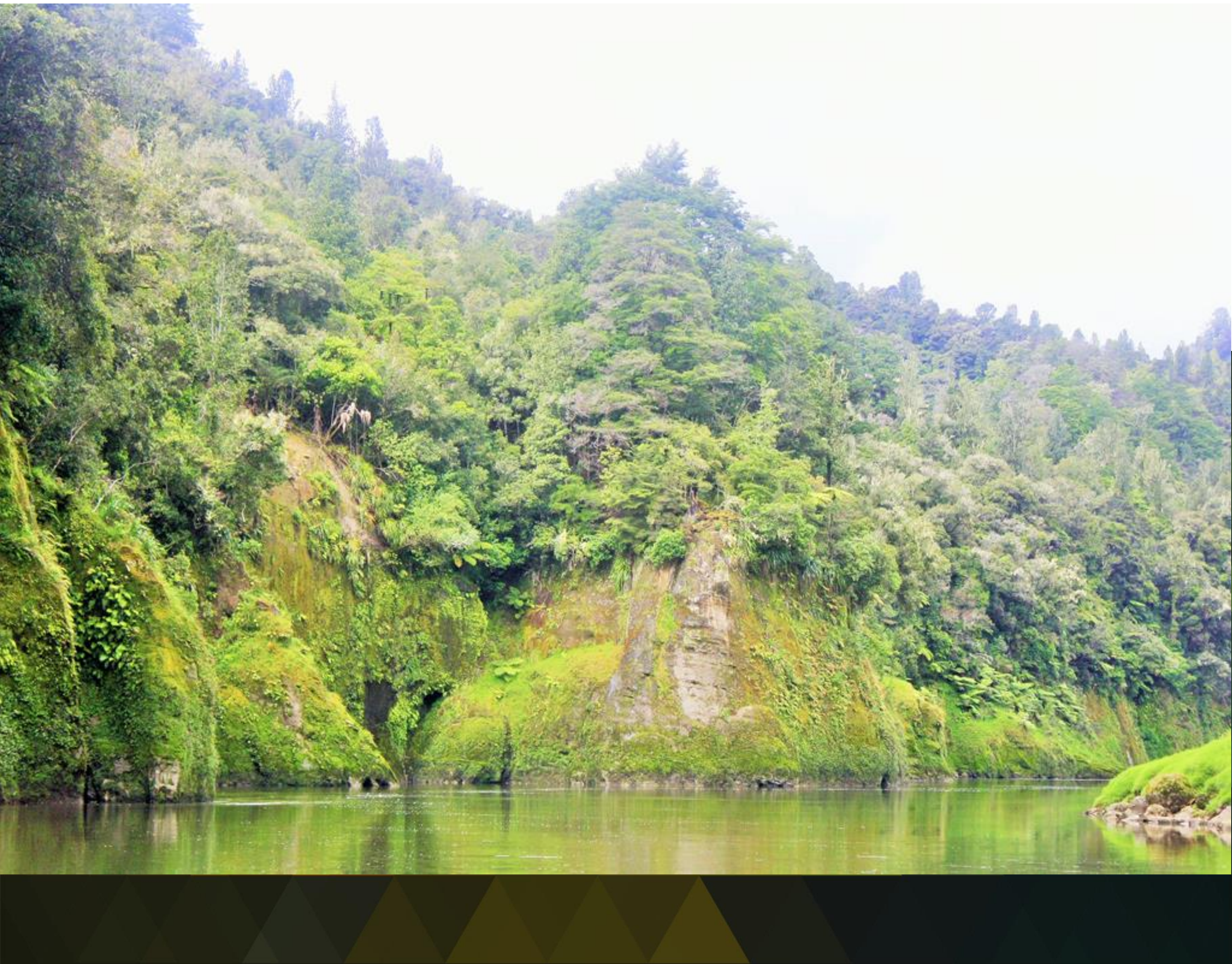
Te Awa Tupua scoping study



Te Awa Tupua scoping study

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Summary

The Whanganui River is central to the existence of Whanganui iwi and their health and well-being. After more than a century of persistent effort to protect and provide for that special relationship, Ruruku Whakatupua, the Whanganui River Deed of Settlement, was signed in 2014. Recently, with the passage of the *Whanganui River Claims Settlement Act 2017*, the Whanganui River has been formally accorded the status of legal personhood as Te Awa Tupua, an indivisible and living whole incorporating its tributaries and all its physical and metaphysical elements from the mountains to the sea. This will change the lens through which all communities and agencies that use or have an interest in the Whanganui River view and make decisions in regard to the River.

Ngā Tāngata Tiaki o Whanganui commissioned a scoping study on the current health and well-being of Te Awa Tupua to assist with setting the vision, guiding principles, and long-term objectives for the River. Manaaki Whenua was contracted to carry out a desktop literature review and gap analysis focused primarily on the biophysical environment of Te Awa Tupua.

The report starts with a broad overview of early life on the Whanganui River to convey the close and inter-dependent relationship of the people of the River with their physical surrounds. In the sections following we collate and review the science information on:

- The physical environment (including landforms and geology, climate, soils, land cover, land use, erosion)
- Terrestrial ecosystems, biodiversity and taonga species (including development of natural vegetation, wetlands, uncommon ecosystems, human influences, fauna, flora, production landscapes)
- River and groundwater hydrology (including impacts on hydrology of human activity, water quality, sediment, aquatic ecology)
- The human and built environment (including population, infrastructure, governance, land tenure, the economy and economic development).

Information gaps and key issues are identified and recommendations made on potential areas of focus and future work.

Overview of key issues and information gaps

Current information on the physical environment for the Whanganui catchment is reasonably comprehensive for regional-scale analysis, and the establishment of the key elements determining its distinctive landscape features, with the exception of detailed soils data.

The Whanganui catchment is characterised by a paucity of high quality land, a predominance of non-arable land, and a significant proportion of moderately steep to steep land with severe physical limitations to productive use. Over 45% of the catchments soils are developed from volcanic ash, of variable natural fertility and susceptible to sheet and

shallow landslide erosion. The steep to very steep, ash free, sandstone terrain is also very susceptible to shallow landslide and sheet erosion under pasture.

This highly erodible land has been identified and mapped. Applying the standard range of soil conservation techniques, as detailed in the report, should reduce the volumes of fine suspended sediment generated and delivered to the waterways, and thus improve water quality. Giving priority to controlling the areas and points of sediment generation at their source will yield the greatest benefit in the shortest time, and this approach is being implemented by Horizons Regional Council under their SLUI initiative and The One Plan.

Information on the state of terrestrial ecosystems and the plants and animals they contain is best from public conservation land, but mostly in upper reaches of the catchment, leading to a geographically biased view. The information derives mostly from a coarse monitoring grid (8 km) and finer scale resolution on public conservation land is patchy.

On private land (including Māori-owned land) the information is very poor. There are no data on the state of biodiversity from most private land where native plant cover is low or absent and non-native plant cover dominates (e.g. pastoral agriculture and plantation forests). Although wetlands and some rare ecosystems (dunes, cliffs) are delineated and mapped, the state of these ecosystems is generally unknown. Defensible estimates of trends in biodiversity (improving or declining) are even more elusive.

For the catchment's water environments, there is a need for better linking of data on land use including land management practices, and water quality and habitat outcomes. Climate variability (storms and droughts) obscure the longer term trends in river and habitat quality as affected by land use practices. A regular and consistent fish monitoring programme throughout the catchment, as well as monitoring attributes such as Macroinvertebrate Community Index (MCI) would provide a more integrated picture of aquatic habitat change.

In several respects, the human dimension of the Whanganui catchment is ailing as much as the natural and spiritual dimensions. Population is in decline and its demography is out of balance, the economy is languishing, infrastructure is only just being maintained, tourism is struggling, agriculture is retrenching, and processing and manufacturing are striving to remain viable. Opportunities exist to reverse this decline and to manage growth of the human environment in directions that benefit Te Awa Tupua and its people. Initiatives such as Accelerate 25, reinforced by the Māori-focused priorities delineated in Te Pae Tawhiti, will serve to unite the iwi/hapū of Te Awa Tupua (and the energy they can provide) behind a vision of a healthy and sustainable river and catchment.

Recommendations

- To further the development of Te Heke Ngahuru, our **key recommendation** is that the **main findings from this report are presented at a hui** attended by members of Te Kōpuka and other selected parties, with the aim of **setting priorities** for actions to restore the health of Te Awa Tupua. Having identified priority catchment issues and actions, Te Kōpuka can consider **potential research partnerships** (e.g. in areas of sediment and erosion management, biodiversity measurement and monitoring, and integrated catchment management) and identify sources of funding additional to Te Korotete o Te Awa Tupua.

Specific recommendations that derive from our study are:

- Support the activities of SLUI and The One Plan to shut down sediment generation from agricultural land at source, through measures like retirement, afforestation, and soil conservation planting and management.
- Rectify the shortfall in detailed soils data by investing in Landcare Research's 'S-Map' program (https://smap.landcareresearch.co.nz/) to extend regional coverage.
- Influence land owners to always manage land with the health of the river in mind, and an aspirational goal of zero off-site impact rather than simple compliance with rules.
- Develop a catchment-wide process to assess state and trend in terrestrial ecosystems. Support continued investment of DOC's Tier One monitoring programme on public conservation land, and encourage regional councils (principally Horizons Regional Council) to extend the same grid-based sampling to all other land.
- For those ecosystems selected as priority areas for management, commission a survey to establish a contemporary baseline against which future trends can be measured. As many attributes as thought necessary can be included – typically the surveys would include vegetation and bird communities. The baseline can be used to assess the effectiveness of any management or restoration activities.
- With tāngata whenua, develop specific methods (combining standard scientific methods with mātauranga-based assessments) to measure and monitor state and trend of taonga species, ecosystems, and geographic areas of importance. If these methods can be integrated, to the greatest extent possible, with those in use by DOC, then defensible comparisons can be made. Established protocols exist for monitoring some species of concern (e.g. kiwi, pekapeka) and these could be adopted in the catchment.
- Invest in specific programmes to measure and monitor state and trends in rare ecosystems (wetlands, dunes) throughout the catchment.
- Establish a holistic catchment-wide process, building on current hydrology and water quality monitoring programmes run by Horizons Regional Council, that incorporates mātauranga-based assessments and monitoring of taonga species (such as tuna and piharau) through time and down river between sites.
- Establish a regular and consistent aquatic monitoring programme for the entire Whanganui river catchment to provide information for the long term health of river system.
- Set up a dedicated study on the historical suspended sediment regimes of the Whanganui catchment to benefit understanding of the natural sediment conditions in the catchment and long-term trends.
- Engage to the fullest extent possible with initiatives under Accelerate 25 and Te Pae Tawhiti and facilitate inclusion of iwi/hapū of Te Awa Tupua in opportunities presented by these (and other) regional development plans.
- Above all, foster whole catchment understanding that links biophysical and social factors to enable holistic management that truly reflects Tupua Te Kawa.

Glossary

Aggradation	The build-up of the earth's surface by deposition
Allophane	A non-crystalline soil mineral; an oxide of silicon and aluminium with a high water content, variable-charge surfaces, and a very high surface area
Allophanic Soils [NZ Soil Classification]	Soils dominated by allophane (and imogolite or ferrihydrite) minerals; have a porous, low-density structure, greasy moistened feel, stable resistant topsoil, low natural fertility and high phosphorus retention.
Alluvium	Material that has been deposited by water action. Alluvial deposits are described as fine where they are dominated by particles less than 2 mm in diameter, and gravelly when particles are greater than 2 mm.
Alluvial soils	Recent soils derived from alluvium, and showing incipient marks of soil forming processes, but with distinct topsoil.
Andesite	A dark-coloured volcanic rock intermediate in composition between rhyolite and basalt.
Andesitic ash	Unconsolidated volcanic ash of intermediate silica content, of Recent and Upper Pleistocene age. Occurs as a primary deposit, or as rewashed material in river and coastal terraces.
Argillite	A mudstone or siltstone that has undergone hardening by pressure, heat or cementation.
Basalt	A type of volcanic rock which has a high iron and magnesium content but low silica. Molten basalt flows easily.
Bedrock	The solid rock that underlies soil or other loose material.
Bioclastic	A sedimentary rock consisting of fragmental or broken remains of organisms such as a limestone composed of shell fragments
Bioturbated	Disturbed by organisms.
Breccia	A coarse-grained rock composed of angular rock fragments held together in a fine-grained matrix.
Brown Soil [NZ Soil Classification]	Have yellowish brown subsoils, stable and well-structured topsoils, are well to imperfectly drained, with low to moderate fertility, and are generally drought free.
Carbonaceous	Rock or sediment that is rich in carbon; coaly.
Calcareous	Rocks consisting mainly of carbonate minerals, specifically >50% by weight of carbonate minerals.
Cenozoic	An era of geological time, from the beginning of the Tertiary period to the present. Considered to have begun about 65 milion years ago.
Clay	Fine grained material consisting of particles <0.002 mm in diameter.
Cleavage	Tendency to split along closely spaced planar structures or textures.
Colluvium	Rock fragments and soil material, which have accumulated on slopes as a result of gravity. Colluvial deposits may also be described as fine or gravelly.
Conglomerate	A coarse sedimentary rock consisting of pebbles or boulders set in a sand and silt matrix.
Coquina	A detrital limestone composed wholly or chiefly of mechanically sorted fossil debris.
Cretaceous	The final period of the Mesozoic era thought to have covered the span between 145 and 65 million years ago.

Dendritic drainage pattern	A drainage pattern in which the streams branch randomly in all directions and at almost any angle, resembling in plan the branching habit of certain trees.
Depocentre	An area or site of maximum deposition; the thickest part of any specific stratigraphic unit in a depositional basin.
Deposition	The constructive processes of accumulation into beds of loose rock material by any natural agent such as the settling of sediment from suspension
Diachronous	Said of a rock unit that is of varying age in different areas or cuts across time planes or biozones.
Dip slope	Slope of the land surface roughly determined by and conforming to the direction and angle of dip of the underlying rocks.
Downlands	Downlands are extensive areas of gently to strongly rolling land often with a deep mantle of windblown loess. Downlands may be underlain by terrace gravels or bedrock, but the loess is often the dominant soil parent material.
Erosion	The wearing away of the lands surface by running water, wind, ice, or other agents.
Facies (sedimentary facies)	A distinctive rock type broadly corresponding to a certain environment or mode of origin.
Fans	Gently sloping, fan-shaped masses of material formed along the margins of hills and mountain ranges by the streams that drain their slopes. A fan commonly occurs where there is a marked decrease in gradient, e.g. where a stream meets the gentler floodplain or river terrace. Fan gravels are generally sub-angular in shape, while those of river terraces and floodplains are more rounded.
Fissile (fissility)	Splitting easily along closely spaced parallel planes.
Flat to gently undulating	One of the seven slope classes used in land resource mapping; land with a slope of 0–3°.
Fossiliferous	Containing fossils.
Floodplain	Relatively smooth land adjacent to a river or stream channel; built of alluvium deposited by that river or stream, which, in the absence of flood protection works, may still be subjected to flooding.
Fluvial	Belonging to a river, produced by river action; growing or living in freshwater rivers.
Foliation	A planar arrangement of textural or structural features, especially that which results from the flattening of the constituent grains of metamorphic rocks.
Fractured (rock)	Rock in which breaks, cracks or joints occur due to mechanical failure by stress, with or without displacement.
Fragipan	A subsoil horizon which has a high bulk density and which is relatively hard when dry but softens when wet. Fragipans usually impede the downward movement of water. The presence of a fragipan frequently gives rise to impeded drainage and perched water tables.
Gley Soils [NZ Soil Classification]	Are saturated by water for prolonged periods and have pale greyish subsoils. Many were originally wetlands before being drained.
Glauconite	A green mineral, closely related to mica, found in marine sedimentary rocks.
Gravel	Rock fragments greater than 2 mm in diameter.
Greywacke	A dark grey sandstone, flecked with angular fragments of finer rock; formed by the hardening of deposits in ocean basins; the major rock type of central New Zealand.
Hard rock	Rocks that have hardness and strength through induration. They ring when struck with a hammer, require a strong blow to fracture and are impractical to dig with a spade.

Igneous	Rocks that were once molten. If they crystallise deep below the earth's surface they are plutonic (e.g. granite); if they are erupted they are volcanic (e.g. rhyolite).
Ignimbrite	Thick sheets of rock formed by the welding together of extremely hot particles of rhyolitic ash during volcanic eruptions.
Interbedded	Beds lying between or alternating with others of different character.
Interfluves	The raised area between two adjacent streams flowing in the same direction.
Intrusive rock	Rock that consolidated from magma beneath the surface of the earth.
Lahar	A flow of volcanic material, both ash and coarser products, mixed with water; often caused by the spilling-over of a crater lake.
Landform	The characteristic shape of the earth's surface on which a soil type is developed. Landform types include floodplains, terraces, fans, downlands, moraines, hill and steep lands.
Lapilli	Pebble-sized fragments of tephra.
Limestone	A rock composed predominantly of calcium carbonate.
Lithology	The nature and composition of rocks.
Loess	A blanket deposit of windblown silt-sized material. Although loess is being deposited continually, extensive deposits occurred mostly during the ice ages, when glaciers were producing large quantities of ground-up rock dust.
Massive	Occurring in thick beds, free from minor joints and lamination.
Mean Annual Flood (MAF)	The average of the peak flow measured each year at a specified river location.
Mean Annual Low Flow (MALF)	The average of the lowest flow measured each year at a specified river location.
Melanic Soils [NZ Soil Classification]	Have high fertility, dark well-structured topsoils, and are associated with lime-rich rocks or dark (basaltic) volcanic rocks.
Metamorphic Rocks	Rock whose nature has been transformed by natural geological processes, usually heat and pressure, from a pre-existing form.
Mesozoic	An era of geological time from about 250 to about 65 million years ago.
Mica	A group of flake like minerals composed of silicon and oxygen combined with aluminium, iron, sodium and calcium.
Miocene	An epoch in the upper Tertiary from about 24 to 5 million years ago.
Moderately steep	One of the seven slope classes used in land resource mapping; land with a slope of 21–25°.
Mudstone	Soft sedimentary rock formed from material which contains a large proportion of clay. Form may be massive, bedded, frittered or bentonitic. Mudstone comprises much of the Tertiary 'soft rock' hill country. Soils formed from mudstones tend to be naturally fertile, but often carry a severe erosion potential.
Oligocene	An epoch in the early Tertiary from about 34 to 24 million years ago.
Organic Soils [NZ Soil Classification]	Formed from partly decomposed plant materials, e.g. peat, are strongly acidic and have high water-tables.
Pallic Soils [NZ Soil Classification]	Have pale coloured high bulk density subsoils, weak structure, are slowly permeable and have limited rooting depths. They are dry in summer and wet in winter.
Paleozoic	An era in geological time, from about 550 to 250 million years ago.
Parent Material	The geological origin of the sediments or rocks from which the soil has formed.

Peneplain	An undulating plain resulting from a very long period of erosion.
Physiographic unit	A region whose pattern of relief features or landforms differs significantly from that of adjacent regions.
Plateau	An extensive flat area elevated above the surrounding land.
Pleistocene	An epoch of the Quaternary period from about 2 million till about 8000 years ago.
Pliocene	An epoch in the late Tertiary from about 5 to 2 million years ago.
Podzol Soils [NZ Soil Classification]	Occur in high rainfall areas, are strongly acidic and strongly leached, with very low fertility. Drainage is variable, from well to poorly drained.
Pumice	A soft, light-coloured, frothy, glassy rock with the appearance of a sponge; usually formed by the trapping of bubbles of volcanic gases in molten rhyolite.
Pumice Soils [NZ Soil Classification]	Sandy or gravelly soils dominated by pumice, or pumice sand with a high content of natural glass, rapid drainage but high water storage capacity, low clay contents, low soil strength, high macroporosity, deep rooting depths, and low macronutrient reserves.
Pyroclastic	A general term for different fragments of rock ejected by a volcano (e.g., lava, scoria, ash.
Quaternary	The second period of the Cenozoic era, beginning 2 million years ago and extends to the present.
Raw [NZ Soil Classification]	Very young soils lacking distinct topsoil, and developed on sites of active deposition or erosion.
Recent [NZ Soil Classification]	Soils formed in young sediments. They have distinct topsoil, but weakly developed subsoil, with moderate to high fertility and well to imperfect drainage. They have widely variable rooting depths and water storage capacities.
Rhyolite	Volcanic rock rich in silica, but poor in iron and magnesium. Molten rhyolite is very stiff and usually gives rise to explosive volcanic eruptions with emissions of large quantities of ash.
Ring plain	The lower and flatter part of the cone of a typical basaltic or andesitic volcano. The upper limit is usually where the lava flows have stopped.
Rolling	One of the seven slope classes used in land resource mapping; land with a slope of 8–15°.
Sand	Material which consists of particles between 0.05 and 2.0 mm in diameter.
Sandstone	Sedimentary rock consisting of compressed or cemented sand-sized particles.
Schist	A metamorphic rock that has developed distinct layering (foliation); can be split into slabs or flakes. Mica appears as characteristic shiny flecks in the rock.
Scoria	Lightweight volcanic rock, usually formed by the trapping of bubbles of volcanic gases in andesitic or basaltic lava; denser and darker than pumice.
Sedimentary	Rocks resulting from the consolidation of loose material that has accumulated in layers, usually on the bed of the sea, in lakes or in rivers.
Shale	Fine-grained detrital sedimentary rock, formed by the consolidation of clay, silt, or mud.
Silt	Material which consists of particles between 0.05 and 0.002 mm in diameter.
Siltstone	Sedimentary rock consisting of compressed or cemented silt-sized particles.
Soft Rock	Weak rocks with minor or insignificant cementation that disaggregate with a mild hammer blow or can be crushed by hand. Soft rock can be cut by hand with a spade.

Slope	Land may be assigned to one of seven slope classes according to the slope angle •A = Flat to gently undulating (0–3°) •B = Undulating (4–7°) •C = Rolling (8–15°) •D = Strongly rolling (16–20°) •E = Moderately steep (20–25°) •F = Steep (26–35°) •G = Very steep (>35°)
Steep	One of the seven slope classes used in land resource mapping; land with a slope of 26–35°.
Stratovolcano	A volcano that is constructed of alternating layers of lava and pyroclastic deposits, along with abundant dikes and sills. Viscous, acidic lava may flow from fissures radiating from a central vent, from which pyroclastics are ejected.
Strongly rolling	One of the seven slope classes used in land resource mapping; land with a slope of 16–20°.
Suspended Sediment Concentration	The concentration of sediment suspended in a water-sediment mixture, usually expressed in milligrams per litre (mg/L) and carried in suspension during river transport
Tephra	A general term for all solid (rather than molten) materials ejected from a volcano during an eruption: boulders, lapilli and ash.
Terrace	A relatively flat or gently inclined surface (tread) less broad than a plain, bounded one edge by a steeper descending slope (riser) and along the other by a steeper ascending slope (riser), and sufficiently elevated to be beyond the reach of the waterway that formed it.
Terrestrial	Pertaining to the land above the tidal reach.
Tertiary	The first period of the Cenozoic era spanning the time between 65 and 2-3 million years ago.
Total Suspended Solids (TSS)	Similar to suspended sediment concentration and often used interchangeably but TSS is not limited to only sediment as the solid material. Units are usually expressed in milligrams per litre (mg/L) and carried in suspension during river transport.
TPS	Tongariro Power Scheme.
Transgression	The spread or extension of the sea over land areas.
Tuff	A general term for consolidated volcanic tephra.
Unconformity	A substantial break or gap in the geologic record where a rock unit is overlain by another that is not next in stratigraphic succession, such as an interruption in the continuity of a depositional sequence of sedimentary rocks.
Undulating	One of the seven slope classes used in land resource mapping; land with a slope of 4–7°.
Volcanic ash	Fine ash-like rock particles ejected from volcanoes during eruptions; may be transported large distances by wind.
Volcano	A vent in the earth's crust from which molten lava, pyroclastic materials, volcanic gasses, etc., issue.
Volcaniclastic	Pertaining to a clastic rock containing volcanic material in whatever proportion, and without regard to its origin or environment.

Very steep	One of the seven slope classes used in land resource mapping; land with a slope of >35°.
Water table	At a depth below the surface, the ground is saturated with water. The upper surface of this zone of saturation is termed the water table.
Xenolith	A foreign inclusion in an igneous rock.

1 Introduction

The Whanganui River is central to the existence of Whanganui iwi and their health and well-being, and has provided both physical and spiritual sustenance to Whanganui whānau and hapū from time immemorial.

Ruruku Whakatupua, the Whanganui River Deed of Settlement, was signed in 2014 and will be implemented following the passage of the settlement legislation. Ruruku Whakatupua is the culmination of over a century of persistent effort to protect and provide for the special relationship of Whanganui iwi with the River. The Treaty of Waitangi claim (WAI 167) primarily concerned Crown actions and omissions in gaining control of the River, including various legislation enacted in the 19th and 20th centuries, the removal of traditional structures and minerals from the River, and the diversion of the headwaters of the River for hydroelectricity (Whanganui River Report 1999).

With the passing of the Te Awa Tupua Bill the Whanganui River is now formally accorded the status of legal personhood as Te Awa Tupua, an indivisible and living whole incorporating its tributaries and all its physical and metaphysical elements from the mountains to the sea (Ruruku Whakatupua 2014).

Te Awa Tupua is further defined by **Tupua te Kawa**, a set of four intrinsic values:

- **Ko Te Kawa Tuatahi**

  Ko te Awa te mātāpuna o te ora (The River is the source of spiritual and physical sustenance).
  Te Awa Tupua is a spiritual and physical entity that supports and sustains both the life and natural resources within the Whanganui River and the health and well-being of the iwi, hapū and other communities of the River.

- **Ko Te Kawa Tuarua**

  E rere kau mai te Awa nui mai i te Kahui Maunga ki Tangaroa (The great River flows from the mountains to the sea)
  Te Awa Tupua is an indivisible and living whole from the mountains to the sea, incorporating the Whanganui River and all of its physical and metaphysical elements.

- **Ko Te Kawa Tuatoru**

  Ko au te Awa, ko te Awa ko au (I am the River and the River is me)
  The iwi and hapū of the Whanganui River have an inalienable interconnection with, and responsibility to, Te Awa Tupua and its health and well-being.

- **Ko Te Kawa Tuawhā**

  Ngā manga iti, ngā manga nui e honohono kau ana, ka tupu hei Awa Tupua (The small and large streams that flow into one another and form one River)
  Te Awa Tupua is a singular entity comprising many elements and communities,

working collaboratively to the common purpose of the health and well-being of Te Awa Tupua (ibid).

The Whanganui River Settlement will change the lens through which all communities and decision-makers view, plan and make decisions in regard to the River.

1.1 Purpose and overall scope of the study

Ngā Tāngata Tiaki o Whanganui (Ngā Tāngata Tiaki) has commissioned a **scoping study on the current health and well-being of Te Awa Tupua**. This is part of the preparatory work required to implement Te Heke Ngahuru ki Te Awa Tupua, the strategy which aims to advance the environmental, social, cultural and economic health and well-being of Te Awa Tupua. The strategy will be developed by Te Kōpuka nā Te Awa Tupua (Te Kōpuka), comprising representatives of persons and groups with interests in the Whanganui. This includes local and central government, environmental groups, commercial and recreational users, as well as iwi.

The overall goal of the scoping study was defined in accordance with Ruruku Whakatupua – Te Mana o Te Awa Tupua (clause 3.35) and is to identify:

- the current state of the health and well-being of Te Awa Tupua;
- the nature and extent of the current interests in and uses of Te Awa Tupua;
- issues affecting the health and well-being of Te Awa Tupua.

This work will help set the vision, guiding principles, and long-term objectives for Te Awa Tupua through the strategy Te Kōpuka.

1.2 Stage One scope and methods

Given the multifaceted and complex nature of the research required to realise the goal of the study, Ngā Tāngata Tiaki has opted to divide the work into discrete phases and work-streams.

Landcare Research - Manaaki Whenua (Manaaki Whenua) has been contracted by Ngā Tāngata Tiaki to complete **Stage One** of the overall study.

The Stage One scope defined by Ngā Tāngata Tiaki comprises the following elements:

- A **literature review and gap analysis** focused primarily on the **biophysical environment**, including customary and commercial activities, of Te Awa Tupua
- A **snapshot** of the current health and well-being of Te Awa Tupua, using information in the literature review
- Identification of the **key issues** affecting the health and well-being of Te Awa Tupua, using information in the literature review

- **Recommendations** on potential areas of focus and future work to address the key issues.

This scoping study is a desktop exercise, utilizing the considerable resources and databases that Manaaki Whenua has at its disposal. Each topic is written by a specialist in the field. We draw on data from third parties as available, in particular from the Department of Conservation, Horizons Regional Council, and Genesis Energy and through co-authors from the Cawthron Institute. Much of the published literature is not catchment-specific and the expertise of our team will interpret, where possible, accurate local context to our findings. Where there is uncertainty in our findings, or alternative views, these are made clear.

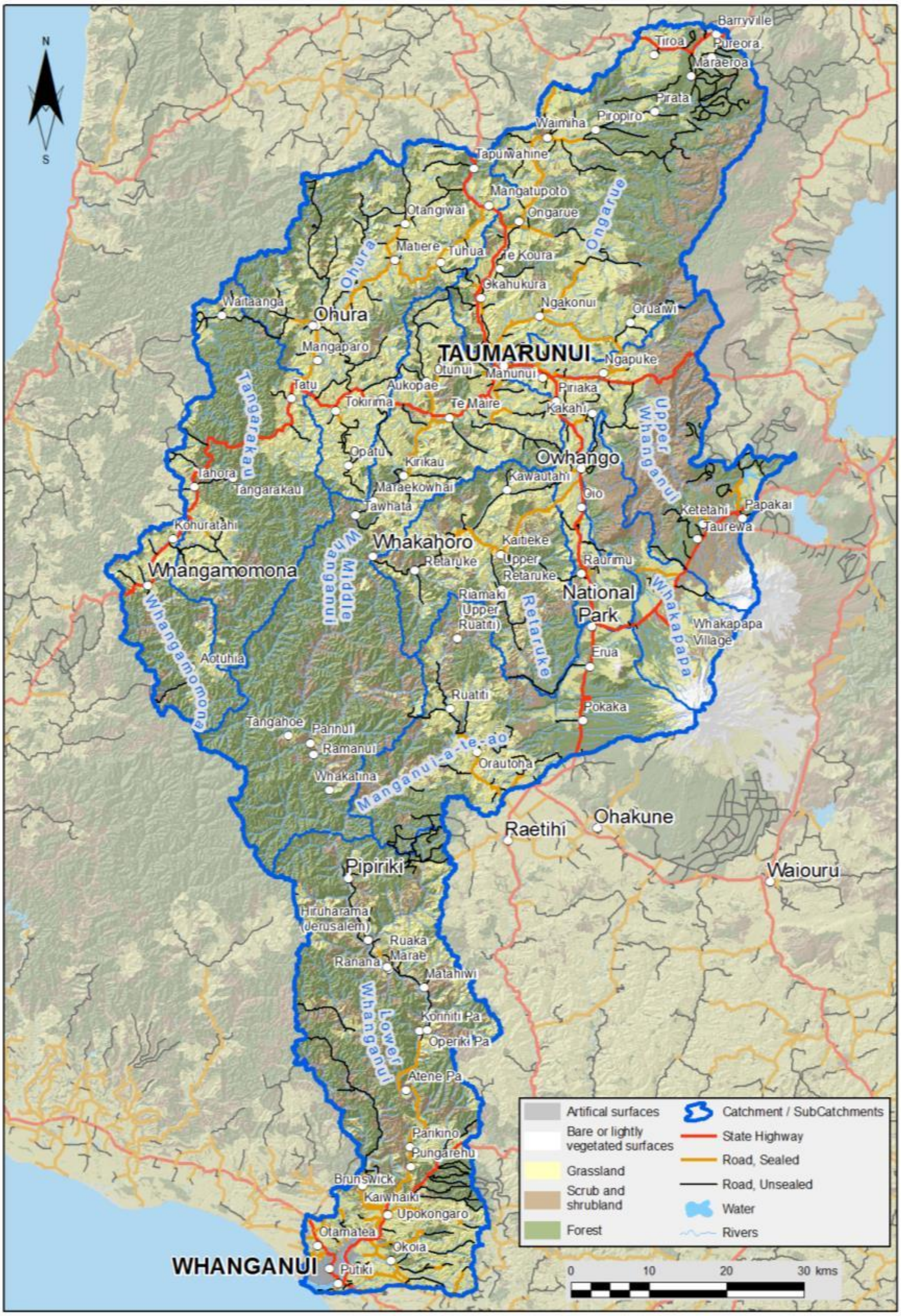

Figure 1: Map showing scope of study: the catchment of the Whanganui River and its major tributaries.

For ease of reference, the current state of scientific knowledge and public information on the various subject areas will be presented in separate chapters. While the report style is 'reductionist' in format, we acknowledge the indivisible spiritual and physical nature of Te Awa Tupua, as defined by Tupua te Kawa.

The report covers the catchment of the Whanganui River and its tributaries (Figure 1). This rugged catchment covers some 7118 square kilometres. The Whanganui River flows north-west from the flanks of Mount Tongariro, then southwest through Taumarunui, before winding its way south 290 kilometres to the Tasman Sea. For much of its length the River cuts through a deep, steep-walled gorge. Most of the area was covered in dense forest (much now regenerated secondary growth), except for the tussock grasslands of the high country, and the river flats and coastal dunes of the river mouth.

1.3 The People of the River – Te Āti Haunui-a-Pāpārangi

Tribal oral traditions maintained through the recitation of genealogy, stories, proverbs, sayings, and songs confirm the origins of the Whanganui River and its people. Kōrero from this mātauranga is carefully laid out in section two of Ruruku Whakatupua –Te Mana o te Iwi o Whanganui (2014), and shows the common links of Whanganui hapū in two principle ancestors, Ruatipua and Paerangi.

Ruatipua was an ancestor of Haunui-a-Pāpārangi, who gave his name to Te Āti Haunui-a-Pāpārangi, a collective name for the peoples of the whole district. Through his descendent Tamakehu, husband of Ruakā, Ruatipua was also an ancestor of Ruakā's descendents, the siblings Hinengākau, Tamaūpoko and Tūpoho – kaitiaki ancestors for the Whanganui River.

The many Whanganui hapū regularly function as separate, independent entities. Names and groupings are dynamic according to circumstance and tikanga. Hapū affiliations can shift over time, growing, dividing, or becoming absorbed into their parent iwi. They sometimes organise themselves regionally according to the respective kaitiaki of the River – Hinengākau (upper reaches), and her brothers Tamaūpoko (middle reaches) and Tūpoho (lower part). Many groups of the northern cluster are defined by themselves or others as Ngāti Maniapoto, as Ngāti Tūwharetoa, or a combination of these groups and Whanganui River hāpu. The complex ties are created through intermarriages between the various lines of descent. Similarly, some Taranaki iwi (such as Ngā Rauru Kiitahi, Ngāti Maru) have land and waters within the catchment and a degree of mana whenua status.

However, the collective identity of Te Āti Haunui-a-Pāpārangi serves a purpose when Whanganui River hapū need to work together to deal with an external force. The concept of iwi and hapū being 'separate but together' is reflected in the phrase Te taura whiri a Hinengākau (the plaited rope of Hinengākau); the River is the thread that binds the people together (Whanganui Land Report 2015).

2 Early life on the Whanganui River

Ngā manga iti, ngā manga nui e honohono kau ana, ka tupu hei Awa Tupua

Formerly, there were dense populations along the River's length: close to 200 kainga on the banks and cliffs along the main River and many more villages along the tributaries. Pā and kainga sites are still the 'homes' of the River people, even though they may no longer live there. The people of early times are the same people today, and the River remains a source of spiritual sustenance even if it no longer provides daily physical needs (Whanganui River Report 1999, 1.3.3).

2.1 Sources of information on traditional cultural values and practices

Among the best contemporary sources on cultural life are the briefs, reports, and documents that formed evidence for the Waitangi Tribunal hearings on the Whanganui River claim (Wai167) and the subsequent Whanganui lands claim (Wai 903). In stating their interests, claimants shared a wealth of traditional knowledge concerning their lands and relationship to the River. Accompanying the evidence of individual kaumātua and hapū were professionally compiled histories also reflecting oral traditions.

The same stories, proverbs, sayings and songs that confirm the origins of Te Awa Tupua and its people contain riches on the environment and cultural life in the pre-contact period. Recent studies, such as those by Wehi (2009) and Wehi et al. (2009, 2013), have looked at the value of oral knowledge and whakataukī (ancestral sayings) as a source of indigenous ecological knowledge to complement documented, archaeological, and palaeoecological evidence. As Wehi et al. (2009) point out, it is not always easy to link oral tradition with current knowledge, and a sound evaluation of the reliability and context of knowledge fragments is crucial. A combination of cultural, linguistic, historical and ecological expertise will work best in interpreting and drawing out the layers of meaning in archival material written in Māori.

For a researcher without te reo Māori and/or the essential tribal links, readily accessible, primary, documented information on early cultural practices on the Whanganui River is relatively limited. Compared with northern New Zealand, there was little European contact with Whanganui hapū before 1840. The region does not have the same wealth of early writings left by Pākehā explorers, missionaries, settlers, and traders keen to record their observations of Māori life and customs.

An important and underutilised source of environmental and cultural information (though not within the reach of this report) is the minutes of the Native Land Court, which operated in the Whanganui district between 1866 and 1900. The Native Land Court worked to convert customary Māori lands into titles held under individual grant from the Crown, and essentially facilitated the alienation of Māori land for settlement purposes. The materials record the evidence of tāngata whenua who presented their claims and counter-claims before the Court, and detail their customary interests in their land. Much evidence was given in Māori, but most of the records that remain are summaries in English. Nonetheless, the records are one of the few sources of cultural information relating to the early and pre-European period and contain valuable insights into early life along the Whanganui River.

Complete copies of the minute books are held by district offices of the Māori Land Court, some large public libraries and tertiary libraries, and can be purchased from Archives New Zealand. There is a databased index to the books available online, but not copies of the pages. The Auckland University Library website has comprehensive information on searching the database (http://magic.lbr.auckland.ac.nz/mlcmbi/guide/comp_guide.htm).

An early Pākehā recorder of river life was the missionary Richard Taylor, who came to the mission at Pukiti in 1843 and lived in Whanganui until his death in 1873. He travelled regularly throughout his mission district, which encompassed the length of the Whanganui River inland to Taupō, the Rangitikei and Whanganui river basins, and the land between the headwaters of the Waitara and Whanganui Rivers. A warm and personable man, fluent in Māori (though not a great linguist), he sought to be a keeper of the peace among Māori tribes and between Māori and settlers. Taylor had wide interests in science and the natural world, and was a prolific writer. His main published work, *Te Ika a Maui*, or *New Zealand and its Inhabitants* (1855), reflects his interest in Māori life, beliefs and customs, geology and natural history. Also of value is Taylor's Leaf from a Natural History of New Zealand, published in 1848, which contains Māori vocabulary for (largely) natural features and resources, including a 'Native pharmacopeia'.

Another important documenter of life on the Whanganui was Thomas Downes, the Whanganui River works supervisor in the 1920s and 1930s. He had a deep interest in everything associated with the Whanganui River, and researched and recorded as much Māori history and traditions as he could from his Māori friends, fearing it might otherwise be lost. He contributed articles to the *Transactions of the New Zealand Institute* and the *Journal of the Polynesian Society* as well as writing the books *Old Whanganui* (1915) and *A History and Guide to the Wanganui River* (1921).

The work of ethnographer Elsdon Best recorded in bulletins such as *Māori Agriculture* (1925), *Forest Lore of the Māori* (1942), *Fishing Methods and Devices of the Māori* (1929) is invaluable. He collected a great deal of information from many sources (not just Tūhoe); while some interpretations may be open to question in the light of modern research, Best's work still stands as the source of much of what is known on early Māori life. More recently, David Young (1998) researched Māori and European history of Te Awa Tupua, which included interviews with kaumātua and kuia of the catchment.

Te Rangi Hiroa, an authority on Māori material culture, used information from Whanganui in his detailed writings on Māori clothing, plaited basketry and woven domestic articles, and the craft of netting. The missionary William Colenso (1868, 1880) recorded much of relevance to Whanganui in his accounts of economic botany in the North Island.

For information on traditional uses of plants and fungi, the Manaaki Whenua database (http://Māoriplantuse.landcareresearch.co.nz/) is a ready source of detailed, documented material.

2.2 Customary activities on the Whanganui River

The Whanganui River and major tributaries were prized for their food resources and as highways through the landscape, for moving people and goods. The forests and fertile terraces and landings that bordered the great River were equally valuable for food and the material resources needed for subsistence living.

The river's limited fall (70 metres over its last 170 kilometres) made the river a highway and made it possible to have a more intimate relationship with this river than virtually all others (Young 1998).

Underlying and sustaining those material benefits was – and is – the deep spiritual relationship of the people of the Whanganui River to their whole physical environment.

E rere kau mai te Awa nui
Mai i te Kāhui Maunga ki Tangaroa
Ko au te Awa, ko te Awa ko au

The Great River flows
From the Mountains to the Sea
I am the River and the River is me

2.3 Whanganui River fisheries

Whanganui iwi built up a profound knowledge of native fish species, their habitats and lifecycles and developed specialised ways to catch them.

2.3.1 Tuna (longfin eel *Anguilla dieffenbachii*, shortfin eel *Anguilla australis*)

Undoubtedly, the most important fish resource was tuna (eel). Tuna were abundant, easily caught, and nutritious, providing high quality protein, vitamins A and D, and essential fats and oils (Shorland & Russell 1948). Scientists have identified two species of native eel inhabiting the Whanganui waterways, the longfin and shortfin (See Section 5.5.3) As an indicator of extensive tribal knowledge of eels and their habits, over one hundred Māori names for tuna are recorded, used to distinguish different appearances, size, taste, habitats and life-cycle phases (Downes 1918). Both Downes and Elsdon Best (1929) record many Whanganui names for tuna, which are replicated in Appendix 4.

Downes (1918) wrote a detailed, illustrated account on tuna varieties and fishing techniques, including the construction of pā-tuna (eel weirs). The latter were a feature of the Whanganui River before most were destroyed in channel clearing operations to allow steamer traffic to navigate upstream. It was estimated that before about 1890, there were some 350 eel-weirs on the Whanganui River (Whanganui River Report 1999). Only a few weirs survived into the 20th century. Young (1998) reports that in the 1940s there were two piharau weirs (for catching lamprey, described below) and some eel weirs at Pipiriki, one piharau and two eel weirs at Hiruhārama, two piharau at Tawhitinui, two weirs at Ranana, two at Matahiwi, and a large one at Parikino as well as some at Koroniti.

Pā-tuna were substantial and sophisticated structures (Fig. 2), requiring great skill, time, and effort to build. They were used in the autumn to harvest large quantities of tunaheke (migrating tuna) which move down waterways in intermittent runs triggered by heavy rains which flood the river and discolour the water (called a freshet, or fresh). Throughout New Zealand there were various styles of weir to accommodate differences in water depth and flow. Commonly, fences of the pā-tuna were built out from both river-banks in a 'V' shape, with the narrow gap channelling migrating tuna into an attached pōhā, (a funnel-shaped guiding net), and then into a hīnaki (fish-trap).

On the Whanganui River, a type called pā auroa was built in the middle of swiftly flowing rapids, comprising two or three fences constructed nearly parallel to the current rather than across it. This was to accommodate fluctuating and often heavy water flows and to prevent driftwood from building up and damaging the weir (Best 1929). The fence served to steer the eels into the hīnaki set at the downstream end. Great skill was required to empty the heavy hīnaki from canoes attached to the weir. Doig (1996) considers a well-maintained weir lasted for generations, withstanding major floods. Smaller and simpler versions of pā-tuna could be quickly built on side-streams to take advantage of the annual tuna migration.

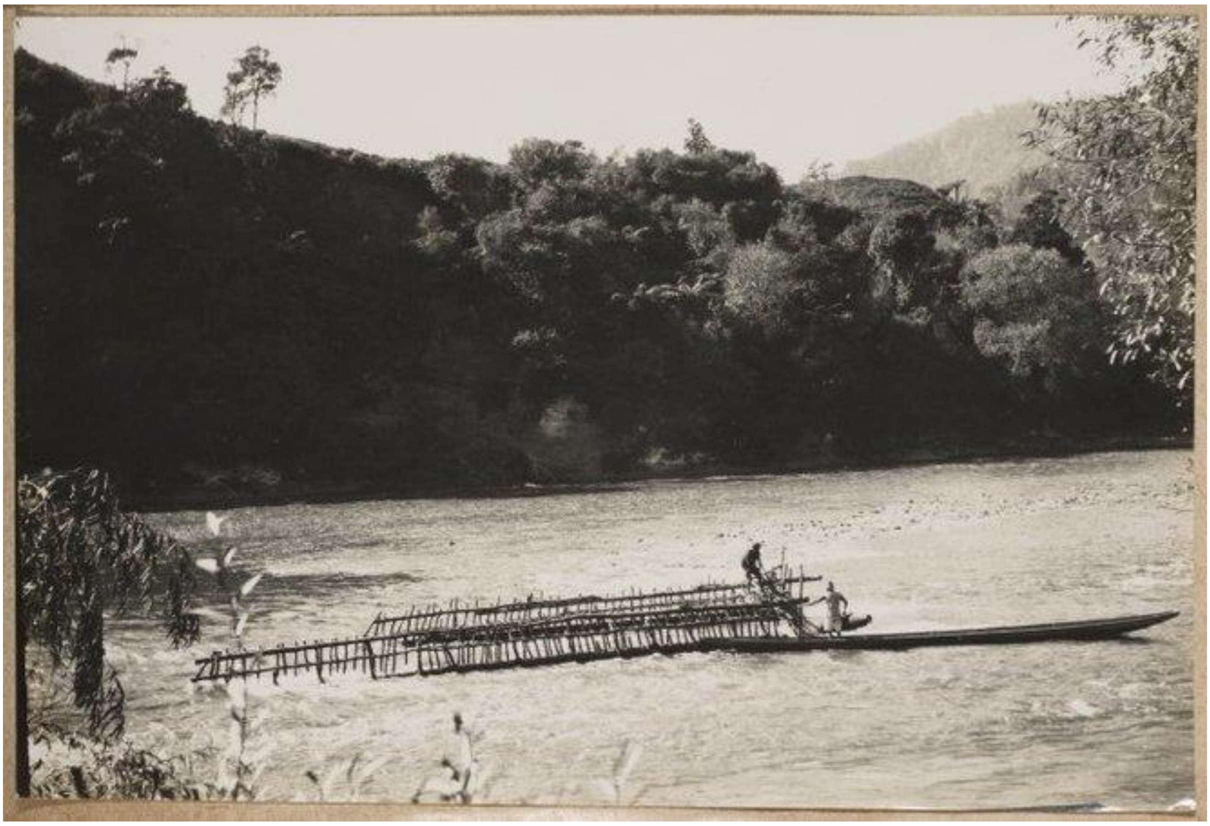

Figure 2: Lamprey and eel weir, Whanganui River (Photo: JI McDonald 1865–1935. Ref: PA1-q-257-76-3. Alexander Turnbull Library, Wellington, New Zealand (http://natlib.govt.nz/records/23109775)).

Tall, straight kōpuka (kānuka, *Kunzea* spp.) saplings were the preferred fencing material. Mānuka (*Leptospermum scoparium*) was used if kōpuka saplings were not procurable. The stakes were sharpened and lashed to horizontal tōtara (*Podocarpus totara*) logs with split kareao (supplejack, *Ripogonum scandens*) vines. Mānuka brush and bundles of bracken stalks (*Pteridium excelsum*) were lashed to the stakes to form a barrier. Downes (1918, p. 308) noted that bracken was used for the parts under water because it lasted much longer when wet. Mānuka was used above the usual water-line, as it is stronger and was more easily replaced. Heavy posts driven in downstream of the weir fence held the pōhā (Fig. 3). The opening ring of the pōhā was made of twisted akatea vines (*Metrosideros* spp.), with the net itself made of strips of harakeke leaf (flax, *Phormium tenax*). In rising water or flood, the pōhā might only last a night or two if torn apart by the strong current and bits of driftwood (Downes 1918, p. 310).

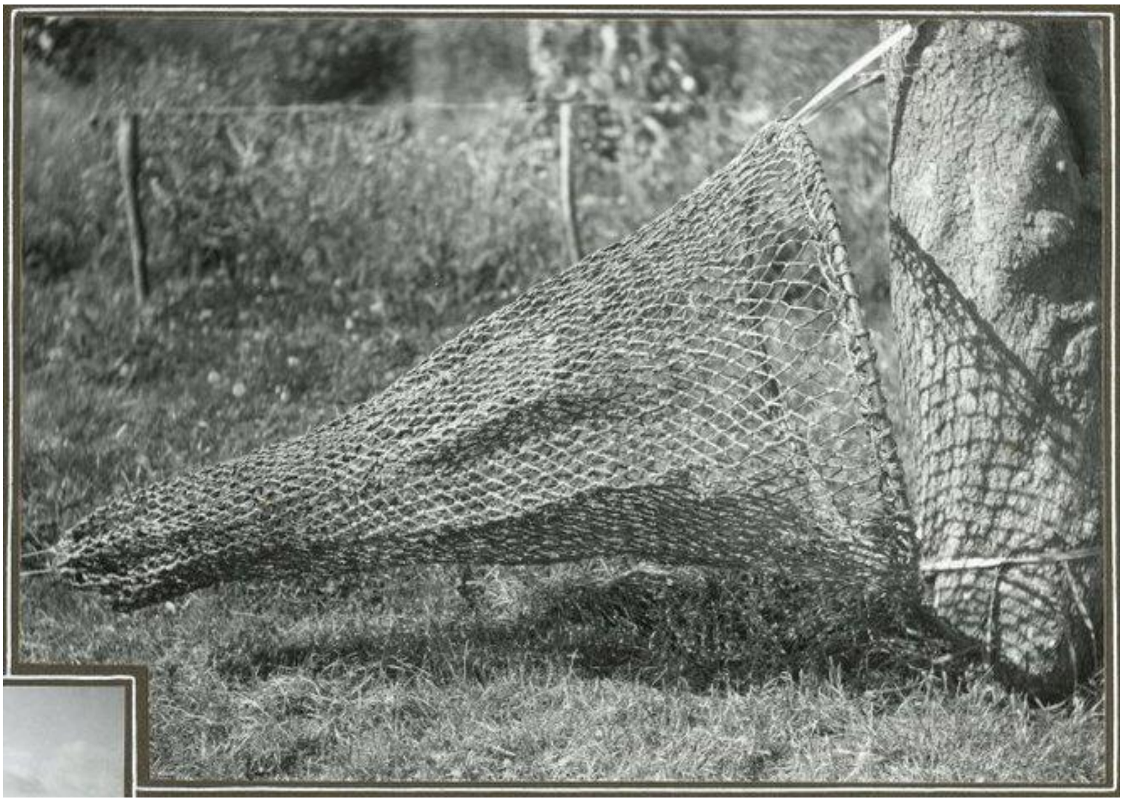

Figure 3: Pōhā, leading net for use with a hinaki, made by Arapata te Hiwi of Ngāti Tukorehe hapū (Photo: GL Adkin 1888–1964. Ref: PA1-f-005-422. Alexander Turnbull Library, Wellington, New Zealand (http://natlib.govt.nz/records/23139477)).

The barrel-shaped trap or hīnaki (Fig. 4) was attached to the small opening of the pōhā. In Whanganui, hīnaki were commonly constructed from the aerial roots of kiekie (*Freycinetia banksii*), as it was the easiest resource to acquire (see Te Rangi Hiroa 1926, p. 29). The roots were steeped in water till pliable, and were light, strong and flexible; however, such hīnaki only lasted 5–7 years (Downes 1918, p. 314). Akatea vines and aka tororaro (*Passiflora tetrandra*) were preferred for their strength and lasting qualities. Pohue vines (*Calystegia* spp.) were also used, and then called aka kōrewa. Downes's paper has illustrations of the different patterns and styles of hīnaki. In northern New Zealand, the preferred construction material was mangemange (*Lygodium articulatum*) (Marshall 1987). While this plant is not present in the Whanganui catchment, it may have been a trade item, since hīnaki made from mangemange could last a lifetime if well cared for (Best 1929).

