# Ahuriri Catchment: The impacts of land and land use change on water quality

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Environmental Science

# Ahuriri Catchment: The impacts of land and land use change on water quality

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# Executive summary

The Ahuriri Catchment covers an area of 14,564 ha and drains into the Ahuriri Estuary, an area recognised as a nationally significant wildlife zone. In recent years, Hawke's Bay Regional Council (HBRC) monitoring has shown a decline in water quality throughout the estuary, reflected in high measured levels of phosphorus, suspended sediment and to a lesser degree, nitrogen.

The purpose of this report was to summarise current land use and soil data for the Ahuriri Catchment that is currently held by HBRC. As well as identifying specific land based issues contributing to high nutrient and sediment loads, the aim was to provide a set of recommendations for future land science work within the catchment. Improving our understanding around the effects of soils, geology, land use and land use management on nutrient generation and transport within the catchment will enable HBRC scientists to provide a set of recommendations to HBRC Land management staff and farmers to improve current land management practices.

Soils and geological information held by HBRC includes spatial data (QMAP, the New Zealand Land Resource Inventory (NZLRI), Fundamental soils layer (FSL) and S-map) as well as point data (National Soils Database (NSD) and soil quality monitoring sites). Measured data (point data) revealed that phosphorous (P) retention is low for many of soils in the Ahuriri Catchment, especially soils located on the flat land surrounding the estuary. Modelled soil properties, extracted from S-map, confirmed data from the NSD and soil quality monitoring sites. I.e. that P-retention is low for soils located on the flat productive land. Low P retaining soils have a high risk of losing soluble forms of P to waterways if managed intensively.

Land use information for the Ahuriri Catchment is available through the Land cover database (LCDB), Agribase and a recent time series map produced by Landcare Research using optical satellite imagery. The most recent land use map shows dryland as the predominant land use (47%), followed by urban (32%), cropping (6.2%) and forestry (5.5%). Using LCDB 1 and LCDB 2, temporal changes in land use from 1996 to 2012 were determined. The most significant changes were increases in exotic forestry and urban land uses of 327 ha and 139 ha, respectively.

Erosion data is available from 3 main data-sets: NZLRI, point analysis surveys and SednetNZ. All three datasets confirm that the highest erosion rates occur in the northern catchments (Brooklands, Puketapu, Taipo and Whareponga catchments). According to Sednet, the total sediment load for the Ahuriri Catchment is 57,900 t/yr, with the northern catchments contributing 51,469 t/yr. Partitioning of erosion types into the different components found landslide erosion to be the dominant process (~80%), implying land stabilisation through tree planting will significantly reduce sediment input into streams.

Based on current information held by HBRC, the following recommendations have been made to enhance our understanding of nutrient and sediment generation within the Ahuriri Estuary:

- More frequent water quality monitoring is required to monitor short-term and seasonal variations in nutrient concentrations at the respective water quality monitoring sites. Frequent monitoring is especially important for detecting changes in soluble forms of N, with losses of N from soil being most significant during rainfall events

- Collection of samples during high intensity (and duration) rainfall events, especially from streams draining the hill-country where erosion rates are high. Erosion rates are greatest during high rainfall events and sediment samples must be collected during these events if accurate annual sediment loads are to be determined. Installation of auto samplers is a good option for accurately sampling during high rainfall events.

- Stream gauging's are required to calculate nutrient and sediment loads at respective monitoring sites.
- Establishment of further soil quality monitoring sites will improve our understanding of soils and land management within the catchment. Obtaining up-to-date farm information will improve our understanding about the spatial variation in fertiliser use (type and rate of application). . More detailed farm information coupled with soils data will enable HBRC to identify high nutrient generating farms.
- Repeat the soil intactness survey (point analysis) every five years to determine changes in erosion over time and identify high risk areas.

# 1 Introduction

## 1.1 Background

Estuaries serve as the interface between land and sea, and support habitats of high ecological value. They experience rapid chemical and physical changes over tidal cycles, yet provide some of the most important and diverse habitats for a wide range of plants, birds and fish. They are productive habitats, and play an important role in water regulation and nutrient cycling.

In a region dominated by alluvial flood plain river mouths, the Ahuriri Estuary (Te Whanganui-a-Orotu) represents one of the few tidal lagoon estuaries in Hawke’s Bay. Formed in the wake of the 1931 earthquake, the Ahuriri Estuary is a remnant of the former Ahuriri Lagoon. Extensive drainage and reclamation occurred in the 1930’s and 1940’s, where some 2430 ha of the former estuary was converted to productive pasture (Byrne and Collin, 1955). Following drainage and reclamation, 470 ha of true estuary and 175 ha of associated wetlands remained (Scott, 1996).

Ahuriri Estuary is listed as a Significant Conservation Area under the Regional Coastal Environment Plan (HBRC, 2006), a Wetland of Ecological and Representative Importance (WERI), and a Site of Special Wildlife Interest (SSWI). Despite this recognised importance, the Ahuriri Estuary has received discharges and undergone modification to the surrounding catchment through land use change and land use intensification. The estuary currently receives 70% of Napier City’s untreated storm water and the flat land surrounding the Ahuriri Estuary has been highly modified by drainage for farming practices.

Water quality monitoring in the Ahuriri Estuary and surrounding tributaries has highlighted high levels of phosphorus, suspended sediment and to a lesser degree, nitrogen (Haidekker et al., 2016). Extensive water quality monitoring has been carried out since 2013 to better understand high sediment and nutrient concentrations entering the estuary. Although water quality data for the Ahuriri Estuary is extensive, there is no information concerning the impact of land use and land use management on nutrient generation and nutrient transport within the catchment.

The following report outlines the current land based data held by HBRC that is relevant to the Ahuriri Catchment, and provides recommendations that may be used to enhance our understanding of the effects of land use and land use management on the nutrient and sediment concentrations entering the Ahuriri Estuary.

## 1.2 Purpose

The objectives of this report are to:

- Give an overview of the geology, soil types, land use and modelled sediment characteristics of the Ahuriri catchment;
- Make some general observations on the effect of land use and land use management on the deteriorating water quality within the Ahuriri Estuary; and
- Provide recommendations for determining source / hotspot areas for sediment and nutrients contributing to the water quality issues observed in the estuary.

## 2 Water quality Issues

Monthly water quality sampling has been carried out within the Ahuriri Estuary since March 2013, and elevated concentrations of some nutrients have been measured. The sampling network was expanded in May 2015 to include several inflowing streams and drains to establish the relative contribution of sub-catchments to total nutrient concentrations within the estuary (Figure 2-1). The purpose of this section is to provide a summary of current water quality data and provide context to better understand the land based issues contributing the elevated nutrient and sediment concentrations within the estuary. For a full synthesis of water quality state and trends for the Ahuriri Estuary, the reader is referred to Haidekker et al. (2016).

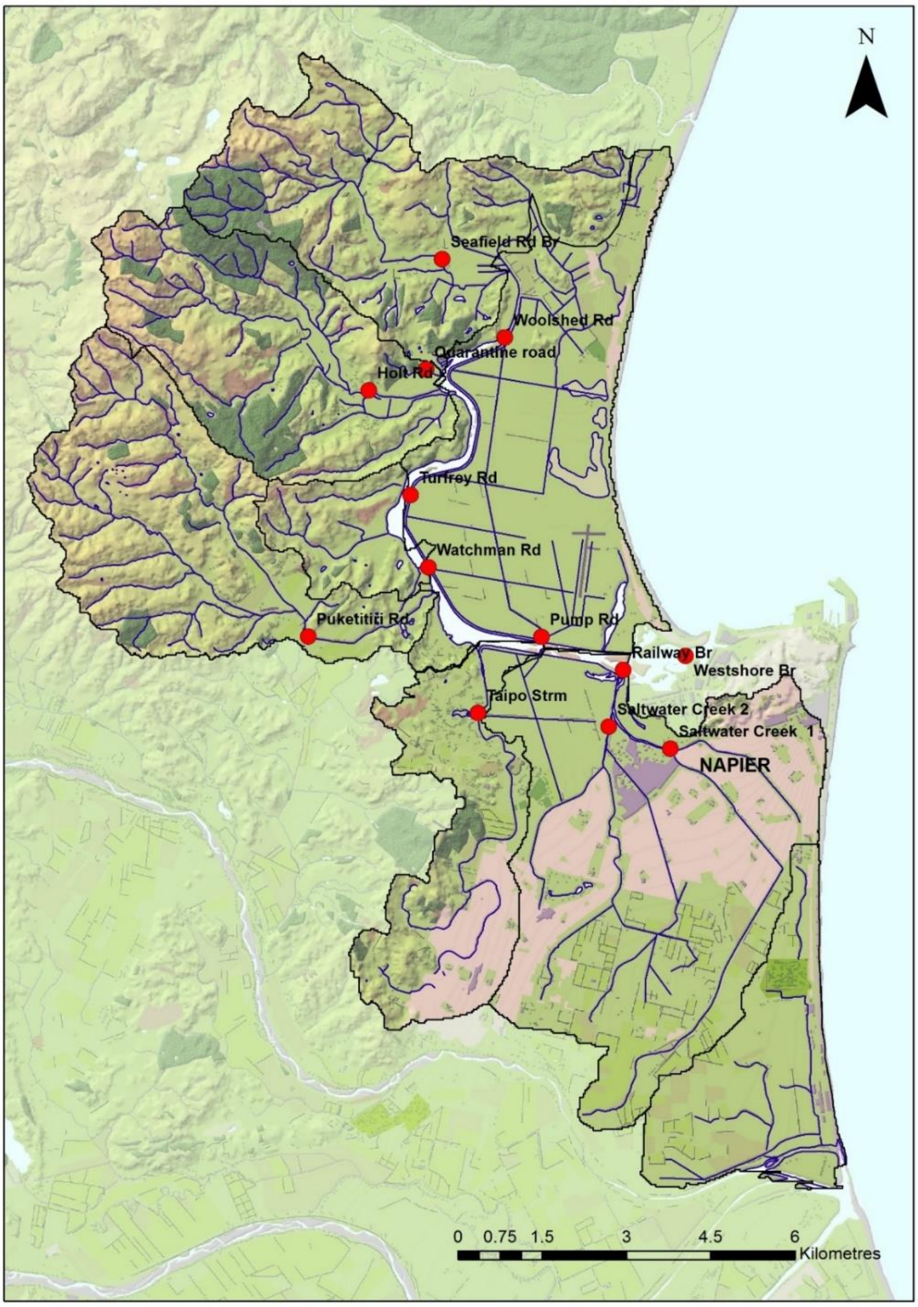


**Figure 2-1: Map showing the water quality sites in and around the Ahuriri Estuary (Madarasz-Smith et al., 2016).**

## 2.1 Nitrogen

Dissolved forms of inorganic nitrogen (DIN) include ammonia ($NH_3$), nitrate ($NO_3$) and nitrite ($NO_2$). DIN concentrations were highest at *Saltwater Creek 1*, *Seafield Rd* and the *Taipo stream* (Figure 2-2). The comparatively high DIN concentrations at these sites suggest most of the total Nitrogen (Figure 2-3) is in dissolved forms rather than in particulate matter. Nitrate concentrations are also relatively high at these sites implying N leaching or direct loss of soluble N fertiliser is occurring (Wilcock et al., 1999).

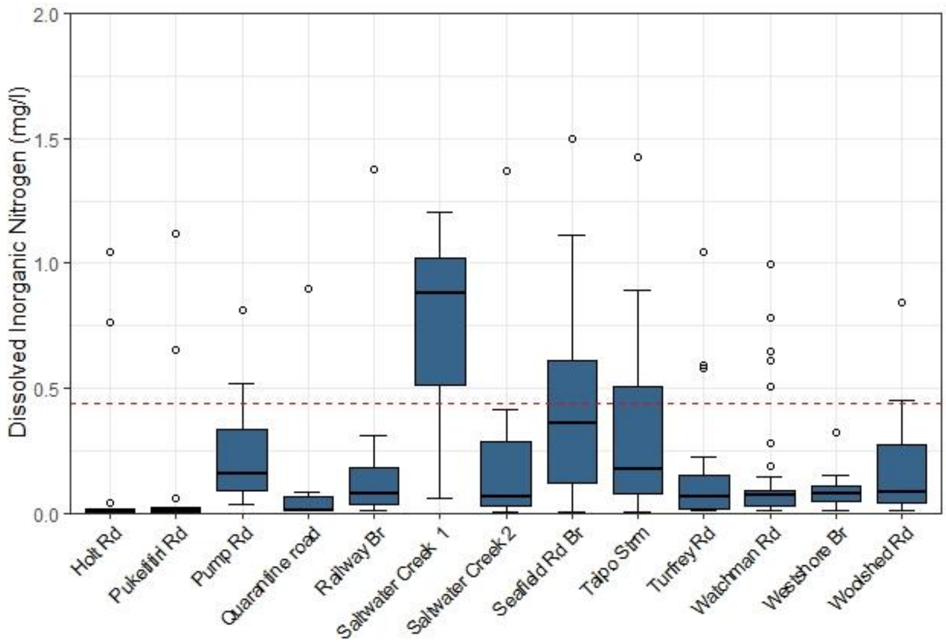


**Figure 2-2: Dissolved inorganic nitrogen (DIN) concentrations in the Ahuriri Estuary. The dotted line represents the trigger value for lowland rivers in New Zealand (ANZECC, 2000).**

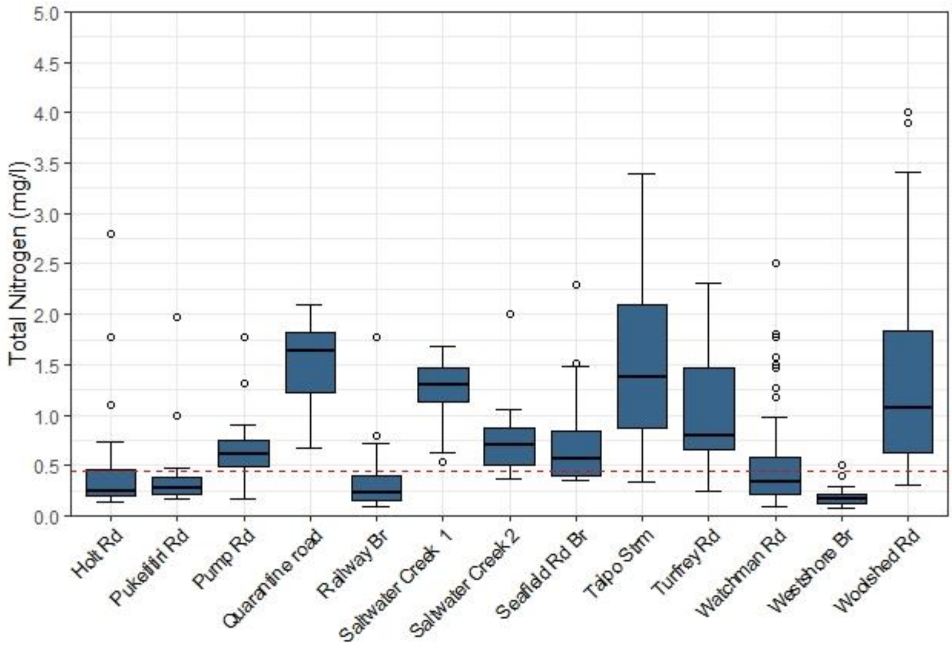


**Figure 2-3: Total nitrogen (TN) concentrations in the Ahuriri Estuary. The dotted line represents the trigger value for lowland rivers in New Zealand (ANZECC, 2000).**

## 2.2 Phosphorus

Phosphorus (P) concentrations in the Ahuriri Estuary are elevated (Figure 2-4), with a high proportion of P being in the dissolved form (Figure 2-5). Highest median concentrations of total phosphorus (TP) and dissolved reactive phosphorus (DRP) were measured in *Saltwater Creek 1* and *2*, both of which drain the productive land within the *Napier Drains* and *Napier South* catchments. High concentrations of DRP may suggest loss of soluble forms of P from the land, either directly from runoff of P fertilizer, or indirectly through P leaching (see sections 3.1 and 3.2). All monitoring sites were above trigger values for lowland rivers in New Zealand (ANZECC, 2000).

