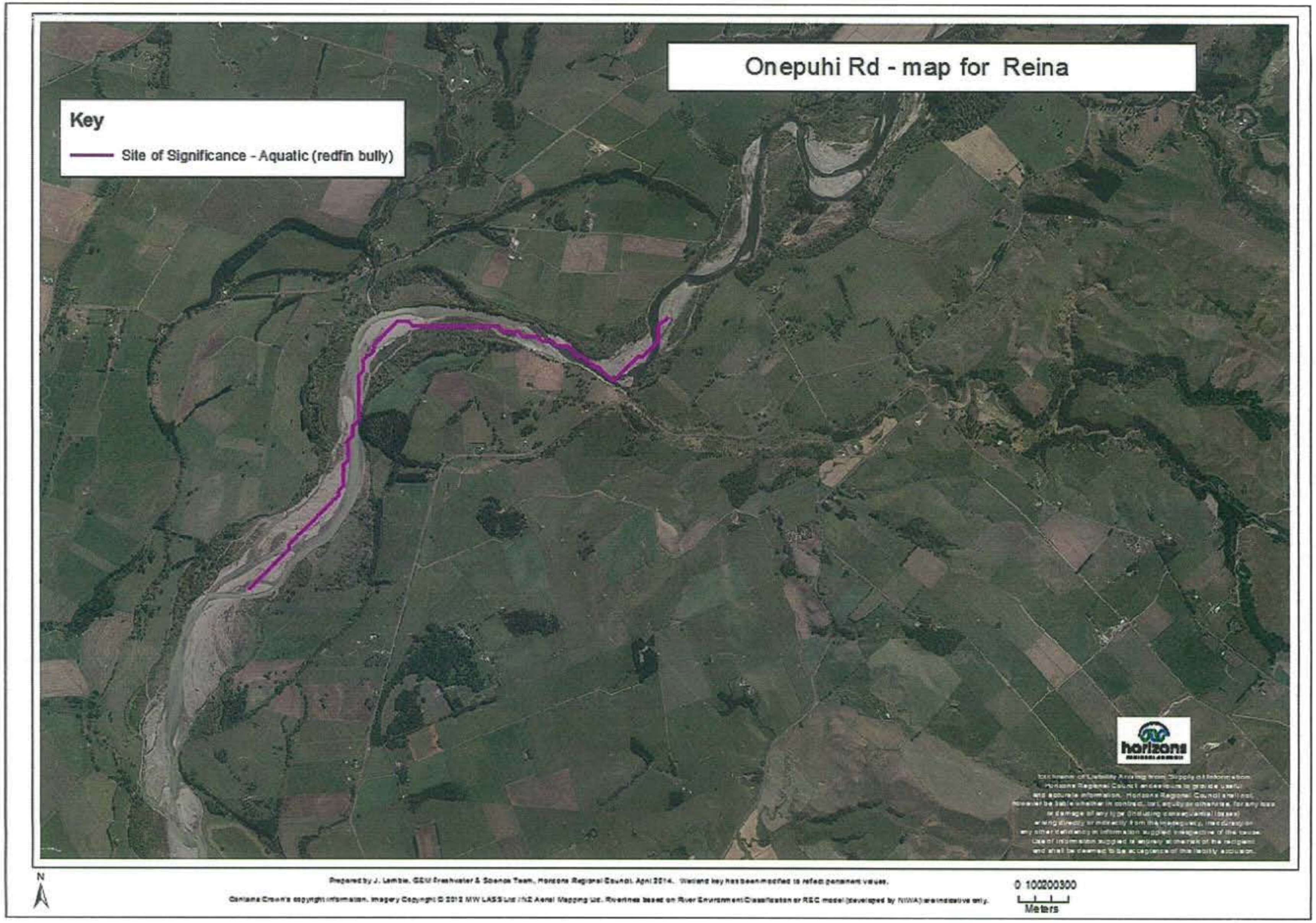
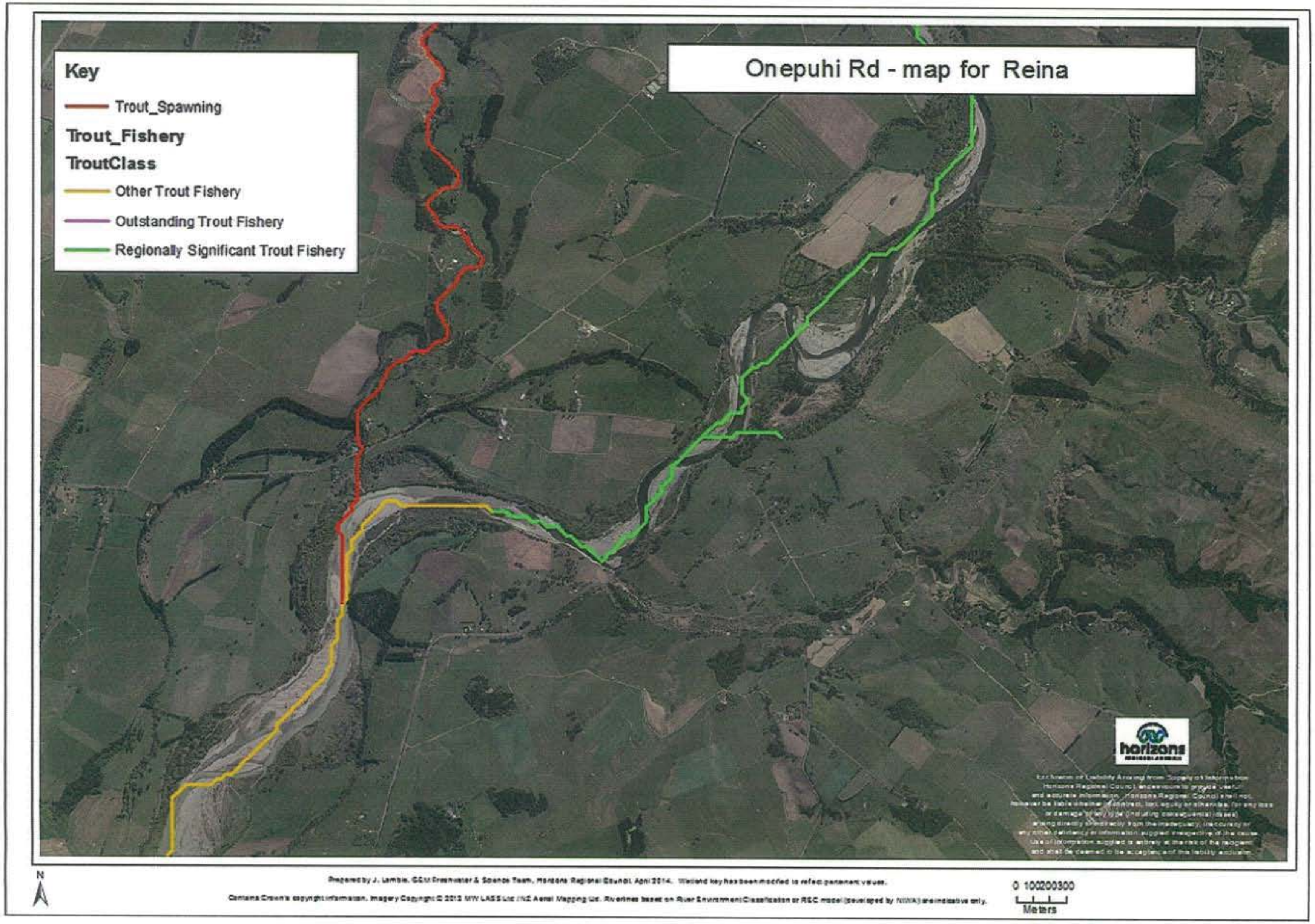
0508 800 800
www.horizons.govt.nz

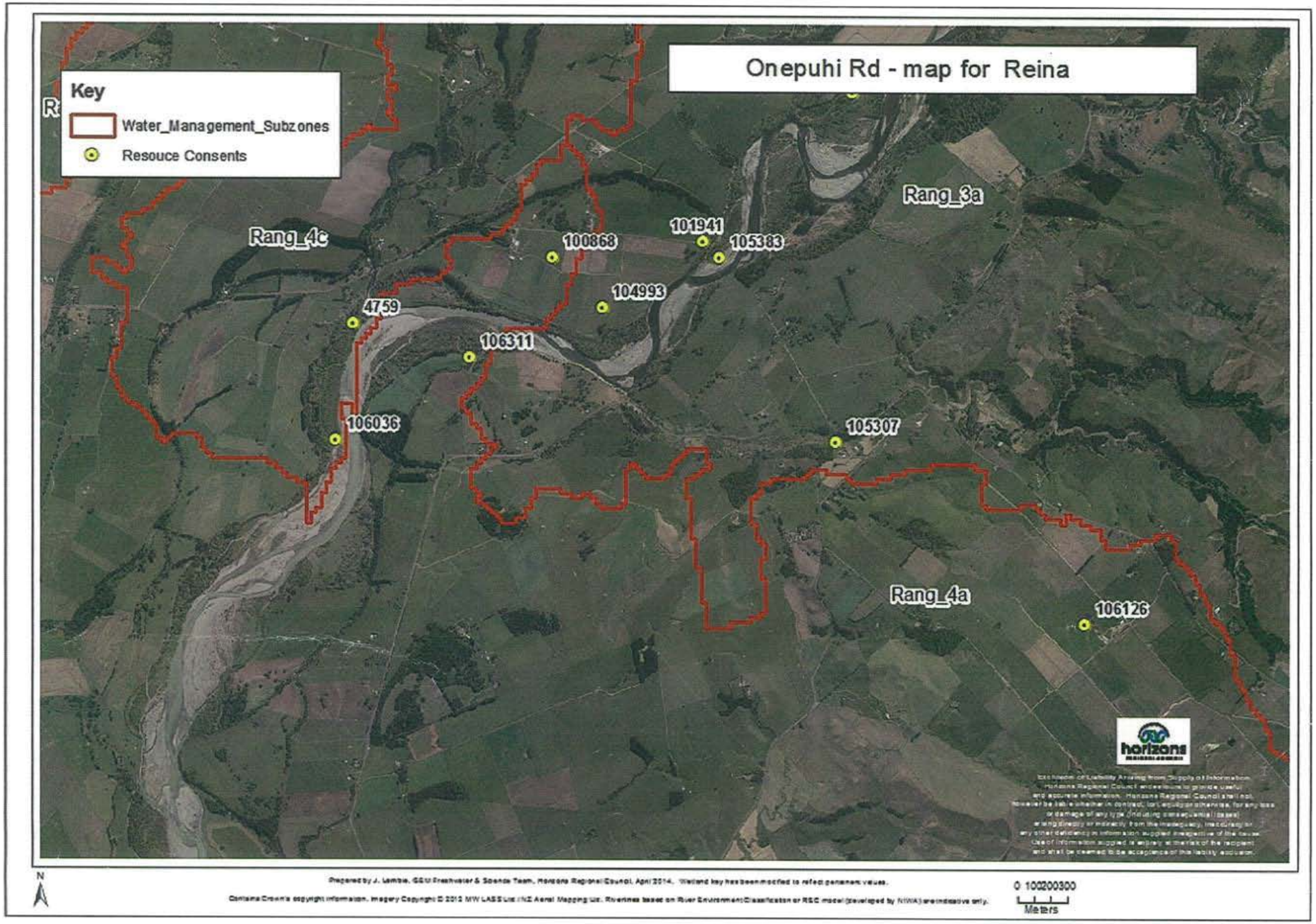
Onepuhi Rd

LUC Map

Prepared by Catchment Information
Feb 2014
CIRef : OT8989
Contains Crown Copyright Data


Onepuhi Rd - map for Reina
Key
Site of Significance - Aquatic (redfin bully)
horizons
N
Prepared by J. Lambie, SEM Freshwater & Science Team, Horizons Regional Council, April 2014. Wetland key has been modified to reflect pertinent values.
Contains Crown's copyright information. Imagery Copyright © 2012 MW LASS Ltd / NZ Aerial Mapping Ltd. Riverlines based on River Environment Classification or REC model (developed by NIWA) are indicative only.
0 100200300
Meters


Onepuhi Rd - map for Reina
Key
Trout_Spawning
Trout_Fishery
TroutClass
Other Trout Fishery
Outstanding Trout Fishery
Regionally Significant Trout Fishery
horizons
N
0 100200300
Meters


Onepuhi Rd - map for Reina
Key
Water_Management_Subzones
Resouce Consents
Rang_4c
Rang_3a
Rang_4a
100868
101941
105383
104993
4759
106311
106036
105307
106126
horizons
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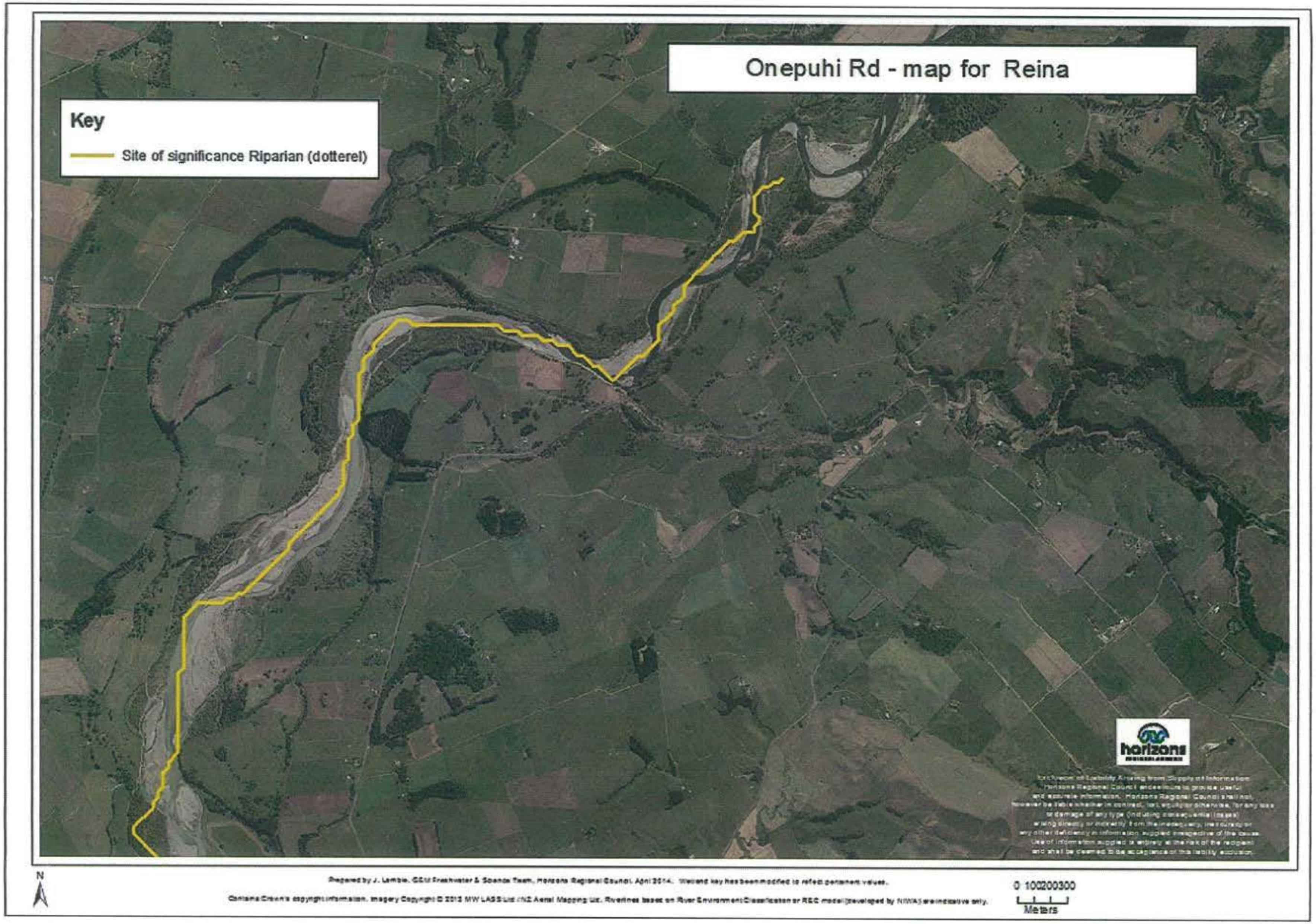
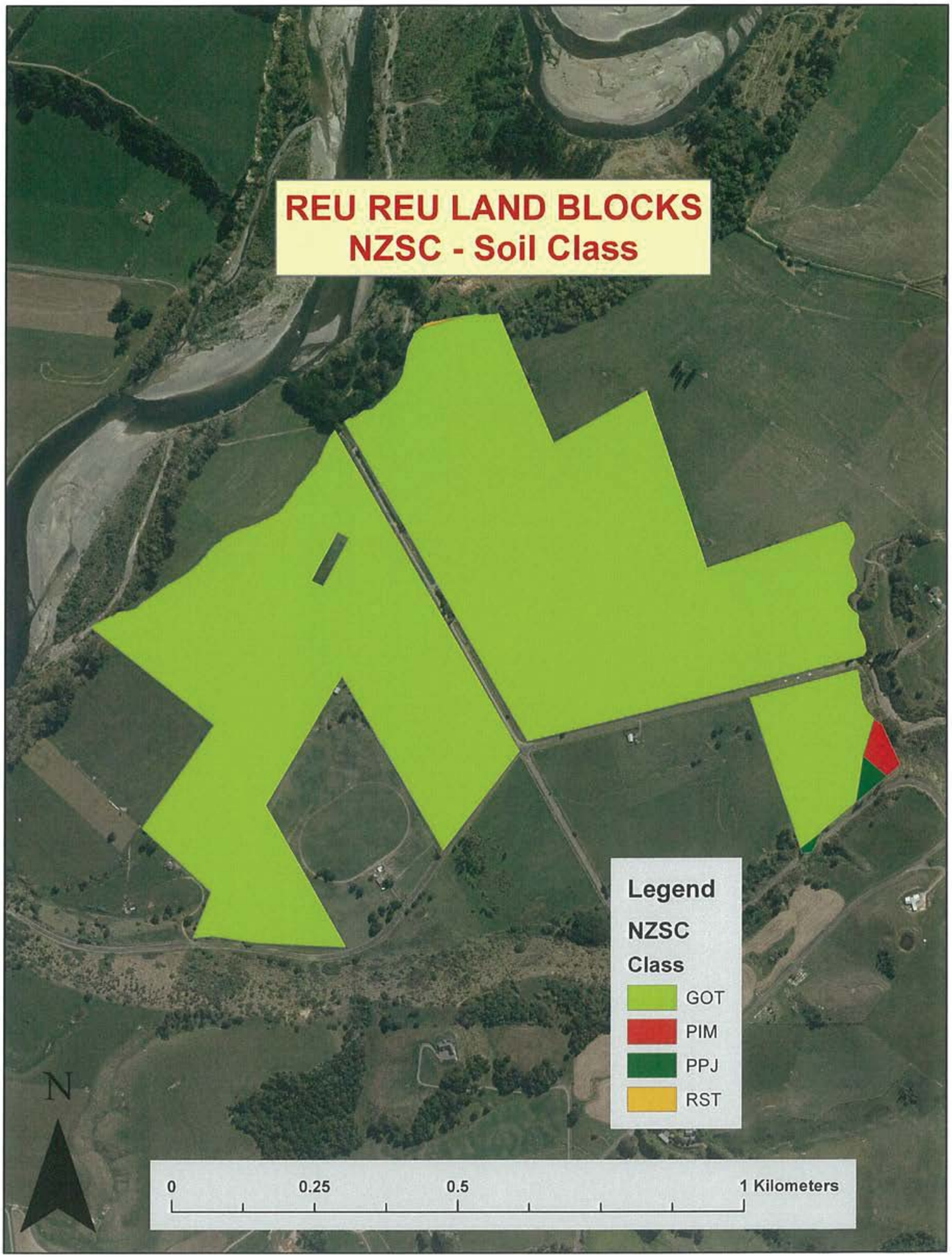
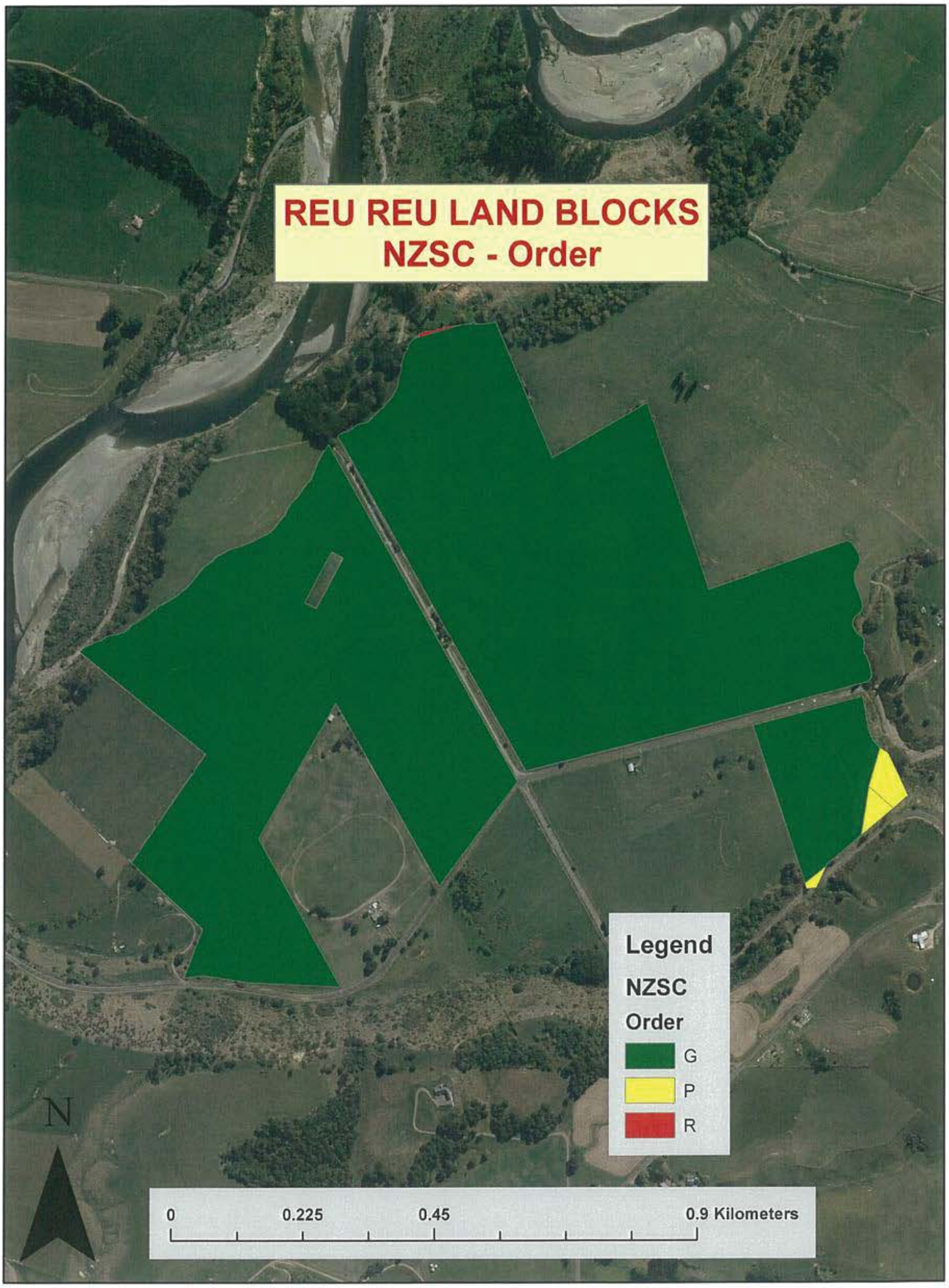
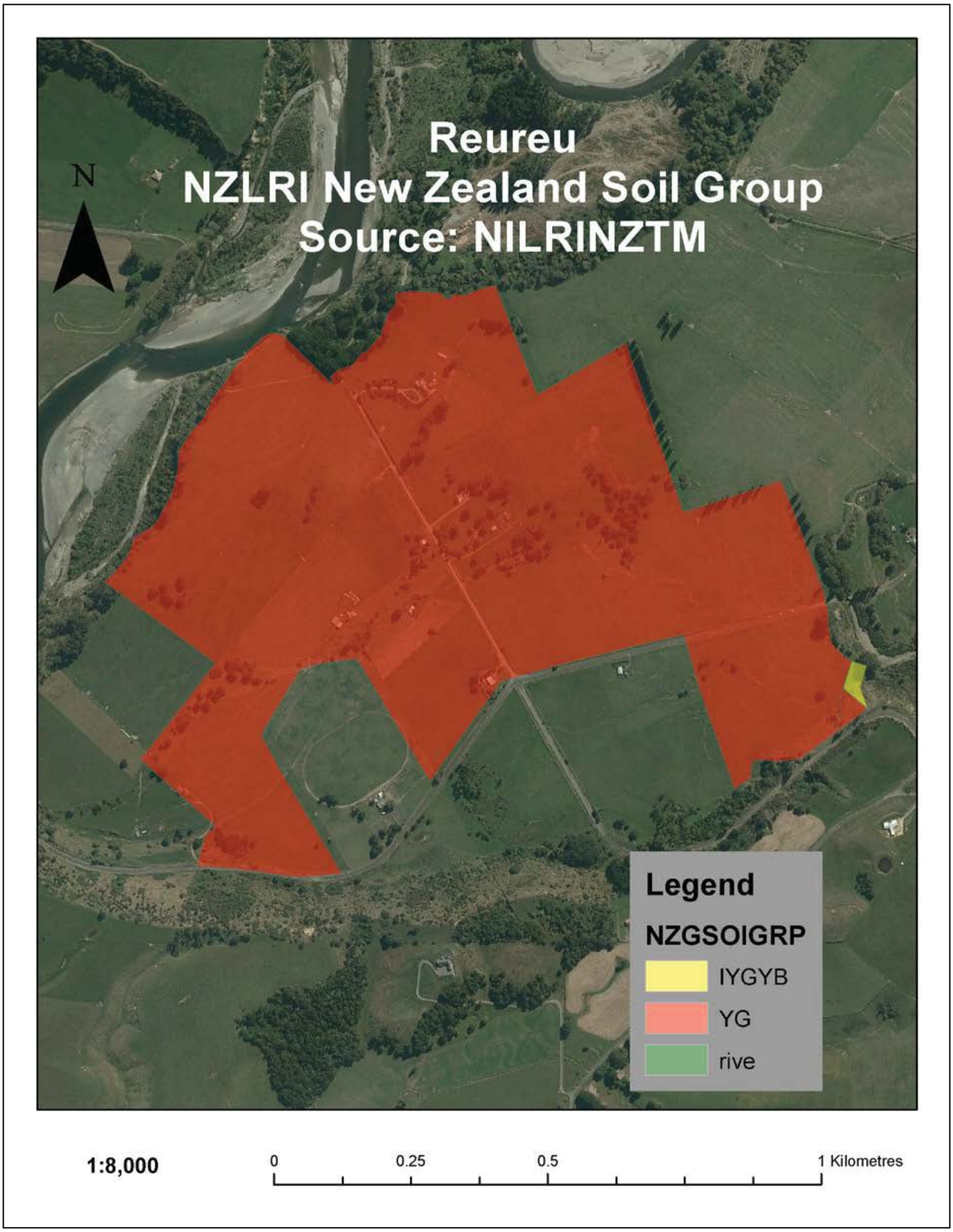
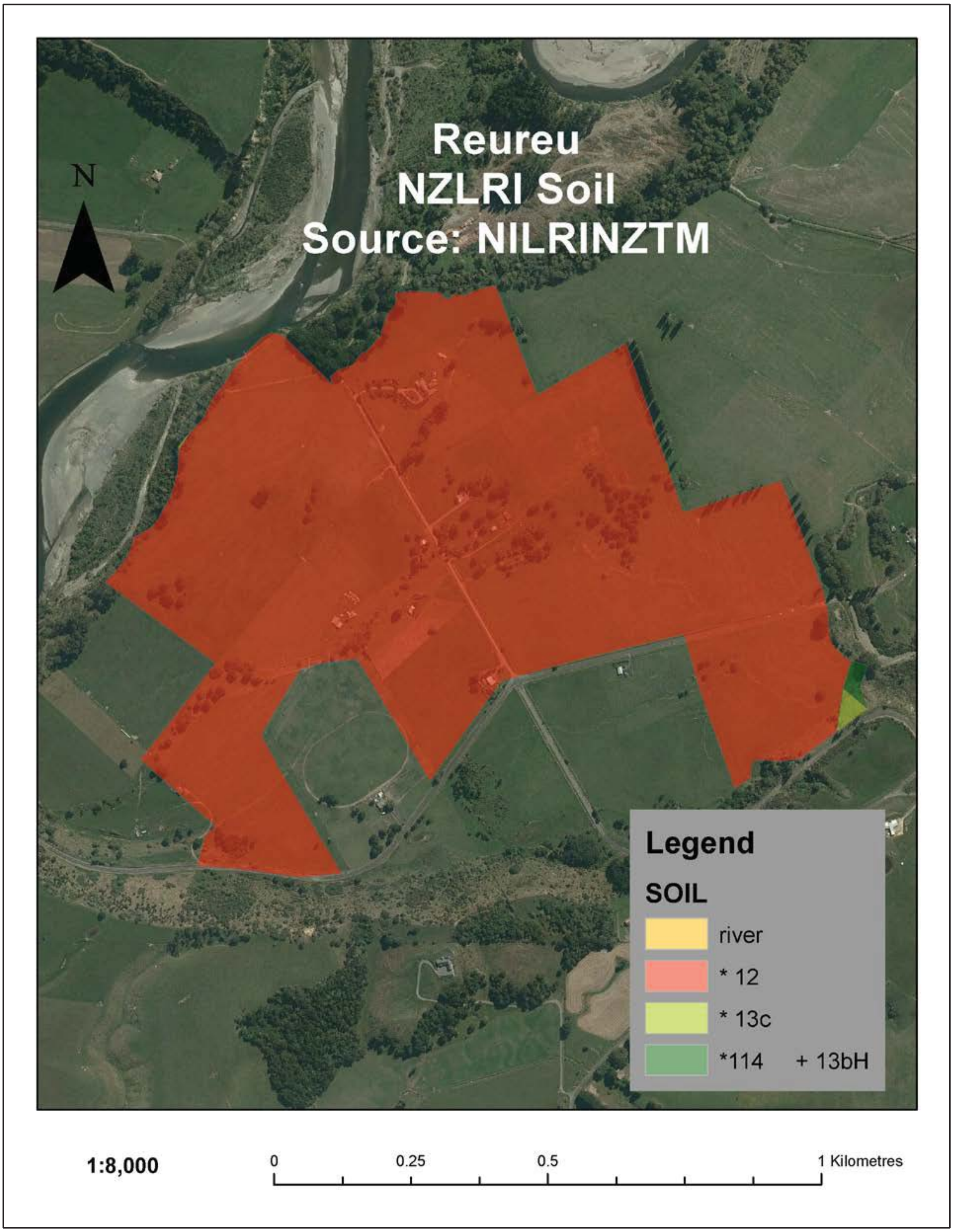
0 100200300
Meters