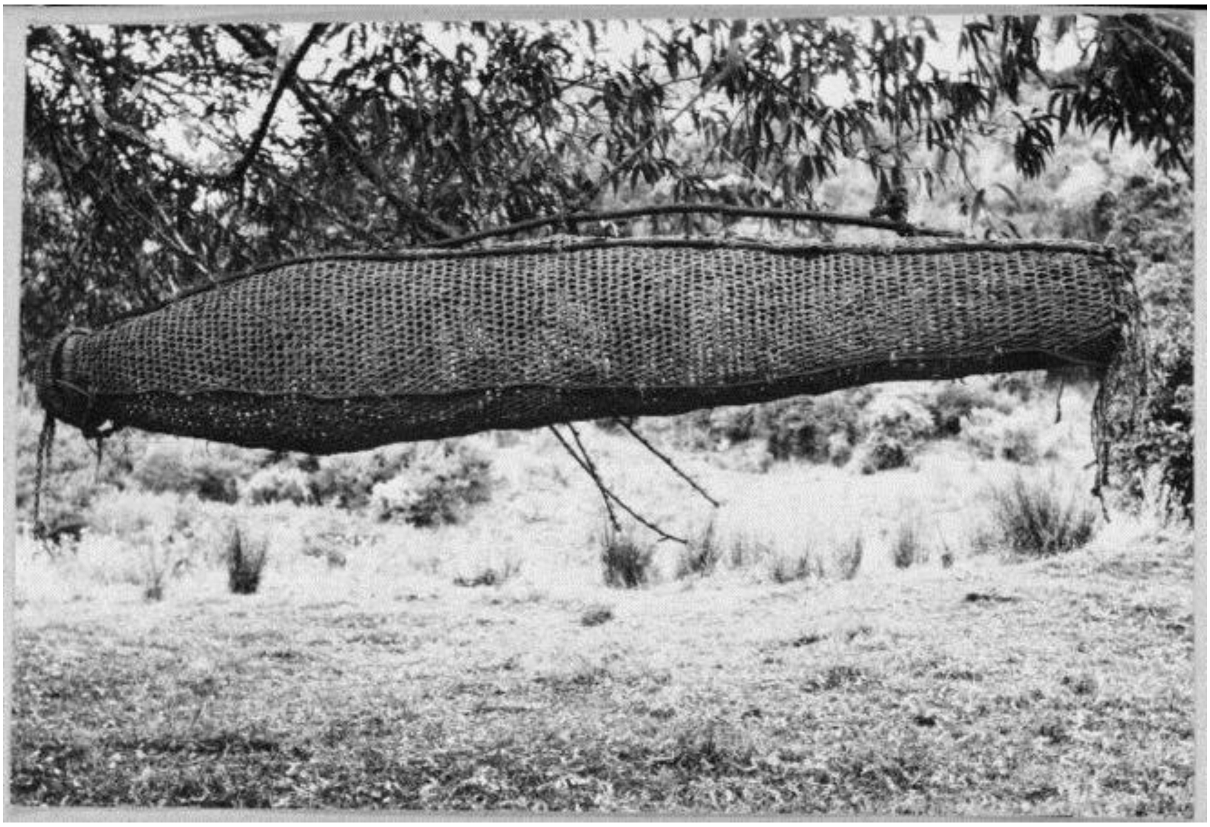

Figure 4: Hīnaki, Whanganui River area (Photo: JI McDonald 1865–1935. Ref: PA1-q-257-72-2. Alexander Turnbull Library, Wellington, New Zealand (http://natlib.govt.nz/records/22712184)).

Pā-tuna could also capture tuna heading upstream, with the log and stakes producing a backwater of which the tuna would take advantage. At the top of the pā-tuna, a sloping, rounded log, carefully smoothed, turns the tuna so that the current carries them back into the pōhā.

The pou used to attach the pōhā in a pā-tuna are a key element of the structure, both functionally and as objects of ritual importance, offering support and sustenance (Marshall 1987). Sometimes the pou was carved into the form of a human head (Downes 1918, p. 308; Best 1929, p. 136). The larger or more important eel-weirs had special names, distinct from the names of the places where they were situated (Best 1929, p. 140). Also important was the depositing of the mauri, usually a stone, to protect the weir and ensure fishing success. Best says it was often placed underwater at the base of the right-hand pou, but goes on to say that Whanganui iwi concealed the mauri away from the weir (Best 1929, p. 148).

A hīnaki could also be set on its own to catch tuna. Bobbing is another method, used year-round, to catch non-migrating eels. Bait is attached to a line of harakeke fibre tied to a strong stick of mānuka. In the summer, juvenile eels or elvers, tunariki, were caught as they migrated upstream from the sea. A favourite site was the mouth of the Ohura tributary. Tunariki congregating in a pool at the base of a waterfall were attracted overnight to balls of ferns and brush placed in the pool. The bundles, called koere, were lifted in the morning and the tunariki shaken into kete (Downes 1918, p. 303). Mair (1879) described the tunariki climbing the falls and being knocked into funnel-shaped harakeke kete. Two or three hundredweight (100–150 kg) were frequently caught in one night.

Claimants giving evidence before the Waitangi Tribunal also spoke of using hīnaki, bob-lines, and spears to catch different types of tuna, and Arthur Anderson recalled from his school years collecting droves of tunariki at the Ohura Falls (Waitangi River Report 1999). Downes (1918 p. 305) also mentions channels or eel-cuts at the dune lakes, Kaitoke and Wiritoa. Channels were cut from swamps and lagoons well out onto the sandflats. When swamp waters rose after heavy rain, eels would try to get out along the cuts, and were collected as they struggled on the sand.

Live storage of eels and methods of preservation are well recorded in the ethnographic literature. Preservation techniques usually involved some form of cooking, smoking, and drying. Properly dried fish could be kept for several years, and this technology allowed vast amounts of food to be distributed around the country (Doig 1996). Downes (1918, p. 303) describes large eels being dried in the sun, after their heads were taken off. They were skinned and split open, the bone taken out, and dried on platforms.

Tuna were also stored in corfs (korotete) placed in deep water until they could be dealt with (Fig. 5). When all available baskets were full, surplus tuna were put into holes dug into the clay and covered with fern, where they would keep alive for a day or two (Downes 1918). Mair (1879) describes how captured tunaheke were kept in wicker-baskets for many months and were fed on boiled potatoes. This is questionable as migrating eels do not eat (McDowall 1990), but Mair may have meant non-migratory tuna.

Marshall (1987) suggests that a reappraisal of the many references from different regions in New Zealand to the creation of channels for capturing eels may reveal evidence that some channels were used for storage as well as capture. It is not clear whether this was a practice in the Whanganui district.

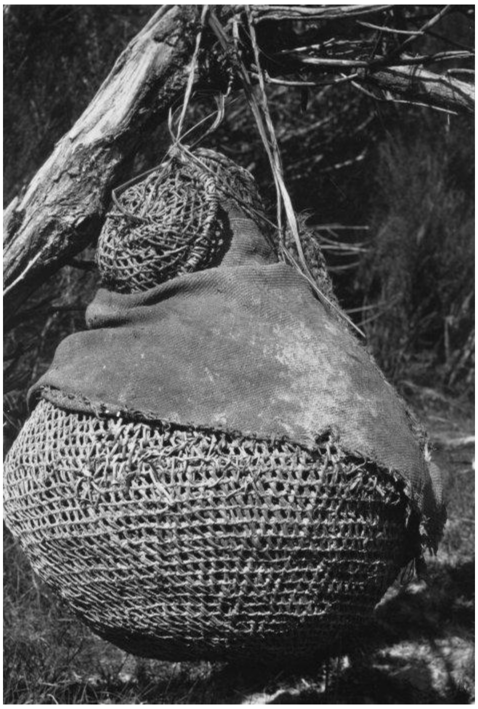

Figure 5: A korotete, wicker fishing pot. (Photo: JI McDonald 1865–1935. Ref: PA1-q-257-71-1. Alexander Turnbull Library, Wellington, New Zealand (**http://natlib.govt.nz/records/23121571)**).

These pots enabled the catch to be stored alive until needed.

Cultural continuity in eel capture

Introduction of European materials, such as wire netting used in hīnaki, rapidly changed the technology of eel capture. Even by the early 20th century, few people knew how to make hīnaki, although harakeke was still used for the pōhā or kupenga. The author has noted a resurgence of interest among weavers in creating traditional hīnaki, though it is probably true that modern netting materials are used by most eel fishers today. However, as Marshall (1987, p. 69) notes, although materials change, the overall form is conservative, and cultural continuity is strongly expressed.

More than food, tuna are kaitiaki, an inherent part of the River's narrative. Stories abound that reveal the potency of the relationship of tuna with Atihaunui (see, for instance, Young 1998, pp. 179–190).

While tuna dominate the Whanganui River fishery, other species are also treasured and were taken in considerable numbers.

2.3.2 Piharau (Lamprey, blind eel, *Geotria australis*)

As well as eel weirs, descriptions of the use of utu piharau (lamprey weirs) overwhelmingly dominated fisheries evidence given to the Native Land Court in the 19th century in Whanganui (Doig 1996).

Piharau (described in Section 5.5.3) were caught in late autumn and winter as they moved upstream to spawn. The weirs, utu piharau, were built perpendicular to the banks as piharau travelled close to shore. Best (1929) watched a 35-foot-long weir being built at Hiruhārama (Jerusalem) in 1921. It was built while the river was low, and well braced to withstand floods. The posts were of kōpuka driven into the stony riverbed using a maul of hard rātā (northern rata, *Metrosideros robusta*) and lashed with kareao (Figure 6). On the upstream side of the utu, a mat of mānuka brush, pinned down with poles, was laid out to prevent scouring of the riverbed.

The construction methods and plant materials used for the funnel net and hīnaki were the same as for eel weirs, but the pihirau hīnaki was smaller. A number of gaps were left in the fences; the force of the water as the piharau tried to pass through washed them back into nets and hīnaki (Doig 1996). Claimants Titapu Henare and Arthur Anderson described the special skills required to build a successful utu, including accurate reading of the river currents, ensuring the ground was solid and flat for the construction, and creating a finely woven funnel that would let the water flow through, but prevent the piharau escaping (Whanganui River Report 1999).

Figure 6: Making a lamprey weir at Hiruhārama, Whanganui River (Photo: JI McDonald 1865–1935. Ref: PAColl-1430-30. Alexander Turnbull Library, Wellington, New Zealand (**http://natlib.govt.nz/records/22912256)**).

Downes (1918) describes a portable mat called a whakarau, comprising bundles of bracken stems. It was laid in the bed of the stream, and the piharau sought shelter in it. The whakarau was then rolled up and taken ashore.

> *In countless millions the piharau are now beginning to ascend the rivers in the Wanganui and Taranaki districts, and the natives have been busy for weeks past placing bunches of fern in the streams. It is here that the piharau rests, clinging to the vegetation with their sucker-like mouths, and they are easily captured in large quantities. Even waterfalls fail to stay the progress of the piharau. At the Ohura Falls, on a tributary of the Wanganui River, the piharau work their way through the wet moss up an almost vertical wall. The natives brush them off with a wisp of fern or nikau leaf, and during the run of the fish the filling of a bucket is quite a simple matter* (Wellington Dominion, 20 May 1927 in Best (1929)).

Fresh piharau were only taken from the lower and middle reaches of the Whanganui River. They are considered unpalatable once they move further upstream (when their heads enlarge and a pouch forms below the eye). Further, bile pigments accumulate in the body of the adult piharau (McDowall 1990) and there are reports of Māori dying from eating large quantities (Taylor 1855, p. 383). They were dried to provide food in the winter.

Utu piharau survived better than pā-tuna because they did not obstruct navigation to the same extent. In 1990 there were six surviving weirs: four at Pipiriki, one at Matahiwi, and one at Upokopoiti (Doig 1996; Whanganui River Report 1999). We were unable to confirm whether these or other weirs exist today.

2.3.3 Other fish species

Various other smaller fishes were also valued, often caught in hīnaki as by-catch or in nets.

Upokororo or Paneroro (grayling, Prototroctes oxyrhynchus)

One of the larger freshwater fish, upokororo were once found in shoals in areas with some forest cover, and were caught in pā auroa (Mair 1879). They were abundant at various (and variable) times of the year. However, even by 1880 they were becoming uncommon, and have been considered extinct since about the 1930s. The causes are not clear, but a major natural post-spawning disease, forest destruction that caused a change in the type of periphyton growing on the stones that formed its food, or predation by trout are possible reasons for its extinction (McDowall 2011).

Ngaore (Smelt, Retropinna retropinna)

Like lamprey, the silvery ngaore also came into the Whanganui River to spawn in spring and summer. The young fish are found in large numbers in the river estuary and can be netted and eaten like whitebait. As adults, the smelt were also caught in channels dug into the riverbed in winter and spring. Norm Hubbard (1979 in Doig 1996) described a modern gravel groyne built at Pipiriki. The stone walls were interlaced with willow branches to minimise escape of the smelt, which were guided into blind channels and removed with muslin nets.

Karohi (whitebait, juvenile Galaxias maculatus) and Atutahi (adult form)

Karohi is the Whanganui name for inanga or whitebait. In the spring, millions of little transparent whitebait make their way from the sea up the River. Once plentiful, their abundance has declined drastically. Like smelt, adults – atutahi - were caught in channels or with nets. Considered a delicacy, both ngaore and karohi were dried for eating in the winter months and on hunting trips:

> *There is a kind of white-bait in most of the rivers in the spring months … The Māories*[sic] *catch them in flax nets, in immense quantities, and cook them in compressed masses in their underground ovens; in this state they resemble a fish-cheese … and are by no means to be despised.*
>
> *The swamps, ponds, and lakes abound with eels and lampreys of various forms and sizes, some of them hideously ugly and snake-like. They are all of them, however, excellent comestibles, particularly when rolled up in Karaka leaves, and cooked in the Māori fashion. Oysters of various kinds and of excellent quality are found on every rock …* (Power 1849, p. 78).

Kanae (grey mullet, Mugil cephalus)

Claimant Te Wera Firmin said that kanae were highly prized for food. He remembered that when he was a boy, large shoals of about 30–40 kanae came up the Whanganui River from the sea in the summer months. They were caught with a net (Whanganui River Report 1999).

Kōkopu, kokopara (banded kōkopu, Galaxias fasciatus; giant kōkopu, Galaxias argenteus)

Phillips (1940, p. 180) regarded banded kōkopu, found from sea level to a great distance inland, as one of the most important fresh water fishes in New Zealand, before the introduction of trout. “It is much eaten yet by Māoris [sic] and I have had accounts of several small preserves near pas kept secret from Europeans”. Best (1929) described kōkopu as of higher value than the grayling, since they were more common. They were taken by kupenga, nets woven from strips of harakeke, or by bobbing, mostly at night.

Toitoi (bullies, Gobiomorphus spp)

Described by Mair as “fair eating but rather full of bones”, these were usually a by-catch of the eel fishery. They seem to have mostly been taken over the winter, when other fish were scarce.

Papanoko (torrent-fish, Cheimarrichthys fosteri)

These small, handsome fish are also known as Te ika hune a Tānemahuta (the hidden fish of Tāne), because they are rarely seen, living among boulders in the swift, white waters of rapids (McDowall 1990). They were caught in hīnaki with tunaheke during flood times. Mair

(1879, p. 315) says that in the summer they are fat, full of spawn, and delicious eating, with few bones. “Great ceremony was observed in cooking them, and they are taken some distance from the village for the purpose”. This was to ensure they would continue to enter the hīnaki.

Patiki, Mohoao (Black flounder, Rhombosolea retiaria)

Flounder were speared or netted on the lower stretches of the river, though black flounder have been known to travel up the Whanganui to Ōhura, about 250 km inland. (Doig 1996)

Kōura (freshwater crayfish, Paranephrops spp)

Kōura added variety to the early diet. They were common in the waterways and coastal dune lakes, preferring pools or slow moving water. They need shelter from predators, and hide in deep water or under banks or boulders. They are now hard to find, although fish surveys between 1980 and 2003 described in evidence at the 2004 hearing for the Tongariro Power Scheme consents suggest koura are still widespread in the catchment (Environment Court 2004 at [243]).

Kākahi (freshwater mussel, Echyridella menziesii)

Kākahi were once abundant and found in slower waters with sandy or silty bottoms, often in shaded areas along river banks (Whanganui River Report 1999). Informants told Hannah Rainforth (2008, p. 11) that kākahi presence was an indication of a good eeling spot. Rainforth noted that kaumātua in the middle reaches of the Whanganui River waited for the return of the sea birds to signal the beginning of the kākahi collection season. This coincided with the warmer times of the year, when the river was low and the birds would come inland to feed on the kākahi.

Claimant Te Wera Firmin maintained they could be taken at any time, and were eaten either fresh or threaded on flax (a string of muka) and hung to dry (Whanganui River report 1999). They added to the winter larder or were eaten when travelling. Of particular interest in Rainforth’s thesis is the outline offered of the whakapapa of kākahi, which provides insight into their habitat needs. Rainforth also details the decline of kākahi populations observed by iwi since the 1950s, their ideas on why this has happened, as well as the conclusions of her own research and possible initiatives to restore kākahi populations.

During the summer months, hapū travelled from places upriver to form temporary kainga on the banks of the river mouth. Rights of northern iwi such as Ngāti Tūwharetoa and Ngāti Hāua to fish there were gained through whakapapa and marriage connections. Tuna, kōura and kōkopu were caught in the dune lakes and kahawai were trolled from the estuary. They were dried and preserved for winter use.

2.3.4 Cultural consequences of fishery decline

Overall, the whole fishery has declined, with species diminished in size and number or gone altogether. The environmental consequences of river changes are covered in the following sections of the report. Noted here are the serious impacts on the integrity and maintenance of Whanganui iwi cultural identity.

Apart from the considerable contribution of tuna and other fish species to a healthy diet, fishing is a significant mechanism for the maintenance and self-definition of culture even among those who may no longer live on associated family lands (Marshall 1987). Working together in a shared activity reaffirms and strengthens the ties between members of a kin group. As Marshall describes, one of the mechanisms by which traditional lifestyles are made operational is in a preference for traditional foods. This does not necessarily mean pre-European. Rather, it is in foods collected versus bought, and the ability to provide sufficient quantities for major social gatherings.

For instance, to eat tunaheke, a person must have access to an eel fishing river, have the appropriate technology to catch them, or know, probably through family relationship, someone who does have such technology. Eeling is a way to continue a relationship with the River. Old rituals are still observed, such as not cooking or eating the eel near the fishing spot. Gifting of eels and other aquatic resources to relations, elders, and the wider community is part of the obligation of those who operate and manage the harvesting places and serves to maintain and strengthen the bonds of whanaungatanga, the broader web of relationships. The concepts of generosity and abundance are inextricably linked – productive eeling sites are so because of the sharing of the catch with the community. Status and respect are accorded in return.

Even though the resource is badly degraded, fishing continues to have an importance and social function beyond the fulfilment of every-day needs. Equally, the intimate spiritual connection between the people who fish and manage the resource and the gods who provide the fish continues to influence and shape perspectives and decisions on restoring the health of Te Awa Tupua.

2.4 Food from the land

Evidence on the role and importance of the fisheries for sustenance and cultural identity dominate accounts of daily life given to the Native Lands Court and to the recent Waitangi Tribunal hearings. Nonetheless, kūmara cultivation, the capture of birds and rats, and gathering forest produce such as fern-root and berries were equally vital components of the Whanganui diet. While it is arguable that tuna played the key dietary and cultural role, the surrounding lands provided bountiful food for the River inhabitants, and the plant resources required to get them. A description of the vegetation patterns and plant species is given in Section 4.

2.4.1 Bird hunting

> *The inhabitants of the villages on the upper part of the river Wanganui are celebrated parrot catchers, and keep great numbers of the tamed birds to be uses as decoys. About the month of June, a great part of the population migrate to the immense forest lying between their river and the more central parts of the island, for the express purpose of catching parrots. Every evening, the birds taken during the day are roasted over fires, and then potted in calabashes in their grease, for they are very fat. Thus preserved, parrots and other birds are considered a delicacy, and are sent as presents to parts of the country, where they are scarce; and in due time a return present of dried fish or something else not to be obtained easily in inland country, is received (Shortland 1856, p. 214).*

Whanganui iwi were renowned birders. Thomas Downes (1928) recorded details on the techniques used from informants Puanaki of Ohura (who lived a traditional lifestyle), Reremai of Pipiriki, formerly of Owairua, Tamatea of Hiruhārama, and Wharawhara and Kauae-o-rangi of Taumarunui. The information below is largely from those notes, unless otherwise stated. Best (1942) also has much information on birding techniques, as does Tamati Ranapiri of Ngati Raukawa (1895).

Kererū (wood pigeon, Hemiphaga novaeseelandiae)

Kererū were taken from mid-May until mid-July when they were at their fattest. They were snared using waka-kererū, pigeon troughs that were set in miro (*Prumnopitys ferruginea*) trees (Fig. 7). All the larger trees had specific names, and the same troughs were used under each tree every year, though removed at the end of the season. The waka-kererū were cut from tōtara and sometimes ornamented with carving. The trapping parties would usually attend their troughs twice a day, to keep them filled with water, remove dead birds, and reset the nooses. Water was carried in gourds, or, occasionally, absorbent moss, kohukohu, as a sponge.

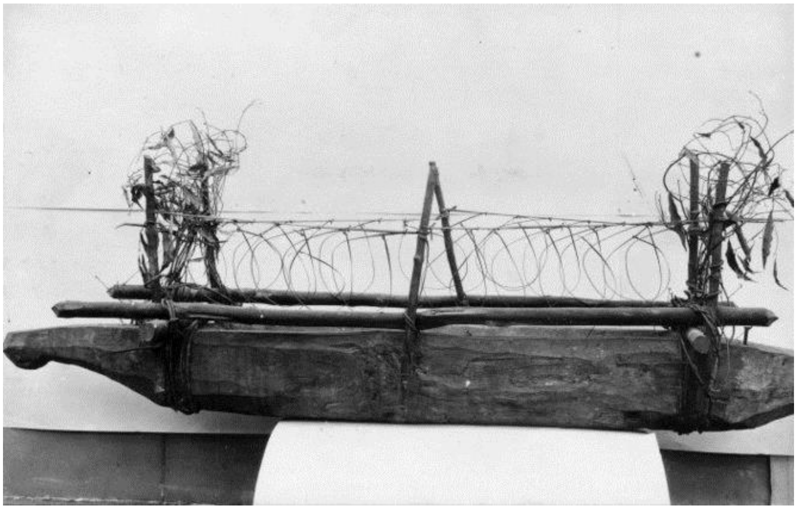

Figure 7: Wooden water trough with snare loops. (Photo: AP Godber 1875–1949. Ref: PAColl-3039-1-001. Alexander Turnbull Library, Wellington, New Zealand. (http://natlib.govt.nz/records/23131581)).

Note that while kohukohu is named by Downes 1928 as *Hypnum clandestimum* (now *Lembophyllum divulsum*), it can be mistaken for *Weymouthia mollis*. *W. mollis* 'forms soft, pale green to fawn veils hanging from branches and twigs in wet forest' (Beever et al. 1992, p. 119). It is a softer moss than Lembophyllum and can be very abundant. [Jessica Beever, pers. com., July 2001].

Puanaki stated that in his youth pigeons were so tame they would sometimes sit and drink from the edge of the trough, while the trappers were setting the nooses. In describing that habit, the missionary Richard Taylor (1855 p. 381) was more forthright: “The kererū … is a very fine bird, but very stupid.”

When trees were hard to climb, teka or temporary ladders were made by securing lengths of karewao round the trunk. These were held in position by perpendicular vines or saplings. But usually a birder would carry a rope made of twisted strands of tī, (cabbage tree, *Cordyline australis*).

Downes (1928, pp. 4–8) details how the troughs were fastened to the boughs and how the nooses were set and worked. The nooses (tari) themselves were made from tī. Downes (1928, p. 6) suggests that tī was stronger than harakeke, but it is likely that the stiffness of the tī leaves was the more pertinent feature. The strips (kotaha) were stiff enough to stand at the required angle, and held their shape in any set position. The kotaha were not plaited, but worked a little between thumb and fingers to separate the fibres. Sometimes the strips were smoked over a fire of kahikatea (*Dacrycarpus dacrydioides*) to give a weathered appearance. The caught pigeons were tied together in bundles with akatea vines and hung to cool two metres above the ground, to prevent depredation by rats.

There were many recognized camps in the upper Whanganui used only during the bird-catching season. Here the appropriate karakia were said each day before the trappers went out. They did not eat all day until they returned at night. At camp, the birds were plucked and the bones and entrails were removed through a small hole made below the wing. These were the only parts of the kererū permitted to be eaten in the camps. The plucked birds were again tied in bundles and covered with the leaves of rangiora (*Brachyglottis repanda*). Ponga fronds (*Cyathea dealbata*) were fastened to the bundles that were then suspended from a tree branch. They would keep for a month or more without attracting flies or developing a strong smell, until they could be cooked and preserved. The feathers were burned, apart from a few fine tail feathers kept to decorate the preserving vessels. Māori believed the sight of the feathers would cause birds to desert the forest.

Kererū were sometimes taken with long spears of tawa (*Beilschmiedia tawa*) or black maire (*Nestegis cunninghamii*), though this practice was damaging to the body of the bird.

Downes (1918, p. 10) records an interesting custom of travelling parties when cooking kererū on the march. Small stones were heated and forced into the pigeon’s body, which was plugged then with the bird’s own head. The body was wrapped in pikopiko (hen and chicken fern, *Asplenium bulbiferum* or shield fern*, Polystichum* sp.) and cooked in 3–4 hours, on the backs of carriers.

Birds were preserved in patua, vessels made from the inner bark of young tōtara. Downes said (1918, p. 10) that if tōtara was unobtainable, hīnau (*Elaeocarpus dentatus*) bark was used, although the bark was too thick to bend well. The bark section was removed from the sunny (northern) side because it came off more easily and was more flexible than bark on the shady side. It was taken off in winter. Downes describes and illustrates the process of removing the bark and then forming the patua by bruising the bark across the fibre where the bends were to start. The ends were made pliable by being placed in a fire. A pin of mānuka or kānuka was used to secure the folds, and a length of twisted vine passed round the lug.

The length of patua varied according to use: large ones for kererū were often about one metre in size. About 80–100 birds could usually be preserved in an ordinary-sized patua. All large patua made for presentation were given special names.

Cooking took place at night time. In one method, raureka (*Coprosma grandifolia*) was used to surround the patua. It was covered with a mat, then earth, and left for 24 hours. A quicker method was using an ordinary hangi, with the stones covered with korokio (probably *Veronica (Hebe) stricta*), and the patua used as the cooking vessel covered with strips of totara bark to catch the steam. Once cooked, birds were repacked while hot into the patua huahua, or the surplus placed in gourds for storage.

A bunch of tail feathers were fixed to each end of the patua, as ornament and to show which species the patua contained – whether tūī, kākā, kererū or korimako. They were split, tied to a little mānuka stick forced into the lug, and tied on with split kiekie root. A handle of mānuka, grooved on the underside to carry the lashings, was inserted under the folds of the lug.

Downes (1928, p. 16) records stories of the value of gourds. Although the fruit was eaten when young, in the absence of pottery the primary use was as containers. Of interest, he says that cultivation of gourds was a thing of the past in the Whanganui district (1920s), and he personally tried to reintroduce gourds up-river. He describes the process of preparing a gourd for storing birds; the gourds were relatively fragile and were enclosed in netting or a piece of closely woven harakeke. The stopper of the calabash was made from a piece of the ‘excrescence’ growing on high-altitude beech trees. This is known usually as punga or puku (Best 1942) and is a woody bracket fungus, also used as tinder in lighting fires.

Other birds – kākā, tūī, weka, kiwi, kākāpō, moa

Both kākā and tūī were taken by means of tame birds (mokai). The latter were preferably taken from their nests when young and hand-reared. However, to catch birds in the forest, the first birds were brought down and captured by imitating their calls on a leaf of the angiangi tree (probably *Coprosma* spp.)

The tame kākā was held by a small ring (often made of human bone) on one leg, attached with a muka (harakeke fibre) cord. The procedure for attracting and taking kākā was much the same as in other districts, with the fowler concealing himself in a shelter and using a variety of snaring methods (see Downes 1918, pp. 22–26; Best 1942, pp. 192–216). The snares were always set under a rātā tree, the favoured roost of the kākā.

There is little detail on the taking of tūī in Downes's paper, although they were esteemed eating, even preferred to kererū. He says they were usually taken on the poroporo (*Solanum* spp.) There is a substantial section in Best (1942, pp. 219–317). This includes information on the practice of keeping tūī as pets since they were easily trained to talk.

The kiwi was also taken, using a trained kuri (Best 1942, pp, 168–170). Feathers were (and are) valued for cloak-making. Weka were captured with noose snares set in their tracks. Kākāpō had started to disappear from most parts of the North Island before the arrival of Europeans, although Mair stated that they were still to be found at the head of the Whanganui River in 1894 (in Best 1942, p. 172).

Downes also describes the snaring of pihipihi, tiny birds that, dspite their lack of size, were esteemed a great delicacy. These are silvereyes (*Zosterops lateralis*), which self-introduced from Australia in 1856.

The four North Island species of moa (the widespread little bush moa, Mantell's moa, the stout-legged moa, and the North Island giant moa) would have been a significant part of early diet. All moa had been hunted to extinction within about 200 years of the first Polynesians arriving in New Zealand. Moa chicks may have also been eaten by kuri. (http://nzbirdsonline.org.nz/; Allentoft et al. 2014).

2.4.2 Kiore (*Rattus exulans*)

Best (1942, pp. 353–387) devotes a large section to describing kiore, the beliefs and rituals that surrounded them, and the ways in which they were captured (snares and pits), cooked and preserved. The Whanganui name was given as kiore tawai, or kiore kai tawai, suggesting they frequented the beech forests and ate the beech-mast. The period when the mast was available was the most important period of the ratting season. Downes (in Best 1942, p. 384) describes a method of cooking kiore particular to Whanganui. A small pit was used, lined with the plucked hairs of the rats, which were then closely packed in layers in the hole. The kiore were covered with leaves, then a layer of earth, on top of which a fire was lit and kept burning for two nights. The heat melted the fat of the top layer of rats, which trickled down and cooked the other layers. The rats were then preserved in vessels.

2.4.3 Food plants

Good plant food needs to provide more energy than is required to harvest it. Enough food also needs to be gathered and preserved for winter months and lean times. Whanganui iwi were able to utilise the fruits of various trees, the rhizomes of bracken, and importantly, the climate allowed the cultivation of kūmara and taro on the lower reaches of the river.

Aruhe (fern root, Pteridium esculentum)

There are many references in the literature to aruhe; see http://Māoriplantuse.landcareresearch.co.nz/. Best (1942, pp. 70–86) has a detailed section on fern root, from various sources. For a contemporary review, see McGlone et al. (2005).

Fern-root was a staple food supply throughout the district. There are copious names to describe the rhizome of the bracken, generally as descriptors of the quality. The best kinds were thick (about 2.5 cm in diameter) and had a greater portion of the meal or flour to the fibres that ran through the root (Fig. 8). After digging, the roots were cut into lengths and stacked to dry. Before being eaten they are soaked in water, then roasted and pounded, to free the meal from the fibres. The roots can be chewed and the fibres spat out, or the meal formed into cakes. The roots (and bracken shoots) are now known to be carcinogenic, but roasting the roots removes the carcinogen (Hirono et al. 1973).

The best kinds of fern root are grown in deep, friable, fertile soil, similar to that suitable for kūmara. Good fern root areas were made by setting fire to an area and destroying competing vegetation. Firing was done in November or December when the hīnau (*Eleaocarpus dentatus*) or tawiri (*Ixerba brexioides*) were in bloom. Bracken also took over areas that were left fallow after kumara cropping had exhausted the soil (Davidson 1984, p. 128)

Figure 8: Aruhe or fern root (***Pteridium esculentum***) showing meal between the inner fibres (Photo: Sue Scheele).

For Whanganui hapū who travelled through the ngahere and up and down the river for seasonal activities, dried aruhe was an ideal food. It was light and would keep for many months.

Three tree fruits were of particular food value:

Karaka (Corynocarpus laevigatus)

Of the fruits of the ngahere, karaka kernels provided one of the best sources of carbohydrate (Fig. 9). The orange flesh surrounding the seed tastes somewhat like dates when ripe, but it is the kernels that are truly nutritious. McCurdy (1947, quoted in Bell 1974) determined that the food value was similar to oatmeal. In their raw state, the kernels are highly toxic and require long soaking and cooking to become edible. Once processed however, the kernels can be dried and will keep a long time.

While regarded by botanists as indigenous to the upper half of the North Island, the karaka was cultivated by Māori and widely distributed (see, for example, Colenso 1868; Beattie 1994; and evidence from the Native Land Courts Minutes recorded in Leach and Stowe 2005). Planted groves of karaka were a noted feature of Whanganui River settlements.

Figure 9: Karaka fruit (Photo: Murray Parsons).

It is possible that these plantations comprised selected forms that produced fruit of a larger size than a karaka growing in a natural location. The author observed very large fruit growing on karaka trees in a grove at Okoki pā, Taranaki, but there is no documented evidence that this is the case for other Whanganui River plantations. Colenso (1880, recorded in Leach & Stowe (2005), was informed by an old tōhunga of a secret way to make a young transplanted karaka bear fruit (given that a karkaka usually takes 10 years). Leach and Stowe state that removing a narrow ring of bark to encourage flowering and fruit-setting is a well-known method for inducing early fruit production. In Stowe's survey of karaka groves, he observed several large karaka trees with bark strips removed vertically up the trunk, which may have had a similar effect. It would be interesting to know if old karaka in extant Whanganui groves bear such scars.

Tawa (Beilschmiedia tawa)

Figure 10: Tawa fruit (Photo: Geoff Walls).

Tawa is the dominant tree species in the Whanganui catchment and produces abundant fruit (Fig. 10). The kernels were boiled, roasted or steamed for 2 days in an umu. They could then be dried and would keep for years, just needing steaming to soften again. The flesh can be eaten but needs to be very ripe to lose a strong turpentine flavour. When tawa kernels were roasted, they would burst with a loud report. Best (1942, p. 42) quotes a saying about chattering children: *Ko te ahi tawa hai whakarite* – they are as noisy as a tawa fire.

An account of the sacred tawa on Mangatiti Stream is given in Young (1998, p. 150).

Hīnau (Elaeaocarpus dentatus)

Figure 11: Hīnau fruit on ground (Photo: Geoff Walls).

The flesh of the hīnau drupe was used rather than the stone. Hīnau produces abundant, olive-like fruit, which drops readily to the ground rather than having to be shaken off or climbed for (Fig. 11).

The fruit was placed in a trough and pounded to dislodge the very hard stone, with the meal then sieved through kete called hītari.

Alternatively, the berries were soaked in water for several months, dried on mats, then sifted to remove the meal in an open-weave basket made from the midribs of tī. The meal was rubbed off, made into cakes and steamed for a day in baskets in an umu. Of note is that harakeke was not used to make the containers because is imparts a bitter taste. Instead tī or kiekie leaves were used. A gruel could be made from the remaining meal attached to the stones, and was regarded as good invalid food. The cakes of hīnau meal were kept in a lined basket placed in a pool of water for a year or two (Best 1942).

2.4.4 Other forest foods

Information on the above and other foods can be found in several sources, notably Best (1942), Colenso (1880), and Taylor (1855), and Crowe (1990) provides an excellent, modern overview.

Small fruit from many trees and shrubs (e.g. kahikatea, rimu, mataī, tōtara, kawakawa, tātarāmoa (*Rubus* spp), wharawhara (*Astelia banksii*)) were also eaten, though they were not a key part of the diet. Leaves of herbaceous species such as pūhā (*Sonchus* spp.), cooked roots such as from taramea (speargrass*, Aciphylla* spp) or rengarenga (*Arthropodium cirratum*), and the tubers of some orchids were all consumed. Other ferns, apart from bracken, provided food. The young, curled shoots of ferns such mouku, (the hen and chicken fern), and pikopiko, (shield fern), were favourite relishes.

Figure 12: Section of cut trunk of mamaku, showing inner pith (Photo: Sue Scheele).

The baked pith of the mamaku (*Cyathea medullaris*) was an excellent food for travellers (Fig. 12), but as a last resort, because the fern takes a long time to mature, and does not regenerate once the trunk is cut. Downes (1921) compares the taste of mamaku to baked apples.

Figure 13: Kiekie bracts and fruit (Photo: Sue Scheele).

A special delicacy was the bracts and fruit of kiekie, pear-like in flavour (Fig. 13): "… they will climb the highest trees and cliffs to secure them" (Downes 1921).

The uppermost leaves of the kiekie were tied over the fruit to protect them from kiore.

Tutu (Coriaria spp)

The highly toxic nature of tutu fruit is well-known. However, juice from the fruit pulp – carefully squeezed and sieved through a very finely woven container, and strained through the flower heads of toetoe (*Austroderia* spp) to remove the poisonous seeds – was a favoured beverage. Aruhe was soaked in the juice.

2.4.5 Horticultural crops

Kūmara (Ipomoea batatas)

The mild, moist climate and sheltered, fertile soil of the river flats suited the cultivation of kūmara, one of the plants brought by Polynesians. There were large kūmara gardens, especially on sloping, sunny land.

In Louise Furey's (2000) study of the archaeological evidence for Māori gardening, she confirms the importance of kūmara as a source of carbohydrate, but equally importantly stresses the role it played in discharging social obligations and exchange transactions with other groups. Reverend Taylor reported that when the Taupō chief, Herekiekie, visited the lower Whanganui River he was presented with 40 kits of dried kūmara and potatoes and that he stored them in a raised platform or whata (Taylor (1855) in Walton 2000, p. 21).

Taylor (1855) reported that artificial soils were needed for growing kūmara, with several inches of sand and gravel being laid on the ground. Because the soil is soon exhausted, only about 3 years cropping were obtained from one spot, then another place was selected. The original site would be left to regenerate into fern or scrub, and cleared and replanted after 7–14 years.

Furey states that the range of gardening sites is poorly represented in the Wanganui region. Borrow pits (sites from which material (commonly sand) has been taken to ameliorate garden soils or (less often) for use in construction) dominate the archaeological evidence of gardening, accounting for 82% of the 78 recorded sites by inference; records of modified sand-added soils should be present in equal numbers, but such sites are not well represented in the records.

Kūmara could not survive cold temperatures and needed to be lifted annually (unlike in Polynesia). Māori developed the technique of storing kūmara in covered pits that often remain in the landscape as evidence of former cultivation sites.

Archaeological sites, some of which will relate to the pits and terraces associated with kūmara cultivation, are recorded on the New Zealand Archaeological Association database which can be viewed online and site details obtained on request http://www.archsite.org.nz/.

Taro (Colocasia esculenta)

Taro was cultivated primarily for the starchy tuber, although the leaves could also be eaten after cooking. Taro has higher moisture requirements than kumara and prefers the alluvial soils of stream banks and swampy areas, as found in the lower part of the Whanganui River. The growing season is 6–7 months long.

Tī tawhiti (Cordyline sp.)

The baked young stems and rhizomes of Cordyline are high in fructose and were a valued source of energy, particularly in southern areas where kūmara could not grow (Fankhauser 1986). Best (1925) states that “The Whanganui natives would appear to have prized the tī as a food-supply – probably this would be the tī kowhiti as they term the tī para. An old saying of that district is: ‘*Ka tu te rua to o te tāngata, ka kiia he tāngata*.’ (A man who has a plentiful supply of this food in his storage-pit is a person of some consequence.)” Downes (1928, p. 17) also refers to a variety called tī tawhiti: “For some reason unknown the cultivation of the gourd is a thing of the past in this district, although taro and ti-tawhiti (*Cordyline* sp.) are still frequently found.”

Tī tawhiti (tī para, tī kowhiti) was a distinctive form of Cordyline, cultivated for food. References and descriptions are found in the early literature (Best 1925; Walsh 1900; Kirk 1873; Potts & Gray 1870), but it was assumed to have disappeared until research by Harris and Heenan (1991) showed that it was almost certainly the ornamental form *Cordyline* “Kirkii” or *Cordyline australis* “Thomas Kirk”, grown by the nursery Duncan and Davies in New Plymouth. The plant grows up to 1.5 m, has dark green leaves, a thick, flexible pulpy stem, (containing a lot of para or meal), and freely suckers, forming multiple, fleshy rhizomes. It has never been known to flower. It is propagated vegetatively.

Early post-European crops

The potato largely came to displace kūmara as a mainstream crop, especially in the South Island and the cooler regions of the central North Island. Taylor (1855, p. 377) said the white potato “may be said to be their staple article of food. It is far more universally cultivated then the kumara, from its taking less labour in planting, and yielding a more certain and larger return” (Fig. 14)

Figure 14: Rīwai, early potato varieties (Photo: Graham Harris).

Maize, pumpkin, and shallots were also cultivated widely after the advent of the European. Maize was quite unlike other plant families that Māori were used to. Like fern root, the cobs were roasted. The second method was to soak the cobs in water for several weeks until they became soft, a technique used for hīnau berries. The fermented grains were then scraped off the cobs and formed into cakes for roasting or steaming (Leach 1984, -p. 101). Kānga wai, fermented corn 'porridge', is still regarded as a delicacy by many, though it is an acquired taste (Yen 1959; Whanganui Land Report 2011, p. 1205).

It must be noted that although we have focussed largely on pre-European customary activities, for most of the 20th century, river communities have still lived by hunting, harvesting, fishing, and gardening. "Traditions continued. Tāngata whenua still harvested kererū – but also hunted pigs, goats, and deer; they trapped eels and whitebait, but fished for trout too" (Whanganui Land Report, p. 1207). The relationship with the environment was still an intimate one. That life has largely disappeared – not least because of Crown control over the gathering of mahinga kai in the scenic reserves and national park.

2.5 Rongoa and spiritual healing

Many plants were used to remedy both physical and mental ailments and there is too much information to present in this chapter. One of the best researched sources of information on what was used, and how, can be found in Murdoch Riley's 500-page tome *Māori Healing and Herbal* (1994). Riley made a thorough study of published literature and manuscripts and compiled sourced evidence on the uses for remedies and rituals of over 200 plants, which are listed under their Māori names. Equally, the database Ngā Tipu Whakaoranga: http://Māoriplantuse.landcareresearch.co.nz/ is easily searchable for information on medicinal (and other) uses of any particular plant.

Apart from individual healing practitioners, there are rongoā clinics, some sponsored by the Ministry of Health, set up to enhance well-being within a Māori cultural context. Te Kāhui Rongoā Trust has been established to promote and protect the practice of rongoā. We suggest consultation with Whanganui healers to find out whether there are issues in accessing and collecting plant resources.

We note too, that as Rob McGowan 2010 (a practitioner and advocate of rongoā Māori who learnt much from Whanganui kaumātua) has pointed out, the basis of traditional Māori medicine is not trees and plants but taha wairua. That is, who we are, how we are connected, and the connection between the mauri of the plant the healer, and the patient for whom the rongoa is destined. Ideally, building that connection means being out in the bush, and getting to know the plants used and their relationship to the rest of the ngahere. In today's world, people have, by and large, lost that intimacy with the bush.

Some claimants discussed the insensitivity of the Crown to traditional healing practices, especially those associated with tohunga. In 1907, the government passed the Tohunga Suppression Act, which is sometimes blamed for the loss of knowledge of rongoā, though there were only ever a few cases brought to Court under the Act, and few succeeded. The decline in knowledge owes more to bush clearance, and people moving away from living off the land and losing their connection to it (Ko Aotearoa Tenei 2011, p. 627).

Of special note is the significance of the Whanganui River itself for spiritual cleansing and healing. Various people gave evidence before the Waitangi Tribunal of the power of the waters to cleanse, purify, and nurture (Waitangi River Report 1999, pp. 71–73). For example, the practices of washing in the River to help cure illness and of baptising children in its waters continue today.

Importantly, people recounted that the spiritual strength of the River stayed with them even after they moved elsewhere to live. This deep sense of belonging affirms how the state of the River is closely bound to the psychological well-being of Atiahaunui. It endorses the ongoing, deep sense of dismay experienced by iwi at the deterioration in the physical health of the River and their lack of control to change these circumstances. Atiahaunui and the taniwha, as kaitaiki, are only too well aware of the consequences of disrespect for the River.

Many lakes were particularly valued for their spiritual healing waters or were associated with wahi tapu. Some significant wetland areas are listed in the Whanganui Land Report (2015, p. 37). Large areas are now destroyed or are not accessible for customary activities

2.6 Other plant resources

2.6.1 Harakeke (*Phormium tenax*)

After food, the most indispensable material was undoubtedly harakeke, *Phormium tenax*. The use of leaf strips and extracted fibre (muka) for clothing, mats, panelling, cordage, and containers – the essentials of daily life – are well known and need not be repeated here. Harakeke was one of the plants that comprised the vegetation cover on the swamps and wetlands of the lower Whanganui River. “Up the Whanganui River it was introduced and cultivated, so that each village had its *pa harakeke*, or flax garden. Even in villages close to flax swamps, flax was grown close to the houses for immediate use. The Māori recognise several varieties with different quality of leaf and different strength of fibre” (Te Rangi Hiroa 1923).

In the late 1860s, the government set up a commission to consider all aspects of flax production, with a view to enhancing the efficiency and productivity of the fledgling pākehā industry. Flax Commissioners travelled through the country, meeting with many Māori communities to discuss their cultivation practices. The Flax Commissioners (1870, D-14, p. 8) stated that “The Rev Mr. Taylor, of Wanganui enumerates ten varieties of flax, several of which are cultivated and used by Natives for their own purposes.”, and Mr Kelly, of New Plymouth, “gives the names of twenty-two supposed varieties in his Province”. Bishop Selwyn (1847) noted that “Flax of the first class is also found in Native plantations on the north shore of Cook Strait, especially in the neighbourhood of Manawatu, Whanganui, and Patea Rivers.”

The nurseryman, W Hulke (Flax Commissioners 1871), grew a selection of cultivars in New Plymouth, some of which were transferred to the Botanic Gardens, Wellington. Some of these varieties are now in the living National New Zealand Flax Collection, on the Manaaki Whenua site at Lincoln. It is impossible now to state whether any of the named varieties we hold are exactly the same genotypes as those referred to in the Commissioner's Report. However, it is likely that some are very similar.

Figure 15: Woman weaving a food basket (rourou or kono) from flax leaves, at Koroniti.
(Photo: JI McDonald 1865-1935. Ref: PA1-q-257-29-2. Alexander Turnbull Library, Wellington, New Zealand (**http://natlib.govt.nz/records/23190751)**).

The harakeke shown in this photo (Fig. 15) are in cultivation and well-tended.

Varieties listed in the Appendix to the Flax Commissioners Report (1871 – G-4, 69), and that were specifically sourced from Whanganui, are: Ate "used for eel nets, and baskets"; Huhiroa "Long fibre. Used for fine and porae mats, fishing lines, nets, ropes, &c."; Koura "best fibre for Korowai, or shaggy mats"; Matoroa" strong and durable; short fibre, used for borders of fine mats"; Parekoritawa "very white, and strong fibre"; Tarariki "fine and soft texture, used for potae, or ornamented mats" (plant features described). Cultivars named Ate, Huhiroa and Parekoritawa are growing in the Collection at Lincoln. The Quaker settlement on Virginia Road, Whanganui, also holds most of the weaving cultivars in the Collection.

Wharariki, *Phormium cookianum*, "was the only original species growing up the Whanganui, where it grew plentifully about the cliffs and steep slopes of the river. On account of its softness and ease of manipulation it was considered by the Wanganui people to be the best material for plaiting purposes" (Te Rangi Hiroa 1923, p. 707). Hiroa notes that Ngati Rauru imported and cultivated wharariki in South Taranaki, where harakeke is plentiful, for plaiting. Wharariki is not suitable for hard-wearing articles, because the fibre is thin and the leaf is not strong enough.

2.6.2 Other plant uses

Plants

The highly esteemed tōtara (*Podocarpus totara*) was common in the upper reaches of the Whanganui River. The wood is hard, straight-grained, and durable. It was the preferred choice for canoes, framing for meeting houses, vessels, posts, and carved works (as it is today).

Seeds of the tītoki (*Alectryon excelsus*) fruit were crushed and squeezed through a koheke (a long, tapering kete woven from muka), to produce a highly prized oil. Fragrant leaves such as raukawa (*Raukaua edgerleyi*), heketara (*Olearia rani*), and mānuka were steeped in the oil which was used on the hair or in scented sachets.

Tī leaves were preferred for use in snares and netting that needed stiffness, strength, and an ability to retain those characteristics when wet. Also essential for constructing fishing and hunting equipment were the various vines such as supplejack, kiekie roots, rātā and kōhia.

Other important plants were raupō (*Typha orientalis)* and the rushes such as toetoe (*Austroderia* spp) used for floor coverings and buildings. The iron-tannic mud called paru, used for dying, is found in kahikatea swamps.

Figure 16: Kete made from paopao (Photo: Sue Scheele).

Spongy paopao or kuta stems (*Eleocharis sphacelata*) were favoured for matting. The soft stems dry to attractive brown shades (Fig. 16).

Once plentiful on the sand-dunes, before the arrival of marram grass and browsing animals, the tough, golden leaves of pīngao (*Ficinia spiralis*) were (and are) valued for colour in tukutuku panels and plaited articles.

2.7 Te Reo Māori

A living culture needs to be expressed in its own language. The Waitangi Land Report 2015: 1159–1163 shows that most Whanganui Māori cannot speak or understand te reo and that there is a dire shortage of fluent kaumātua and kuia.

Nonetheless, higher numbers of young Whanganui Māori than the national average are being educated in te reo. Claimant Che Wilson told the Tribunal that this revitalisation has had the unfortunate side effect of marginalising te reo Whanganui and replacing the local dialect and pronunciation with a standardised form.

During this research, we have come across many instances of specific Whanganui names for the natural world. In the appendices on plant, bird, and fish names, we have endeavoured to provide these, with the disclaimer that they may not be valid. However, it is a starting point for those fluent in te reo Whanganui to check.

2.8 Conclusion

Although the focus of this report is to provide scientific information on the biophysical state of the rohe, we also recognize the complexity of relationships that resonate in the landscape. Stories of the 'life that was' indicate a time when the River and its people truly sustained each other. We trust that the information contained in the following sections, and identification of knowledge gaps, can show a way forward to restoring the full health of Te Awa Tupua.

3 The physical environment

All or parts of the physical environment of the Whanganui catchment have been briefly described in a number of publications, e.g. Edbrooke (2005), Townsend et al. (2008), Leonard et al. (2010), Lee et al. (2011), Fletcher (1987), Department of Conservation (2012), Maunder & Browne (1971), and Thompson (1981, 1984). The key elements determining the characteristics of the Whanganui catchment are briefly discussed below.

3.1 Landforms and geology

Landforms and geology of the northern headwaters, the north-eastern headwaters, and the bulk of the central and southern Whanganui catchment are outlined in Edbrooke (2005), Leonard et al. (2010), Lee et al. (2011), and Townsend et al. (2008) respectively. Fletcher (1987) and Neall (1992) provide an overview in terms of the Taranaki-Manawatu region, while the Department of Conservation (2012) briefly describe the geology, landform, and landscape of the Whanganui National Park. Landform and geology is also briefly described in the Protected Natural Areas Programme reports that cover the bulk of the catchment, Ravine (1996) and Bibby et al. (2000).

Fletcher (1987) recognises 9 broad physiographic units within the Taranaki-Manawatu region. The distinctive landscape features and characteristics of these units reflect the combination of the underlying rock type's relative hardness and permeability, regional uplift rates, rainfall (total, intensity and duration) and erosion susceptibility. Five of these broad physiographic units are represented in the Whanganui catchment and provide a useful breakdown of the terrain to assist in the understanding of the physical environment (Fig. 17).

The Whanganui River originates on the western slopes of Mounts Ruapehu, Ngauruhoe and Tongariro and drains southwards via a sinuous, entrenched course to the coast at Whanganui. Major tributaries include the Ohura, Ongarue, Tangarakau, and Whangamomona Rivers, which drain the central dissected hill country to the north, and the Whakapapa, Retaruke and Manganuioteao Rivers, which drain the volcanic plateau and mountain slopes in the east (see Fig. 1).

Between the Central North Island volcanic plateau and Taranaki Peninsula and south into the northern Whanganui area lies a large expanse of subdued topography, underlain by soft Miocene to Pleistocene sediments of mainly fine-grained sandstone, siltstone, and mudstone.

The **Hill country** unit of Fletcher (1987) is deeply dissected, with narrow ridge crests and mainly moderately steep to steep sloping valley sides, (Figs 18, 19). Streams and rivers are deeply entrenched, have an incised dendritic drainage pattern, and typically have very small and narrow or no floodplains. Interbedded calcareous or volcaniclastic strata tend to be more resistant and locally form prominent dip slopes and steep escarpments. Small areas of rolling land occur particularly in the north of the unit on what is considered to be the remnant of a former peneplain. To the north east this physiographic unit extends into a lower altitude basin in the King Country where the interfluves may be capped with ignimbrite sheets that are now dissected to give escarpments with characteristic flat tops.

Within the hill country of the lower catchment a tilted block held up by thin limestone beds forms the >700-m high, east–west trending Matemateaonga Range, the eastern slopes of which drain to the Whanganui River.