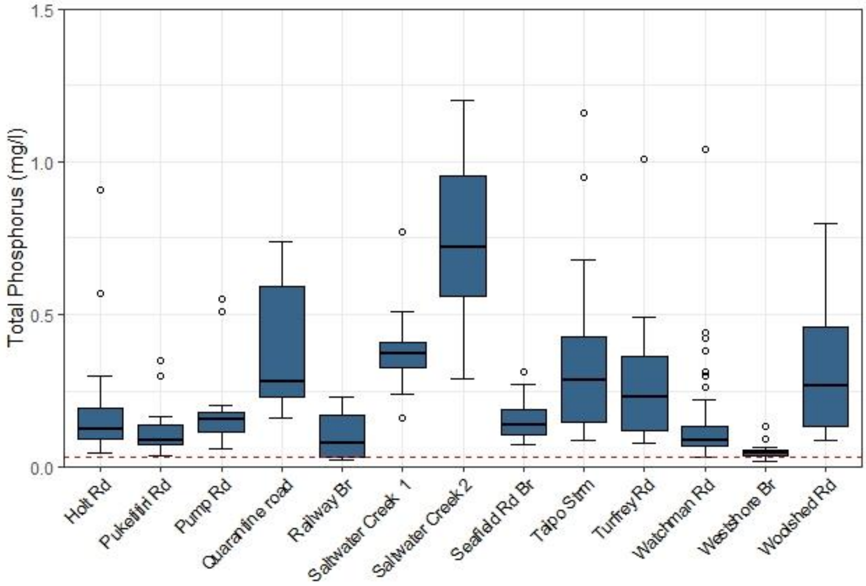


**Figure 2-4: Dissolved reactive phosphorus (DRP) concentrations in the Ahuriri Estuary. The dotted line represents the trigger value for lowland rivers in New Zealand (ANZECC, 2000).**

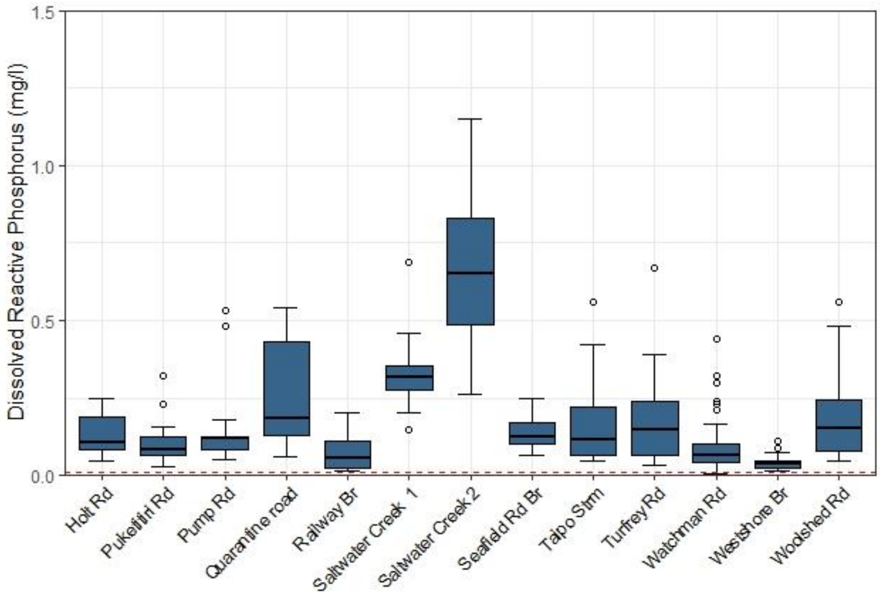


**Figure 2-5: Total phosphorus concentrations in the Ahuriri Estuary. The dotted line represents the trigger value for lowland rivers in New Zealand (ANZECC, 2000).**

## 2.3 Suspended sediment

Sediment concentrations strongly influence the transport and dynamics of P in fluvial systems, since a high proportion of total P is often bound to particulate material (McDowell and Wilcock, 2004). Figure 2-6 is only indicative because samples were not collected during high flows when sediment concentrations are highest. Sites at *Quaranine Road* and *Taipo Stream* recorded highest suspended solid concentrations, which is not surprising given that these streams drain steep catchments where erosion rates are likely to be high (see section 3.3).

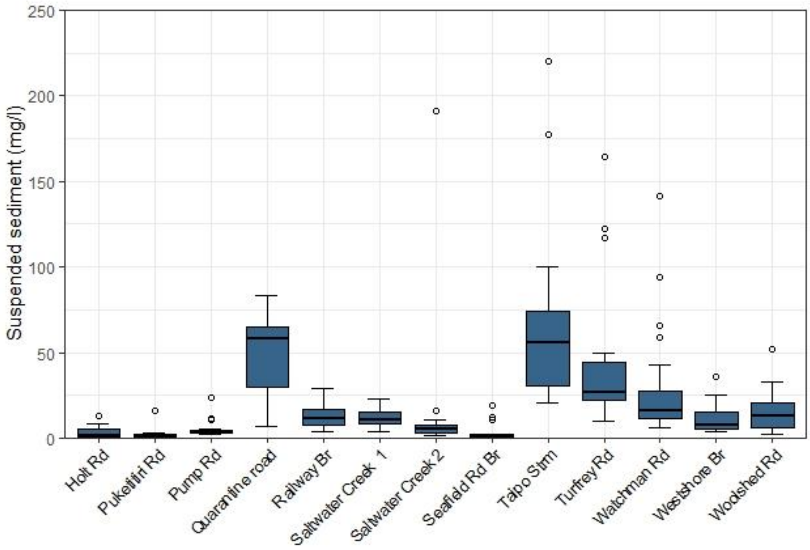


**Figure 2-6: Suspended sediment concentrations in the Ahuriri Estuary.**

# 3 Information currently held by Land Science

The aim of this section is to provide a summary and description of soils, land use and erosion data that HBRC currently holds for the Ahuriri Catchment. By compiling the various land based datasets and comparing to water quality data (Section 2), our aim was to identify specific land based issues contributing to high nutrient and sediment inputs into the Ahuriri Estuary. More importantly, an understanding of our current data-set will provide scope for future land-based research within the catchment.

## 3.1 Geological and soil data

Table 3-1 provides a summary of the current soil and geological data available for the Ahuriri Catchment. Spatial data (e.g. NZLRI, QMAP, S-map) are extracted from national data-sets and contain modelled parameters at scales ranging from 1:25,000 to 1:250,000. Point data (e.g. NSD and SQM sites) were measured directly from the field and provide a more accurate assessment of inherent soil properties but only a few sites have been established within the Ahuriri Catchment. In sections 3.1.1 - 3.1.3, each of the data-sets listed in Table 3-1 are discussed in more detail and where applicable, raw data is provided.

**Table 3-1: Geological and soil information for the Ahuriri Catchment**

| Name | Description | Scale | Comments |
|---|---|---|---|
| QMAP | National geological map | 1: 250,000 | Available as a digital map. |
| New Zealand Land Resource Inventory (NZLRI) | The LRI is compiled as an assessment of physical factors considered to be critical for long-term land use and management. The LRI is used for the Land use capability (LUC) classification, whereby land is categorised into eight classes according to its long-term capability to sustain one or more productive uses. | 1:50,000 & 1:63,360 | Liberal use of existing soil maps and some new mapping. Near nationwide coverage. Provides geological, soil and erosion information. |
| NSD (National soils data base) | A 'point' database containing descriptions of about 1500 New Zealand profiles. The database also provides soil chemistry and soil physics measurements | Paddock scale | A total of 5 NSD sites were established on the productive flat land in the Ahuriri Catchment. Sites were sampled between 1971 and 1982. |
| Historic reports | Several reports, specific to the Ahuriri Catchment were compiled by the Department of Science and Industrial Research (DSIR, Daly and Rijkse, 1976) and others (Grimett and Hughes, 1939; Byrne et al., 1955). Reports provide basic soil chemistry measurements at some sites. | Farm scale | Most of these reports focused on the soils and hydrology of the flat land that was converted to productive agricultural land between the 1930's and 1950's. Soils data is outdated but provides some important information on inherent soil properties. |
| HBRC Soil Quality Monitoring sites | HBRC has 86 soil quality monitoring (SQM) sites for state of the environment reporting. Two SQM sites are located in the southern part of the Ahuriri Catchment. | Paddock scale | Comprehensive soil chemical and physical parameters are measured at each SQM site. Sites are resampled every 3-5 years to provide information on temporal changes in soil parameters. |
| Fundamental Soils | Derived from the New Zealand Land Resource Inventory (NZLRI) along with the National Soils Database (NSD). | 1:50 000 – 250 000 | The scale of the map varies depending on location. Has some information that is not included within the new s-map platform. |
| S-map | S-map is a digital soil map, where data from different sources have been integrated to create an accurate understanding of soil distribution. | 1:25 0000 – 1:50 000 | Provides comprehensive soil data. Soil parameters determined using a combination of models and field measurements. |

### 3.1.1 QMAP and New Zealand Land Resource Inventory

Current geological information is available from QMAP and the New Zealand Land Resource Inventory (NZLRI). The underlying geology or parent material is one of the five key soil forming factors and gives insight into the current distribution of soils in the landscape. According to the NZLRI, the geology of the Ahuriri Catchment is a complex of limestone, sandstone and mudstone in the hill-country, and a mixture of gravels and muds on the flats (Figure 3-1). Geology plays a critical role in the transport and attenuation of nutrients within the ground water and strongly influences soil physical and chemical properties. Allophanic soils for example, have had a strong influence from volcanic ash, rich in minerals with short-range order, especially allophane, imogolite and ferrihydrite (Hewitt, 2010).

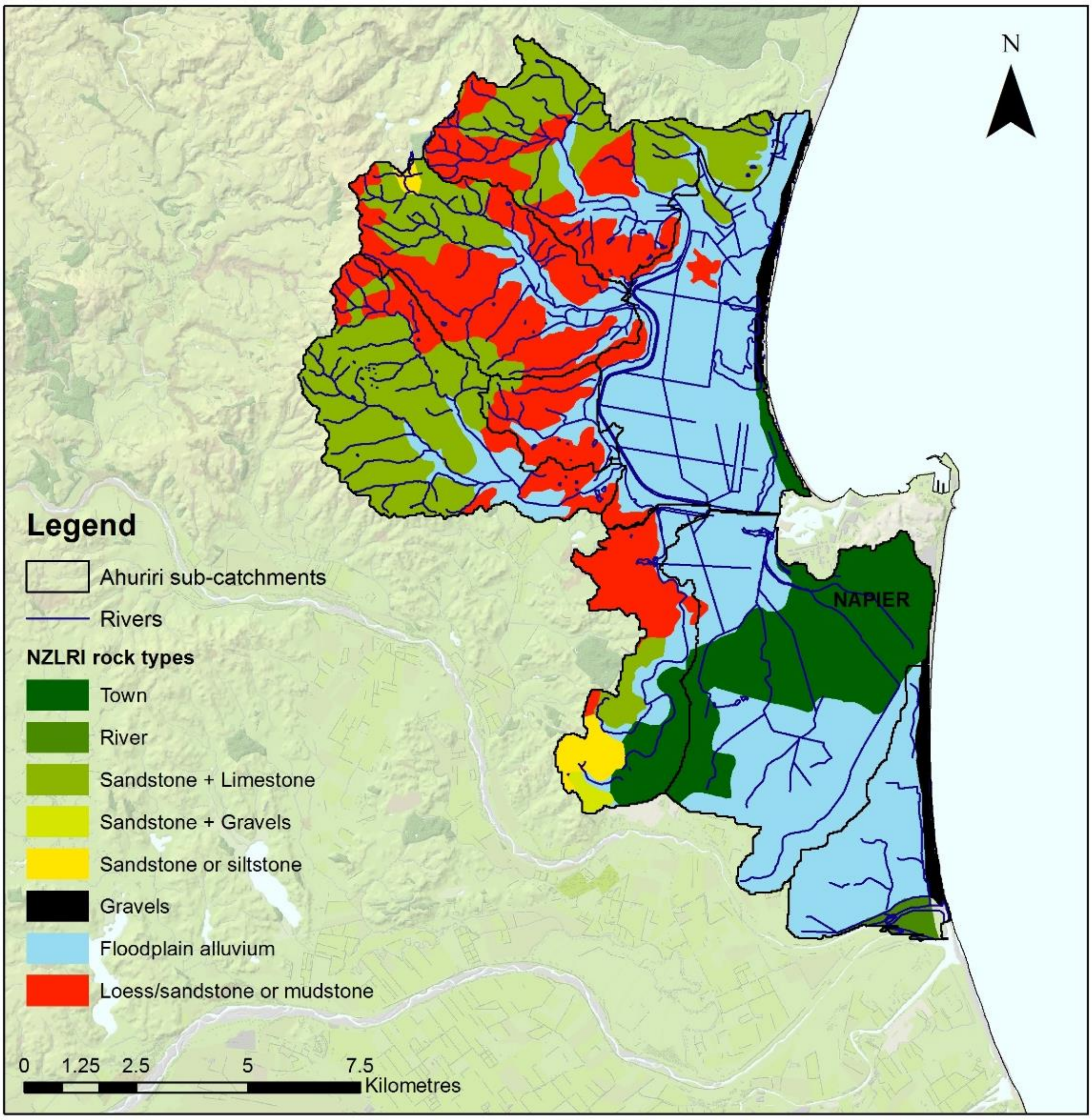


**Figure 3-1: Geology of the Ahuriri Catchment, extracted from the New Zealand Land Resource Inventory (NZLRI). Note that S-map uses geological data from the NZLRI.**

### 3.1.2 Historic reports and Fundamental Soils Layer

Soil information for the Ahuriri Flats stretches back to the 1930's, where several investigations were instigated by the *Lagoon Reclamation Project,* which saw some 2,430 ha of the former estuary converted to productive pasture (Byrne and Collin, 1955). In fact, for the reclaimed land, soils were mapped and described as early as 1939 (Grimett and Hughes, 1939). In the 1970's, the Department of Science and Industrial Research (DSIR) collected further soils information from the reclaimed land to determine the effects of salinity on farm productivity. Although comprehensive soils information was determined for the 2,430 ha of reclaimed land, little information was available for the remainder of the Ahuriri Catchment. In fact, spatial soil maps were only available at a 1:2,000,000 scale in the 1940's and in the 1968, a 1:1000,000 map was produced. By the year 2000, the Fundemental Soils Layer, a 1:25 000 to 1:250 000 map, had been produced for Hawke's Bay and was derived from the New Zealand Land Resource Inventory (NZLRI) along with the National Soils Database (NSD). The Fundemental Soils layer defined soil type based on 16 attributes, including: slope, pH, salinity total carbon, phosphorus retention, soil moisture and drainage.