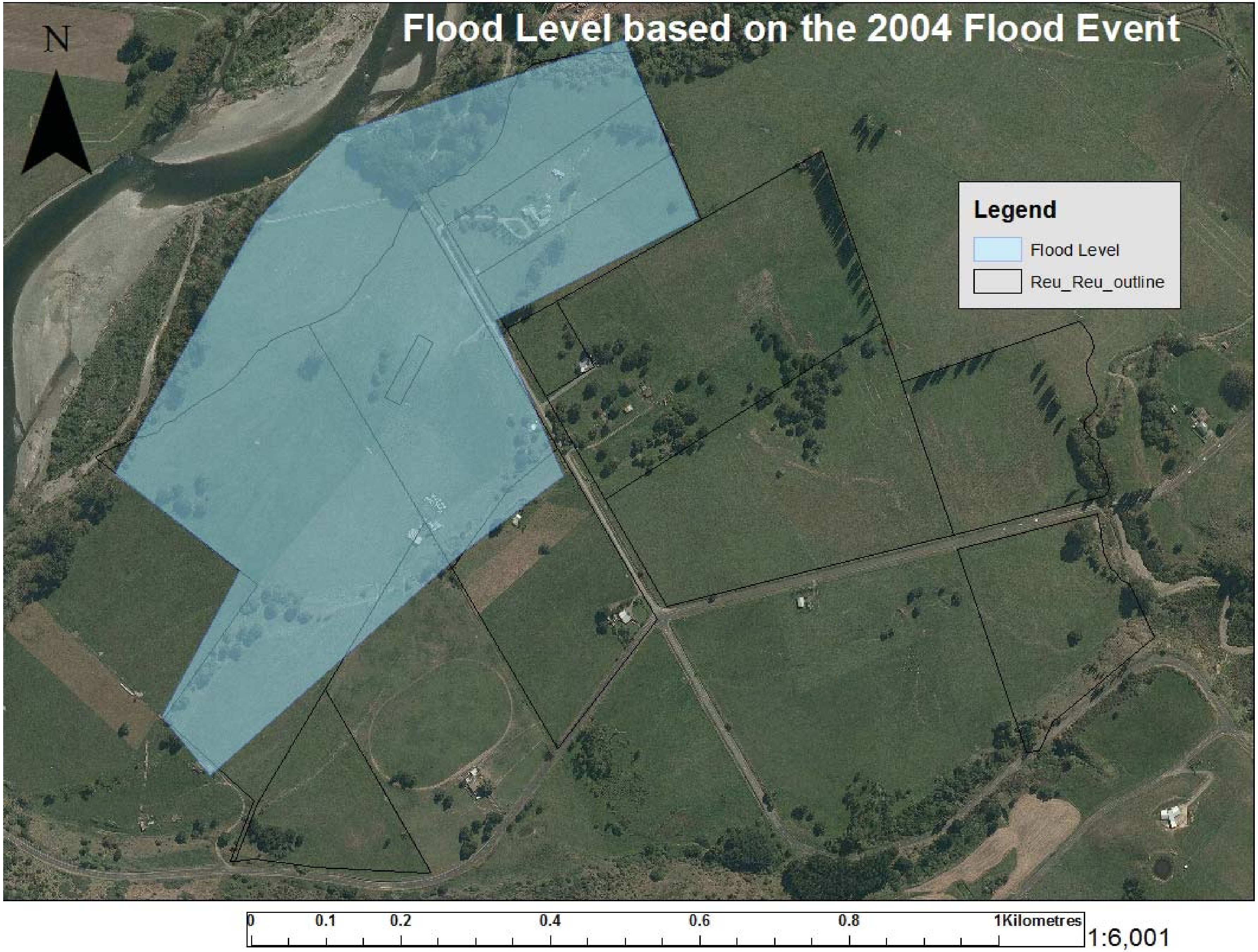

Onepuhi Rd - map for Reina
Key
Site of significance Riparian (dotterel)
horizons
N
0 100200300
Meters


REU REU LAND BLOCKS
NZSC - Soil Class
Legend
NZSC
Class
GOT
PIM
PPJ
RST
N
0
0.25
0.5
1 Kilometers

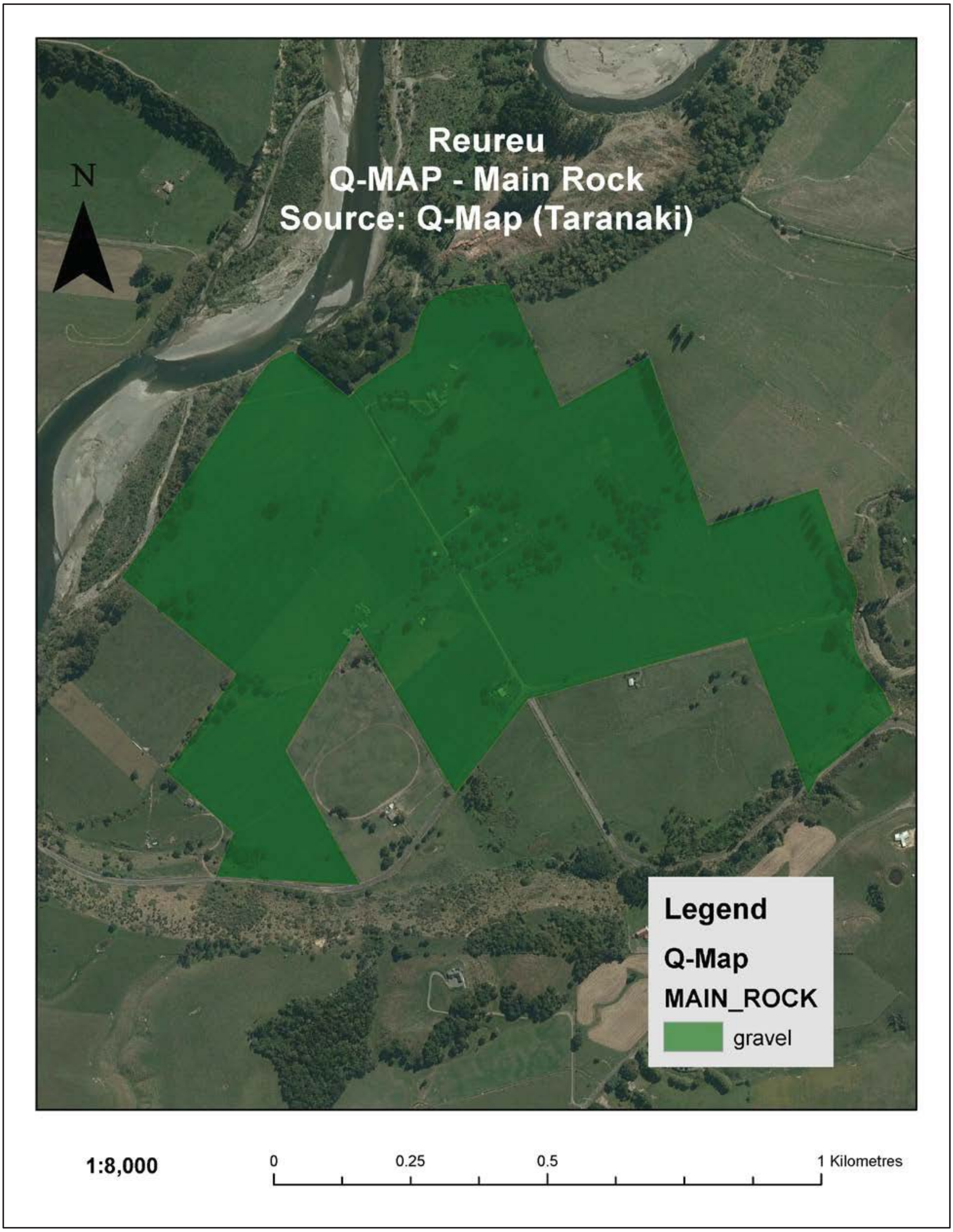

REU REU LAND BLOCKS
NZSC - Order
Legend
NZSC
Order
G
P
R
N
0
0.225
0.45
0.9 Kilometers


Reureu
NZLRI New Zealand Soil Group
Source: NILRINZTM
N
Legend
NZGSOIGRP
IYGYB
YG
rive
1:8,000
0
0.25
0.5
1 Kilometres


Reureu
NZLRI Soil
Source: NILRINZTM
N
Legend
SOIL
river
* 12
* 13c
*114 + 13bH
1:8,000
0
0.25
0.5
1 Kilometres

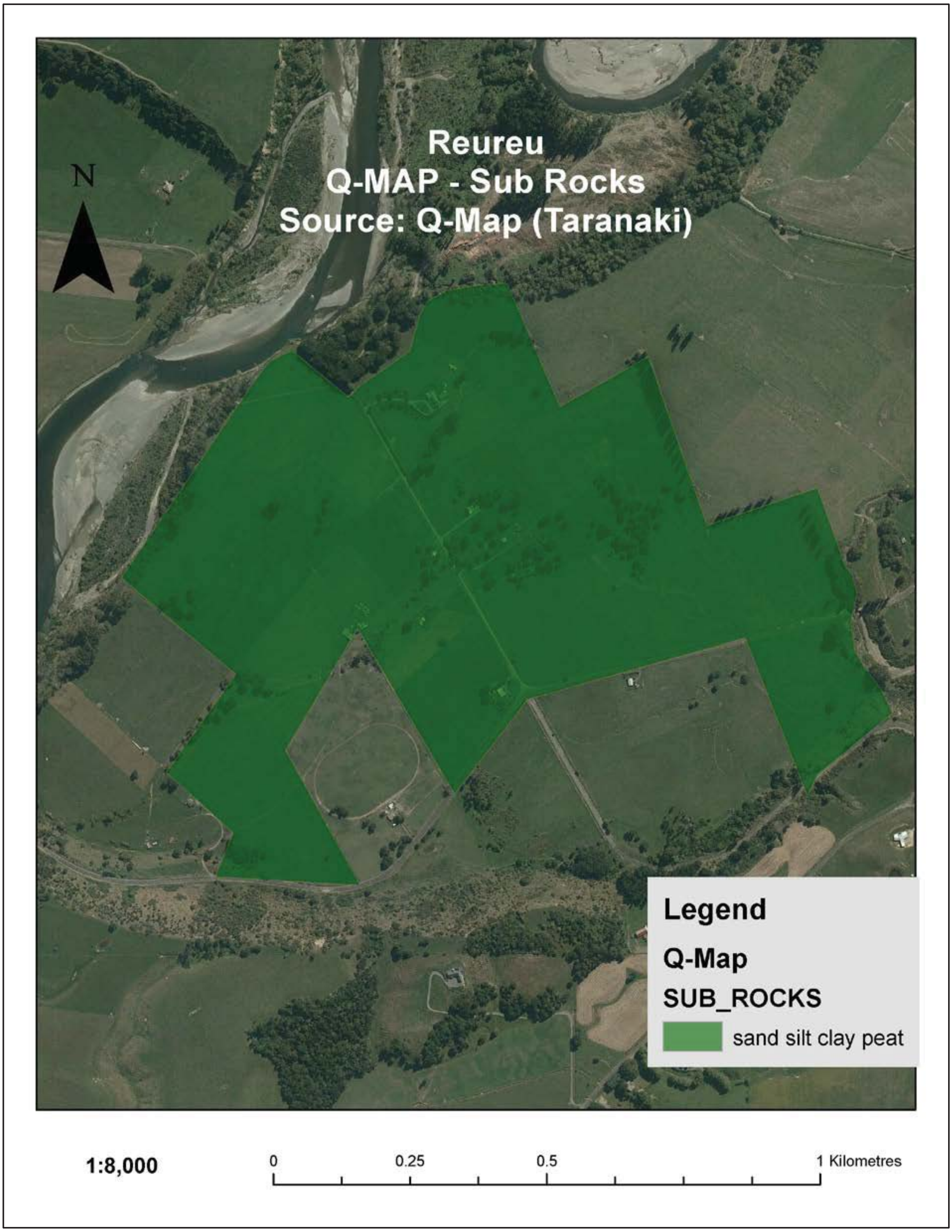

Flood Level based on the 2004 Flood Event
N
Legend
Flood Level
Reu_Reu_outline
0 0.1 0.2 0.4 0.6 0.8 1Kilometres
1:6,001


Reureu
Q-MAP - Description
Source: Q-Map (Taranaki)
N
Legend
Q-Map
DESCRIPTION
Alluvial gravel, sand, silt, mud and clay with local peat; includes modern river beds.
1:8,000
0
0.25
0.5
1 Kilometres

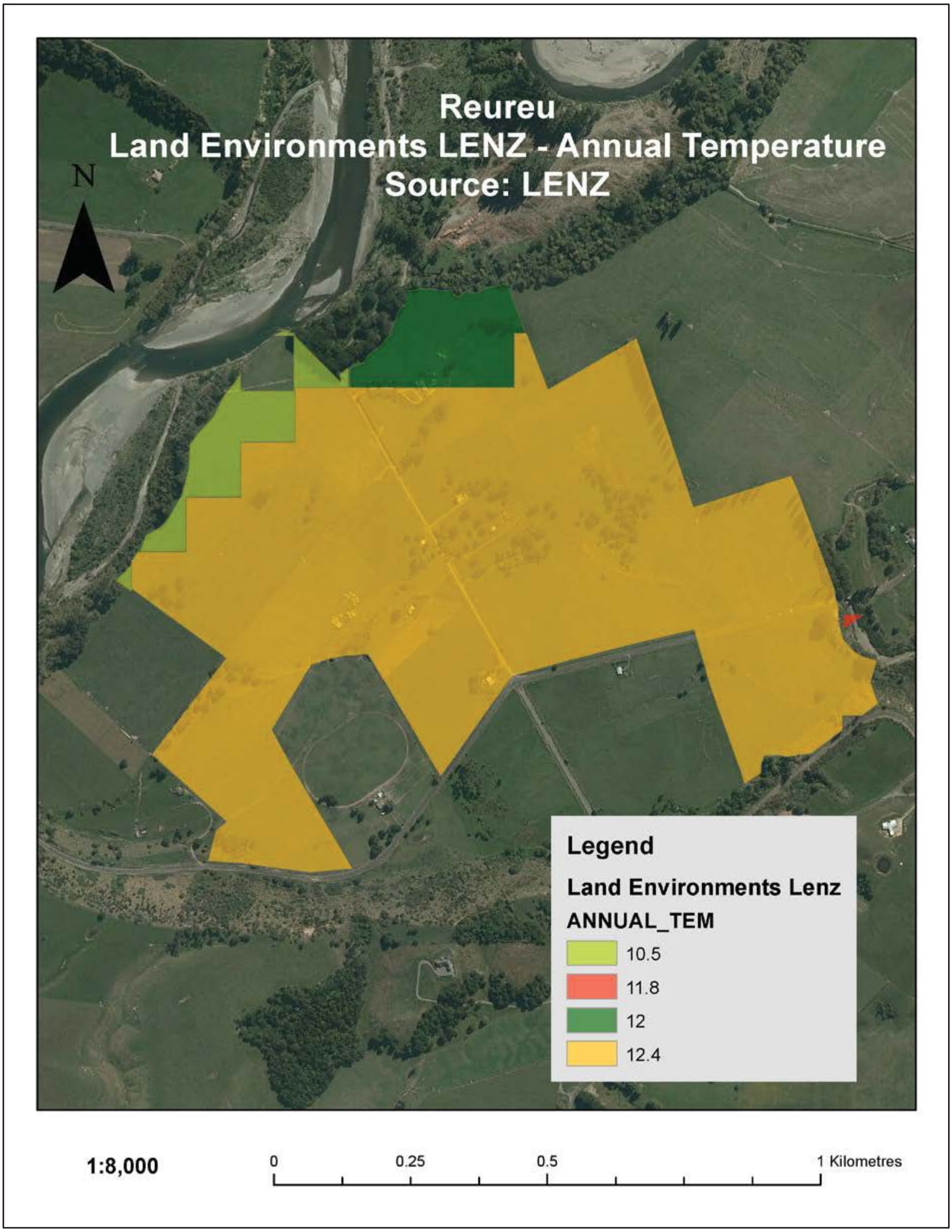

Reureu
Q-MAP - Main Rock
Source: Q-Map (Taranaki)
N
Legend
Q-Map
MAIN_ROCK
gravel
1:8,000
0
0.25
0.5
1 Kilometres

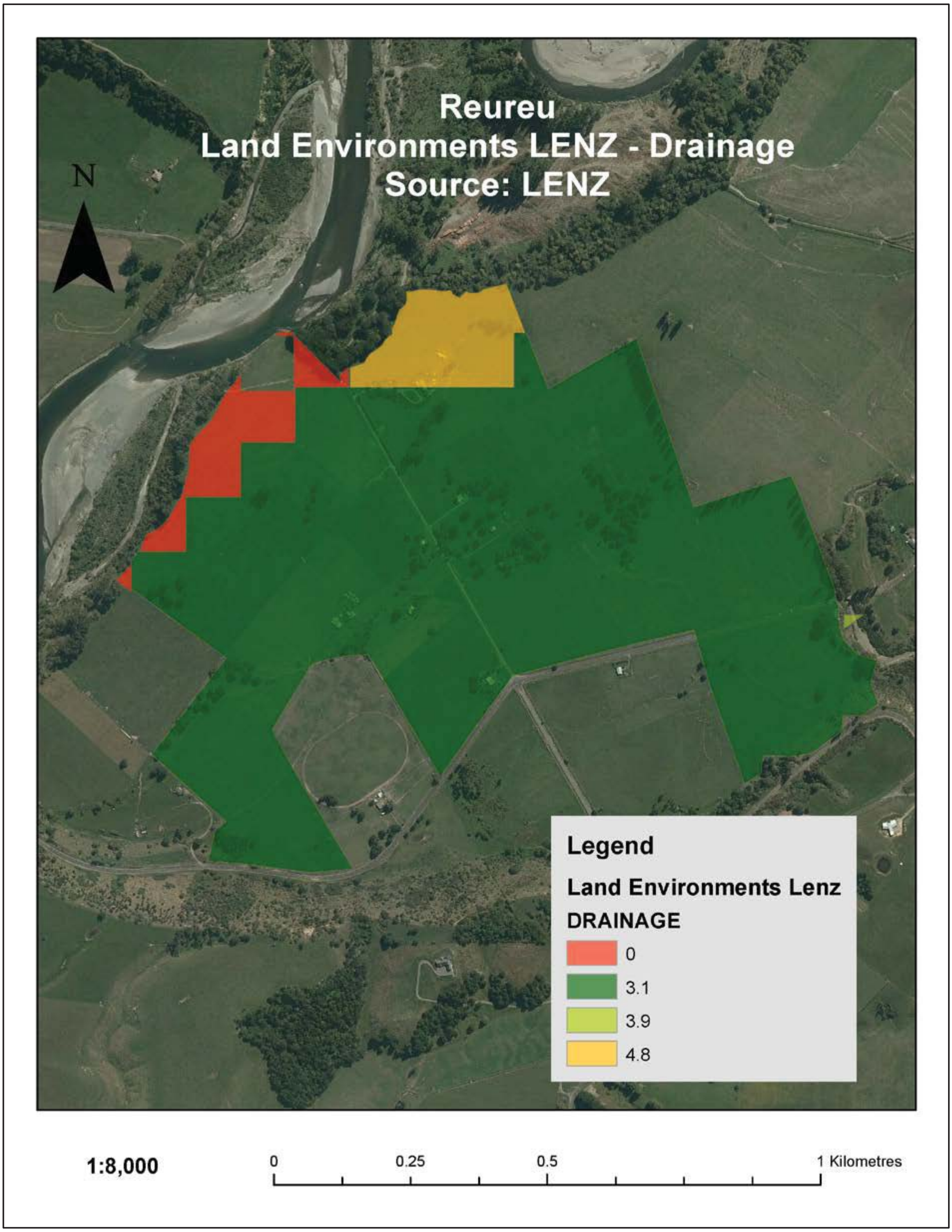

Reureu
Q-MAP - Rock Class
Source: Q-Map (Taranaki)
N
Legend
Q-Map
ROCK_CLASS
clastic sediment
1:8,000
0
0.25
0.5
1 Kilometres

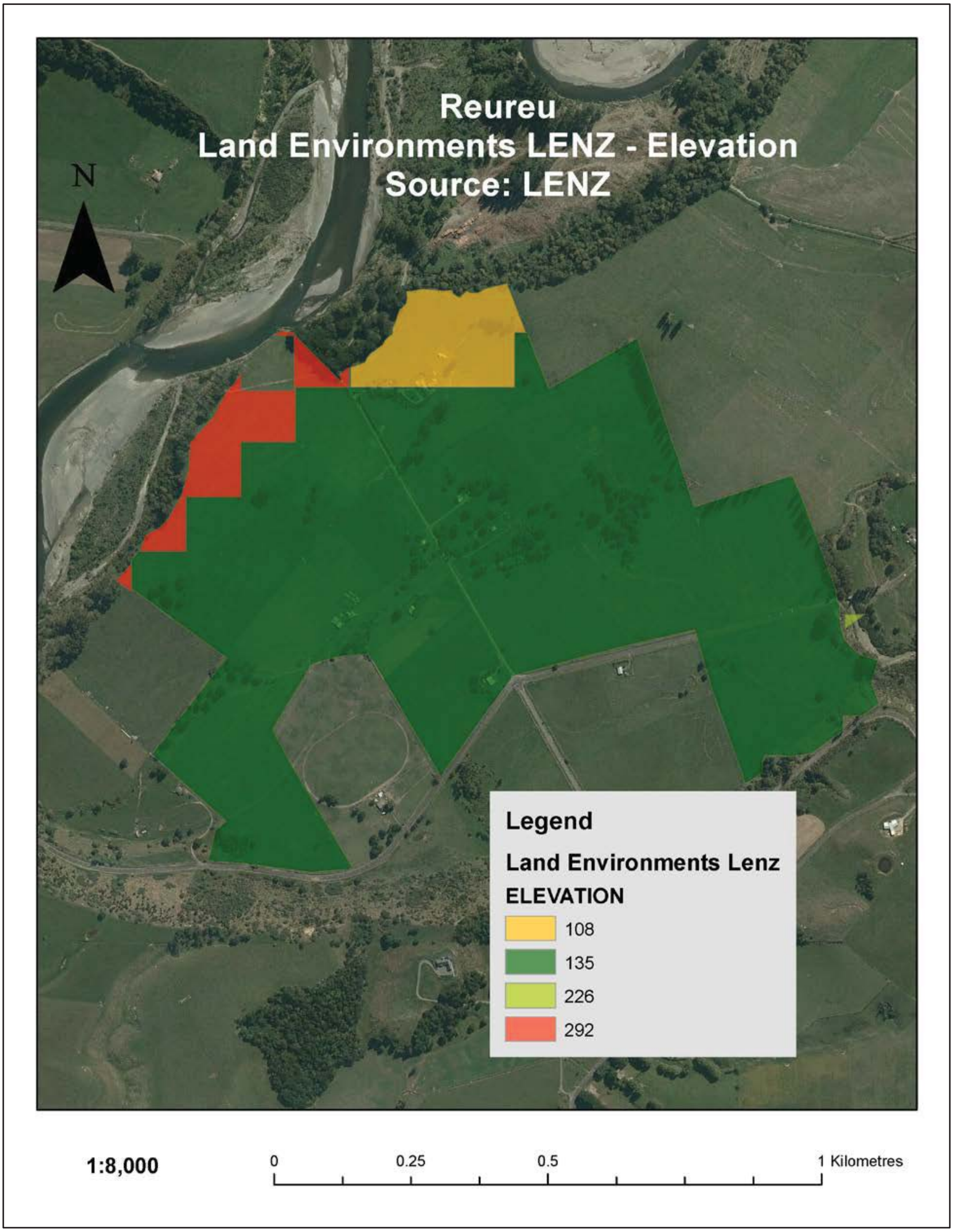

Reureu
Q-MAP - Strat Age
Source: Q-Map (Taranaki)
N
Legend
Q-Map
STRAT_AGE
Q1
1:8,000
0
0.25
0.5
1 Kilometres

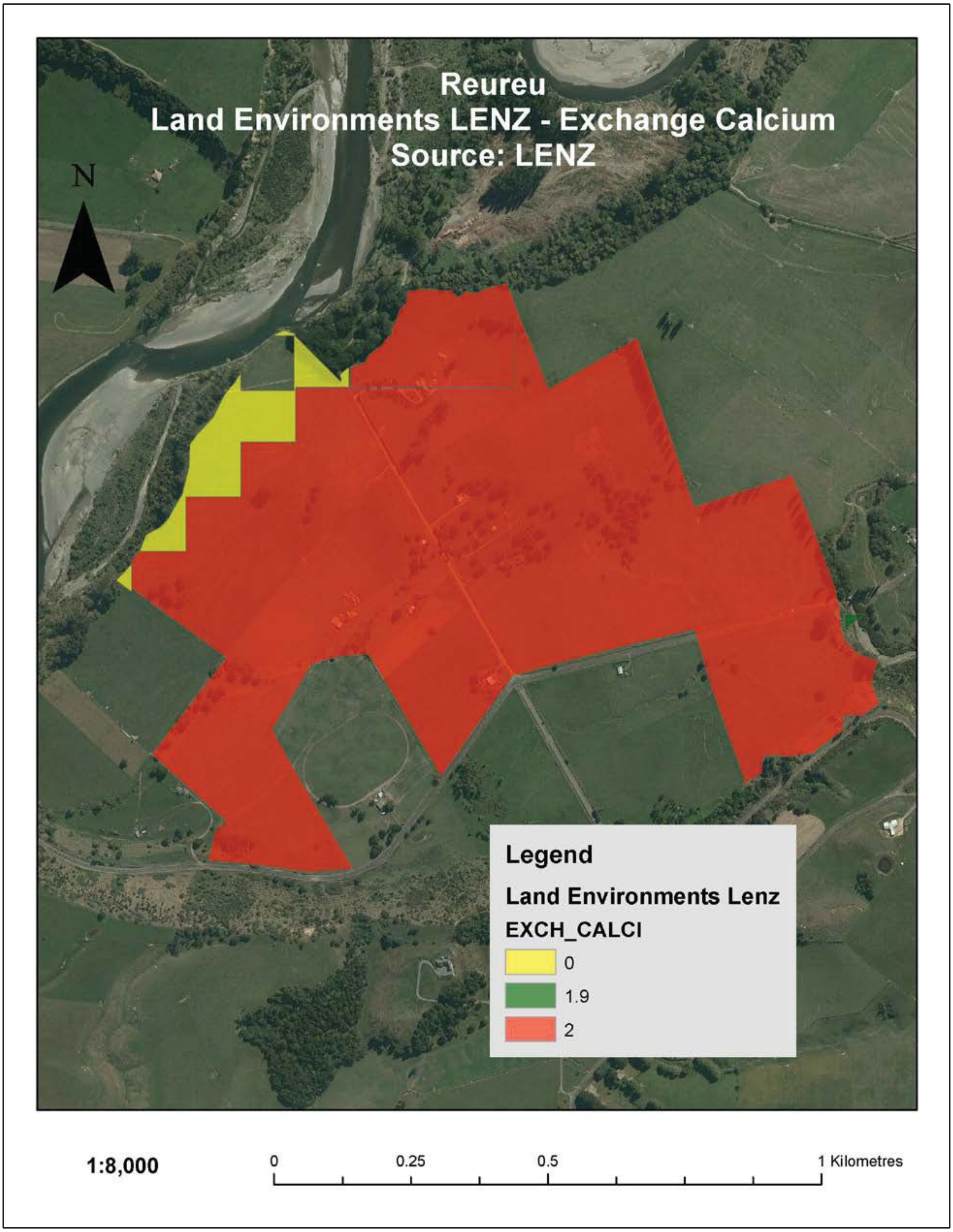

Reureu
Q-MAP - Sub Rocks
Source: Q-Map (Taranaki)
N
Legend
Q-Map
SUB_ROCKS
sand silt clay peat
1:8,000
0
0.25
0.5
1 Kilometres