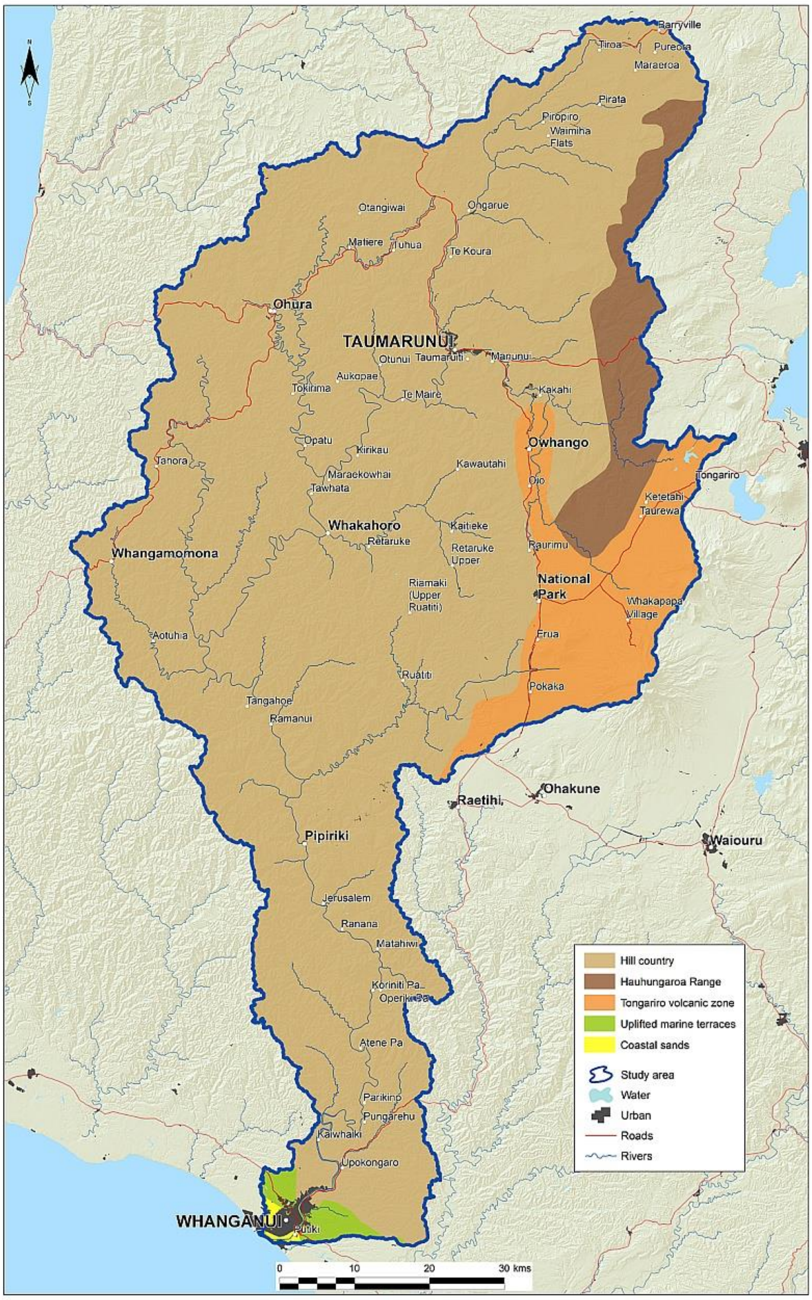

Figure 17: Major physiographic units in the Whanganui Catchment (adapted from Fletcher 1987).

Figure 18: Aerial view looking southeast from above Tangarakau township showing heavily vegetated hill country underlain by soft Miocene lithologies (Photo CN8656/16: D L Homer).

The **Tongariro Volcanic Zone** of Fletcher (1987) comprises the steep western slopes of the andesitic stratovolcanoes of Mounts Ruapehu (2797 m), Ngauruhoe (2291 m), and Tongariro (1968 m), and their rolling to strongly rolling volcanic ring plains consisting of an extensive apron of coalescing fans of laharic, pyroclastic and alluvial volcaniclastic detritus (Palmer & Neall 1989; Lecointre et al. 1998). The major Whanganui River tributaries are deeply entrenched into the ring plain which is also traversed by the active north-south trending Waimarino Fault.

The **Hauhungaroa Range** of Fletcher (1987) forms the north-eastern catchment boundary. It consists of indurated Mesozoic basement greywacke projecting through the western ignimbrite plateau of the central volcanic region, with Tertiary aged sandstones and siltstones in the south. Altitude ranges between 800 and 1100 m above sea level, resulting in a cooler climate than the adjacent hill country. Moderately steep to very steep slopes predominate (e.g. eastern slopes of Tuhua), with some large-scale mass movement features evident on the margins.

The **Uplifted marine terraces** of Fletcher (1987) extend from North Taranaki south along the coast and inland to Marton and Palmerston North. The uplifted marine terraces form a minor landscape component of the Whanganui catchment at the mouth, and in the Rapanui-Brunswick area (Fig. 20). They are part of a well-developed set of Quaternary marine terraces forming step-like benches in the landscape up to 300 m above sea level, and up to 20 km inland from the present-day coastline. They attest to sustained regional uplift of approx. 0.5 mm per year at the coast (Pillans 1990a, b, c). The uplifted marine terraces consist of steep to very steep 'soft rock' former sea cliffs; extensive flat to gently undulating terrace treads often surfaced with remnant fixed and active sand dune and beach complexes; steep to very steep erosional side slopes of incised rivers, streams, and gullies; and minor valley floor terraces and floodplains. In the Whanganui catchment, elevations range from 0 to 120 m above sea level.

The **Coastal sands** physiographic unit of Fletcher (1987) comprises a complex of sand dunes, sand plains, and swamps that extend from near Hawera to the Manawatu River, and is most extensive south of Whanganui (extending 19 km inland) where the coast is actively prograding. The coastal sands form a very minor landscape component of the Whanganui catchment fringing the river mouth. Significant areas of the coastal sands unit form part of the Gonville and Springvale suburbs of urban Whanganui (Fig. 20).

Figure 19: Fluvially dissected hills of the King Country near Ohura with characteristic narrow ridges and steep valley sides formed on gently dipping to sub horizontal Miocene sedimentary rocks. To the southeast are the central North Island volcanoes (from left to right) Tongariro, Ngauruhoe, and Ruapehu (Photo CN8657/16. DL Homer).

Figure 20: The Whanganui River reaches the coast at Whanganui. The brown colour of the river indicates a high sediment load, produced by erosion of the soft Miocene and Pliocene sedimentary rocks that dominate the catchment. The uplifted Quaternary marine terraces are clearly visible in the fore and middle background, fringed by a coastal sand dune belt to the north and south of the river mouth (Photo CN37146/24. DL Homer).

3.2 Lithology and rock types

The Whanganui catchment is dominated by young (<30 million years old) soft Miocene to Pleistocene aged sediments of mainly fine-grained sandstone, siltstone, and mudstone. The age of these sediments decreases progressively downstream towards the coastline at Whanganui. Regional uplift and major lowering of sea levels during the last ice age (between 80,000 and 15,000 years ago) have created a landscape of steep, sharp ridges of fairly uniform height, and the deeply entrenched dendritic drainage pattern that are key characteristics of the region.

The national QMAP series produced by GNS Science updates the earlier 1:250,000 geological maps covering the Whanganui catchment of Hay (1967), Grindley (1960), and Lensen (1959). Since the publication of those earlier maps, new geological concepts such as plate tectonics, terranes and sequence stratigraphy have been developed. These new concepts are incorporated in the QMAP series covering the catchment (Edbrooke 2005; Leonard et al. 2010; Lee et al. 2011; Townsend et al. 2008).

The geology in this region is complex, and the maps have been considerably simplified for presentation at 1:250,000. Rock units have been mapped primarily in terms of their age of deposition or eruption (a time-stratigraphic classification) which only indirectly indicates rock type. A generalised geological legend for the Whanganui catchment is given in Figure 21.

The rocks of the Whanganui catchment can be described in terms of 5 groupings based on age:

1. Paleozoic to early Cretaceous basement rocks
2. Oligocene to early Miocene sedimentary rocks
3. Middle Miocene to Pliocene sedimentary rocks
4. Quaternary sediments
5. Quaternary volcanic rocks and associated sediments

The younger rocks overlying the well indurated basement lithologies contain sequences separated by major unconformities or by discrete periods of basin formation and infilling.

Age		Symbol	Formation or Group		description
	Tongariro	IQh			Undifferentiated late Quaternary lahars
	Volcanic	Q4h	Waimarino Formation		Debris-hyperconcentrated flow and fluvial deposits
	Centre	uQh			Undifferentiated Quaternary lahars
Quaternary	Taupo	Qv1	Taupo Formation		Primary non-welded ignimbrite and minor reworked deposits from 1.8 ka Taupo eruption
	Volcanic	Q3v	Oruanui Formation		Non-welded ignibrite and phreatomagmatic deposits. Includes minor reworked ignimbrite
	Zone	mQw	Whakamanu Group		Variable welded, crystal-rich, ignimbrite, commonly with well-developed vertical jointing
		eQo	Ongatiti Formation		Mangakino Volcanic Centre; compound variably welded, vitrophyric, pumice-and crystal-rich ignimbrite with abundant lithics. [Flanks Hauhungaroa Ra]
			unconformity		
					Wanganui and King Country Sedimentary Basins
Pliocene	late	Pm	Maxwell Group	Rangitikei Supergroup	Sandstone, mudstone, limestone, carbonaceous siltstone & lignite
		Pn	Nukumaru Group		Bioclastic limestone, locally pebbly interbedded with coarse or medium sandstone and fine to medium sandstone (Nukumaru Formation & Nukumaru Brown Sand Formation)
		Pku	Upper Okiwa Group		Sandy bioclastic limestone, medium well sorted sandstone and mudstone and siltstone
		Pkl	Lower Okiwa Group		Bioclastic limestone, fine sandstone and sparsely fossiliferous siltstone
		Pp	Paparangi Group		in west includes pebbly shell beds and sandstone; (including the basal Mangapani Shell Conglomerate member) in east massive locally fossiliferous mudstone (Mangaweka Formation)
	mid	Pw	Whenuakura Group		Bioclastic limestone, pebbly sandstone, fine well sorted micaceous sandstone and massive siltstone
		Pit	Tangahoe Mudstone		Massive to weakly bedded mudstone & well sorted, fine to medium micaceous sandstone, concretionary in the east
	early	Pga	Matemateaonga Formation	Whangamomona Group	Predominantly muddy sandstone, but includes >15 repeated cycles of shell bed, siltstone, sandstone & minor conglomerate; includes the basal Umukiwi Shell bed member
			unconformity		
Miocene	late	Mga	Matemateaonga Formation		Predominantly muddy sandstone, but includes >10 repeated cycles of shell bed, siltstone, sandstone & minor conglomerate
		Mgk	Kiore Formation		Massive to laminated siltstone & sandstone with discontinuous channels filled with sandstone, siltstone, conglomerate & limestone.
		Mgm	Mount Messenger Formation		fine to very fine sandstone, siltstone, mudstone, with local channelised conglomerate
	mid	Mgo	Mangarara & Otunui Formation		Basal sandy to pebbly limestone & massive to weakly bedded fine sandstone & sandy siltstone
	early	Mea	Taumarunui Formation	Maheonui Group	Thin medium bedded sandstone, siltstone, mudstone
		Met	Taumatamaire Formation		massive to weakly bedded calcareous mudstone with basal glauconite and local interbedded limestone
			unconformity		
Oligocene	late	Ot	Te Kuiti Group		Thin coal measures, quartzose, calcareous and/or glauconitic sandstone and thinly bedded bioclastic limestone
			unconformity		
Early Cretaceous - Jurassic				"Torlesse greywacke"	Waipapa (composite) and Kaweka terranes
		Jtk	Kaweka terrane		Massive to poorly bedded, fine to medium sandstone and interbedded thin siltstone and rare conglomerate; some alternating sandstone and siltstone. Sheared locally with common quartz veins. Western contact with Waipapa (composite) terrane locally foliated and/or metamorphosed (Haast Schist)
		Jm	Waipapa (composite) terrane		Manaia Hill Group (Jm) Indurated, massive to weakly bedded, fine to medium volcaniclastic sandstone, interbedded thin siltstone and sandstone, laminated siltstone, and rare conglomerate. Metamorphosed to prehnite-pumpellyite grade and sheared locally with common quartz vein. Eastern contact with Kaweka terrane locally foliated and/or metamorphosed (Haast Schist)

Figure 21: Generalised stratigraphic column for the Whanganui catchment (adapted from Townsend et al. 2008).

3.2.1 Paleozoic to early Cretaceous basement rocks

The exposure of the regional basement rocks in the Whanganui catchment is limited. They outcrop on the north-western slopes of the Hauhungaroa Range and on the hill slopes west of the Whakapapa River, in the Tongariro Forest. The regional basement rocks consist of well-indurated, massive to weakly bedded, fine to medium volcaniclastic sandstone, interbedded thin siltstone and sandstone, laminated siltstone, and rare conglomerate (collectively known as 'greywacke' rocks). These rocks are metamorphosed to prehnite-pumpellyite grade and locally sheared, with common quartz veins.

3.2.2 Oligocene to early Miocene sedimentary rocks

The sedimentary rocks of the Oligocene to early Miocene, the Te Kuiti Group, unconformable overlie the regional basement rocks, and include a total of up to 200 m of laterally discontinuous thin coal measures, bioclastic limestone, and calcareous and glauconitic sandstone. The limestone forms a discontinuous veneer up to 15 m thick, and commonly contains boulders and cobbles of greywacke (Fig. 22).

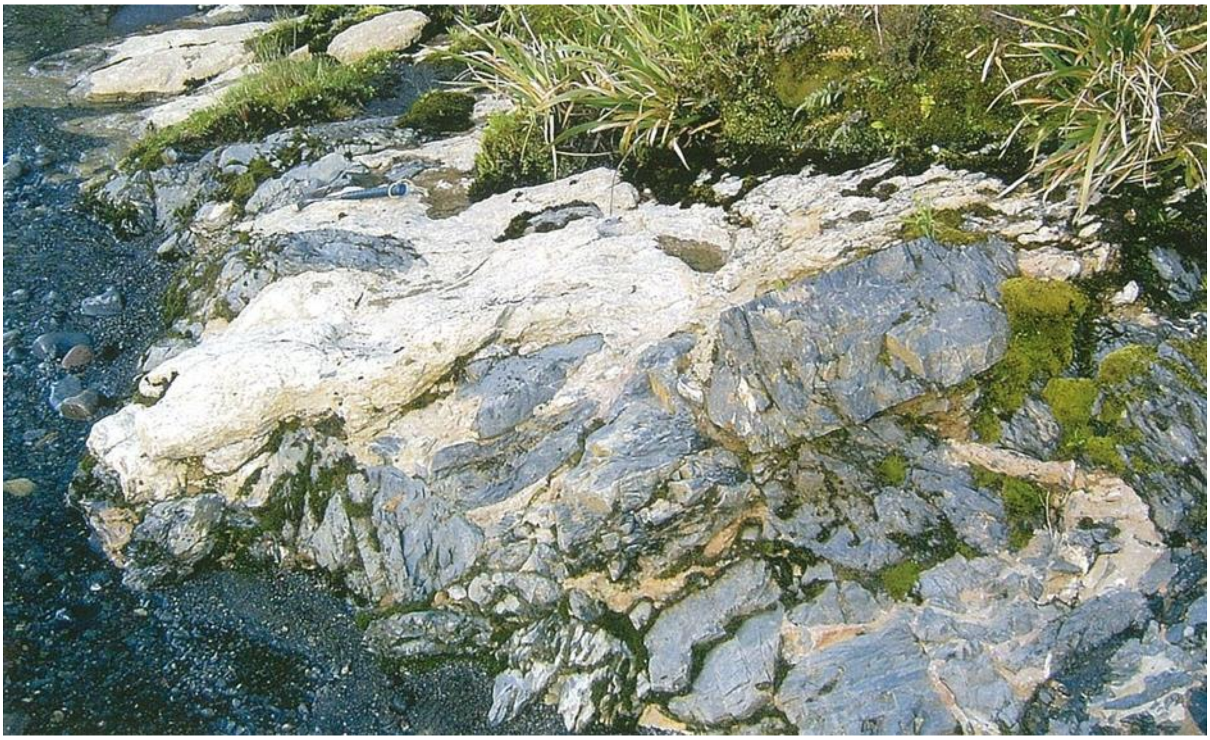

Figure 22: Te Kuiti Group limestone with clasts of siltstone overlying a bored contact basement of Manaia Hill Group rocks (source Qmap7).

The overlying Taumatamaire Formation rests unconformably on the Te Kuiti Group and consists of massive to weakly bedded calcareous mudstone to fine sandy mudstone with basal glauconite and local interbedded limestone. The overlying Taumarunui Formation consists of well-bedded, redeposited sandstone, siltstone and mudstone, and outcrops extensively west of Raurimu and in tributaries of the Whanganui River (Fig. 23).

Figure 23: Taumarunui Formation a sequence of graded, redeposited sandstone beds interspersed with mudstone (source Qmap7).

3.2.3 Middle Miocene to Pliocene sedimentary rocks

The sedimentary rocks of the middle Miocene to Pliocene period comprise the Whangamomona Group, a transgressive sequence including the Mangarara and Otunui Formations of conglomerate and sandy to pure limestone exposed in sporadic and discontinuous outcrops (Fig. 24). The Otunui Formation is predominantly massive to weakly bedded sandy siltstone and silty sandstone with intervals of blue-grey fissile mudstone containing thin glauconitic beds, and shelly granule to pebble conglomerate lenses. It is up to 200m thick and typically form bluffs (Fig. 25). East of the Ohura Fault the Mangarara and Otunui Formations unconformably overlie the Mahoenui Group, whereas west of the fault they overlie Mokau Group rocks. The Otunui Formation grades upwards into the Mount Messenger Formation in the west. To the east, the Otunui Formation consists predominantly of well-sorted medium sandstone containing lenses and beds of well-rounded greywacke pebble conglomerate. The Mount Messenger Formation in the east grades upward from the massive sandy siltstone-silty sandstone of the Otunui Formation into blue-grey mudstone and sandstone separated by units of fissile mudstone. The overlying Kiore Formation is a massive to laminated siltstone, sandy siltstone, and sandstone up to 500 m thick. In the east, organic rich micaceous and carbonaceous sandstone and shale are present.

Figure 24: Mangarara Formation shell bed unconformably overlying Taumarunui flysch deposits, Whanganui River near Paparoa Stream (source Qmap7).

Figure 25: Basal Otunui Formation is divided by a glauconitic horizon (centre of photo) into a lower mudstone and an upper silty sandstone facies (source Qmap7).

The Matemateaonga Formation is characterised by repeated cycles of deposition comprising predominantly muddy sandstone with siltstone, mudstone, limestone or shell beds, coal and locally conglomerate up to 1 km thick in the west and 2 km thick in the east (Fig. 26).

The base of the Rangitikea Supergroup comprises the Tangahoe Mudstone, a massive to weakly bedded, blue-grey mudstone containing packets of amalgamated, well-sorted, micaceous fine sandstone beds, and represents a major regional subsidence event and the establishment of the Wanganui Basin as a separate depocentre (Fig. 27).

Figure 26: Alternating repetitive shell bed, siltstone, and sandstone lithologies of the Matemateaonga Formation (source Qmap7).

Figure 27: Tangahoe Mudstone comprises pale grey, massive, calcareous mudstone interbedded with brown, micaceous, fine to medium sandstone (source GNS Qmap7).

The overlying Whenuakura Group rocks comprise cyclical repetitions of bioclastic limestone, pebbly sandstone, and bioturbated, fine, well-sorted micaceous sandstone and massive siltstone (Fig. 28).

Rocks of the Paparangi Group were deposited during the middle Late Pliocene. In the west, it includes pebbly shell beds and sandstone (including the basal Mangapani Shell Conglomerate member); and to the east, massive locally fossiliferous mudstone where it increases in thickness to 500 m. The Upper and Lower Okiwa Groups consist of diverse carbonate and siliceous rocks with coarse, basal limestones overlain by sparsely fossiliferous siltstone and sandstone.

The Nukumaru Group comprises pebbly sandstone, coquina limestone with sandstone lenses, and well sorted sandstone. It typically rests conformably on finer Okiwa Group rocks and thickens eastwards to c. 220 m near the Whanganui River.

Contrasting with the rocks below and above, the Maxwell Group consists of interbedded terrestrial, non-marine, and marginal marine deposits. The base of the group is diachronous, being generally older in the west. This group of rocks is 100 m thick at the coast and thickens eastwards to over 300 m in the Turakina valley.

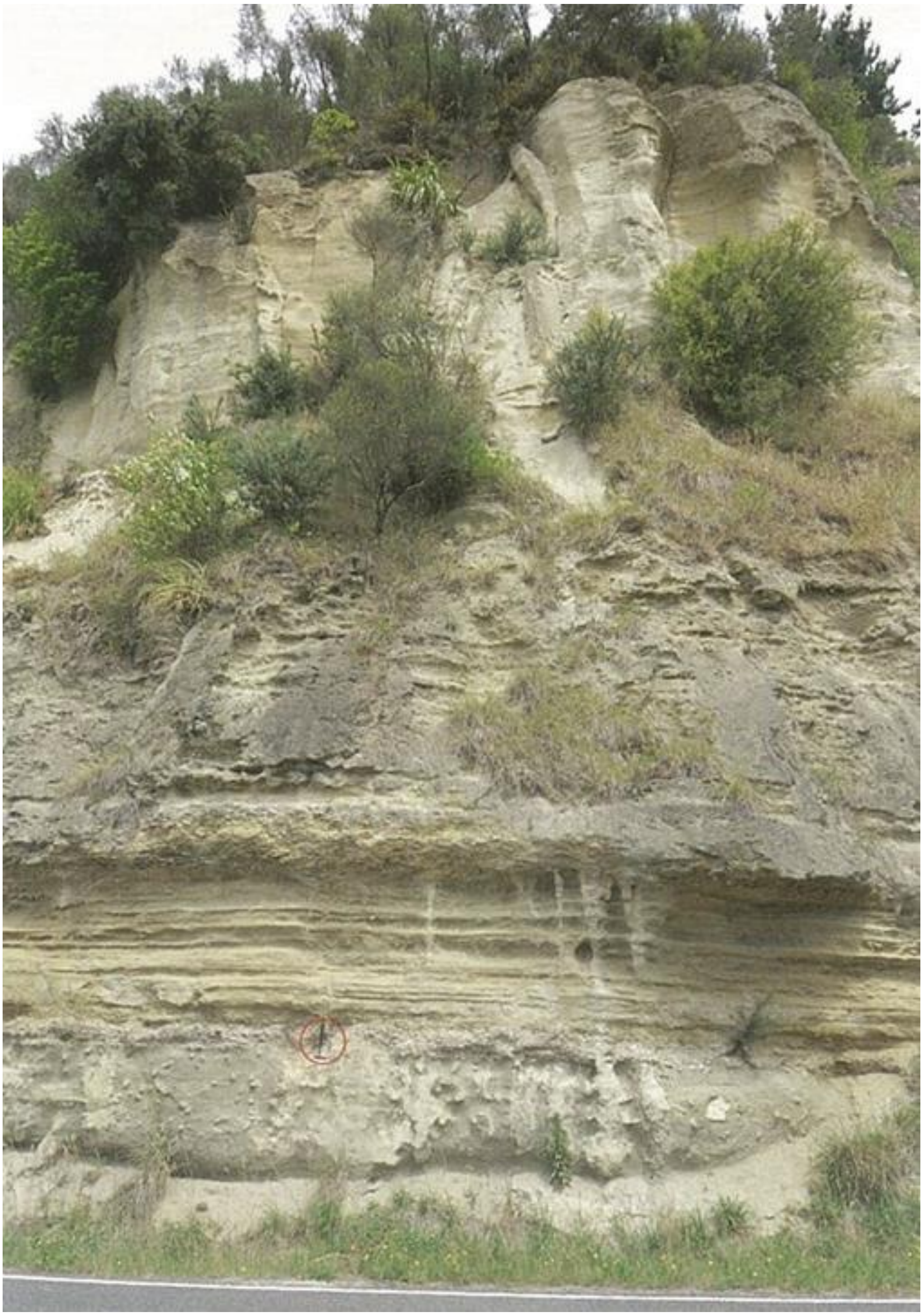

Figure 28: Bioturbated Whenuakura Group sandstone unconformably overlain by Paparangi Group coquina and sandstone, overlain by massive to weakly bedded sandstone (source Qmap7).

3.2.4 Quaternary Sediments

During the early Quaternary, the Whanganui Basin continued to be a locus for marine sedimentation, and sea-level fluctuations were a major influence on the pattern of deposition and erosion. Later in the Quaternary, steady tectonic uplift in combination with sea level oscillations formed wave-cut coastal platforms and facilitated the preservation of extensive flights of marine terraces.

Aggradational river terraces

Alluvial gravel and floodplain deposits are dominated by rounded, poorly sorted to well-sorted gravel, sand, and silt. Within the gravel deposits Torlesse-derived sandstone (greywacke) is the predominant rock type in the south, but around the volcanic ring plain andesitic clasts dominate. Clasts from Cenozoic limestone and reworked conglomerate beds are locally abundant in the central catchment and pumice reworked from the Taupō eruption is locally abundant along the Whanganui River.

Loess deposits

Loess deposits locally form significant sheets up to several metres thick on older terraces *(Q4 and older)* in the Taranaki-Manawatu region but are largely restricted to the coastal marine terrace surfaces in the Whanganui catchment.

Coastal sand deposits

Fixed and mobile sand dunes fringe the Whanganui River mouth and form a minor component of the catchments landscape.

3.2.5 Quaternary Volcanic Rocks and associated deposits.

Volcanic rocks include lava and tephra (ash, ignimbrite, and other pyroclastic deposits). Lava from Mt Ruapehu and related vents consists primarily of calc-alkaline, medium-K basic and acidic andesites with common xenoliths originating from greywacke terranes. The oldest feature in the Tongariro Volcanic Centre within the Whanganui catchment is Mt Hauhungatahi, a partially eroded cone capped by up to 50 m of pyroclastic material and *c.* 10 m andesite lava resting on Miocene sediments. The Ruapehu Group comprises all the igneous rocks forming Mt Ruapehu, and includes andesitic lava flows, pyroclastic flows, breccias, and tuff, as well as small intrusive bodies, underlying the upper slopes, which drain into the Whanganui Catchment.

Taupō Volcanic Zone

Remnants of three large middle to late Quaternary ignimbrite eruptions from the Taupō Volcanic Zone are present in the Whanganui catchment. The oldest (the Whakamaru group ignimbrite) is preserved mainly as ridge-capping remnants of a once extensive sheet east of the Whakapapa River. The Oruanui Formation ignimbrite is predominantly valley-filling, forming mid-level terraces (between Waimarino lahars and Taupō Formation) in the upper Whanganui and Whakapapa valleys. Coeval with the ignimbrite, air-fall products of the Orunanui eruption (variously named Aokautere Ash, Kawakawa Tephra or Kawakawa/Orunaui tephra) consist of up to 10 separate members with wide dispersal collectively forming a significant inter-regional marker bed. The Taupō Formation ignimbrite of about 1.8 ka ago was deposited over approx. 22,000 km^2 of the central North Island (Fig. 29), mantling much of the area with a fine layer of ash.

Figure 29: Taupō Formation include primary and reworked ignimbrite both of which ponded in valleys, exposed in c. 7-m-high road cutting on the banks of the Whanganui River at Te Maire (source Qmap7).

Quickly eroded from the steeper slopes much of this ignimbrite was fluvially reworked along the Whanganui and Whakapapaiti Rivers, forming extensive low-level terraces of pumiceous alluvium.

Laharic and associated volcaniclastic deposits

Lahar deposits are ubiquitous on the lower flanks of Mt Ruapehu and are volumetrically the largest constituent of the ring plain. Massive boulder gravel and coarse sandy fluvial gravels of the Waimarino Formation *(Q4h)* crop out extensively on the flanks of Mt Ruapehu (Fig. 30) forming laterally extensive sheets. The only conspicuous debris avalanche deposit in the catchment is on the north-western slopes of Mt Ruapehu, the Murimotu Formation (Fig. 31).

Figure 30: Well-bedded debris flow deposits of the Waimarino Formation (source Qmap7).

Figure 31: Mounded topography of the Morimotu Formation debris avalanche deposit (CN2844 DL Homer).

Rock type from the New Zealand Land Resource Inventory

The rock type classification used in the New Zealand Land Resource Inventory (NZLRI) (NWASCO 1975–79; NWASCA 1986a, b; Lynn & Crippen 1991; Newsome et al. 2008) was designed to group those rocks with similar erosion susceptibilities and characteristics regardless of age, and to concentrate on those rocks which directly influence landform, and hence land use. It records the lithology of the map unit stratigraphically, from the surface and/or the dominant rock type. 'Baserock' identifies the principle basement lithology, and 'Toprock' the first-named rock type, i.e. the surface lithology.

Baserock

Analysis of the NZLRI baserock rock type for the Whanganui catchment indicates that over 71% of the catchment is underlain by soft sedimentary rocks (Table 1, Fig. 32). Weak to very compact, massive sandstone (Sm), prone to soil slip (shallow landslide) and sheet erosion underlies 50% (356,757 ha) of the catchment (Fig. 33). Very weak to weak, massive (Mm), banded (Mb) and jointed mudstone (Mj), susceptible to soil slip and earthflow erosion, underlies a further 21% (150,624 ha). Thick, compact to very compact, moderately to completely weathered, clay rich, ash and lapilli (Mo), and very loose to compact, fresh to moderately weathered, pumiceous lapilli and ash deposits (Tp), occupy 90,560 ha (12.7%). Weak to extremely strong, basaltic to rhyolitic volcanic rocks, lavas, welded ignimbrite, shallow intrusives and minor interlayered pyroclastics are mapped on 52,542 ha (7.4%), primarily on the western flanks of the volcanos. The regional basement rocks of strong to extremely strong greywacke occupy only 3% (21,134 ha) of the area.

Table 1: Underlying rock type (baserock) from the NZLRI for the Whanganui catchment

BASEROCK	**area ha**	**% catchment**	**lithology**	**%**
Sm massive sandstone	356757.01	50.1	Sandstone	50.1
Mb banded mudstone	63856.67	9.0		
Mm massive mudstone	45209.08	6.4		
Mj jointed mudstone	41558.08	5.8	Mudstone	21.2
Mo Ashes older than Taupō ash	64676.34	9.1	Mo/Xx; Tp	12.7
Tp Taupō & Kaharo breccia & pumiceous alluvium	25882.69	3.6		
Vo lavas, ignimbrite	52541.56	7.4	Lava	7.4
La Lahar	11896.51	1.7		
Gw Greywacke	21133.76	3.0	Greywacke	3
Al Alluvium	14134.70	2.0		
Gr Gravels	66.91	0.0		
Us Unconsolidated clays, silts, sands	5197.80	0.7		
Lo Loess	3388.01	0.5		
Wb sand	1306.67	0.2		
lake	27.22	0.0		
river	1461.24	0.2		
town	2666.83	0.4		

Consolidated lahar deposits, loose to compact gravels and finer alluvium, loess, unconsolidated sands and gravels, and windblown sand make up the balance of the area (25,095 ha, 5%).

Figure 32: On thin soils derived from and resting on a greasy 'back' of papa, simple slumping sets in during the second decade after bush burning, Mangapurua Valley, inland Wanganui (caption and illustration published in Cumberland 1944, photo sourced from the Public Works Department).

Surface deposits – toprock

Analysis of the NZLRI toprock rock type for the Whanganui catchment indicates that over 44.5% of the catchment is overlain by volcanic ash (Table 2, Fig. 34). Surface deposits of compact to very compact, and very loose to compact, ash or pumiceous alluvium from the Taupō and earlier eruptions mantles the landscape on 361,845 ha. On slopes >20^{0} these landscapes are susceptible to sheet and soil slip erosion, and sheet, wind, rill, and gully erosion, especially on the Kt and Tp toprock classes.

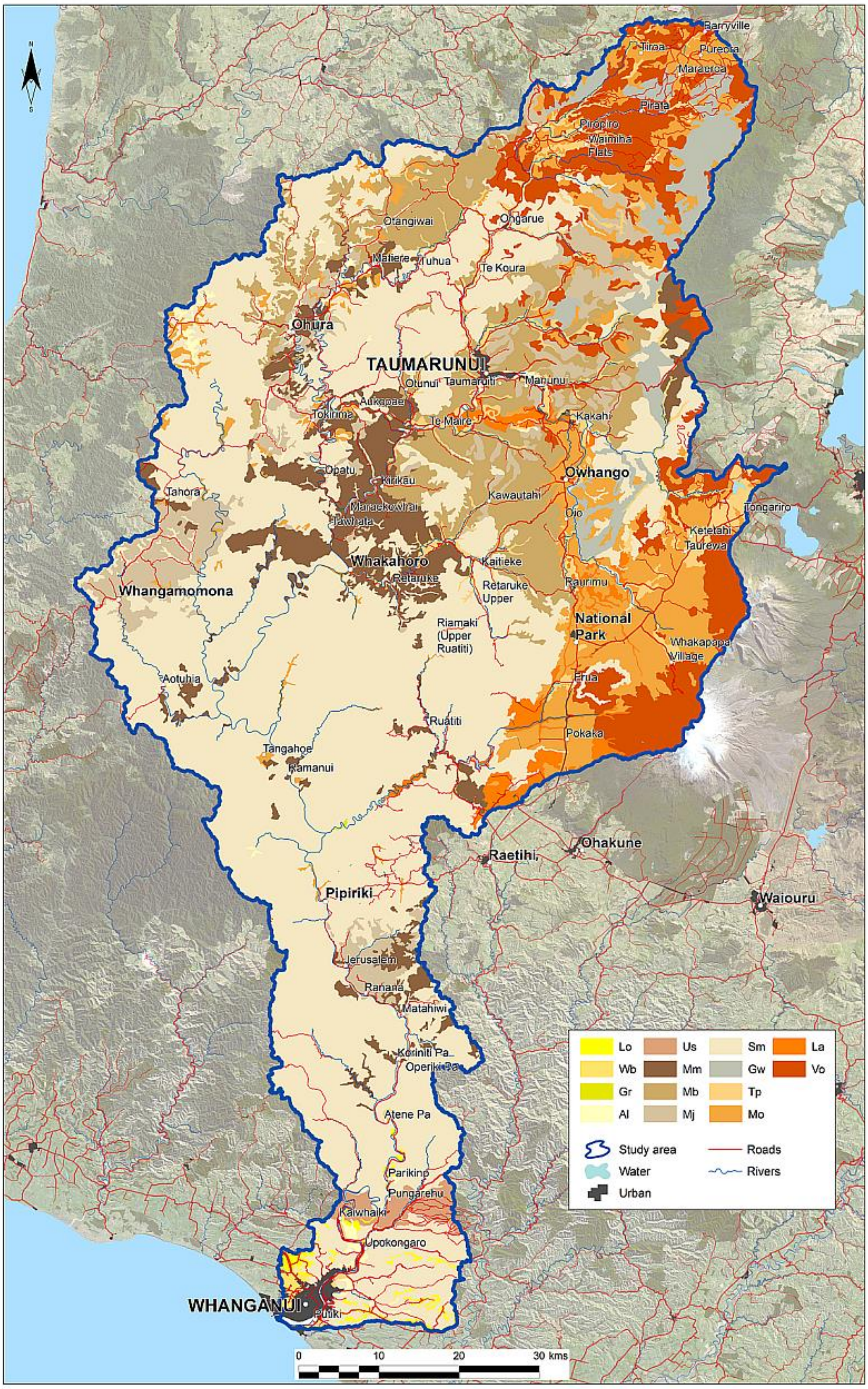

Figure 33: Distribution of NZLRI baserock for the Whanganui catchment.

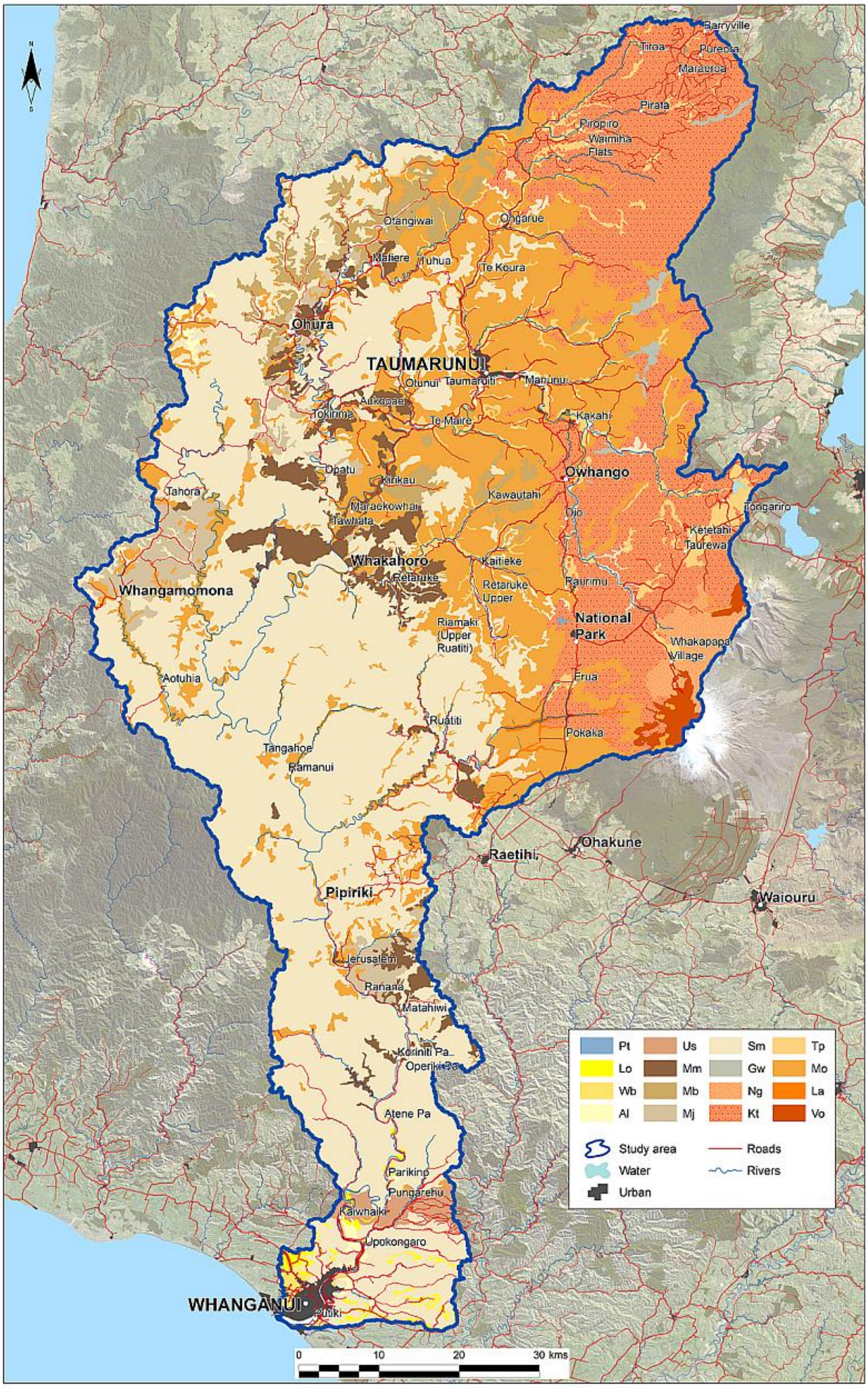

Figure 34: Distribution of NZLRI toprock for the Whanganui catchment.

Massive sandstone (Sm) is mapped as the lithology forming or directly underlying the soil mantle on 41.3% (294,006 ha) of the catchment. This terrain is prone to soil slip and sheet erosion, the natural soil fertility is usually less than that on finer-grained lithologies (Mm, Mb), and erosion scars tend to be slower to revegetate.

Only 9.1% of the catchment has massive, banded and jointed mudstone mapped as forming or directly underlying the soil mantle. This mudstone terrain is susceptible to soil slip and earthflow erosion. Earthflows are especially common on the dip slopes of bedded mudstone. Both deep and shallow earthflow, gully, and slump erosion are features on jointed mudstone terrain.

Other lithology's ranging from extremely weak (Wb, Al) to extremely strong (Gw) are mapped as forming or directly underlying the soil mantle on the balance of the catchment.

Table 2: Toprock from the NZLRI for the Whanganui catchment

TOPROCK	area ha	% catchment	lithology	%
Mo Ashes older than Taupō ash	161819	22.7	Ash	44.5
Kt Kaharoa & Taupō ashes	120851	17.0		
Tp Taupō & Kaharo breccia & pumiceous alluvium	26217	3.7		
Ng Ngauruhoe ash	7959	1.1		
Sm massive sandstone	294006	41.3	Sandstone	41.3
Mm massive mudstone	26417	3.7	Mudstone	9.1
Mb banded mudstone	20350	2.9		
Mj jointed mudstone	18209	2.6		
Al Alluvium	13345	1.9		
Us Unconsolidated clays, silts, sands	4825	0.7		
Vo lavas, ignimbrite	4271	0.6		
Lo Loess	3509	0.5		
Gw Greywacke	2555	0.4		
La Lahar	1892	0.3		
Wb sands	1307	0.2		
Pt Peat	75	0.0		
lake	27	0.0		
river	1461	0.2		
town	2667	0.4		

3.3 Climate

Climate data for the catchment are summarised in Maunder and Brown (1971), Thompson (1981, 1984), the 1:500 00 isohyet map of New Zealand (New Zealand Meteorological Service 1978), the 1:2 000 000 map of Climate Regions (New Zealand Meteorological Service 1983b), and rainfall normals (New Zealand Meteorological Service 1983a). The climatic regions for the Whanganui catchment as defined in New Zealand Meteorological Service 1983b) are climate types A_2, C_3, D_1, and M, (Fig. 35). Rainfall varies between 900 and 1300 mm in the south and south-east of the catchment and increases to between 1300 and 2500 mm in the north. The catchment generally has warm summers and mild winters although in high rainfall mountain climates temperatures vary greatly with elevation and exposure.

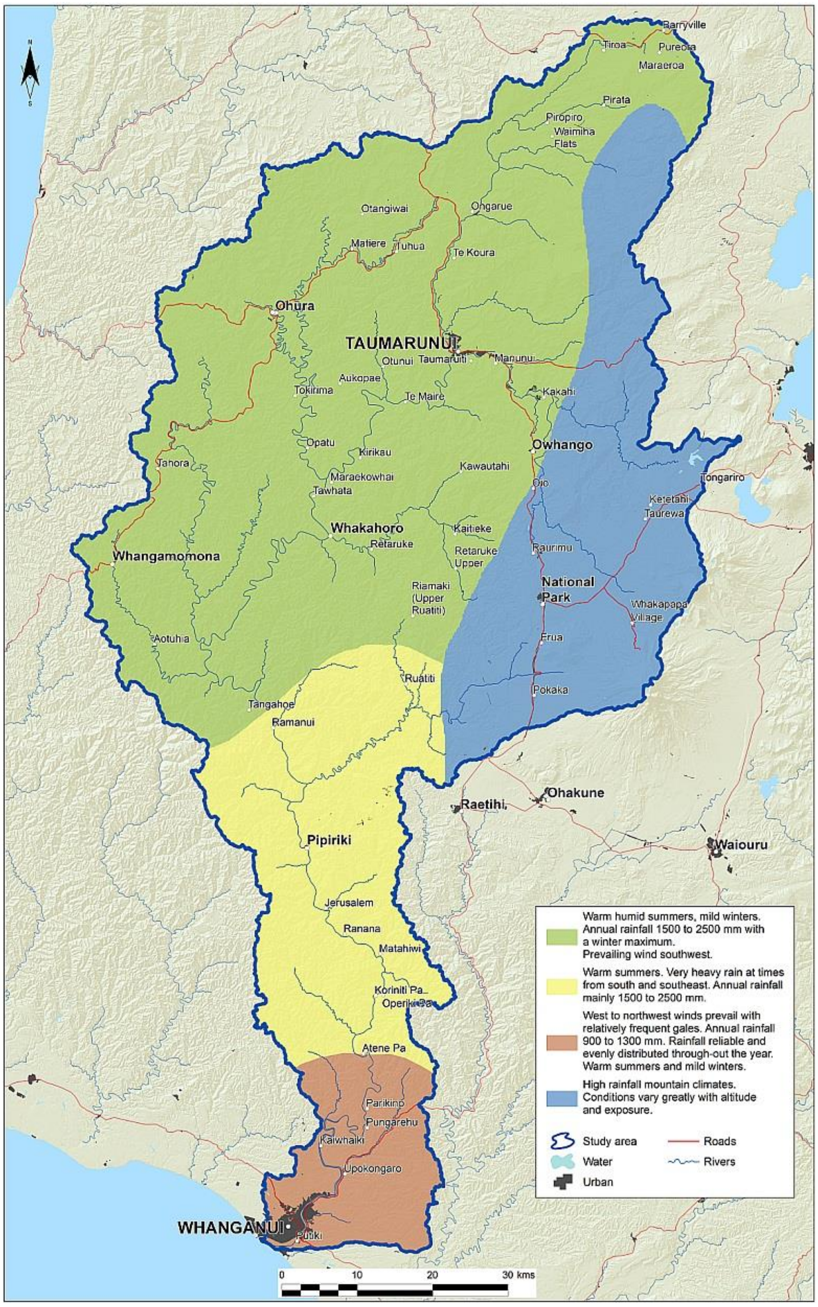

Figure 35: Climatic regions of the Whanganui Catchment (adapted from New Zealand Meteorological Service 1983b).

Climate type A_2 in the north-west of the catchment centred on Taumarunui has warm humid summers and mild winters. Annual rainfall is between 1500 and 2500 mm with a winter maximum and prevailing south-westerly winds.

The central section of the catchment around Pipiriki has a type C_3 climate. It has warm summers with very heavy rain at times from the south and southeast. Annual rainfalls are between 1500 and 2500 mm.

The lower catchment has a type D_1 climate. Prevailing winds are from the west to northwest with frequent gales. Annual rainfalls are between 900 and 1300 mm, reliable and evenly distributed throughout the year. The summers are warm and the winters are mild.

The high rainfall mountain climates to the east, M, have rainfalls >2500 mm, and conditions vary greatly with elevation and exposure.

3.4 Soils

A range of soils are mapped in the Whanganui catchment. Soil development and distribution is a function of parent material, topography (especially slope, elevation, and aspect), climate, the impact of organisms and time. The soils in parts of the catchment are described in detail in Campbell (1971, 1977) and Wilde (1976). The dominant soil orders mapped in the Whanganui catchment and their distribution is shown in Table 3 and Figure 36.

On over 45% of the catchment the soils are developed from volcanic ash, are classified predominantly as Allophanic, Podzol, Recent or Pumice soils (Hewitt 2010), and are concentrated in the north east of the region adjacent to the source volcanoes. Ash derived soils vary from moderate to very low natural fertility depending on the composition of the primary source materials (andesitic or rhyolitic). On slopes >20^o these ash-mantled landscapes are susceptible to sheet and shallow landslide erosion.

Table 3: Classification of soils mapped in the Whanganui catchment

NZSC Soil Order†	area ha	% catchment
Allophanic	141528	19.9
Brown	187357	21.3
Gley	7504	1.0
Melanic	1636	0.2
Organic	15	0.0
Pallic	22109	3.1
Podzol	114176	16.0
Pumice	55005	7.7
Raw	15275	2.2
Recent	162700	22.9
ice	211	0.0
lake	27	0.0
river	1461	0.2
town	2667	0.4

† New Zealand Soil Classification (Hewitt 2010).

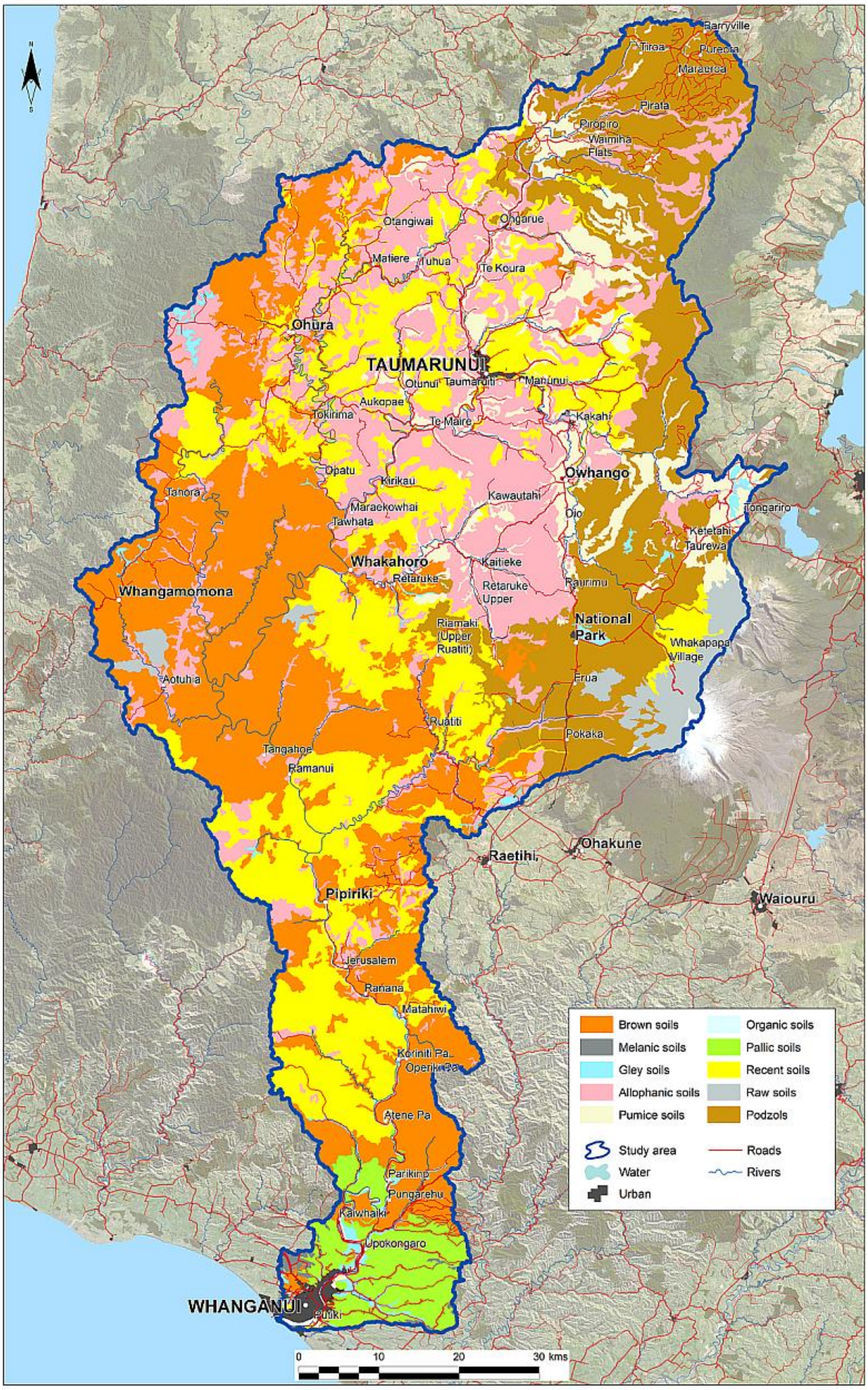

Figure 36: Distribution of the dominant Soil Order for the Whanganui catchment as mapped in the NZLRI.

On the steep to very steep massive sandstone terrain in the west and southern regions of the catchment (>41%), predominantly Brown, Recent and Raw soils are mapped. This terrain is very susceptible to shallow landslide and sheet erosion under pasture, frequently stripping the colluvial mantle down to the bedrock. As a result of the low natural fertility of these sandstones, erosion scars and debris tails are very slow to revegetate.

Pallic soils are mapped in the lower catchment on loess and weakly consolidated alluvium in the low rainfall areas.

Minor amounts of other soil orders, Gley, Melanic and Organic Soils are mapped within the catchment.

3.5 Land Use Capability and Erosion

Land Use Capability (LUC) 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). Capability is used in the sense of suitability for productive use or uses after taking into account the physical limitations of the land.

The classification has three components as illustrated in Figure 37. The LUC Class assesses the land's capability for use, taking into account its physical limitations and its versatility for sustained production. There are eight Classes with limitations to use increasing, and versatility of use decreasing, from LUC Class 1 to LUC Class 8, Figure 38.

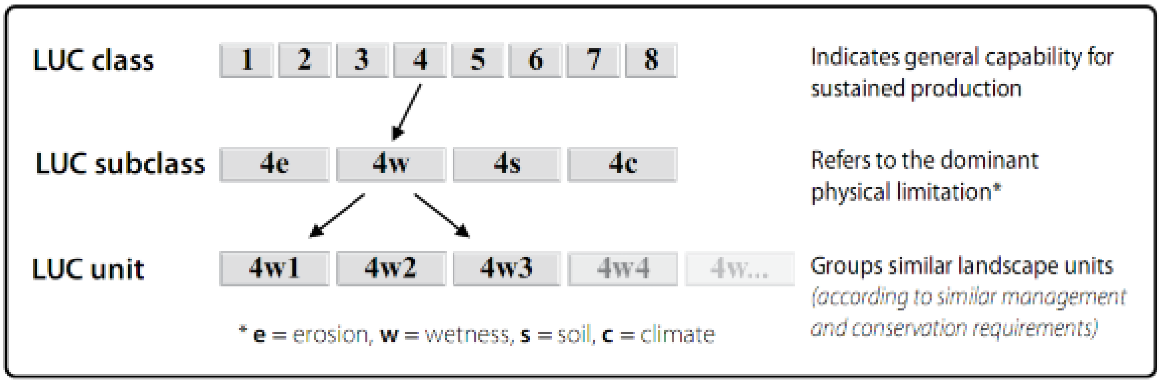

Figure 37: Components of the Land Use Capability classification (from Lynn et al. 2009).