### 3.1.3 National Soils Database (NSD) and HBRC soil quality monitoring sites

A total of 5 NSD sites were established in the Ahuriri Catchment between 1960 and 1982 (Figure 3-2), and the soil information is summarised in Table 3-2. General observations were that phosphorus (P) retention was low to medium across sites and as Byrne and Collin (1955) noted, natural levels of available P were high because of the large accumulation of decomposed marine life within the marine sediments. P retention (Table 3-2) gives an indication of the potential P storage capacity of a soil (i.e. How much P can be stored), while Olsen P measures the plant available form of P. The low to medium P retention at some sites may pose a risk for soluble forms of P to leach into ground water if large quantities P fertiliser are applied, meaning that there is a limited capacity within the soils to hold onto soluble, plant available P. Measured total carbon (C) levels were generally low (≤ 3%) because all sites were located on young, recent alluvial deposits which are characterised by weak soil development (Hewitt, 2010).

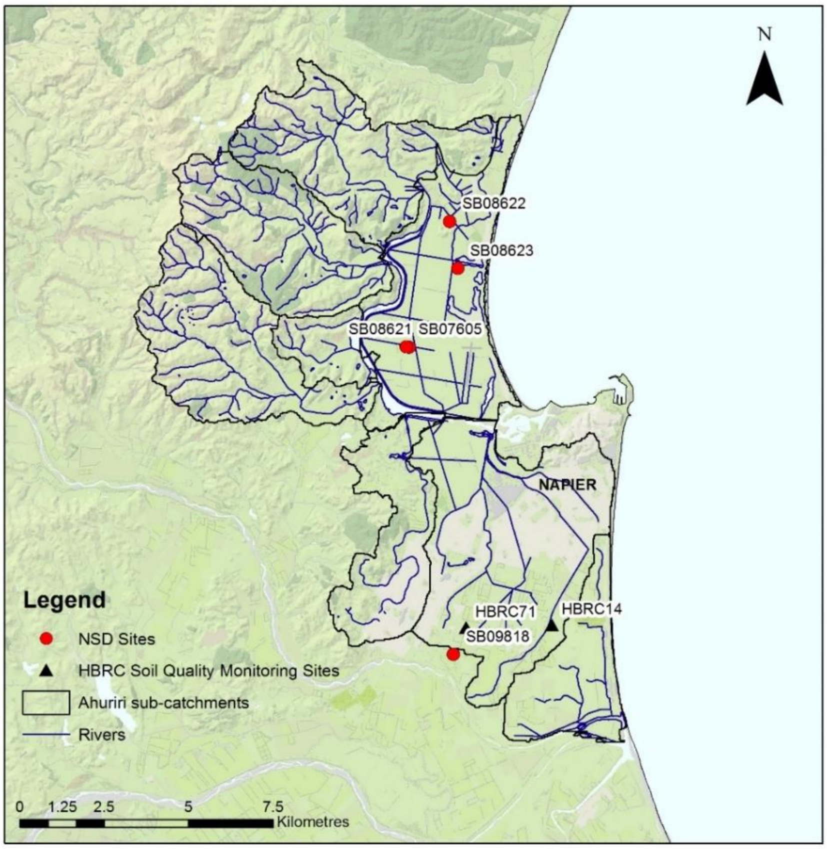


**Figure 3-2: Location of NSD sites (5) and HBRC soil quality monitoring sites (2) within the Ahuriri Catchment.**

**Table 3-2: Basic soil chemical properties for 5 NSD sites (Figure 3-2) that were established between 1971 and 1982 on the Ahuriri Flats.**

| Site[1] | Date Sampled | Horizon | Sample depth (cm) | pH | Carbon (%) | Nitrogen (%) | CEC | Sum Bases | P retention (%) |
|---|---|---|---|---|---|---|---|---|---|
| SB08622 | 1-Apr-71 | Ap (Milne) | 0 - 8 | - | 2 | 0.15 | 12.5 | 14.1 | 6 |
| SB08622 | 1-Apr-71 | Cg (Milne) | 8 - 25 | - | 0.8 | 0.08 | 10.3 | 11.6 | 7 |
| SB08622 | 1-Apr-71 | Cr (Milne) | 25 - 51 | - | | 0.02 | 5.2 | - | 5 |
| SB08623 | 1-Apr-71 | Ah (Milne) | 0 - 8 | - | 3.5 | 0.35 | 15.4 | - | 10 |
| SB08623 | 1-Apr-71 | Cg (Milne) | 8 - 25 | - | 0.9 | 0.07 | 9.5 | - | **50** |
| SB08621 | 1-Apr-71 | Ap (Milne) | 0 - 8 | - | 1.7 | 0.18 | 13.6 | - | 13 |
| SB08621 | 1-Apr-71 | Cr1 (Milne) | 8 - 25 | - | 1.7 | 0.19 | 15.1 | - | 14 |
| SB08621 | 1-Apr-71 | Cr2 (Milne) | 25 - 41 | - | 0.9 | 0.09 | 16.7 | - | 20 |
| SB07605 | 12-Apr-60 | A1g (Taylor and Pohlen) | 0 - 8 | 7 | 3 | 0.26 | 22.3 | - | - |
| SB07605 | 12-Apr-60 | GC11 (Taylor and Pohlen) | 8 - 25 | 7.7 | 1.1 | 0.1 | 17.9 | - | - |
| SB07605 | 12-Apr-60 | GC12 (Taylor and Pohlen) | 30 - 51 | 7.7 | 0.9 | 0.08 | 19.3 | - | - |
| SB09818 | 12-Oct-82 | Ap (Taylor and Pohlen) | 0 - 24 | 7.4 | 1.4 | 0.14 | 12.2 | 16.7 | 10 |
| SB09818 | 12-Oct-82 | 2Bw (Taylor and Pohlen) | 24 - 41 | 8 | 1.3 | 0.12 | 16.6 | - | **31** |
| SB09818 | 12-Oct-82 | 4Bwg2 (Taylor and Pohlen) | 41 - 48 | 8 | 1 | 0.1 | 14 | - | 24 |
| SB09818 | 12-Oct-82 | 5Cr1 (Taylor and Pohlen) | 48 - 79 | 8.2 | 1 | 0.1 | 15 | - | 22 |

- No available data

[1] Site locations are indicated in Figure 3-2

P retention values that are in bold indicate medium values (30-60%). All other sites had very low (<10%) to low (10-30%) P retention values.

Hawke's Bay Regional Council (HBRC) is required under section 35 of the Resource Management Act (1991) to provide information to its community on the region's state of the environment in environmental domains such as air, water, coasts and soils. The aim of *state of the environment reporting* is to "assess the life supporting capacity of soils" and "ensure that current practices will meet the foreseeable need of future generations" (Sparling et al., 2004; Chibnell and Curran-Courane, 2015). Hawke's Bay Regional Council has identified and characterised 2 soil quality monitoring sites in the Ahuriri Catchment, including one cropping site and a single orchard site (Figure 3-2).

To evaluate the contribution of nutrients from different land management practices and/or soil types, several more soil monitoring sites would be required. However some general observations can be drawn from the two current sites (Table 3-3). Note that both monitoring sites are located in the southern part of the catchment and only represent a single soil type. It is evident that Olsen P levels are high given the intensity of the land uses. I.e. Site 14 is an orchard and site 71 is a market garden. P retention at site 71 was low (11 mg/kg) and confirms the low P retention data collected from the 5 historic NSD sites (Table 3-2, Figure 3-2). It is likely that the low P retention of the soils in the south of the catchment coupled with the high land use intensity is contributing to the high dissolved reactive phosphorous levels in the *Napier drains* (Figure 2-4). However, current data is only indicative and further soil testing/land use information is required to better understand the factors contributing to the high P levels that are being generated in the southern part of the catchment.

**Table 3-3: Soil chemical and physical characteristics for 2 HBRC soil quality monitoring sites within the Ahuriri Catchment.**

| Site | year | NZSC | Land use | TC | TN | C:N | pH | OP | AMN | P retention | BD |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | % | % | | | mg/kg | mg/kg | % | g/cm$^3$ |
| HBRC14 | 2015 | Recent | Orchard | 2.1 | 0.2 | 8.7 | 6.5 | 94 | 65.5 | * | 1.3 |
| HBRC71 | 2014 | Recent | Cropping | 1.6 | 0.2 | 8.8 | 7.6 | 58 | 42.0 | * | 1.3 |
| HBRC71 | 2018 | Recent | Cropping | 1.7 | 0.2 | 8.6 | 8.0 | 38 | 23.0 | **11** | 1.3 |

TC = Total C (%), TN = Total N (%), C:N = Carbon: Nitrogen ratio, OP = Olsen P (µg/L), BD = Bulk density (g/cm$^3$)
* P retention was not measured

### 3.1.4 S-map

S-map is a digital soil map, where data from different sources have been integrated to create an accurate understanding of soil distribution (Figure 3-3). In contrast to traditional soil mapping, which provides a single GIS layer of polygons and basic attributes, S-map provides comprehensive soils information on a regional scale (Lilburne et al., 2012). Soil properties at the landscape scale are predicted using a series of soil-only pedo-transfer functions, soil climate models, and soil-climate-land management models (Lilburne et al., 2014). Since August 2018, Hawke's Bay Regional Council has had full coverage with S-map and the associated soil attributes that have been determined using a combination of models and field observations. It is important to note that many of the parameters in S-map are based on modelled soil properties, and therefore do not take specific land management practices into account. For example, permeability is the ability of a soil to drain, based on texture, structure and soil density. The estimate of soil permeability is dependent on the inherent soil properties and does not take management factors such as stocking rate, vehicle traffic etc. into account. Appendix 1 provides an example of a soil report produced by s-map and a list of the various soil parameters provided by the tool.

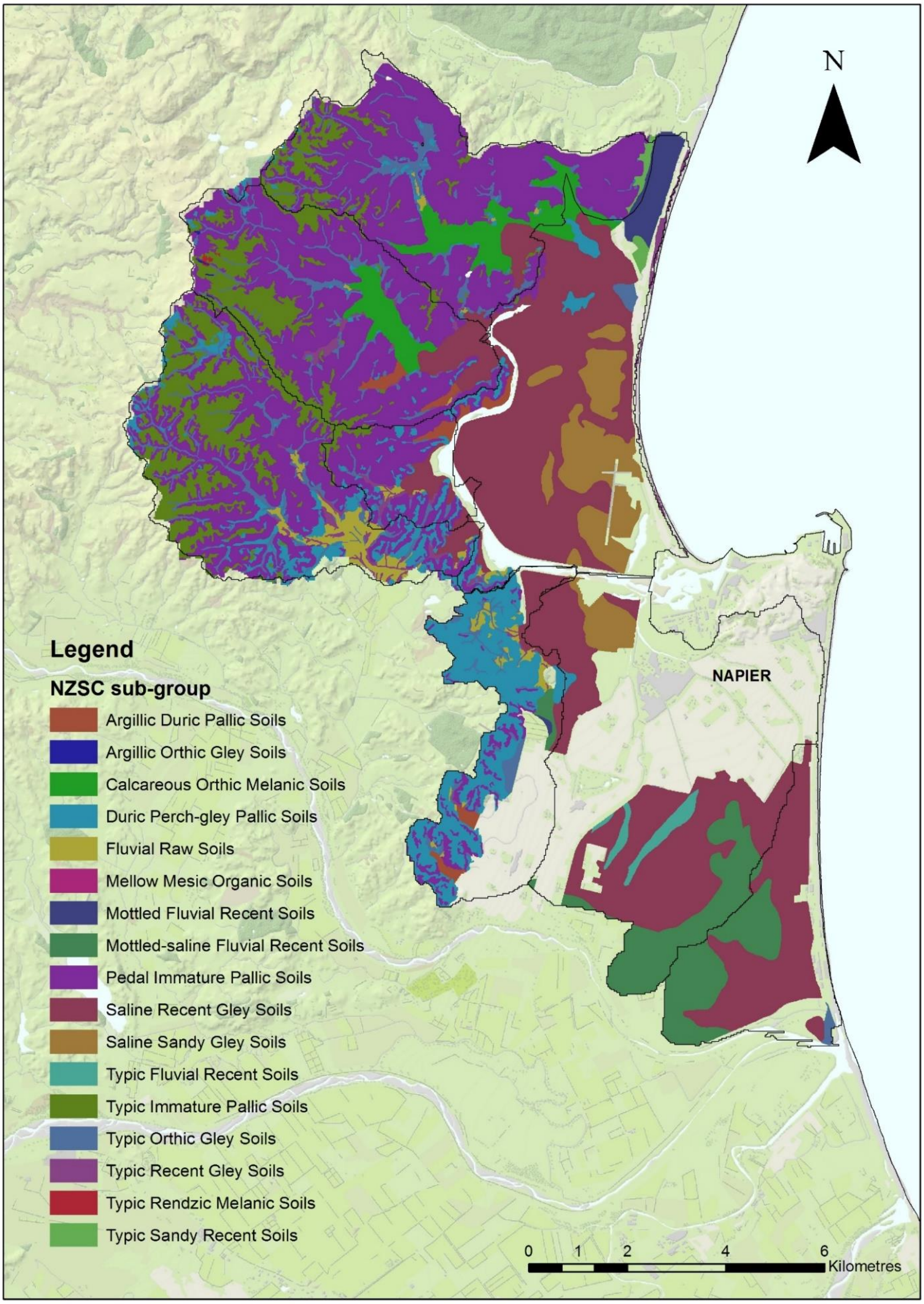


**Figure 3-3: The New Zealand Soil Classification (NZSC), extracted from S-map, for soils in the Ahuriri Catchment**

S-map data is an important component of the Overseer nutrient model, which is designed to model nutrient loss at the farm scale. The Overseer model is a nutrient model that "captures information about how a farm is run and models it through a series of complex sub-models that mimic the known bio-physical processes operation across a farm system" (Wheeler and Shepherd, 2013a). Inherent soil properties such as P retention, bulk density, rooting depth and soil texture are important inputs into Overseer and provided by the S-map platform. From the soil components, estimates on the vulnerability of a specific soil type to nutrient loss can be estimated. As an example, Figure 3-4 demonstrates the vulnerability of soils to N leaching in the Ahuriri Catchment, based on inherent soil properties. However, S-map data only provides information on how a soil will respond to management. I.e. it is an input into Overseer. To use overseer as a means of predicting N loss from land, specific farm management information (e.g. fertilizer input and stocking rate), climate information and measured soil nutrient data (e.g. Olsen P) is required (see sections 3.3 and 4).