Reureu
Q-MAP - Unit Code
Source: Q-Map (Taranaki)
N
Legend
Q-Map
UNIT_CODE
Q1al
1:8,000
0
0.25
0.5
1 Kilometres


Reureu
Land Environments LENZ - Annual Temperature
Source: LENZ
N
Legend
Land Environments Lenz
ANNUAL_TEM
10.5
11.8
12
12.4
1:8,000
0
0.25
0.5
1 Kilometres


Reureu
Land Environments LENZ - Drainage
Source: LENZ
N
Legend
Land Environments Lenz
DRAINAGE
0
3.1
3.9
4.8
1:8,000
0
0.25
0.5
1 Kilometres


Reureu
Land Environments LENZ - Elevation
Source: LENZ
N
Legend
Land Environments Lenz
ELEVATION
108
135
226
292
1:8,000
0
0.25
0.5
1 Kilometres


Reureu
Land Environments LENZ - Exchange Calcium
Source: LENZ
N
Legend
Land Environments Lenz
EXCH_CALCI
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1.9
2
1:8,000
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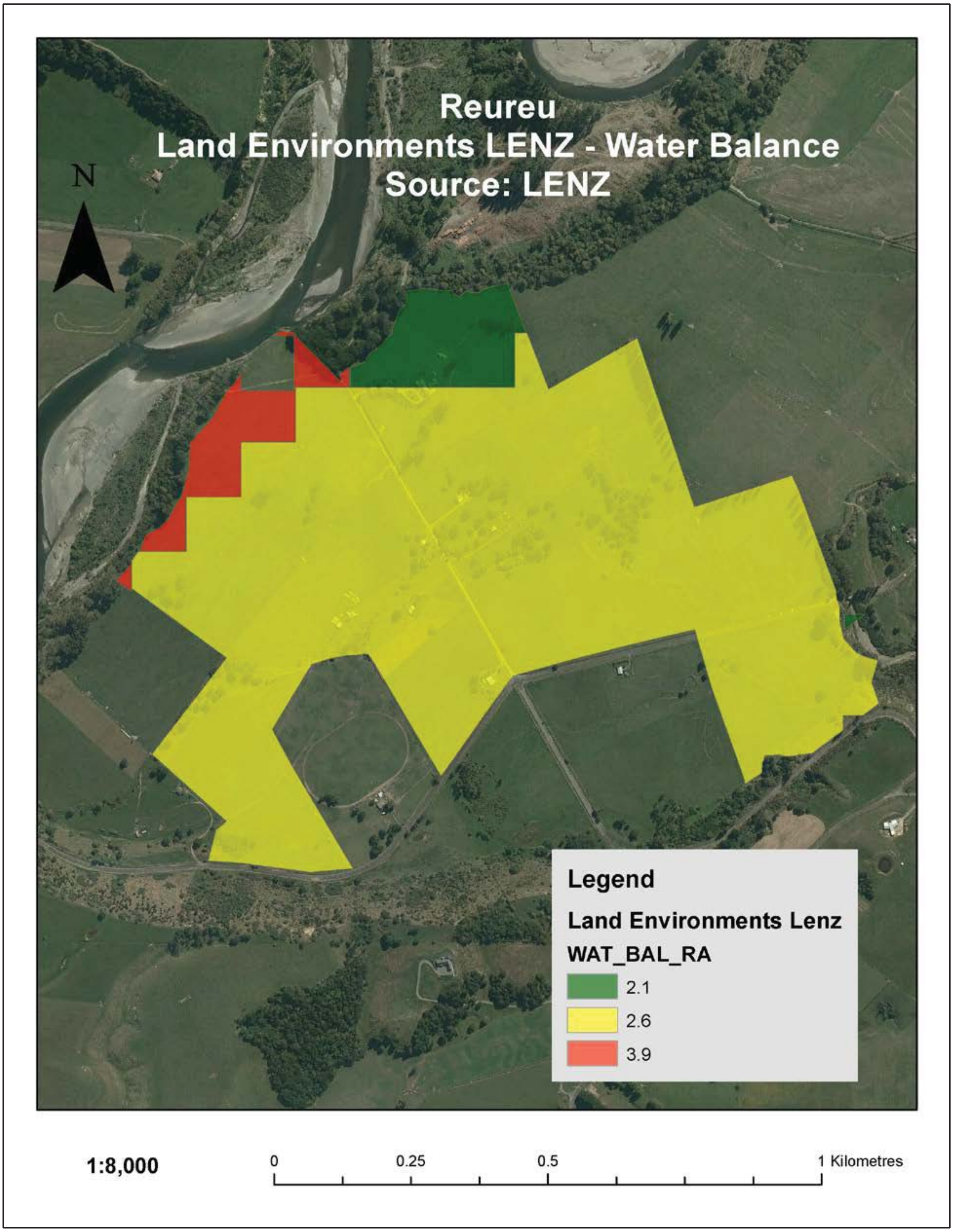
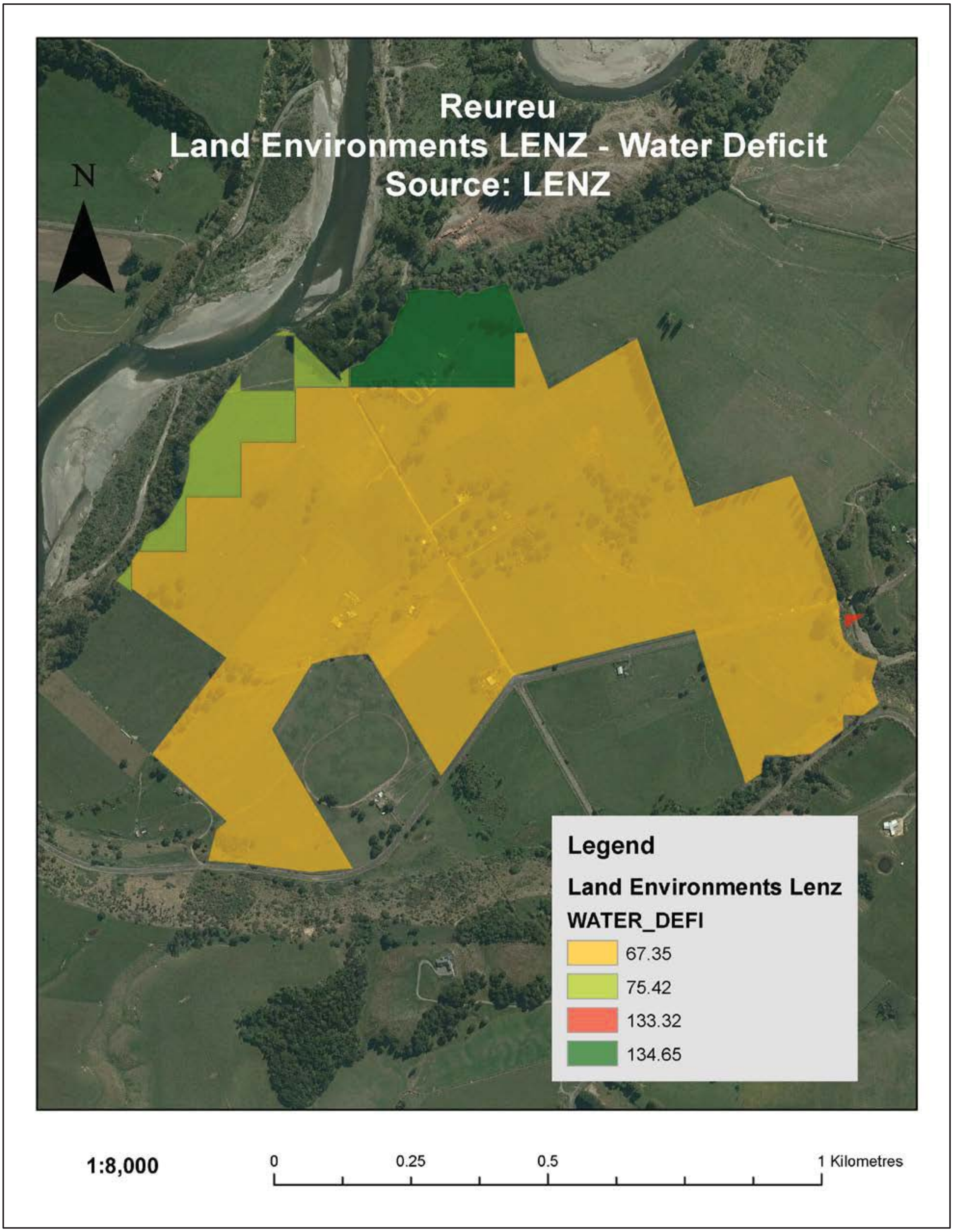
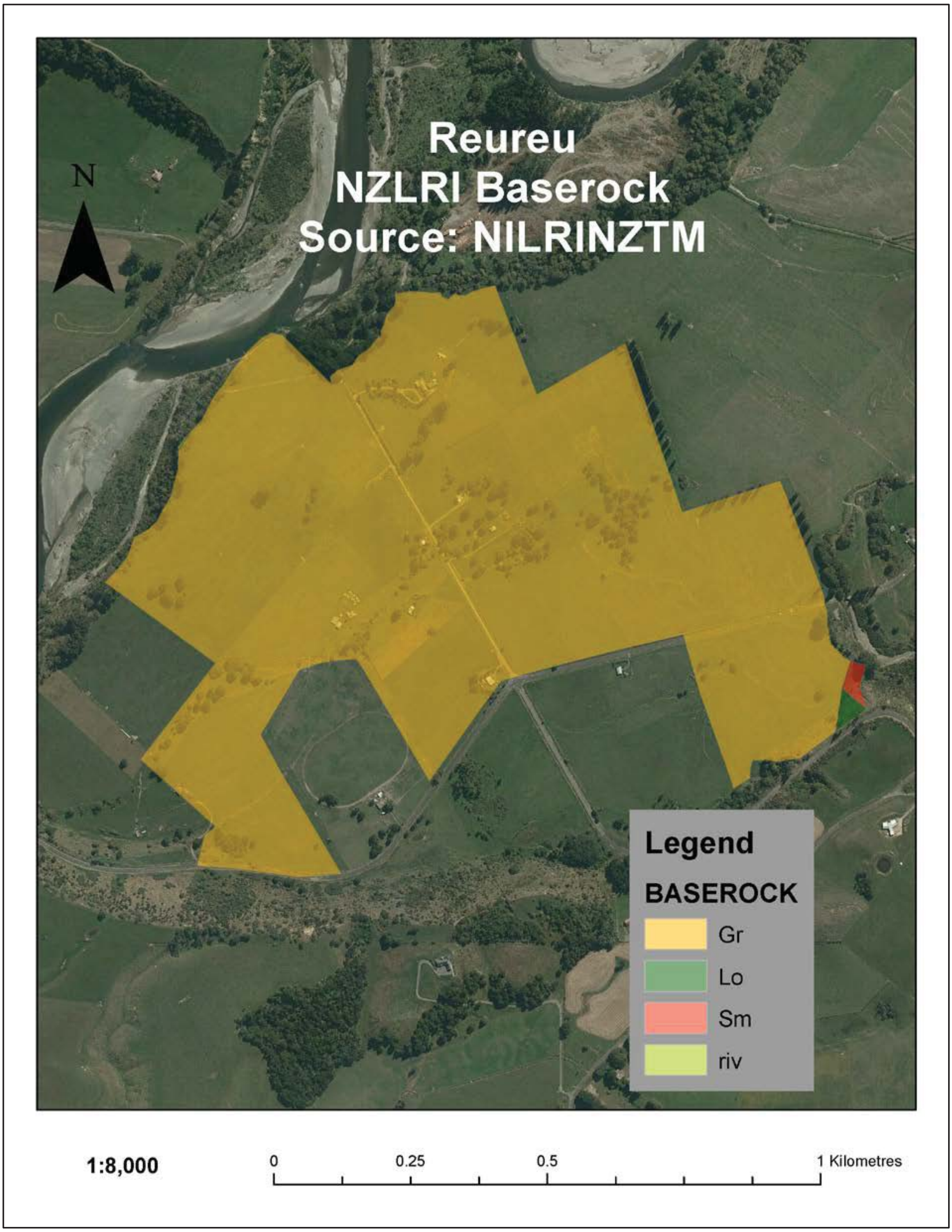
0.25
0.5
1 Kilometres


Reureu
Land Environments LENZ - Water Balance
Source: LENZ
N
Legend
Land Environments Lenz
WAT_BAL_RA
2.1
2.6
3.9
1:8,000
0
0.25
0.5
1 Kilometres


Reureu
Land Environments LENZ - Water Deficit
Source: LENZ
N
Legend
Land Environments Lenz
WATER_DEFI
67.35
75.42
133.32
134.65
1:8,000
0
0.25
0.5
1 Kilometres


Reureu
NZLRI Baserock
Source: NILRINZTM
N
Legend
BASEROCK
Gr
Lo
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riv
1:8,000
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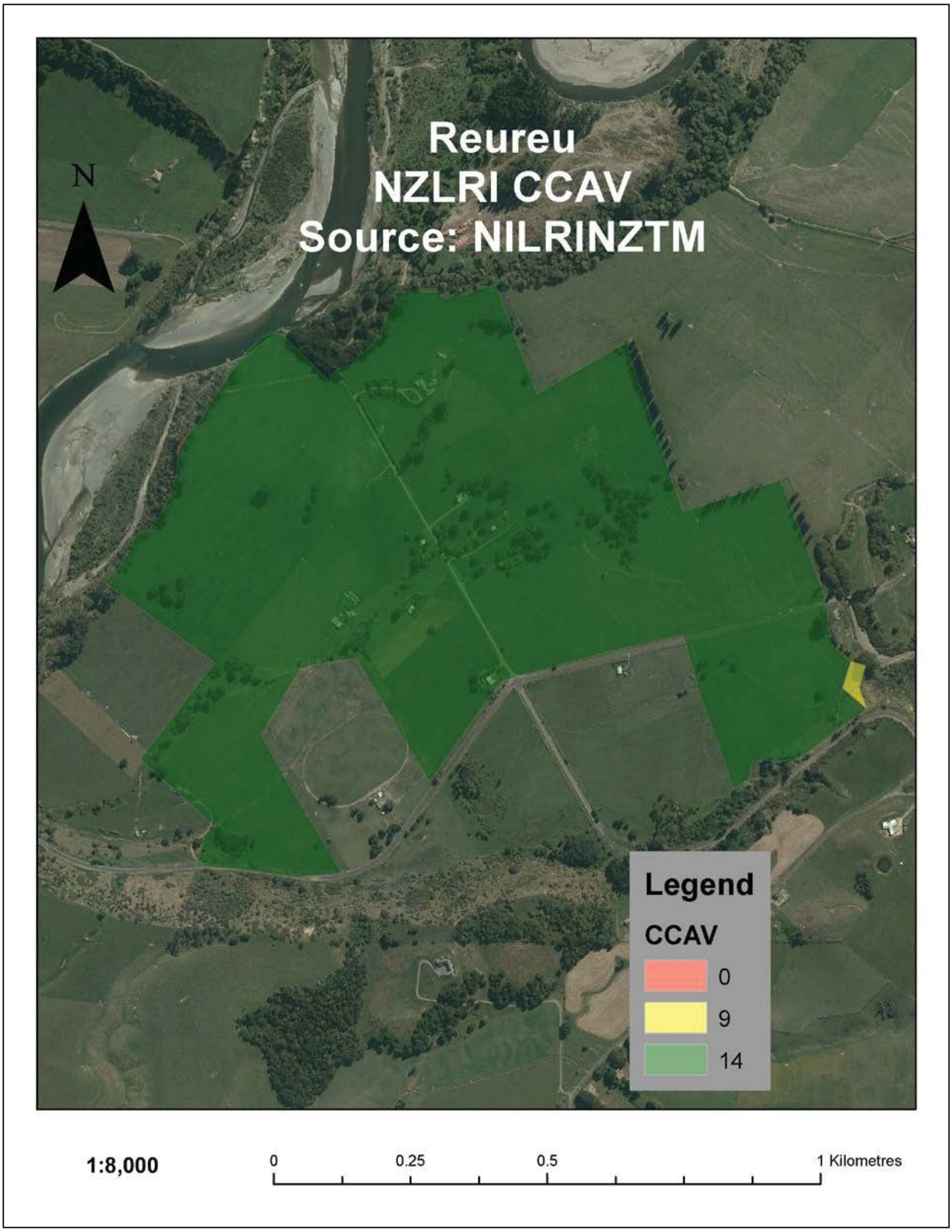
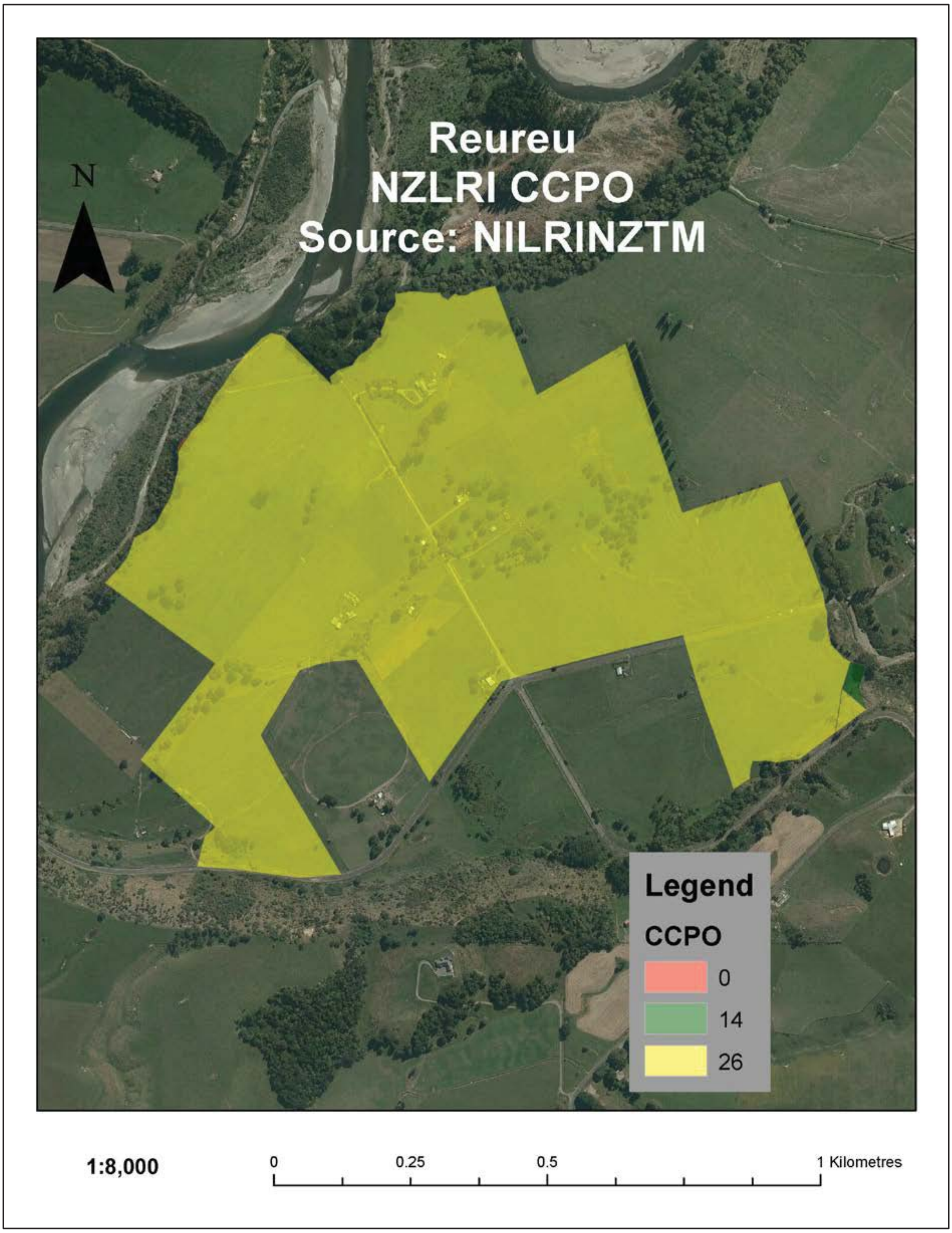
0.25
0.5
1 Kilometres


Reureu
NZLRI CCAV
Source: NILRINZTM
N
Legend
CCAV
0
9
14
1:8,000
0
0.25
0.5
1 Kilometres


Reureu
NZLRI CCPO
Source: NILRINZTM
N
Legend
CCPO
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14
26
1:8,000
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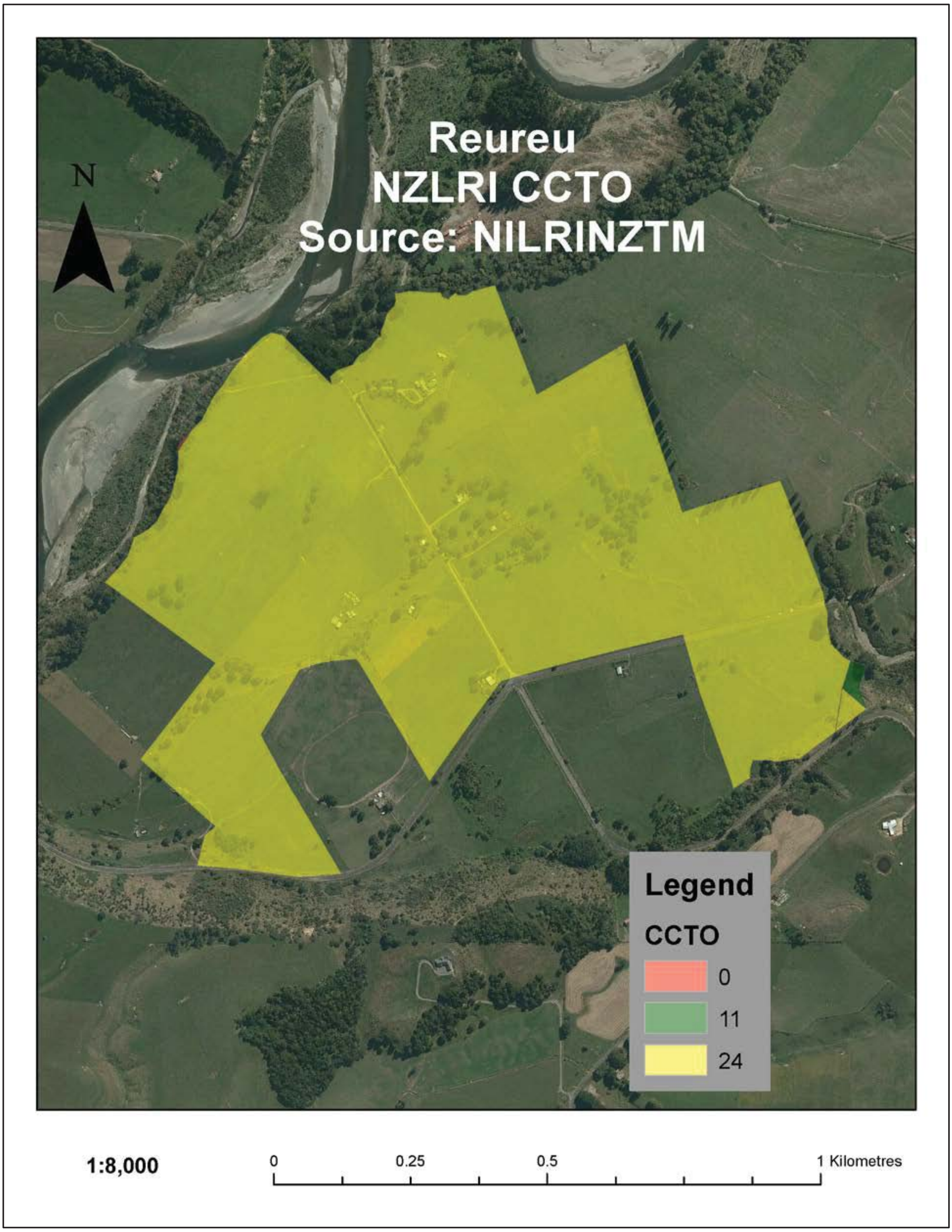
1 Kilometres


Reureu
NZLRI CCTO
Source: NILRINZTM
N
Legend
CCTO
0
11
24
1:8,000
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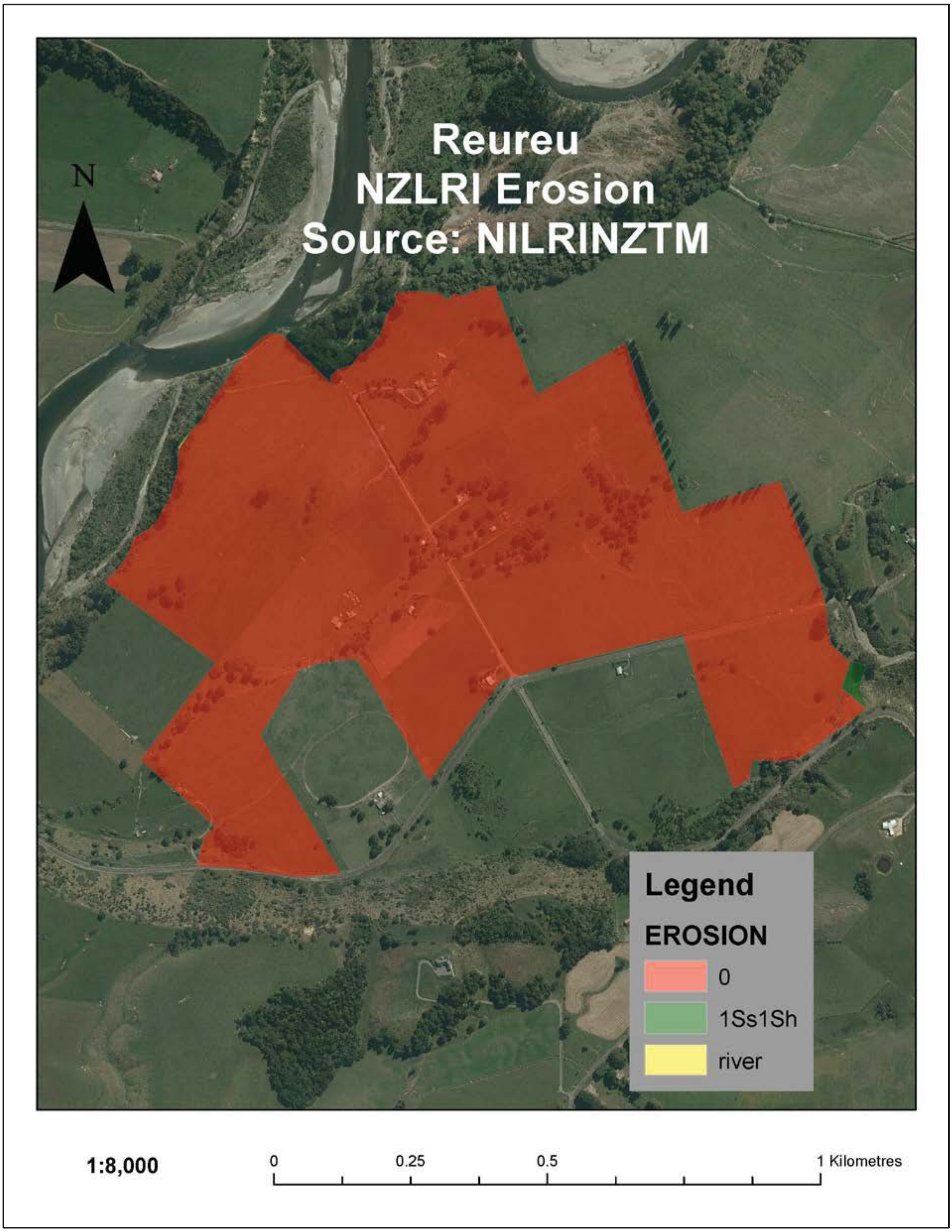
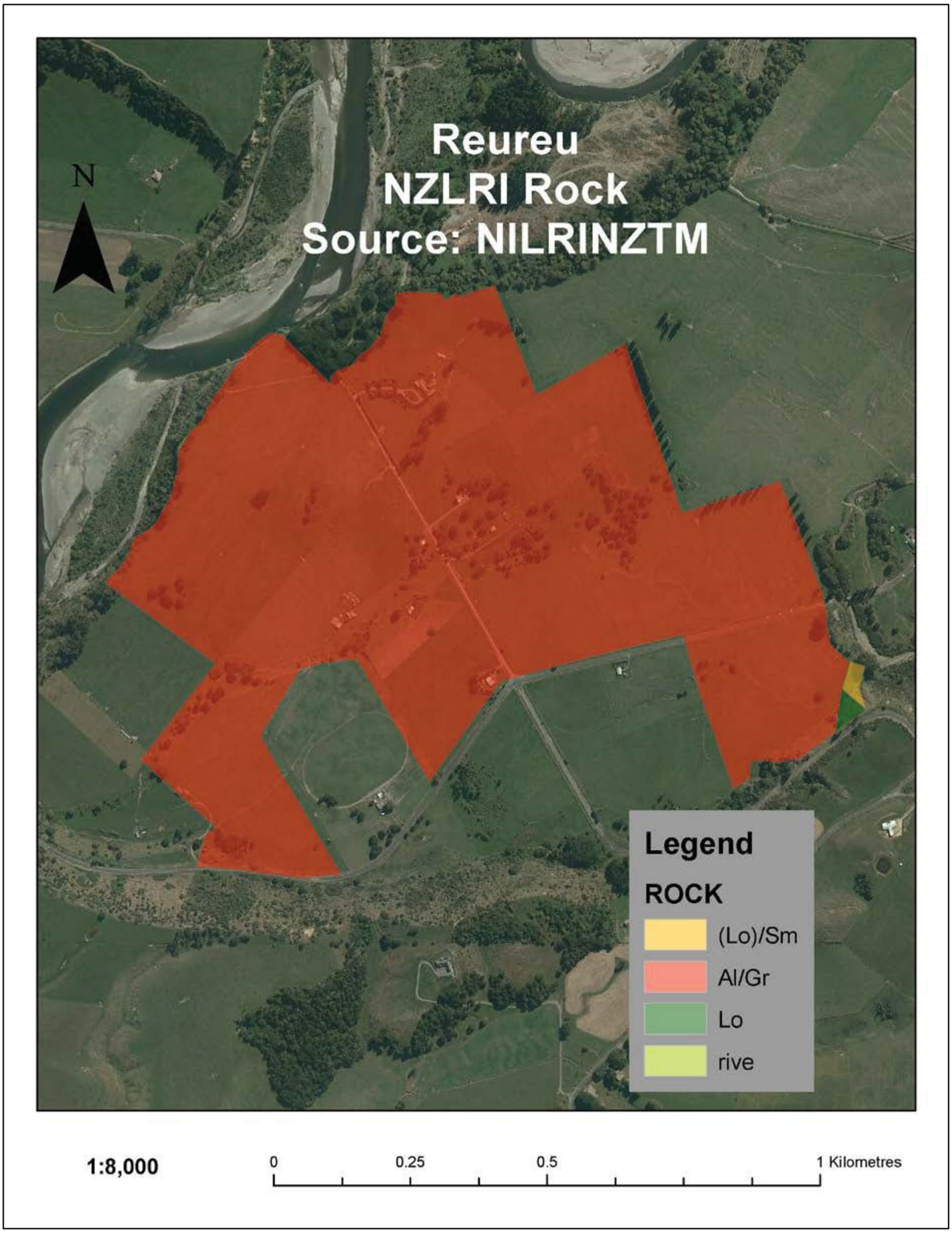
0.25
0.5
1 Kilometres