LUC Classes 1–4 are suitable for arable cropping (including vegetable cropping), horticultural (including vineyards and berry fields), pastoral grazing, tree crop or production forestry use. Classes 5–7 are not suitable for arable cropping but are suitable for pastoral grazing, tree crop or production forestry use, and in some cases vineyards and berry growing. The use limitations reach a maximum with LUC Class 8 land, which is unsuitable for sustainable grazing or production forestry, and is best managed for catchment protection and/or conservation or biodiversity.

The LUC Subclass denotes the main kind of physical limitation or hazard to use. Four limitations are recognised:

- ‘e’ erodibility – where susceptibility to erosion is the dominant limitation.
- ‘w’ wetness – where a high water table, slow internal drainage, and/or flooding constitute 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.

Increasing limitations to use ↓

LUC Class	Arable cropping suitability†	Pastoral grazing suitability	Production forestry suitability	General suitability
1	High	High	High	Multiple use land
2	↓	↓	↓	
3				
4	Low			
5	Unsuitable			Pastoral or forestry land
6				
7		Low	Low	
8		Unsuitable	Unsuitable	Conservation land

Decreasing versatility of use ↓

Figure 38: Increasing limitations to use and decreasing versatility for use from LUC Class 1 to LUC Class 8. † includes vegetable cropping (source: Lynn et al. 2009).

The LUC Unit groups together areas where similar land inventories have been mapped, which require the same kind of management, the same kind and intensity of conservation treatment, and are suitable for the same kind of crops, pasture or forestry species, with similar potential yields. Regional productivity indices were created for LUC units as part of the NZLRI mapping project. Indices include three levels of stock carrying capacity for pastoral use and a *Pinus radiata* site index for forestry, now largely superseded by the 300 Index (Kimberley et al. 2005).

Fletcher (1981, 1987) documents in detail the regional LUC units and productivity indices applicable to the Whanganui catchment.

3.5.1 Distribution of LUC Classes in the Whanganui catchment

The distribution of the NZLRI LUC Classes in the Whanganui catchment is summarised in Table 4 and Figure 39. The Whanganui catchment is characterised by its limited amount of high quality land, the predominance of non-arable land, and its significant proportion of moderately steep to steep land with severe physical limitations to productive use.

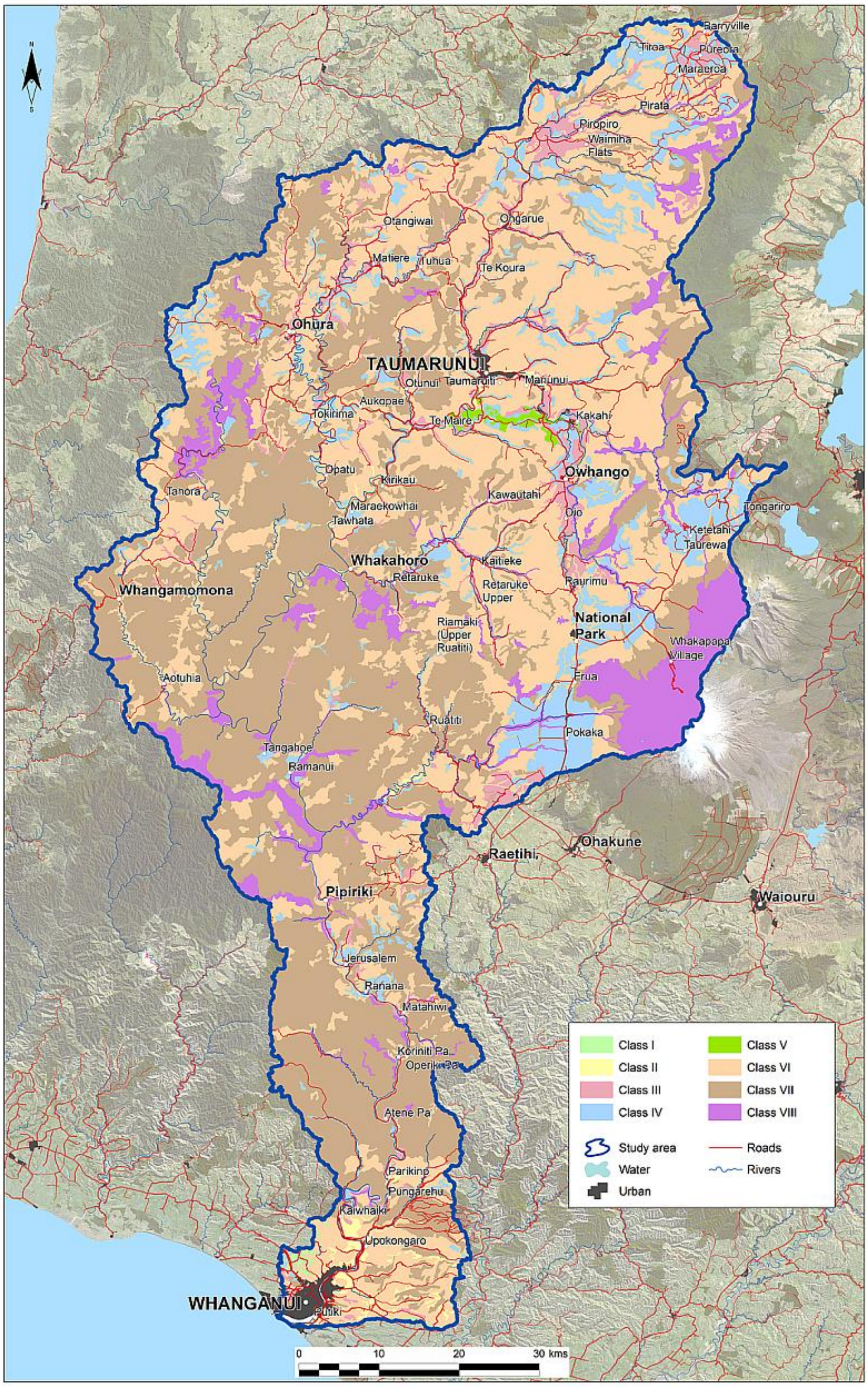

Figure 39: Distribution of land use capability class in the Whanganui catchment.

Table 4: Distribution of NZLRI LUC Classes in the Whanganui catchment

LUC Class & Subclass	Area (ha)	% catchment		%
1c	1 177.21	0.2		
1w	145.16	0.0		
2c	383.90	0.1		
2s	3 265.65	0.5		
2w	2 633.26	0.4		
3c	3 420.17	0.5		
3e	11 151.84	1.6	Arable land, 98 658ha	13.9
3s	10 956.23	1.5		
3w	4 617.82	0.6		
4c	12 013.34	1.7		
4e	43 146.93	6.1		
4s	67.50	0.0		
4w	5 679.20	0.8		
5s	1 839.15	0.3		
6c	18 084.18	2.5		
6e	221 433.91	31.1		
6s	31 681.19	4.5		
6w	1 216.99	0.2	Non-arable land, 556 252ha	85.6
7c	5 371.96	0.8		
7e	274 920.73	38.6	LUC Classes 6e+7e, 496 355ha	69.7
7s	1 703.44	0.2		
8c	5 322.77	0.7		
8e	47 227.18	6.6	LUC Class 8	7.4
8w	146.09	0.0		
lake	27.22	0.0		
river	1 461.24	0.2		
town	2 666.83	0.4		
Total area	**711 761**			

Arable Land

Less than 14% of the catchment is classified as arable (98,658 ha). Arable land is ‘suitable for cultivation for cropping, and capable of growing at least one of the common annual field crops, or more per season, with average yields under good management and without permanently degrading soil conditions’.

Most of the arable terrain is restricted to the lower catchment on the uplifted marine terraces, confined to the small, narrow and discontinuous floodplains and terraces within the entrenched river valley network, or mapped on undulating to strongly rolling slopes in the upper catchment King Country and Waimarino districts, with a mantle of Taupō air-fall or flow tephra derived Pumice soils, or Allophanic soils developed in Tongariro tephra.

LUC Classes 1 and 2

Just over 1% of the catchment has minimal or slight physical limitations to arable use, LUC Classes 1 (1,322ha) and LUC Class 2 (6,282ha), respectively. The limited LUC Class 1 land is either flat to undulating terrace land with soils developed on deep andesitic tephra (1c3), or loess (1c2), with a climatic limitation. The LUC Class 2 land is dominated by flat river terraces with deep soils that retain a wetness limitation after drainage (2w2), and flat to gently undulating terraces with a loess mantle and a subsurface pan that impedes drainage (2s2).

Most of the arable land has severe (LUC Class 4, 60 907 ha, 8.6%), or moderate (LUC Class 3, 30 146 ha, 4.2%) physical limitations to arable use.

LUC Class 3

LUC Class 3 land is mapped on 30,146 ha (4.2%) of the catchment, over 70% of which is classified as one of five LUC units. Flat terraces formed on fine textured Taupō tephra, (LUC Class 3s6, 8 471ha) occurs mainly in the King Country where the cropping versatility is limited by periods of soil moisture deficit, cool winter temperatures, poor soil structure, and low natural fertility. Similarly, undulating downlands in the King Country with Pumice soils developed from Taupō air-fall tephra with a potential for moderate sheet, rill and gully erosion when cultivated are mapped on 4,656 ha (LUC Class 3e7). Flat, narrow, alluvial valley floors with Recent or Gley soils subject to runoff from adjacent slopes and with a continuing moderate wetness limitation after drainage comprise some 41,334 ha (LUC Class 3w2). Flat to undulating slopes between 550 and 750 m above sea level, in the Waimarino district with Allophanic soils developed on Tongariro tephra and cool winter temperatures which limit cropping have been mapped on some 2,406 ha (LUC Class 3c1). Similar Allophanic soils in the same district but mapped on undulating to rolling slopes, (LUC Class 3e5), with a potential for slight to moderate sheet and rill erosion when cultivated occupy some 1,922 ha. Components of another 12 LUC Class 3 units make up the balance of the Class 3 land in the Whanganui catchment.

LUC Class 4

LUC Class 4 land is mapped on 60,907 ha (8.6%) of the catchment, over 70% of which is classified as one of six LUC units. Rolling slopes below 900 m above sea level, in the King Country with Pumice soils developed from Taupō air-fall tephra, with a potential for severe sheet, rill and gully erosion when cultivated, and rainfalls > 1500 mm p.a. which limits cropping versatility are mapped on 17,043 ha (LUC Class 4e9). On the western flanks of the Hauhungaroa Range and in the Taurewa area a complex of rolling slopes mantled with Taupō air-fall tephra and undulating valleys infilled with Taupō flow tephra, LUC unit 4e11, is mapped on some 7,516 ha. The valleys contain ephemeral waterways that have the potential for severe gully erosion if the grounds surface is broken. There is also a potential for severe sheet and gully erosion when the slopes are cultivated. Near National Park, flat, high elevation (900–1,000 m above sea level) plateau land with Pumice soils, >2,000 mm p.a. rainfall, and cool winter temperatures which severely limit cropping (LUC Class 4c4) is mapped on 7,173ha. LUC unit 4c1 is mapped on flat to undulating slopes between 750 and 1,000 m above sea level, in the Waimarino district with Allophanic soils developed from Tongariro tephra on some 4,840 ha. The cool winter temperatures and rainfall of >1,600 mm p.a., severely limits cropping suitability. Also in the Waimarino district, LUC unit 4e6 is mapped on the rolling to strongly rolling downlands with Allophanic soils and a potential for severe sheet and rill erosion when cultivated on 3,506 ha. LUC unit 4e13 is mapped in the King Country on 4,230 ha of undulating valleys infilled with finely textured Taupō flow tephra which is dissected by shallow ephemeral waterways which have the potential to develop into severe gullies. There is also potential for severe sheet, rill and gully erosion when cultivated. Components of another 22 LUC Class 4 units make up the balance of the arable Class 4 land in the Whanganui catchment.

Non-arable land

Over 86% of the Whanganui catchment is classified as non-arable or unproductive land (613,103 ha). Over 78% of the catchment is classified as non-arable land with slight to moderate, or severe physical limitations or hazards to productive use under perennial vegetation cover, LUC Class 6 and LUC Class7 respectively, (554,412 ha). Non-arable land is unsuitable for arable cropping but is suitable for pastoral grazing, tree crops or production forestry use. There are insignificant amounts of LUC Class 5 land mapped within the catchment, (1,839 ha) – high-producing land with physical limitations that make it unsuitable for arable cropping, but with only negligible to slight limitations or hazards to pastoral or production forestry use.

LUC Class 6

Non-arable land with slight to moderate physical limitations or hazards to productive use, LUC Class 6 land, co-dominates the catchment, and is mapped on 272,416 ha (38%). Over 77% of this land is classified as one of eight LUC units, moderately steep to steep slopes dominate and seven of these units have erodibility identified as the dominant physical limitation to use. The LUC Class 6 land is concentrated in the upper and middle catchment centred on Taumarunui, and in the lower reaches from Parikino to the coast.

Moderately steep to steep fertile mudstone and siltstone hillslopes below 1,000 m above sea level with Brown, Pallic and Allophanic soils in moderate to high (1,200–2,000 mm) rainfall areas and a potential for moderate soil slip and shallow earthflow, and slight sheet and gully erosion are mapped on 38,518 ha (LUC Class 6e3).

Moderately steep to steep hills on very hard sandstone with a discontinuous mantle of andesitic tephra and areas of bare rock below 600 m above sea level with infertile Allophanic and Recent soils in moderate to high (>1,200 mm) rainfall areas and a potential for moderate soil slip and sheet erosion, where the soil slips exposing bedrock are slow to revegetate are mapped on 36,882 ha (LUC Class 6e17).

Moderately steep to steep hills developed on banded mudstone below 600 m above sea level with a mantle of andesitic tephra, Allophanic and Recent soils in moderate to high (1,200–2,000 mm) rainfall areas with a potential for moderate soil slip erosion, and slight sheet and gully erosion are mapped on 26,824ha (LUC Class 6e5).

Moderately steep to steep hills developed on consolidated siltstone below 600 m above sea level with significant andesitic tephra in patches, and Allophanic, Brown, and Recent soils in moderate to high (1,200–2,000 mm) rainfall areas and a potential for moderate soil slip erosion and slight sheet erosion are mapped on 23,469 ha (LUC Class 6e10).

Rolling to moderately steep hill country on mudstone and siltstone with a patchy tephra mantle, Brown, Allophanic or Pumice soils, below 800 m above sea level, a rainfall >1,200 mm p.a., and a potential for moderate to severe deep earthflow, slump and gully erosion, and slight soil slip erosion is mapped on 22,217 ha (LUC Class 6e20).

Moderately steep to steep hills with a mantle of Taupō tephra on older tephra over stable consolidated rock types, below 1,000 m above sea level with Pumice and Podzol soils in high (>1,600 mm) rainfall areas with cool winter temperatures which limit the growing season, and a potential for moderate sheet erosion are mapped on 21,689 ha (LUC Class 6e18).

Moderately steep to steep hill country with a discontinuous mantle of andesitic tephra over consolidated sandstone up to 700 m above sea level with Brown, Recent and Allophanic soils in moderate to high (1,200–2,000 mm) rainfall areas with a potential for moderate soil slip and slight sheet erosion are mapped on 21,205 ha (LUC Class 6e23).

Strongly rolling hills with a deep mantle of Taupō air-fall tephra over more weathered tephra over stable ignimbrite below 800 m above sea level with medium to low fertility Pumice, Podzol, and Allophanic soils in areas in moderate to high (>1,200 mm) rainfall and a potential for slight sheet erosion are mapped on 19,919 ha (LUC Class 6s5).

Components of another 32 LUC Class 6 units make up the balance of the Class 6 land in the Whanganui catchment.

LUC Class 7

Non-arable LUC Class 7 land with severe physical limitations or hazards to productive use, co-dominates the catchment, and is mapped on 255,602 ha (40%). Over 91% of this land is classified as one of five LUC units, steep to very steep slopes dominate and all have the potential for severe soil slip and sheet erosion identified as the dominant physical limitation to use. LUC Class 7 land is concentrated in the western and middle sections of the catchment upstream of Parikino and fringing the catchment boundary especially along the eastern mountainous section. Brief descriptions of the dominant LUC Class 7 units are as follows.

Twenty-three percent of the catchment consists of steep to very steep hills of consolidated sandstone and massive siltstone below 600 m above sea level. These hills with Recent, Brown, Allophanic, and Podzol soils are in moderate to high (1,200–2,000 mm) rainfall areas, and have a potential for severe soil slip erosion. The revegetation of erosion scars in this terrain is slow. This LUC Class 7e11 land is mapped on 163,400 ha.

Steep to very steep slopes of hard consolidated sandstone with numerous bluffs and slip scars below 600 m above sea level and Recent, Brown, and Podzol soils in moderate to high (1200-2500mm) rainfall areas with a potential for severe soil slip, sheet and debris avalanche erosion is mapped on a further 39 735ha (LUC Class 7e17).

Steep to very steep hills of consolidated massive siltstone and banded mudstone below 600 m above sea level with Brown, Pallic, Recent, and Allophanic soils in moderate to high (>1,200–2,000 mm) rainfall areas with a potential for severe soil slip erosion, and slight sheet, gully and earthflow erosion is mapped on 29,609 ha (LUC Class 7e9).

Steep hills on jointed mudstone and siltstone below 600 m above sea level with fertile Brown, Pallic, Recent, and Allophanic soils in moderate to high (1,200–2,000 mm) rainfall areas with a potential for severe soil slip and shallow earthflow erosion, and moderate gully erosion is mapped on 11,572 ha (LUC Class 7e1).

Steep hills, scarps, and gorges with a variable depth mantle of Taupō air-fall tephra over more weathered tephra over stable rock types below 800 m above sea level with Pumice, Allophanic, and Podzol soils in moderate to high (>1,200–2,000 mm) rainfall areas with a potential for severe sheet erosion and moderate soil slip erosion is mapped on 11,286 ha (LUC Class 7e8).

Components of another 14 LUC Class 7 units make up the balance of the Class 7 land (26,394 ha) in the Whanganui catchment.

LUC Class 8

LUC Class 8 land has very severe to extreme physical limitations or hazards that make it unsuitable for arable, pastoral, or commercial forestry use. Erosion control, water management, and conservation of flora and fauna are the main uses of this land. The most common limitation is extreme actual or potential erosion, often combined with severe climatic and/or soil fertility limitations. LUC Class 8 has been mapped on 52,696 ha (7.4%) of the catchment. Over 77% of this land is classified as one of three LUC units, moderately steep to precipitous slopes dominate and all have the potential for severe to extreme soil slip, debris avalanche, and sheet and gully erosion.

Very steep to precipitous gorges, cliffs and bluffs in mudstone and sandstone hill country below 1000 m above sea level with Raw, Recent, Brown, and Pallic soils in moderate to high (<2000 mm) rainfall areas with a potential for very severe to extreme soil slip erosion was mapped on 22,600 ha (LUC Class 8e3). The majority of this terrain is scattered throughout the mid and upper catchment on the soft sedimentary baserocks.

Very steep to steep long forested mountain slopes on greywacke and indurated igneous rocks up to the treeline, (<1,400 m above sea level), with Pumice, Brown, Recent, and Allophanic soils in high (2,000–4,000 mm) rainfall areas with slight to moderate (to severe) present erosion BUT with a potential for very severe to extreme soil slip, debris avalanche erosion, and moderate to very severe sheet and gully erosion was mapped on 9,350 ha (LUC Class 8e4). This terrain is concentrated in the eastern mountains and on the Hauhungaroa Range.

Moderately steep to precipitous slopes on greywacke and andesite above the treeline (>1,000 m above sea level) with Brown, Podzol, Pumice, and Recent soils in high (2,000–4,000 mm) rainfall areas with slight to moderate wind, sheet, scree and debris avalanche erosion and a potential for extreme erosion was mapped on 8,585 ha (LUC Class 8e8).

Components of another 13 LUC Class 8 units make up the balance of the Class 8 land (12,160 ha) in the Whanganui catchment.

3.6 Erosion and Highly Erodible land

Erosion is widespread in the Whanganui catchment. It has long been recognised that the adverse effects of erosion not only include the degradation of water quality by high suspended sediment loads, but also the degradation of the soil resource, and the reduction of the productive capacity of the land. The combination of the dominance of relatively 'soft' fine-grained sedimentary rocks, the widespread distribution of volcanic ash, regional uplift rates, the relatively high rainfalls, intensities and durations, and the current land cover and land use in the Whanganui catchment, combine to produce a region that is very susceptible to erosion.

Following the February 2004 Manawatu-Whanganui storm, Horizons Regional Council examined options to reduce hill country erosion risk. They commissioned work to improve definitions and guidelines for the assessment of erosion to identify Highly Erodible Land (HEL). HEL is defined as hill country with a potential for 'severe erosion', or hill country with a potential for moderate erosion, but where erosion debris will directly enter waterways (Page et al. 2005). At the regional scale, Page et al. 2005 provided a list of LUC units that fit the HEL criteria and a map of the distribution of HEL.

The areas of hill country LUC Class 6 and 7 units identified as HEL in the Whanganui catchment by Page et al. 2005 are given in Table 5. Over 60% of the catchment comprises hill country which is classed as highly erodible.

Table 5: Hill country LUC Class 6 and 7 units identified as HEL in the Whanganui catchment

Terrain and main erosion types	Total area (ha)	area of LUC Class 6 (ha)	area of LUC Class 7 (ha)
Consolidated sandstone hill country, shallow landslide erosion	303264	94304	208960
Moderate to unconsolidated sandstone hill country, shallow landslide, and gully erosion	5701	2517	3184
Mudstone hill country, shallow landslide erosion	87016	68261	18755
Mudstone hill country, earthflow erosion	24378	23297	1081
Greywacke hill country, shallow landslide, and scree erosion	11286	na	11286
Total hill country HEL	431645		

The areas of highly erodible land without a protective woody vegetation cover as determined by the EcoSat woody layer (http://landcareresearch.co.nz/services/ecosat/) as in 2012 are given below in Table 6, and their distribution in Figure 40.

Table 6: Type of HEL in the Whanganui catchment without protective woody cover in 2012.

Type of unprotected highly erodible land	Area (ha)	% catchment
Severe landslide erosion delivering sediment to watercourse	48363	6.8
Severe landslide erosion NOT delivering sediment to watercourse	25879	3.64
Moderate earthflow risk	15035	2.11
Severe earthflow risk	591	0.08

The areas of HEL unprotected by woody cover by major sub-catchment are shown on Table 7. Eighty-seven perecent of the HEL with severe landslide erosion delivering sediment directly to watercourses is concentrated in the central region of the catchment, especially in the Middle Whanganui, Lower Whanganui, Ohura, Retaruke, Tangarakau and Manganui-a-te-ao sub-catchments. The eastern sub-catchments draining the Tongariro Volcanic Zone and the Hauhungaroa Range contain only 8% of the HEL with severe landslide erosion delivering sediment directly to watercourses.

Table 7: Areas of HEL unprotected by woody cover by sub-catchment

Sub-catchment	HEL with severe landslide erosion delivering sediment to watercourse (ha)	HEL land with severe landslide erosion NOT delivering sediment to watercourse (ha)	HEL with a moderate earthflow risk (ha)	HEL with a severe earthflow risk (ha)
Middle Whanganui	9374	3605	1181	92
Lower Whanganui	8850	3299	582	na
Ohura	8456	7018	3466	na
Retaruke	6305	2535	498	26
Tangarakau	4799	3878	368	63
Manganui-a-te-ao	4535	1338	106	na
Ongarue	3179	2088	6065	207
Whangamomona	2220	1480	na	25
Upper Whanganui	629	635	2769	179
Whakapapa	15	3	na	na

The majority of the HEL without a protective woody vegetation cover is pastoral hill country. The application of the standard range of soil conservation techniques, space planting, afforestation, controlled grazing to maintain a vigorous vegetative cover, debris dams, sediment traps, revegetation and riparian management would be expected to reduce the volumes of fine suspended sediment delivered to the waterways. Because of the characteristics of the terrain in the Whanganui catchment an emphasis on control-at-source is likely to be more effective.

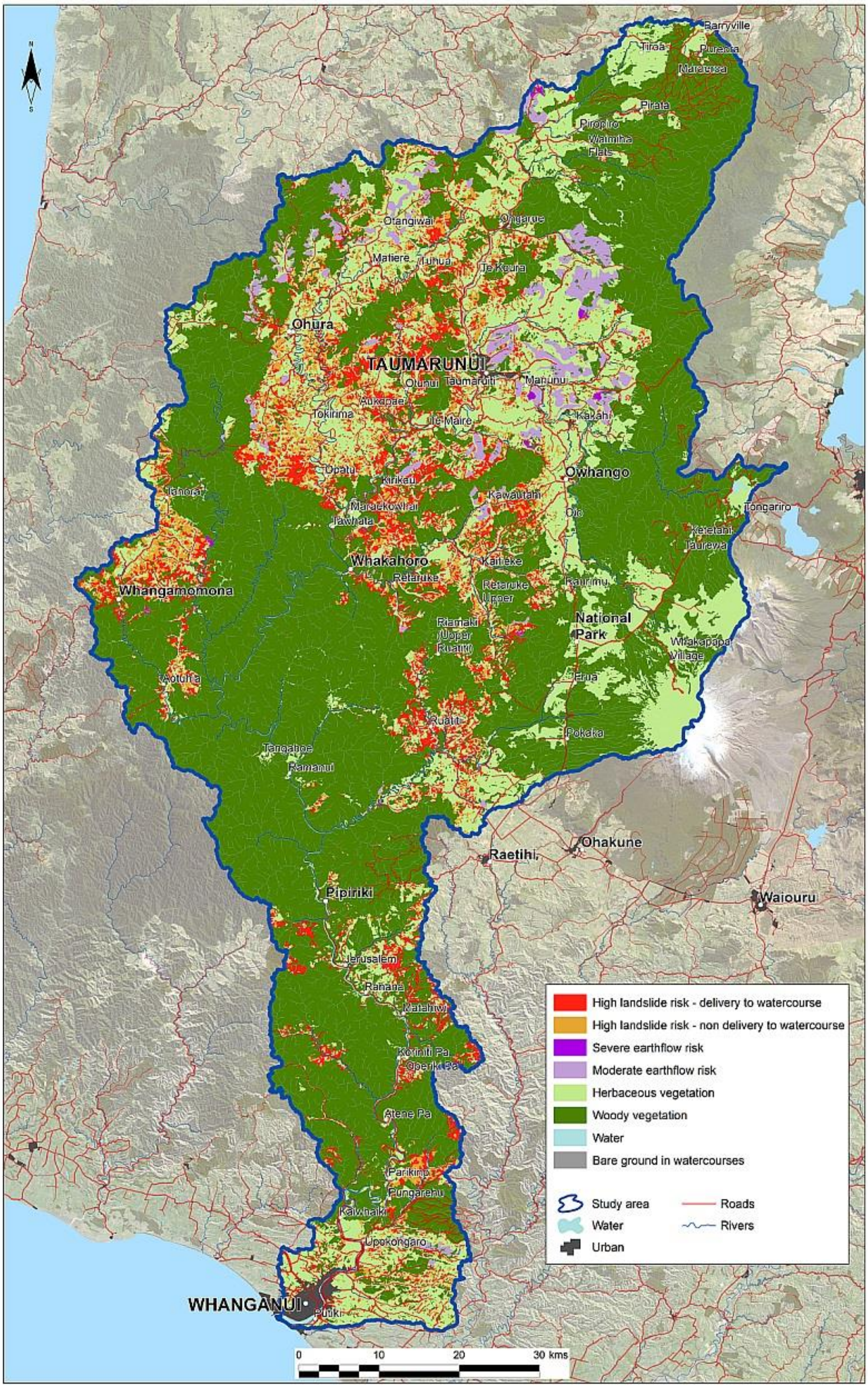

Figure 40: Distribution of highly erodible land identified in 2012, and woody vegetation cover for the Whanganui catchment.

3.7 Land cover and land use

3.7.1 Land cover

Originally the Whanganui catchment was almost entirely covered in forest, except for the mountain slopes above the bushline and the coastal dune country. Podocarp-broadleaved forest dominated the upper catchment region of the Taumarunui ecological district (ED) (Bibby et al. 2000), and podocarp-hardwood forest with black beech on the dry ridges in the mid and lower catchment region of the Matemateaonga ED (Ravine 1996). In the Taumarunui ED, extensive milling operations over the past century, followed by farming, have resulted in the loss of forest cover over much of this area. Currently most indigenous forest is absent from the valley floors and gently sloping land, although forest remnants are common throughout the hill country, with extensive tracts present along the eastern boundary on the Hauhungaroa Range. In the steep hill country of the Matemateaonga ED substantial areas are still forested or are now in an advanced state of reversion.

Analysis of the dominant vegetation as recorded in the NZLRI for the Whanganui catchment indicates that during the 1976–79 period, over 400,432 ha (56%) were covered by native forest or scrub, including land in an advanced state of reversion (Table 8, Fig. 41). At that time, improved and semi improved pasture occupied 273,395 ha (38%). Only 12,220 ha of exotic forest was present in the catchment in the mid- to late-1970s. Over 2% (16,624 ha) was mapped as alpine grassland or herbfields. Wetlands, exotic scrub, cropland, and sand dune vegetation were mapped on the balance of the catchment.

Table 8: Land Cover in the Whanganui catchment from 1970s to 2012 from the New Zealand Land Resource Inventory and New Zealand Land Cover Database

SOURCE (year)	**NZLRI (1976-79)**		**LCDB (1996)**		**LCDB (2001)**		**LCDB (2008)**		**LCDB (2012)**	
	area ha	**%**	**area ha**	**%**	**area ha**	**%**	**area ha**	**%**	**area ha**	**%**
Cropland	116	0.0	584	0.1	798	0.1	960	0.1	996	0.1
Pasture grassland	273395	38.4	255408	35.9	244970	34.4	245279	34.5	246169	34.6
Tall tussock grassland	9268	1.3	8167	1.1	8167	1.1	8167	1.1	8167	1.1
Alpine herbfield	10602	1.5	1648	0.2	1648	0.2	1648	0.2	1648	0.2
Indigenous forest	246110	34.6	262956	36.9	262830	36.9	262769	36.9	262748	36.9
Indigenous scrub	154322	21.7	118433	16.6	118775	16.7	117352	16.5	115569	16.2
Exotic Forest	12220	1.7	45407	6.4	55349	7.8	56253	7.9	57292	8.0
Exotic scrub	590	0.1	5612	0.8	5611	0.8	5665	0.8	5490	0.8
Wetlands	793	0.1	3504	0.5	3504	0.5	3494	0.5	3494	0.5
Unvegetated & Dunelands	189	0.0	4279	0.6	4306	0.6	4313	0.6	4317	0.6
Lakes & Rivers	1488	0.2	2610	0.4	2611	0.4	2611	0.4	2611	0.4
Built-up areas	2667	0.4	3155	0.4	3194	0.4	3254	0.5	3263	0.5
Total Area	**711,766 ha (7118 km^2)**									

The distribution of vegetation classes as mapped in the New Zealand Land Cover Database (Version 4.2) (LCDB4) c. 2012 are shown in Figure 42. Although the vegetation classifications used in the NZLRI and LCDB are not exactly the same, broad correlations are possible (Table 8).

Between c. 1976–79 and c. 2012 the area of pasture grassland within the catchment has decreased slightly from 38% and 35% respectively. Native forest and scrub appears to have decreased from 56% in the late 1970s to 53% in c. 2012. It is most likely that the significant increase in exotic forest to 57,290 ha c. 2012 has taken place on terrain formerly mapped as grassland or reverting the scrubland. There has been a significant increase in exotic forest mapped in the lower catchment centred on Pungarehu, and in the mid-catchment to the north east of Pipirki, between Kaitieke and Raurimu, and west of Owhango on land mapped as improved and semi improved grassland in the 1970's. In the north-eastern catchment, exotic forest has replaced scrub land to the west of Okahukura, to the east of Ongarue, and to the east of Piropiro. There have also been significant areas of conversion of former grassland to exotic forest centred on Tapuiwahine. There is an apparent increase in cropland from the late 1970s, from 116 to 997 ha, and in the area mapped as 'wetland' vegetation.

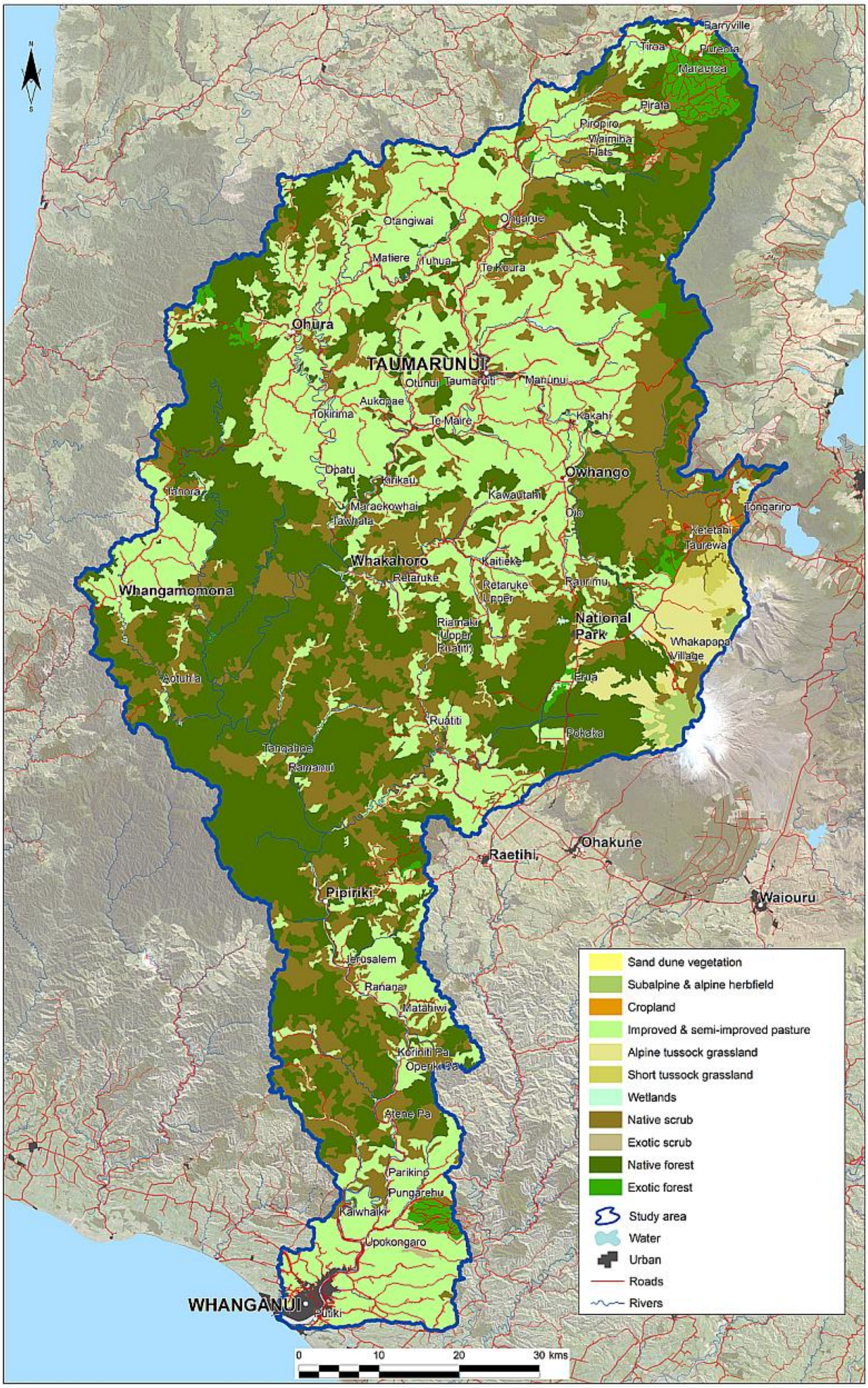

Figure 41: Dominant vegetation cover from the NZLRI (c. 1976–79) for the Whanganui catchment.

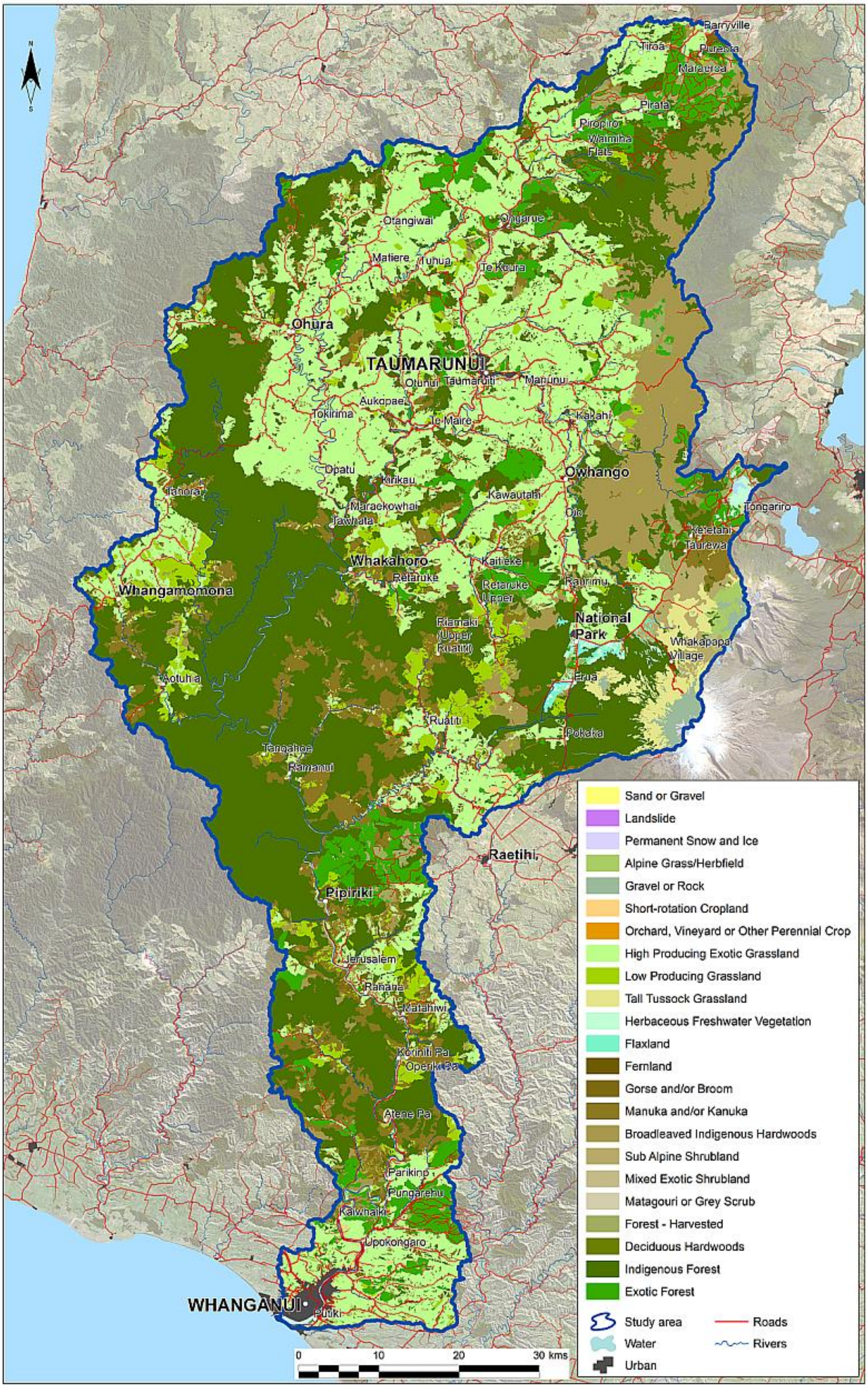

Figure 42: Land cover from the New Zealand Land Cover Database (LCDB v4.1, c. 2012) for the Whanganui catchment.

3.7.2 Land use

A high-level land use classification was devised using public-domain New Zealand Land Cover Database (Version 4.1) and NZLRI data (NWASCO 1975–79) informed by knowledge of the region. This classification was mapped (Fig. 43) and analysed (Table 9) below. The figures, based primarily on 2012 data, approximate the present state of land use in the Whanganui catchment.

Table 9: Land use in the Whanganui catchment, based primarily on 2012 data

Use Category	Land Use	Area (km2)	Percent
Protection	Forestland	2,628	36.9
	Shrubland	1,211	17.0
	Tussockland & Barrens	156	2.2
	Wetland & Flaxland	35	0.5
Production	Horticulture & Cropping	10	0.1
	Intensive Pastoral Agriculture	298	4.2
	Semi-intensive Pastoral Agriculture	612	8.6
	Extensive Pastoral Agriculture	1,536	21.6
	Exotic Plantation Forestry	573	8.0
Other	Urban & Infrastructure	33	0.5
	Water	26	0.4
TOTAL		7,118	100

'Protection' land covers over 56% of the catchment, most clothed in woody vegetation (54%) but including tussocklands, wetlands and alpine/barren areas. Almost all land not in productive use is considered to be performing some 'protective' role, either actively, because they are in the conservation estate, or passively, because they are reverting or otherwise clothed with protective vegetation. Historically, there have been big swings in the area of woodlands outside the conservation estate, with scrublands being cleared when the economy favoured agriculture, and left to revert when conditions were less favourable.

'Production' land use includes pastoral agriculture, silviculture and horticulture and occurs on a little over 42% of the catchment. Pastoral agriculture is concentrated in the upper catchment, centred on Taumarunui, and in the lower catchment within 20 km of Whanganui. Stocking rates are generally moderate to low (< 14 stock units per hectare) apart from on the narrow floodplains and coastal terraces, and on the ring-plain components of the landscape. Exotic Plantation Forestry is distributed along the length of the catchment where roading permits economic extraction to processing facilities. Exotic forestry has increased significantly from 12,220 ha in the mid- to late-1970s, to over 57,292 ha in 2012. Horticulture and Cropping have a very restricted distribution, being conspicuous only around Ohakune with patches in the vicinity of Matiere, Taumarunui and Whanganui.

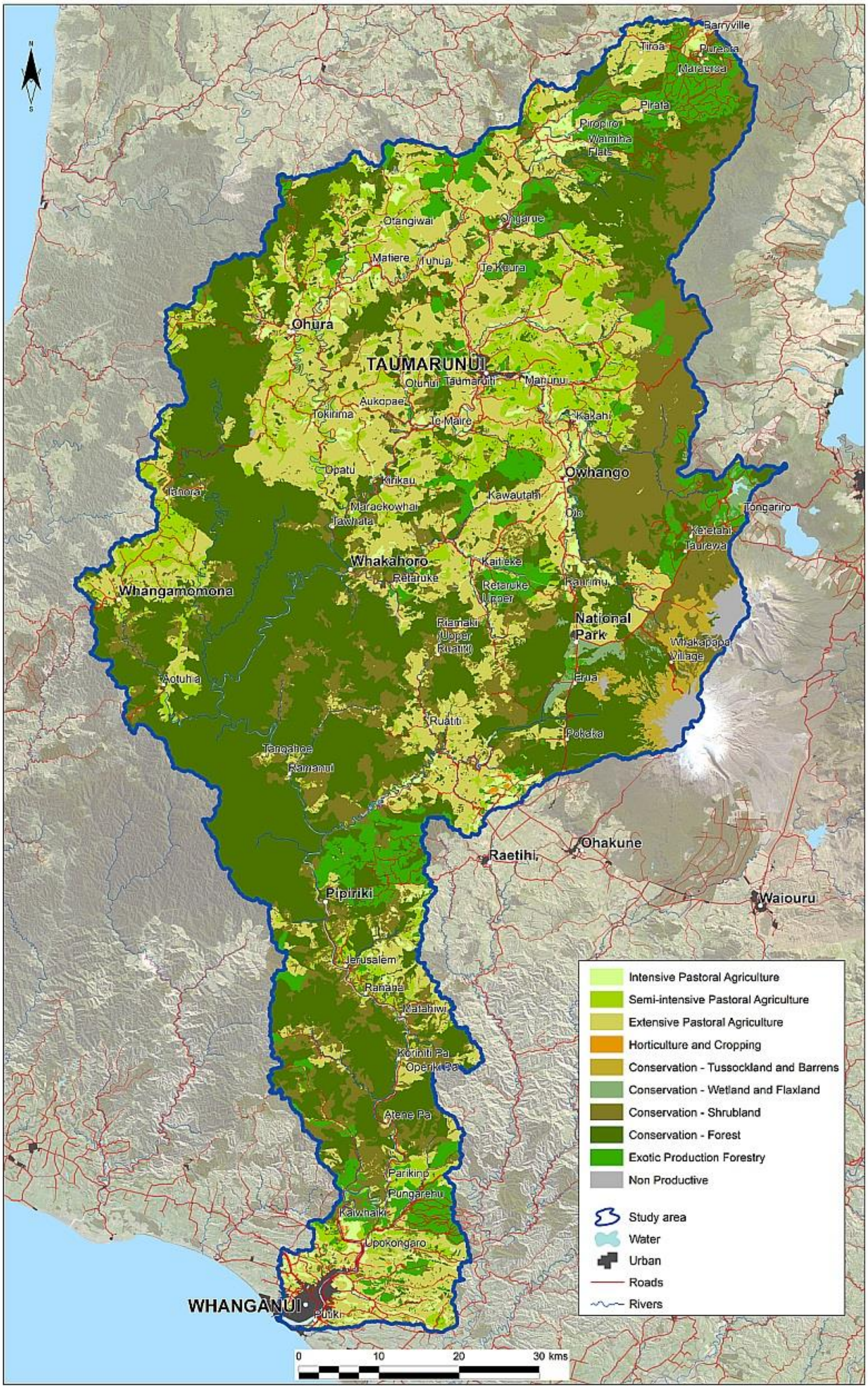

Figure 43: Land use in the Whanganui catchment (c. 2012).

3.8 Information gaps and Recommendations

Current information on the physical environment for the Whanganui catchment is reasonably comprehensive for regional scale analysis, and the establishment of the key elements determining its distinctive landscape features, with the exception of detailed soils data.

The 5 broad physiographic units recognised in the catchment reflect the combination of the underlying rock type's relative hardness and permeability, regional uplift rates, rainfall (total, intensity, and duration), and erosion susceptibility. The region is dominated by the large expanse of subdued topography, underlain by soft Miocene to Pleistocene sediments of mainly fine-grained sandstone, siltstone, and mudstone. This landscape of deeply dissected hill country, with narrow ridge crests, moderately steep to steep sloping valley sides, deeply incised dendritic drainage pattern and very small and narrow or no floodplains, is vulnerable to erosion and the production of large volumes of fine sediment.

The Whanganui catchment is characterised by its limited amount of high quality land, the predominance of non-arable land, and its significant proportion of moderately steep to steep land with severe physical limitations to productive use. Over 45% of the catchments soils are developed from volcanic ash, of variable natural fertility, susceptible to sheet and shallow landslide erosion. The steep to very steep, ash-free sandstone terrain is also very susceptible to shallow landslide and sheet erosion under pasture.

This highly erodible land has been identified. The application of the standard range of soil conservation techniques, space planting, afforestation, retirement, controlled grazing to maintain a vigorous vegetative cover, debris dams, sediment traps, revegetation, and riparian management would be expected to reduce the volumes of fine suspended sediment generated and delivered to the waterways, and thus improve water quality. Because of the characteristics of the terrain, an emphasis on 'control-at-source', of the areas and points of sediment generation is likely to be most effective.

It is also critical to match sustainable land use with land capability, establish best management practice guidelines, and to monitor these activities.

4 Terrestrial ecosystems, biodiversity and taonga species

4.1 How the natural vegetation of the Whanganui catchment has developed

When Māori first arrived in the Whanganui region in the late 13th or early 14th century, they would have encountered a region almost entirely forested, from the sand dunes at the mouth of the river along the river valleys and to the tops of nearly all he mountains except Ruapehu, where a natural treeline forms and alpine vegetation begins. It had not always been this way. The cold climates that attended successive Ice Ages (during the Pleistocene epoch, from about 2,588,000 to 11,700 years ago) reduced forest cover throughout the region to small patches in a matrix of shrubland and grassland (Fig. 44). Forest patches remaining in the region at the end of the last glacial advances began to spread out to cover the region from about 12,000 years ago.

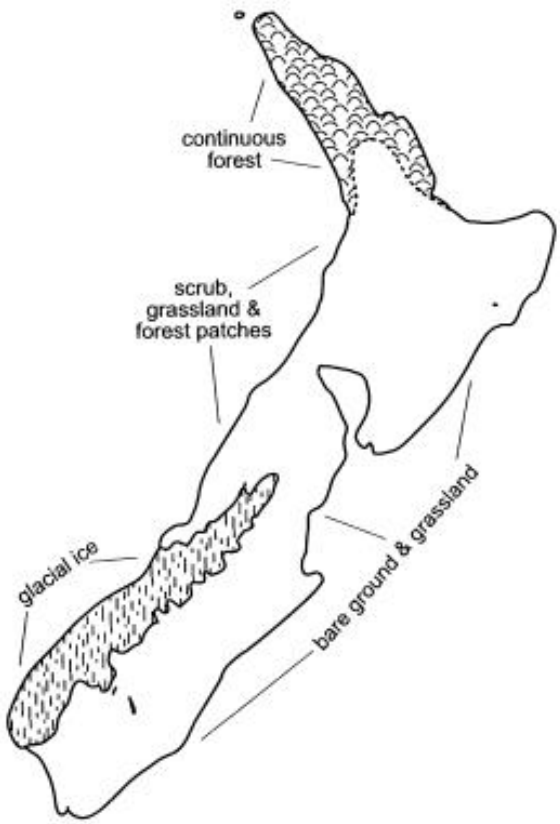

Figure 44: Distribution of glacial ice, continuous forest, and lowered shoreline at the height of the last glaciation, about 20,000 years ago (reproduced from McGlone et al. 2001).

The net effect of successive glacial advances is the likely reason for local extinctions of some native plants that were in the region before then. This is also the most likely reason for some of the local distributions of some tree species. The distribution of the beeches (tawhai and hututawhai, *Nothofagaceae*) is a good example of this in the modern forests of the Whanganui River catchment. Beeches are slow to spread from patches left behind so this is likely to be the reason for their current absence from ranges that are otherwise identical in geology and soils to those nearby (notably they are absent from the Matemateaonga Range; Wardle 1984; Nicholls 1956, 1989a). Successive glacial advances are also likely to be the reason that some trees that occur in the very northern part of the Whanganui region extend no further south, including trees such as tānekaha (*Phyllocladus trichomanoides*), tāwheowheo (*Quintinia serrata*), mountain neinei (*Dracophyllum traversii*) (Wardle 1991; Barkla 1992; Bibby et al. 2000; McGlone et al. 2001). For these, it is unlikely that current climate or soils south of their current distributions are unsuitable for them but rather that they were driven north and eliminated from much of the Whanganui catchment, and that, so far, they have not recolonised their former range. These trees occur in the northern South Island, and there are fossils of these and other species (even kauri, *Agathis australis*) from near the mouth of the Whanganui River that date from 400,000 years ago, before the most recent glaciations (Bussell 1986; Kohn et al. 1992).

An implication is that we should not expect forests of the region to be in equilibrium with the environment. They are adjusting still to the effects of past climates. Even in the period since the last glaciation climate has not been stable, so that some native trees became more common and then less so before Māori settlement. For example, a very humid period between 5000 and 10,000 years ago favoured hutu (*Ascarina lucida*) so that it became much more abundant in the forests then than it is now (McGlone & Moar 1977).

The forests are also dynamic because of the effects of current natural disturbances. The steeply eroding hill country is prone to landslides, even with forest cover present, and forest regeneration on landslides creates a mosaic in terms of forest age and the tree species that they comprise. On recent landslides, trees such as tutu (*Coriaria arborea*) are common, but they do not persist as the forests age. On floodplains, silt and alluvium can bury or fell some forests, while affording new opportunities for species that are common in these sites to regenerate, such as kahikatea (*Dacrycarpus dacrydioides*, Duncan 1993). Volcanic eruptions (from Taranaki, Ruapehu) locally alter soil fertility, and could favour local dominance by some species (Smale et al. 2016; Veblen et al. 2016). Major storms, including infrequent but intense tropical cyclones, can have major effects, felling mature trees at sometimes large scales (Martin & Ogden 2006). All these natural disturbances, and the interactions among them, determine the structure and composition of the forests of the region, providing circumstances that favour some tree species over others at a range of scales (Allen et al. 2013).

4.2 Characterising the vegetation of the Whanganui catchment

The National Forest Survey of the late 1940s to the early 1950s was a major effort to characterise New Zealand's natural forests and their resources (Thomson 1946; Masters et al. 1957). This systematic survey across New Zealand covered most of the larger forested areas of the Whanganui River catchment, and classified broad Forest Classes that are recognised nationally (McKelvey & Nicholls 1957; Nicholls 1976). These Forest Classes were mapped for the Whanganui River catchment (Nicholls 1989a, b; Table 10, Fig. 45).