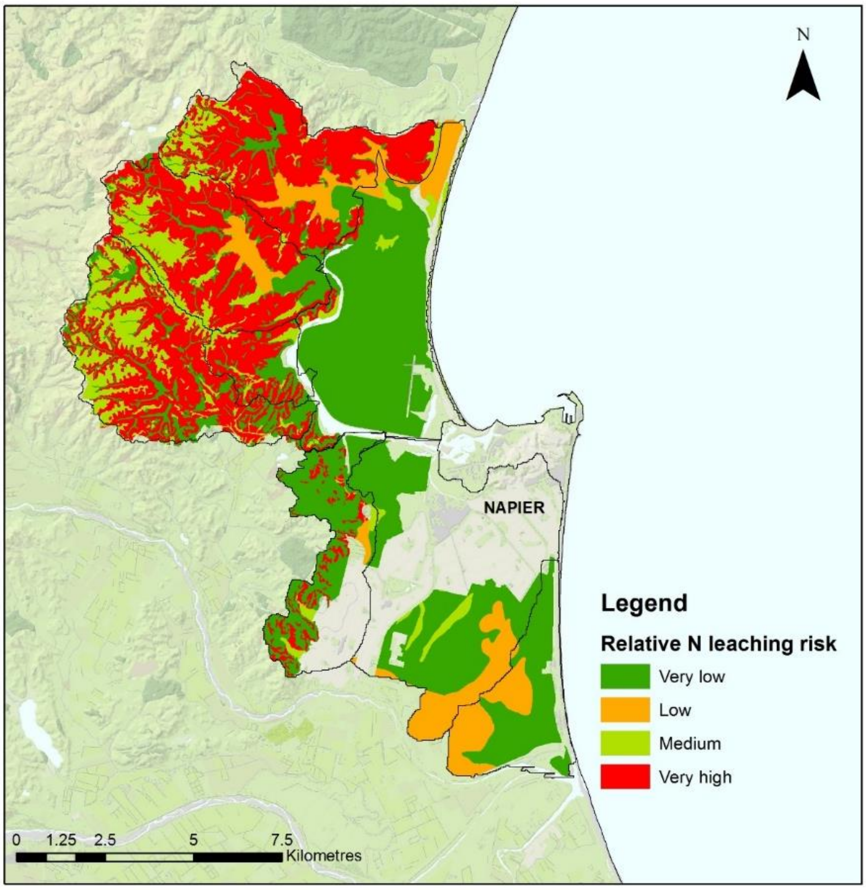


**Figure 3-4: N leaching risk of soils in the Ahuriri Catchment based on inherent soil properties. Note that map is a risk map and does not provide any information on actual nitrogen losses.**

Although the Overseer model provides good estimates of N loss, estimates of P losses are less accurate (Webb et al., 2015). Webb et al. (2015) modelled P loss vulnerability classes in Canterbury based on estimates of P leaching, bypass flow and surface runoff. S-map was used as the primary source of soils data, along with the NZRLI and unpublished soil maps from 1:25, 000 to 1:150, 000. Webb et al. (2015) calculated P leaching vulnerability using horizon thickness, percentage of fine material and P retention, all of which is available through the S-map database. P leaching is still to be modelled for all New Zealand soils, but since P retention is closely linked to P leaching, it can be assumed that low P retaining soils will be highly vulnerable to P leaching. According to S-map, low P retaining (<30 mg/kg) soils characterise most of the Ahuriri Catchment (Figure 3-5) and confirms the NSD and HBRC soil quality measurements. The areas of most concern are the

Ahuriri Flats, where low P retaining soils are likely to receive high inputs of soluble P fertilizer in response to high intensity land uses.

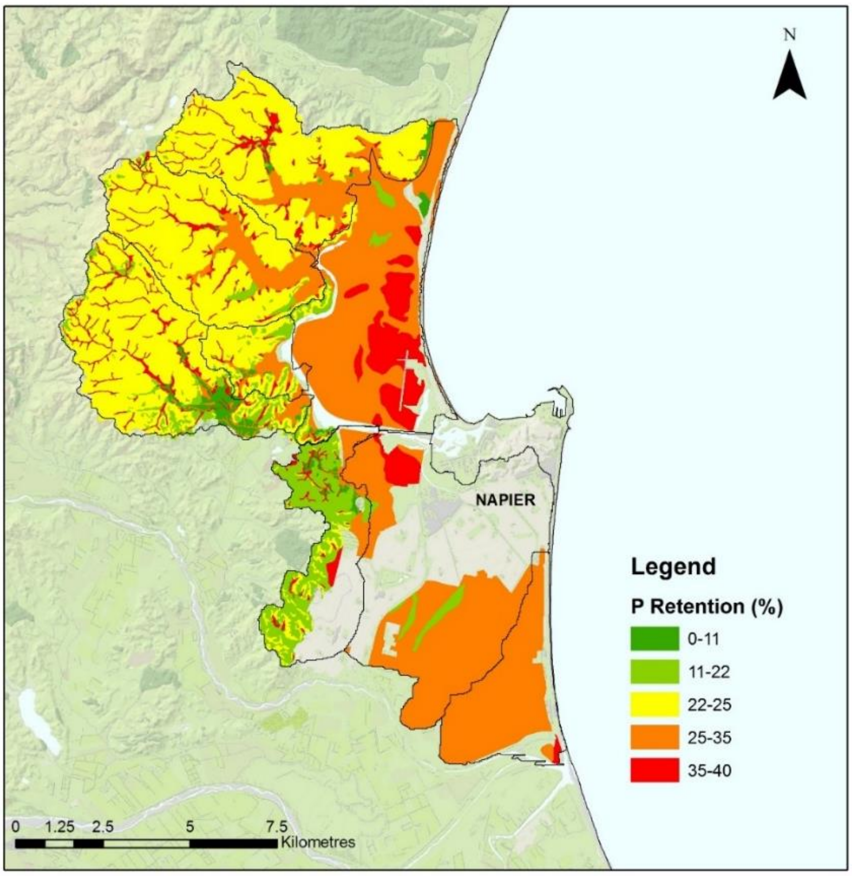


**Figure 3-5: Modelled S-map soil P retention in the Ahuriri Catchment. P retention is based on inherent soil properties such as mineralogy. Most of the Ahuriri Catchment is characterised by low p retaining soils (<30 mg/kg) and are prone to P leaching, especially if large quantities of soluble P are applied.**

Leaching of P can occur in soils with a high vulnerability to bypass flow, even though the P retention may be high (Webb et al., 2015). Bipass flow occurs when P (either soluble or bound to soil colloids) moves through large pores in the soil when rainfall or irrigation exceeds the soils infiltration capacity. This may occur under recent fertliser application, flood irrigation, effluent irrigation (dairy, industrial, municiple waste water and septic tank discharge), and intensive rain/irrigation on grazed land (manure patches), especially at sites with permeable soils and aquifers (Webb et al., 2015). Table 3-4 provides information on bypass flow classes and the relationship to NZSC soil orders (Webb et al., 2015). Relating Table 3-4 to Figure 3-6, it is evident that a high proportin of soils in the catchment are prone to byplass flow.

**Table 3-4: Relationship between bypass flow classes and soil type/soil characteristics. Since a high proportion of the Ahuriri Catchment includes Raw, Pallic and Gley soils, the risk of P loss through bypass flow is high for much of the catchment.**

| Bypass flow class | Soil class and soil characteristics |
|---|---|
| High | • Melanic, Gley, and Raw soils<br>• Depth to slowly permeable horizon < 60 cm<br>• Depth to extremely stony horizon < 30 cm<br>• Soils with an argillic horizon when drained |
| Medium or high | • Soils classified as 'perch-gley'<br>• Pallic soils with underlying fragipan |
| Medium | • Brown and Pallic soils<br>• Soils with slow permeability between 60 and 100 cm<br>• Soils with an argillic horizon<br>• Depth to sand < 30 cm<br>• Organic soils when drained |
| Low | • Freely draining shallow to deep, loamy Recent Soils that do not have extrmemly stony or sandy horizons close to the soil surface. |

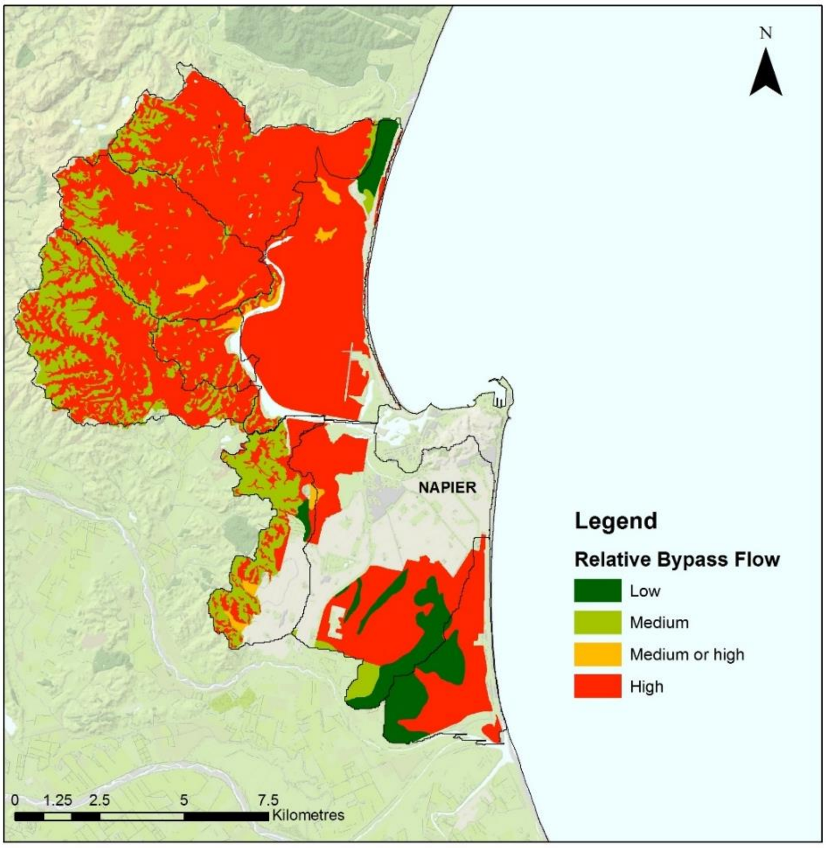


**Figure 3-6: Vulnerability of soils in the Ahuriri Catchment to bypass flow.**

In addition to P leaching and bypass flow, a third component which drives loss of P from the land is surface runoff. The vulnerability of land to surface runoff reflects the potential transport of sediment bound P and P particles (e.g. fertilizer) from land into surface water bodies (Webb et al., 2015). Runoff potential is related to a soils infiltration capacity and is dependent on inherent soil properties, such as soil permeability and water storage capacity. It is important to note that the runoff potential model does not take land management factors (e.g. stocking rate) and climate (e.g. rainfall intensity) into account. Figure 3-7 indicates the runoff potential risk of soils in the Ahuriri Catchment. The highest risk of surface runoff (red areas in Figure 3-7) occurs on steeper slopes in the hill-country and especially hills surrounding Poraiti. These areas are likely to be hot-spot sources for sediment transport and generation during high rainfall events.