Reureu
NZLRI Erosion
Source: NILRINZTM
N
Legend
EROSION
0
1Ss1Sh
river
1:8,000
0
0.25
0.5
1 Kilometres


Reureu
NZLRI Rock
Source: NILRINZTM
N
Legend
ROCK
(Lo)/Sm
Al/Gr
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rive
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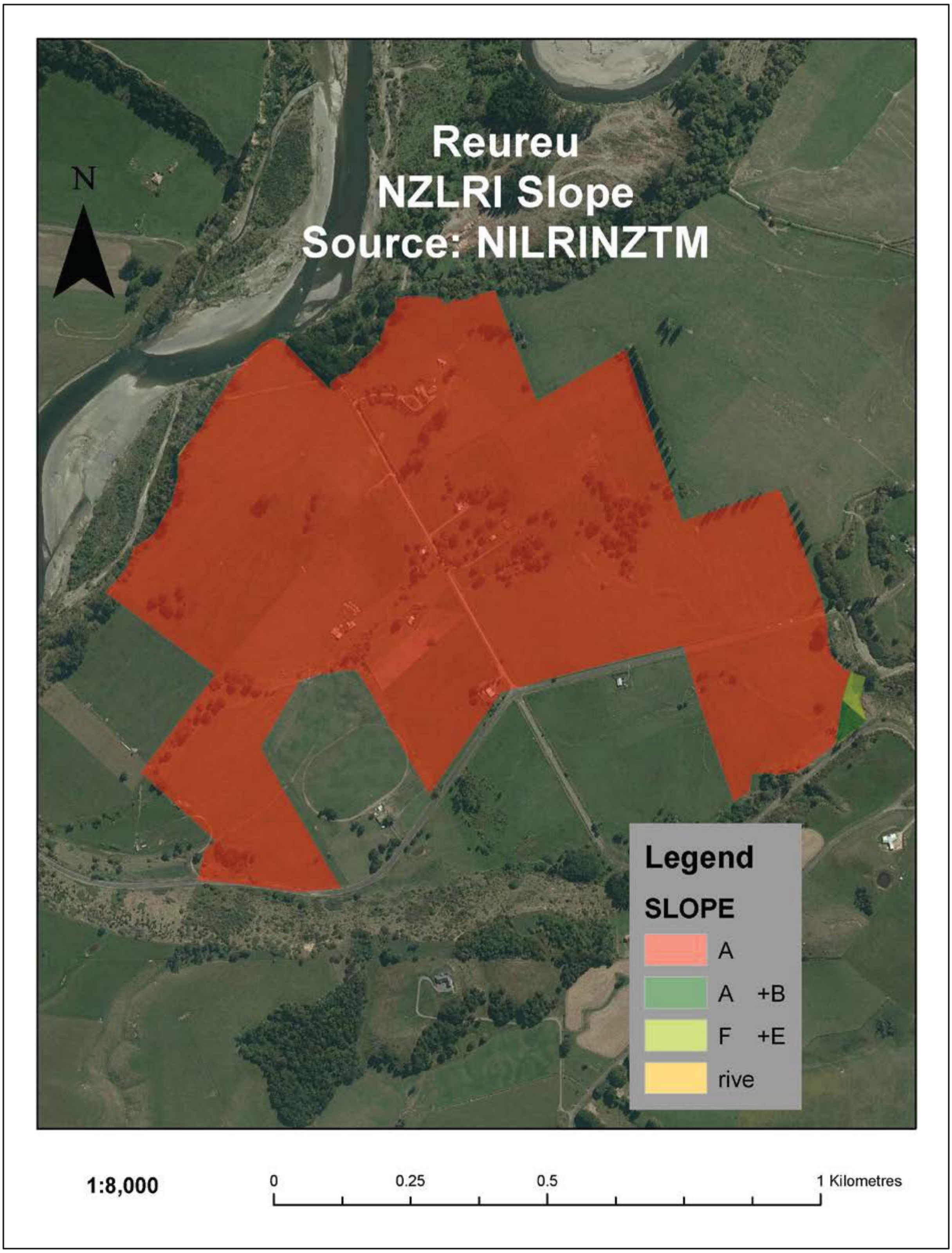
0.25
0.5
1 Kilometres


Reureu
NZLRI Slope
Source: NILRINZTM
N
Legend
SLOPE
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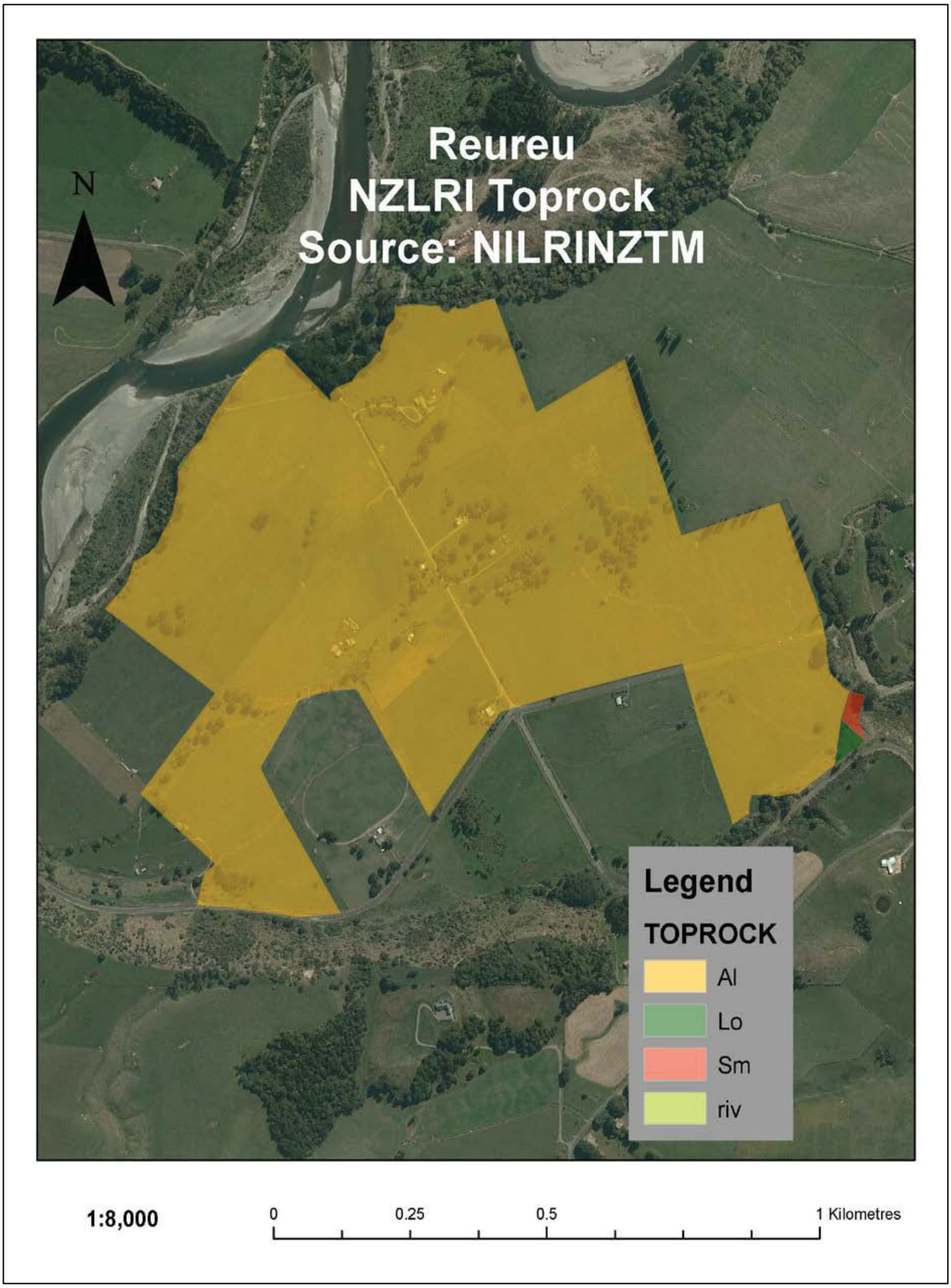
A +B
F +E
rive
1:8,000
0
0.25
0.5
1 Kilometres


Reureu
NZLRI Toprock
Source: NILRINZTM
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Legend
TOPROCK
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0.25
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1 Kilometres

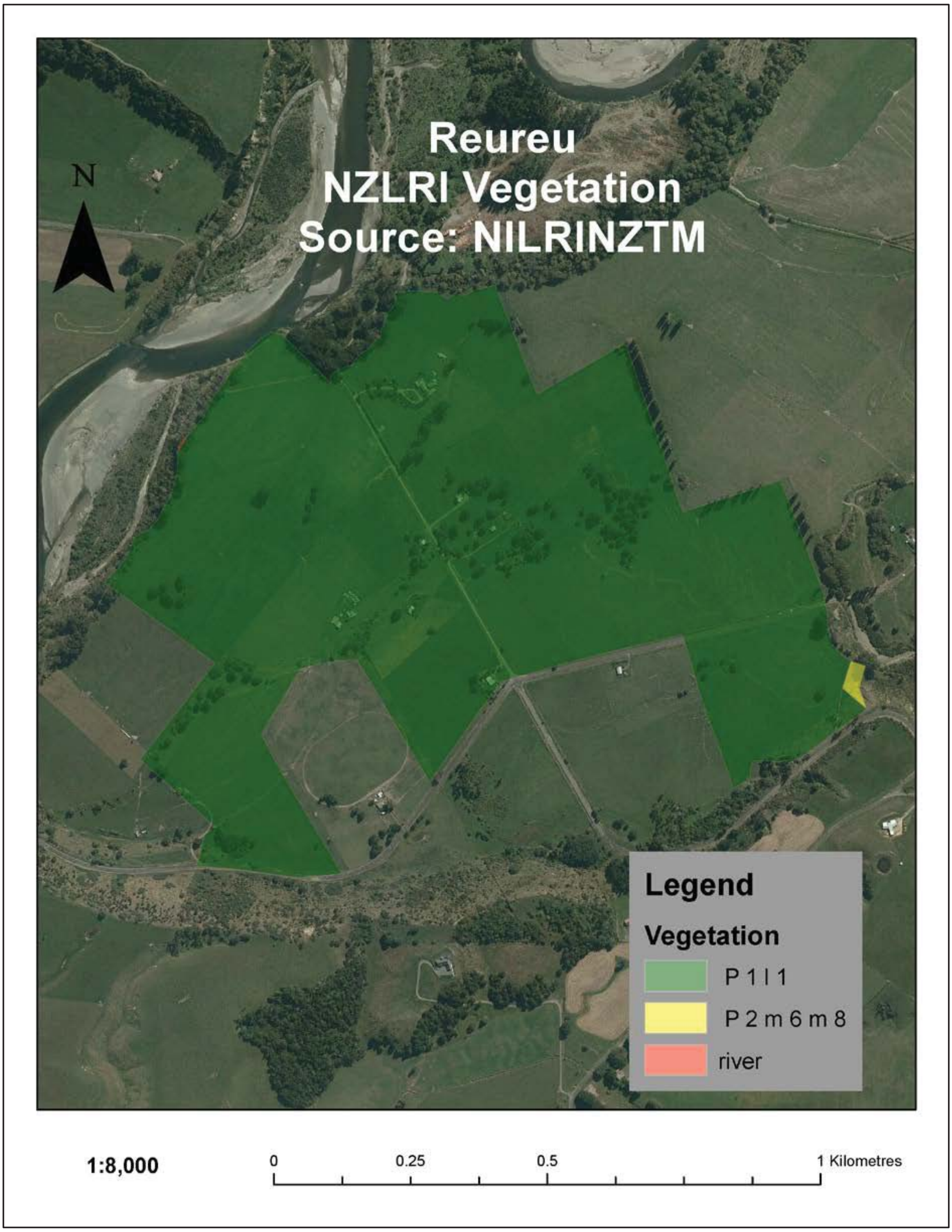
Reureu
NZLRI Vegetation
Source: NILRINZTM
N
Legend
Vegetation
P 1 l 1
P 2 m 6 m 8
river
1:8,000
0
0.25
0.5
1 Kilometres

Table 3.1.1 Commonly used soil tests in New Zealand

Test name	Extracting reagent	Measures
Olsen P	0.5 M Na HCO_3 at pH 8.5 (soil:soln, 1:20, 30 min)	Phosphate adsorbed on Fe and Al oxides plus a small amount of organic P
Resin P	Anion and cation resin exchange membranes (soil:soln, 1:30, 16hr)	the above plus a small amount of calcium bound P in limed soils and RPR treated soils.
Extractable Sulphate	0.01M Ca $(H_2PO_4)_2$ (soil:soln, 1:5, 30 min)	Sulphate adsorbed on Fe and Al oxides
Extractable Organic Sulphur	0.01M Ca $(H_2PO_4)_2$ (soil:soln, 1:5, 30 min)	Soluble organic S
Exchangeable Cations Ca^{2+}, K^+, Mg^{2+}, Na^+,	1M NH_4CH_3COO at pH7 leaching (soil:soln, 1:50, 1hr)	Cations on organic matter and clay surfaces
Soil pH	Water (soil:soln, 1:2.5, overnight)	hydrogen ions
Phosphate retention (anion storage capacity)	1000 ppm P in acetate buffer pH 4.65(soil:soln, 1:5, 16hr)	Storage of phosphate through adsorption onto soil surfaces

Table 3.1.2 Infrequently used soil tests in New Zealand

Soil Test (reference)	Extracting reagent	Nutrient extracted
Bray1 (Bray and Kurtz, 1945)	0.03 M Ammonium fluoride plus 0.025 M Hydrochloric acid (pH3, soil:soln, 1:7, 1 min)	Phosphate adsorbed on Fe and Al oxides plus a small amount of acid soluble P (care with RPR fertilised soils)
Bray2 (Bray and Kurtz, 1945)	0.03 M Ammonium fluoride plus 0.1 M Hydrochloric acid (pH1, soil:soln, 1:7, 40 secs)	Phosphate adsorbed on Fe and Al oxides plus slightly greater amounts of acid soluble P (care with RPR fertilised soils)
Colwell (Colwell, 1963)	0.5 M Na HCO_3 at pH 8.5 (soil:soln, 1:20, 16 hr)	Phosphate adsorbed on Fe and Al oxides plus a small amount of organic P (used in Australia as alternative to Olsen P, extracts more P than Olsen)
Mehlich-3 (Mehlich, 1984)	0.2M CH_3COOH, 0.25M NH_4NO_3, 0.015M NH_4F, 0.013M HNO_3 and 0.001M EDTA	Potentially a multi-element extraction for anions and cations (care with RPR fertilised soils)
Mineralisable N (Keeney, (1982).	(soil:soln, 1:4, anaerobic incubation for 15 days, then extraction soil:soln, 1:6, 1M KCl, 20 min)	Decomposes readily degradable organic matter, N released stays as NH_4^+ in anaerobic conditions

DRAFT CONDITIONS

General (apply to both consents)

1. The consent holder must undertake the activity in general accordance with the consent application including all accompanying plans and documents first lodged with the Manawatu-Wanganui Regional Council on < date >, and:

    a. further information received <date> via <email/phone/letter> being <description>;
    b. The latest Dairy Effluent Storage Calculator Summary Report.
    c. Nutrient Management Plan Technical Summary and any subsequent updates approved by the Regulatory Manager.
    d. Nutrient Management Plan (NMP)

    Where there may be inconsistencies between information provided by the applicant and conditions of the resource consent, the conditions of the resource consent take precedence.

    Advice Note: The purpose of the Nutrient Management Plan is to satisfy the Regional Council that the consent holder can operate in a way that will achieve the requirements of the Rule and meet the conditions of consent. It is not intended that there will be enforcement of any specific management practices, as it is acknowledged these can vary, particularly because of climatic conditions. Rather, it is an assurance that the framework within which the farm will operate will not be altered to the extent that it may compromise the ability of the consent holder to achieve compliance with the following conditions.

2. This consent authorises the use of the property and the discharge of associated dairy farm animal effluent into and onto land, legally described as XYZ XYZ XYZ for a new dairy farming operation located at approximate NZTopo50 map reference xxxxxxx (hereafter referred to as the property) which is shown in Plan C< number >A attached to and forming part of this resource consent.

3. There must be no offensive or objectionable odour, dust, or effluent drift beyond the property boundary.

4. The Manawatu-Wanganui Regional Council, under section 128 of the Act, may initiate a review of all conditions of this resource consent during July in the year(s) < number > for the purpose of reviewing the effectiveness of these conditions in avoiding or mitigating any adverse effects on the environment. The review of conditions shall allow for:

    a. deletion or amendments to any conditions of this resource consent to ensure adverse effects are appropriately mitigated; or
    b. addition of new conditions as necessary, to avoid, remedy or mitigate any unforeseen adverse effects on the environment; or
    c. if necessary and appropriate, the adoption of the best practicable options to avoid, remedy or mitigate any adverse effects on the environment.

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Discharge conditions

10. The activities authorised by this resource consent shall be restricted to the discharge of Farm Animal Effluent (hereafter referred to as effluent) into and onto land.

    Advice note: Dairy Farm Animal Effluent includes faeces and urine from dairy cattle used for milk production including associated process water, washdown water, contaminants and sludge. It also includes effluent generated from the use of feedpads, farm races and underpasses if this infrastructure is present on the property.

11. In addition to Condition 10, the consent holder must undertake the activity in accordance with the latest Dairy Effluent Storage Calculator Summary Report which has been accepted and approved by the Manawatu-Wanganui Regional Council.

    Advice note: If you make changes to your infrastructure (i.e. additions to the effluent storage facility, additions to yard area) or increase your herd size, to remain compliant with this condition, a new Dairy Effluent Storage Calculator Summary Report will need to be produced and submitted to the Manawatu-Wanganui Regional Council.

12. This resource consent will not commence until the existing resource consent (< number >) has expired or been surrendered to Manawatu-Wanganui Regional Council. < only include this condition if the applicant has not surrendered it via the application form and it is for a replacement consent (not to be used for renewals)

Storage Requirements

13. The consent holder must construct and maintain an effluent storage facility able to contain at least the effluent volume specified in the Dairy Effluent Storage Calculator Summary Report accepted and approved under Condition 11.

    Advice note: Storage ponds should be operated at low levels when conditions for effluent disposal are suitable in order to maintain storage for wet weather periods. In particular, storage ponds should be emptied in late summer / early autumn to ensure sufficient storage capacity for the following late winter / early spring period.

    Advice note: Please contact your local District Council to find out if they have any requirements about the construction and location of your pond or other farm infrastructure.

14. The effluent storage facility (including sumps and ponds) required by Condition 13 and any other effluent storage facility (including sumps, new ponds and pond extensions) that is constructed, extended or deepened, must at all times have a surface or a lining with a permeability not exceeding 1×10^{-9} m/s.

15. REFER TO AS BUILT CONDITIONS

Surface and Groundwater Contamination

16. The consent holder must ensure that the discharge of effluent into and onto land, including from the effluent storage facility, does not result in any:

    a. ponding of effluent on the soil surface; or

NUTRIENT MANAGEMENT
NEW INTENSIVE FARMING CONVERSIONS IN THE HORIZONS REGION

New intensive farming activities (dairying, commercial vegetable growing, cropping, and irrigated sheep and beef) will need to apply for a Land Use (nutrient management) consent which will allow you to sustainably run your operation into the future. This applies to a complete conversion or bringing new land into an existing intensive operation anywhere in the Horizons Region.

The purpose of this new consent is to manage nutrient (N and P), sediment, and faecal bacteria loss from the farm so water quality in streams, rivers, or groundwater is either maintained or improved. The preparation of a Nutrient Management Plan is the basis of the consent application. The new aspect of this approach is the calculation of an amount of nitrogen that can be leached (kg per hectare per year) based on the Land Use Capability of the farm.

SHOULD YOU WISH TO PROCEED WHAT DO YOU NEED TO DO?

1

Have a Nutrient Management Plan prepared. This will identify all the physical characteristics of the farm and how the farm will be managed. Importantly, it will show the nitrogen leaching allowance. **We can provide a list of qualified consultants** (they must at least have a Certificate of Completion in Advanced Sustainable Nutrient Management from Massey University). If you choose a consultant not on the Horizons list **make sure the person is appropriately qualified otherwise your consent application may not be accepted.**

2

The consultant will prepare a Nutrient Management Plan (NMP) for your proposed farming operation. All consent applications require a NMP. Please note that NMPs and soil mapping take time to complete. The earlier your NMP is prepared the more time you will have to understand the implications of the consent to your business. If it is a dairy conversion don't forget to include in your NMP any run-offs used or proposed to be used to graze mixed aged dairy cows.

3

Apply for resource consent
Contact Horizons for a New Land Use Consent application form. The NMP will form the basis of your consent application.

How long will you get consent for?

- **If your farming system meets the leaching numbers identified for your land class(es)** for year one through to year 20, you will be granted a long-term consent (20-25 years).
- **If your farming system is leaching over the leaching numbers identified for your land class(es)** you may be able to apply for a restricted discretionary consent. However this process will not be straight forward and early consultation with the council is strongly advised. Justification as to why the N leaching allowance cannot be met will need to be discussed and accepted by the council.

Soil Profile Descriptions:

Hole 1: Manawatu shallow silt loam

Location:	Reureu Road, north of Halcombe. Located 175°29'.383"E, 40°4'54.292"S.
Parent Material:	Alluvial gravels, possibly some colluvium from nearby hill
Slope:	1°
Topography:	Flat
Drainage:	Well drained
Vegetation/Land Use:	Pasture and grazing
Classification:	Recent Soil

Profile:

Ap	0-20cm	Brown (10YR 4/3) silt loam; friable; slightly stick; non plastic; weakly developed fine nutty and very fine crumb structure; diffuse smooth boundary.
Bw	20-60cm	Dark yellowish brown (10YR 4/4) sand (fine to medium grained); extremely gravelly (Gravel layer present at 60cm cannot auger further); friable; non sticky; non plastic; extremely weak fine to very fine crumb structure, fine few roots; indistinct occluded boundary.
2Cu	60cm on	On un-weathered sandy gravels present

Note: At 50cm gravel layer, worms visible in the top horizon

Hole 2: Manawatu shallow silt loam

Location:	Reureu Road, north of Halcombe. Located at 40°4'55.28"S, 175°29'27.22"E.
Parent Material:	Alluvial gravels.
Slope:	1°
Topography:	Flat
Drainage:	Well drained
Vegetation/Land Use:	Pasture and grazing
Classification:	Recent Soil

Profile:

Ap	0-10cm	Dark brown yellowish (10YR 4/6) silt loam; weak; slightly sticky; slightly plastic; fine blocky structure; coarse many roots; indistinct boundary.
Bg	10-30cm	Light brown to grey (10YR 6/2) silt clay loam; very fine few mottles 1 – 5%; firm; friable; slightly sticky; slightly plastic; moderate development; fine blocky structure; wavy boundary.
2Cu	30cm on	On un-weathered gravels present

Note: Gravel layer at 30cm cannot auger further.

Hole 3: Otaki silt loam

Location: Reureu Road, north of Halcombe. Located at 40°4'52.786"S, 175°29'26.366"E. 40m from bottom of hill, on Rangitikei river terrace.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Well drained

Vegetation/Land Use: Pasture and grazing

Classification: Recent Soil

Profile:

Ap	0-20cm	Brown (7.5YR 4/3) silt loam; medium to coarse gravel; moderately gravelly to very gravelly; slightly sticky; slightly plastic; weak to slightly firm; weakly developed structure; fine crumb structure; fine few roots; indistinct boundary.
2Cu	20cm on	On un-weathered gravels present

Note: Becomes extremely gravelly at 22cm cannot auger anymore.

Hole 4: Manawatu deep silt loam over sand

Location: Reureu Road, north of Halcombe. Located at 40°4'51.326"S, 175°29'24.187"E. Located 15m from boundary fence, near Rāmgangā stream 20m from main road on the Rangitikei River Terrace.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Well drained

Vegetation/Land Use: Pasture and grazing

Classification: Recent Soil

Profile:

Ap	0-30cm	Dark brown (10YR 3/3) silt loam; friable; non sticky; moderate plasticity; weak development, fine to very fine crumb structure; fine few roots present; smooth boundary.
Bw	30-60cm	Brown (7.5YR 5/3) sandy loam; fine sized sand; very friable; non sticky; non plastic; weak development; fine crumb structure; no roots present, occluded horizon.
Cu	60-100cm	Light brown (7.5YR 6/4) sandy loam; very friable; non sticky; non plastic; weak to extremely weak; no roots present.

Note: Silt is fine sized and more silt is present than sand.

Hole 5: Rangitikei deep silt loam over sand

Location: Reureu Road, north of Halcombe. Located at 40°4'52.641"S, 175°29'21.456"E. Located 20m from main road in the centre of the paddock in line with the water trough.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Well drained

Vegetation/Land Use: Pasture and grazing

Classification: Recent Soil

Profile:

Ap	0-5cm	Brown (7.5YR 4/2) silt loam; slightly firm; brittle; slightly sticky; slightly plastic; moderately developed very fine blocky; fine few roots; smooth boundary.
Bw	5-20cm	Light brown (7.5YR 6/3) sandy loam; friable; non sticky; non plastic; very weak development; fine crumb structure; few fine roots; smooth boundary.
Cw	20-60cm	Very Light brown (10YR 6/3) fine sand; friable; non sticky; non plastic; very weak; apedal singe grain; no roots, indistinctive boundary.
2Cu	60cm on	Sand becomes too fine falls out of auger.

Note: Could not auger after 60cm, sand kept falling out of auger (too fine)

Hole 6: Rangitikei deep silt loam over sand

Location: Reureu Road, north of Halcombe. Located at 40°4'56.21"S, 175°29'22.894"E. Located 35m from corner fence opposite side to hole 1.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Well drained

Vegetation/Land Use: Pasture and grazing

Classification: Recent Soil

Profile:

Apg	0-15cm	Brown (7.5YR 4/2) silt loam; slightly firm; few (5%) fine mottles present ; brittle; slightly sticky; slightly plastic; moderately developed; very fine blocky structure; fine few roots; smooth boundary.
Bw	15-30cm	Light/dark brown (7.5YR 6/3) sandy loam; very weak; friable; slightly sticky; non plastic; fine crumb structure; few fine roots; smooth boundary.
Cw	30-100cm	Very Light brown (10YR 6/3) fine sand; very weak; friable; non sticky; non plastic; apedal singe grain; no roots, indistinctive boundary.

Note: Iron oxide staining present

Hole 7: Manawatu moderately deep silt loam

Location: Reureu Road, north of Halcombe. Located at 40°4'58.036"S, 175°29'19.745"E. Located in gully in boundary paddock closet to house.

Parent Material: Alluvial gravels.