Rimu–Tawa forests occupy nearly half of today's indigenous forest of the Whanganui River catchment, and this is the typical forest class of the western hill country (Nicholls 1956, 1989b; Fig. 45). In this forest scattered, and occasionally large, rimu (*Dacrydium* *cupressinum*) and, more frequently, northern rātā (*Metrosideros robusta*) tower above dense canopies composed mostly of tawa (*Beilschmiedia tawa*). Kāmahi (*Weinmannia racemosa*) becomes more prevalent in the canopy with increasing elevation (up to 750 m), and rewarewa (*Knightia excelsa*) is locally frequent.

General Hardwoods, which comprise nearly a quarter of the forest in the catchment, are the next most extensive forest class, and are scattered throughout the catchment especially in the centre and northeast (Fig. 45). These are secondary forests that have regrown since the near-complete destruction of the original tall forest by either fire, and heavy logging, or clearance for and later abandonment of agriculture (Nicholls 1956, 1989a, b). These forests are often dense, with common species including kāmahi, kānuka (*Kunzea serotina* and *K. robusta*), mānuka (*Leptospermum scoparium*), māhoe (*Melicytus ramiflorus*), and the tree ferns wheki (*Dicksonia squarrosa*) and kātote (*Cyathea smithii*).

Rimu–Tawa–Beeches comprise a fifth of today's forest. They occur in the western hill country (Fig. 45), where black beech (*Fuscospora solandri*) and hard beech (*F. truncata*) are the beeches in this forest class. The beeches occur on narrow ridges and clifftops in these forests, but not above 480 m elevation (Nicholls 1989a). Where both species are present, black beech tends to occupy the sharpest and most infertile spurs and ridges (Wardle 1984). Mixtures of the two beech species occur in the north-western part of the catchment. In the central and southern western uplands only black beech is present, and there are no beeches on the Matemateaonga Range (Nichols 1956; Wardle 1984). Where beeches are on the ridge crests, Rimu–Tawa forests are on the broader ridges and in the valleys.

Tawa, at 19% of the forest of the catchment, is the next most extensive forest class. This is the logged variation of the Rimu–Tawa forest class from which rimu and other conifers, and even northern rātā, have been logged so heavily that, as adults, they are either not present or substantially reduced (Nicholls 1989a, b). Some of this forest was also affected by fires. The forest class is most extensive in the upper part of the Whanganui River catchment, e.g. around Owhango, which was a town dependent on commercial logging. Tawa is also in some of the western hill country (Nicholls 1956) and the southern part of the catchment (Fig. 45), where it has developed as an outcome of partial burning and occasional selective extraction of timber trees (Nicholls 1989b). Tawa is a more-or-less continuous cover, with lesser amounts of kāmahi and rewarewa.

Rimu–Mataī–Hardwoods comprise 9% of today's forest. In this forest class, conifers, especially rimu and mataī (*Prumnopitys taxifolia*), some scattered kahikatea and, below 650 m elevation, tōtara (*Podocarpus totara*) are moderately abundant over a canopy of flowering trees that include kāmahi, black maire (*Nestegis cunninghamii*), hīnau (*Elaeocarpus dentatus*), pōkākā (*Elaeocarpus hookerianus*), and pāpāuma (*Griselinia littoralis*). Some of the major examples are in the north-eastern upper part of the catchment, on volcanic soils from Ohakune to Raurimu, especially on pumice terraces (Nicholls 1989b). There are fragments in the hill country of the lower parts of the catchment; those in Department of Conservation Scenic Reserves are all less than 50 ha (Bayfield et al. 1986; Fuller & Edwards 1989).

Lowland-Steepland and Wetland and Highland Softwoods Hardwoods (8% of the forest) include stands of kahikatea in the lowlands and upland poorly drained forests of silver pine

(*Manoao colensoi*), bog pine (*Halocarpus bidwilliii*) and others on the slopes of Mount Hauhangatahi and other areas (Ogden et al. 1991).

Tawa–Beeches (7% of the forests) are the logged variation of the Rimu–Tawa–Beeches (i.e. the conifer component removed). The beech components on ridges include some mature relict patches, and in other cases are abundant secondary stands of beech. The valleys and gullies are heavily modified by logging, and now-abandoned agriculture. Steep upper slopes contain kāmahi, kānuka, and rewarewa (Nicholls 1989b).

Highland Softwoods Beeches also comprise 5% of the forests. These are predominantly mountain beech (*Fuscospora cliffortioides*) forests in Tongariro National Park (Ogden et al. 1993), which also contain conifers such as kaikawaka (*Libocedrus bidwillii*), mountain toatoa (*Phyllocladus alpinus*), and pink pine (*Halocarpus biformis*).

Another three forest classes in the Whanganui River catchment collectively comprise 5% of the indigenous forests (none individually more than 2%), and a further 3% of the forests are unclassified (Fig. 45).

Table 10: Forest types found in the Whanganui River Catchment. Data adapted from NZ Forest Service Indigenous forest class maps, Sheets 9/11, Taranaki (1990) and 12, Ruapehu (1991)

Forest Type	Total Area (Hectares)	Percentage of forested area
General Hardwoods	64,694	24
Highland Softwoods Beeches	12,904	5
Lowland Wetland & Highland Softwoods Hardwoods	21,846	8
Rimu General Hardwoods	5,348	2
Rimu General Hardwoods Beeches	4,210	2
Rimu Matai Hardwoods	23,652	9
Rimu Tawa	122,888	46
Rimu Tawa Beeches	56,244	21
Softwoods	1,852	1
Tawa	49,777	19
Tawa Beeches	19,208	7
Unclassified	8,985	3
Total	**382,624**	**100**

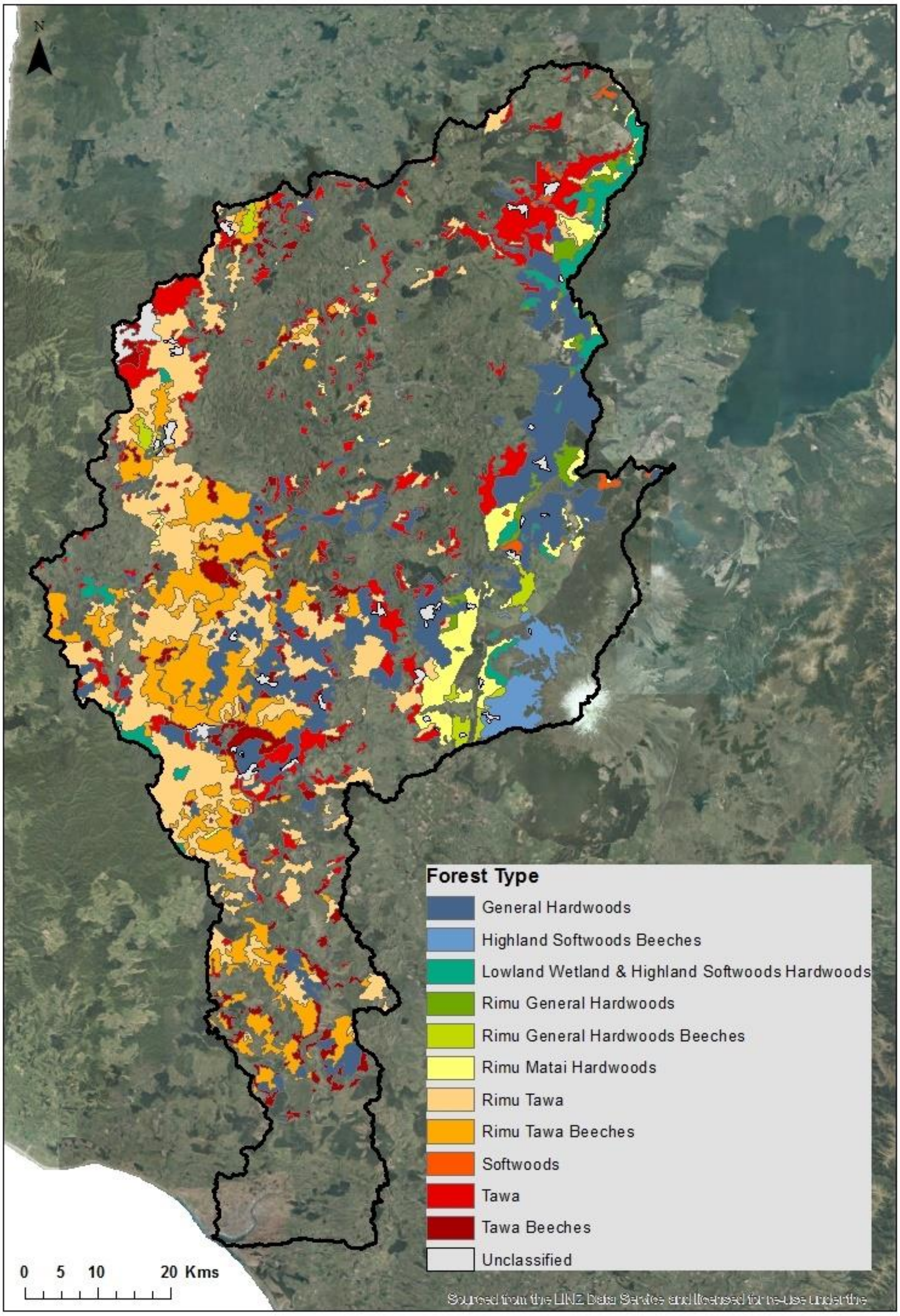

Figure 45: Forest classes (Nicholls 1989a, b) of the Whanganui River catchment.

Other non-quantitative classifications of the forests and shrublands have been applied to parts of the catchment, for example, as part of the surveys of Department of Conservation Scenic Reserves within the catchment (Bayfield et al. 1986; Fuller & Edwards 1989), and surveys conducted as part of the Protected Natural Areas Programme (Ravine 1996; Bibby et al. 2000), the subjects of which were mostly small forest or shrubland fragments. Non-quantitative classifications of forest were completed for Whanganui National Park (unpublished data from W. Baxter; Department of Conservation 2012):

1. Silver beech (*Lophozonia menziesii*) forests in the Retaruke area
2. Northern rātā–kāmahi forests on the Matamateaonga Range
3. Tāwheowheo–tawa forests
4. Hard beech–tāwheowheo–black beech forests in the Retaruke area
5. Lowland terrace forest remnants in the Whanganui River basin.

Quantitative evaluations of the vegetation of indigenous forests and shrublands across the Whanganui River catchment generally support non-quantitative classifications such as those of Figure 45 and Table 10. For example, an evaluation of 470 plots across 50 randomly located transects within Whanganui National Park, in which vegetation cover was quantified in each plot (Hawcroft & Husheer 2009), classified the forests and shrublands as:

1. Beech: Plots where beech was present, regardless of other species present
2. Tawa: Plots where tawa had the highest cover score
3. Kāmahi: Plots where kāmahi had the highest cover
4. Mixed: Plots where tawa and kāmahi had the equal highest cover scores
5. Seral vegetation, i.e. young stages of forest development after disturbance, with common species including makomako (*Aristotelia serrata*), rangiora (*Brachyglottis repanda*), putaputawētā (*Carpodetus serratus*), tutu, mānuka, and others (Levy 1923a, b)
6. Unclassified: Plots where any other species (e.g. porokaiwhiri, *Hedycarya arborea*) had the greatest cover scores.

It is apparent that quantitative approaches such as these achieve closest matches to those that emphasise flowering trees (beeches, tawa), but they de-emphasise scattered, large conifers (rimu, mataī). Seral vegetation, as described by Hawcroft and Husheer (2009) corresponds most closely with the General Hardwoods forest class described by Nicholls (1989a, b).

From the early 2000s until the present, forests and shrublands nationally have been quantified in composition, structure and growth in a systematic approach, siting permanent 0.04 ha plots on a 8-km x 8-km grid superimposed across all areas mapped as indigenous forest or shrubland. These data are used to evaluate the total carbon stored and rates of carbon storage in forests and shrublands (the Land Use Carbon Analysis System (LUCAS)). The data provided the basis for an objective classification of New Zealand’s forest and shrubland communities (Wiser et al. 2011), further revised by Wiser and De Cáceres (2013).

Data from the most recent measurement of these plots across all forests and shrublands in the Whanganui River catchment (2009–2014) show that there are 10 forest and shrubland alliances (Table 11) and 18 associations (Table 12). The alliances and associations were assigned to the fifty-four LUCAS plots in the Whanganui catchment, amended from Wiser (2016). Thirty-two plots were assigned based on LUCAS 2009–2014 measurement, 12 plots were assigned based on LUCAS 2002–2007 measurement, and three plots based on DOC Tier 1 2011–2014 measurement. Seven plots were not assigned to an alliance or association as data were not available. The highest number of plots (14) were assigned to the Tawa forest association (Table 11).

Table 11: Vegetation alliances found in the Whanganui River Catchment. Alliances are defined in Wiser and De Cáceres (2013), plot assignment is based on Wiser (2016)

Species-group-based category	Alliance code	Alliance Scientific Name	Alliance Common Name	Number of Plots
BEECH-BROADLEAVED-PODOCARP FOREST	A: BBPF2	*Pseudowintera colorata – Griselinia littoralis – Fuscospora fusca* (*Lophozonia menziesii*) / *Microlaena avenacea* forest and successional shrubland	Pepperwood–hardwood forest and successional shrubland	4
BEECH-BROADLEAVED-PODOCARP FOREST	A: BBPF3	*Weinmannia racemosa – Cyathea smithii – Prumnopitys ferruginea / Blechnum discolor* forest	Kāmahi forest	2
BEECH-BROADLEAVED-PODOCARP FOREST	A: BBPF4	*Weinmannia racemosa – Cyathea dealbata – Knightia excelsa* (*Beilschmiedia tawa*) / *Leucopogon fasciculatus* forest	Kāmahi – silver fern forest	9
BEECH FOREST	A: BF2	*Fuscospora solandri – Lophozonia menziesii / Coprosma pseudocuneata – Hymenophyllum multifidum* forest	Black/mountain beech – silver beech forest/subalpine shrubland	1
BROADLEAVED-PODOCARP FOREST (including kauri)	A: BPF2	*Melicytus ramiflorus – Cyathea smithii – Dicksonia squarrosa – Carpodetus serratus (Beilschmiedia tawa)* forest	Mahoe forest	8
BROADLEAVED-PODOCARP FOREST (including kauri)	A: BPF3	*Beilschmiedia tawa – Weinmannia racemosa – Melicytus ramiflorus / Ripogonum scandens* forest	Tawa forest	14
BROADLEAVED-PODOCARP FOREST (including kauri)	A: BPF4	*Cyathea dealbata – Melicytus ramiflorus – Freycinetia baueriana – Ripogonum scandens* forest	Silver fern – mahoe forest	2
BROADLEAVED-PODOCARP FOREST (including kauri)	A: BPF5	*Pseudowintera colorata – Fuchsia excorticata – Griselinia littoralis / Polystichum vestitum* forest	Pepperwood – fuchsia – broadleaf forest	3
OTHER FOREST	A: OF1	*Kunzea ericoides – Cyathea dealbata* – (*Leptospermum scoparium*) / *Leucopogon fasciculatus* (*Coprosma rhamnoides*) forest and tall shrubland	Kānuka forest and tall shrubland	1
SHRUBLANDS	A: S2	(*Kunzea ericoides*) / *Coprosma rhamnoides / Dactylis glomerata – Anthoxanthum odoratum* successional shrubland	Grey scrub with kānuka	3

Table 12: Vegetation associations found in the Whanganui River Catchment. Associations are defined in Wiser and De Cáceres (2013), plot assignment is based on Wiser (2016)

Species-group-based category	Association code	Association Scientific Name	Association Common Name	Number of Plots
BEECH-BROADLEAVED-PODOCARP FOREST	a: BBPF1	*Weinmannia racemosa – Nothofagus solandri – Metrosideros umbellata – Podocarpus hallii / Coprosma foetidissima / Blechnum discolor* forest	Kāmahi – mountain beech – southern rata – Hall's totara forest	2
BEECH FOREST	a: BF22	*Weinmannia racemosa – Nothofagus solandri – Cyathea dealbata – Knightia excelsa* / *Leucopogon fasciculatus* forest	Kāmahi – black/mountain beech – rewarewa – silver fern forest	6
BROADLEAVED FOREST	a: BL2	*Beilschmiedia tawa – Melicytus ramiflorus – Hedycarya arborea – Knightia excelsa* / *Cyathea dealbata – Ripogonum scandens* forest	Tawa – māhoe – pigeonwood – rewarewa forest	1
BROADLEAVED FOREST	a: BL3	*Fuchsia excorticata – Pseudowintera colorata – Griselinia littoralis – Nothofagus menziesii* / *Blechnum fluviatile* forest	Fuchsia – horopito – broadleaf forest with silver beech	1
BROADLEAVED FOREST	a: BL4	*Melicytus ramiflorus – Hedycarya arborea – Beilschmiedia tawa / Schefflera digitata* / *Ripogonum scandens – Asplenium bulbiferum* forest	Māhoe – pigeonwood – tawa forest	1
BROADLEAVED FOREST	a: BL6	*Melicytus ramiflorus – Weinmannia racemosa – Carpodetus serratus* / *Cyathea smithii – Coprosma grandifolia* / *Microlaena avenacea* forest	Māhoe – kāmahi – marbleleaf forest	3
BROADLEAVED-PODOCARP FOREST	a: BLP1	*Beilschmiedia tawa – Melicytus ramiflorus – Hedycarya arborea / Cyathea dealbata – Freycinetia banksii – Ripogonum scandens* forest	Tawa – māhoe – pigeonwood forest with silver fern	1
BROADLEAVED-PODOCARP FOREST	a: BLP13	*Weinmannia racemosa – Pseudowintera colorata – Carpodetus serratus – Griselinia littoralis / Asplenium flaccidium – Blechnum discolor* forest	Kāmahi – horopito – marbleleaf – broadleaf forest with crown fern	2
BROADLEAVED-PODOCARP FOREST	a: BLP15	*Weinmannia racemosa – Hedycarya arborea* (*Melicytus ramiflorus*) / *Dicksonia squarrosa – Freycinetia banksii – Ripogonum scandens* forest	Kāmahi – pigeonwood forest with hard fern and kiekie	1
BROADLEAVED-PODOCARP	a: BLP16	*Weinmannia silvicola – Beilschmiedia tarairi – Beilschmiedia tawa*	Tawhero – tarairi – tawa forest with	2

FOREST		– (*Dysoxylum spectabile – Agathis australis*) / *Freycinetia banksii – Dicksonia squarrosa* forest	kohekohe and kauri	
BROADLEAVED-PODOCARP FOREST	a: BLP2	*Beilschmiedia tawa – Weinmannia racemosa* – (*Melicytus ramiflorus*) / *Cyathea smithii* / *Metrosideros diffusa – Ripogonum scandens* forest	Tawa – kāmahi forest with hard and soft tree ferns	1
BROADLEAVED-PODOCARP FOREST	a: BLP3	*Beilschmiedia tawa – Weinmannia racemosa – Hedycarya arborea* / *Cyathea smithii – Dicksonia squarrosa* / *Blechnum discolor* forest	Tawa – kāmahi forest – pigeonwood forest with hard and soft tree ferns	6
BROADLEAVED-PODOCARP FOREST	a: BLP4	*Beilschmiedia tawa – Weinmannia racemosa – Hedycarya arborea* – (*Knightia excelsa*) / *Cyathea dealbata – Ripogonum scandens* forest	Tawa – kāmahi forest – pigeonwood forest with silver fern	6
BROADLEAVED-PODOCARP FOREST	a: BLP7	*Metrosideros umbellata – Griselinia littoralis – Pseudowintera colorata / Raukaua simplex – Coprosma foetidissima / Microlaena avenacea* forest	Southern rata – broadleaf – horopito forest	1
BEECH-PODOCARP FOREST	a: BP4	*Nothofagus truncata–Weinmannia racemosa* / *Blechnum discolor* forest	Hard beech – kāmahi forest with crown fern	1
OTHER FOREST	a: OF1	*Kunzea ericoides – Cyathea dealbata – Geniostoma rupestre – Melicytus ramiflorus / Coprosma rhamnoides – Leucopogon fasciculatus* forest	Kānuka – silver fern – hangehange – mahoe forest	7
SHRUBLANDS	a: S13	*Dracophyllum pronum* / *Phyllachne colensoi – Anisotome flexuosa* – (*Poa colensoi – Raoulia grandiflora*) subalpine shrubland	Trailing neinei subalpine shrubland	2
SHRUBLANDS	a: S2	(*Kunzea ericoides*) / *Coprosma rhamnoides* / *Dactylis glomerata – Anthoxanthum odoratum – Plantago lanceolata* – (*Agrostis capillaris*) successional shrubland	Grey scrub with kanuka and exotic grasses	3

Since 1946 a range of types of vegetation plots measured throughout the Whanganui River catchment. The National Vegetation Survey Databank (NVS) is a nationally significant database that contains vegetation survey information from across New Zealand. NVS holds data from 2454 unique plots in the Whanganui catchment. The majority (over 80%) of these plots fall on public conservation land. Of those plots on private land only 52 have been measured in the last 20 years as part of two separate surveys.

This vegetation information held in NVS includes national-level surveys such as:

- LUCAS (Holdaway et al. 2017) and Tier 1 monitoring, which contain 48 permanent plots in the Whanganui catchment, established in 2002 and remeasurement is ongoing.
- The National Forest Survey was carried out between 1940 and1970 as an inventory of New Zealand's forests (Masters et al. 1957). In the Whanganui catchment, 1265 non-permanent plots were measured, many of which are in areas that have subsequently been logged.
- Protected Natural Area Programme surveys (Dickinson & Mark 1988) were carried out in the 1980s and 1990s to assess the condition of natural areas. In the Whanganui catchment, 76 temporary plots were measured.

Regional surveys:

- Permanent plots are where fixed area plots or transects have been established, and the vegetation has been measured precisely. There are 104 permanent plots, some of which have been remeasured at least once.
- Exclosure plots are established to quantify the impact of deer and goat browsing on the vegetation. There are 30 plots, some of which have been remeasured.
- Another 921 other non-permanent plots have been measured for various reasons.

Details of surveys are available in Appendix 2.

In addition to these vegetation plots, over 600 plant checklists exist for areas within the Department of Conservation's Whanganui Conservancy (Beale et al. 2010), many of which are available from the New Zealand Plant Conservation Network (2013).

4.3 Wetlands

Extensive wetlands were not a prominent feature of much of the landscape of the Whanganui River catchment, currently covering approximately 2953 hectares (0.4%). Because the catchment is mostly hilly or mountainous, wetlands were confined to flatter parts of valleys (Ravine 1996; Bibby et al. 2000), other than in the broad floodplain and dunelands at the mouth of the Whanganui River. Throughout the catchment, wetlands are among the most depleted and modified of ecosystems because they were in the flat parts of the valleys that were most easily cleared of vegetation. The fertile soils that are in many wetlands were valuable for agriculture, hence many of those that were cleared were drained. Woody vegetation, in some cases tall forests, covered most of New Zealand's wetlands before human settlement (McGlone 2009), which contrasts with the state of most modern wetlands, where a combination of deforestation, fertiliser use in adjacent landscapes, and altered drainage around many of them has had an homogenising effect on the vegetation, and where invasion by non-native plants is widespread (McGlone 2009). Because they were never a major part of the Whanganui River catchment and because of their subsequent degradation and conversion, wetlands form only a small current part of the area of the catchment, most extensively in the central eastern part (Fig. 46), with scattered small wetlands in the upper and lowermost part.

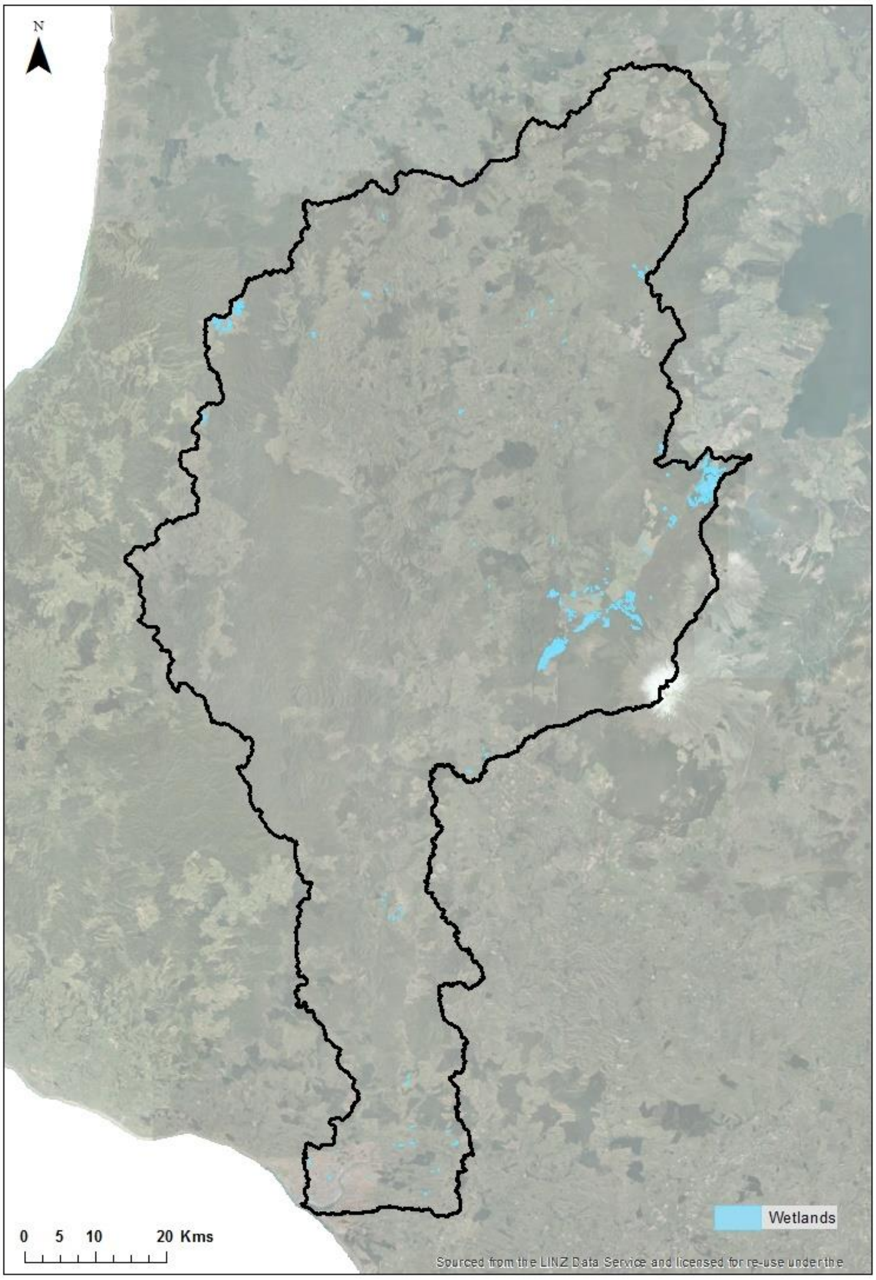

Figure 46: Wetlands in the Whanganui River catchment. Adapted from Freshwater Ecosystems of New Zealand (2010).

In the Whanganui River catchment, an example of a forested wetland has survived near Parikino, on an old cut-off meander of the lower River, partly silted over in floods; however, it is drier than it would have been because of drainage in adjacent areas and it has been logged in part (Ravine 1996). Kahikatea forms the main canopy, with pukatea (*Laurelia novae-zelandiae*) (Ravine 1996). Much more modified wetlands occur in the upper part of the catchment, including one in the upper catchment near Matiere, where raupō (*Typha orientalis*) is dominant over pūrei (*Carex secta*) and harakeke (*Phormium tenax*), and woody plants are scattered throughout, including tī kōuka (*Cordyline australis*), wheki, and mānuka, and non-native herbaceous plants and grasses are common (Bibby et al. 2000). At another, near Ngākonui, open water is surrounded by raupō and pūrei, with scattered non-native grey willow (*Salix cinerea*) and mānuka (Bibby et al. 2000). Within Whanganui National Park, there are no lakes or wetlands of significant size; the wetlands that are present include poorly drained valley floors, and perched lakes trapped by subsidence, and spring-fed systems. These wetlands are variously dominated by harakeke, mānuka, raupō, pūrei, and rushes (*Juncus* spp.) typical of wetlands modified by humans, but they provide habitat for many wetland plants that are not found elsewhere, including the fern *Hypolepis distans* (Department of Conservation 2012).

4.4 Naturally uncommon ecosystems

Naturally uncommon ecosystems are those that were rare (less than 0.5% of New Zealand's land area) before human colonisation. These ecosystems (Table 13) often contain highly specialised and diverse flora and fauna (Williams et al. 2007). Cliffs, scarps, and tors of acidic rocks are a naturally uncommon ecosystem (Williams et al. 2007) that occur throughout the mid- to upper reaches of the Whanganui River catchment. Ravine (1996, quoting an unpublished 1991 report by W. Baxter) describes wet and dry variants of the vegetation of this ecosystem, where the cliffs are too steep to support large trees. On the wet variant, typical species include a large sedge, tūhara (*Machaerina sinclairii*), the fern kiokio (*Blechnum novae-zelandiae*), and the large herb, parataniwha (*Elatostema rugosum*). On the dry variant, typical species include toetoe (*Austroderia fulvida*), wharariki or mountain flax (*Phormium cookianum*), and tutu.

Table 13: Naturally uncommon ecosystems present in the Whanganui catchment

Ecosystem	Class	Type	Public conservation land	Other formal protection	Not legally protected	Watershed Total	NZ Total
Active sand dunes	Endangered	ha	-	-	4.70	4.70	33,258
Moraines	Vulnerable	ha	2,631	-	-	2,631	526,494
Old tephra (>500 years) plains (= frost flats)	Critically endangered	ha	1.1	-	-	1.10	4,544
Recent lava flows (<1000 years)	Other	ha	126	-	-	126.00	3,649
Ultrabasic hills	Other	ha	0.4	-	-	0.4	82,914
Young tephra (<500 years) plains and hillslopes	Vulnerable	ha	163	-	-	163	87,859
Tors of acidic rocks	Other	Count	1		17.00	18	9,832
Cliffs and scarps of acidic rocks	Other	km	117	5.8	400	523	15,512
Basic cliffs and scarps	Vulnerable	km	23	-	0.05	23	4,688
Calcareous cliffs and scarps	Vulnerable	km	2.4	-	6.4	8.8	1,722

4.5 Human influences on vegetation

4.5.1 Māori

Māori arrived in the area most likely in the 14th century (Walton 2000). They settled in the lower reaches of the Whanganui River where there were ideal growing conditions for the tropical root crops that they had brought from Hawaiiki, including kūmara (*Ipomoea batatas*) and taro (*Colocasia esculenta*). These crops would have flourished on the alluvial terraces of the Whanganui River, and making this land available for agriculture entailed clearing the forest by fire and felling trees, a practice mastered by their tupuna on encountering new islands for settlement throughout Polynesia. Use of bracken roots (aruhe) as food became important to Māori settlement in the inland parts of the North Island, where frosty conditions made their tropical crops difficult to cultivate, so fire was used to promote bracken (*Pteridium esculentum*) growth (McGlone et al. 2005). However, levels of bracken and charcoal caused by fires in the upper Whanganui River catchment are low compared with those east of the Whanganui River (e.g. around Lake Taupō and north of it; McGlone et al. 2005), and most of the inland hill country was under continuous forest cover well into the 19th and 20th centuries (Walton 2000).

Within 150 years of settlement, Māori had hunted all North Island species of moa – North Island giant moa (*Dinornis novaezealandiae*), Mantell's moa (*Pachyornis geranoides*), and coastal moa (*Euryapteryx curtus*) – to extinction (Holdaway & Jacomb 2000). These extinctions are likely to have had indirect effects on the forests and vegetation, since these large herbivorous birds may have consumed some woody plants disproportionately. For example, among New Zealand's trees and shrubs, there are several cases of species that have a densely twiggy ("divaricate") architecture with small leaves, whereas their closest relatives lack that architecture and have larger leaves (the juveniles of pōkākā and hīnau are one example; the former twiggy, the latter not). Divaricate, small-leaved plants are most abundant and diverse in frosty and droughty sites (Lusk et al. 2016) but they are also likely to have been more resistant to browsing by extinct moa (Greenwood & Atkinson 1977; Bond et al. 2004). The period after the extinction of moa and before the introduction of non-native goats, deer, and other browsers in the 19th century may have favoured the non-twiggy woody species (Greenwood & Atkinson 1977).

Māori also introduced kiore (*Rattus exulans*). This non-native rat had profound effects on terrestrial ecosystems since it was the first predatory mammal in these ecosystems for millions of years. The effect of its introduction on native invertebrates (large beetles, weevils, wētā, stick insects, snails), lizards, and on some birds, was catastrophic, reducing many species to small relict populations or causing complete extinctions of others (Worthy & Holdaway 2002). For example, kiore are likely to have caused the extinction of two species of New Zealand wrens (Lyall's wren, *Traversia lyalli*, and North Island stout-legged wren, *Pachyplichas jagmi*), which are related to the tītitipounamu (rifleman, *Acanthisitta chloris*) (Worthy & Holdaway 2002). The reductions of native invertebrates, birds, and reptiles are likely to have had significant effects on ecosystems and how they function. Kiore are also predators of seeds of native plants, including trees such as miro (*Prumnopitys ferruginea*; Wilmshurst et al. 2008), which in turn is likely to have resulted in reduced levels of seedling regeneration of some trees (Campbell & Atkinson 2002).

4.5.2 Pākehā

The effects of Pākehā on the terrestrial ecosystems of the Whanganui River catchment were profound. Whereas Māori deforestation was restricted and use of fire in the catchment limited, Pākehā conducted widespread deforestation, fire, and logging throughout much of the catchment. While Māori arrived with a limited cargo of introduced plants for agriculture and two introduced mammals (kiore and kurī, *Canis lupus familiaris*), over more than a century, Pākehā introduced many thousands of non-native plant species (Williams & Cameron 2006), 54 species of non-native land mammals (King 2005), 120 species of non-native birds (of which 34 species were successful in sustaining wild populations; Duncan et al. 2006), predatory non-native freshwater fish (Townsend & Simon 2006); numerous species of non-native invertebrates (such as European social wasps, *Vespula* spp., Beggs & Wardle 2006); non-native fungi (Dickie et al. 2010); and non-native parasites and diseases (Tompkins & Poulin 2006). The net result of deforestation and introductions by Pākehā was wholesale transformation of parts of the landscape of the Whanganui River catchment into agricultural landscapes where non-native plants and animals predominated and formed the basis of the modern economy, and major alteration of the remaining forested landscapes.

Deforestation by Pākehā began from the mouth of the Whanganui River. Tall forests on the alluvial plains by the coast, dominated by species such as kahikatea, were deforested to make way for introduced crops such as wheat and potatoes; in contrast, Māori had retained these forests as important seasonal habitat for native bird species that were kai, especially kererū (*Hemiphaga novaeseelandiae*; Park 1995).

After the New Zealand Land Wars, Pākehā began further deforestation in the upper part of the Whanganui River from the 1880s for sheep and cattle farming. Deforestation accelerated rapidly after the completion of the North Island Main Trunk Railway, which reached Taumarunui in 1903 and was completed in 1908. Extension and completion of the railway brought increasing numbers of Pākehā settlers, and a large-scale timber industry developed (Bibby et al. 2000). After logging, remaining forest was burned to make way for agriculture; grass was sown into ash beds. Deforestation by fire was widespread on the steep and generally infertile hill country throughout the catchment. Deforesting steep, infertile hill country in the Whanganui River catchment continued after World War I, in places where the government sent returned soldiers to farm blocks of land they had promised them (Fig. 47; Fig. 48). In the Mangapūrua Valley, the new farmers deforested hillsides to make way for 450-ha farms. The land was too infertile to sustain farming; the infrastructure of roads and bridges was inadequate and destroyed by storms that eroded the hillsides. The combination of falling prices, falling yields from farms, and ultimately the Great Depression of the 1930s ruined the farms in this valley and by 1942, only three families were left. In that year, heavy rain destroyed the road link, the Government would not restore it, and the families were ordered out. Here and elsewhere, after failed agriculture, secondary forests, mostly of native species, have revegetated these hillsides.

In other hilly, deforested parts of the catchment, pastoral agriculture continues, made possible by use of fertilisers. Alternative land uses, especially planting hillsides in non-native conifers (especially *Pinus radiata*) as a timber crop, became a more widespread land use since the 1950s. Logging of natural forests, especially for high-value conifers (rimu and mataī) continued in the catchment until the 1970s and 1980s.

The net result of deforestation, mostly by Pākehā, over more than a century, is that the lowermost parts and most of the upper parts of the Whanganui River catchment are non-forested agricultural landscapes, where European grasses (especially ryegrass, *Lolium perenne*, cocksfoot, *Dactylis glomerata*) are the main cover, providing fodder for non-native sheep and cattle that are the basis of the rural economy. Locally plantations of mostly North American conifers are on some steep hillsides, where they are periodically clear-cut and then replanted. Some hillslopes are stabilised with European trees such as willows and poplars.

Across the deforested landscape, there are fragments of original forest. The long-term trends in these fragments are still unclear, since many of the canopy trees in them developed when the current fragments were part of a wider continuous forest. In small fragments, more light penetrates from the edge, and understoreys are drier (Young & Mitchell 1994). If they are unfenced, sheep and cattle can modify the interiors, reducing regeneration and eliminating some plant species. Some bird species can be confined to forest fragments; for example, toutouwai (*Petroica longipes*) very seldom fly across more than 110 m of pasture to other forest fragments (Richard & Armstrong 2010).

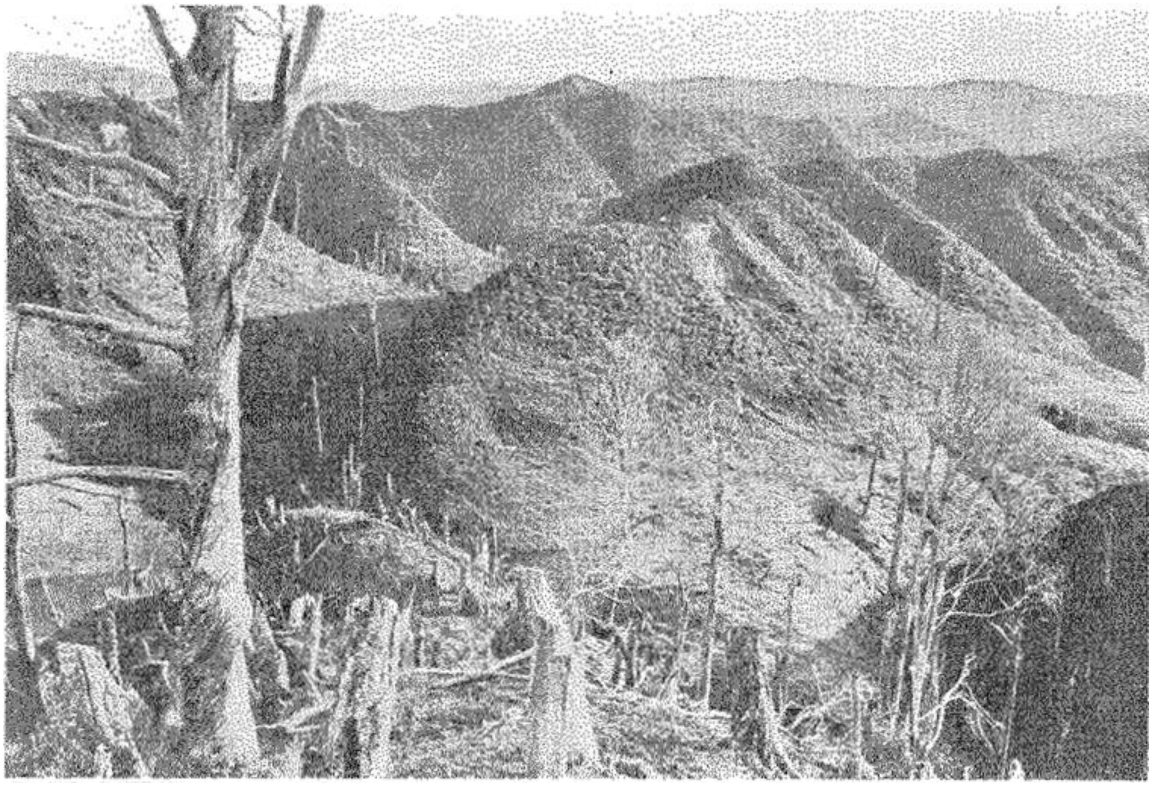

Figure 47: Ridges and slopes of the Taranaki uplands, cleared for agriculture in the 1920s; the stumps in the foreground are mainly of kāmahi; the dead standing tree at left is Hall’s tōtara (*Podocarpus laetus*) (Photo reproduced from Levy (1923a)).

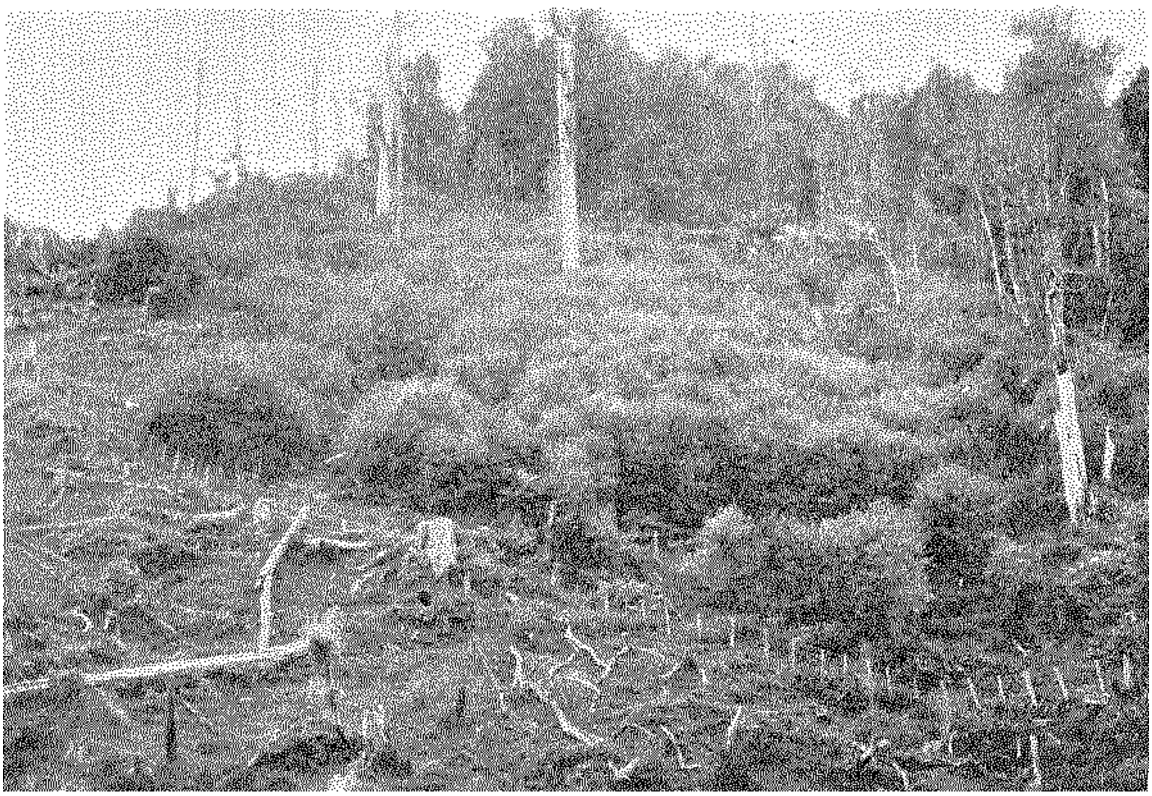

Figure 48: Makamaka colonising land in the 1920s deforested recently for agriculture (Photo reproduced from Levy (1923a)).

Many of the plants introduced by Pākehā have naturalised and become widespread. Gorse (*Ulex europeaus*) is probably the most widespread. Since the landscape naturally supports forest, woody plants, both native and non-native, readily colonise grasslands, and when agriculture becomes uneconomic, species such as native kānuka and non-native gorse readily colonise former pasture, and ultimately are overtopped by other native tree species (Sullivan et al. 2007). Other widespread non-native plants become persistent parts of landscapes, e.g. old man's beard (*Clematis vitalba*) on bluffs and at forest margins.

Non-native plants are very prevalent in small fragments of lowland forest. Within the larger forested areas of the catchment, non-native plants are least common under tall forest canopies and invade at sites of natural disturbances (landslides and treefall areas), sites of human disturbance such as tracks and roads, and along forest margins, including rivers (Department of Conservation 2012). Some of the non-native plants that DOC ranks as high-priority species to control include: African feather grass (*Pennisetum macrourum);* Scotch broom (*Cytisus scoparius*); Japanese honeysuckle (*Lonicera japonica*); Japanese spindle tree (*Euonymus japonicus*); common pampas grass (*Cortaderia selloana*); tutsan (*Hypericum androsaemum*).

Tussock grasslands in the upper parts of the catchment are invaded by non-native conifers, of which lodgepole pine (*Pinus contorta*) is currently the most invasive, especially in Tongariro National Park (Williams & Cameron 2006). Heather (*Calluna vulgaris*) is also a major invasive non-native woody plan in tussock grasslands in Tongariro National Park (Chapman & Bannister 1990). Dunes at the coast are heavily invaded by non-native plants, including gorse and marram grass (*Ammophila arenaria*; Hilton 2006).

Animals introduced by Pākehā have had widespread effects in the Whanganui River catchment. Some of the mammals introduced (ship rat, *Rattus rattus*, stoat, *Mustela erminea*) are major predators of native birds. These and other predators are the most likely reason for the extinction of birds that were widespread in the Whanganui River catchment and became extinct after Pākehā settlement, including tieke (*Philesturnus rufusater*), kākāpō (*Strigops habroptilus*), huia (*Heteralocha acutirostris*), hihi (*Notiomystis cincta*), and piopio (*Turnagra tanagra*) (Worthy & Holdaway 2002). Rats, stoats, and other predators are also likely to have eliminated populations of seabirds that bred on inland hills. For example, they are almost certainly the reason for extinction of populations of kōrure (mottled petrel, *Pterodroma inexpectata*), which formerly bred plentifully in the inland mountain ranges of the North Island (Oliver 1955), and which were an important source of food for inland Māori. Kōrure and other seabirds provided important sources of marine nutrients to soils, and altered plant and soil biology through their burrowing at their nests; once these seabirds were eliminated by predators, ecosystem processes changed fundamentally (Fukami et al. 2006). Predatory mammals are almost certainly the reason for declining numbers of some forest birds that were widespread in the Whanganui River catchment, such as kākā (*Nestor meridionalis*).

Other mammals introduced by Pākehā are both predators and herbivores (brushtail possums, *Trichosurus vulpecula*, and pigs, *Sus scrofa;* rats and mice, *Mus musculus*). Possums prey upon native birds such as kererū and kōkako (*Callaeas wilsoni*), and they also preferentially browse some native plant species, from the forest floor to forest canopies. They can reduce populations of some species, such as the green mistletoe (*Ileostylus* *micranthus*) which is now rare in the Whanganui River catchment (Ravine 1996, Bibby et al. 2000). Deer (mostly red deer, *Cervus elaphus*) and goats (*Capra hircus*) can browse forest understoreys and retard the rate at which new forests develop on natural clearings, such as landslides, and on pastures. Goats, in particular, are abundant throughout much of the western hill country of the catchment (Hawcroft & Husheer 2009).

4.6 Flora of the Whanganui River Catchment

4.6.1 Rare plants

The geological history of the Whanganui River catchment and the comparatively recent origin of most of it (most of the catchment emerged from the sea after about 2.58 million years ago) mean that there have been few opportunities for plants and animals to evolve that are unique to the area (McGlone et al. 2001). There are no species of plants or lizards that are unique (endemic) to the Whanganui River catchment, although this may not be the case for invertebrates.

Among the native forest and shrubland plant species, a tree daisy (*Brachyglottis turneri*) that occurs in the Whanganui River gorge and the Tangarakau River valley (Ravine 1996) is mostly centred in the Taranaki–Whanganui region and it is considered Nationally Endangered (de Lange et al. 2013). Another short tree, *Pittosporum turneri*, is most common in shrublands developing after disturbance and occurs in the far northeast of the catchment, especially near Erua (Bibby et al. 2000); this species is considered Nationally Vulnerable (de Lange et al. 2013). At the coast and river mouth, the turf-forming herb, *Selliera rotundifolia* occurs on occasionally flooded sand plains behind foredunes, such as near the mouth of the Whanganui River; it is not unique to the area, extending between the Waitotara and Ohau Rivers (Heenan 1997) and is considered to be At Risk (de Lange et al. 2013). The small shrub, *Pimelea actea*, occurs along the same sand dunes and is now severely depleted from its former range. One of its few known sites is at Castlecliff Beach, Whanganui (Burrows 2008); it is considered Nationally Critical (de Lange et al. 2013).

Other rare plants that occur in the Whanganui River catchment are reduced because of loss of habitat (especially deforestation) and pressures from the mammals introduced by Pākehā. Young forests arising after deforestation provide habitat for one such species, Pua o te reinga (*Dactylanthus taylorii*), which is parasitic, attaching itself to the roots of native trees, from which it obtains its nutrients. It occurs in various sites in the upper part of the Whanganui River catchment (Bibby et al. 2000). It is Nationally Vulnerable (de Lange et al. 2013) because it is eaten by introduced browsing mammals and because its major pollinator, pekapeka-tou-poto, has been reduced in numbers by rats and other predators.

4.7 Fauna of the Whanganui River catchment

4.7.1 Birds

At least 69 native bird species and 30 non-native bird species are currently found in the Whanganui River catchment (Appendix 2; Ravine 1996; Bibby et al. 2000; Frost 2008). The threatened and at risk native bird species currently known from the Whanganui River catchment are listed in Table 14.

Table 14: Threatened and at risk native bird species, defined according to Robertson et al. (2013), currently known from the Whanganui River catchment

Status	Māori, Pākehā name	Scientific name
Threatened, nationally critical	Pārera, grey duck	*Anas superciliosa*
	Tarāpunga, black-billed gull	*Larus bulleri*
Threatened, nationally endangered	Matuku-hūrepo, Australasian bittern	*Botaurus poiciloptilus*
	Tara piroe, black-fronted tern	*Chlidonias albostriatus*
Threatened, nationally vulnerable	Ngutu parore, wrybill	*Anarhynchus frontalis*
	North Island brown kiwi	*Apteryx mantelli*
	Pohowera, banded dotterel	*Charadrius bicinctus bicinctus*
	Kārearea, bush falcon	*Falco novaeseelandiae* "bush"
	Taranui, Caspian tern	*Hydroprogne caspia*
	Whio, blue duck	*Hymenolaimus malacorhynchos*
	Tarāpunga, red-billed gull	*Larus novaehollandiae scopulinus*
	North Island kākā	*Nestor meridionalis septentrionalis*
	Weweia, New Zealand dabchick	*Poliocephalus rufopectus*
At risk	Tītitipounamu, North Island rifleman	*Acanthisitta chloris granti*
	Pīhoihoi, New Zealand pipit	*Anthus novaeseelandiae novaeseelandiae*
	Mātātā, North Island fernbird	*Bowdleria punctata vealeae*
	Tōrea tuawhenua, South Island pied oystercatcher	*Haematopus finschi*
	Poaka, pied stilt	*Himantopus himantopus leucocephalus*
	Kuaka, eastern bar-tailed godwit	*Limosa lapponica baueri*
	Tara, white-fronted tern	*Sterna striata striata*

Many native land birds have their strongholds in the catchment's remaining forests, but several of them have either become extinct (see above) or contracted substantially in abundance and range, as is the case for kōkako and kākā (Ravine 1996; Bibby et al. 2000). North Island brown kiwi (*Apteryx mantelli*) and kārearea (*Falco novaeseelandiae* "bush") range beyond forests into shrublands and pasture, but they too have contracted substantially in abundance and range. Parts of the Whanganui River catchment are national strongholds for North Island brown kiwi, with an estimated 2011 population of 1500 pairs in the Matemateaonga Ecological District (about half the District is in the Whanganui River catchment) (Scrimgeour & Pickett 2011). Some water birds, such as whio (*Hymenolaimus malacorhynchos*), are also much reduced in abundance and range, but have important remnant populations within forested parts of the catchment (Bibby et al. 2000).

Wetland birds are limited in range in the Whanganui River catchment because of their small extent. The nationally endangered matuku-hūrepo (*Botaurus poiciloptilus*) was found, in very low abundance, from only one wetland in the upper catchment, west of Raurimu (Bibby et al. 2000). Other wetland birds, including weweia (*Poliocephalus rufopectus*) on open bodies of water (which are few in the catchment), and mātātā (*Bowdleria punctata vealeae*), which prefers dense wetland vegetation, are more widespread in the catchment (Ravine 1996; Bibby et al. 2000).