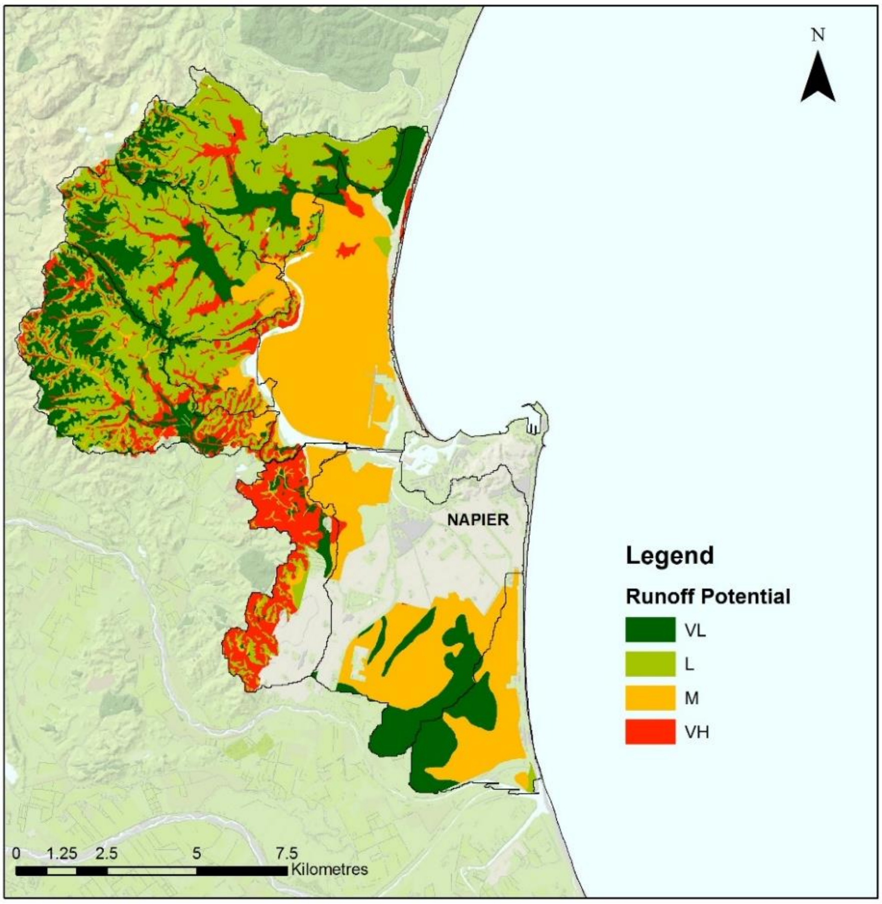


**Figure 3-7: Runoff potential for Ahuriri**

## 3.2 Land use information

Land use information is available from several sources at a range of different scales. The Land cover database (LCDB) is a multi-temporal, thematic classification of New Zealand, containing 33 classes at a scale of 1:50,000. Four versions of LCDB have been created (LCDB1 – 1996/1997, LCDB2 – 2001/2002, LCDB3 – 2008, LCDB4 – 2012), with the next version currently under development. Although LCDB records temporal changes in land use, the classification lacks the resolution required to detect changes at the paddock scale. For e.g. All crop types are categorised as “short-rotation cropping” within the LCDB data-base. HBRC has improved the resolution of LCDB by merging the layer with information from Agribase – a database containing specific farm information, including land use for 142,000 farms in New Zealand. Although the combined LCDB-Agribase layer greatly improved the accuracy of the land use classification, specific crop information at the paddock scale was still missing. To improve the resolution of land use information held by HBRC, Landcare

Research was contracted in 2014 to produce a paddock scale land use map using optical satellite images for three time periods – Summer 2013/14, Winter 2014, and Summer 2014/15 (Pairman et al., 2016). The Landcare Research Map is the most up-to-date and detailed land use map for the Ahuriri Catchment. Table 3-5 summarises the land cover and land use datasets currently held by HBRC.

**Table 3-5: A summary of land use / land cover databases currently held by HBRC**

| **Land use data-source** | **Comments** |
|---|---|
| Land cover database (LCDB) | A new version of LCDB is produced every 4-5 years. The LCDB is a national dataset, covering 33 land use types/categories. The map is at a scale of 1:50,000 and lacks the resolution required to detect crop types at the paddock scale. |
| Agribase | A national spatial farms database which holds land use information for about 142,000 properties. Land use information is only available at the farm scale. |
| LCDB + Agribase | HBRC created a merge of LCDB and Agribase to improve the accuracy of both datasets. LCDB has national coverage and Agribase has updated farm information. The merged land use map was an improvement on both individual data-sets but is still only accurate at the farm scale. |
| Landcare Research time series map* | Using a new methodology developed by Landcare Research, a calibrated time series of satellite images over Hawke's Bay was assembled. Accurate land cover classifications were derived at the paddock scale. |

*The time series map produced by Landcare Research was only produced for the Tutaikuri, Ahuriri, Ngaruroro and Karamu (TANK) Catchments.

The Ahuriri Catchment consists of 14,564 ha of land and includes a significant part of Napier City. According to the Landcare Research time series map (Figure 3-8), land use in the Ahuriri Catchment is predominantly low-intensity sheep and beef farming (47.5%), with 32% of the catchment being covered by urban land uses (Table 3-6). Most of the intensive land uses – orchards, cropping and vineyards – are constrained to the flat land in the southern part of the catchment (Table 3-6). Forestry only covers 5.5% of the catchment and is located mostly in the hill-country and within the northern part of the catchment.

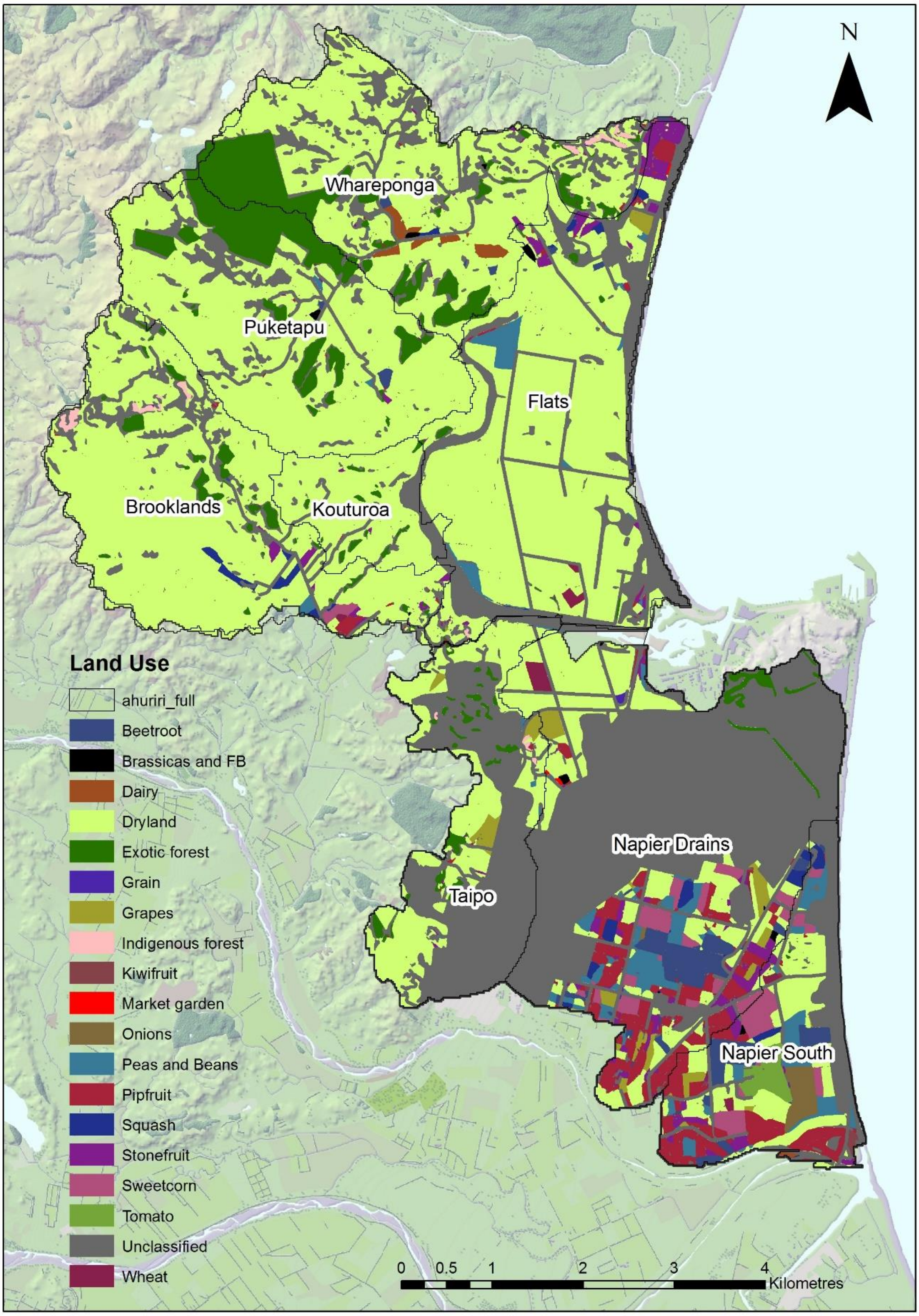


**Figure 3-8: Ahuriri Catchment land use map. Unclassified areas in this region are built-up urban areas and water channels.**

**Table 3-6: Land use in area (ha) and percentage of total land area for the Ahuriri Catchment. Data is obtained from the Landcare Research time series land use map.**

| Land Use | Area(Ha) | Percentage (%) |
|---|---|---|
| Beetroot | 208.8 | 1.43 |
| Brassicas and Fodder beets | 14.3 | 0.10 |
| Dairy | 517.4 | 3.55 |
| Dryland* | 6910.8 | 47.46 |
| Exotic forest | 802.5 | 5.51 |
| Grain | 2.3 | 0.02 |
| Grapes | 121.2 | 0.83 |
| Indigenous forest | 33.1 | 0.23 |
| Kiwifruit | 9.0 | 0.06 |
| Market garden | 2.6 | 0.02 |
| Onions | 48.0 | 0.33 |
| Peas and Beans | 272.8 | 1.87 |
| Pipfruit | 426.1 | 2.93 |
| Squash | 82.0 | 0.56 |
| Stonefruit | 191.1 | 1.31 |
| Sweetcorn | 181.1 | 1.24 |
| Tomato | 52.6 | 0.36 |
| Unclassified | 4649.3 | 31.93 |
| Wheat | 36.4 | 0.25 |
| **Total** | 14561.2 | 100 |

*Dryland includes low intensity sheep and/or sheep and beef farming

### 3.2.1 Temporal changes in land use

To determine temporal changes in land use within the Ahuriri Catchment, 1996 data (LCDB 1) was compared to 2012 (LCDB 4) data (Table 3-7). Population growth in Napier over the past 20 years has seen an increase in urban development, reflected in the 139 ha increase in the "built-up Area". Plantation forestry has increased by 327 ha since 1996, which includes some newly planted areas and regrowth from harvested plantations. Cropland decreased by 103 ha, most likely a result of land conversion to "orchards, vineyards or other perennial crops", which increased by 84 ha. Although land use monitoring gives an indication of land use change, it doesn't provide information about change in land use intensity. For example, despite a decrease in the land area of cropping sites over the past 20 years, the management of these sites (crop type, fertilizer use, etc.) may have changed significantly but is not reflected in the land use database. Monitoring programmes such as *soil quality monitoring* is essential in supplementing land use data with measured soils data and land management information.

**Table 3-7: Changes in land cover between 1996 and 2012, calculated using the Land Cover Database (LCDB). Shaded numbers indicate significant changes in land area for the respective land uses.**

| LCDB Land use class | Change from 1996-2012 (ha)* |
|---|---|
| Broadleaved Indigenous Hardwoods | 0.0 |
| Built-up Area (settlement) | **139.4** |
| Deciduous Hardwoods | -1.7 |
| Estuarine Open Water | 0.0 |
| Exotic Forest | **327.2** |
| Forest - Harvested | **-426.8** |
| Gorse and/or Broom | 9.1 |
| Gravel or Rock | 0.0 |
| Herbaceous Freshwater Vegetation | 0.0 |
| Herbaceous Saline Vegetation | 0.0 |
| High Producing Exotic Grassland | **-111.6** |
| Indigenous Forest | 0.0 |
| Lake or Pond | 1.7 |
| Low Producing Grassland | **71.2** |
| Manuka and/or Kanuka | 0.0 |
| Mixed Exotic Shrubland | 1.9 |
| Orchard, Vineyard or Other Perennial Crop | **83.9** |
| River | 0.0 |
| Sand or Gravel | 0.0 |
| Short-rotation Cropland | **-102.7** |
| Urban Parkland/Open Space | 8.5 |

*The change in land use between 1996 and 2012 was calculated by: *land use area in 2012 – land use area in 1996.* Negative numbers indicate a decrease in land area, while positive numbers reflect an increase in land area.

## 3.3 Erosion

Loss of soil from the land through erosive processes not only diminishes soil quality and productivity but adversely impacts water quality through increased sediment and nutrient concentrations. Elevated sediment concentrations negatively impacts river and estuarine ecology, by reducing light available for photosynthesis (Haidekker et al., 2016). Furthermore, suspended sediment can smother benthic organisms and habitats in receiving waters, causing damage to the gills of fish and reducing the efficiency of filter feeding. Sediment concentrations strongly influence the transport and dynamics of P in fluvial systems, since a high proportion of total P is bound to particulate material (McDowell and Wilcock, 2004). The transport of sediment bound P is of particular importance in Hawke's Bay because of the high incidence of erosion within the soft sandstone and mudstone hill-country. Hicks et al. (2011) for example calculated sediment loads for the Ngaruroro and Tutaikuri Rivers to be 0.21 and 1.3 million tonnes respectively.

HBRC holds several data-sets containing erosion based information, including the NZLRI (Lynn et al., 2009), a soil intactness survey (Burton, 2018) and SednetNZ – an erosion risk model (Pairman et al., 2016). The NZLRI is a national dataset of physical land resource information, comprising of two datasets: an inventory of five physical factors (rock type, soil, slope, present erosion, and vegetation) and the Land use Capability (LUC), which rates the ability of each polygon to sustain agricultural production. A soil intactness survey uses aerial imagery and a set of pre-defined points to identify stable or unstable landforms and then determine the impact of current vegetation cover on soil disturbance (Burton, 2018). Both the NZLRI and soil intactness surveys give important information on the spatial distribution of erosion and erosive processes, but no information is provided on the magnitude or extent of erosion (i.e. how much erosion is occurring). The SednetNZ model is able to estimate the magnitude of different erosive processes (e.g. landslides, gully erosion) by routing sediment through the river network. The model is based on a physical representation of hillslope and channel processes at the reach scale and accounts for losses of sediment in water bodies and floodplains (Palmer et al., 2016). The respective erosion data-sets currently held by HBRC are summarised in Table 3-8 and discussed in detail thereafter.

**Table 3-8: Summary of erosion data that is currently held by HBRC**

| Erosion data source | Comments |
|---|---|
| NZLRI | A national database of physical and land resource information. It comprises two sets of data, including: An inventory of five physical factors (rock type, soil, slope, present erosion, and vegetation) and the Land Use Capability (LUC). |
| Soil intactness survey using point analyses | Uses a grid of pre-defined points to assess the stability of landforms and the risk of each point to soil disturbance based on current vegetation cover. The survey also determines whether soil disturbance is caused by natural processes or land use management practices. |
| SednetNZ | A spatially distributed, time averaged (decadal to century) model that estimates the magnitude of sediment movement through the river network. The model is based on hillslope and channel processes at the reach scale, and accounts for losses of sediment in water bodies and floodplains. |

### 3.3.1 New Zealand Land Resource Inventory (NZLRI)

The NZLRI is at a scale of 1:50,000 and the classification was compiled from a field assessment of rock types, soils, landform and slopes, erosion types and severities, and vegetation cover (Lynn et al., 2009). Field data was supplemented with stereo aerial photography, as well as published and unpublished reference material. Table 3-9 defines the erosion symbols used in the LRI, while Figure 3-9 shows the spatial distribution of erosion type and severity throughout the Ahuriri Catchment.