Slope: 1^{o}

Topography: Flat

Drainage: Well drained

Vegetation/Land Use: Pasture and grazing

Classification: Recent Soil

Profile:

Ap	0-30cm	Brown (7.5YR 5/2) silt loam; weak; no mottles; friable; slightly sticky; non plastic; moderately developed; medium crumb structure; top 5cm have fine few roots; smooth horizon boundary.
Bw	30-70cm	Brown (7.5YR 5/2) sandy loam; weak; no mottles, friable; non sticky; non plastic; weakly developed; fine crumb structure ;fine sized sand; indistinctive boundary.
2Cu	60cm on	On un-weathered gravels present

Hole 8: Manawatu moderately deep silt loam

Location: Reureu Road, north of Halcombe. Located at 40°4'54.424"S, 175°29'18.36"E. Located above gully on flat land 2m from fence and 5m from gate.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Well drained

Vegetation/Land Use: Pasture and grazing

Classification: Recent Soil

Profile:

Ap	0-10cm	Brown (7.5YR 4/3) silt loam; firm; moderately sticky; moderately plastic; moderate development blocky; brittle to semi-deformable; fine few roots present; distinct boundary.
Bw	10-40cm	Brown (7.5YR 4/2) sandy clay; firm; moderately sticky, moderately plastic; moderate development blocky; brittle; distinct boundary.
Cu	40-100cm	Brown (7.5YR 4/4) sand; friable; non sticky; non plastic; weak development; apedal single grain; sand is fine textured.
2Cu	60cm on	On un-weathered gravels present

Note: Cannot auger past 40cm as becomes fine sand.

Hole 9: Manawatu deep sandy loam

Location: Reureu Road, north of Halcombe. Located at 40°4'52.335"S, 175°29'18.175"E. Located 10m from fence gate and 5m from boundary fence.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Well drained

Vegetation/Land Use: Pasture and grazing

Classification: Recent Soil

Profile:

Ap	0-4cm	Brown (7.5YR 4/2) loamy sand; weak; friable; slightly plastic to non-plastic; non sticky; weakly developed; fine crumb structure; fine many roots present; sand is medium to fine sized; distinct boundary.
Bg	4-25cm	Brown (7.5YR 5/3) loamy sand; weak; distinct (25%) fine red mottles present; friable; slightly plastic; slightly sticky; weakly developed; fine crumb structure; few very fine roots present; sand is medium to fine sized; distinct boundary.
BCg	25-80cm	Brown (7.5YR 5/3) loamy sand; weak; distinct (25%) fine red mottles present; friable; slightly plastic; slightly sticky; weakly developed; fine crumb structure; sand is coarse sized; distinct boundary.
Cg	80-100cm	Light grey brown (7.5YR 6/1) silt; weak; prominent fine to medium many mottles present 50% red in colour; friable; slightly plastic; slightly sticky; apedal single grain.

Hole 10 Parewanui deep sandy loam

Location: Reureu Road, north of Halcombe. Centre of the farm is located at 40°4'49.52"S, 175°29'22.541"E. Located 10m from fence in slight dip in paddock.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Poorly drained

Vegetation/Land Use: Pasture and grazing

Classification: Gley Soil

Ap 0-25cm Brown (10YR 5/3) loamy sand; weak; distinct (20%) fine to medium mottles present; very friable to friable; non plastic; non sticky; moderately developed; fine to medium crumb structure; sand is fine grained; distinct boundary.

Bg 25-60cm Greyish brown (10YR 5/2) loamy sand; weak; prominent (50%) fine to medium abundant mottles present orange/red in colour; very slightly gravelly; friable; non plastic; non sticky; weakly to moderately developed; fine crumb structure; distinct boundary. At 45cm 10mm thick band of clayey sand.

Cg 60-92 Brown (7.5YR 4/4) sand; very weak;; prominent medium many mottles present; slightly gravelly less than 5mm in size; very friable; non plastic; non sticky; apedal single grain; sand is coarse sized; distinct boundary.

2Cu	92cm on	On un-weathered gravels present

Note: At 92cm gravel layer present.

Hole 11 Parewanui deep sandy loam

Location: Reureu Road, north of Halcombe. Located at 40°4’47.936”S, 175°29’20.249”E. Located 50m from fence and 50m from stream boarding corner of paddock.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Poorly drained

Vegetation/Land Use: Pasture and grazing

Classification: Gley Soil

Profile:

Ap	0-20cm	Brown (7.5YR 4/4) sandy loam; weak; faint (<5%) fine many mottles present; slightly gravelly ranging from 5- 15mm; friable; non plastic; non sticky; weakly to moderately developed; nutty structure fine to very fine; sand is medium sized; very fine few roots present; wavy boundary.
Bg	20-40cm	Brown (7.5YR 4/3) loamy sand; distinct (25%) fine mottles present, red/orange in colour; very slightly gravelly less than 5mm; friable; non plastic; non sticky; weak development; apedal single grain; extremely fine few roots present; wavy boundary.
Cg1	40-80cm	Dark yellowish brown (10YR 4/6) loamy sand; distinct medium many mottles present; friable; non plastic; non sticky; weak development; apedal single grain; sand is fine sized; wavy boundary.
Cg2	80-94cm	Pale brown (10YR 8/4) sand; distinct (25- 30%) medium mottles present, orange/red in colour; very friable; non plastic; non sticky; very weak development; apedal single grain; sand is coarse sized. At 94cm extremely gravelly (river gravels).
2Cu	94cm on	On un-weathered gravels present

Note: At 94cm looks like river gravels.

Hole 12 Parewanui deep sandy loam

Location: Reureu Road, north of Halcombe. Located at 40°4'45.067"S, 175°29'21.289"E. Corner boundary paddock near stream, same side as maize paddock.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Poorly drained

Vegetation/Land Use: Pasture and grazing

Classification: Gley Soil

Profile:

Ap 0-20cm Brown (7.5YR 4/6) sandy loam; weak; faint (<2%) mottles present; friable; slightly plastic non sticky; sand is fine sized; weakly developed; nutty structure; extremely fine common roots present; distinct boundary.

Bg 20-40cm Brown (7.5YR 5/3) loamy sand; weak; prominent (>50%) fine mottles present red/orange in colour; very slightly gravelly ranging from 5-25mm; friable; non plastic; non sticky; weakly developed; fine crumb structure; sand is medium sized; distinct boundary.

Cg1 40-65cm Yellowish brown (10YR 5.6) loamy sand; weak; prominent (>50%) fine mottles present red/orange in colour; friable; non plastic; non sticky; weakly developed; fine crumb structure; sand is fine sized; distinct boundary.

Cg2	65-100cm	Light grey (10YR 7/1) silt; very weak; prominent (>50%) fine to medium mottles present red/orange in colour; friable; non plastic; non sticky, apedal single grain.

Hole 13: Parewanui deep sandy loam

Location: Reureu Road, north of Halcombe. Located at 40°4'46.797"S, 175°29'24.567"E. Located near back paddock, 5m from fence and 10m from back fence.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Poorly drained

Vegetation/Land Use: Pasture and grazing

Classification: Gley Soil

Profile:

Apg	0-10cm	Brown (7.5YR 5/2) sandy loam; slightly firm; distinct (25%) fine mottles; slight gleying (5 5PD); brittle; slightly plastic; slightly sticky; weakly to moderately developed; fine nutty structure; medium common roots; distinct boundary.
Br	20-40cm	Brown (7.5YR 5/2) sandy loam; weak; distinct (25%) medium mottles present; friable; non plastic; non sticky; weakly developed; fine nutty structure.
Cg1	40-60cm	Dark grey (7.5YR 4/1) sandy loam; firm; prominent (50%) medium mottles present, red/orange in colour; fine sized sand; friable; non plastic to slightly plastic; non sticky to slightly sticky; weakly developed; fine crumb structure.
Cg2	60-100cm	Grey (7.5YR 5/1) loamy sand; weak;; prominent (>50%) medium mottles present; fine sized sand; friable; non plastic; non sticky; apedal single grain.

Note: Soil moisture is moist in the top horizons becoming wet by 70cm, possibility of high water table.

Hole 14: Rangitikei deep silt loam over sand

Location: Reureu Road, north of Halcombe. Located at 40°4'52.924"S, 175°28'37.05"E. Located on the second river terrace.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Well drained

Vegetation/Land Use: Pasture and grazing

Classification: Recent

Profile:

Ap 0-10cm Brown (7.5 YR 5/2) silt loam; slightly firm; no mottles present; brittle; slightly plastic; slightly sticky; weakly developed; fine nutty structure; very fine many roots present; wavy boundary.

Bw	10-35cm	Light brown (7.5YR 6/4) sandy loam; weak; friable; non plastic; non sticky; weakly developed; fine to very fine crumb structure; fine sized sand; distinct boundary.
Cu	35-70cm	Grey/brown (10YR 6/1) sand; very friable; non plastic; non sticky; very slightly gravelly; very weakly developed; apedal single grain; coarse sized sand.
2Cu	70cm on	On, un-weathered gravels present

Note: at 70cm gravel layer – ranging from coarse gravel to boulders cannot auger, soil moisture is moist.

Hole 15: Rangitikei deep silt loam

Location: Reureu Road, north of Halcombe. Located at 40°4’52.695”S, 175°28’37.968”E. Located in middle paddock near stream running through farm, 10m from fence and on second river terrace.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Well drained

Vegetation/Land Use: Pasture and grazing

Classification: Recent

Profile:

Apg	0-10cm	Reddish brown (5YR 4/3) silty clay loam; firm; faint (<5%) fine mottles present, red in colour; brittle; slightly plastic; slightly sticky; moderate development; fine few blocky structure; medium few roots present; wavy boundary.
Bg	10-70cm	Brown (7.5YR 5/2) silt; weak; faint (<5%) fine mottles present red in colour; friable; non plastic; non sticky; weakly developed; fine to very fine crumb structure; distinct boundary.
Cw	70-100cm	Brown (7.5 5/2) sand; weak; apedal single grain; no mottles present; very friable; non plastic; non sticky; fine grained sand.

Hole 16: Rangitikei deep silt loam over sand

Location: Reureu Road, north of Halcombe. Located at 40°4'50.655"S, 175°28'41.327"E. Located 100m from the old Urupa.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Well drained

Vegetation/Land Use: Pasture and grazing

Classification: Recent

Profile:

Ap 0-10cm Brown (7.5YR 4/3) silt loam; slightly firm; brittle; slightly plastic; slightly sticky; moderate to weakly development; blocky structure; wavy boundary.

Bw 10-60cm Greyish Brown (10YR 5/2) loamy sand; very friable; non sticky; non plastic;

		weakly developed; fine to very fine crumb structure; fine sized sand; distinct boundary.
Cw	60-100cm	Brown (10YR 4/3) sand; very friable; non sticky; non plastic; very weak; apedal single grain; fine sized sand.
2Cu	100cm	Sand becomes very fine, falls out of auger.

Hole 17: Rangitikei shallow silt loam

Location: Reureu Road, north of Halcombe. Located at 40°4'48.109"S, 175°28'42.924"E.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Well drained

Vegetation/Land Use: Pasture and grazing

Classification: Recent

Profile:

Ap	0-5cm	Brown (10YR 4/3) silt loam; slightly firm to weak; faint (5%) fine mottles present; friable; slightly plastic; slightly sticky; weakly developed; fine nutty structure; very fine to medium common roots present; wavy boundary.
Bg	5-40cm	Brown (10YR 5/3) silt; weak; friable; non plastic; non sticky; weakly developed; fine crumb structure; extremely fine few root present. Becoming extremely gravelly at 40cm.
2Cu	40cm on	/ Un-weathered Sandy Gravels present @ 40cm

Hole 18: Rangitikei shallow silt loam

Location: Reureu Road, north of Halcombe. Located at 40°4′53.243″S, 175°28′41.694″E.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Well drained

Vegetation/Land Use: Pasture and grazing

Classification: Recent

Profile:

Ap	0-5cm	Dark yellowish brown (10YR 4/4) silt loam; slightly firm to weak; faint (5%) fine mottles present, red in colour ; friable; slightly plastic; slightly sticky; weakly developed; fine nutty structure; very fine to medium common roots present; wavy boundary.
Cu	5-40cm	Brown (10YR 5/3) silt; weak; friable; non plastic; non sticky; apedal single grain; weak; extremely fine few root present. Becoming extremely gravelly at 40cm.
2Cu	40cm on	On Un-weathered Sandy Gravels present @ 40cm

Note: At 40cm gravel layer present cannot auger, soil moisture is moist.

Hole 19: Rangitikei moderately deep sandy loam

Location: Reureu Road, north of Halcombe. Located at 40°4'50.238"S, 175°28'33.41"E.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Well drained

Vegetation/Land Use: Pasture and grazing

Classification: Recent

Profile:

Apg	0-5cm	Brown (10YR 4/3) sandy loam; weak; faint (5%) fine mottles present red in colour; friable; non plastic; non sticky; weakly developed; fine crumb structure; fine sized sand; wavy boundary.
Bg	5-25cm	Dark grey (10YR 4/1) sandy loam; weak; friable to very friable; non plastic; non sticky; weakly developed; fine crumb structure; medium sized sand; distinct boundary.
Cg	25-55cm	Brown/grey (10YR 4/1) sand; very weak; very friable; non plastic; non sticky; fine sized sand; apedal singe grain. At 55cm soil becomes extremely gravelly with gravels ranging from coarse to boulders.
2Cu	55cm on	On un-weathered sandy gravels

Note: Cannot auger past 55cm – gravel layer to thick, soil moisture is moist.

Hole 20: Rangitikei deep silt loam

Location: Reureu Road, north of Halcombe. Located at 40°4′45.694″S, 175°28′36.461″E.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Well drained

Vegetation/Land Use: Pasture and grazing

Classification: Recent

Profile:

Ap 0-15cm Brown (7.5YR 5/3) silt loam: friable; at 7cm band of gleying present (2 5/5PB) and mottles fine (5%) present; slightly plastic; non sticky; weakly developed; fine to very fine crumb structure; extremely fine common roots.

Bu	15-35cm	Brown (7.5YR 5/3) silt loam; extremely gravelly; friable to very friable; non sticky; non plastic; weakly developed; fine crumb structure; sand is fine sized. At 15cm a 5mm gravel layer is present ranging from 5mm to 15mm and is extremely gravelly.
Cu	35-100cm	Grey (7.5YR 5/1) silt; very weak;; very friable; non plastic; non sticky; apedal single grain.

Note: Soil moisture ranges from moist in the top horizon to dry in the bottom horizon.

Hole 21: Rangitikei moderately deep sandy loam

Location: Reureu Road, north of Halcombe. Located at 40°4'42.359"S, 175°28'37.757"E.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Well drained

Vegetation/Land Use: Pasture and grazing

Classification: Recent

Profile:

Ap	0-7cm	Brown (7.5YR 4/2) sandy loam; slightly firm; distinct (25%) fine mottles present red in colour; brittle; slightly plastic; slightly sticky; weakly developed; fine to very fine nutty structure; very fine common roots; wavy boundary.
Bg	7-30cm	Brown (7.5YR 5/4) silt loam; weak; faint (5%) fine few mottles present; friable; slightly plastic; slightly sticky; weakly developed; fine crumb structure; extremely fine few roots; wavy boundary.
Cg	30-50cm	Grey (7.5YR 6/1) sand; very weak; very friable; non plastic; non sticky; apedal single grain; at 50cm becomes very gravelly with gravels ranging from medium to coarse size.
2Cu	50cm on	On un-weathered sandy gravels.

Note: Cannot auger past 50cm gravels present, soil moisture is moist.

Hole 22: Otaki silt loam

Location: Reureu Road, north of Halcombe. Located at 40°4'38.842"S, 175°28'39.754"E.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Well drained

Vegetation/Land Use: Pasture and grazing

Classification: Recent

Profile:

Ap 0-15cm Brown (7.5YR 4/3) silt loam; weak; slightly plastic; slightly sticky; weakly developed; nutty fine to very fine structure; extremely gravelly at 15cm with gravels ranging from 10mm to 100mm in size; at 5cm grey silt layer

		present; fine abundant roots.
2Cu	15cm on	On un-weathered sandy gravels

Note: Cannot auger past 15cm too gravelly.

Hole 23: Otaki silt loam

Location: Reureu Road, north of Halcombe. Located at 40°4'38.481"S, 175°28'44.864"E.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Well drained

Vegetation/Land Use: Pasture and grazing

Classification: Recent

Profile:

Ap	0-10cm	Brown (7.5YR 4/3) silt loam; weak; slightly plastic; slightly sticky; weakly developed; fine to very fine nutty structure; extremely gravelly at 10cm with Gravels ranging from 10mm to 100mm in size; fine abundant roots.
2Cu	15cm on	On un-weathered sandy gravels

Note: Cannot auger past 10cm too gravelly.

Hole 24: Otaki silt loam

Location: Reureu Road, north of Halcombe. Located at 40°4’46.192”S, 175°28’50.321”E.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Well drained

Vegetation/Land Use: Pasture and grazing

Classification: Recent

Profile:

Ap	0-5cm	Brown (7.5YR 4/3) silt loam; weak; slightly plastic; slightly sticky; weakly developed; fine to very fine nut structure; extremely gravelly at 5cm with gravels ranging from 10mm to 100mm in size.
2Cu	15cm on	On un-weathered sandy gravels

Note: Cannot auger past 5cm too gravelly.

Hole 25: Rangitikei shallow silt loam

Location: Reureu Road, north of Halcombe. Located at 40°4'43.011"S, 175°28'50.32"E.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Well drained

Vegetation/Land Use: Pasture and grazing

Classification: Recent

Profile:

Ap	0-5cm	Brown (10YR 4/3) silt loam; slightly firm to weak; faint fine(5%) few mottles present; friable; slightly plastic; slightly sticky; weakly developed; fine nut structure; very fine to medium common roots present; wavy boundary.
Cu	5-40cm	Brown (10YR 5/3) silt; weak; friable; non plastic; non sticky; apedal single grain; extremely fine few root present. Becoming extremely gravelly at 40cm.
2Cu	40cm on	On un-weathered sandy gravels

Note: At 40cm gravel layer present cannot auger, soil moisture is moist.

Hole 26: Manawatu deep silt loam

Location: Reureu Road, north of Halcombe. Located at 40°4'52.915"S, 175°28'57.001"E.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Well drained

Vegetation/Land Use: Pasture and grazing

Classification: Recent

Profile:

Ap	0-10cm	Brown (7.5YR 4/2) silt loam; very firm; faint (5%) fine few mottles present; brittle; moderately plastic; moderately sticky; weakly developed; very fine crumb structure; very fine abundant roots; wavy boundary.
Bw	10-50cm	Brown (7.5YR 4/3) silt loam; firm; distinct (25%) fine mottles present; brittle; moderate plastic; moderately sticky; weakly developed; fine nutty structure; distinct boundary.
BC	50-70cm	Pinkish grey (7.5YR 6/2) clayey sand; weak; distinct (25%) medium mottles red in colour; friable; slightly plastic; non sticky; weakly developed; fine nut structure; distinct boundary.
Cg	70-100cm	Light grey (7.5YR 7/1) sand; very weak; distinct (25%) fine mottles present red/orange in colour; very friable; non plastic; non sticky; apedal single grain; sand is medium to fine sized; at 70cm woody/pumice material found.

Note: 70cm woody/pumice material found (cemented sand or stream material)

Hole 27: Manawatu deep silt loam

Location: Reureu Road, north of Halcombe. Located at 40°4′56.636″S, 175°28′53.322″E.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Well drained

Vegetation/Land Use: Pasture and grazing

Classification: Recent

Profile:

Ap	0-30cm	Very Dark brown (7.5YR 2.5/2) silt loam; firm; brittle; moderately plastic; moderately sticky; weakly developed; fine nut structure; distinct boundary.
Bw	30-70cm	Light brown (7.5YR 6/4) silt loam; firm; faint (<5%) to distinct (15%) fine mottles red/orange in colour; brittle; slightly plastic; slightly sticky; weakly developed; fine nut structure.
Cu	70-100cm	Light brown (7.5YR 6/3) clayey sand; distinct (25%) fine mottles red/orange in colour; friable; slightly plastic; slightly sticky; sand is fine grained; apedal single grain.

Note: Mottles becoming more prominent at 1m.

Hole 28 Otaki sandy loam

Location: Reureu Road, north of Halcombe. Located at 40°4’54.275”S, 175°29’1.901”E.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Well drained

Vegetation/Land Use: Pasture and grazing

Classification: Recent

Ap 0-30cm Brown (7.5YR 5/2) sandy loam: weak; faint (5%) fine mottles; very friable; non plastic; non sticky; weakly developed; fine crumb structure; becomes extremely gravelly at 20cm ranging from medium gravels to coarse gravels.

2Cu 30cm on On un-weathered sandy gravels

Note: Cannot auger past 30cm too gravelly.

Hole 29: Otaki sandy loam

Location: Reureu Road, north of Halcombe. Located at 40°4′53.057″S, 175°29′5.999″E.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Well drained

Vegetation/Land Use: Pasture and grazing

Classification: Recent

Ap 0-30cm Brown (7.5YR 5/3) sandy loam: weak; faint (5%) fine mottles, red/orange in colour; very friable; non plastic; non sticky; weakly developed; fine crumb structure; becomes extremely gravelly at 20cm ranging from medium gravels to coarse gravels.

2Cu 30cm on On un-weathered sandy gravels

Note: Cannot auger past 30cm too gravelly.

Hole 30: Parewanui deep silt loam

Location: Reureu Road, north of Halcombe. Located at 40°4’52.254”S, 175°29’2.427”E.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Poorly drained

Vegetation/Land Use: Pasture and grazing

Classification: Gley

Ap	0-15cm	Brown (7.5YR 4/2) silt loam; slightly firm to firm; distinct (15%) fine mottles; brittle; moderately plastic; moderately sticky; weakly developed; fine crumb structure; very fine few roots; wavy boundary.
Bg	10-45cm	Brown (7.5YR 5/2) silt loam; weak; distinct (15%) fine mottles present red/orange in colour; friable; slightly plastic; slightly sticky; weakly developed; fine crumb structure; distinct boundary.
Cg1	45-70cm	Pinkish grey (7.5YR 6/2) sand; weak; prominent (50%), fine mottles red/orange in colour; very friable; non plastic; non sticky; apedal single grain; sand is coarse sized; distinct boundary.
Cg2	70-100cm	Light Brown (7.5YR 6/3) sand; weak; distinct (15%) fine mottles red/orange in colour, very friable; non plastic; non sticky; apedal single grain.

Note: Hard to auger at 60cm due to pure sand falling out of auger, soil moisture is dry.

Hole 31: Rangitikei deep sandy loam

Location: Reureu Road, north of Halcombe. Located at 40°4'49.735"S, 175°29'2.772"E.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Well drained

Vegetation/Land Use: Pasture and grazing

Classification: Recent

Ap	0-10cm	Light brown (7.5YR 5/3) silt loam; weak; faint (<5%) fine mottles; friable; slightly plastic; slightly sticky; weakly to moderate development; fine nut structure; very fine few roots; distinct boundary.
Bg	10-40cm	Light brown (7.5YR 5/3); silt loam; weak; distinct (15%) fine mottles; some large gravels found ranging from 20-30mm; friable; slightly plastic; slightly sticky; weakly to moderate development; fine nut structure; distinct boundary.
Cu1	40-60cm	Yellow brown (10YR 5/6) sandy clay loam; weak; faint (<5%) fine mottles; friable; slightly plastic; slightly sticky; sand is fine sized; weakly developed; fine crumb structure; distinct boundary.
Cu2	60-100cm	Yellow brown (10YR 5/6) sand; very weak; faint fine few mottles; very friable; non plastic; non sticky; sand is fine sized; sticky; apedal single grain, distinct boundary.

Hole 32 Rangitikei deep sandy loam

Location: Reureu Road, north of Halcombe. Located at 40°4'50.604"S, 175°29'5.201"E.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Well drained

Vegetation/Land Use: Pasture and grazing

Classification: Recent

Profile:

Ap	0-10cm	Brown (7.5YR 5/3) silt loam; weak; faint (<5%) fine mottles; friable; slightly plastic; slightly sticky; weakly developed; fine to very fine crumb structure; very fine few roots; distinct boundary.
Bw	10-40cm	Brown (7.5YR 5/3); silt loam; weak; distinct (20%) fine mottles red/orange in colour; some large gravels (15%) found ranging from 20-30mm in size; friable; slightly plastic; slightly sticky; weakly developed; fine to very fine crumb structure; distinct boundary.
Cu1	40-60cm	Yellow brown (10YR 5/6) sandy loam; weak; faint (<5%) fine mottles; friable; slightly plastic; slightly sticky; sand is fine sized; apedal single grain distinct boundary.
Cu2	60-100cm	Yellow brown (10YR 5/6) sand; very weak; faint (<5%) fine mottles; very friable; non plastic; non sticky; sand is fine sized; apedal single grain.

Hole 33: Rangitikei deep sandy loam

Location: Reureu Road, north of Halcombe. Located at 40°4'47.498"S, 175°29'5.579"E.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Well drained

Vegetation/Land Use: Pasture and grazing

Classification: Recent

Profile:

Ap	0-10cm	Brown (7.5YR 5/2) silt loam; weak; faint (<5%) fine mottles; friable; slightly plastic; slightly sticky; weak to moderate development; fine nut structure; very fine few roots; distinct boundary.
Bg	10-40cm	Brown (7.5YR 5/3); silt loam; weak; distinct (20%) fine mottles red/orange in colour; some large gravels (15%) found ranging from 20-30mm in size; friable; slightly plastic; slightly sticky; weak development; fine to very fine crumb structure; distinct boundary.
Cu1	40-60cm	Strong brown (7.5YR 5/6) sandy loam; weak; faint (<5%) fine mottles; friable; slightly plastic; slightly sticky; sand is fine sized; apedal, single grain distinct boundary.

Cu2 60-100cm Pinkish grey (7.5YR 7/2) sand; very weak; faint fine few mottles; very friable; non plastic; non sticky; sand is fine sized; apedal, single grain.

Hole 34: Rangitikei deep sandy loam

Location: Reureu Road, north of Halcombe. Located at 40°4′52.898″S, 175°29′9.481″E.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Well drained

Vegetation/Land Use: Pasture and grazing

Classification: Recent

Profile:

Ap 0-10cm Light brown (7.5YR 5/3) silt clay loam; weak; faint fine few mottles; friable; slightly plastic; slightly sticky; weakly developed; fine crumb structure; very fine few roots; distinct boundary.

Bg	10-30cm	Brown (7.5YR 5/3); silt loam; weak; distinct (20%) fine mottles red/orange in colour; some large gravels (15%) found ranging from 20-30mm in size; friable; slightly plastic; slightly sticky; weakly developed; fine to very fine crumb structure; distinct boundary.
Cu1	30-60cm	Strong brown (7.5YR 5/6) sandy loam; weak; faint (<5%) fine mottles; friable; slightly plastic; slightly sticky; sand is fine sized; apedal single grain distinct boundary.
Cu2	60-100cm	Pinkish grey (7.5YR 7/2) sand; very weak; faint (<5%) fine mottles; very friable; non plastic; non sticky; sand is fine sized; apedal single grain.

Hole 35: Rangitikei deep silt loam over sand

Location: Reureu Road, north of Halcombe. Located at 40°4'43.555"S, 175°28'54.209"E.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Well drained

Vegetation/Land Use: Pasture and grazing

Classification: Recent

Profile:

Ap	0-15cm	Dark brown (7.5YR 3/3) silt loam; slightly firm; some humic material (plant material); brittle; slightly plastic; moderately sticky; moderate development; very fine blocky structure; medium many roots; distinct boundary.
Bu	15-40cm	Brown (10YR 5/3) silt loam; very weak to weak; very friable; slightly plastic; slightly sticky; weakly developed; fine to very fine crumb structure; extremely fine few roots; distinct boundary.
Cu1	40-60cm	Pinkish grey (7.5YR 6/2) sandy loam; friable; slightly plastic; slightly sticky; apedal single grain; distinct boundary.
Cu	60-100cm	Light grey (7.5YR 7/1) sand; very friable; non plastic; non sticky; sand is fine Grained; apedal single grain.

Hole 36: Parewanui deep silt loam

Location: Reureu Road, north of Halcombe. Located at 40°4’432.051”S, 175°28’56.062”E.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Poorly

Vegetation/Land Use: Pasture and grazing

Classification: Gley

Profile:

Apg 0-10cm Brown (7.5YR 5/2) silt loam; firm to very firm; distinct medium many mottles present (red/yellow in colour 20%); brittle; moderately plastic; moderately sticky; weakly developed; fine to very fine crumb structure; distinct boundary.

Bg	10-45cm	Brown (7.5YR 5/2) clayey silt; slightly firm; faint (<5%) fine mottles present; friable; slightly plastic; slightly sticky; weakly developed; fine to very fine crumb structure.
Cu	45-100cm	Pinkish grey (7.5YR 6/2) clayey silt; weak to slightly firm; faint (<5%) fine mottles present; friable; slightly plastic; slightly sticky; apedal single grain.

Hole 37: Manawatu deep silt loam

Location: Reureu Road, north of Halcombe. Located at 40°4’42.575”S, 175°29’0.778”E.

Parent Material: Alluvial gravels.

Slope: 1^0

Topography: Flat

Drainage: Well drained

Vegetation/Land Use: Pasture and grazing

Classification: Recent

Profile:

Ap	0-5cm	Brown (10YR 5/3) silt loam; slightly firm; faint (<5%) fine mottles present; friable; slightly plastic; slightly sticky; weakly to moderate development; fine to medium nut structure; distinct boundary.
Bw	5-40cm	Yellow brown (10YR 6/6) clayey sand; weak; very friable; non plastic; non sticky; weakly developed; fine to very fine crumb structure; sand is fine sized; distinct boundary.
Cu1	40-85cm	Yellowish brown (10YR 5/4) sand; very weak; very friable; non plastic; non sticky; weak development; fine nut structure; distinct boundary.
Cw	85-100cm	Light brownish grey (10YR 6/2) silt loam; firm; brittle; moderately plastic; moderately sticky; weakly developed extremely; fine very; few nutty peds

Hole 38: Parewanui deep sandy loam

Location: Reureu Road, north of Halcombe. Located at 40°4′44.411″S, 175°29′6.407″E.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Poorly drained

Vegetation/Land Use: Pasture and grazing

Classification: Gley

Profile:

Ap 0-9cm Brown (7.5YR 5/3) sandy loam; weak; distinct (20%) fine mottles present red/orange in colour; very friable; non plastic; non sticky; weakly developed; fine to very fine crumb structure; extremely fine many roots present; distinct boundary.