The Whanganui River estuary is an important habitat for wading birds and water birds. A survey of the estuary between April 2006 and August 2008 recorded 17,836 birds of 25 wader and water bird species, most of which migrate from breeding grounds in the South Island (e.g. ngutu parore, *Anarhynchus frontalis*) or the northern hemisphere (e.g. kuaka, bar-tailed godwit, *Limosa lapponica*) (Frost 2008). Only karoro (southern black-backed gull, *Larus dominicanus*) and spur-winged plover (*Vanellus miles*) were common local breeding residents. Pohowera (*Charadrius bicinctus bicinctus*) breeds there and is considered Nationally Vulnerable (they have also been recorded breeding nearby at Whanganui Airport; Frost 2010). Importantly, the estuary was used regularly or intermittently during that period by pārera (*Anas superciliosa*) and tarāpunga (black-billed gull, *Larus bulleri*), which are both considered Nationally Critical; tara piroe (*Chlidonias albostriatus*), considered Nationally Endangered; and ngutu parore, taranui (*Hydroprogne caspia*), and tarāpunga (red-billed gull, *Larus novaehollandiae scopulinus*), all three of which are considered Nationally Vulnerable. At Risk bird species seen at the estuary included kuaka, poaka (*Himantopus himantopus leucocephalus*), tara (*Sterna striata striata*), and tōrea tuawhenua (*Haematopus finschi*).

Whio

Whio (*Hymenolaimus malacorhynchos*) are an iconic species found in clear fast-flowing rivers. They are a taonga species with cultural, spiritual, historic, and traditional significance for Māori (Young 2006). Whio are an endangered species, listed as nationally vulnerable it is recognised that they need active management to ensure the species survival (Glaser et al. 2009). Major threats to whio populations include the modification of waterways, in particular the removal of riparian vegetation, and the introduction of mammalian predators (Glaser et al. 2010).

A stretch of river at the Wanganui/Mangatepopo/Okupata confluence has the highest density of territorial whio pairs known in the Tongariro/Taupō Conservancy (Adams et al. 1997), and a number of tributaries within the catchment are strongholds for whio populations (Department of Conservation 2012).

Nankeen night heron

Nankeen night herons (*Nycticorax caledonicus australasiae*) have recently dispersed from Australia and become established in Aotearoa and their only breeding population is in the Whanganui River catchment. The ancestors of most of New Zealand's plants and animals have arrived, over the last 60 million years, from Australia, so the recent arrival of nankeen night herons is part of an ongoing process (McGlone 2006): it is a native bird. Nankeen night herons were first observed near Pipiriki in 1994 (Marsh 1995), and first recorded breeding near Hiruhārama in November 1995 (Marsh & Lövei 1997), and they are currently (September 2016, Peter Frost, Birds New Zealand Whanganui Region Representative, pers. comm.) at a roost near the mouth of Kaurapaoa Stream at which they have been present since the early 2000s.

Some bird species that dispersed to Aotearoa from Australia during the 20th century became established as breeding birds and their populations have expanded rapidly so that they have become common birds, including in the Whanganui River catchment (i.e. spur-winged plover, first breeding in the 1930s; white-faced heron, *Egretta novaehollandiae*, first breeding in the 1940s; welcome swallow, *Hirundo neoxena*, first breeding in the 1950s) but others have not and their New Zealand populations have come and gone several times (red-necked avocet, *Recurvirostra novaehollandiae*; Australian pelican, *Pelecanus conspicillatus*, the latter in the Whanganui River in the 1890s). There has been no change in numbers of nankeen night herons between 2008 and 2016 (Peter Frost, unpublished data), so it remains to be seen whether the population in the Whanganui River catchment is tenuously established, albeit enduring, population or the first stage of a successful widespread colonisation of Aotearoa.

Birds on public conservation land

Since 2011, the Department of Conservation has determined bird abundance and composition across public conservation land systematically, with locations sampled regularly on a national 8-km × 8-km grid. Vegetation and bird communities, and the presence and abundance of some non-native mammals are assessed at each point (Bellingham et al. 2013). Across 17 sample points across public conservation land in the mid to upper Whanganui River catchment, on average 10 species of bird were recorded across the sample points, of which 8 species, on average, were native.

There was little difference in the abundance of native birds (all species combined) across most sample points in the catchment; the exceptions were two high-elevation non-forested sites in Tongariro National Park where abundances were much lower (Fig. 49).

The abundances of non-native birds throughout the catchment were almost always less than those of native birds at the same sample points (compare symbols sizes in Fig. 49 with Fig. 50). Abundances of non-native birds at sample points in the northeast of the catchment (mostly in Pureora Forest Park) were slightly greater than at other sample points in the catchment (Fig. 50). There is no such information avaiable from areas that are not public conservation land.

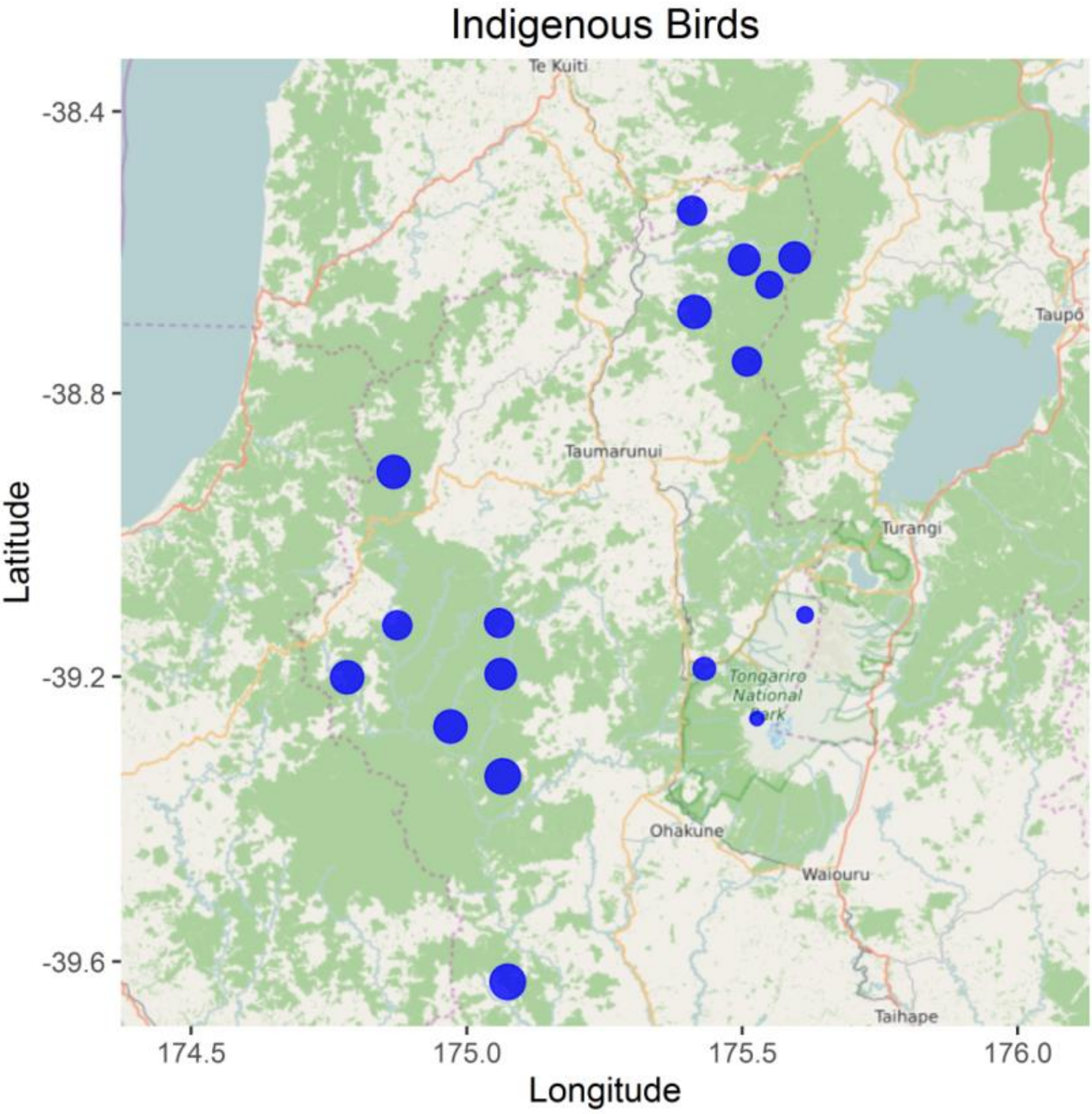

Figure 49: Abundance of native birds (all species of native birds combined) across 17 sample points on public conservation land in the Whanganui River catchment. The larger the blue symbol the greater the total abundance.

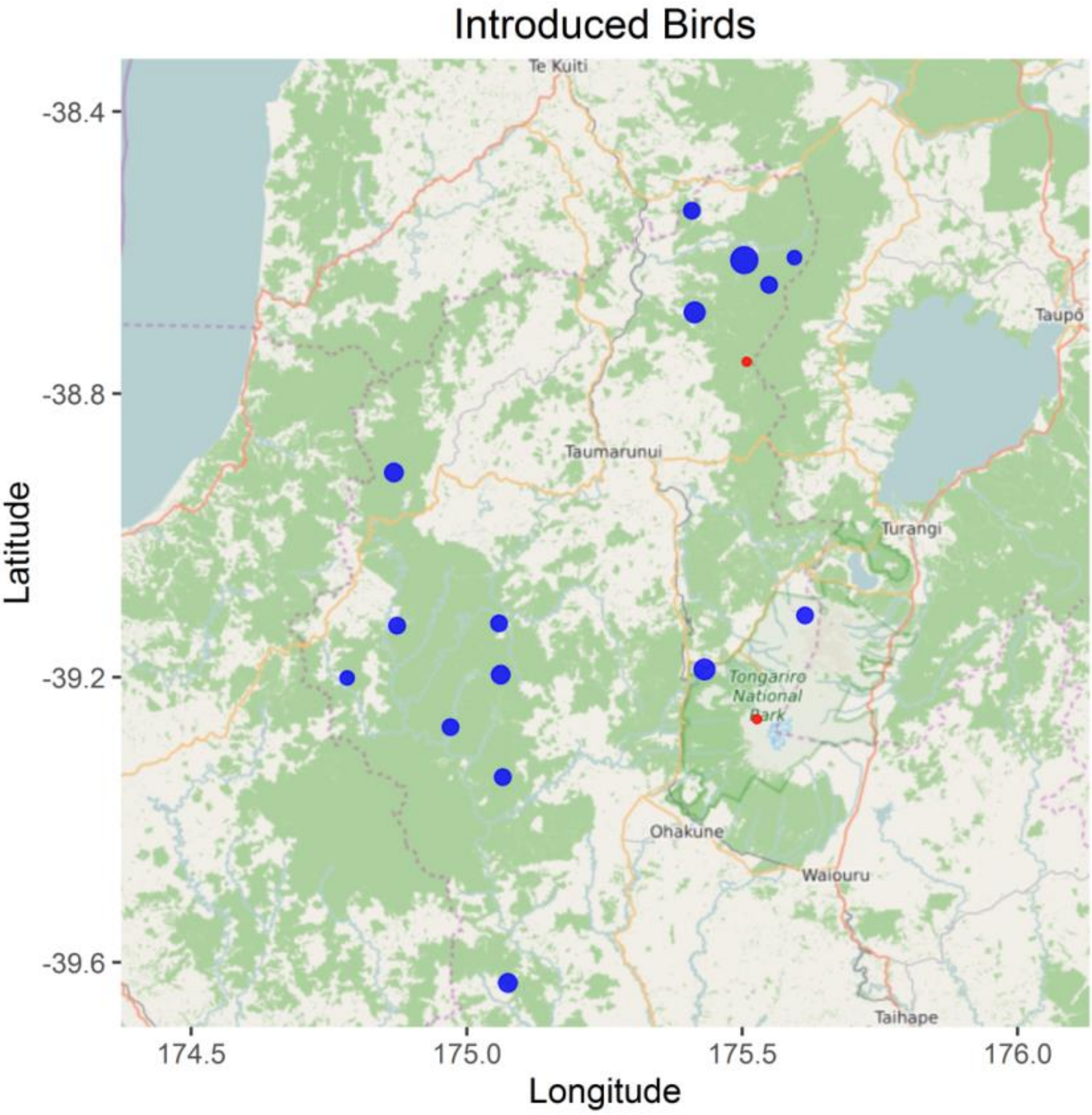

Figure 50: Abundance of non-native birds (all species of non-native birds combined) across 17 sample points on public conservation land in the Whanganui River catchment. The larger the blue symbol the greater the total abundance. The red symbol represents a sampling location at which no non-native birds were recorded.

4.7.2 Lizards and frogs

Five species of native lizards are known from the Whanganui River catchment, but there are very few data about them. Forest gecko (*Mokopirirakau granulatus*) and Wellington green gecko (*Naultinus punctatus*) are known at least from forests at Waitewhena, west of Ohura (O'Donnell 1983). Copper skink (*Oligosoma aeneum*) occurs in the Whanganui River catchment (Chapple et al. 2008) and common skink (*Oligosoma polychroma*) reaches its northern limit near Mangakahu, northeast of Taumarunui (Bibby et al. 2000). Striped skink (*Oligosoma striatum*) is known from the upper part of the catchment, near Ohura (Bibby et al. 2000), and inhabits rotten logs in forests (as well as logs remaining in pastures) and epiphytes (perching plants) in forest canopies. Of the native lizards found in the catchment, Forest gecko, Wellington green gecko, and striped skink are species considered to be Declining (Hitchmough et al. 2013), and all are vulnerable to predation, especially by rats.

Rainbow skink (*Lampropholis delicata*) is New Zealand's only non-native wild lizard. It was accidentally introduced from eastern Australia in the 1960s and is spreading across New Zealand, and it has been recorded from Whanganui (Peace 2004). The non-native Australian southern bell frog (*Litoria raniformis*) was deliberately introduced to New Zealand in the 1860s and is present in the catchment.

4.7.3 Invertebrates

Information about land invertebrates in the Whanganui River catchment is very limited (Ravine 1996; Bibby et al. 2000) and an inventory of species is needed from collections and published and unpublished lists and papers.

4.7.4 Mammals

Bats

There are two native bat species in the Whanganui River catchment, pekapeka-tou-roa (New Zealand long-tailed bat, *Chalinolobus tuberculata*) and pekapeka-tou-poto (central lesser short-tailed bat, *Mystacina tuberculata rhyacobia*). Pekapeka-tou-roa is distributed throughout the middle and upper parts of the Whanganui River catchment (Bibby et al. 2000; O'Donnell 2005), whereas pekapeka-tou-poto is in the middle parts of the catchment, including Whanganui National Park and in some of the upper parts of the catchment (at Raurimu Scenic Reserve and Tongariro Conservation Area; Bibby et al. 2000) but they were not found in surveys in other apparently suitable habitat there (Lloyd 2005). The habitat of pekapeka-tou-roa is across a range of forests, including young secondary forests that have developed after fire or other clearance, and although they roost mostly in trees, they can also roost in caves, buildings, under bridges or on cliffs (O'Donnell 2005). Pekapeka-tou-roa often feeds at forest edges and ranges out across farmland to feed. In contrast, pekapeka-tou-poto is dependent on forest in which there are at least some old-growth trees in which they roost (Lloyd 2005). Pekapeka-tou-roa of the North Island is considered Nationally Vulnerable (O'Donnell et al. 2010), while the subspecies of pekapeka-tou-poto found in the Whanganui River catchment is considered as Declining (O'Donnell et al. 2010); both are vulnerable to predators, especially rats and stoats.

Introduced mammals

Introduced rats, mice, stoats, brushtail possums, goats, and pigs are widespread throughout the Whanganui River catchment. The Department of Conservation has determined the abundance of some of the introduced mammals in the catchment as part of its national assessment across all public conservation land (methods described in Bellingham et al.

2013). For the sample points for which data were available, possums were least abundant on public conservation land in the northeast of the catchment (the volcanic parts close to Tongariro National Park and toward Pureora) (Fig. 51). They were most abundant in the western hill country, where they browse kāmahi, a locally dominant canopy tree, most heavily (Duncan et al. 2011).

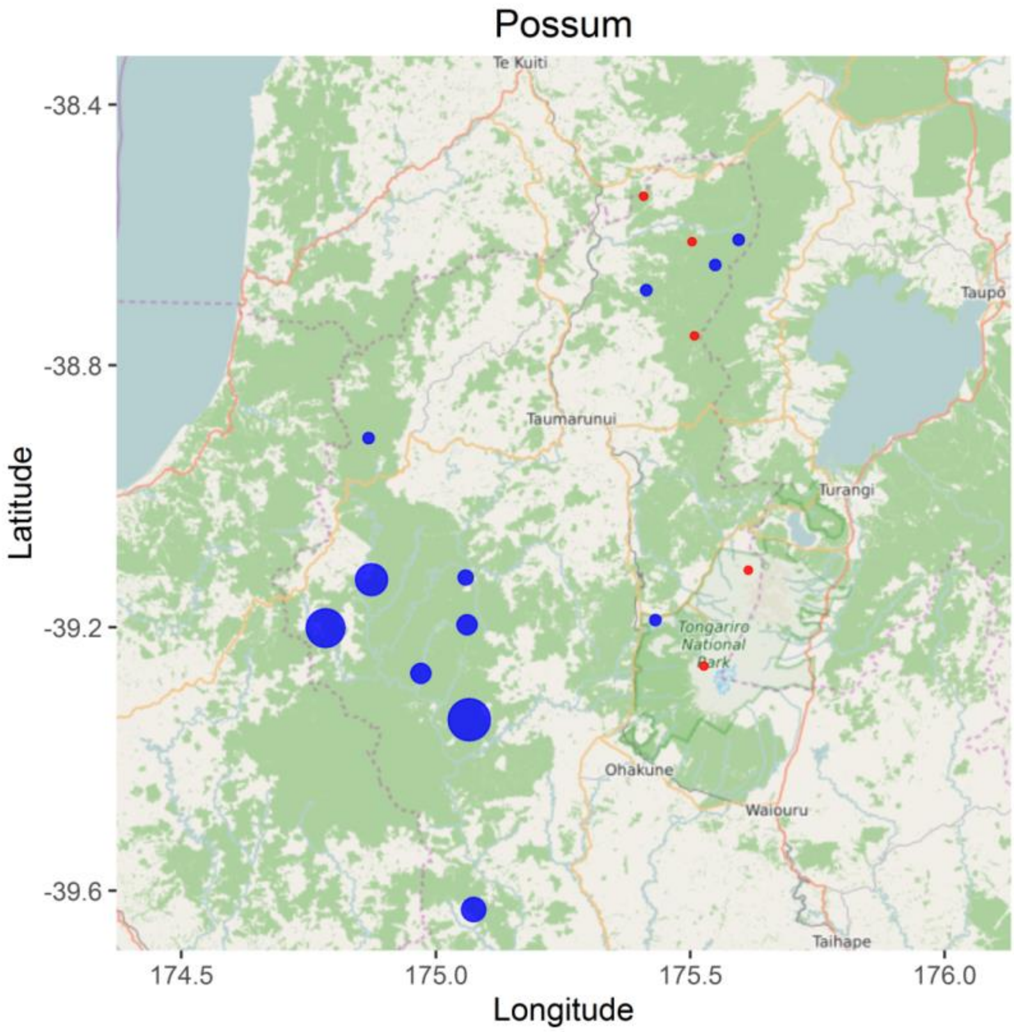

Figure 51: Brushtail possum abundance assessed by trap catch indices at some of the regular sampling points across public conservation land in the middle to upper parts of the Whanganui River catchment, sampled between 2011 and 2013. Red symbols represent sampling points where no possums were detected. Blue symbols represent sampling points where possums were detected; the larger the symbol, the more abundant possums were at that point.

The technique that the Department of Conservation uses, of counting faecal pellets, cannot readily distinguish goats from deer, hence they are assessed together (as "ungulates"). Ungulate abundance (Fig. 52) in the western hill country mostly represents the abundance of goats, which are long established there, but red deer have spread westward into this region in recent decades (Nugent & Fraser 2005) and could contribute to ungulate pellets counted there; in the east and northeast of the catchment, both deer and goats are present.

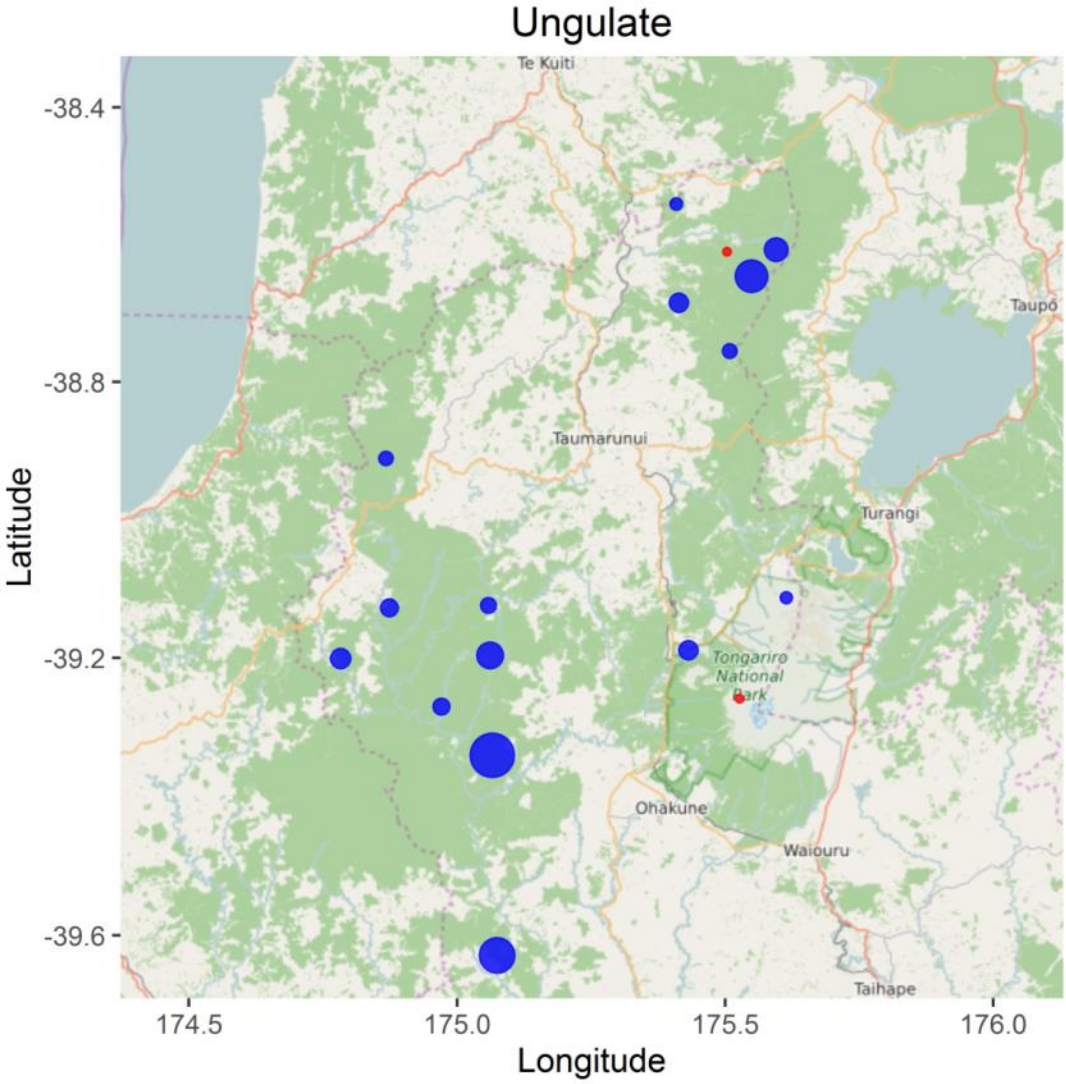

Figure 52: Ungulate (goat and deer) abundance assessed by faecal pellet indices at some of the regular sampling points across public conservation land in the middle to upper parts of the Whanganui River catchment, sampled between 2011 and 2013. Red symbols represent sampling points where no ungulates were detected. Blue symbols represent sampling points where ungulates were detected; the larger the symbol, the more abundant ungulates were at that point.

The main habitat of brown hares (*Lepus europaeus*) is open country and they very seldom occur in forest (Norbury & Flux 2005). Since most of the sites sampled by the Department of Conservation in the Whanganui River catchment are in forests or shrublands, it is unsurprising that they were not recorded at most of the sites sampled (Fig. 53), and that the sites where they were recorded were in open country at the highest elevation in the catchment, in Tongariro National Park. European rabbits (*Oryctolagus cuniculus*) occur in the catchment, but were not recorded at the points sampled by the Department of Conservation.

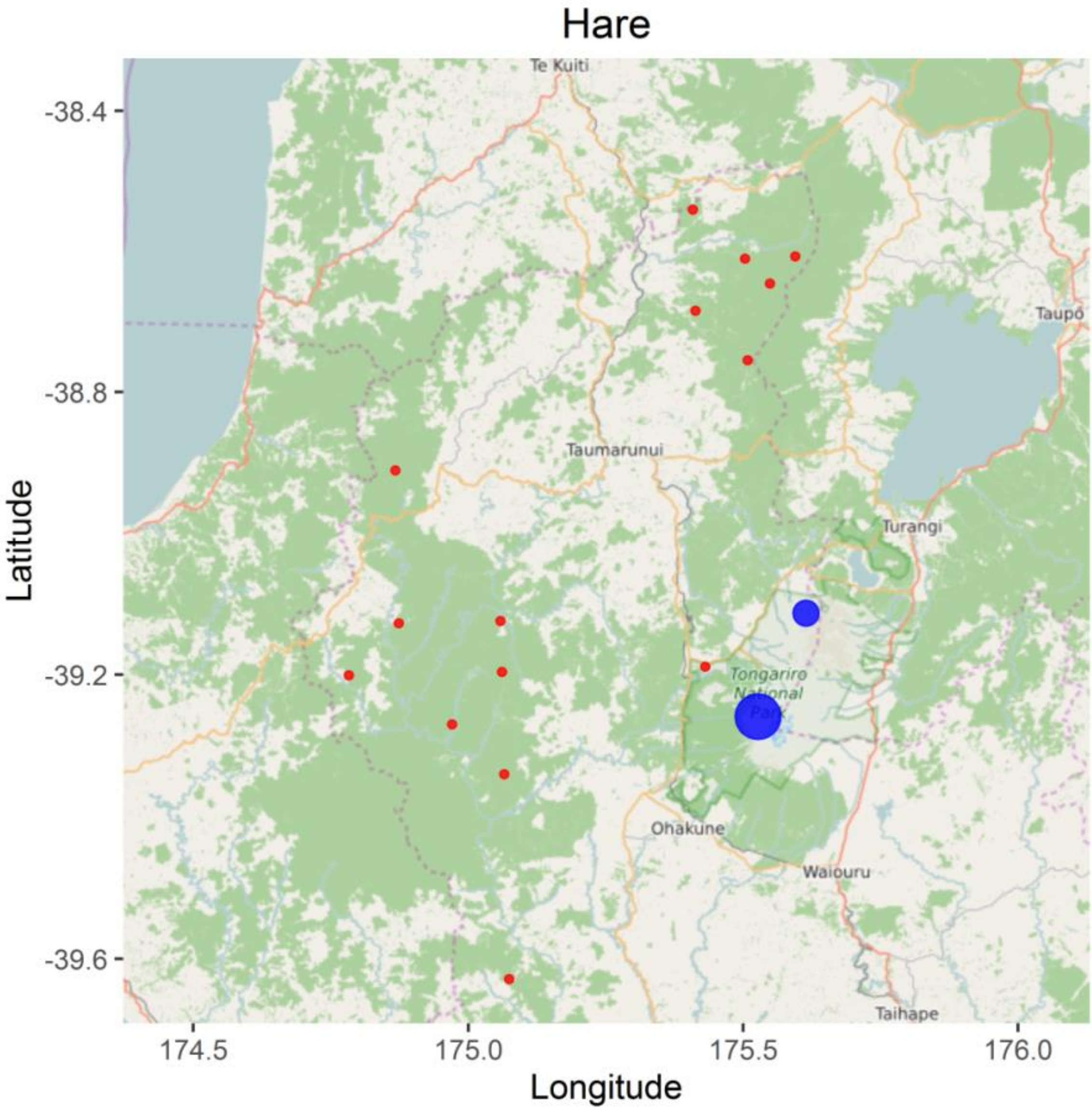

Figure 53: Brown hare abundance assessed by faecal pellet indices at some of the regular sampling points across public conservation land in the middle to upper parts of the Whanganui River catchment, sampled between 2011 and 2013. Red symbols represent sampling points where no hares were detected. Blue symbols represent sampling points where hares were detected; the larger the symbol, the more abundant hares were at that point.

4.8 Production landscapes

Surveys of terrestrial biodiversity in the Whanganui River catchment have mostly focused in native forests, shrublands, wetlands, and the coast, and there has been little, if any, attention paid to biodiversity in its agricultural landscapes or in plantation forests. Both agricultural landscapes (MacLeod et al. 2008) and pine plantations (Pawson et al. 2010) can be important habitat for some native bird species. For example, North Island brown kiwi occur in radiata pine plantations near Tongariro in the upper part of the Whanganui River catchment (Pawson et al. 2010).

While the Department of Conservation has undertaken systematic surveys of some terrestrial biodiversity across public conservation land, there are no equivalent data from agricultural landscapes, pine plantations and other land uses from most of New Zealand and none in the Whanganui River catchment. These are needed if we are to understand the relative importance of each as habitats, the interconnections among them, and to determine trends in biodiversity across them.

4.9 Protected areas

Areas in the Whanganui River catchment that are intended to protect mostly native vegetation and habitat comprise over half of the catchment area (Table 15). Land that is currently public conservation land comprises by far the largest proportion of this, and includes land within Whanganui National Park and a part of Tongariro National Park (Fig. 54)). Land protected through the Ngā Whenua Rāhui programme and other Māori Reservations is about 2% of the catchment area, scattered throughout the catchment (Figure 54).

Table 15: Summary of the major protected areas in the Whanganui River Catchment. Data adapted from Protected Areas of New Zealand (PAN-NZ) database (http://www.landcareresearch.co.nz/resources/maps-satellites/pannz)

Protection Type	Sum of Area (Hectares)	Percentage of catchment area
Ngā Whenua Rāhui and Māori Reservations	15,741	2.2
QEII Covenant	2,403	0.3
National parks and Conservation Reserves	385,558	54.2
Other Reserves	8,789	1.2
Total	**412,491**	**58**

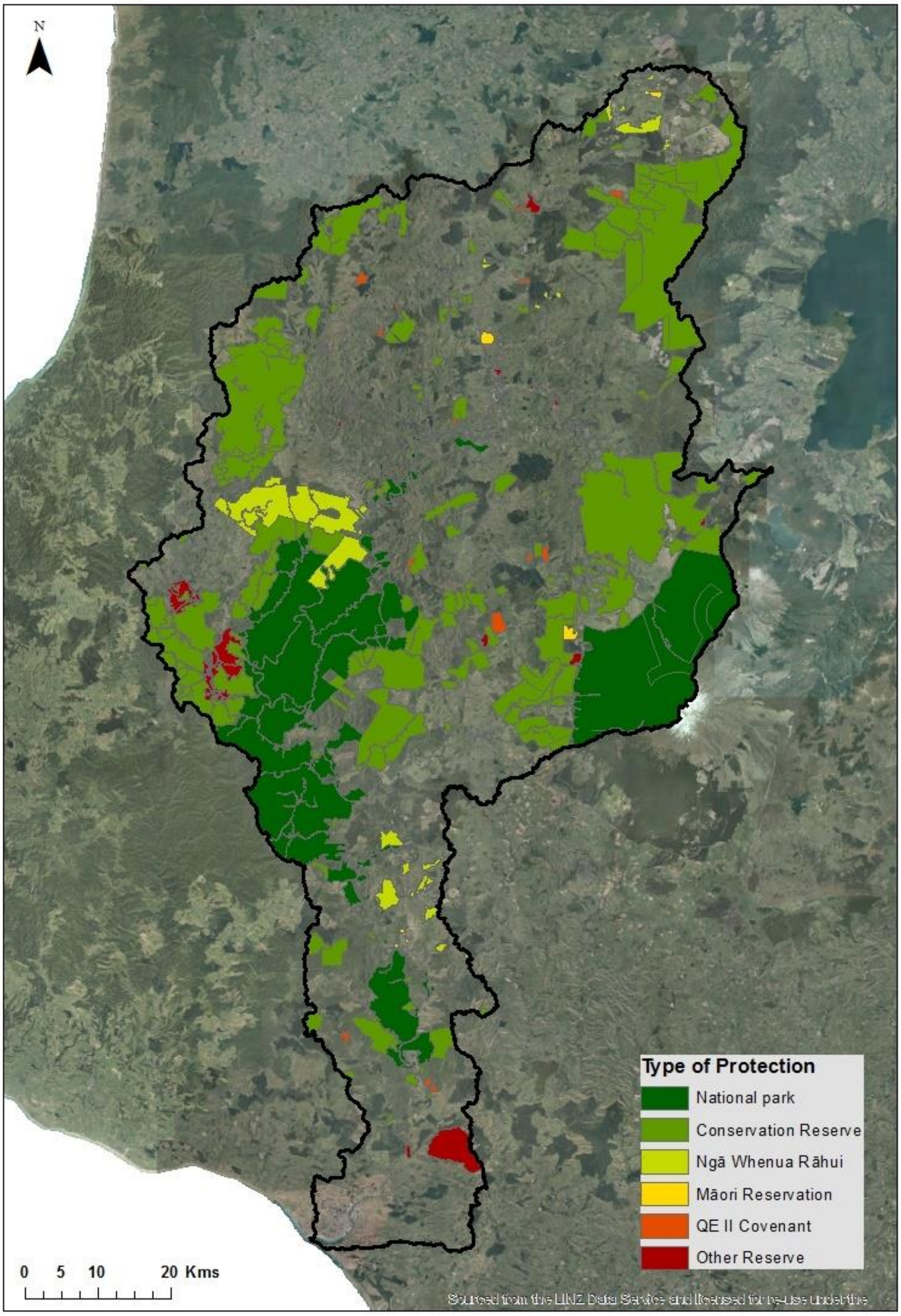

Figure 54: Protected areas in the Whanganui River Catchment. Data adapted from Protected Areas of New Zealand (PAN-NZ) database (http://www.landcareresearch.co.nz/resources/maps-satellites/pannz).

4.10 Information gaps and Recommendations

Current information about the state of terrestrial ecosystems and the plants and animals that they contain is best from public conservation land. The information about plant communities, birds, and pest mammals (e.g. Figs 49–53) are at a coarse scale (8-km grid) and finer scale resolution on public conservation land is patchy. Moreover, since most public conservation land is in the upper reaches of the catchment, we have a geographically biased view of what we do know. On private land, including iwi-owned land, information about the state of terrestrial ecosystems and the plants and animals they contain is very poor. Assessments of fragments of original native vegetation (conducted as part of the Protected Natural Areas programme) were conducted up to the end of the 1990s and there has been little recent information. There are no data on the state of biodiversity from most other private land, where native plant cover is low or absent and non-native plant cover dominates (e.g. pastoral agriculture and plantation forests).

For taonga species of interest, or geographic areas that may be of specific interest to tangata whenua, information available derives from small and often unrepresentative areas; building up a view of the state of these species or areas at a whole-catchment level is not currently possible. Information about some native species (mosses, lichens, fungi, most insects) in the catchment is entirely haphazard and an incomplete view results.

Although wetlands and some rare ecosystems (dunes, cliffs) are delineated and mapped, the state of these ecosystems is largely unknown.

If the state of biodiversity is generally poorly known throughout the terrestrial ecosystems of the Whanganui River catchment, defensible estimates of the trends in biodiversity are even more elusive. Much relies on oral history and reconstruction, with assumed causes that may not stand scrutiny.

4.10.1 Recommendations

- A catchment-wide process is needed to assess state and trend in all terrestrial ecosystems of the Whanganui River catchment. This can be achieved at a coarse scale by supporting continued investment of DOC’s Tier One monitoring programme on public conservation land, and by encouraging the relevant regional councils (Taranaki and Horizons) to extend the same grid-based sampling to all other land.
- Specific methods, developed with tangata whenua, can focus on state and trend in taonga species, ecosystems, and geographic areas of importance. If these methods can be integrated, to the greatest extent possible, with those in use by DOC, then defensible comparisons can be made (e.g. of the trends in species such as kererū). Some species of concern (e.g. kiwi, pekapeka) have established protocols for monitoring that can be adopted in the catchment.
- State and trends in rare ecosystems (wetlands, dunes, etc.) requires specific investment throughout the catchment.

5 River and groundwater hydrology

5.1 River physiography

The Whanganui River catchment drains its 7118 km^2 catchment over a 290-km path to the sea. The river includes 239 named rapids but over a gentle gradient, lacking falls from the mountains of the Tongariro volcanic zone. Its geomorphology through deeply incised hill country terrain (Fig. 55) would generally be classified as a meandering planform due to the high sinuosity, although there are some reaches upstream of Taumarunui which could be characterized as wandering.

The river and tributaries pass through narrow steep-sided confined channels in a typical dendritic drainage pattern, flowing through rugged hill country through siltstone, sandstone, and limestone basement rocks (Blackwood & Bell, 2016). The channels mostly have small or no floodplains (Fig. 56) until the lowest reach where a small alluvial plain has formed where the city of Whanganui is situated. A low gradient persists inland creating a very large tidal exchange capacity that causes strong tidal flows along with large volumes of sea water flowing up the lower river (Blackwood & Bell 2016).

Figure 55: Whanganui River looking downstream from Pipiriki, higher flow conditions.

Figure 56: Whanganui River above Mangapapa campsite, low flow conditions.

The most significant modifications to the river system have occurred as a consequence of flow diversions for the Tongariro Power Scheme (TPS) commencing in 1971. The scheme collects water from the upper tributaries of the Whanganui River, re-routes it through artificial canals and tunnels into lakes for use in power generation. The full description of this scheme and the impacts on flow is discussed in 5.4.1.

Stopbanks and channelization have been implemented in alluvial plains adjacent to urban areas, notably Taumarunui and Whanganui townships, in order to reduce bank erosion and protect infrastructure. In Taumarunui this includes armouring (for erosion protection) of banks with large rocks to prevent scouring on river bends and to protect infrastructure such as bridges and is managed through the Upper Whanganui River Control Scheme (Ruapehu District Council 2015). Channelization has also occurred in the lower reaches of the Whanganui River alongside the urban areas.

The Whanganui River mouth is locked in place, with the southern side of the river mouth marked by terrace formation of Landguard Bluff, and the northern side marked by a terrace remnant at Castlecliff. Large training walls known as moles at the river mouth in addition to protection works on the spit and adjacent coast maintain the mouth position. The northern mole started being built in 1875 and by 1910 was 350 m, at which point the 800-m south mole was constructed. Two later extensions of 20 m and 50 m were added to the south and north mole in 1921 and 1929 respectively (Blackwood 2007). Previously, the river mouth shifted naturally due to wave action and spit development and flood flows would have formed break-outs as it washed over the spit (Blackwood & Bell 2016).

The headwaters of the Whanganui River – the upper Whanganui and Whakapapa Rivers respectively – are found on the western flanks of Mt. Tongariro and Ruapehu in the central plateau. This flow is joined by a variety of different sized tributaries (Fig. 57), the larger of which are the Ongarue including Taringamotu (1100 km^2), Upper Whanganui including Whakapapa (957 km^2), Ohura (780 km^2), Retaruke (466 km^2), Manganuioteao (643 km^2), Tangarakau (624 km^2), and Whangamomona Rivers (231 km^2). The major sub-catchments and their general water quality are described in Table 16.

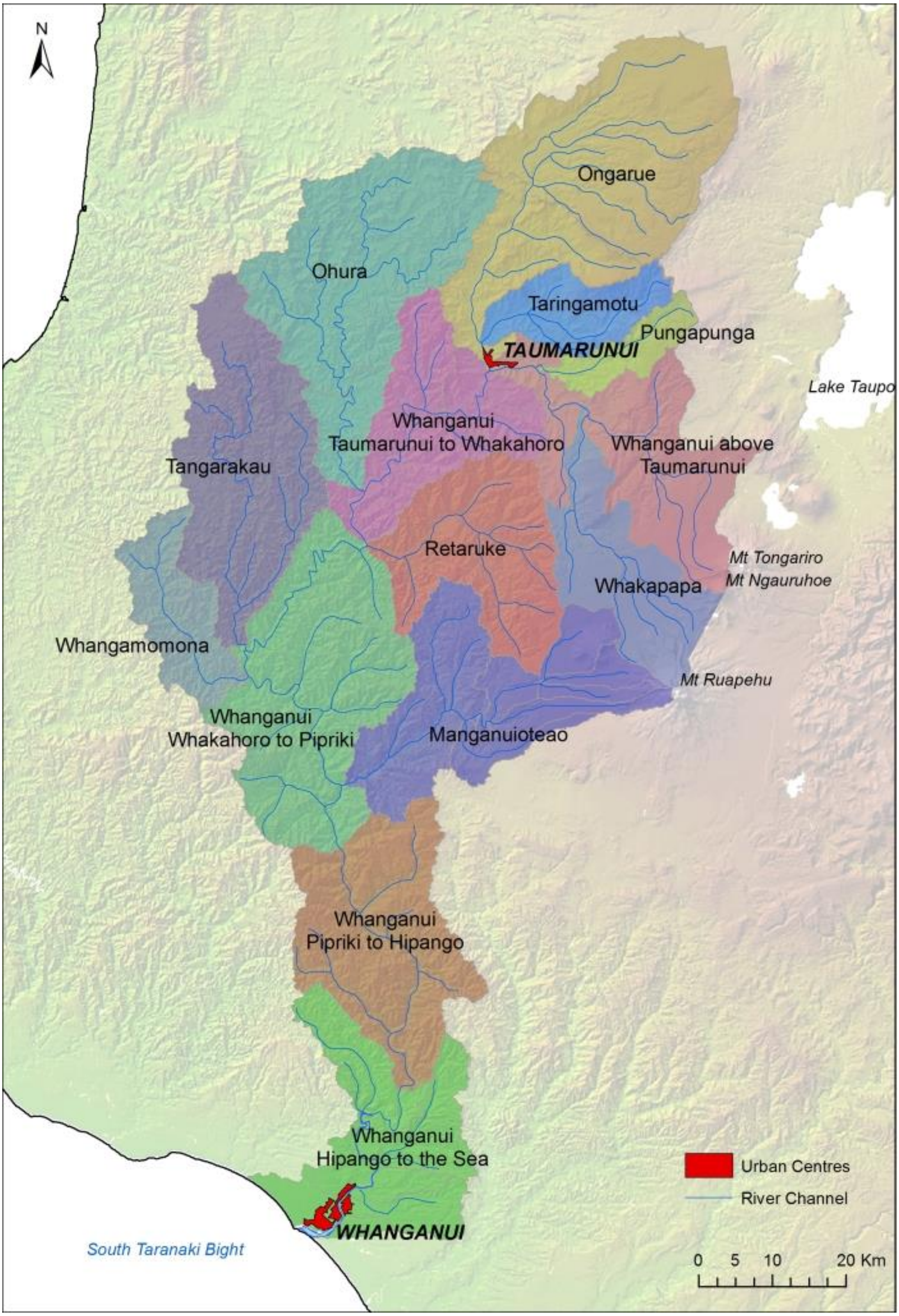

Figure 57: Sub-catchments and reaches of the Whanganui River.

Table 16: Summary of main Whanganui sub-catchments and reaches (after Horizons Regional Council 2003)

Whanganui above Taumarunui, and Whakapapa	• These rivers drain the slopes of Mt Tongariro and Ruapehu as the headwaters for the Whanganui River catchment, with much of the flow diverted to the Tongariro Power Scheme. • Beyond the slopes the rivers flow through land developed for farming with soils predominantly light pumice, of volcanic origin, that are easily eroded. • The two flows of the Upper Whanganui and Whakapapa combine about 10 kilometres north of Taumarunui. • The mountain waters are of exceptionally good quality, and tributaries from farmland are of poorer quality. The Piopiotea Stream has recorded high counts of bacteria in the past, the source of which is uncertain.
Pungapunga and Taringamotu	• The Pungapunga and Taringamotu are medium sized tributaries which flow west from the Hauhungaroa range, respectively entering the Whanganui and Ongarue upstream of Taumarunui • The headwaters are forested but the rivers mostly flow through farmland. • The soil types are mixed, including pumice soils, mudstones, and areas prone to deep-seated earthflows and slumps. • Water quality in these rivers is moderate at best, and both clarity and bacterial counts are of concern.
Ongarue	• The Ongarue is a large tributary joining the Whanganui River south of Taumarunui. • The headwaters are largely pumice soils in the Hauhungaroa range forested both with indigenous forest and large exotic forest plantations. In the middle reaches the soils change to predominantly sandstone, with many striking plateau formations that provide good farmland on the flats, plus inaccessible steep cliffs. • The lower reaches of the river meander through a floodplain of soft alluvial material. • The Ongarue Turbidity Investigation report showed that turbidity increases significantly from the confluence of the Mangakahu Stream. Other tributaries, such as the Paraketu stream and the Taringamotu River, also showed a significant increase in turbidity during rainfall.
The Hikumutu, Te Maire and Otunui	• The Hikumutu and Te Maire enter the Whanganui from the south while the Otunui flows in from the North, all entering the Whanganui catchment between Taumarunui and Ohura confluence. • The catchment is dominated by pastoral land underlain by mudstone geology. • These streams have been found to contribute high turbidity to the Whanganui River and recommended that erosion control be a priority in these sub-catchments.

Ohura	• The Ohura is a large tributary catchment west of Taumarunui draining south into the Whanganui River. • The land is predominantly pastoral farming underlain by siltstone with a significant area classified as Class VII land. The hillsides are steep and land is prone to spoil slip and sheet erosion. • The valley floors are flat, fertile land comprising soft alluvium and colluvium. There is very little riparian vegetation other than grass in many places.
Retaruke	• The Retaruke is a catchment south of Taumarunui. Indigenous bush dominates the headwaters providing generally clear waters, and a significant trout fishery while substantial areas of the sub-catchment are in pastoral farming. This reach is also an important location for population and recovery of whio (blue duck). • The predominant soils are a mixture of siltstone, mudstone, and sandstone. Many streams are in steep-sided valleys where indigenous vegetation has been left in riparian areas. • The Retaruke has been the scene of very large slumps. • The Oio and Kawautahi Streams are significantly dirtier, and while it is apparent that these catchments have more farming they also have more easily erodible soils.
Tangarakau River & Heao stream; and Whangamomona River	• These rivers flow south draining land in the west of the catchment, mostly under indigenous forest, but also including some pastoral land. • Farmland is a small proportion of the Whangamomona, and is restricted mainly to the Heao stream within the Tangarakau, but a large proportion of the pastoral land is Class VII land where erosion is prevalent which influences the water clarity. • The pastoral areas are predominantly underlain by jointed mudstone soils while hard sandstone underlies the indigenous forest.
Manganuioteao River	• The Manganuioteao drains the western slopes of Mt. Ruapehu through indigenous forest. The channels are deeply entrenched in the headwaters and more meandering in the lower reaches before joining the Whanganui River north of Pipiriki. • There are sizeable areas of Class VII land; however, erosion is not as widespread as other Whanganui tributaries. • Water quality and clarity are generally higher than most other tributaries. • The Manganuioteao has a water conservation order in recognition of its outstanding wild and scenic characteristics, its outstanding habitat for whio (blue duck), and an outstanding recreational fishery.
The Whanganui (Taumarunui to Whakahoro)	• This section of the river has high scenic and recreational use and includes a significant amount of Class VII land. • A number of small streams flow into the Whanganui River in this section; however, there is little data available on these streams but streams with similar geology indicate that both turbidity and bacterial counts are high.

Whanganui (Whakahoro to Pipiriki)	• This section of the river has very high scenic value, and recreational use as a popular stretch for canoeing as it winds through the Whanganui National Park and includes one of New Zealands "Great Walks". • Most of the small streams which flow into the Whanganui River have good water clarity if they originate from indigenous forest; an exception is the Mangapurua Stream (where the Bridge to Nowhere is located) which has high turbidity.
Whanganui (Pipiriki to Hipango)	• This part of the river is used less for recreational use than upstream stretches and has a number of small streams flowing into the river coming from a mixture of farmland, exotic forest and indigenous forest. • Many of the streams flowing into the river are regarded as poor quality, draining a relatively high proportion of Class VII farmland and soft erodible sandstone. • The water in the main river is very turbid and has bacterial counts which reflect the tributaries from the whole catchment.
Whanganui (Hipango to the sea)	• Hipango marks the normal limit of the tidal influence located about 22 km upstream, and streams flowing into the river in this section are very small. The water is generally very turbid and has high bacterial counts. • The area is predominantly soft sandstone, loess, and sandy soils prone to erosion

5.2 Surface Water Hydrology

5.2.1 Flow Statistics

River levels and flows are monitored continuously at a network of monitoring stations through the Whanganui River and its tributaries to characterise the flow regime. These monitoring stations are shown in Figure 58 and summary flow statistics in Table 17.

Table 17: Basic Hydrological statistics from monitoring stations on the Whanganui River. L/s is litres per second. 1 cubic metre per second is 1000 litres per second

Site	Upstream Catchment Area (km^2)	Mean Flow (m^3/s)	Median Flow (m^3/s)	Mean Flow Specific Discharge ($L/s/km^2$)	MALF (m^3/s) based on 1-day	MAF (m^3/s)	Period of Record[1]
Whakapapa at Footbridge (33320)	180	7.92	3.59	43.9	3.13	283	12 Nov 59 – 24 Apr 01
Ohura at Tokorima (33313)	681	23.80	11.90	34.9	1.06	279	7 Sep 61 – 17 Oct 05
Whanganui at Piriaka (33356)	834	27.22	18.55	32.6	9.24	600	1 Dec 70 – 1 Jun 04
Ongarue at Taringamotu (33316)	1107	35.05	24.54	31.7	8.25	293	5 Aug 62 – 1 Jul 04
Whanganui at Te Maire (33302)	2212	77.79	52.42	35.2	22.54	902	29 Jun 62 – 11 Apr 05
Whanganui at Paetawa (33301)	6643	216.17	128.69	32.5	39.13	2316	26 Jul 57 – 4 Apr 05

Mean flow represents the average flow rate at the specified site in Table 17, whereas the median flow which is always lower is the flow exceeded 50 % of the time. The specific discharge ($L/s/km^2$) allows a comparison among sites to indicate which combinations of primarily rainfall and geology affect the generation of runoff per unit area. Specific discharge for the Whanganui at Piriaka is lower than would occur naturally because of the flows diverted out of the upper Whanganui by the Tongariro Power Scheme.

In Table 17 it should be noted that the flow statistics are affected by the period of record for which flow data are available, and are therefore not able to be compared accurately unless they apply to the same period. Also, actual rather than natural flows are reported in Table 17.

[1] More recent data may be available for these sites but had not been analysed or audited at the time of writing this report

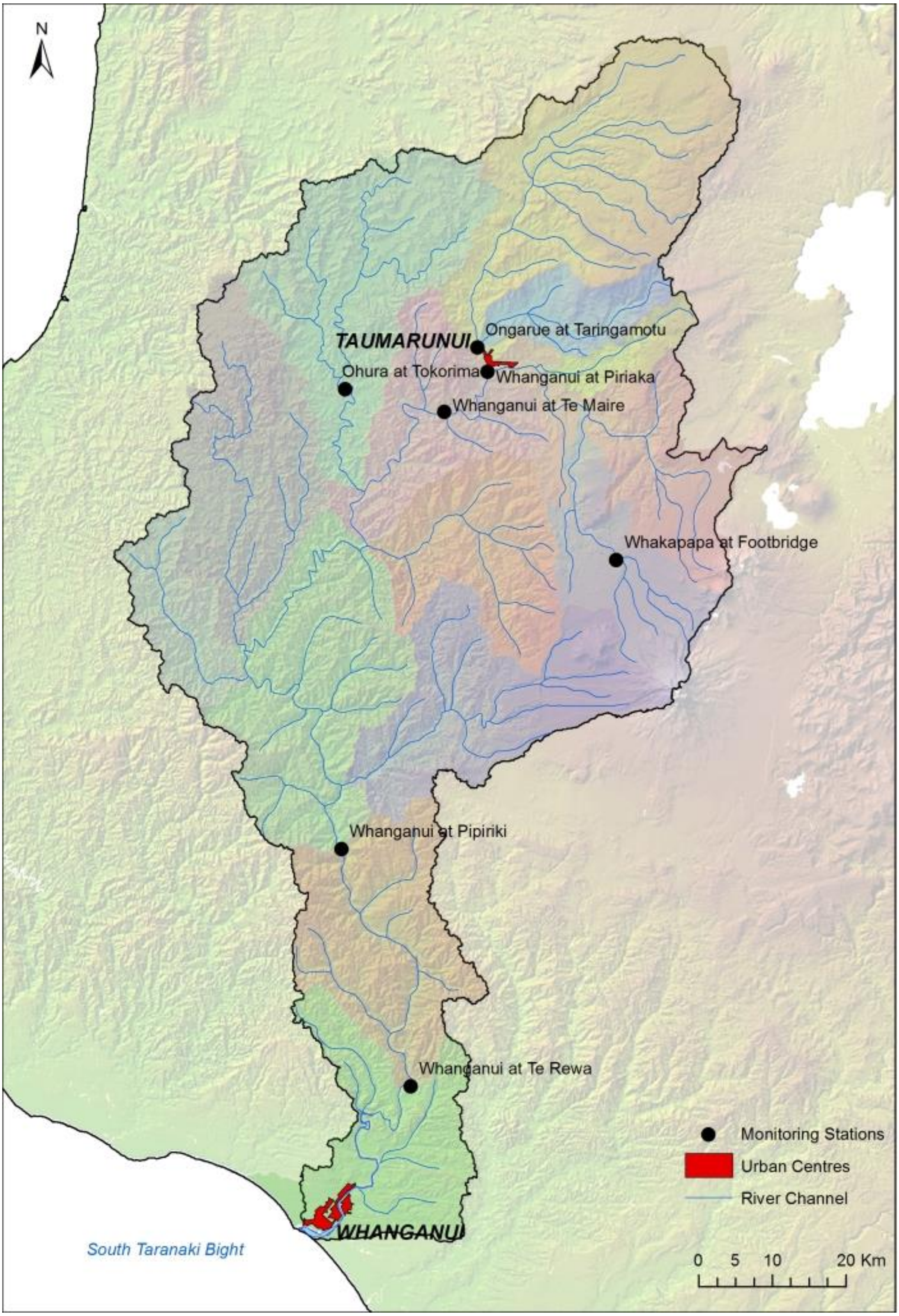

Figure 58: Sub-catchment map showing key flow monitoring sites. Note that Whanganui at Te Rewa is the replacement monitoring site for Whanganui at Paetawa (essentially the same location).