**Table 3-9: Erosion types and symbols (Lynn et al., 2009). For definitions, see Lynn et al. (2009).**

| 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** | |

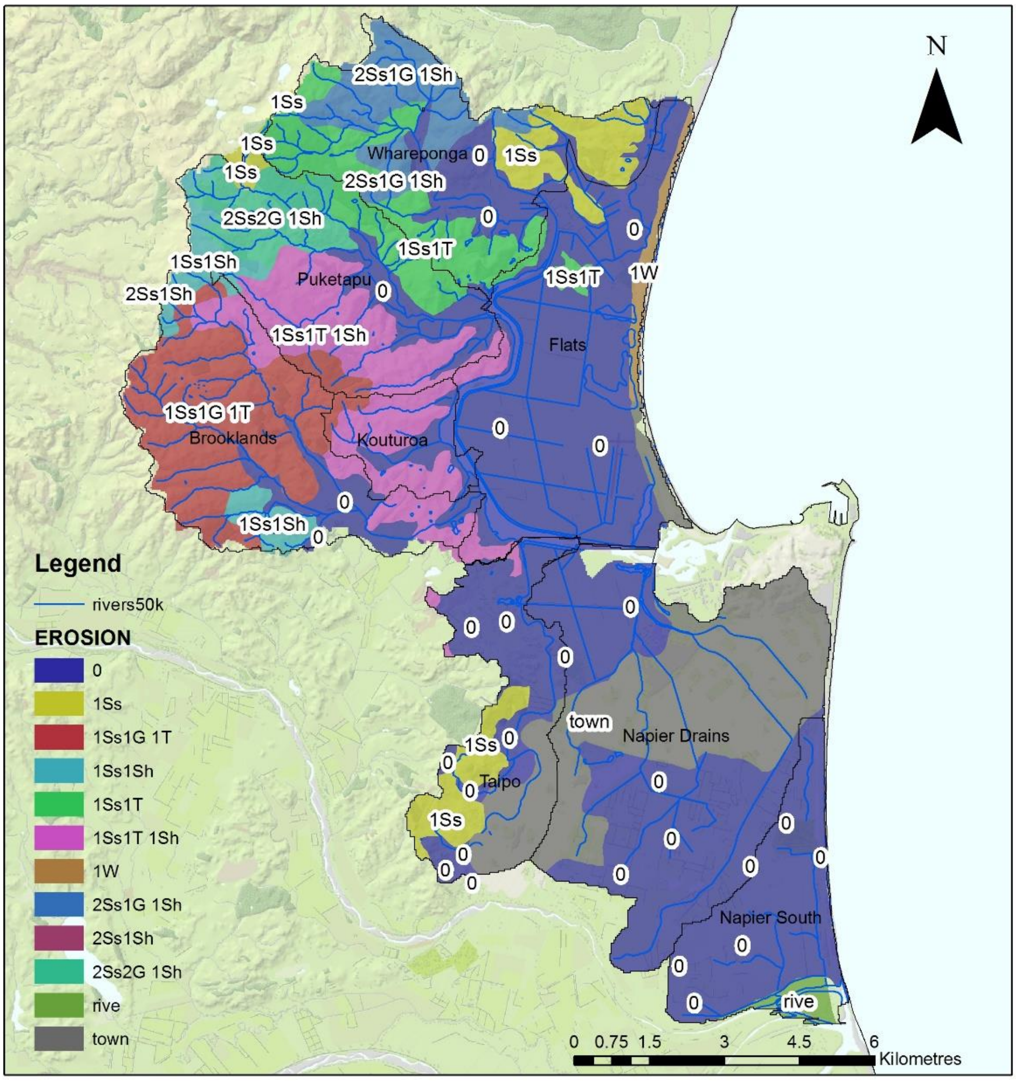


**Figure 3-9: Spatial distribution of erosion type and severity in the Ahuriri Catchment. The code (e.g. Ss) represents the type of erosion (Table 3-9), while the number refers to the severity of erosion (0 = no erosion; 1 = slight erosion; 2 = moderate erosion; 3 = severe erosion; 4 = very severe erosion; 5 = extreme erosion).**

According to the NZLRI and as a percentage of the total catchment area, 34% of land is at no risk to any form of erosion (Table 3-10). About 32% of land has slight soil slip erosion, 13% of land is prone to moderate forms of soil slip erosion and 22 % of land is at risk to sheet erosion. While the NZLRI gives an overview of the distribution of erosion types, the current data-set is at a 1:50,000 scale, meaning fine scale erosive processes at the farm scale are missed. Furthermore, the NZLRI is derived from information attained from a fixed time period, and unless areas are remapped using updated information, temporal changes in erosive processes are not detected.

**Table 3-10: Percent coverage of Ahuriri Catchment for respective erosion type and severity classes. Erosion type/severity classes relate to Figure 3-9.**

| Erosion type and severity (NZLRI) | % of total catchment area |
|---|---|
| 0 | 34 |
| 1Ss | 7 |
| 1Ss1G 1T | 12 |
| 1Ss1Sh | 2 |
| 1Ss1T | 4 |
| 1Ss1T 1Sh | 7 |
| 1W | 1 |
| 2Ss1G 1Sh | 7 |
| 2Ss1Sh | 3 |
| 2Ss2G 1Sh | 3 |
| rive | 10 |
| town | 11 |

### 3.3.2 Soil intactness survey

Soil intactness expresses whether a soil is currently staying in place and is statistically calculated using point analysis, where a series of sample points overlaying an aerial image are individually assessed (Burton, 2018). A regularly spaced grid of sample points is placed over an aerial image using GIS software, and each point is assessed to determine land use, land stability, soil disturbance, landform and percentage of bare soil. In contrast to the NZLRI, point analyses is a statistical process that uses up-to-date aerial imagery and therefore, changes in erosive processes can be detected and documented through time.

A recent point analysis study (Burton, 2018) of the Ahuriri Catchment found 49% of sample sites, equivalent to 7,218 ha, have stable surfaces that show no sign of geomorphological instability (Table 3-11). Erosion prone surfaces cover 17.1% (2497 ha) of the catchment area, while eroded and eroding surfaces cover 11% (1,595 ha) and 0.7% (98 ha) respectively. Bare soil currently covers 2.9% (428 ha) of the catchment, with 11% (47 ha) of the bare soil occurring on erosion prone or currently eroding surfaces. The distribution of eroded or currently eroding surfaces is shown in Table 3-11. Not surprisingly, natural erosion was most prevalent in the hill-country (Whareponga, Puketapu, Brooklands and Kouturoa Catchments), with 41% of natural erosion caused by landslides/slips, 57% by sheet wash erosion and 3% by streambank scour.

**Table 3-11: Occurrence of stable surfaces, erosion-prone surfaces, eroded and eroding surfaces and other surfaces (urban, estuary and rural buildings) in the Ahuriri Catchment.**

| | Points | Points as % of total area | hectares | Bare soil as % of total area | Bare soil hectares |
|---|---|---|---|---|---|
| **Stable surfaces (S)** | | | | | |
| - with intact soil | 277 | 30.6 | 4463 | 0 | 0 |
| - with soil disturbed by land use | 171 | 18.9 | 2755 | 2.52 | 368 |
| **Erosion-prone surfaces (U)** | | | | | |
| - with intact soil | 114 | 12.6 | 1837 | 0 | 0 |
| - with soil disturbed by land use | 41 | 4.5 | 660 | 0.14 | 21 |
| **Eroded (R) and eroding (E) surfaces** | | | | | |
| - (R) with re-vegetating soil | 99 | 11 | 1595 | 0.15 | 23 |
| - (E) with soil disturbed by natural processes | 6 | 0.7 | 98 | 0.02 | 3 |
| **Other surfaces** | | | | | |
| - (u) urban | 173 | 19.1 | 2787 | 0.09 | 13 |
| - (e) estuary | 22 | 2.4 | 355 | 0 | 0 |
| - (bi) rural building | 1 | 0.1 | 16 | 0 | 0 |
| **All surfaces** | 904 | 100 | 14566 | 2.94 | 428 |

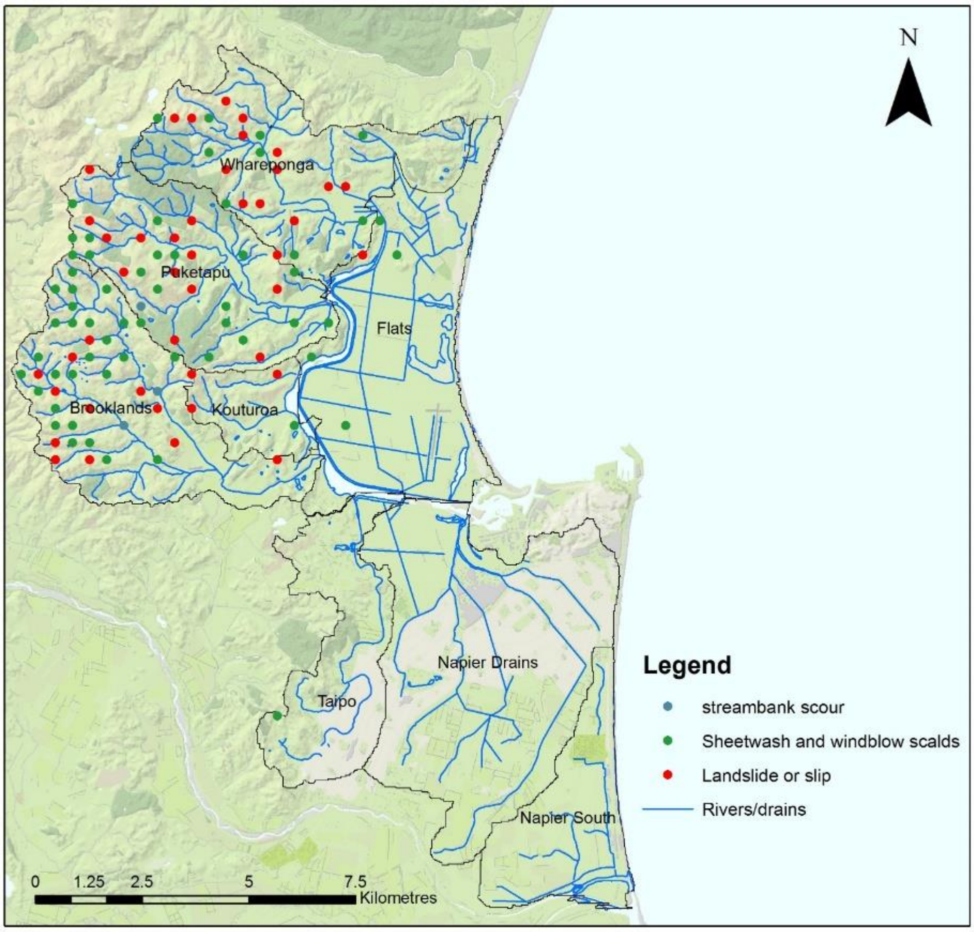


**Figure 3-10: Distribution of natural erosion (not cultivated) processes in the Ahuriri Catchment**

The point analyses of the Ahuriri Catchment revealed 427 ha of bare soil. Most of the bare soils (68%) can be attributed to cultivation of intensively managed systems (market gardening, orchards/viticulture and crops) on flat land, where the risk of erosion is negligible (Table 3-12). Of more concern is the 26% of bare soil that was found on pastoral farms, where risk of soil loss due to erosion is high because most pastoral farms are located in the hill-country. In fact, about 20% of points located on pastoral sites had evidence of erosion and 1% of sites were actively eroding. The high risk of erosion in the hill-country demonstrates the importance of stabilisation through limiting cultivation on steep slopes and revegetating unstable slopes where possible.

**Table 3-12: Occurrence of soil disturbance, aggregated by land use.**

| Land use | % of survey area | Area (ha) | Bare soil (ha) | Bare soil (% of total) |
|---|---|---|---|---|
| Market gardens | 1.22 | 177 | 35.77 | 9 |
| Orchard and viticulture | 6.75 | 983 | 51.56 | 12 |
| Greenfeed crops | 4.31 | 628 | 201.89 | 47 |
| Pastoral farming | 55.31 | 8056 | 111.98 | 26 |
| Exotic forest | 4.53 | 661 | 5.64 | 1 |
| Scrub | 0.22 | 32 | 0 | 0 |
| Natural forest | 0.66 | 97 | 0 | 0 |
| Lifestyle blocks | 5.20 | 757 | 7.41 | 2 |
| Urban areas | 19.14 | 2788 | 12.89 | 3 |
| estuary | 2.43 | 355 | NA | NA |
| Other (buildings, wetlands) | 0.22 | 32 | 0.48 | <1 |
| TOTAL | 99.99 | 14566 | 427.62 | 100 |

### 3.3.3 SednetNZ and Highly Erodible Land Layer (HEL)

To establish an estimate of spatially distributed sediment sources, HBRC contracted Landcare Research to model sediment load and yield for the entire region. SedNet has three main components – (1) an erosion submodel, (2) a hydrological submodel, and (3) a sediment-routing submodel (Palmer et al., 2016). The model produces a sediment budget for individual stream links, which are defined using the River Environment Classification (REC). The sediment budget is modelled by calculation of 5 erosion components, including: landslide, earthflow, gully, surficial, and bank erosion. For each modelled zone, the sediment budget is a sum of all erosion components, minus deposition.

The Sednet model was applied to four zones within the Ahuriri Catchment, including: Napier south catchment, Napier drains catchment, Taipo catchment and northern catchments (Whareponga, Puketapu, Brooklands and Kouturoa catchments) (Figure 3-11). Highest erosion rates occur in the northern catchments, with sediment loads in excess of 1,500 t/yr in some areas. High erosion rates are confirmed by the soil intactness survey, which recorded several instances of sheetwash, landslides and slips in the northern catchments (Figure 3-11). Erosion rates are low to negligible in the Napier drains and Napier South catchments because of the low slope angle of the land.