Bg	9-40cm	Pinkish grey (7.5YR 6/2) sandy loam; very weak; prominent (50%)fine mottles present red/orange in colour; very friable; non plastic; non sticky; weakly developed; very fine to fine crumb structure; sand is fine grained distinct boundary.
Cg	40-100cm	Grey (7.5YR 6/1) sand; very weak; distinct (20%) fine mottles red/orange in colour; friable; non plastic; non sticky; sand is medium grained; apedal single grain; distinct boundary.

Hole 39: Kairanga clay loam

Location: Reureu Road, north of Halcombe. Located at 40°4'42.156"S, 175°29'10.748"E.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Poorly drained

Vegetation/Land Use: Pasture and grazing

Classification: Gley

Profile:

Ap	0-2cm	Brown (7.5YR 4/3) clay loam; firm; gleying is present (1 6/n); prominent(>50%) medium mottles present red/orange in colour; brittle; moderately plastic; moderately sticky; weakly developed; many polyhedral peds; coarse many roots; distinct boundary.
Bg	2-25cm	Grey (10YR 6/1) clay loam; firm; prominent (>50%) fine mottles present red/orange in colour; very slightly gravely; brittle; very plastic; moderately sticky; weakly developed; few nutty peds; wavy boundary.
Cg	25-27cm	Grey (10YR 6/1) sand; weak; prominent (>50%) fine mottles present red/orange in colour; extremely gravelly (60% - 80%) ranging from 1mm to 100mm in size, sub-rounded to rounded shape; friable; very plastic; moderately sticky; apedal single grain.
2Cg	27cm on	On unweathered sandy gravels

Note: Cannot auger past 27cm gravels present

Hole 40: Rangitikei deep silt loam

Location: Reureu Road, north of Halcombe. Located at $40^{o}4'39.469''S$, $175^{o}29'1.603''E$.

Parent Material: Alluvial gravels.

Slope: 1^{o}

Topography: Flat

Drainage: Well drained

Vegetation/Land Use: Pasture and grazing

Classification: Recent

Profile:

Ap	0-10cm	Brown (7.5YR 5/2) silt loam; firm; distinct (20%) medium mottles present; brittle; moderately plastic; moderately sticky; weakly developed; very fine crumb structure; distinct boundary.
Bg	10-45cm	Brown (7.5YR 5/2) silt loam; slightly firm; faint (<5%) fine many mottles present; friable; slightly plastic; slightly sticky; weakly developed; fine crumb structure.
Cu	45-100cm	Pinkish grey (7.5YR 6/2) silt loam; weak to slightly firm; faint fine few mottles present; friable; slightly plastic; slightly sticky; apedal single grain.

Hole 41: Rangitikei deep sandy loam

Location: Reureu Road, north of Halcombe. Located at 40°4’40.056”S, 175°28’52.412”E.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Well drained

Vegetation/Land Use: Pasture and grazing

Classification: Recent

Profile:

Ap	0-12cm	Dark brown (7.5YR 3/3) sandy loam; slightly firm; some hemic material (plant material); brittle; slightly plastic; moderately sticky; moderate development; fine to medium blocky structure; medium many roots; distinct boundary.
Bw	12-35cm	Brown (10YR 5/3) sandy silt; very weak to weak; very friable; slightly plastic; slightly sticky; weakly developed; fine to very fine crumb structure; extremely fine few roots; distinct boundary.
Cu1	35-60cm	Brown (7.5YR 4/3) sand; friable; slightly plastic; slightly sticky;; apedal single grain; distinct boundary.
Cu2	60-100cm	Pinkish grey (7.5YR 6/2) sand; very friable; non plastic; non sticky; sand is fine grained; apedal single grain.

Hole 42: Rangitikei deep silt loam

Location: Reureu Road, north of Halcombe. Located at 40°4’35.969”S, 175°28’51.96”E.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Well drained

Vegetation/Land Use: Pasture and grazing

Classification: Recent

Profile:

Ap 0-7cm Light brown (7.5YR 6/4) silt loam; firm to very firm; distinct medium many mottles present (yellow/orange in colour) >15%; brittle; moderately plastic; moderately sticky; weakly developed; fine to very fine crumb structure; distinct boundary.

Bg 7-45cm Light brown (7.5YR 6/3) silt loam; slightly firm; faint (<5%) fine mottles present; friable; slightly plastic; slightly sticky; weakly developed; very fine crumb structure.

Cu 45-100cm Pinkish grey (7.5YR 6/2) silt; weak to slightly firm; faint (<5%) fine mottles present; friable; slightly plastic; slightly sticky; apedal single grain.

Hole 43: Rangitikei deep sandy loam

Location: Reureu Road, north of Halcombe. Located at 40°4'48.443"S, 175°29'8.028"E.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Well drained

Vegetation/Land Use: Pasture and grazing

Classification: Recent

Profile:

Ap 0-30cm Brown (7.5YR 5/2) sandy loam; weak; faint (<5%) fine mottles present; friable; slightly plastic; slightly sticky; weakly developed; fine to very fine nut structure; distinct boundary.

Bw 30-60cm Brown (7.5YR 4/4) sandy loam; weak; faint (<5%) fine mottles present (yellow/red in colour); friable; non plastic; non sticky; weakly developed;

		fine to very fine nut structure; sand is medium sized; distinct boundary
Cu	60 – 100cm	Brown (7.5YR 4/4) sand; weak; faint (<5%) fine few mottles present; fri non plastic; non sticky; sand is medium sized; apedal single grain. At 60cm 10cm thick band of cemented sand or clay.

Hole 44 Otaki sandy loam

Location: Reureu Road, north of Halcombe. Located at 40°4'45.026"S, 175°29'13.734"E.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Well drained

Vegetation/Land Use: Pasture and grazing

Classification: Recent

Profile:

Ap	0-20cm	Brown (7.5YR 5/2) sandy clay loam; weak; distinct (20%) medium mottles present red/orange in colour; very friable; non plastic; non sticky; weakly developed; fine to medium nut structure. At 20 cm soil becomes extremely gravelly (60 – 80%) ranging from pebbles to 200mm gravels in size some as large as boulders, rounded to sub rounded in shape.
2Cu	20cm on	On unweathered sandy gravels

Note: Cannot auger from 20cm – too many gravels present

Hole 45 Parewanui deep sandy loam

Location: Reureu Road, north of Halcombe. Located at 40^{o}4'51.076"S, 175^{o}29'12.48"E.

Parent Material: Alluvial gravels.

Slope: 1^o

Topography: Flat

Drainage: Poorly

Vegetation/Land Use: Pasture and grazing

Classification: Gley

Profile:

Ap	0-10cm	Dark brown (7.5YR 3/3) sand; weak; distinct (20%) fine mottles present red/orange in colour; very friable; non plastic; non sticky; weakly developed; fine to medium crumb to nutty structure; very fine many roots; sand is fine sized; distinct boundary.
Bg	10-40cm	Brown (7.5YR 5/2) sand; weak; faint (5- 10%) fine mottles present; very friable; non plastic, non sticky; weakly developed; very fine crumb structure; very fine many roots; sand is medium sized; distinct boundary.
Cg	40-100cm	Grey (7.5YR 5/1) sand; weak; faint (5 – 10%) fine mottles present; very friable; non plastic; non sticky; sand is fine sized; apedal single grain.

Hole 46 Parewanui deep sandy loam

Location: Reureu Road, north of Halcombe. Located at 40°4'51.246"S, 175°29'16.575"E.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Poorly

Vegetation/Land Use: Pasture and grazing

Classification: Gley

Profile:

Ap 0-7cm Brown (7.5YR 5/2) sandy loam; weak; faint (5 – 10%) fine mottles present; very friable; non plastic; non sticky; weakly developed; fine to medium crumb and nut structure; very fine few roots present, sand is medium grained, distinct boundary.

Bw 7-35cm Brown (7.5YR 5/3) sandy loam; weak; very friable; non plastic; non sticky; sand is coarse to medium sized; weakly developed; very fine crumb structure; very fine few roots present, distinct boundary.

Cu1 35-70cm Light brown (7.5YR 6/3) sandy loam; weak; very friable; non plastic; non sticky; apedal single grain; sand is fine sized, distinct boundary.

Cu2 70-83cm Light brown (7.5YR 6/3) sandy loam; weak; slightly gravelly; very friable; non plastic; non sticky; apedal, single grain; sand is coarse sized. At 83cm becomes extremely gravelly (60 – 80%) with gravels ranging from 2mm to 15mm in size, rounded in shape.

2Cu2 On un weathered sandy gravels

Note: Cannot auger past 83cm.

Hole 47 Otaki sandy loam

Location: Reureu Road, north of Halcombe. Located at 40°4'48.882"S, 175°29'16.355"E.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Well drained

Vegetation/Land Use: Pasture and grazing

Classification: Recent

Profile:

Ap 0-17cm Brown (7.5YR 5/2) sandy loam: weak; crumb fine structure, weakly developed; faint (5%) fine mottles; very friable; non plastic; non sticky; weakly developed; fine crumb structure; becomes extremely gravelly at 20cm ranging from medium gravels to coarse gravels.

2Cu 17cm on On un-weathered sandy gravels

Note: Cannot auger/dig past 17cm too gravelly

Hole 48	**Rangitikei shallow sandy loam**
Location:	Reureu Road, north of Halcombe. Located at 40°4′58.866″S, 175°29′40.526″E.
Parent Material:	Alluvial gravels.
Slope:	1°
Topography:	Flat
Drainage:	Well drained
Vegetation/Land Use:	Pasture and grazing
Classification:	Recent

Profile:

Ap	0-5cm	Brown/yellowish (7.5YR 4/4) sandy loam; slightly firm to weak; faint (5-10%) fine mottles present; friable; slightly plastic; slightly sticky; weakly developed; fine crumb structure; very fine to medium common roots present; wavy boundary.

Cu	5-40cm	Brown (7.5YR 5/3) sand; weak; weak; friable; non plastic; non sticky; apedal single grain; extremely fine few root present.
2Cu	40cm on	Becoming extremely gravelly (60 – 80%) at 40cm, gravels ranging between 2mm – 10mm in size, rounded in shape.

Hole 49 Karapoti Silt Loam

Location: Reureu Road, north of Halcombe. Located at 40°5′2.005″S, 175°28′42.986″E.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Well drained

Vegetation/Land Use: Pasture and grazing

Classification: Recent

Profile:

Ap	0-20cm	Brown (7.5YR 5/2) silt loam; slightly firm; brittle; slightly plastic; slightly sticky; weakly developed; fine to medium nutty crumb structure; extremely fine common roots present; distinct boundary.

Bw	20-37cm	Light yellowish brown (2.5YR 6/3) silt loam; slightly firm; brittle; slightly plastic; slightly sticky; weakly to moderately developed; fine to very fine crumb structure; fine common roots present, wavy boundary.
Bw/Cw	37-57	Olive yellow (2.5YR 6/6) sandy silt loam; firm; brittle; moderately plastic; moderately sticky; weakly to moderately developed; fine nut structure; distinct boundary.
Cw	57-90cm	Olive brown (2.5YR 5/3) fine sand; weak; brittle; non plastic; non sticky; sand is fine sized; apedal single grain. At 70cm 20cm band of gravels ranging from small gravels 5mm to boulders.

Hole 50 Karapoti silt loam

Location: Reureu Road, north of Halcombe. Located at 40°5′3.91″S, 175°28′45.401″E.

Parent Material: Alluvial gravels.

Slope: 1°

Topography: Flat

Drainage: Well drained

Vegetation/Land Use: Pasture and grazing

Classification: Recent

Profile:

Ap 0-20cm Reddish Brown (5YR 4/3) silt loam; weak; brittle; slightly plastic; slightly sticky; weakly to moderate development; fine to medium nutty structure; few boulders present; distinct boundary.

Bw 20-40cm Dark Reddish Brown (5YR 4/2) silt loam; slightly firm; moderately gravelly (20%); friable; non plastic; non sticky; weakly developed, fine to very fine crumb structure.

2Cu 40cm on On sandy un weathered gravels at 40cm becomes extremely gravelly (60 – 80%), size ranges from 1mm to 10mm, rounded to angular in shape.

Note: Cannot dig/auger past 40cm due to gravels

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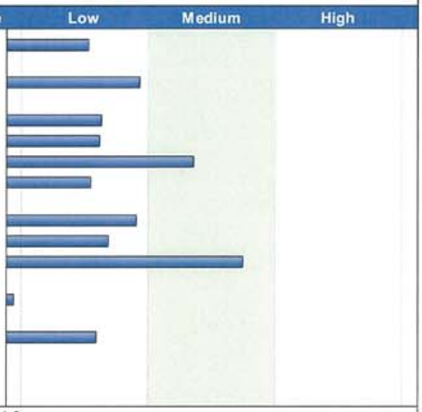
ANALYSIS REPORT

shpv1

Client:	Massey University	**Lab No:**	1276725
Address:	C/- The Registrar	**Date Registered:**	17-May-2014
	Private Bag 11222	**Date Reported:**	21-May-2014
	PALMERSTON NORTH 4442	**Quote No:**	
		Order No:	PN157073
		Client Reference:	
Phone:	06 356 9099 X 81440 - Christin	**Submitted By:**	Reina Tamepo

Sample Name: A **Lab Number:** 1276725.1
Sample Type: SOIL Mixed Pasture (S1)

Analysis		Level Found	Medium Range
pH	pH Units	5.4	5.8 - 6.2
Olsen Phosphorus	mg/L	19	20 - 30
Potassium	me/100g	0.31	0.40 - 0.60
Calcium	me/100g	3.2	4.0 - 10.0
Magnesium	me/100g	1.22	1.00 - 1.60
Sodium	me/100g	0.11	0.20 - 0.50
CEC	me/100g	12	12 - 25
Total Base Saturation	%	42	50 - 85
Volume Weight	g/mL	0.90	0.60 - 1.00
Sulphate Sulphur	mg/kg	2	10 - 12
Organic Matter*	%	4.2	7.0 - 17.0
Total Carbon*	%	2.4	
Soil Sample Depth*	mm	0-75	
Base Saturation %		K 2.7 Ca 28	Mg 10.5 Na 1.0
MAF Units		K 6 Ca 4	Mg 25 Na 5



The above nutrient graph compares the levels found with reference interpretation levels. NOTE: It is important that the correct sample type be assigned, and that the recommended sampling procedure has been followed. R J Hill Laboratories Limited does not accept any responsibility for the resulting use of this information.
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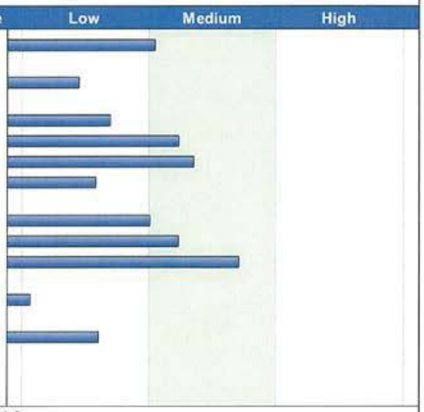
ANALYSIS REPORT

Page 2 of 6

Client:	Massey University	**Lab No:**	1276725 shpv1
Address:	C/- The Registrar Private Bag 11222 PALMERSTON NORTH 4442	**Date Registered:**	17-May-2014
		Date Reported:	21-May-2014
		Quote No:	
		Order No:	PN157073
		Client Reference:	
Phone:	06 356 9099 X 81440 - Christin	**Submitted By:**	Reina Tamepo

Sample Name: B **Lab Number:** 1276725.2
Sample Type: SOIL Mixed Pasture (S1)

Analysis		Level Found	Medium Range
pH	pH Units	5.8	5.8 - 6.2
Olsen Phosphorus	mg/L	12	20 - 30
Potassium	me/100g	0.32	0.40 - 0.60
Calcium	me/100g	5.4	4.0 - 10.0
Magnesium	me/100g	1.21	1.00 - 1.60
Sodium	me/100g	0.12	0.20 - 0.50
CEC	me/100g	12	12 - 25
Total Base Saturation	%	58	50 - 85
Volume Weight	g/mL	0.89	0.60 - 1.00
Sulphate Sulphur	mg/kg	3	10 - 12
Organic Matter*	%	4.2	7.0 - 17.0
Total Carbon*	%	2.5	
Soil Sample Depth*	mm	0-75	
Base Saturation %		K 2.7 Ca 45	Mg 10.0 Na 1.0
MAF Units		K 6 Ca 6	Mg 24 Na 5



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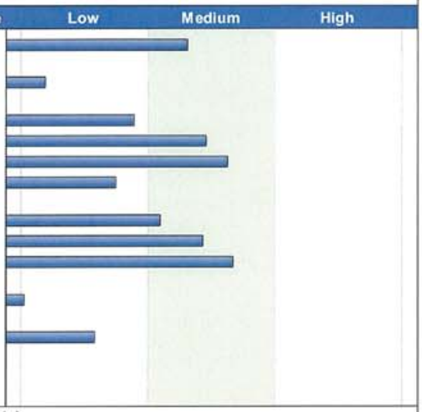
Client:	Massey University	**Lab No:**	1276725
Address:	C/- The Registrar	**Date Registered:**	17-May-2014
	Private Bag 11222	**Date Reported:**	21-May-2014
	PALMERSTON NORTH 4442	**Quote No:**	
		Order No:	PN157073
		Client Reference:	
Phone:	06 356 9099 X 81440 - Christin	**Submitted By:**	Reina Tamepo

shpv1

Sample Name: C **Lab Number:** 1276725.3
Sample Type: SOIL Mixed Pasture (S1)

Analysis		Level Found	Medium Range
pH	pH Units	5.9	5.8 - 6.2
Olsen Phosphorus	mg/L	8	20 - 30
Potassium	me/100g	0.37	0.40 - 0.60
Calcium	me/100g	6.8	4.0 - 10.0
Magnesium	me/100g	1.38	1.00 - 1.60
Sodium	me/100g	0.15	0.20 - 0.50
CEC	me/100g	13	12 - 25
Total Base Saturation	%	65	50 - 85
Volume Weight	g/mL	0.87	0.60 - 1.00
Sulphate Sulphur	mg/kg	2	10 - 12
Organic Matter*	%	4.1	7.0 - 17.0
Total Carbon*	%	2.4	
Soil Sample Depth*	mm	0-75	
Base Saturation %		K 2.8 Ca 51	Mg 10.4 Na 1.1
MAF Units		K 7 Ca 7	Mg 27 Na 6



The above nutrient graph compares the levels found with reference interpretation levels. NOTE: It is important that the correct sample type be assigned, and that the recommended sampling procedure has been followed. R J Hill Laboratories Limited does not accept any responsibility for the resulting use of this information.
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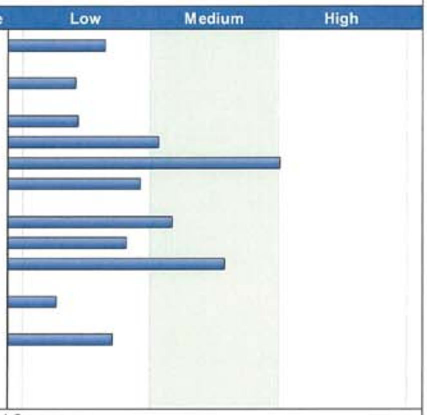
Client:	Massey University	**Lab No:**	1276725	shpv1
Address:	C/- The Registrar	**Date Registered:**	17-May-2014	
	Private Bag 11222	**Date Reported:**	21-May-2014	
	PALMERSTON NORTH 4442	**Quote No:**		
		Order No:	PN157073	
		Client Reference:		
Phone:	06 356 9099 X 81440 - Christin	**Submitted By:**	Reina Tamepo	

Sample Name: D **Lab Number:** 1276725.4
Sample Type: SOIL Mixed Pasture (S1)

Analysis		Level Found	Medium Range
pH	pH Units	5.5	5.8 - 6.2
Olsen Phosphorus	mg/L	11	20 - 30
Potassium	me/100g	0.26	0.40 - 0.60
Calcium	me/100g	4.4	4.0 - 10.0
Magnesium	me/100g	1.65	1.00 - 1.60
Sodium	me/100g	0.19	0.20 - 0.50
CEC	me/100g	14	12 - 25
Total Base Saturation	%	45	50 - 85
Volume Weight	g/mL	0.83	0.60 - 1.00
Sulphate Sulphur	mg/kg	4	10 - 12
Organic Matter*	%	4.9	7.0 - 17.0
Total Carbon*	%	2.9	
Soil Sample Depth*	mm	0-75	
Base Saturation %		K 1.8 Ca 31	Mg 11.5 Na 1.3
MAF Units		K 4 Ca 5	Mg 31 Na 7



The above nutrient graph compares the levels found with reference interpretation levels. NOTE: It is important that the correct sample type be assigned, and that the recommended sampling procedure has been followed. R J Hill Laboratories Limited does not accept any responsibility for the resulting use of this information.
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Address:	C/- The Registrar	**Date Registered:**	17-May-2014	
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		Order No:	PN157073	
		Client Reference:		
Phone:	06 356 9099 X 81440 - Christin	**Submitted By:**	Reina Tamepo	

Analyst's Comments

Samples 1-4 Comment:
The medium range guidelines shown in the histogram report relate to sampling protocols as per Hill Laboratories' crop guides and are based on reference values where these are published. Results for samples collected to different depths than those described in the crop guide should be interpreted with caution.
For pastoral soils, the medium ranges are specific for a 75mm sample depth, but if a 150mm sampling depth is used the nutrient levels measured may appear low against these ranges, as nutrients are typically more concentrated in the top of the soil profile. These soil profile differences are altered upon cultivation or contouring.

Sample 1 Comment:
The low CEC level found in this soil indicates that it can only retain cation nutrients (potassium, calcium, magnesium and sodium) at low levels. The normal ranges and the derived histograms are based on a typical soil with a CEC level between 12 and 25 me/100g. The % base saturation data for each element provides an alternative presentation that may be more appropriate for soils with atypical CEC values. Normal %BS levels, as a general guide, are: K 2%-5%, Ca 50%-75%, Mg 5%-15%, Na 1%-2%.

Samples 1-4 Comment:
While soil Mg MAF levels of 8-10 are sufficient for pasture production, soil levels of 25-30 are required to ensure adequate Mg content in pasture for animal health (greater than 0.22%).

SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Soil

Test	Method Description	Default Detection Limit	Sample No
Sample Registration*	Samples were registered according to instructions received.	-	1-4
Soil Prep (Dry & Grind)*	Air dried at 35 - 40°C overnight (residual moisture typically 4%) and crushed to pass through a 2mm screen.	-	1-4
pH	1:2 (v/v) soil:water slurry followed by potentiometric determination of pH.	0.1 pH Units	1-4
Olsen Phosphorus	Olsen extraction followed by Molybdenum Blue colorimetry.	1 mg/L	1-4
Sulphate Sulphur	0.02M Potassium phosphate extraction followed by Ion Chromatography.	1 mg/kg	1-4
Potassium (MAF)	1M Neutral ammonium acetate extraction followed by ICP-OES.	1 MAF units	1-4
Calcium (MAF)	1M Neutral ammonium acetate extraction followed by ICP-OES.	1 MAF units	1-4
Magnesium (MAF)	1M Neutral ammonium acetate extraction followed by ICP-OES.	1 MAF units	1-4
Sodium (MAF)	1M Neutral ammonium acetate extraction followed by ICP-OES.	2 MAF units	1-4
Organic Matter*	Organic Matter is 1.72 x Total Carbon.	0.2 %	1-4
Total Carbon*	Determined by NIR, calibration based on Total Carbon by Dumas combustion.	0.1 %	1-4
Potassium	1M Neutral ammonium acetate extraction followed by ICP-OES.	0.01 me/100g	1-4
Calcium	1M Neutral ammonium acetate extraction followed by ICP-OES.	0.5 me/100g	1-4
Magnesium	1M Neutral ammonium acetate extraction followed by ICP-OES.	0.04 me/100g	1-4
Sodium	1M Neutral ammonium acetate extraction followed by ICP-OES.	0.05 me/100g	1-4
Potassium (Sat)	1M Neutral ammonium acetate extraction followed by ICP-OES.	0.1 %BS	1-4
Calcium (Sat)	1M Neutral ammonium acetate extraction followed by ICP-OES.	1 %BS	1-4

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		Client Reference:	
Phone:	06 356 9099 X 81440 - Christin	**Submitted By:**	Reina Tamepo

shpv1

Sample Type: Soil

Test	Method Description	Default Detection Limit	Sample No
Magnesium (Sat)	1M Neutral ammonium acetate extraction followed by ICP-OES.	0.2 %BS	1-4
Sodium (Sat)	1M Neutral ammonium acetate extraction followed by ICP-OES.	0.1 %BS	1-4
CEC	Summation of extractable cations (K, Ca, Mg, Na) and extractable acidity. May be overestimated if soil contains high levels of soluble salts or carbonates.	2 me/100g	1-4
Total Base Saturation	Calculated from Extractable Cations and Cation Exchange Capacity.	5 %	1-4
Volume Weight	The weight/volume ratio of dried, ground soil.	0.01 g/mL	1-4

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

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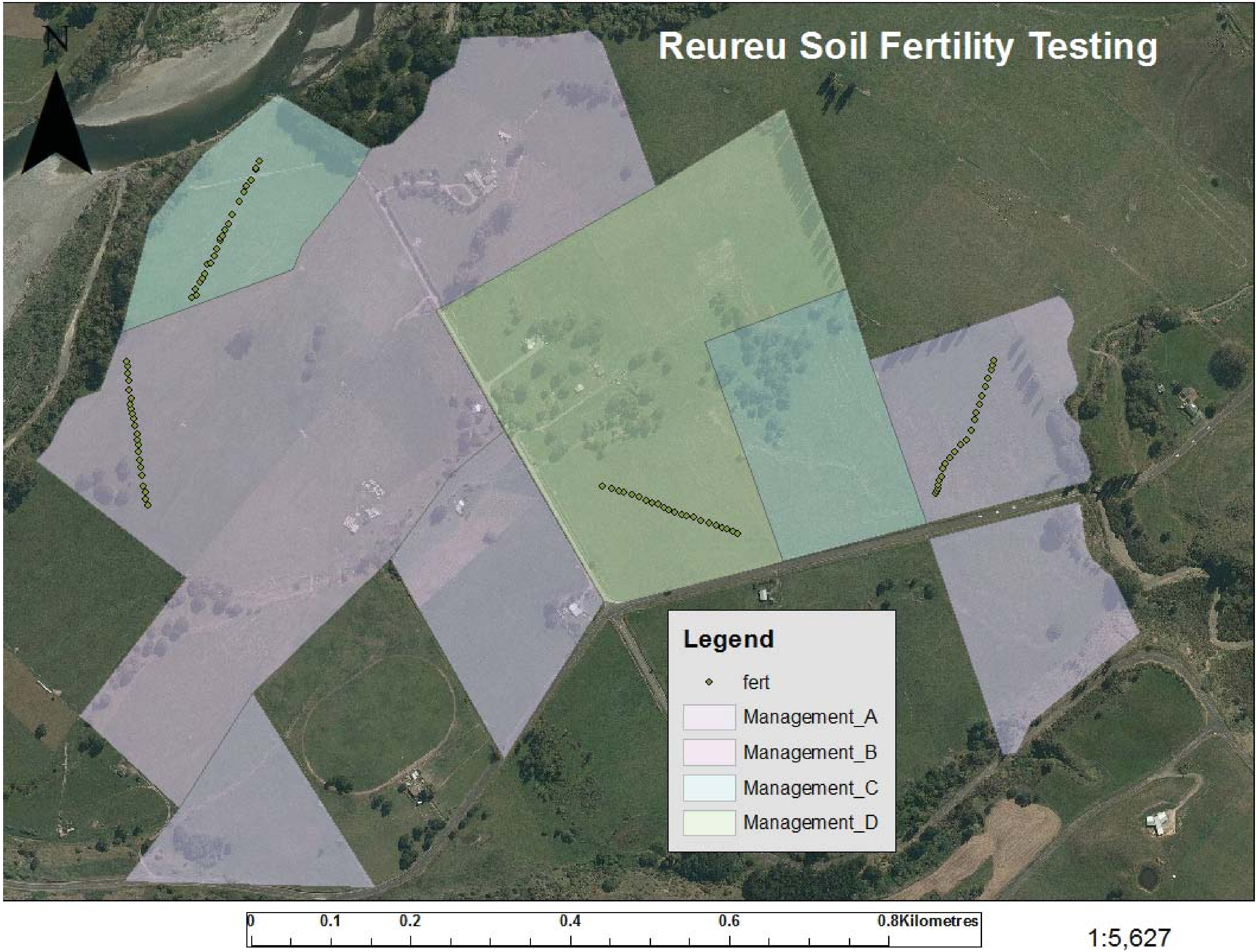
W. M. Homewood.