The Tongariro Power Scheme was implemented in 1972 with subsequent changes to operating requirements occurring in 1983, 1992, 1993 and 2004 (Genesis Power 2000 – TPS AEE report). The main changes to the operating conditions are outlined by Henderson & Diettrich (2007) as follows:

- 28 November 1972: Western Diversion begins
    - Small release flows of 600 L/s at Whakapapa for fish
    - Temperature based minimum flow of 7.1 m^3/s at Piriaka
- 25 December 1983: minimum flow rule at Te Maire implemented
    - 16 m^3/s minimum flow rule
    - Exception: 22 m^3/s from 1st Dec to 15th Feb & Easter
- 1 September 1992: Planning Tribunal rules
    - 3 m^3/s minimum flow at Whakapapa
    - 29 m^3/s^{-1} minimum flow at Te Maire from 1st Dec to 31st May
- 20 April 1993: Otamangakau sluice valve used to provide minimum flows at Te Maire in preference to Whakapapa releases
- 1 December 2004: Minimum flow changes due to resource consent hearings (see 5.4.1)
    - Minimum flow at Mangatepopo Intake of 0.5 m^3/s
    - Minimum flow at Whanganui Intake of 0.3 m^3/s

The implication of the influence caused by the Tongariro Power Scheme on recorded flow rates is that affected sites are artificially altered from natural flow rates. In order to evaluate effectively the flow data in the Whanganui River for the affected sites requires modelling of the naturalised flow, especially for historical trends. Three different values for flow are provided by (Henderson & Diettrich 2007). “All data” displays flow rates at the respective site as measured by the recording site as well as two simulated flow models: “Sim Natural” models the expected river flow without construction of the Tongariro Power Scheme, and “Sim Consent” models the flow rates expected while adhering to the operating requirements. Comparing these three flow conditions for Annual Low Flow (ALF) and Annual Flood (AF) allows for a clearer evaluation of the hydrological characteristics of the catchment.

5.2.2 Low Flows and Annual Minima Trends

As with increased flooding, Young (1998, p. 209) also records that land clearance by the early European settlers meant the Whanganui River “more often ran below its previous mean flows, especially notable in summer”. He mentions a huge drought in autumn 1919 that reduced flows down to Parikino, and shallow water problems for the riverboats above Pipiriki in the summers of 1920, 1921, and 1922.

More recent Annual Low Flow records show natural variability from year to year determined by the presiding weather patterns for each respective year combine with effects of upstream diversions of water.

The commencement of the Tongariro Power Scheme (TPS) is observable in the MALF records for each of the recorded sites affected by the Tongariro Power Scheme. Effects of the flow restrictions are most pronounced in the smaller sub-catchments further upstream during low flow periods. Similar patterns can also be observed at downstream sites experiencing flow-on effects with the addition of any restrictions imposed at each respective site. Further downstream, tributary inflows and a consequentially larger overall flow diminish the relative effect of the upstream diversions. By the time the Whanganui reaches Te Paetawa, the reduction of flow caused by the TPS is barely discernible (Fig. 63).

The Whakapapa at Footbridge recording site clearly shows commencement of the TPS, with ALF dropping from over 6 m^3/s to less than 0.8 m^3/s (Fig. 59). Minimum flow requirements were applied from 1992, after which the recorded values increase to approximately 3 m^3/s.

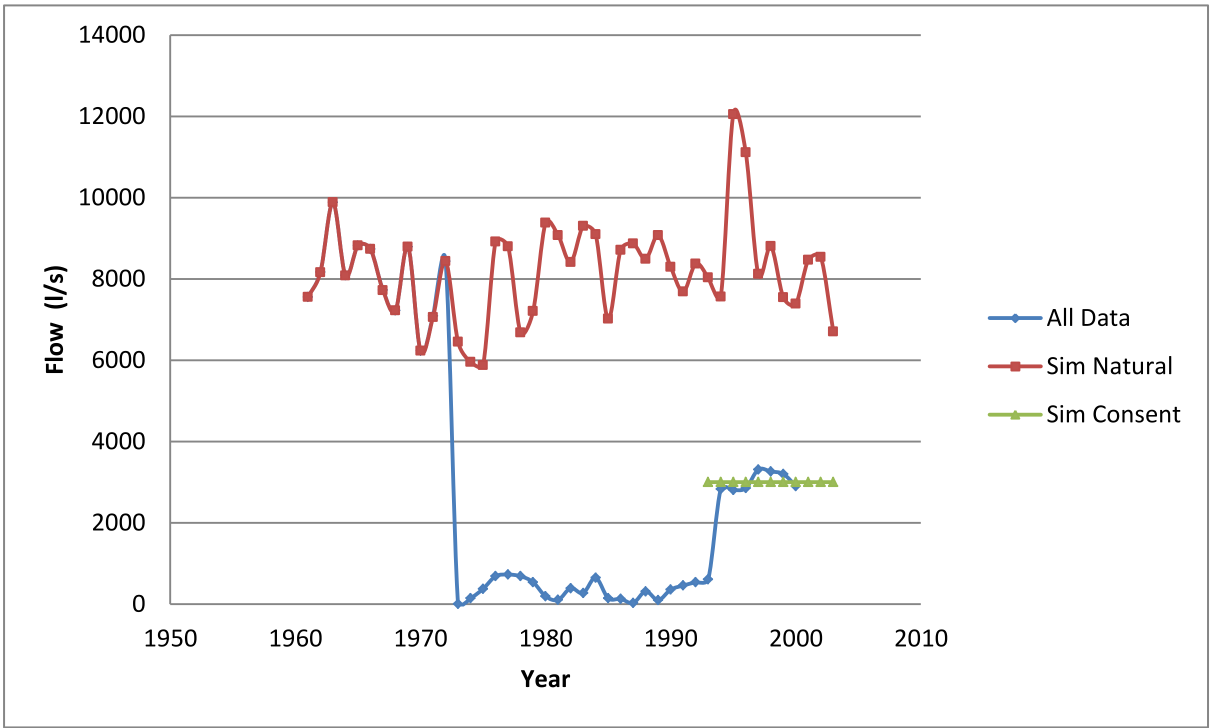

Figure 59: Annual low flow for Whakapapa at Footbridge (33320).

Whanganui at Piriaka had an estimated ALF in the order of 15 m^3/s, but it drops to a little over 5 m^3/s upon commencement of the TPS until changes in minimum flow requirements in 1993 increase it to over 10 m^3/s (Fig. 60). The Ongarue catchment is not influenced by the TPS with annual low flows reported in Figure 61.

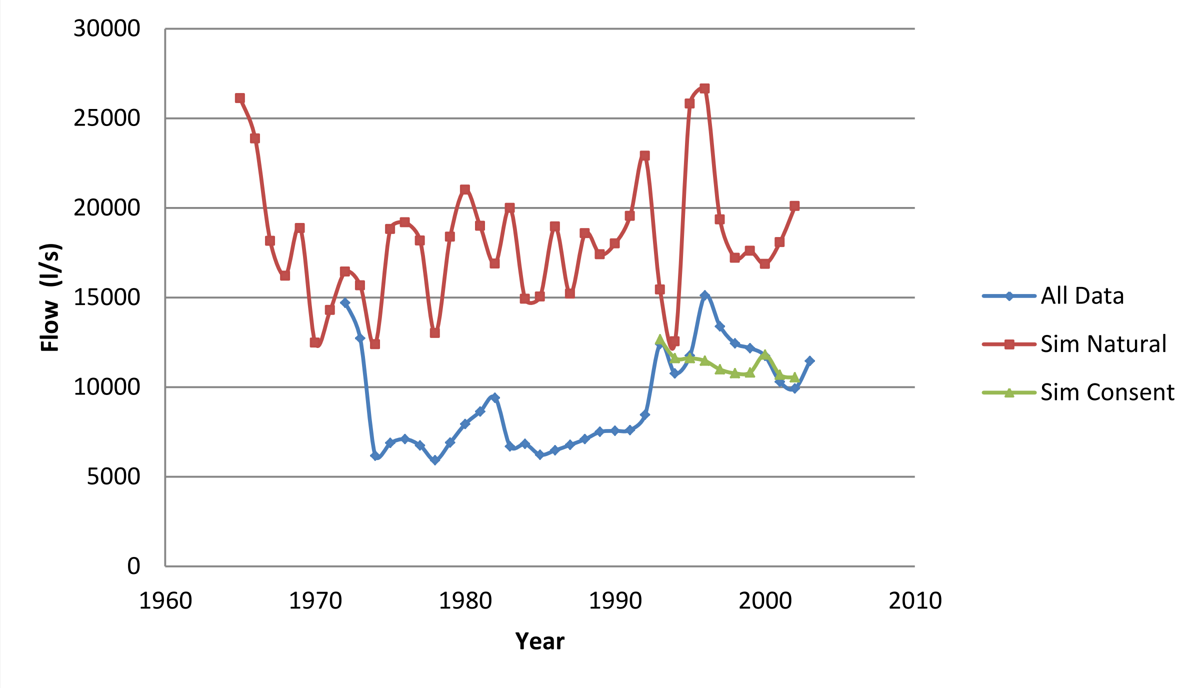

Figure 60: Annual low flows for Whanganui at Piriaka (33356).

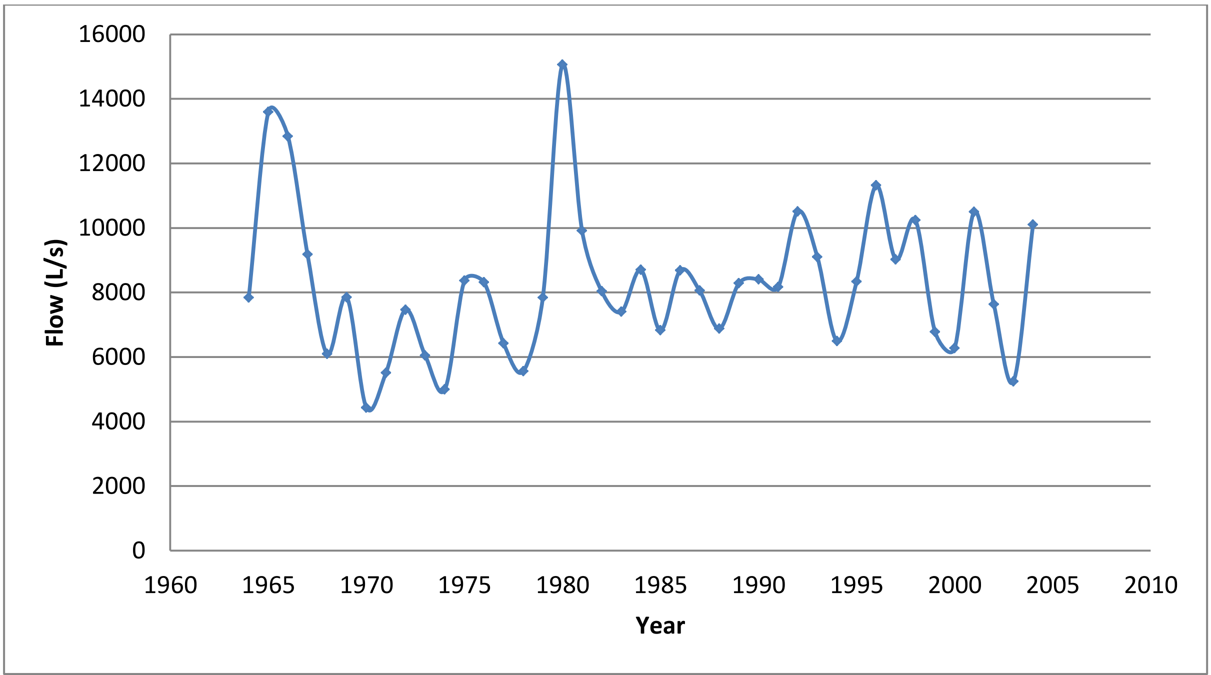

Figure 61: Annual low flows for Ongarue at Taringamotu (33316).

Whanganui at Te Maire had an estimated ALF generally between 20 and 30 m^3/s with some estimates over 40 m^3/s. This initially drops down between 12 and 18 m^3/s at the commencement of the TPS before minimum flow restrictions raised it to 16 m^3/s in 1983, and then increases in summer minimum flow in 1992 raised this again to between 20 and 30 m^3/s (Fig. 62).

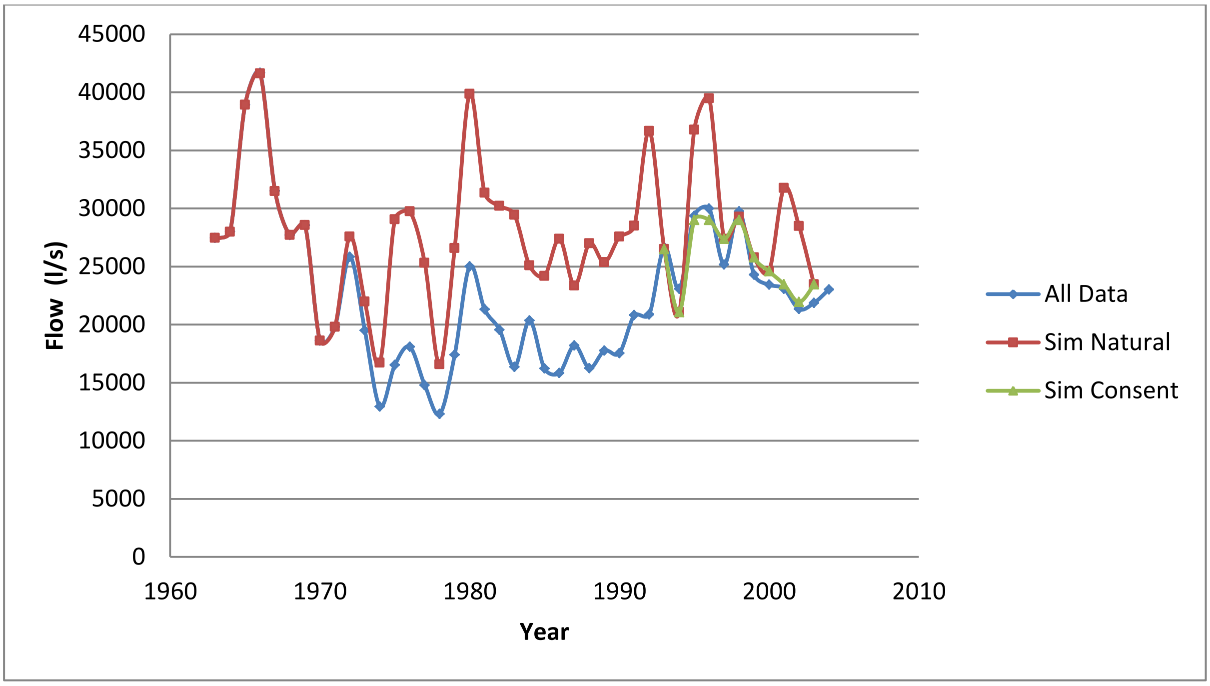

Figure 62: Annual low flows for Whanganui at Te Maire (33302).

Whanganui at Paetawa had an estimated ALF generally between 40 and 60 m^3/s, which reduced to between 25 and 35 m^3/s after the 1972 commencement; however, simulated natural flows also decrease to between 25 and 45 m^3/s during that period. After a minimum flow was first required at Te Maire in 1983, the recorded ALF at Paetawa ranged generally between 30 and 35 m^3/s compared with between 35 and 45 m^3/s simulated ALF rates. The 1992 increased minimum flow requirements during summer – which most affect low flows – bring the recorded ALF values into close agreement with simulated natural and consented flow rates (Fig. 63).

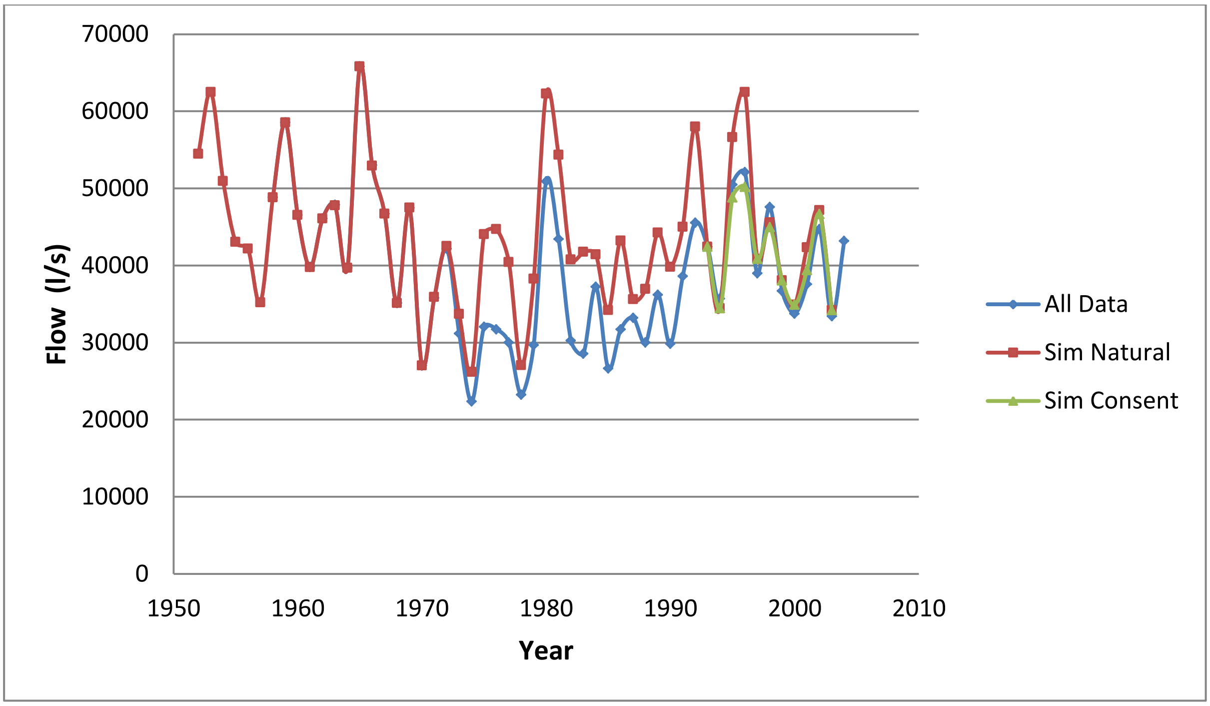

Figure 63: Annual low flows for Whanganui at Paetawa (33301).

5.2.3 Flood Records and Annual Maxima

Annual Flood (AF) represents the annual maximum flood measured in each year. Flow restrictions have less of an impact on the flood flows compared to low flows because the elevated flow rates driven by large storm events overwhelm the quantities of water diverted. Overall, there are relatively small differences between simulated AF values, and in most cases the simulated flow rates overestimate relative to actual recorded values for AF (e.g. Figs 64, 65, 66, 67, and 68). The largest divergence in values is seen in the sub-catchments further upstream with diminishing effects downstream.

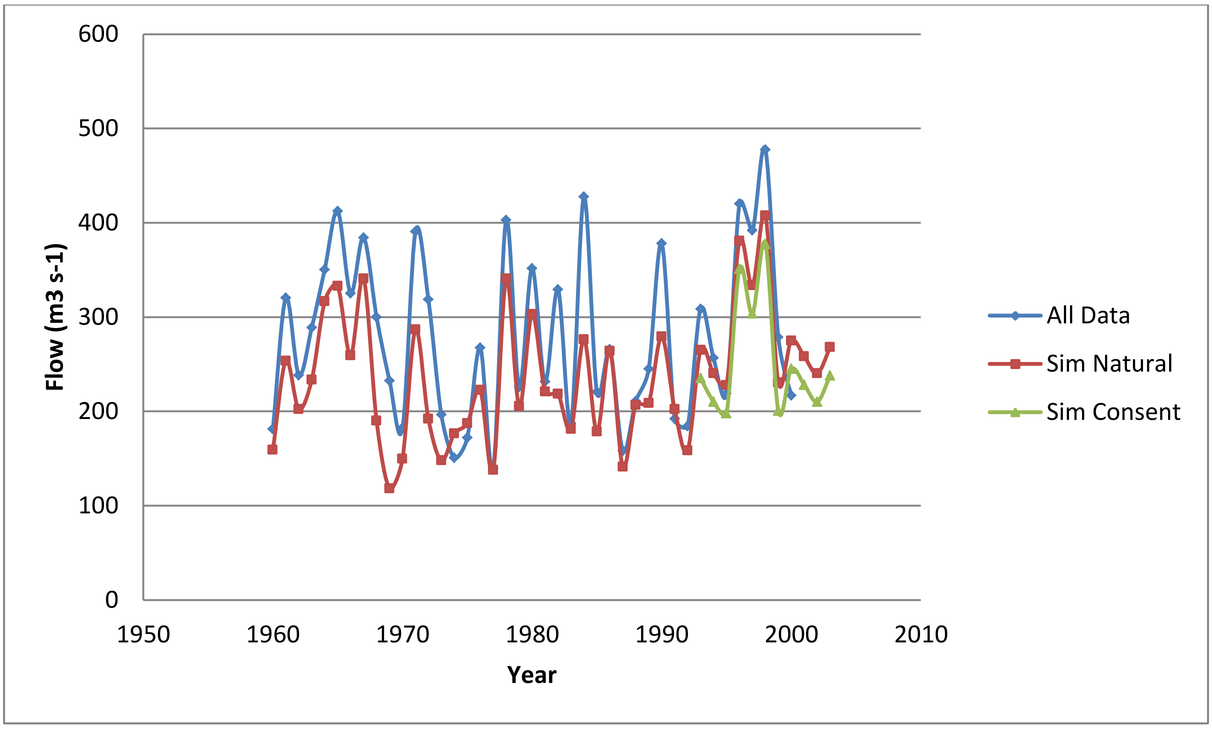

Figure 64: Annual floods for Whakapapa at Footbridge (33320).

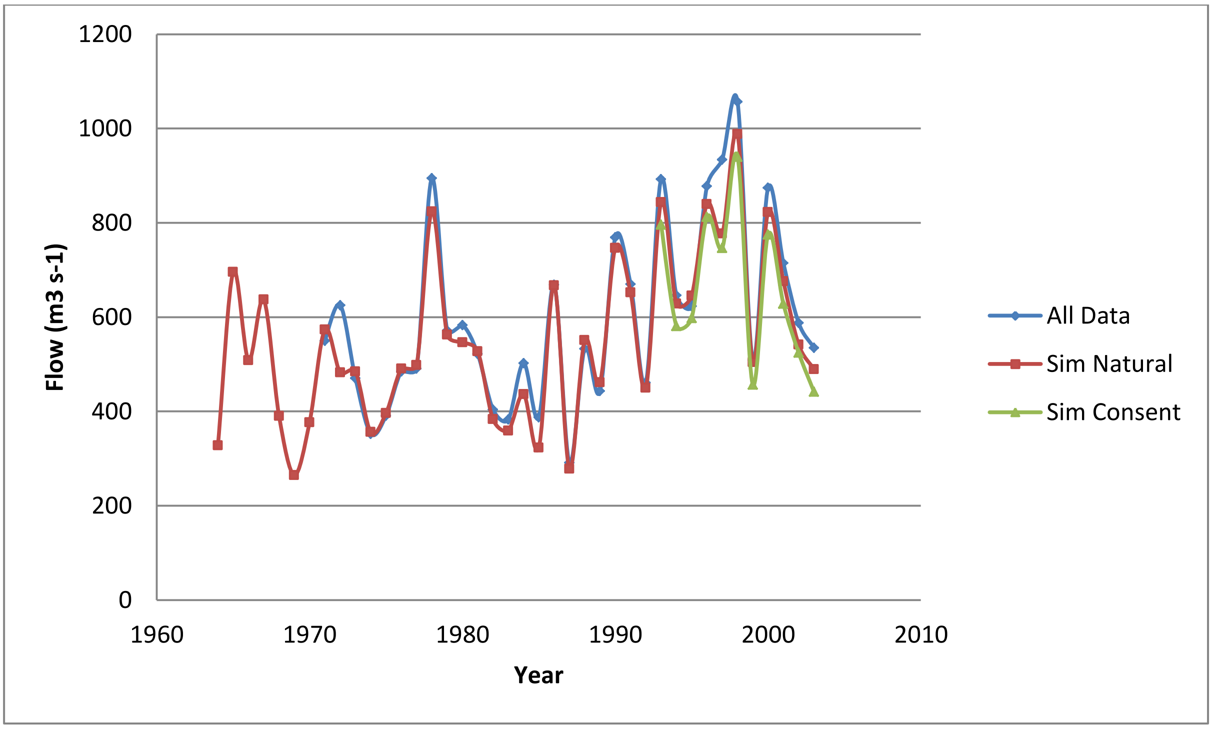

Figure 65: Annual floods for Whanganui at Piriaka (33356).

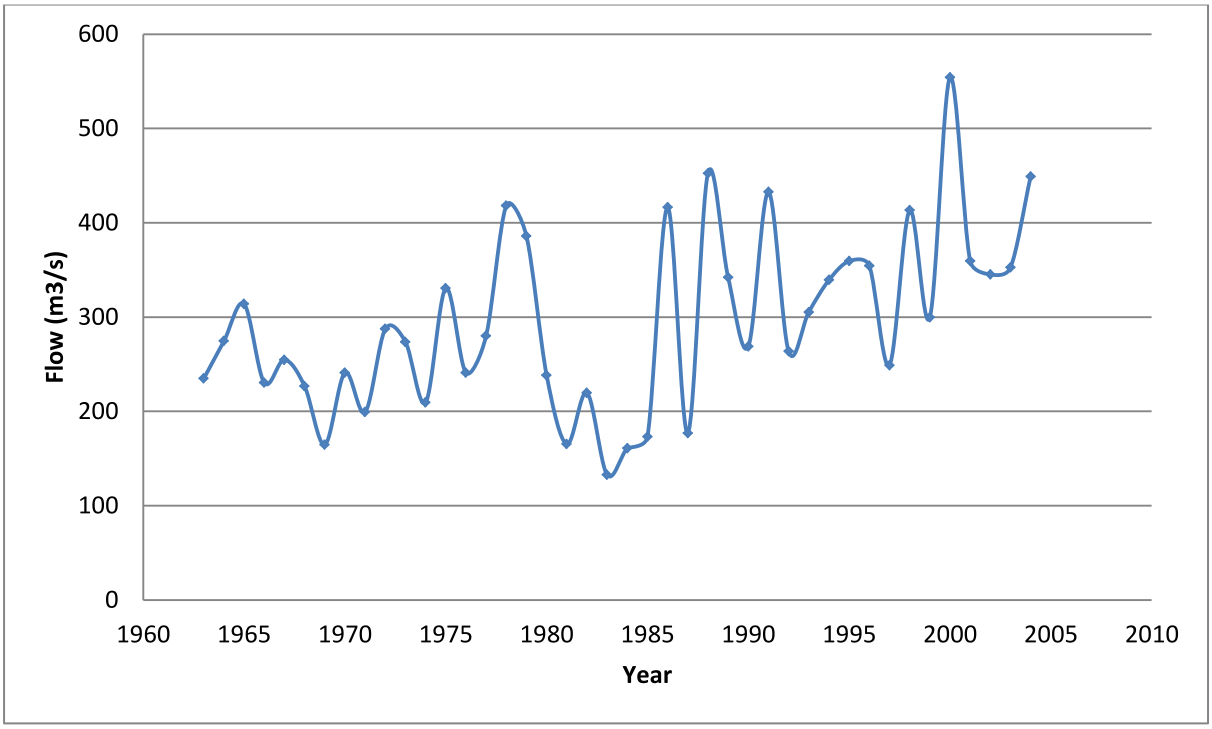

Figure 66: Annual floods for Ongarue at Taringamotu (33316).

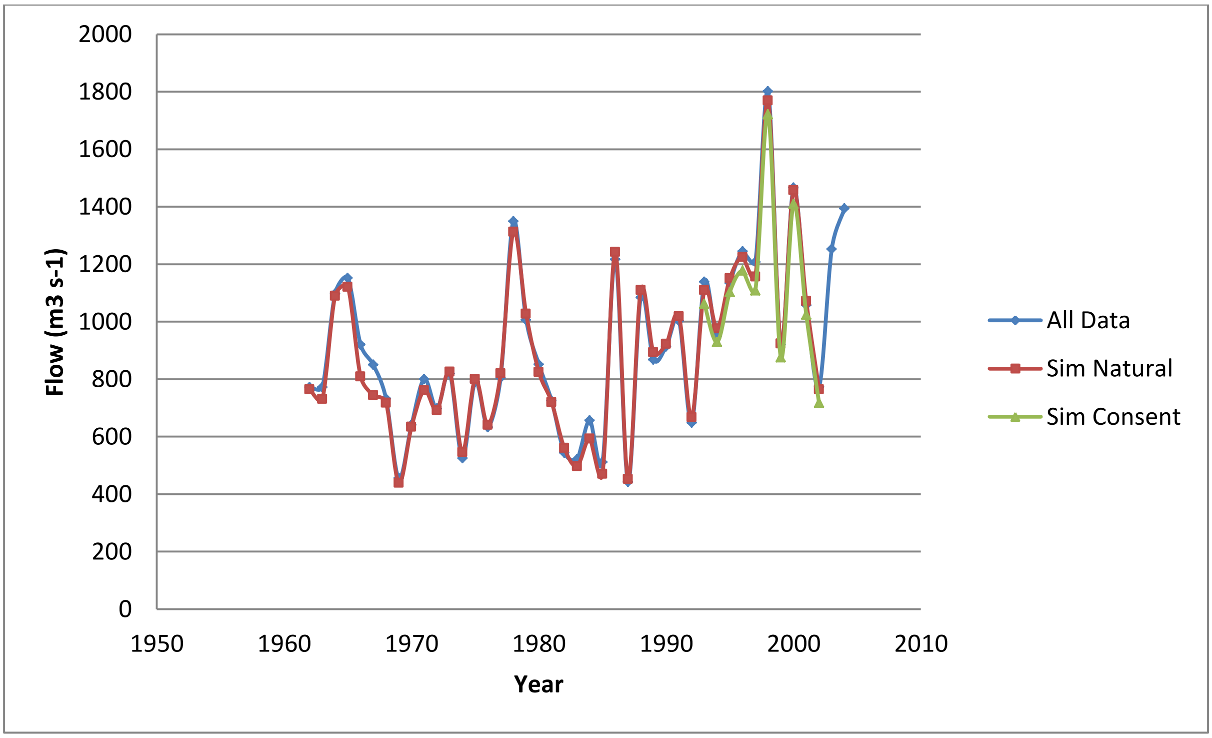

Figure 67: Annual floods for Whanganui at Te Maire (33302).

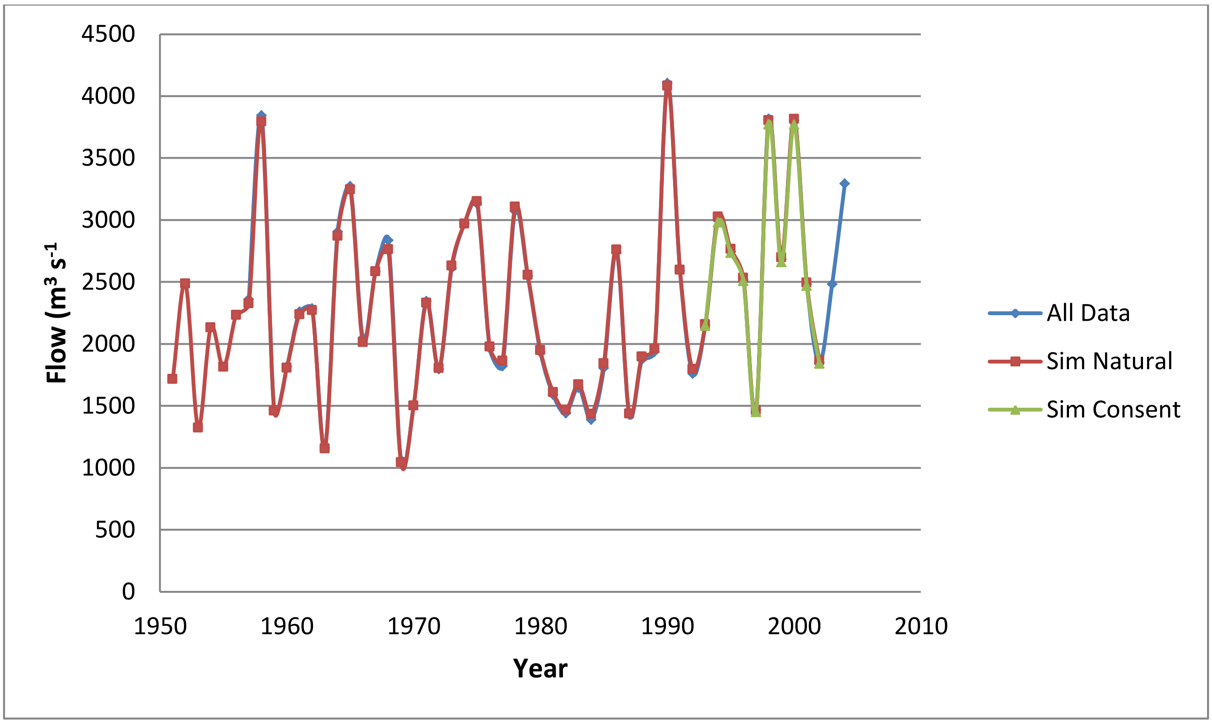

Figure 68: Annual floods for Whanganui at Paetawa (33301).

5.2.4 Flood Trends and focus on the 2015 Flood

A more in-depth analysis of flood peaks is provided by Blackwood and Bell (2016) for the main stem of the Whanganui River. This incorporates three main sources of information: information prior to continuous recording, flow records at Paetawa, and flow records at Te Rewa. Prior to continuous recording, large floods have been estimated for the Whanganui River from a combination of flood level information obtained from photographs, newspaper records and hydraulic modelling of corresponding discharges (Blackwood & Bell 2016). These floods are shown in Table 18.

Table 18: Whanganui River at Paetawa Historic Floods (after Blackwood & Bell 2016)

Year	Discharge (Cumecs)	Year	Discharge (Cumecs)
1858	4293	**1904**	4325
1864	4293	**1926**	3856
1875	4293	**1935**	3700
1883	3856	**1936**	3732
1891	4231	**1939**	4011
1897	3917	**1940**	4689

Two flow sites are used to record the Whanganui flow: the Whanganui at Paetawa, which provided flood flow records from 1957 to 2014; which was replaced by a new recorder site at Te Rewa, which has provided flow records since 2006. The two sites are considered analogous, with essentially the same catchment areas, and Table 19 displays the annual maxima for these sites.

There appears to be a general increase in flood magnitude between 1957 and 2015 (Fig. 69). The 1st and 3rd highest flows with estimated peak flows of 3947 m^3/s in 2013 and 4755 m^3/s in 2015 have contributed to the general increasing trend flood magnitude. Before these two floods, the increasing trend was much less significant. Interestingly, before the 2015 flood, the historic floods (before 1957) provided the six largest flood estimates for the Whanganui River (Table 19), while a flood of 4106 cumecs recorded in 1990 provided the largest recorded flood during the continuous series until 2015 (Blackwood & Bell 2016).

Flooding has been exacerbated by land clearance. Young (1998, p. 209) records that with indiscriminate tree felling and burning came “unaccustomed flood, bringing down more work for the snagging teams” clearing the river channel for the riverboats. Records mention two large floods in 1907 and 1910, neither of which years are listed in Table 18, so large floods must have seemed common in the years of early European settlement.

Floods may also be correlated with the Interdecadal Pacific Oscillation (IPO). The IPO is a pattern of ocean-atmosphere climate variability which is separated into positive and negative phases which indicate different climate patterns. The positive phase causes the west Pacific to cool and eastern ocean to warm, while the opposite occurs in the negative phases. Interestingly, evaluation of flood peak trends shows that nine of the top ten floods since 1957 have occurred during the negative phase of the IPO with negative shifts in mid 1940s, 1977/78 and around 1997/98 (Blackwood & Bell 2016).

Table 19: Whanganui River at Paetawa & Te Rewa Annual Maxima 1957–2015 (after Blackwood & Bell 2016)

Year	Discharge (Cumecs)	Rank	Year	Discharge (Cumecs)	Rank
1957	2359	27	**1987**	1430	55
1958	3845	4	**1988**	1872	39
1959	1470	51	**1989**	1937	37
1960	1816	43	**1990**	4106	2
1961	2259	31	**1991**	2589	21
1962	2285	30	**1992**	1760	46
1963	1163	58	**1993**	2151	32
1964	2906	13	**1994**	2996	11
1965	3272	8	**1995**	2745	15
1966	2047	34	**1996**	2516	24
1967	2586	22	**1997**	1466	52
1968	2836	14	**1998**	3815	5
1969	1063	59	**1999**	2683	18
1970	1502	50	**2000**	3804	6
1971	2346	28	**2001**	2483	25
1972	1798	45	**2002**	1848	40
1973	2612	20	**2003**	2482	26
1974	2971	12	**2004**	3293	7
1975	3134	9	**2005**	1239	57
1976	1965	36	**2006**	1830	41
1977	1821	42	**2007**	1582	49
1978	3071	10	**2008**	2326	29
1979	2546	23	**2009**	1440	54
1980	1933	38	**2010**	2130	33
1981	1590	48	**2011**	2729	17
1982	1441	53	**2012**	2617	19
1983	1648	47	**2013**	3947	3
1984	1390	56	**2014**	2003	35
1985	1805	44	**2015**	4755	1
1986	2739	16			

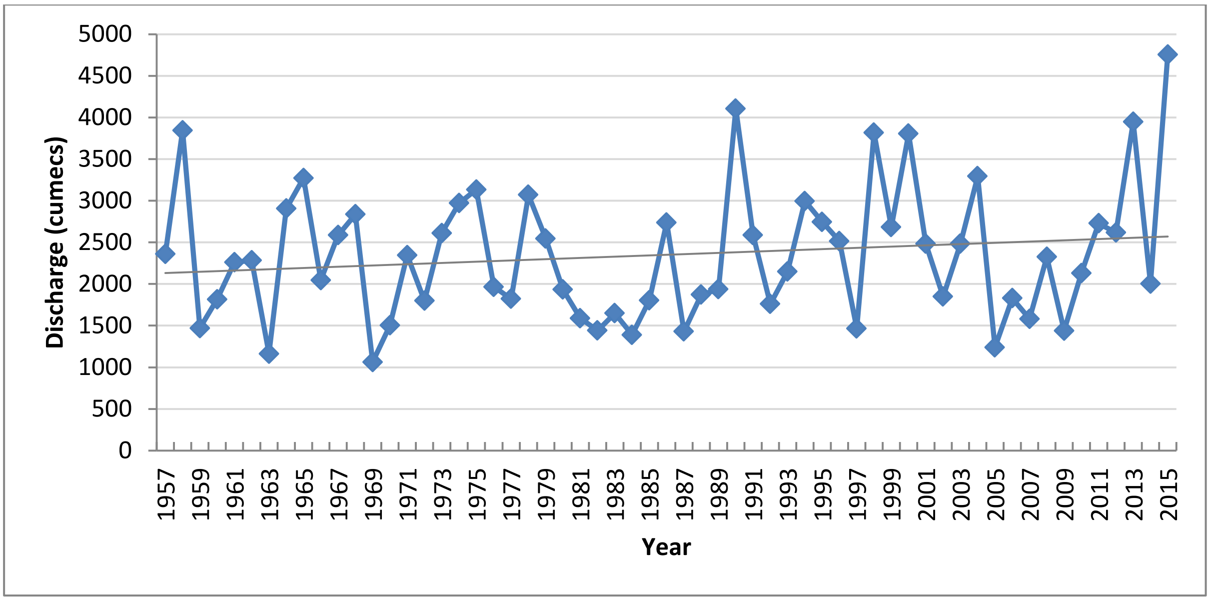

Figure 69: Whanganui River at Paetawa & Te Rewa Annual Maxima 1957 – 2015 (after Blackwood & Bell 2016)**.**

The largest recorded flood event to date occurred in the Whanganui River in 2015 between 19 and 21 June 2015. A very major rainfall event caused significant flooding in the Whanganui River at Whanganui, particularly around Anzac Parade-Kowhai Park locality, where water flooded numerous houses and reached depths of up to 2 m in some (Blackwood & Bell, 2016). The Te Rewa gauging site (50 km upstream of the river mouth) recorded a peak flow of 4755 cumecs at a stage of 21.975 m at 0105 hours on 21 June 2015. This represented a 1.2% Annual Exceedance Probability (AEP) (1 in 85 year) flood event, the highest recorded in the Whanganui river and the second highest ever recorded in the North Island (Blackwood & Bell 2016). Rainfall during the 48-hr storm period experienced rainfall in excess of 1% AEP (1 in 100 years) downstream of Te Rewa on top of wet antecedent conditions due to well above average rainfalls for the preceding months. It was concluded that the majority of tributary flows in the lower Whanganui catchment would have been higher than 1% AEP magnitude (Blackwood & Bell 2016).

After the 2015 flood, Horizons Regional Council updated the flood frequency analysis in 2016 (Table 20) to include this flood event and the additional 9 years of flood data since the previous analysis. This incorporates 59 annual maxima from 1957 to 2015, as well as a censored assessment including 12 historic peaks dating back to 1858 (Blackwood & Bell 2016).

Table 20: Whanganui at Paetawa & Te Rewa Design Flood Frequency Estimates (Updated 2016) (after Blackwood & Bell 2016)

Return Period (Years)	Probability of occurrence in any year (%)	Discharge (Cumecs)
1.5	67	1935
2	50	2232
2.33	43	2369
5	20	2963
10	10	3448
20	5	3912
30	3.3	4179
50	2	4513
100	1	4964
200	0.5	5413
500	0.2	6005

5.3 Groundwater Hydrology

Because of the lack of intensive or irrigated land use in the Whanganui catchment, there is low utilisation of groundwater from aquifers in the catchment. Whanganui town drilled its first groundwater bore in 1892, and the Nukumaru Group interbedded sands and limestone from which 600–700-m-deep bores supply the town are seen as the most important aquifer (Rosen & White 2001).

The Whanganui Groundwater Management Zone encompasses 938 km^2 of the coastal area surrounding Whanganui city and approximately downriver of Parikino. Shallow wells of less than 30 m depth intercept Late Quaternary deposits along with the deeper Nukumaru formation bores. Horizons Regional Council estimates recharge of this zone at 266 M m^3/year, of which around 62% of total annual allocable groundwater is consented for use, with an estimated annual usage of approximately 14 million cubic metres (32% of total available allocation).

The Northern Whanganui GMZ which covers the remaining upper part of the catchment has little groundwater use. Horizons Regional Council has not specified an annual allocation limit for the Northern Whanganui GMZ. At present, approximately 641,000 cubic metres of groundwater is utilised by industry and agriculture on an annual basis for consented takes.

Groundwater is a primary source of low flows in rivers, so groundwater investigations can help understanding of surface water sources and water quality. Mean residence times (MRT) estimated from tritium dating of water at low baseflow conditions at four river sites down the Whanganui river (Ongarue, Te Maire, Pipiriki, Te Rewa) resulted in values between 6 and 7 years (Morgenstern et al. 2014).

Tritium is a radioactive isotope of Hydrogen produced naturally in the atmosphere from cosmic rays with a half-life of 12.32 years. Measuring the tritium concentrations allows estimation of the lag time between rainfall infiltrating to groundwater and then arriving in the stream channel. This is expressed as a Mean Residence Time (Morgenstern et al. 2010, 2014).

The MRT has implications for the arrival of nutrients associated with different land use at the river and is useful for prediction of changes in river water quality as a result of land use change (Morgenstern et al. 2014). It should be noted that low-flow conditions may not contribute a large fraction of total discharge, but are important in summer when recreational use is higher.

Morgenstern et al. (2014) recommend that improvements to water management could be gained through understanding the lag time of water discharge in a wider array of geological formations, particularly:

- volcanic formations which may display much higher MRT values
- mudstone formations which may have different MRT values compared to the Sandstone terrain, and
- lava formations found on the Tongariro.

5.4 Impacts on hydrology from human activity (land use change, consented dams, diversions of water)

5.4.1 Tongariro Power Scheme

Concerns about Cultural Values

The Tongariro Power Scheme was planned and constructed progressively between 1960 and 1983, and the Tokaanu power station first generated electricity in 1973. There were no residual (minimum) flow requirements on Whanganui streams subject to diversion when it first began operation; however, in 1988 a special tribunal appointed by the then Rangitikei-Wanganui Catchment Board heard submissions on setting minimum flows, including iwi submissions presented at Ngā Puwaiwaha Marae.

The tribunal recommended minimum flows be set at Te Maire (22 cumecs Dec – 15 Feb plus Easter, 16 cumecs otherwise) and below the Whakapapa River intake. Electricorp (the then operator of TPS), and then Whanganui Māori Trust Board and DOC appealed that decision. What followed was one of the longest Planning Tribunal (now Environment Court) appeal hearings, which included hearing days at Pūtiki Marae. Their decision was one of the first to "include Māori perspectives and recognise values other than 'progress'" (Young 1998, p. 256). The court set a minimum flow from 1 December to 31 May of 29 cumecs at Te Maire, and 3 cumecs below the Whakapapa diversion all year round. Electricorp's appeal in 1992 to the High Court was not successful in changing these minimum flow requirements in the scheme's water rights.

These authorisations for the scheme were deemed to expire in 2001, 10 years after the Resource Management Act came into effect. Genesis Energy carried out various environmental studies of the TPS and the catchment to support their renewal applications in 2000 for 53 resource consents, including those for the continuing dam, take and discharge of water from the Whanganui headwaters (the 'western diversion') into the power scheme.

The 30 regional council consents were appealed by parties including Ngati Rangi, Tamahaki Inc. and various parties represented by the Whanganui River Māori Trust Board. In its 2004 decision, the Environment Court found that the Māori witnesses had "effectively established that the diversion of the waters has had a substantial and detrimental effect on their spiritual values." However, the Māori appellants were unable to specify what changes to the operation of the Whanganui diversions would address their concerns. To allow discussion of mitigation options, the Court granted the consents for a term of 10 years, not the 35 years sought by Genesis, to enable time for a 'meeting of the minds' (Environment Court 2004). The Environment Court gave the following reasons for its decision:

1. the magnitude of the effects on Māori
2. the immense depth of feeling apparent from the Māori witnesses which reflects the magnitude of those effects
3. the greater ameliorating power of a fresh application over review proceedings, and
4. a term of 10 years recognises the national interest factors and provides a correct balance.

Genesis, especially concerned about the short 10-year consent term, appealed that decision to the High Court who agreed and referred the matter of the term of consents back to the Environment Court (High Court 2006). Ngati Rangi, Tamahaki, and Whanganui River Māori Trust Board appealed the High Court decision to the Court of Appeal. That Court's decision (with one of three judges dissenting) dismissed the appeal and again referred the matter of the term of consents back to the Environment Court (Court of Appeal 2009). The Māori appellants sought to appeal to the Supreme Court but on 21 December 2010 reached an agreement with Genesis to progress resolution of outstanding issues in a non-adversarial manner outside the courts. Finally, in June 2011, the Environment Court approved the Genesis TPS consents with terms of 35 years, expiring in 2039 (Environment Court 2011).

Infrastructure and Resource Consents

The Western Diversion collects water from the headwaters of the Whakapapa and Whanganui Rivers, a catchment size of about 320km^2, approximately 5 % of the Whanganui River catchment.

Water is routed from the Whakapapa River, and four smaller intakes that intercept water from the Tawhitikuri, Okupata, Taurewa, and Mangatepopo streams into a 16.5-km tunnel into Lake Te Whaiau. Water is also diverted from the Whanganui River into the Te Whaiau Stream, which in turn discharges into Lake Te Whaiau. From Lake Te Whaiau water is discharged into Lake Otamangakau which is then discharged into Lake Rotoaira via the Wairehu Canal.

The Whakapapa Intake just below the confluence of the Papamanuka Stream and the Whakapapa River has a flow capacity of 35 cubic metres per second (Horizons Regional Council consent 101282). Upstream of the Whakapapa intake, the catchment area of the Whakapapa River headwaters is 176 km^2, with an estimated mean flow of 15.3 m^3/s. A minimum flow of 3 m^3/s – unless the flow is naturally lower – is maintained downstream of the intake at the monitoring site, Whakapapa River at Footbridge. On two weekend days during February to September each year, the consent requires release of at least 16 m^3/s natural flow for recreational users such as canoeists.

Intakes on the smaller streams have the following flow capacities: Okupata 2 m^3/s, Taurewa 2 m^3/s, Tawhitikuri 2 m^3/s, Mangatepopo 5 m^3/s (resource consents 101283-6). A minimum flow downstream of 0.5m^3/s is required downstream of Mangatepopo Intake.

The Whanganui Intake diverts up to 14 m^3/s[2] from the Whanganui River via a short tunnel into the Te Whaiau Stream, which then flows into Lake Te Whaiau (consent 101288). A minimum flow of 0.3 m^3/s is required and maintained below this intake. The Whanganui River intake has a mean flow of 1.55 m^3/s draining a catchment area of 32 km^2 (Jowett et al. 2000).

The Otamangakau Canal allows up to 74 m^3/s to be taken from Lake Te Whaiau to Lake Otamangakau (consents 101291-2). Lake Otamangakau is also fed by the Otamangakau Stream (mean flow rate of 0. 6 m^3/s) and drains a 23-Km^2 area. Lake Otamangakau provides short term storage for the western diversion flows, with controlled releases of up to 3 m^3/s into Otamangakau Stream provided for under consent 101294. Lake Otamangakau has a total catchment drainage area of 46 km^2 and a maximum depth of 12 m near the Otamangkau Dam. A description of the bathymetry can be found in Mitchell (1989).

The Otamangakau Dam also contains a release valve to maintain flow conditions for the Whanganui River at Te Maire. This requires the valve to be opened from December to May when needed to re-establish a dry stream bed to help with Te Maire minimum flow.

The Wairehu Canal allows up to 55 m^3/s to be taken from Lake Otamangakau to Lake Rotoaira. There, combined with inflows from the scheme's Eastern Diversion, power is generated at the end of a 6.1km tunnel in the 240MW Tokaanu power station (commissioned 1973) and enters the Waikato catchment.

Consents 101288 and 101294 are required to operate together so that a minimum flow of at least 29 m^3/s – unless the flow would naturally be lower – is provided in the Whanganui River at Te Maire (58 kilometres downstream from the Whakapapa Intake) from 1 December to 31 May. No minimum flow is prescribed for June to November at Te Maire.

[2] Genesis Energy flow monitoring data since 2014 indicate the actual maximum take is below 10m^3/s

The following changes in flow reductions following the Western Diversion are reported for the period up to 1998 by Henderson (1998) as outlined in Genesis Power Limited (2000):

- Low flows (average annual seven-day low flows) are reduced by 65% at the Whakapapa footbridge site. Twenty-seven km downstream the low flow reduction is 45% and this is reduced to 10% by Te Maire and Paetawa
- Seasonal variation in base or low flows is eliminated, as the base flow of 3 m^3/s is always maintained as a minimum flow requirement.
- Peak or flood flows are reduced by 13% at the Whakapapa footbridge. At Paetawa, 255 km downstream, the effect on flood flows in the Whanganui is reduced to 1%.
- Following a flood, the flood recession is truncated as increasing flows are diverted to the tunnel up to its capacity. Above that capacity spill occurs and the flow in the river downstream increases rapidly to a maximum and then recedes rapidly.

5.5 Water quality (including sediment) and aquatic ecology

5.5.1 Historical Understanding

It is difficult to evaluate the historical water quality and sediment regimes for the Whanganui catchment due to the absence of recorded data and alternative historical research methods. However, anecdotal evidence and an understanding of conditions before European and Māori settlement can provide some understanding.

Before human settlement and land use change, the Whanganui catchment was heavily forested. Subsequent land use change to farming and forestry following human settlement has replaced native forest. A common result of changing land use from native forest to agricultural land is an increase in runoff and sediment levels in the river.