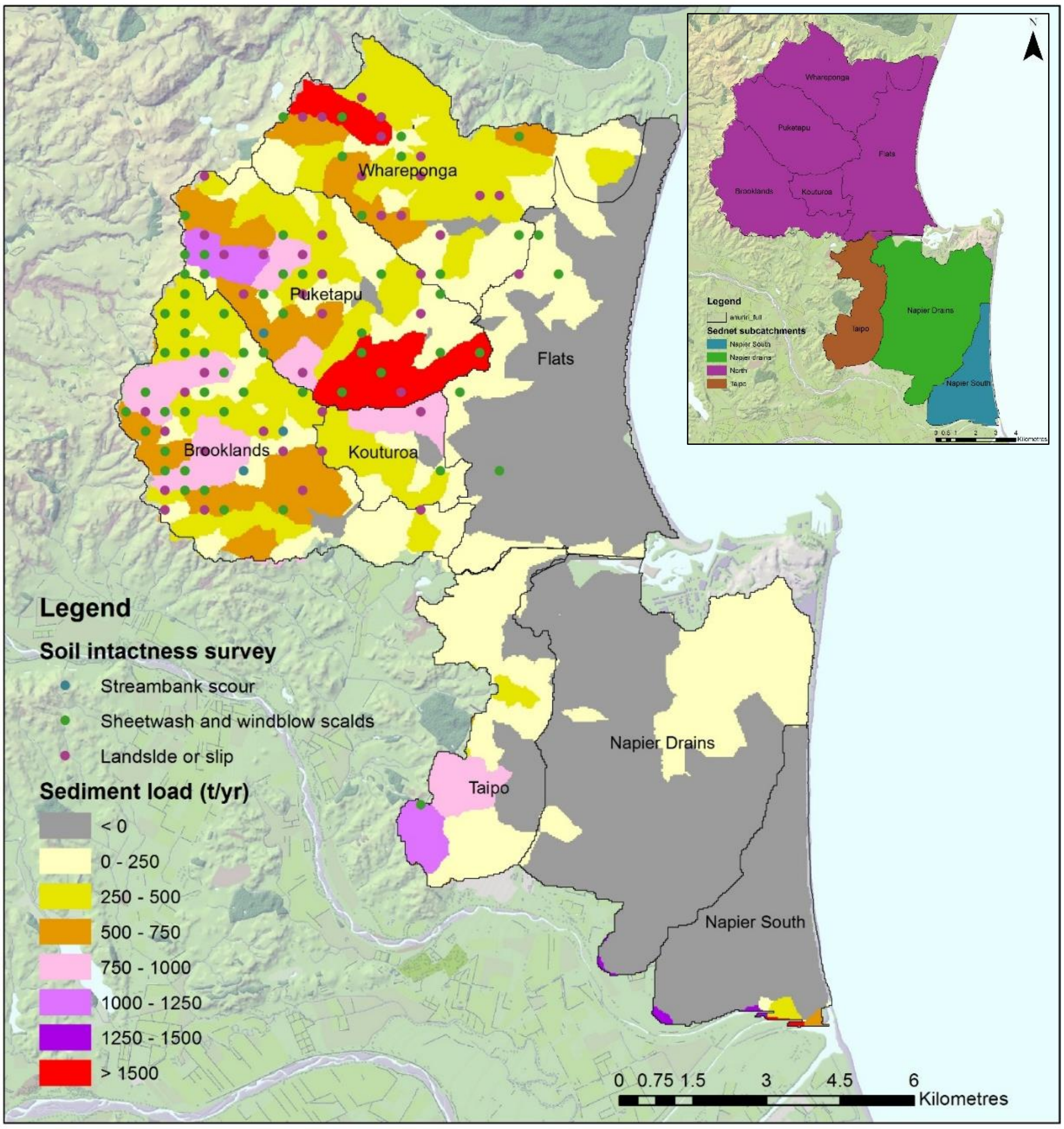


**Figure 3-11: Modelled annual sediment loads for the Ahuriri Catchment based on the Sednet model (Palmer et al., 2016). Points represent areas of erosion identified from the soil intactness survey (Burton, 2017).**

The total sediment load for the Ahuriri Catchment is 57,000 t/yr, with Napier south, Napier drains, Taipo and northern catchments contributing 1956 t/yr (3%), -4023 t/yr (net deposition), 8498 t/yr (15%) and 51469 t/yr (90%), respectively (Figure 3-12). Of the total sediment load, landslide erosion delivers the greatest quantity of sediment (79%), with the majority occurring in the northern catchments. Landslide occurrence is strongly correlated with slope angle, with the majority of failures occurring above 26 degrees, but landslides can occur on slopes as low as 15 degrees (Palmer et al., 2016). Landslide erosion can be reduced by planting susceptible slopes with deep rooting plant/tree species that stabilise the slope.

Bank erosion contributes 14,268 t/yr (18%) of the total sediment load, with the highest bank erosion occurring in the Napier south catchment. The small contribution of bank erosion to over-all sediment loads has implications for the effect of riparian planting on sediment reduction. According to Sednet, fencing and planting stream banks results in a 70% reduction in bank erosion rates (Palmer et al., 2016). Applying the sednet calculation to the Ahuriri Catchment, full fencing and riparian planting of stream banks would result in a 9,987 t/yr (12%) reduction in total sediment load. It is difficult to determine the effect of riparian vegetation on trapping entrained sediment that is supplied from hillslope processes (landslide and surficial erosion), however, current modelling would suggest that hillslope stabilisation will have the greatest effect on reducing total sediment loads.

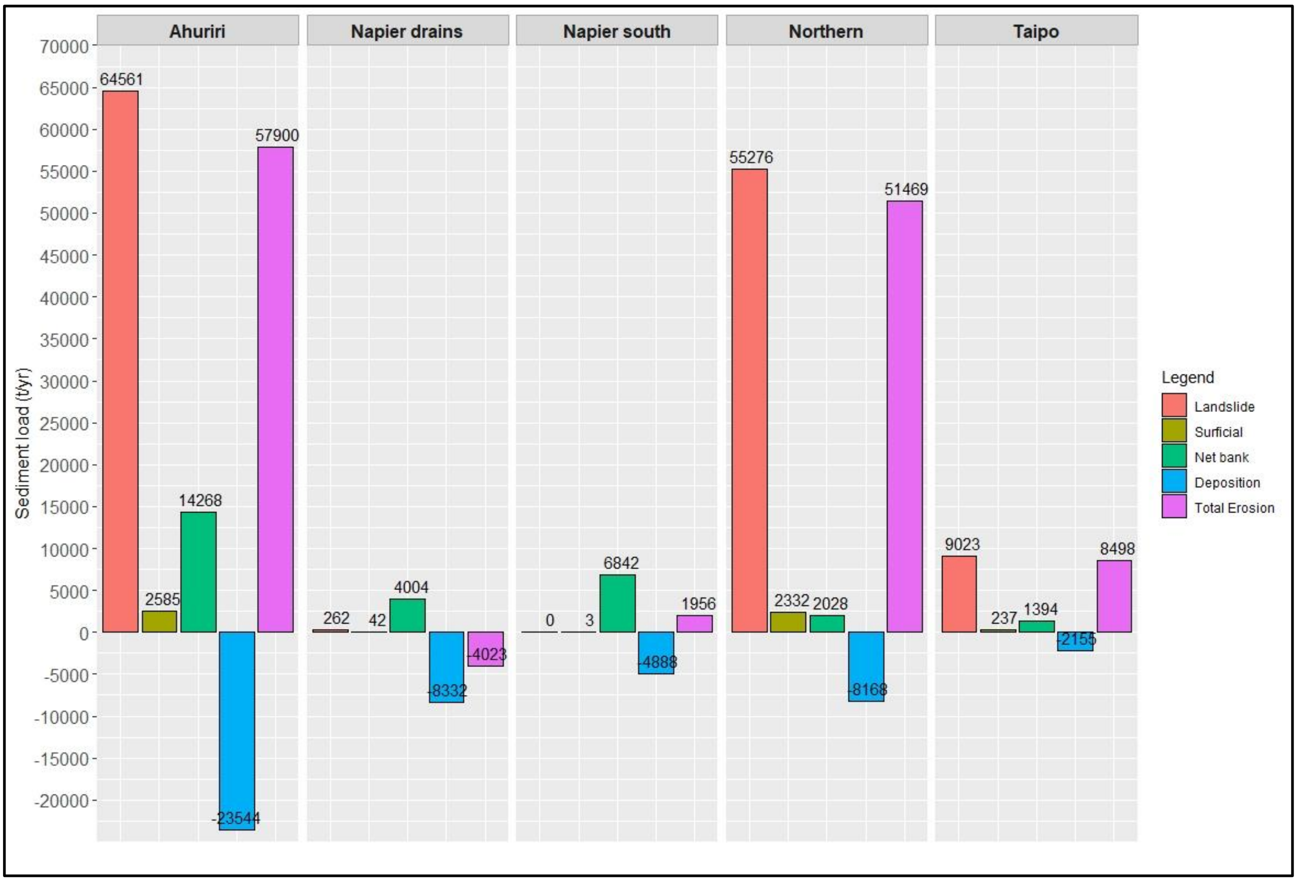


**Figure 3-12: Contribution of erosion processes to sediment loads in the Ahuriri Catchment and sub-catchments. Note that earthflow and gully erosion are not plotted as contribution from these erosion types to total sediment load was negligible. Number above each bar indicate sediment load (t/yr).**

Sediment yield is defined as the sediment load (t/yr) per unit area (km$^2$) and is an important measurement for determining hot-spot areas for sediment generation. In terms of sediment loss, a comparatively low nutrient load may in fact correlate to a high yield because of the small land area generating the sediment. For example, a sediment load of 250 t/y for a 1 km$^2$ parcel of land equates to a yield of 250 t/km$^2$/yr, while the same sediment load produced from a 0.25 km$^2$ parcel of land equates to a much higher yield of a 1000 t/km$^2$/yr. As indicated in Figure 3-13, most of the high sediment yielding areas occur in the Brooklands and Puketapu sub-catchments and focussing sediment reduction programmes in these catchments is likely to have the biggest impact on reducing total sediment loads.

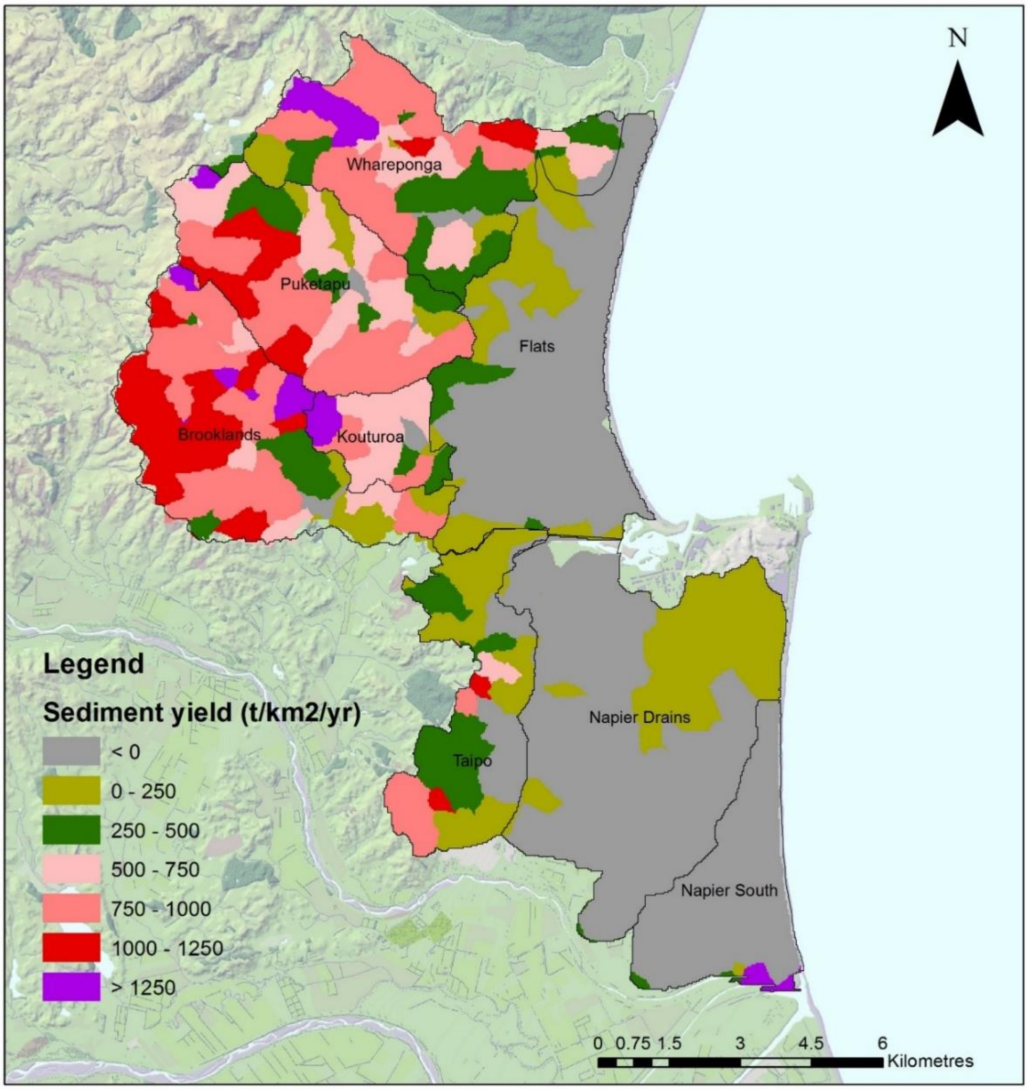


**Figure 3-13: Sediment yield (t/km²/yr) map for the Ahuriri Catchment. Highest yields occur in the Brooklands and Puketapu catchments.**

Highly erodible land is defined as the susceptibility of land to severe erosion (landsliding, earthflow, and gullying) where there is an absence of woody vegetation (Dymond et al., 2010; Palmer et al., 2016). The Highly Erodible Land (HEL) layer is derived from Land Use Capability (LUC) erosion data, land cover data (LCDB4), and particle size data from the Fundamental Soils Layer (FSL). The HEL layer is based on erosion risk and is useful for identifying parcels of land that are highly susceptible to erosion. The HEL model produces five categories of erodible land, namely: high land slide risk – delivery to stream; high landslide risk – non delivery to stream; moderate earthflow risk; severe earthflow risk; and gully risk. Figure 3-14 shows HEL for the Ahuriri Catchment and classifies 2% of the total land area as highly erodible, with 50% of the eroded material likely to be delivered to streams. The HEL model confirms the Sednet results, that erosion is most prevalent in the Brooklands and Puketapu Catchments.