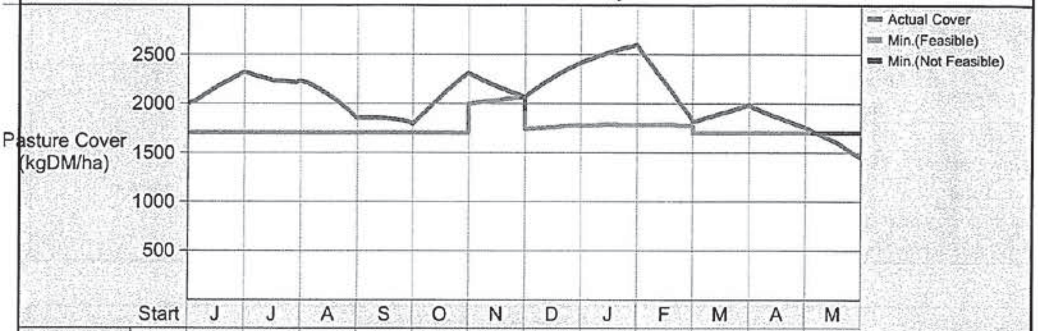
Wendy Homewood
Operations Support - Agriculture Division


Reureu Soil Fertility Testing
N
Legend
fert
Management_A
Management_B
Management_C
Management_D
0 0.1 0.2 0.4 0.6 0.8Kilometres
1:5,627

FARMAX YOUR ADVANTAGE

Pasture Cover for New Farm 1

Jun 15 - May 16



	Start	J	J	A	S	O	N	D	J	F	M	A	M
Forecast/Actual	2,000	2,318	2,225	1,852	1,791	2,308	2,067	2,416	2,598	1,816	1,986	1,755	1,449
Minimum	998	946	1,197	1,104	1,280	1,675	2,065	1,781	1,782	1,774	1,040	1,186	1,540

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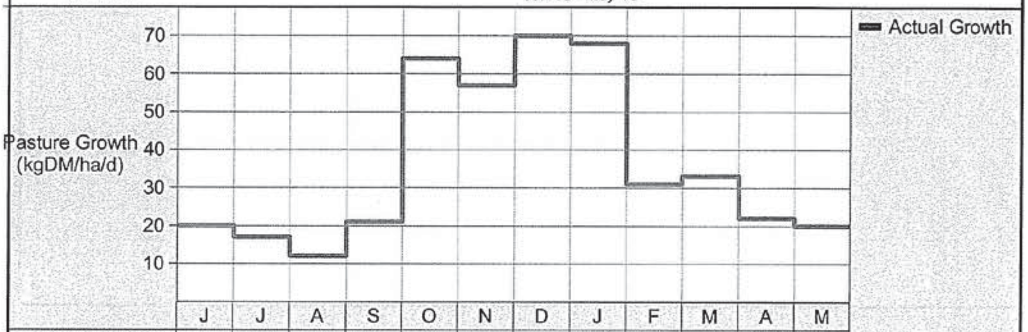
Potential Pasture Growth for New Farm 1

Jun 15 - May 16



	J	J	A	S	O	N	D	J	F	M	A	M
Actual / Forecast	20.0	17.0	12.0	21.0	64.0	57.0	70.0	68.0	31.0	33.0	22.0	20.0
Total Pasture Growth kg DM/ha	13,303											

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Supplement Usage Summary for New Farm 1

Jun 15 - May 16

Feed	tonnes DM offered													kg
	Jun 15	Jul 15	Aug 15	Sep 15	Oct 15	Nov 15	Dec 15	Jan 16	Feb 16	Mar 16	Apr 16	May 16	Total	/milker
Bulb Turnip							31	31	29				92	437
New Pasture										12			12	58
Maize bought	25	26	18	17	3	6	3	3	3	26	25	24	180	855
Pasture silage bought			6	11	13								30	144
Total													**314**	**1,494**

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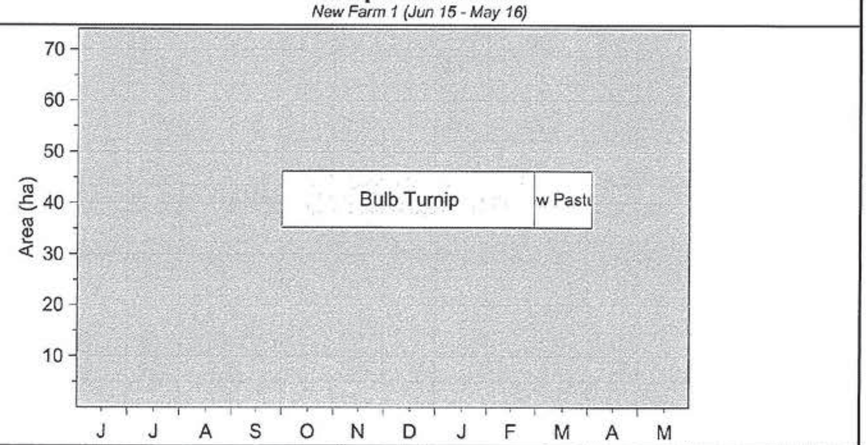
Crops for Block

New Farm 1 (Jun 15 - May 16)



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Crops for Block
New Farm 1 (Jun 15 - May 16)

Name	Area	Out of Pasture			Crop		Utilised Yield			Total	Notes
	ha	From	To	Days	Type	DM %	Per Ha	Total	Units	Cost $	
Bulb Turnip	11.0	01 Oct 15	29 Feb 16	152	Bulb Turnip	100	7.7	84	tonnes DM	16,500	
New Pasture	11.0	29 Feb 16	02 Apr 16	34	New Pasture	100	1.0	11	tonnes DM	13,200	
Total										**29,700**	

[a] No production cost for crops which begin on start date (01 Jun 15), or which follow an exactly similar crop.
[b] Crop is followed by new pasture - regrassing cost applies.

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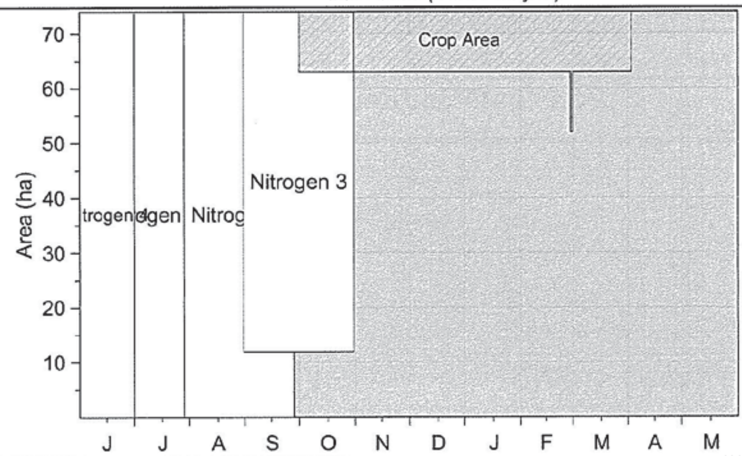
Nitrogen for Block
New Farm 1 (Jun 15 - May 16)



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Nitrogen for Block
New Farm 1 (Jun 15 - May 16)

Name	Date	Rate	Response		Area	Amount	Cost	Notes
		kgN/ha	kgDM/kgN	days	ha	kgN	$	
Nitrogen 4	01 May 15	40	10	61	74	2,960		[a]
Nitrogen	05 Jun 15	40	10	61	74	2,960	6,334	
Nitrogen 2	29 Jul 15	40	10	61	74	2,960	6,334	
Nitrogen 3	31 Aug 15	40	10	61	62	2,480	5,307	
Total (whole block)		**114**			**74**	**8,400**	**17,976**	

[a] No cost for applications made on or before start date (01 Jun 15)

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Mob Numbers for Dairy
New Farm 1 (Jun 15 - May 16)

Mob	Open	Born	Die	Buy	Sell	Transfer		Close
						In	Out	
Cows	210							210
Bobby Calves		160			160			
Heifer Calves		50						50
Total	**210**	**210**	**0**	**0**	**160**	**0**	**0**	**260**

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Mob Numbers by Month for Dairy
New Farm 1 (Jun 15 - May 16)

Mob	30 Jun	31 Jul	31 Aug	30 Sep	31 Oct	30 Nov	31 Dec	31 Jan	29 Feb	31 Mar	30 Apr	31 May
Cows	210	210	210	210	210	210	210	210	210	210	210	210
Bobby Calves		5	13	2								
Heifer Calves		7	50	50	50	50	50	50	50	50	50	50
Total	**210**	**222**	**273**	**262**	**260**	**260**	**260**	**260**	**260**	**260**	**260**	**260**

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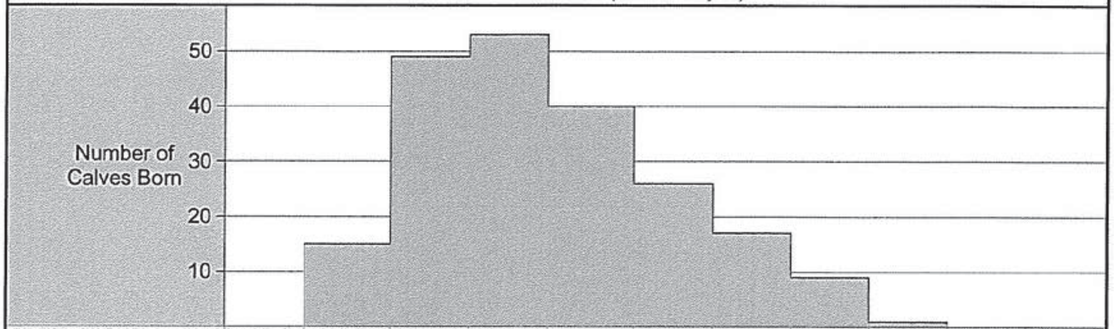
2015 Calving Spread for Dairy: Cows

New Farm 1 (Jun 15 - May 16)



Period	11-20 Jul	21-31 Jul	1-10 Aug	11-20 Aug	21-31 Aug	1-10 Sep	11-20 Sep	21-30 Sep	1-10 Oct	11-20 Oct	Total
Forecast from mating results		15	49	53	40	26	17	9	1	0	210

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2015 Calf Destinations for Dairy: Cows

New Farm 1 (Jun 15 - May 16)

Heifer Calves (105)					Bull Calves (105)			
First	50	into	Heifer Calves	(50)	All	into	Bobby Calves	(105)
Remainder		into	Bobby Calves	(55)				

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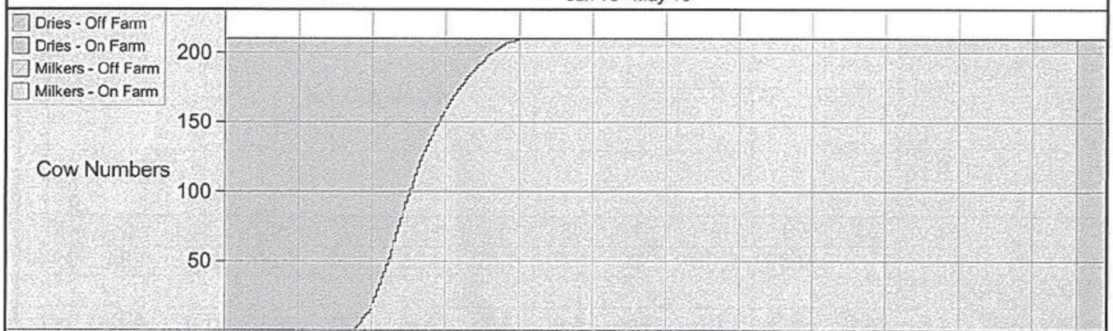
Location

Jun 15 - May 16



End of Month	J	J	A	S	O	N	D	J	F	M	A	M
Total Off-Farm	0	0	0	0	0	0	0	0	0	0	0	0
Total On-Farm	210	210	210	210	210	210	210	210	210	210	210	210
Total	210	210	210	210	210	210	210	210	210	210	210	210

All cows – combined milking + dry cows

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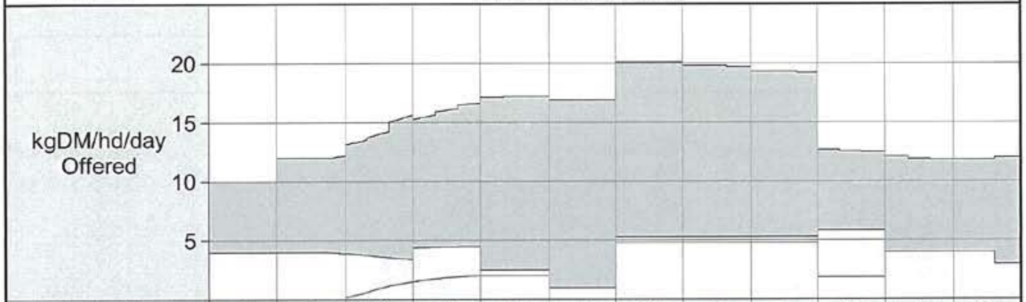
Feed Offered for Dairy: Cows

New Farm 1 (Jun 15 - May 16)



Select a Feed	J	J	A	S	O	N	D	J	F	M	A	M
Pasture	6.0	8.1	10.4	11.5	14.7	15.9	14.8	14.5	14.0	6.7	7.9	8.3
Maize bought	4.0	4.0	2.8	2.6	0.5	1.0	0.5	0.5	0.5	4.0	4.0	3.6
Bulb Turnip							4.8	4.8	4.8			
New Pasture										1.9		
Pasture silage bought			0.9	1.8	2.0							
Total (Utilised)	8.8	10.5	11.8	14.4	16.7	16.9	19.4	19.0	18.5	12.6	11.9	11.1

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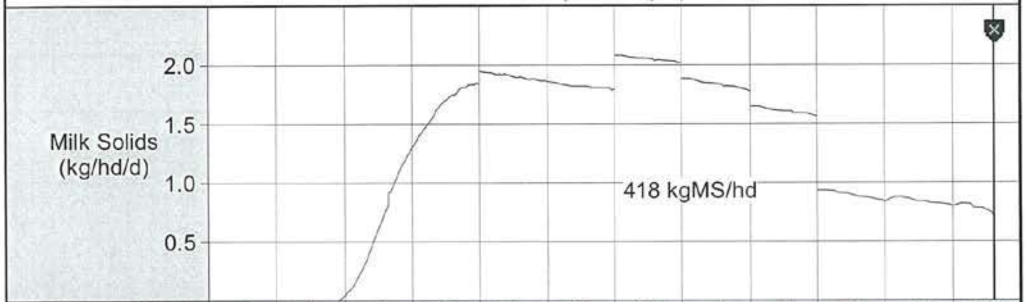
Production for Dairy: Cows

New Farm 1 (Jun 15 - May 16)



	Start	J	J	A	S	O	N	D	J	F	M	A	M
Model MS (kg/hd/d)			0.00	0.66	1.66	1.90	1.82	2.05	1.83	1.60	0.89	0.84	0.48
Actual MS (kg/hd/d)													
Actual/Forecast BCS	4.5	4.9	5.3	5.1	4.5	4.4	4.4	4.6	4.9	5.1	5.0	4.8	5.1
Model Lwt (kg)	455	477	502	464	434	429	429	436	444	451	447	442	450

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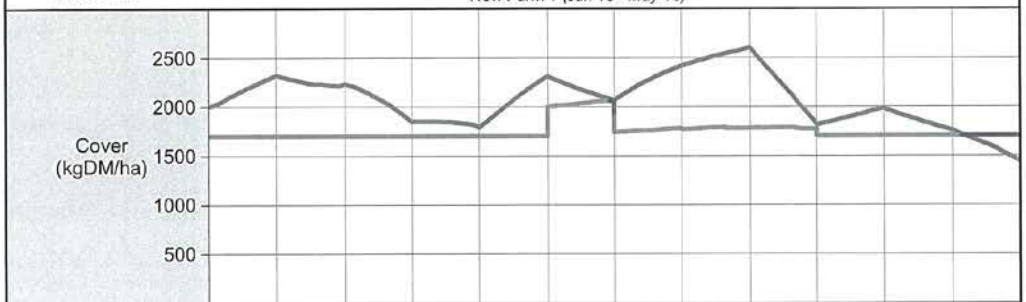
Cover for Dairy: Cows

New Farm 1 (Jun 15 - May 16)



	Start	J	J	A	S	O	N	D	J	F	M	A	M
Forecast/Actual	2,000	2,318	2,225	1,852	1,791	2,308	2,067	2,416	2,598	1,816	1,986	1,755	1,449
Minimum	998	946	1,197	1,104	1,280	1,675	2,065	1,781	1,782	1,774	1,040	1,186	1,540
Potential Pasture Growth (kgDM/ha/d)		20	17	12	21	64	57	70	68	31	33	22	20

Milking cows

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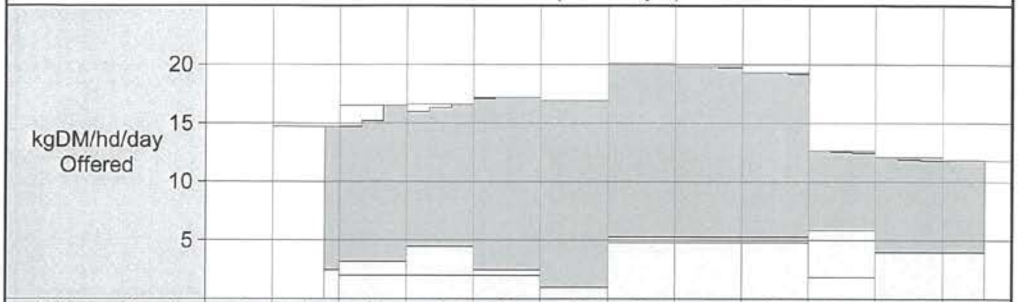
Feed Offered for Dairy: Cows

New Farm 1 (Jun 15 - May 16)

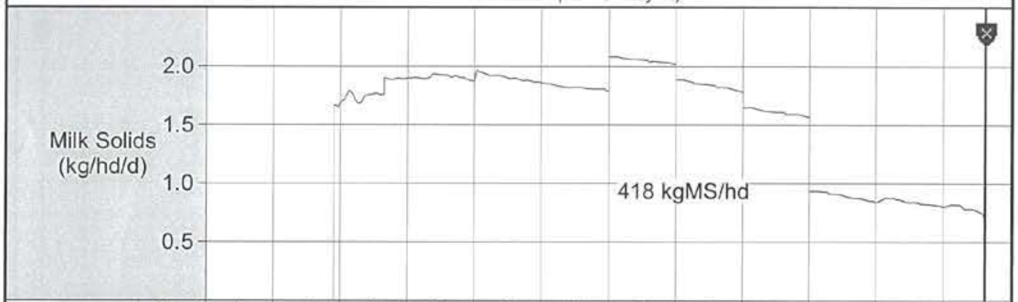


Select a Feed	J	J	A	S	O	N	D	J	F	M	A	M
Pasture		17.4	12.3	11.8	14.7	15.9	14.8	14.5	14.0	6.7	7.9	7.8
Maize bought		2.5	1.2	2.5	0.5	1.0	0.5	0.5	0.5	4.0	4.0	4.0
Bulb Turnip							4.8	4.8	4.8			
New Pasture										1.9		
Pasture silage bought			2.0	2.0	2.0							
Total (Utilised)		16.3	12.5	14.6	16.7	16.9	19.4	19.0	18.5	12.6	11.9	11.0

FARMAX YOUR ADVANTAGE

Production for Dairy: Cows

New Farm 1 (Jun 15 - May 16)

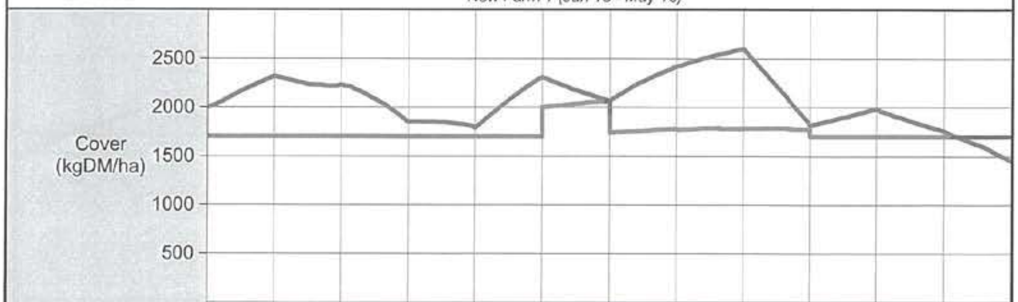


	Start	J	J	A	S	O	N	D	J	F	M	A	M
Model MS (kg/hd/d)			1.67	1.83	1.91	1.90	1.82	2.05	1.83	1.60	0.89	0.84	0.78
Actual MS (kg/hd/d)													
Actual/Forecast BCS	4.5		5.2	4.9	4.5	4.4	4.4	4.6	4.9	5.1	5.0	4.8	
Model Lwt (kg)			441	439	434	429	429	436	444	451	447	442	

FARMAX YOUR ADVANTAGE

Cover for Dairy: Cows

New Farm 1 (Jun 15 - May 16)



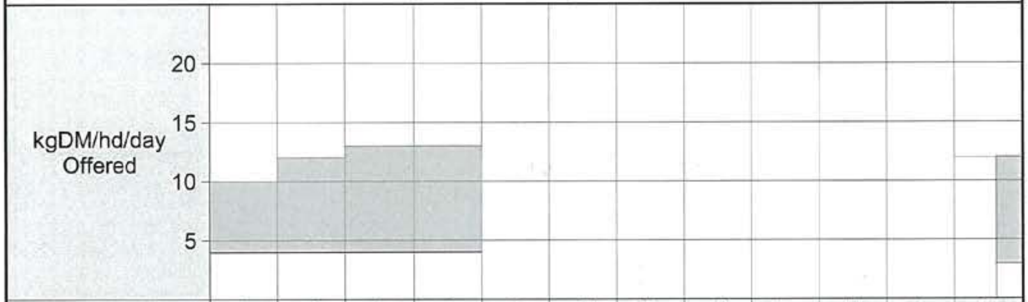
	Start	J	J	A	S	O	N	D	J	F	M	A	M
Forecast/Actual	2,000	2,318	2,225	1,852	1,791	2,308	2,067	2,416	2,598	1,816	1,986	1,755	1,449
Minimum	998	946	1,197	1,104	1,280	1,675	2,065	1,781	1,782	1,774	1,040	1,186	1,540
Potential Pasture Growth (kgDM/ha/d)		20	17	12	21	64	57	70	68	31	33	22	20

Dry Cows

FARMAX YOUR ADVANTAGE

Feed Offered for Dairy: Cows

New Farm 1 (Jun 15 - May 16)

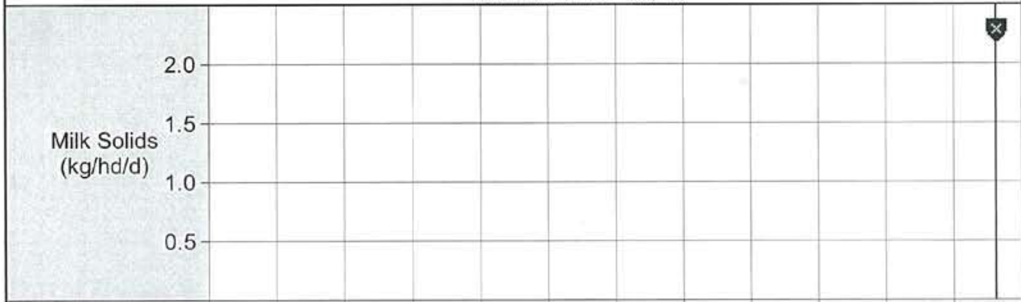


Select a Feed	J	J	A	S	O	N	D	J	F	M	A	M
Pasture	6.0	8.0	9.0	9.0								9.0
Maize bought	4.0	4.0	4.0	4.0								3.0
Bulb Turnip												
New Pasture												
Pasture silage bought												
Total (Utilised)	8.8	10.4	11.2	12.1								11.1

FARMAX YOUR ADVANTAGE

Production for Dairy: Cows

New Farm 1 (Jun 15 - May 16)

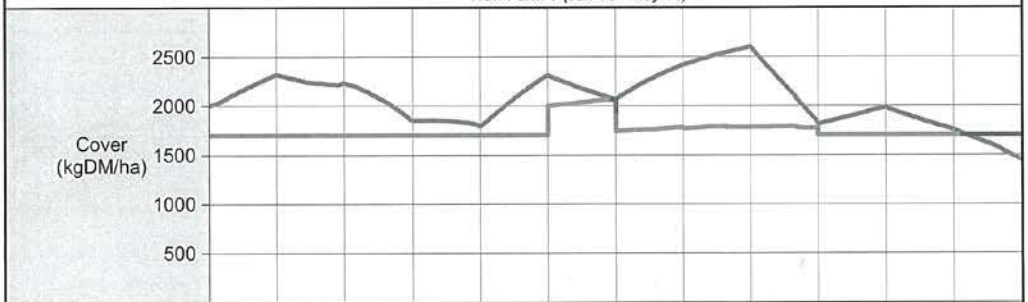


	Start	J	J	A	S	O	N	D	J	F	M	A	M
Model MS (kg/hd/d)													
Actual MS (kg/hd/d)													
Actual/Forecast BCS	4.5	4.9	5.3	5.8	6.0								5.1
Model Lwt (kg)	455	477	507	541	558								450

FARMAX YOUR ADVANTAGE

Cover for Dairy: Cows

New Farm 1 (Jun 15 - May 16)



	Start	J	J	A	S	O	N	D	J	F	M	A	M
Forecast/Actual	2,000	2,318	2,225	1,852	1,791	2,308	2,067	2,416	2,598	1,816	1,986	1,755	1,449
Minimum	998	946	1,197	1,104	1,280	1,675	2,065	1,781	1,782	1,774	1,040	1,186	1,540
Potential Pasture Growth (kgDM/ha/d)		20	17	12	21	64	57	70	68	31	33	22	20

Client reference:

Farm name: Reureu Farm - copy 1 (2014)

Parameters

Farm details

Type	Farm type	Full range
Assessment	Assessment year	2014
Region	Region	Manawatu/Wanganui

Farm blocks

Kairanga	Pastoral	1.1
Karapoti	Pastoral	1.6
Otaki	Pastoral	6.8
Parewanui	Pastoral	7.6
Effluent (Rangitikei deep and mod deep	Pastoral	24.3
Manawatu Deep	Pastoral	7.8
Manawatu Mod-deep	Pastoral	2.8
Manawatu Shallow	Pastoral	0.2
Rangitikei Shallow	Pastoral	8.7
Fodder Crop 1	Fodder Crop	
Total farm area declared in blocks	ha	72
Total farm area	ha	74
Non-productive area	ha	2

Farm animals

Stock numbers

Stock numbers entered via RSU - Dairy

Peak number of cows milked		210
Peak numbers are constant over year		Yes
Breed		F x J cross
Replacements grazed off farm from		Off farm from weaning
Replacement grazing	%	Not entered

Production

Milk solids	kg/yr	87000
Milk volume yield	l/yr	Not entered
Fat yield	kg/yr	Not entered
Lactation length	days	Not entered
Average weight	kg/animal	Not entered

Calving times

Median calving date		15 August
Drying off		1 May

Stock management

Dairy - Feed pad

Effluent management

Manure removal method		Scraping (no water)
Solid management method		
Solid storage method		
Time in storage	months	0

Client reference:

Farm name: Reureu Farm - copy 1 (2014)

Parameters

Scraped material added to FDE		True
Time spent on structure		
January	100	2
February	100	2
March	100	2
April	100	2
May	100	2
June	100	2
July	100	2
August	100	2
September	100	2
October	100	2
November	100	2
December	100	2

Animal excreta distribution

Relative productivity assessment method		No difference between blocks
All blocks have a relative productivity value of 1		
Ratio of stock types on pastoral blocks is the same as the farm stock ratios		
Farm dairy effluent management system		
Effluent management method		Holding pond
Pond solids management method		Spread on selected blocks
Solid separation and disposal	False	Spread on selected blocks
Liquid management method		Spray regularly

Animal health supplements

Animal - Dairy

No animal supplementation has been entered

Animal - Dairy replacements

No animal supplementation has been entered

Left over feeding

No left over feeding specified

No supplements from storage added to this farm

Imported supplements

Supplement information		
Conservation type		Silage
Name		Maize silage
Pasture type		
Supplement amount		
Dry weight basis	T	184
Silage cutting method		
Utilisation		Very good
Destination		Feed pad
Animal		Dairy

Client reference:

Farm name: Reureu Farm - copy 1 (2014)

Parameters

Animal		Dairy
Supplement information		
Conservation type		Silage
Name		Pasture good quality silage
Pasture type		
Supplement amount		
Dry weight basis	T	138
Silage cutting method		
Utilisation		Very good
Destination		Feed pad
Animal		Dairy

Block Information

Block - Kairanga

Block name		Kairanga
Block type		Pastoral
Area	ha	1.4
Relative productivity		1
Pasture block type		Yes
Topography		Flat
Distance from coast	km	51
Cultivated in last 5 years		False
Climate		
Annual average rainfall	mm/yr	1041
Mean annual temperature		12.2
Seasonal variation in rainfall		731-1450 mm, Low
Annual potential evapotranspiration		801-950 mm/yr
Seasonal variation in PET		Moderate
Soil description		
Soil type		KAIRANGA
Soil order (default)		Sedimentary
Soil group (default)		Gley
Top soil texture		
Stony top soil		False
Compacted top soil		False
Non-standard soil layer		Stony matrix
Depth to non-standard layer		0.27
Depth to impeded drainage layer		0
Maximum rooting depth		0
Soil drainage		
Profile drainage class		Use default
Hydrophobic condition		Use default

Drainage method

Client reference:

Farm name: Reureu Farm - copy 1 (2014)

Parameters

Method	Mole/tile system
Percent of paddock drained	100
Occurence of pugging damage	Winter or rain

Soil settings

K leaching (%s)	Medium
N immobilisation status	Standard

Soil tests

Olsen P	QT K	QT Ca	QT Mg	QT Na
30	7	9	21	8

Organic S	9
Anion storage capacity or phosphate retention	Not entered
TBK reserve K test	Not entered
K reserve status	Use default

Pasture

Pasture type	Grass only

Supplements removed

No supplements removed from this block

Fertiliser application

Fertiliser products - May

Category	Ballance other
Product	N-rich urea
Amount	87

Fertiliser products - June

Category	Ballance other
Product	N-rich urea
Amount	87

Fertiliser products - July

Category	Ballance other
Product	N-rich urea
Amount	87

Fertiliser products - August

Category	Ballance other
Product	N-rich urea
Amount	87

Fertiliser products - October

Category	Ballance super
Product	Superten 10K (20% potash superten)
Amount	450

Client reference:
Farm name: Reureu Farm - copy 1 (2014)

Parameters

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Irrigation
No irrigation entered

Irrigation concentrations

N	P	K	S	Ca	Mg	Na	H
0	0	0	0	0	0	0	0

Animals on block

Ratio and type of stock based on whole farm values due to this option being selected on block set up

Animals grazing		
Dairy	%	0
Water connectivity		
Direct access to streams		False

Animal grazing
Dairy graze block all year round

Effluent application

Receives no liquid or solid effluents

Block - Karapoti

Block name		Karapoti
Block type		Pastoral
Area	ha	2.1
Relative productivity		1
Pasture block type		Yes
Topography		Flat
Distance from coast	km	51
Cultivated in last 5 years		False
Climate		
Annual average rainfall	mm/yr	1041
Mean annual temperature		12.2
Seasonal variation in rainfall		731-1450 mm, Low
Annual potential evapotranspiration		801-950 mm/yr
Seasonal variation in PET		Moderate
Soil description		
Soil type		KARAPOTI
Soil order (default)		Recent/YGE/BGE
Soil group (default)		Recent
Top soil texture		
Stony top soil		False
Compacted top soil		False
Sub-soil textural group		Medium
Non-standard soil layer		Sandy
Depth to non-standard layer		0.87

Client reference:

Farm name: Reureu Farm - copy 1 (2014)

Parameters

Depth to non-standard layer	0.87
Depth to impeded drainage layer	0
Maximum rooting depth	0
Soil drainage	
Profile drainage class	Use default
Hydrophobic condition	Use default
Drainage method	
Method	None
Soil settings	
K leaching (%s)	Medium
N immobilisation status	Standard

Soil tests

Olsen P	QT K	QT Ca	QT Mg	QT Na
30	7	9	21	8

Organic S	9
Anion storage capacity or phosphate retention	Not entered
TBK reserve K test	Not entered
K reserve status	Use default

Pasture

Pasture type	Grass only

Supplements removed

No supplements removed from this block

Fertiliser application

Fertiliser products - May	
Category	Ballance other
Product	N-rich urea
Amount	87
Fertiliser products - June	
Category	Ballance other
Product	N-rich urea
Amount	87
Fertiliser products - July	
Category	Ballance other
Product	N-rich urea
Amount	87
Fertiliser products - August	
Category	Ballance other
Product	N-rich urea
Amount	87

Client reference:
Farm name: Reureu Farm - copy 1 (2014)

Parameters

OVERSEER®

Fertiliser products - October

Category	Ballance super
Product	Superten 10K (20% potash superten)
Amount	450

Irrigation
No irrigation entered

Irrigation concentrations

N	P	K	S	Ca	Mg	Na	H
0	0	0	0	0	0	0	0

Animals on block

Ratio and type of stock based on whole farm values due to this option being selected on block set up

Animals grazing

Dairy	%	0

Water connectivity

Direct access to streams	False

Animal grazing
Dairy graze block all year round

Effluent application

Receives no liquid or solid effluents

Block - Otaki

Block name		Otaki
Block type		Pastoral
Area	ha	8.8
Relative productivity		1
Pasture block type		Yes
Topography		Flat
Distance from coast	km	51
Cultivated in last 5 years		False

Climate

Annual average rainfall	mm/yr	1041
Mean annual temperature		12.2
Seasonal variation in rainfall		731-1450 mm, Low
Annual potential evapotranspiration		801-950 mm/yr
Seasonal variation in PET		Moderate

Soil description

Soil type	OTAKI
Soil order (default)	Recent/YGE/BGE
Soil group (default)	Recent

Client reference:

Farm name: Reureu Farm - copy 1 (2014)

Parameters

Top soil texture	
Stony top soil	False
Compacted top soil	False
Sub-soil textural group	Medium
Non-standard soil layer	Stony matrix
Depth to non-standard layer	0.15
Depth to impeded drainage layer	0
Maximum rooting depth	0
Soil drainage	
Profile drainage class	Well
Hydrophobic condition	Use default
Drainage method	
Method	None
Soil settings	
K leaching (%s)	Medium
N immobilisation status	Standard

Soil tests

Olsen P	QT K	QT Ca	QT Mg	QT Na
30	7	9	21	8

Organic S	9
Anion storage capacity or phosphate retention	Not entered
TBK reserve K test	Not entered
K reserve status	Use default

Pasture

Pasture type	Grass only

Supplements removed

No supplements removed from this block

Fertiliser application

Fertiliser products - May	
Category	Ballance other
Product	N-rich urea
Amount	87
Fertiliser products - June	
Category	Ballance other
Product	N-rich urea
Amount	87
Fertiliser products - July	
Category	Ballance other
Product	N-rich urea

Client reference:

Farm name: Reureu Farm - copy 1 (2014)

Parameters

Product		N-rich urea
Amount		87
Fertiliser products - August		
Category		Ballance other
Product		N-rich urea
Amount		87
Fertiliser products - October		
Category		Ballance super
Product		Superten 10K (20% potash superten)
Amount		450

Irrigation

No irrigation entered

Irrigation concentrations

N	P	K	S	Ca	Mg	Na	H
0	0	0	0	0	0	0	0

Animals on block

Ratio and type of stock based on whole farm values due to this option being selected on block set up

Animals grazing		
Dairy	%	0
Water connectivity		
Direct access to streams		False

Animal grazing

Dairy graze block all year round

Effluent application

Receives no liquid or solid effluents

Block - Parewanui

Block name		Parewanui
Block type		Pastoral
Area	ha	9.9
Relative productivity		1
Pasture block type		Yes
Topography		Flat
Distance from coast	km	51
Cultivated in last 5 years		False
Climate		
Annual average rainfall	mm/yr	1041
Mean annual temperature		12.2
Seasonal variation in rainfall		731-1450 mm, Low
Annual potential evapotranspiration		801-950 mm/yr

Client reference:

Farm name: Reureu Farm - copy 1 (2014)

Parameters

Annual potential evapotranspiration	801-950 mm/yr
Seasonal variation in PET	Moderate
Soil description	
Soil type	PAREWANUI
Soil order (default)	Sedimentary
Soil group (default)	Gley
Top soil texture	
Stony top soil	False
Compacted top soil	False
Non-standard soil layer	Sandy
Depth to non-standard layer	0.4
Depth to impeded drainage layer	0
Maximum rooting depth	0
Soil drainage	
Profile drainage class	Poor
Hydrophobic condition	Use default
Drainage method	
Method	Mole/tile system
Percent of paddock drained	100
Occurence of pugging damage	Winter or rain
Soil settings	
K leaching (%s)	Medium
N immobilisation status	Standard

Soil tests

Olsen P	QT K	QT Ca	QT Mg	QT Na
30	7	9	21	8

Organic S	9
Anion storage capacity or phosphate retention	Not entered
TBK reserve K test	Not entered
K reserve status	Use default

Pasture

Pasture type	Grass only

Supplements removed

No supplements removed from this block

Fertiliser application

Fertiliser products - May

Category	Ballance other
Product	N-rich urea
Amount	87

Client reference:

Farm name: Reureu Farm - copy 1 (2014)

Parameters

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Fertiliser products - June

Category		Ballance other
Product		N-rich urea
Amount		87

Fertiliser products - July

Category		Ballance other
Product		N-rich urea
Amount		87

Fertiliser products - August

Category		Ballance other
Product		N-rich urea
Amount		87

Fertiliser products - October

Category		Ballance super
Product		Superten 10K (20% potash superten)
Amount		450

Irrigation

No irrigation entered

Irrigation concentrations

N	P	K	S	Ca	Mg	Na	H
0	0	0	0	0	0	0	0

Animals on block

Ratio and type of stock based on whole farm values due to this option being selected on block set up

Animals grazing

Dairy	%	0

Water connectivity

Direct access to streams		False

Animal grazing

Dairy graze block all year round

Effluent application

Receives no liquid or solid effluents

Block - Effluent (Rangitikei deep and mod deep

Block name		Effluent (Rangitikei deep and mod deep
Block type		Pastoral
Area	ha	24.3
Relative productivity		1
Pasture block type		No

Client reference:

Farm name: Reureu Farm - copy 1 (2014)

Parameters

Pasture block type		No
Topography		Flat
Distance from coast	km	51
Cultivated in last 5 years		False
Climate		
Annual average rainfall	mm/yr	1041
Mean annual temperature		12.2
Seasonal variation in rainfall		731-1450 mm, Low
Annual potential evapotranspiration		801-950 mm/yr
Seasonal variation in PET		Moderate
Soil description		
Soil type		RANGITIKEI
Soil order (default)		Recent/YGE/BGE
Soil group (default)		Recent
Top soil texture		
Stony top soil		False
Compacted top soil		False
Sub-soil textural group		Light
Non-standard soil layer		Sandy
Depth to non-standard layer		0.6
Depth to impeded drainage layer		0
Maximum rooting depth		0
Soil drainage		
Profile drainage class		Well
Hydrophobic condition		Use default
Drainage method		
Method		None
Soil settings		
K leaching (%s)		Medium
N immobilisation status		Standard

Soil tests

Olsen P	QT K	QT Ca	QT Mg	QT Na
30	7	9	21	8

Organic S	9
Anion storage capacity or phosphate retention	Not entered
TBK reserve K test	Not entered
K reserve status	Use default

Pasture

Pasture type	Grass only

Supplements removed

No supplements removed from this block

Client reference:

Farm name: Reureu Farm - copy 1 (2014)

Parameters

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Fertiliser application
No fertiliser application applied on block

Irrigation
No irrigation entered

Irrigation concentrations

N	P	K	S	Ca	Mg	Na	H
0	0	0	0	0	0	0	0

Animals on block

Ratio and type of stock based on whole farm values due to this option being selected on block set up

Animals grazing		
Dairy	%	0
Water connectivity		
Direct access to streams		False
Animal grazing		
Dairy graze block all year round		

Effluent application

Liquid effluents		
Receives farm dairy effluent		
Effluent application depth		< 12 mm
Active management occurs		
Percentage of block effluent applied to	%	100
Solid effluents		
Effluent type added	January	Pond solids/sludge

Block - Manawatu Deep

Block name		Manawatu Deep
Block type		Pastoral
Area	ha	10.2
Relative productivity		1
Pasture block type		Yes
Topography		Flat
Distance from coast	km	51
Cultivated in last 5 years		False
Climate		
Annual average rainfall	mm/yr	1041
Mean annual temperature		12.2
Seasonal variation in rainfall		731-1450 mm, Low
Annual potential evapotranspiration		801-950 mm/yr
Seasonal variation in PET		Moderate

Client reference:

Farm name: Reureu Farm - copy 1 (2014)

Parameters

Soil description	
Soil type	MANAWATU
Soil order (default)	Recent/YGE/BGE
Soil group (default)	Recent
Top soil texture	
Stony top soil	False
Compacted top soil	False
Sub-soil textural group	Medium
Non-standard soil layer	Sandy
Depth to non-standard layer	0.7
Depth to impeded drainage layer	0
Maximum rooting depth	0
Soil drainage	
Profile drainage class	Well
Hydrophobic condition	Use default
Drainage method	
Method	None
Soil settings	
K leaching (%s)	Medium
N immobilisation status	Standard

Soil tests

Olsen P	QT K	QT Ca	QT Mg	QT Na
30	7	9	21	8

Organic S	9
Anion storage capacity or phosphate retention	Not entered
TBK reserve K test	Not entered
K reserve status	Use default

Pasture

Pasture type	Grass only

Supplements removed

No supplements removed from this block

Fertiliser application

Fertiliser products - May	
Category	Ballance other
Product	N-rich urea
Amount	87
Fertiliser products - June	
Category	Ballance other
Product	N-rich urea

Client reference:

Farm name: Reureu Farm - copy 1 (2014)

Parameters

Amount	87

Fertiliser products - July

Category	Ballance other
Product	N-rich urea
Amount	87

Fertiliser products - August

Category	Ballance other
Product	N-rich urea
Amount	87

Fertiliser products - October

Category	Ballance super
Product	Superten 10K (20% potash superten)
Amount	450

Irrigation

No irrigation entered

Irrigation concentrations

N	P	K	S	Ca	Mg	Na	H
0	0	0	0	0	0	0	0

Animals on block

Ratio and type of stock based on whole farm values due to this option being selected on block set up

Animals grazing

Dairy	%	0

Water connectivity

Direct access to streams	False

Animal grazing

Dairy graze block all year round

Effluent application

Receives no liquid or solid effluents

Block - Manawatu Mod-deep

Block name		Manawatu Mod-deep
Block type		Pastoral
Area	ha	3.7
Relative productivity		1
Pasture block type		Yes
Topography		Flat
Distance from coast	km	51
Cultivated in last 5 years		False

Client reference:

Farm name: Reureu Farm - copy 1 (2014)

Parameters

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Climate		
Annual average rainfall	mm/yr	1041
Mean annual temperature		12.2
Seasonal variation in rainfall		731-1450 mm, Low
Annual potential evapotranspiration		801-950 mm/yr
Seasonal variation in PET		Moderate
Soil description		
Soil type		MANAWATU
Soil order (default)		Recent/YGE/BGE
Soil group (default)		Recent
Top soil texture		
Stony top soil		False
Compacted top soil		False
Sub-soil textural group		Medium
Non-standard soil layer		Stony matrix
Depth to non-standard layer		0.6
Depth to impeded drainage layer		0
Maximum rooting depth		0
Soil drainage		
Profile drainage class		Well
Hydrophobic condition		Use default
Drainage method		
Method		None
Soil settings		
K leaching (%s)		Medium
N immobilisation status		Standard

Soil tests

Olsen P	QT K	QT Ca	QT Mg	QT Na
30	7	9	21	8

Organic S	9
Anion storage capacity or phosphate retention	Not entered
TBK reserve K test	Not entered
K reserve status	Use default

Pasture

Pasture type	Grass only

Supplements removed

No supplements removed from this block

Fertiliser application

Fertiliser products - May

Category Ballance other

Client reference:

Farm name: Reureu Farm - copy 1 (2014)

Parameters

Category	Ballance other
Product	N-rich urea
Amount	87

Fertiliser products - June

Category	Ballance other
Product	N-rich urea
Amount	87

Fertiliser products - July

Category	Ballance other
Product	N-rich urea
Amount	87

Fertiliser products - August

Category	Ballance other
Product	N-rich urea
Amount	87

Fertiliser products - October

Category	Ballance super
Product	Superten 10K (20% potash superten)
Amount	450

Irrigation

No irrigation entered

Irrigation concentrations

N	P	K	S	Ca	Mg	Na	H
0	0	0	0	0	0	0	0

Animals on block

Ratio and type of stock based on whole farm values due to this option being selected on block set up

Animals grazing

Dairy	%	0

Water connectivity

Direct access to streams	False

Animal grazing

Dairy graze block all year round

Effluent application

Receives no liquid or solid effluents

Block - Manawatu Shallow

Block name	Manawatu Shallow
Block type	Pastoral

Client reference:

Farm name: Reureu Farm - copy 1 (2014)

Parameters

Area	ha	0.3
Relative productivity		1
Pasture block type		Yes
Topography		Flat
Distance from coast	km	51
Cultivated in last 5 years		False
Climate		
Annual average rainfall	mm/yr	1041
Mean annual temperature		12.2
Seasonal variation in rainfall		731-1450 mm, Low
Annual potential evapotranspiration		801-950 mm/yr
Seasonal variation in PET		Moderate
Soil description		
Soil type		MANAWATU
Soil order (default)		Recent/YGE/BGE
Soil group (default)		Recent
Top soil texture		
Stony top soil		False
Compacted top soil		False
Sub-soil textural group		Medium
Non-standard soil layer		Stony matrix
Depth to non-standard layer		0.5
Depth to impeded drainage layer		0
Maximum rooting depth		0
Soil drainage		
Profile drainage class		Well
Hydrophobic condition		Use default
Drainage method		
Method		None
Soil settings		
K leaching (%s)		Medium
N immobilisation status		Standard

Soil tests

Olsen P	QT K	QT Ca	QT Mg	QT Na
30	7	9	21	8

Organic S	9
Anion storage capacity or phosphate retention	Not entered
TBK reserve K test	Not entered
K reserve status	Use default

Pasture

Pasture type	Grass only

Client reference:
Farm name: Reureu Farm - copy 1 (2014)

Parameters

Supplements removed
No supplements removed from this block

Fertiliser application

Fertiliser products - May	
Category	Ballance other
Product	N-rich urea
Amount	87
Fertiliser products - June	
Category	Ballance other
Product	N-rich urea
Amount	87
Fertiliser products - July	
Category	Ballance other
Product	N-rich urea
Amount	87
Fertiliser products - August	
Category	Ballance other
Product	N-rich urea
Amount	87
Fertiliser products - October	
Category	Ballance super
Product	Superten 10K (20% potash superten)
Amount	450

Irrigation
No irrigation entered

Irrigation concentrations

N	P	K	S	Ca	Mg	Na	H
0	0	0	0	0	0	0	0

Animals on block

Ratio and type of stock based on whole farm values due to this option being selected on block set up

Animals grazing		
Dairy	%	0
Water connectivity		
Direct access to streams		False

Animal grazing
Dairy graze block all year round

Client reference:

Farm name: Reureu Farm - copy 1 (2014)

Parameters

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Effluent application

Receives no liquid or solid effluents

Block - Rangitikei Shallow

Block name		Rangitikei Shallow
Block type		Pastoral
Area	ha	11.3
Relative productivity		1
Pasture block type		Yes
Topography		Flat
Distance from coast	km	51
Cultivated in last 5 years		False
Climate		
Annual average rainfall	mm/yr	1041
Mean annual temperature		12.2
Seasonal variation in rainfall		731-1450 mm, Low
Annual potential evapotranspiration		801-950 mm/yr
Seasonal variation in PET		Moderate
Soil description		
Soil type		RANGITIKEI
Soil order (default)		Recent/YGE/BGE
Soil group (default)		Recent
Top soil texture		
Stony top soil		False
Compacted top soil		False
Sub-soil textural group		Medium
Non-standard soil layer		Stony matrix
Depth to non-standard layer		0.4
Depth to impeded drainage layer		0
Maximum rooting depth		0
Soil drainage		
Profile drainage class		Well
Hydrophobic condition		Use default
Drainage method		
Method		None
Soil settings		
K leaching (%s)		Medium
N immobilisation status		Standard

Soil tests

Olsen P	QT K	QT Ca	QT Mg	QT Na
30	7	9	21	8

Organic S 9

Client reference:

Farm name: Reureu Farm - copy 1 (2014)

Parameters

Anion storage capacity or phosphate retention	Not entered
TBK reserve K test	Not entered
K reserve status	Use default

Pasture

Pasture type	Grass only

Supplements removed

No supplements removed from this block

Fertiliser application

Fertiliser products - May

Category	Ballance other
Product	N-rich urea
Amount	87

Fertiliser products - June

Category	Ballance other
Product	N-rich urea
Amount	87

Fertiliser products - July

Category	Ballance other
Product	N-rich urea
Amount	87

Fertiliser products - August

Category	Ballance other
Product	N-rich urea
Amount	87

Fertiliser products - October

Category	Ballance super
Product	Superten 10K (20% potash superten)
Amount	450

Irrigation

No irrigation entered

Irrigation concentrations

N	P	K	S	Ca	Mg	Na	H
0	0	0	0	0	0	0	0

Animals on block

Ratio and type of stock based on whole farm values due to this option being selected on block set up

Animals grazing

Dairy	%	0

Client reference:

Farm name: Reureu Farm - copy 1 (2014)

Parameters

Dairy	%	0
Water connectivity		
Direct access to streams		False
Animal grazing		
Dairy graze block all year round		
Effluent application		
Receives no liquid or solid effluents		
Block - Fodder Crop 1		
Block name		Fodder Crop 1
Block type		Fodder Crop
Area	ha	11
Cultivated area	% of area	0
Headland area	% of area	0
Other area	% of area	0
Distance from coast	km	51
Final grid month		March
Climate		
Annual average rainfall	mm/yr	1041
Mean annual temperature		12.2
Seasonal variation in rainfall		731-1450 mm, Low
Annual potential evapotranspiration		801-950 mm/yr
Seasonal variation in PET		Moderate
Soil description		
Soil order (default)		Recent/YGE/BGE
Soil order (default)		Recent
SMaps	Sibling	Fodder Block Average
Wilting point	0 - 30cm	14
	30 - 60cm	12
	> 60	0
Field capacity	0 - 30cm	32
	30 - 60cm	26
	> 60	0
Saturation	0 - 30cm	46
	30 - 60cm	42
	> 60	0
Depth to impeded layer	cm	0
Top soil horizon chemical and physical parameters		
ASC/PR		Not entered
Sand	%	Not entered
Natural drainage class		Use default
Bulk density	kg/m³	Not entered
Clay	%	Not entered
Sub soil clay	%	Not entered

Top soil texture

Client reference:

Farm name: Reureu Farm - copy 1 (2014)

Parameters

Top soil texture

Stony top soil	False
Compacted top soil	False
Sub-soil textural group	Medium
Depth to impeded drainage layer	0
Maximum rooting depth	0

Soil settings

K leaching (%s)	Medium

Soil tests

Olsen P	QT K	QT Ca	QT Mg	QT Na
22.3333333333333	7	7.66666666666667	19.6666666666667	8

Anion storage capacity or phosphate retention	Not entered
TBK reserve K test	Not entered
K reserve status	Use default

Crop block history

Years in pasture	0
Prior history	Pasture

Source of animal information

Animal source

Crop information

Previous assesment year

April	Grazed pasture
May	Grazed pasture
June	Grazed pasture
July	Grazed pasture
August	Grazed pasture
September	Grazed pasture
October	Grazed pasture
November	Grazed pasture
December	Grazed pasture
January	Grazed pasture
February	Grazed pasture
March	Grazed pasture

Client reference:

Farm name: Reureu Farm - copy 1 (2014)

Parameters

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Current assessment year 2014		
April	Grazed pasture	
May	Grazed pasture	
June	Grazed pasture	
July	Grazed pasture	
August	Grazed pasture	
September	Grazed pasture	
October	Grazed pasture	
November	Turnips leafy	
Crop management	See details below	Crop sown
December	Turnips leafy	
January	Turnips leafy	
February	Turnips leafy	
March	Grazed	
Crop management	See details below	Crop sown
Crop sowing information - November of the Current assessment year 2014		
Crop category		Fodder
Crop type		Turnips leafy
Product yield	tonnes/ha 5	8
Cultivation practice at sowing		Minimum till
Crop sowing information - March of the Current assessment year 2014		
Crop category		Permanent pasture
Crop type		Grazed
Source of animals		

Fertiliser application

No fertiliser application applied on block

Effluent application

Receives no liquid or solid effluents

Report settings

Greenhouse gas emission report units: Use default

Target N application rate as effluent: kg N/ha/yr

Dairy Effluent Storage Calculator
Summary Report

Regional authority:	Horizons Regional Council
Authorised agent:	
Client:	
Program version:	1.44
Report date:	Tuesday, 17 February 2015
General description:	

Climate

Rainfall site:	Sanson
Mean annual rainfall:	930 mm/year

Effluent Block

Area of low risk soil:	0.0 hectares
Minimum area of high risk soil:	20.0 hectares
Surplus area of high risk soil:	0.0 hectares

Wash Water

Yard wash:

- No. of cows milked in spring:	210 cows
- Milking time:	5 hrs/day
- Yard wash volumes:	Custom average daily values (cubic metres/day)
- Season start:	01 August
- Season end:	15 May

Month	Wash Volume (cubic metres)
January	13.7
February	13.7
March	13.7
April	13.7
May	13.7
June	0.0
July	0.0
August	13.7
September	13.7
October	13.7
November	13.7
December	13.7

Feedpad wash:

Month	Number of cows	Hours on pad	Wash volume (cubic metres)
January	210	2.0	0.0

February	210	2.0	0.0
March	210	2.0	0.0
April	210	2.0	0.0
May	210	2.0	0.0
June	210	4.0	0.0
July	210	4.0	0.0
August	210	4.0	0.0
September	210	2.0	0.0
October	210	2.0	0.0
November	210	2.0	0.0
December	210	2.0	0.0

Irrigation

Winter-spring depth:	8 mm
Spring-autumn depth:	16 mm
Winter-spring volume:	50 cubic metres
Spring-autumn volume:	100 cubic metres
Irrigate all year?	Yes

Catchments

Yard area:	600 square metres
Diverted?	No
Shed roof area:	175 square metres
Diverted?	Yes
Feedpad area:	1200 square metres
Covered?	No
Diverted?	Yes
- diversion start:	01 November
- diversion end:	30 April
Other areas:	0 square metres

Storage

Pond/s present?	Yes
No. of ponds:	One pond
Includes irregular ponds?	No
Pond 1	
- total volume:	4845 cubic metres
- pumpable volume:	3606 cubic metres
- surface area:	1806 square metres
- pumped?	Yes
Emergency storage period:	3 days

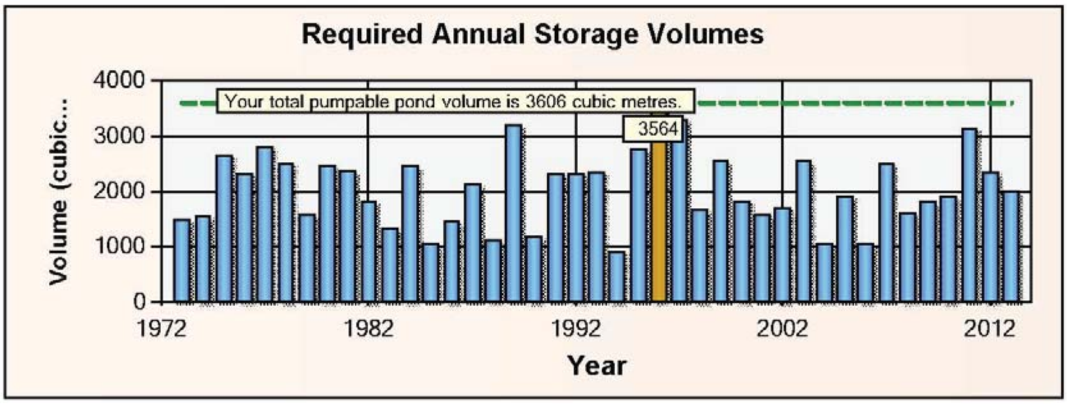
Outputs

Maximum required volume: 3564 cubic metres

90 % probability volume: 2926 cubic metres

During the period from: 01 July 1972

To: 30 June 2013



Dairy Effluent Storage Calculator
Summary Report

Regional authority:	Horizons Regional Council
Authorised agent:	
Client:	
Program version:	1.44
Report date:	Tuesday, 17 February 2015
General description:	

Climate

Rainfall site:	Sanson
Mean annual rainfall:	930 mm/year

Effluent Block

Area of low risk soil:	20.0 hectares
Minimum area of high risk soil:	0.0 hectares
Surplus area of high risk soil:	0.0 hectares

Wash Water

Yard wash:

- No. of cows milked in spring:	210 cows
- Milking time:	5 hrs/day
- Yard wash volumes:	Custom average daily values (cubic metres/day)
- Season start:	01 August
- Season end:	15 May

Month	Wash Volume (cubic metres)
January	13.7
February	13.7
March	13.7
April	13.7
May	13.7
June	0.0
July	0.0
August	13.7
September	13.7
October	13.7
November	13.7
December	13.7

Feedpad wash:

Month	Number of cows	Hours on pad	Wash volume (cubic metres)
January	210	2.0	0.0

February	210	2.0	0.0
March	210	2.0	0.0
April	210	2.0	0.0
May	210	2.0	0.0
June	210	4.0	0.0
July	210	4.0	0.0
August	210	4.0	0.0
September	210	2.0	0.0
October	210	2.0	0.0
November	210	2.0	0.0
December	210	2.0	0.0

Irrigation

Winter-spring depth:	8 mm
Spring-autumn depth:	16 mm
Winter-spring volume:	50 cubic metres
Spring-autumn volume:	100 cubic metres
Irrigate all year?	Yes

Catchments

Yard area:	600 square metres
Diverted?	No
Shed roof area:	175 square metres
Diverted?	Yes
Feedpad area:	1200 square metres
Covered?	No
Diverted?	Yes
- diversion start:	01 November
- diversion end:	30 April
Other areas:	0 square metres

Storage

Pond/s present?	Yes
No. of ponds:	One pond
Includes irregular ponds?	No
Pond 1	
- total volume:	1453 cubic metres
- pumpable volume:	1062 cubic metres
- surface area:	702 square metres
- pumped?	Yes
Emergency storage period:	3 days

Outputs

Maximum required volume:	1070 cubic metres
90 % probability volume:	492 cubic metres
During the period from:	01 July 1972
To:	30 June 2013