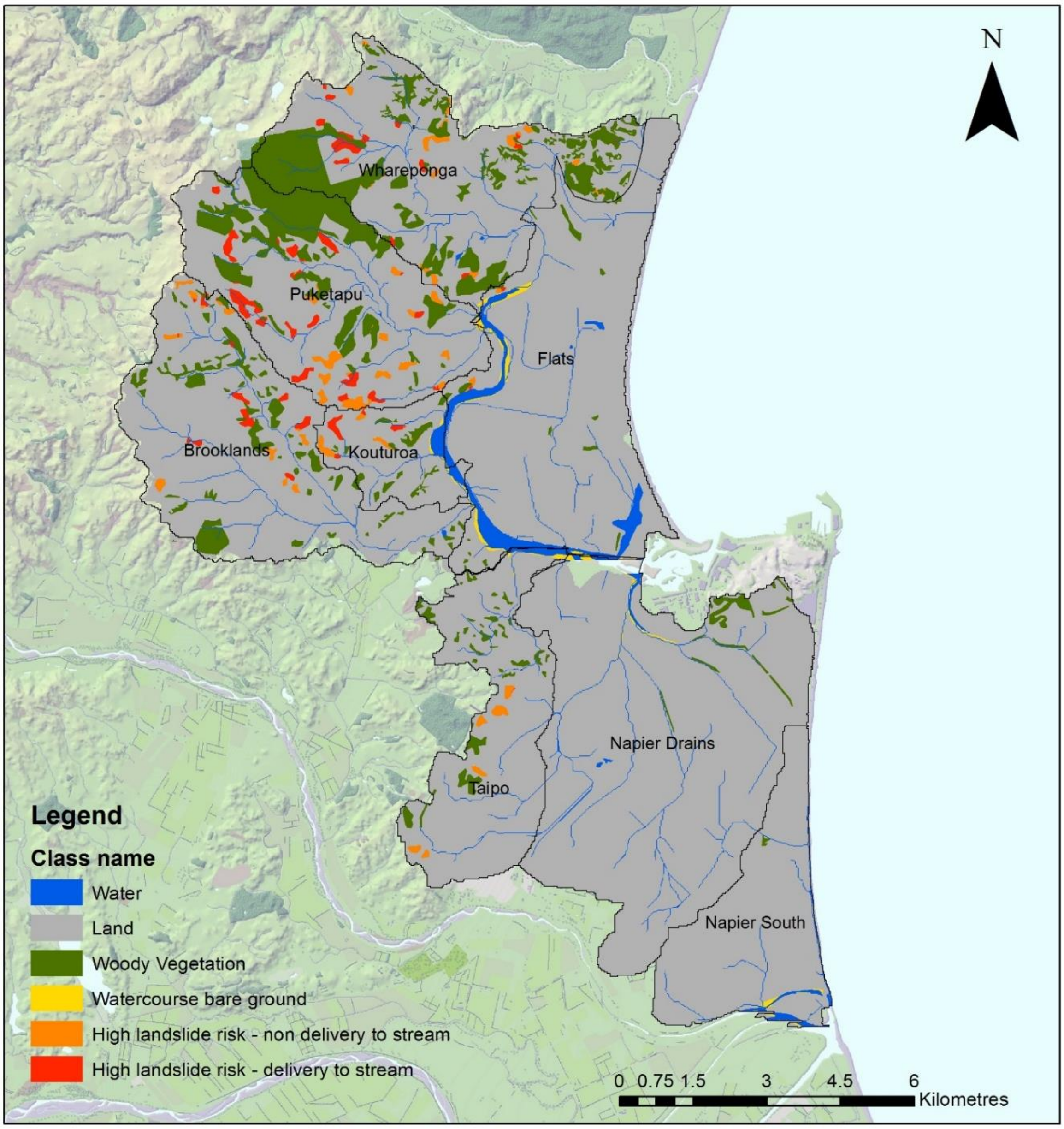


**Figure 3-14: The Highly Erodible Land (HEL) layer for the Ahuriri Catchment and sub-catchments. Most HEL is constrained to the Brooklands and Puketapu Catchments.**

# 4 Conclusions

The purpose of this this report was to carry out a thorough investigation into land based data currently held by HBRC that is relevant to the Ahuriri Estuary. By analysing currently available datasets, the goal was to identify land based issues that are contributing to the high nutrient and sediment levels in the estuary, and provide a scope for future land science work within the catchment. Current datasets held by Land Science include: geological and soils data, land use data and erosion data. Comparing the current water quality data with land based data-sets, the main findings are summarised in Table 4-1 and discussed thereafter.

**Table 4-1: Summary of main water quality issues and the links to land based data.**

| Water quality data findings | Land based data |
|---|---|
| High N concentrations in *Napier South* and *Napier Drains* Catchments | High land use intensity (high proportion of cropping, market gardening and orchards to the South of Napier), requiring high inputs of N fertilizer. Difficult to measure soluble forms of N in soil but given the intensity of land use in the catchment, N losses are likely to be high. |
| High soluble P concentrations in *Napier South* and *Napier Drains* Catchments | Low P retaining soils, implying high risk of P leaching. High risk of bypass flow at some sites. High Olsen P was recorded at HBRC soil quality monitoring sites. |
| High sediment concentrations at *Quarantine road* and *Taipo Stream* | Erosion rates in Taipo, Brooklands and Puketapu Catchments are relatively high, as demonstrated by Sednet, HEL and point analyses. Landslide erosion contributes the most to overall erosion. |

*High nutrient concentrations in Napier Drains and Napier South Catchments*

Soils in the *Napier south* and *Napier Drains* catchments are intensively managed (section 3.2) and this is reflected in the high Olsen P values measured at the HBRC soil quality monitoring sites. Only two SQM sites have been established and caution must be taken when extrapolating this data to the entire *Napier South* Catchment. However, the high risk of P leaching from soils in the southern part of the catchment (Section 3.1.4) coupled with high measured DRP values (Section 2.2) in surface water suggests loss of soluble P fertilizer from high intensity land uses is an important factor to consider. More rigorous water quality monitoring to include sampling during high rainfall events is required to more accurately determine the contribution of Napier South catchments to overall nutrient loads (see section 5).

Dissolved forms of nitrogen (DIN) were found to be high in *Saltwater creek 1,* which drains the intensively managed *Napier Drains* catchment. The high DIN concentrations imply N leaching or direct loss of soluble N fertilizer from the land is occurring (Wilcock et al., 1999). Since most soluble N is lost from the soil through leachate (water containing soluble forms of N), monitoring surface water concentrations during high flows is required (see section 5). The current water quality dataset has minimal data relating to high flow events.

*High suspended sediment concentrations*

Sednet modelling, point analysis and the highly erodible land (HEL) layer suggest that most erosion is confined to steep hill-county in the northern catchments. Current water quality data doesn't support modelling due to the lack of suspended sediment measurements during high rainfall events. Total modelled sediment load from the northern catchments is 51,469 t/yr, 89% of the total sediment load for the whole catchment (57,900 t/yr). Landslide erosion delivers the greatest quantity of sediment (79%) and can be reduced by stabilising erosion prone hill-slopes through planting deep-rooting tree species.

# 5 Recommendations

- More frequent water quality monitoring is required to monitor short-term and seasonal variations in nutrient concentrations. This is especially important for transport of soluble forms of N through the soil, with losses of N from soil being highest during rainfall events. Losses of N from soils will also vary seasonally in response to fertilizer application, crop type, grazing management, etc.

- Collection of samples during high rainfall events, especially from streams draining the hill-country, is required to more accurately determine erosion rates and sediment inputs into the estuary. Installation of automatic samplers (ISCO's) at the bottom of key catchments will enable consistent sampling during high rainfall events. Furthermore, measured data will improve the calibration of models such as Sednet and enable HBRC to more accurately identify erosion prone areas.

- Stream gauging's are required to calculate nutrient and sediment loads. As Haidekker et al. (2016) stated - *"In order to evaluate the contribution of the streams to the estuary on an ongoing basis, streams gauging's to estimate flow and calculate loads are required. Stream gaugings have been initiated recently, but it is not yet possible to calculate loads. However, the streams are small and generally of low flow, so these streams are not expected to be the sole contributing origin of ongoing elevated phosphorus in the Ahuriri Estuary. The estuary may be experiencing legacy effects from long-term inputs of nutrients from these streams that have bound to sediments."*

- Increasing the number of soil quality monitoring (SQM) sites will improve our understanding of soils and land use management within the catchment. Land management surveys are collected for each SQM site and enable HBRC scientists to relate land management information (e.g. fertilizer rate) to soils data. More detailed farm information coupled with soils data will enable HBRC to identify high nutrient generating farms.

- Repeat the soil intactness survey (point analysis) every five years to determine changes in erosion over time and identify high risk areas.

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# Appendix A S-map fact sheet

# S-map Soil Report

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Report generated: 31-Jan-2019 from https://smap.landcareresearch.co.nz

S-map maps soils at a nominal scale of 1:50,000. At this scale it is common to identify two or more soil siblings that are likely to be present at the selected location. A more detailed resolution is needed to produce map units comprising a single soil sibling. Therefore, it is recommended that users consider the characteristics of each of the identified siblings, the expected proportion of each, and select the S-map sibling that best matches their field observations of the paddock. If no local information is available then it is common practice to select the dominant S-map sibling, i.e. the first listed sibling.

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.

## Motukararaf

**Saline Recent Gley Soil**

Motu_11a.1 (100% of the mapunit at location (1932973, 5625771), Confidence: Low)

| Key physical properties | | |
|---|---|---|
| Depth class (diggability) | | Deep (> 1 m) |
| Texture profile | | Loam |
| Potential rooting depth | | Unlimited |
| Rooting barrier | | No significant barrier within 1 m |
| Topsoil stoniness | | Stoneless |
| Topsoil clay range | | 19 - 21 % |
| Drainage class | | Very poorly drained |
| Aeration in root zone | | Very limited |
| Permeability profile | | Moderate Over Rapid |
| Depth to slowly permeable horizon | | No slowly permeable horizon |
| Permeability of slowest horizon | | Moderate (4 - 72 mm/h) |
| Profile available water | (0 - 100cm or root barrier) | Moderate to high (127 mm) |
| | (0 - 60cm or root barrier) | High (93 mm) |
| | (0 - 30cm or root barrier) | High (60 mm) |
| Dry bulk density, topsoil | | 1.22 g/cm³ |
| Dry bulk density, subsoil | | 1.38 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 (35%) |

**About this publication**

- This information sheet describes the *typical average properties* of the specified soil to a depth of 1 metre.
- 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.
- Landcare Research shall not be liable on any legal basis (including without limitation negligence) and expressly excludes all liability for loss or damage howsoever and whenever caused to a user of this factsheet.

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## *Motukararaf*

S-map ref: Motu_11a.1

Motu_11a.1 (100% of the mapunit at location (1932973, 5625771), Confidence: Low)

### Additional factors to consider in choice of management practices

Vulnerability classes relate to soil properties only and do not take into account climate or management

***Soil structure integrity***

| | |
|---|---|
| Structural vulnerability | Very high (0.72) |
| 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 |
| Irrigability | Flat to very gently undulating land with moderate drainage/permeability restrictions and soils with high PAW |

***Contaminant management***

| | |
|---|---|
| N leaching vulnerability | Very Low |
| P leaching vulnerability | not available yet |
| Bypass flow | High |
| Dairy effluent (FDE) risk category | B |
| Relative Runoff Potential | Medium |

### Additional information

| | |
|---|---|
| Soil classification | Saline Recent Gley Soils |
| Family | *Motukararaf* |
| Sibling number | 11 |
| Profile texture group | Loamy |
| Soil profile material | Stoneless soil |
| Rock class of stones/rocks | Not Applicable |
| Rock origin of fine earth | From Soft Mudstone Rock |
| Parent material origin | Lacustrine |

***Characteristics of functional horizons in order from top to base of profile:***

| Functional Horizon | Thickness | Stones | Clay* | Sand* |
|---|---|---|---|---|
| Loamy Weak | 30 - 45 cm | 0 % | 19 - 21 % | 40 - 45 % |
| Sandy Loose | 55 - 70 cm | 0 % | 1 - 4 % | 85 - 95 % |

* clay and sand percent values are for the mineral fines (excludes stones). Silt = 100 - (clay + sand)

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## Soil information for OVERSEER

The following information can be entered in the OVERSEER® Nutrient Budget model. This information is derived from the S-map soil properties which are matched to the most appropriate OVERSEER categories. Please read the notes below for further information.

### *Soil description page*

1. Select **Link to S-map**
2. Under S-map sibling data enter the S-map name/ref: **Motu_11a.1**

### Considerations when using Smap soil properties in OVERSEER

- The soil water values are estimated using a regression model based on soil order, parent rock, soil functional horizon information (stone content, soil density class), as well as texture (field estimates of sand, silt and clay percentages). The model is based on laboratory - measured water content data held in the National Soils Database and other Manaaki Whenua datasets. Most of this data comes from soils under long-term pasture and may vary from land under arable use, irrigation, etc.

- Each value is an estimate of the water content of the whole soil within the target depth range or to the depth of the root barrier (if this occurs above the base of the target depth). Where soil layers contain stones, the soil water content has been decreased according to the stone content.

- S-map only contains information on soils to a depth of 100 cm. The soil water estimates in the > 60 cm depth category assume that the bottom functional horizon that extends to 100 cm, continues down to a depth of 150cm. Where it is known by the user that there is an impermeable layer or non-fractured bedrock between 100 and 150 cm, this depth should be entered into OVERSEER. Where there is a change in the soil profile characteristics below 100 cm, the user should be aware that the values provided on this factsheet for the > 60 cm depth category will not reflect this change. For example, the presence of gravels at 120 cm would usually result in lower soil water estimates in the > 60 cm depth category. Note though that this assumption only impacts on a cropping block, as OVERSEER uses soil data from just the top 60 cm in pastoral blocks.

- OVERSEER requires the soil water values to be non-zero integers (even though zero is a valid value below a root barrier), and the wilting point value must be less than the field capacity value which must be less than the saturation value. The S-map water content estimates supplied by the S-map web service have been rounded to integers and may be assigned minimal values to meet these OVERSEER requirements. These modifications will result in a slightly less accurate estimate of Available Water to 60 cm (labelled PAW in OVERSEER) than that provided on the first page of this factsheet, but this is not expected to lead to any significant difference in outputs from OVERSEER .

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