Anecdotal evidence suggests that the water quality has diminished and the Whanganui River carries more silt than it did in pre-European times, referred to as a “paradise for salmon and trout” by early European settlers (Rainforth 2008; Young 1998).

Several excerpts from Young 1998 provide a capture of historical sediment conditions:

“Kuia from the Whanganui, born 1912 at Pūtiki recalling childhood immediately after WW1, interviewed in 1997:

> *‘The river in those days tasted like kowhai. The trees used to grow over the river and drop into the water, and the water tasted like kowhai. I would have been about nine, and although I didn’t grow up there I had relatives at Parikino and would spend six weeks over the summer there. That’s where the water had the kowhai taste….*
>
> *At Pūtiki, in those days, the silt hadn’t silted up in the river like now. You couldn’t possibly go down to the river and be up to your knees in silt. The river bottom*

was stoney and they were big stones, not gravel. We didn't hurt our feet walking on them – you walked out to them....

For someone to paint the river blue, it wasn't. It was always green – if it wasn't green, it was muddy

My mother regularly whitebaited – she was never there once my sister and I were old enough to help around the house. She was either whitebaiting on the river or going to Castlecliff for tunagi, which is a special pipi. We also ate piharau, the blind eel, from Pipiriki, the Anglican minister, Henare Keremenate used to send them down to us. My mother also had an eel basket, a hinaki she used to use. We also used to pick up kakahi, freshwater mussels, down at Corliss Island....

On salmon and trout:

In 1880 H.M. Brewer took 3,500 fingerlings up the river to a spot near Mangaporau, presumably Mangapurau, near Jerusalem, where he liberated them. Trout and perch had already been released. In those days, the river flowed 'for miles over gravelly reaches interspersed with rapids and deep, dark pools, looking a very paradise for salmon and trout' (H.M. Brewer, paper read before Otago Institute, 18 Feb. 1881.)

Five years later a number had returned to their natal streams, evidence of the clarity and quality of the Whanganui (Wanganui Chronicle, 6 January 1886).

On river life as a bioindicator:

One of the most sensitive animals to the ecology of the river is the lamprey or piharau. These once ran in such numbers on the river that Richard Taylor tells us that death from a surfeit of lampreys was "far from uncommon" (Elsdon Best, Fishing Methods and Devices of the Māori, p. 189). Up to 600 lampreys may be caught on a good night, with a total season's catch amounting to several thousand. (T. W. Downes, Notes on eels and eel weirs (tuna and pa-tuna; Transactions and Proceedings of the New Zealand Institute 50; 296-316). 'Blind eel' were still being caught in considerable numbers as far up the river as Maraekowhai in 1922 (Arthur Anderson, oral conversation, Taumarunui, June 1988).

Today, however, there is occasionally but one piharau weir in use on the entire river, at Pipiriki. Because the fish is still prized, such a decline in the practice is far more a measure of ecological than cultural decline.

5.5.2 Recent Water Quality

Water quality refers to the chemical, physical, and biological characteristics of water. For the purposes of this section, water quality is separated into two categories: physicochemical and biological. Physicochemical properties of water quality include suspended sediment, water clarity, nitrogen, phosphorus, pH, and dissolved oxygen. Biological measures of water quality include bacteria, macroinvertebrates, and periphyton.

A primary source of water quality information is found on the Land Air Water Aotearoa (LAWA) website[3] (Horizons Regional Council, 2013). LAWA brings together environmental monitoring data from all New Zealand's regional councils, unitary authorities and NIWA, as well as information provided by the Ministry for the Environment. For the Whanganui catchment, water quality data from 10 monitoring sites are presented from 2005 to the present day. Seven monitoring sites are located in Te Awa Tupua itself, while the remaining three are in the Ongarue, Ohura, and Manganui tributaries (Fig. 70). Additional information on the suspended sediment component is sourced from several research reports which cover suspended sediment components in more detail.

Each monitoring site reports one of three types of information that is presented on the LAWA website: ecological, scientific, recreational, and/or flow data. The ecological category is composed of MCI, taxonomic richness, and percent EPT richness. Scientific data are composed of bacteria (*E. coli*), clarity (black disc and turbidity), nitrogen (total nitrogen, total oxidised nitrogen, and ammoniacal nitrogen), phosphorus (dissolved reactive phosphorus and total phosphorus), and other (pH). In terms of recreation, LAWA provides information from recent spot measurements of *E. coli* and an Overall Recreation Risk indicator calculated from *E. coli* measurements at the site over the previous 3 years. The Overall Recreation Risk indicator is a precautionary approach to managing health risk and it is not designed to represent health risk on a particular day. As such, a site can have an Overall Recreation Risk of 'High' but still be suitable for swimming some of the time.

[3] www.lawa.org.nz

Figure 70: Water quality monitoring sites in the Whanganui catchment (Source: www.lawa.org.nz).

Sediment and pollutant sources and sinks

Suspended sediment is the proportion of mud, sand and silt that is transported down river and stream channels in suspension within the flow rather than the larger cobbles, gravels and boulders that comprise the bedload. Values are typically reported as Suspended Sediment Concentration (SSC), or Total Suspended Sediment (TSS), the proportion by volume of suspended sediment (or total solids for TSS) in each cubic metre of water passing the monitoring site in mg/l, i.e. g/m^3), or specific suspended sediment yield (the tonnes of suspended sediment recorded per km^2 per year, similar to specific discharge described above.

Total suspended sediment is recorded at 14 monitoring sites in the Whanganui catchment. Sediment loads are lowest in the upper reaches of the catchment around the volcanoes, and increase with distance downstream (Fig. 71). The highest median suspended sediment concentrations occur at the most downstream monitoring station, Whanganui Estuary at Wharf St Boat Ramp. Median suspended sediment concentrations are also notably elevated in the Ohura River and in the Whanganui River at Te Rewa (Fig. 71).

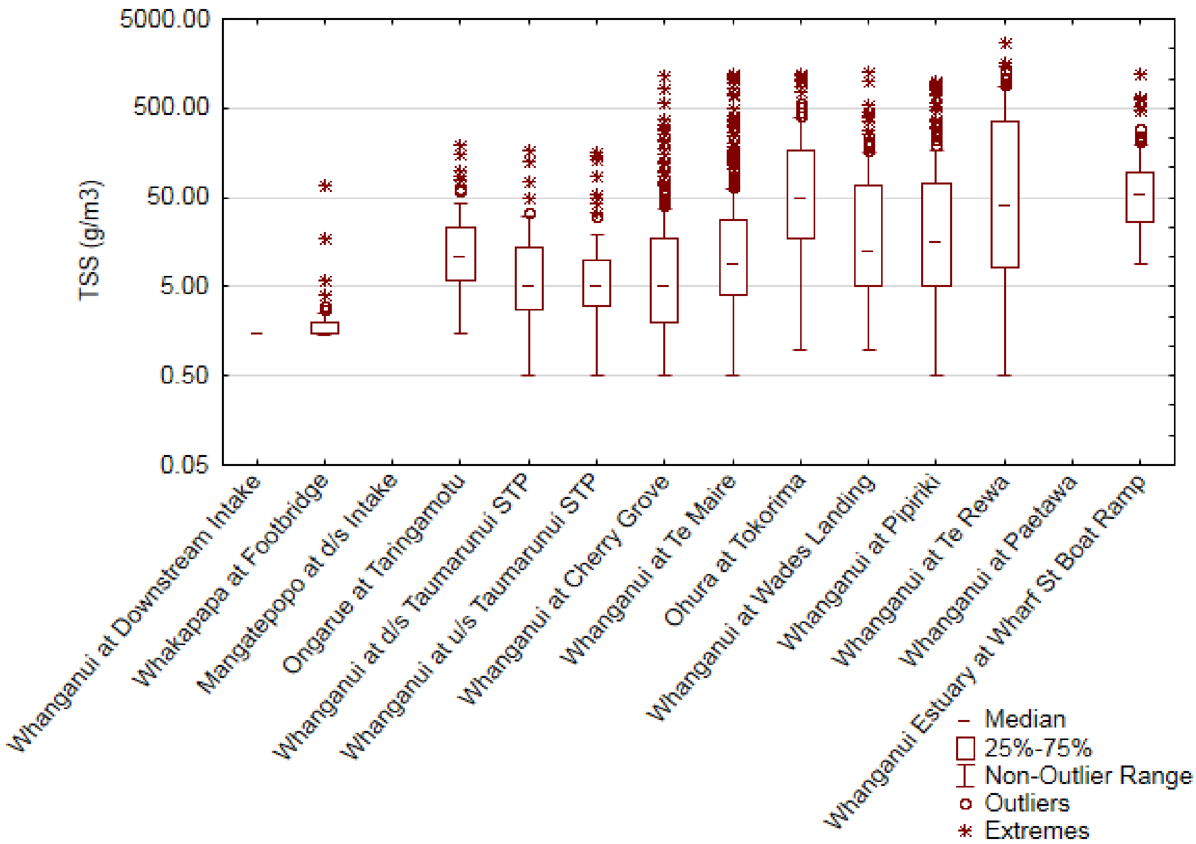

Figure 71: Total suspended sediments (TSS) at 14 monitoring sites in the Whanganui catchment. Note the logarithmic scale on the y-axis.

Suspended sediment yields reported by Hicks and Hoyle (2012) estimate 507 (± 31.2%) and 500 (± 18.7%) t/km^2/year for Ohura at Nihoniho and Whanganui at Te Rewa respectively. The Ohura sub-catchment produces slightly higher suspended sediment yields (Table 21) as also evidenced in the Total Suspended Sediment (TSS) (Fig. 71) as well as in the higher average suspended sediment concentrations of 180 mg/l compared with 150 mg/l found at the Te Rewa station (Table 21). The maximum sediment concentration measured in the Ohura of 15980 mg/l is five times the 3125 mg/l concentration experienced at the Te Rewa station (Table 21).

Table 21: Monitoring Site data summary after Hicks and Hoyle (2012). SS = Suspended Sediment, SSC = Suspended Sediment Concentration and Q = Discharge

River and site	Ohura at Nihoniho	Whanganui at Te Rewa
Duration of SS record	17/5/2007 – 11/11/2009	2/6/1999 – 29/7/2011
Years of actual record	2.27	11.44
% gaps in flow or SS record	8.65	5.89
Q_{min} (m^3/s)	0	31.77
Q_{mean} (m^3/s)	12.45	210.75
Q_{max} (m^3/s)	153	3804
SSC_{min} (mg/l)	0	0
SSC_{mean} (mg/l)	180	150
SSC_{max} (mg/l)	15980	3125

Whanganui at Te Rewa shows substantial variability in annual loads (Table 22); however, it has the least variability when compared with other catchments in the Horizons Region, including the Manawatu (Hicks & Hoyle 2012).

Table 22: Annual Sediment Loads (thousands of tonnes) after Hicks and Hoyle (2012)

	Annual loads (t x 1000)	
Year	**Ohura at Nihoniho**	**Whanganui at Te Rewa**
2000		5207
2001		3052
2002		3331
2003		1424
2004		4777
2005		1473
2006		2891
2007		2193
2008	119	3516
2009		1851
2010		2847
Average (t)	119000	2960182

The mean hysteresis Index (Table 23) provides an indication of sediment load before and after the flood peak. Values of 2.7 and 1.9 for the Ohura at Nihoniho and Whanganui at Te Rewa indicate the sediment concentration is higher before the flood peak; however, overall the majority of the sediment load is carried after the flood peak in relation to the longer recession duration. The high sediment load late in event recessions occurs when the phase of rapid, mainly surface derived runoff blends with the delayed flow sourced from groundwater. Hicks and Hoyle (2012) state the cause of this behaviour is not clear but may be related to catchment lithology and erosion processes; in theory it increases fine sediment drapes over the substrate potentially causing degradation of benthic habitat and fish browsing.

Hicks and Hoyle (2012) provide plots on the relationship between event sediment yield and event peak discharge (top two plots in Fig. 72) and event sediment yield and trend with time (bottom two plots in Fig. 72). Whanganui Te Rewa has a clearer relationship between sediment load and peak discharge above a threshold, while the Ohura, a smaller tributary has a much less predictable sediment load based on peak discharge. Both the Ohura and Whanganui appear to have no significant trends over the sampling periods 2007–2009 and 1998–2012 respectively. Basically, the bigger the flood, the more tonnes of sediment washed down the river; however, smaller floods have highly variable sediment yields presumably because the storm patterns generating each flood may vary.

Table 23: Event Characteristics after Hicks and Hoyle (2012)

Characteristic	Ohura at Nihoniho	Whanganui at Te Rewa
Area (km^2)	324	6643
Record length (yrs)	2.273	11.44
Number of events	51	187
Average duration (hrs)	135	246
Mean annual yield (t)	55088	3322124
% in events	98.5	98.6
Largest event yield (t)	27143	2990004
% of annual yield	49	90
Start date of largest event	4/10/08	25/09/00
Mean % error on event yield	92	122
Overall maximum C (mg/l)	15980	3125
Mean peak C (mg/l)	1495	1299
Mean % before Q peak	92	39
Mean hysteresis Index (Crise/Cfall)	2.7	1.9
Mean recession Index (Cend/Cstart)	1.2	14.8

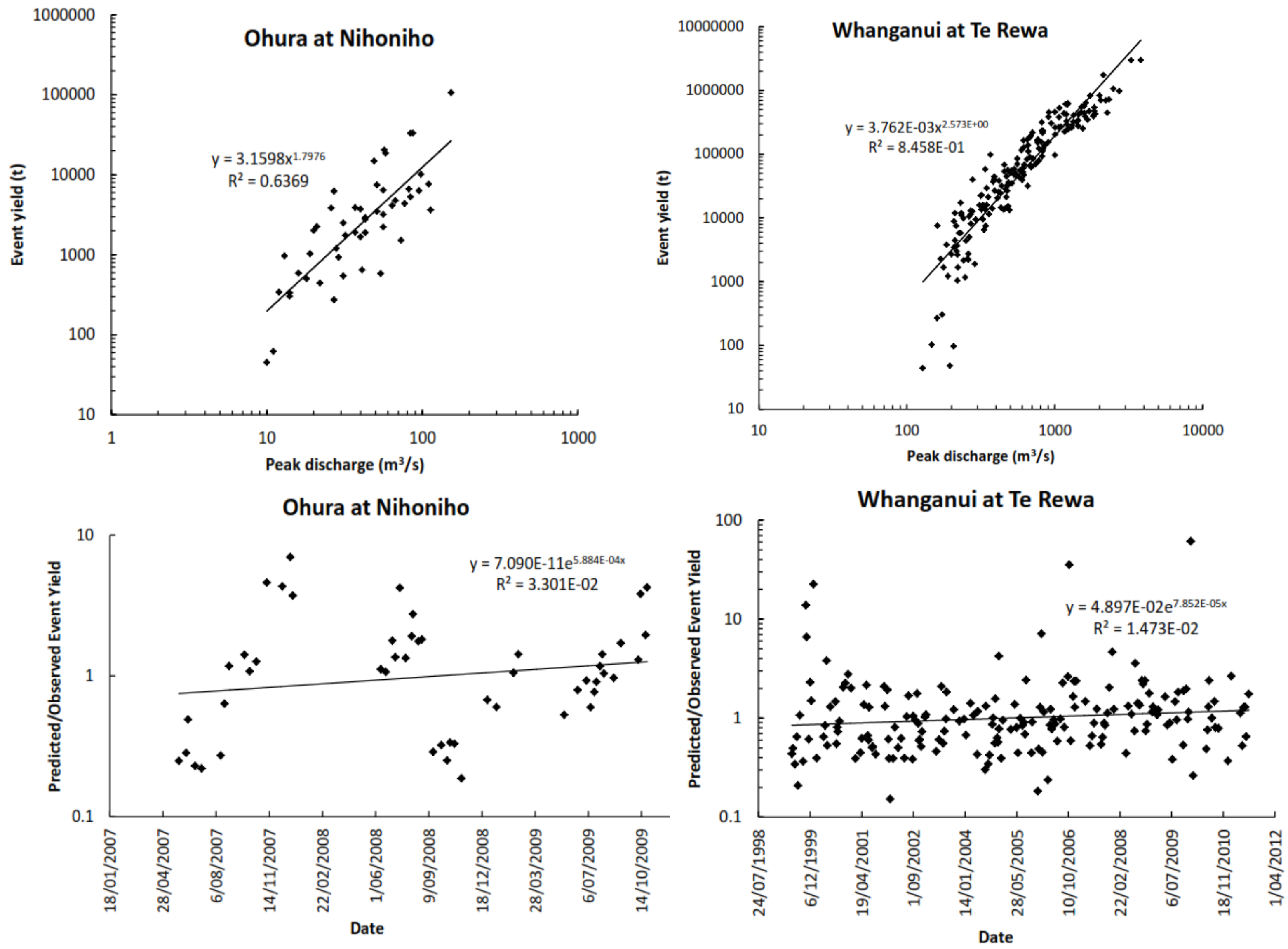

Figure 72: Event yield ratings and time trends for Whanganui at Te Rewa and Ohura at Nihoniho.

Clarity

Water clarity is a key visible measure of water quality. Poor water clarity affects the visual amenity of a waterway, and affects light- and sight-dependant aquatic species. Clarity deteriorates with increasing suspended sediment in the water, and can be measured by TSS (discussed above), black disc, and turbidity. Clarity can be affected by many factors, such as stream bank erosion, pastoral runoff, forestry runoff, geology, and earthworks. Methods to improve water clarity include, for instance, control-at-source sediment management, and riparian planting, especially where bank erosion is a primary cause of low clarity.

Clarity in the Whanganui catchment was the focus of a study by Davies-Colley et al. (1995) who compared river water clarity in forested and cleared sub-catchments. The study found that pastoral agriculture is responsible for degradation in clarity, while acknowledging that other factors such as geological variability and steepness of slopes may complicate the results.

Horizons Regional Council monitors turbidity levels at 14 sites throughout the Whanganui catchment. These data are presented graphically on the LAWA website and compared in relation to all other streams and rivers of New Zealand. According to LAWA, turbidity at Cherry Grove, Te Maire, and Ongarue at Taringamotu are in the worst 50% of rivers nationally, while all other monitored sites downstream in the catchment are even worse, being in the worst 25% nationally (Fig. 73). This downstream deterioration matches downstream increases in suspended sediment described above.

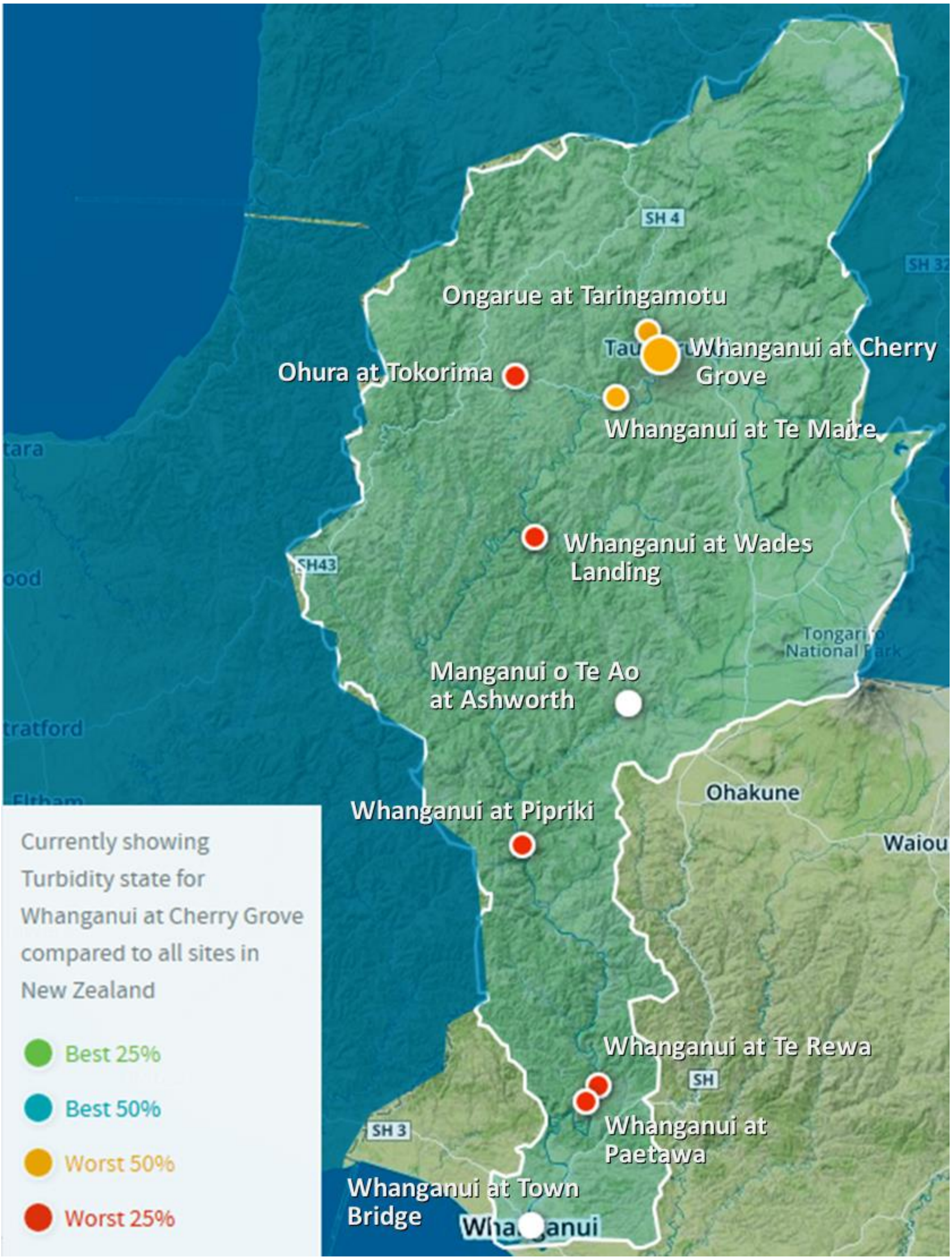

Figure 73: Relative turbidity of Whanganui River catchment sites.

Another way to assess turbidity is to compare it against ANZECC guidelines (ANZECC 2000). The ANZECC guideline trigger values for turbidity in unmodified or slightly disturbed ecosystems are an upper limit of 4.1 NTU, and 5.6 NTU in upland and lowland rivers, respectively. Turbidity levels typically exceed ANZECC guideline values in the middle and lower reaches of the catchment (Fig. 74). At many sites such as Ohura, Wades Landing, Pipiriki, Te Rewa, Paetawa, and Whanganui Estuary, turbidity levels are so high that even median levels exceed ANZECC values.

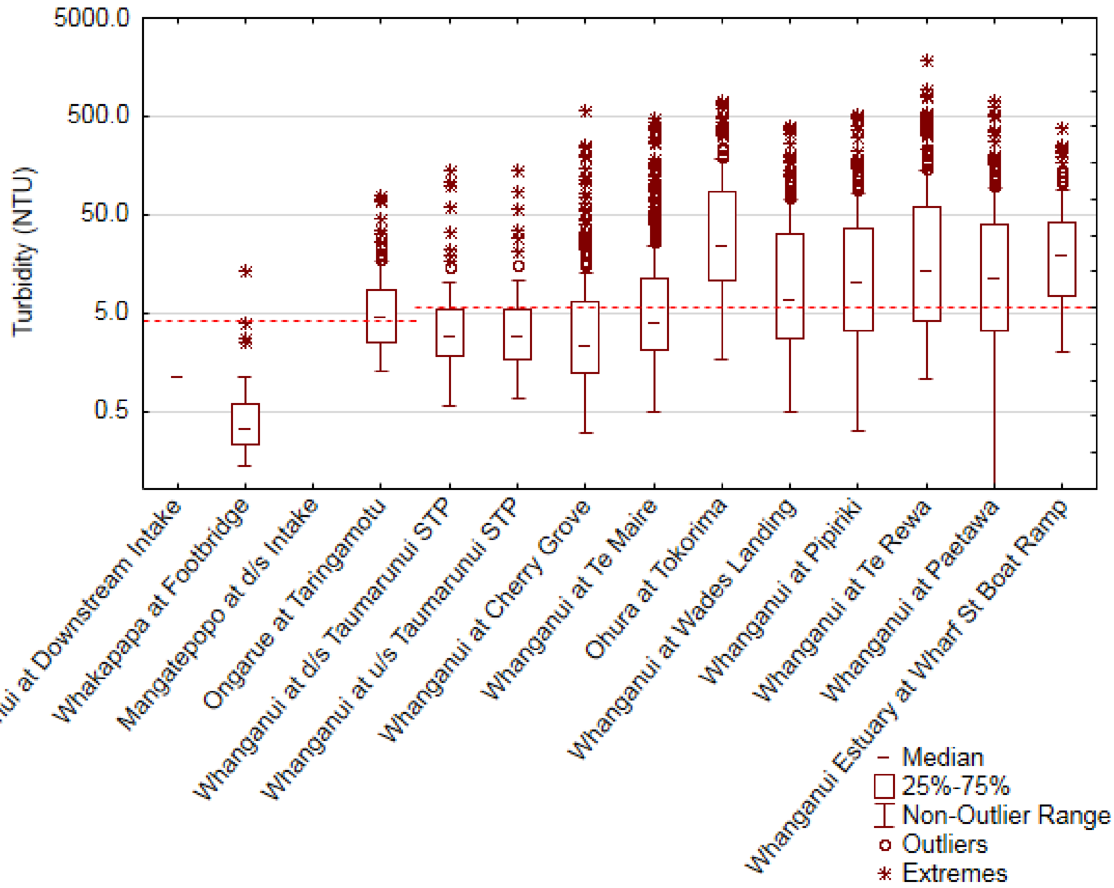

Figure 74: Turbidity levels in the Whanganui catchment, 1989–2016. Red dashed line denotes ANZECC trigger values for water clarity (upper limit) indicative of unmodified or slightly disturbed ecosystems in New Zealand. Red dashed line breaks between Ongarue at Taringamotu and Whanganui at d/s Taumarunui STP as this is the cutoff between upland and lowland values under ANZECC. Monitoring sites are ordered left-right on the x axis, upstream-downstream.

Water clarity is also monitored by Horizons Regional Council using the black disc method. ANZECC guideline trigger values for black disc visibility in unmodified or slightly disturbed ecosystems are a lower limit of 0.8 m, and 0.6 m in upland and lowland rivers, respectively.[4]

[4] Note that ANZECC (2000) has mistakenly reversed the water quality guideline limits for upland and lowland rivers, as notified at http://www.mfe.govt.nz/node/20505. The corrected values are in the text above.

Like turbidity, clarity is highest in the upper reaches of the catchment, and lowest in the lower reaches, with the Ohura River also exhibiting notably low clarity (Fig. 74). Clarity breaches ANZECC guideline trigger values at all sites except for the Whakapapa in the upper catchment.

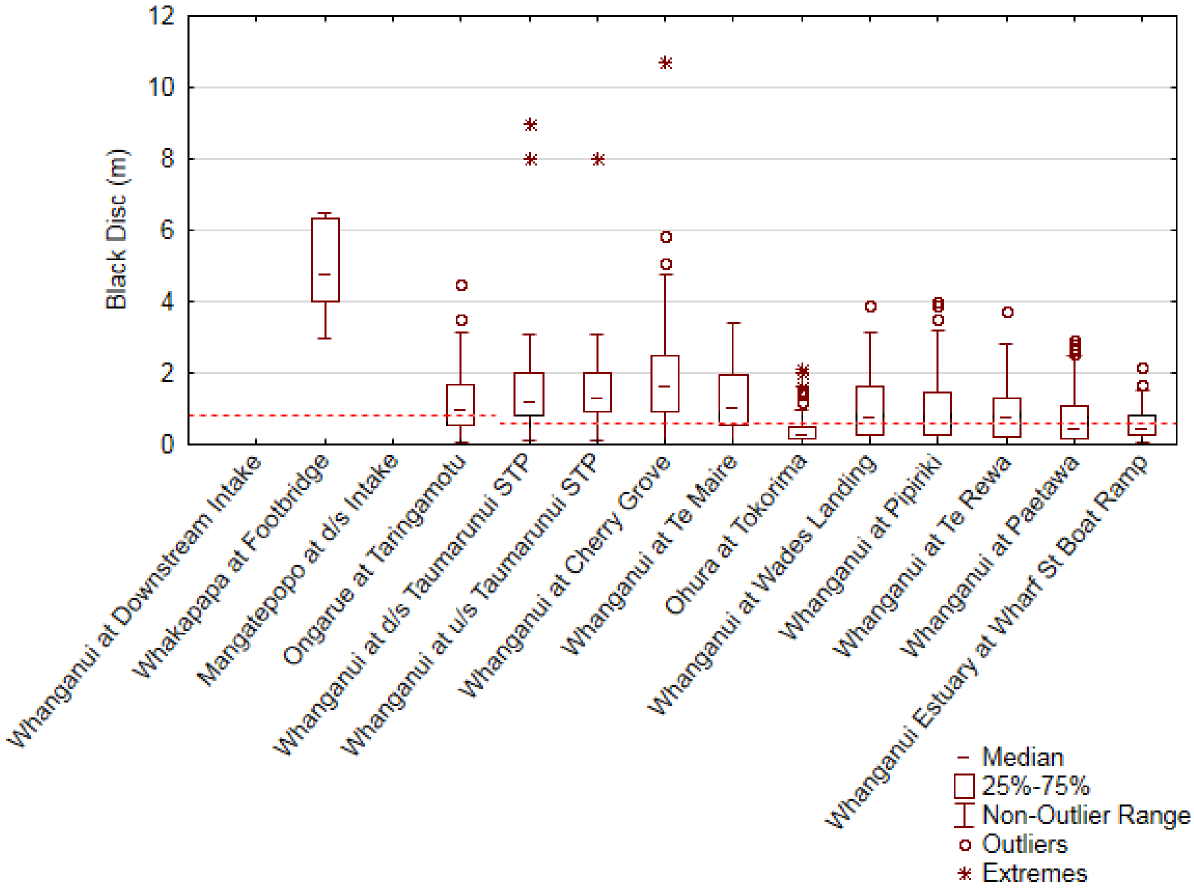

Figure 75: Water clarity measured as Black Disc Visibility in the Whanganui River (1989–2016). Records began at Paetawa as early as 1989, with black disc measurements beginning at other monitoring sites in later years. Red dashed line denotes ANZECC trigger values for water clarity (lower limit) indicative of unmodified or slightly disturbed ecosystems in New Zealand. Red dashed line breaks between Ongarue at Taringamotu and Whanganui at d/s Taumarunui STP as this is the cutoff between upland and lowland values under ANZECC. Monitoring sites are ordered left-right upstream-downstream.

The very low turbidity levels above the Ongarue monitoring station are associated with the coarse volcanic sediments of the headwaters which, while easily eroded, do not tend to remain suspended in the water column and therefore do not affect turbidity and clarity. Declining turbidity and clarity in the Whanganui River downstream of Ongarue may be due to the effect of bank erosion, or tributaries with high loads of finer sediment that remain suspended in the water column and affect turbidity and clarity (Nicholson & Cooper 2016).

The Ohura River exhibits low clarity and high turbidity, which supports other research into sediment loads of rivers in the catchment. As reported by Nicholson and Cooper (2016), research by Horizons and Landcare Research has shown that the Ohura Catchment is the biggest contributor of sediment into the Whanganui River, and that a combination of natural processes, the underlying geology, and land uses that were beyond the inherent capability of the land are responsible for much of the sediment load of the Ohura catchment (Nicholson & Cooper 2016).

Bacteria (E. coli)

Water contaminated by human or animal excreta may contain a range of bacteria, viruses and protozoa that can cause illness to people who ingest the water and pose a health hazard to people undertaking recreational activities in rivers and lakes. *Escherichia coli* (*E. coli*) are bacteria that live in the gut of warm blooded animals and people and are a useful indicator of the presence of a range of potentially harmful bacteria and micro-organisms.

The National Policy Statement for Freshwater Management (NPSFM) (MfE, 2014) includes secondary contact (i.e. boating and wading) as a compulsory national objective and provides guidance on *E. coli* concentrations that are required to meet this objective. For a river to be classed as having the lowest risk to human health (A-band river) under the NPSFM, median annual *E. coli* concentrations must be equal to or lower than 260 *E.coli*/100 ml. B-band rivers carry a slightly elevated risk of infection, and have an annual median of between 260 and 540 *E.coli*/100 ml. A national bottom line is set at 1000 *E.coli*/100 ml, which, when exceeded, exposes people to a higher risk of infection.

More stringent requirements relate to primary contact with waterbodies (i.e. swimming) where the risk of ingesting water is higher. The NPSFM does not provide guidance on *E. coli* values to support primary contact, but the MfE/MOH (2003) *Microbiological Water Quality Guidelines* suggest 95th percentiles less than 130 *E.coli*/100 ml, 260 *E.coli*/100 ml, and 550 *E.coli*/100 ml to represent transitions from A-band, B-band, C-band and D-band rivers.

Horizons Regional Council monitors *E. coli* at 12 different sites in the Whanganui catchment, 1989–2016. For primary contact activities as defined by the MfE/MOH (2003) guidelines, just one monitoring site – Whakapapa at Footbridge – falls within the A-band *E.coli* level of 95th percentile ≤130 *E. coli*/100 ml (Fig. 76). From Taringamotu downstream to the estuary, 95th percentile values are considerably higher, with most sites falling into the D-band category, meaning that these sites are poor–very poor for primary contact activities such as swimming. Two monitoring sites at Taumaranui appear to fall within the C-band category, fair–poor for primary contact activities (Fig. 76).

For secondary contact activities such as wading, 11 of the 12 monitoring sites have a median *E. coli* concentration that falls within the A-band category (Fig. 76). The median concentration of *E. coli* in the Ohura River is higher, 520 *E. coli*/100 ml, than all other monitoring sites and sits within the B-band under the NPSFM. According to the LAWA website, meaningful improvement in *E. coli* levels has occurred in the Ohura River, and in the Whanganui River at Te Rewa over the monitoring period. For all other sites the trend is indeterminate (Fig. 77).

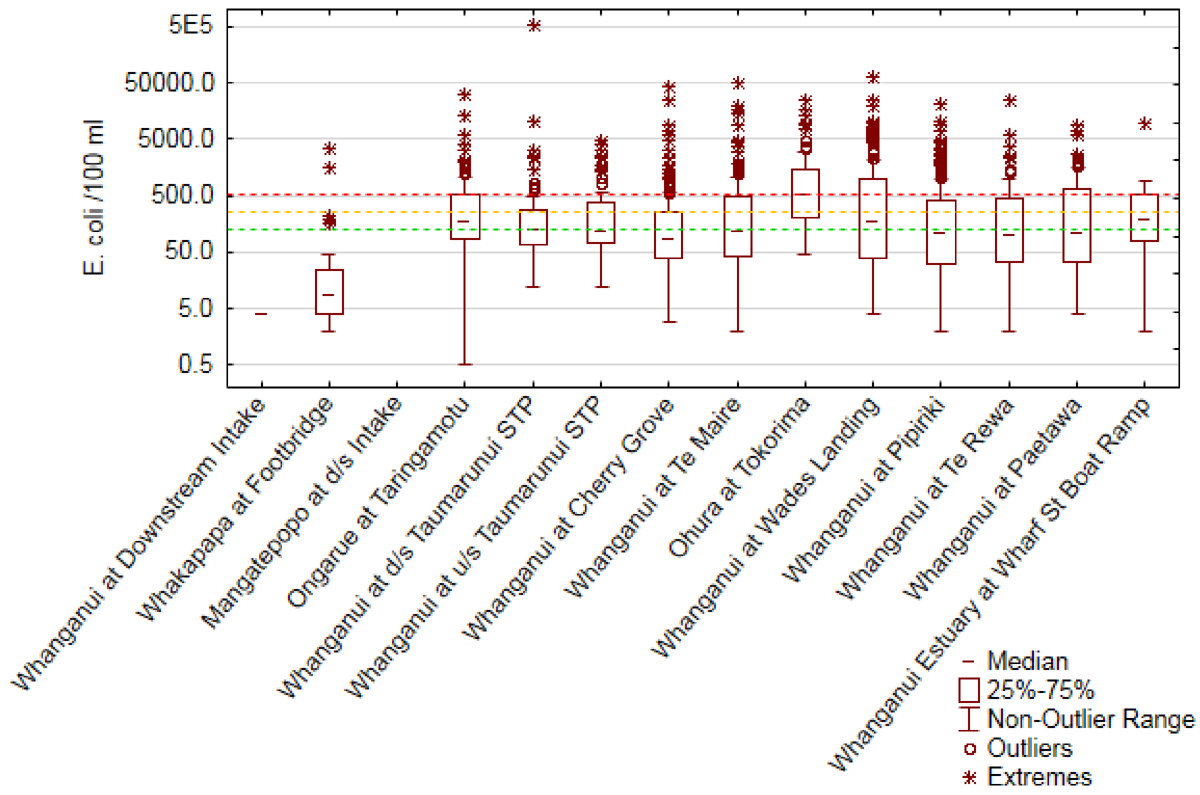

Figure 76: *E. coli* concentrations at 14 monitoring sites in the Whanganui catchment, 1989–2016. Note that no *E. coli* monitoring records exist for Whanganui at Downstream Intake and Mangatepopo at d/s Intake. Green dashed line denotes A-Band level for 95th percentile ≤130 *E. coli*/100 ml for *primary contact* activities (e.g. swimming) under the MfE/MOH (2003) guidelines. Orange dashed line denotes the annual median value for A-band rivers (≤260 *E. coli*/100 ml) for *secondary contact* activities under the NPSFM, and red dashed line B-band (>260 and ≤540 *E. coli*/100 ml). Monitoring sites are ordered left-right on the x axis, upstream-downstream.

Figure 77: Relative *E. coli* of Whanganui River catchment sites.

Nitrogen

Nitrogen and phosphorus are the two main nutrients that influence water quality and are commonly monitored. Nitrogen is an essential nutrient for plants and animals, but excessive concentrations in water bodies can cause excessive growth of aquatic plants and algae, leading to excessive blooms and low dissolved oxygen levels. Nitrogen is commonly measured and reported in one of three forms: ammoniacal nitrogen (NH_{3}-N); nitrate nitrogen (NO_3); and total nitrogen (TN). Ammoniacal nitrogen measures the amount of ammonia – a toxic pollutant often found in, for example, sewage, manure, and landfill leachate. Nitrate nitrogen can also be toxic at higher levels, and is a major source of nitrogen for aquatic plant growth. Sources of NO_3 include livestock waste, excess inorganic fertiliser, septic tanks and leaking sewerage systems. Both nitrate nitrogen and ammoniacal nitrogen are toxic to aquatic life at high concentrations. Total nitrogen is the sum of all forms of nitrogen in a waterway, both organic and inorganic. All three forms have been monitored by Horizons Regional Council, 1989–2016.

Acceptable limits for NO_3 under the NPSFM are a national bottom line of an annual median of ≤6.9 g/m^3 based on toxicity, not the effects of nitrogen on stimulating algal growth. To ensure a high conservation value system that is unlikely to have toxic effects even on sensitive species (i.e. to be an A-band river), the annual median must be ≤1 g/m^2. In the Whanganui catchment, all monitoring sites have measured annual median NO_3 concentrations that are well within A-band levels. Very low NO_3 levels, <0.1 g/m^3, are recorded in the upper reaches, while median values range between 0.1 and 0.3 g/m^3 downstream of Ongarue at Taringamotu (Fig. 78).

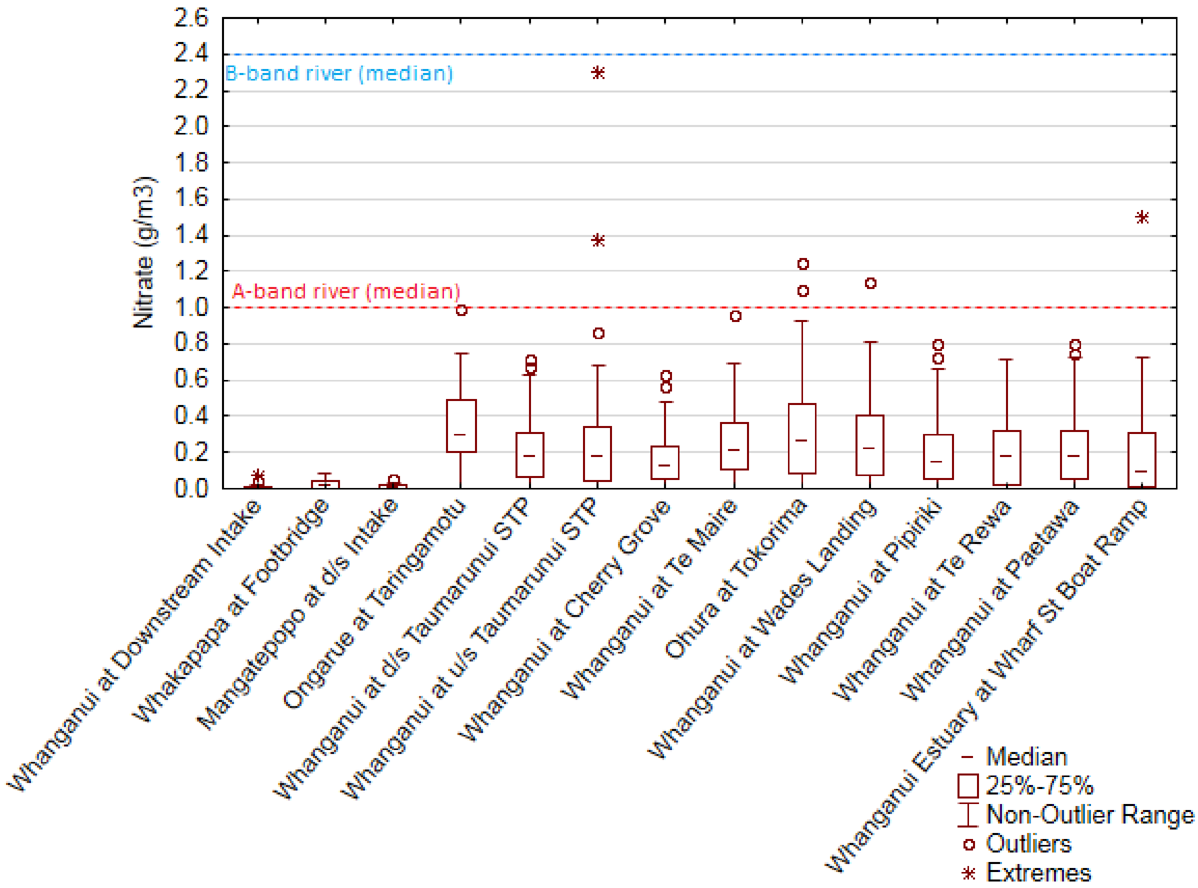

Figure 78: Nitrate concentrations at 14 monitoring sites in the Whanganui catchment, 1989–2016. Dashed red and blue lines denote NPSFM A- and B-band thresholds for the annual median. Monitoring sites are ordered left-right on the x axis, upstream-downstream.

The NPSFM sets a national bottom line for NH_4-N toxicity of 1.3 mg/L for the annual median, and 2.2 mg/L for the annual maximum. At this concentration, an 80% species protection level is achieved, while it is accepted that there will be reduced survival of most sensitive species. To ensure 99% species protection level from the harmful effects of NH_4-N (i.e. to be an A-band river), the annual median must be ≤0.03 mg/L and the annual maximum ≤0.05 mg/L. Rivers in the Whanganui catchment all fall within A-band levels for annual median, while the annual maximum at all sites bar two (Whanganui at Downstream Intake and Whakapapa at Footbridge) have been exceeded at some point during the monitoring period, 1989–2016.

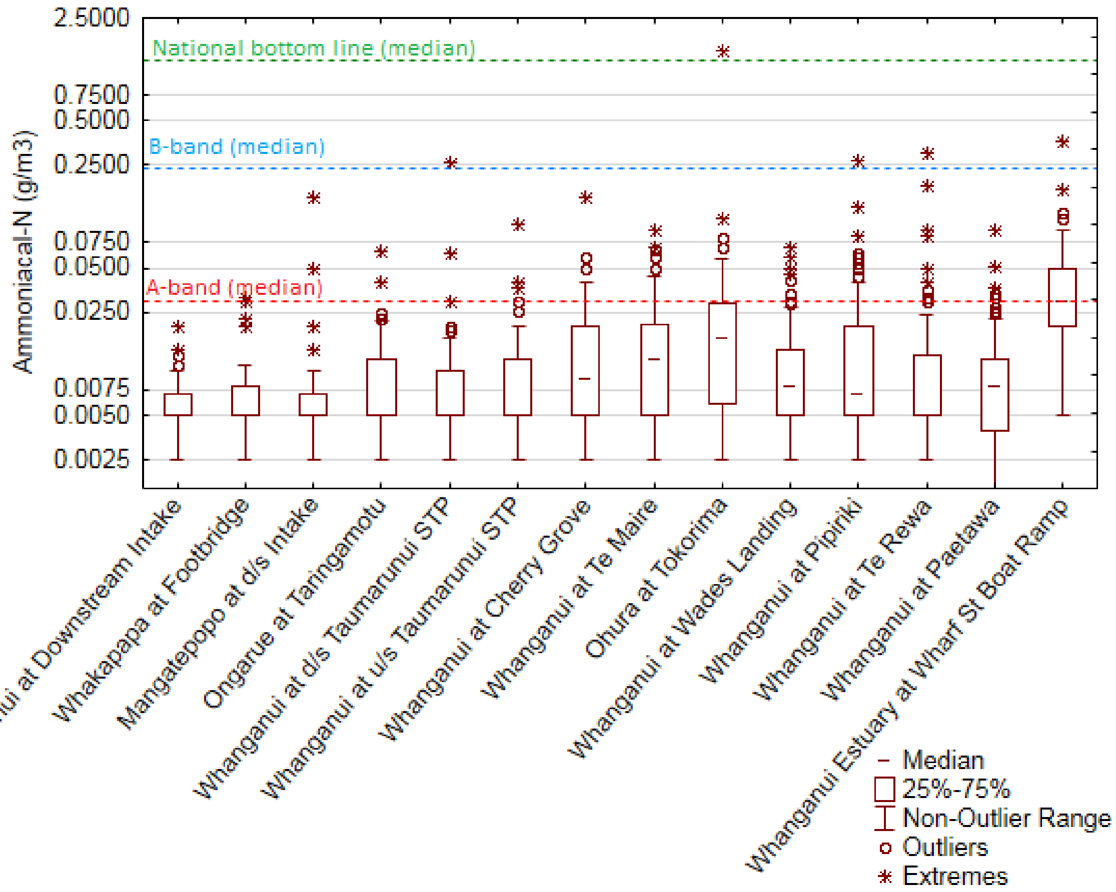

Figure 79 Ammoniacal nitrogen at 14 monitoring sites in the Whanganui catchment. Red dashed line denotes NPSFM annual median for A-band river, blue B-band, and green is the national bottom line. Monitoring sites are ordered left-right on the x axis, upstream-downstream.

There is no NPSFM limit for total nitrogen in rivers; however, Figure 80 shows relative total-N concentrations across the catchment, with higher values in the Ohura sub-catchment reflecting the higher ammoniacal-N shown in Figure 79.

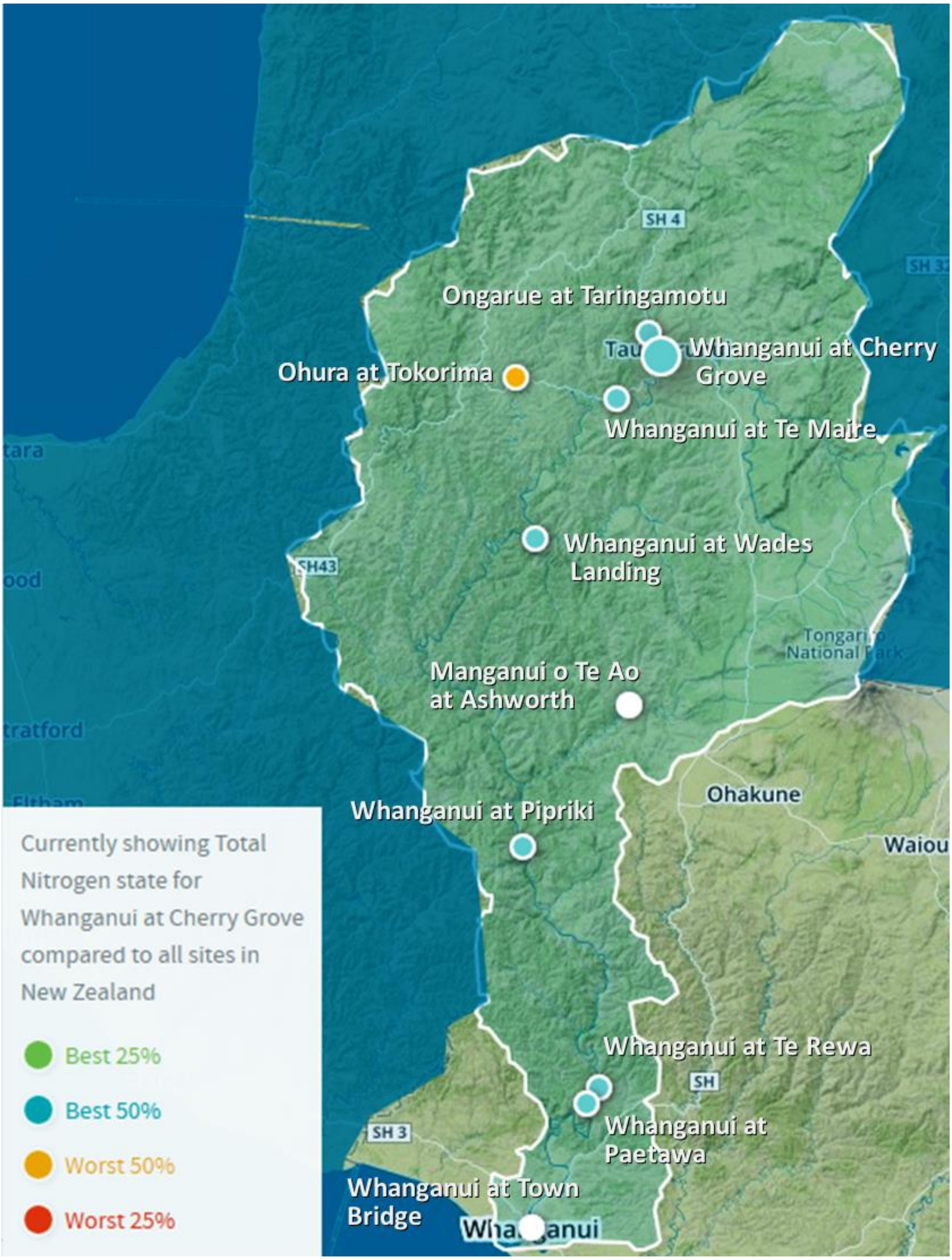

Figure 80: Total Nitrogen of Whanganui River catchment sites.

Phosphorus

Phosphorus is the second key nutrient affecting water quality. High concentrations of phosphorus, especially in combination with high nitrogen concentrations, can result in excessive plant and algal growth such as phytoplankton, cyanobacteria, macrophytes, seagrasses, and filamentous and attached algae, in a range of ecosystems. This can lead to increased toxicity, a reduction in dissolved oxygen (DO) and recreational amenity, a change in instream biodiversity, and clogged waterways (ANZECC & ARMCANZ 2000). There are two main measures of phosphorus for the purposes of measuring water quality. Total phosphorus (TP) is a measure of phosphorus in its various forms, including phosphate that is attached to sediment, as well as phosphorus that is dissolved in water. Over time, phosphorus that is bound to sediments can be released and become available for uptake by aquatic plants. Dissolved reactive phosphorus (DRP) is the amount of phosphorus dissolved in water, which is most immediately and readily available for plant and algae growth. Phosphorus enters waterways via soil particles, and in dissolved form in the water. Sources of phosphorus in rural waterways are mainly runoff from farms, and waste-water treatment plants (PCE 2015). Phosphorus concentrations are often relatively high naturally in catchments draining volcanic geology.

Both TP and DRP are measured at 14 sites (Fig. 81) in the Whanganui catchment by Horizons Regional Council as part of their environmental monitoring programme, 1989–2016. Guideline TP values under ANZECC are that the 80th percentile does not exceed 0.026g/m^3 for upland waterways, and 0.033 g/m^3 for lowland waterways. The waterways of the Whanganui catchment typically exceed these guideline values – except for the monitoring locations at Taumarunui and Cherry Grove – suggesting that TP concentrations are high enough to enable nuisance plant and algal growth – provided TP rather than nitrogen is the limiting factor for plant growth in the waterways.

Total phosphorus data are also presented on the LAWA website and compared with other rivers of New Zealand. According to LAWA, waterways in the Whanganui catchment in the catchment are in the worst 50% in the country, except for Whanganui at Cherry Grove which is in the best 50% (Fig. 82). Total phosphorus may also be compared more accurately between sites within the catchment by graphing Horizons Regional Council's monitoring data for each of the 14 monitoring sites (Fig. 81). Total phosphorus levels typically range between 0 and 0.1 g/m^3, with the exception of multiple extreme values at each site that in some cases reach levels as high as 2 g/m^3 in the case of Whanganui at Paetawa, and Whakapapa at Footbridge.

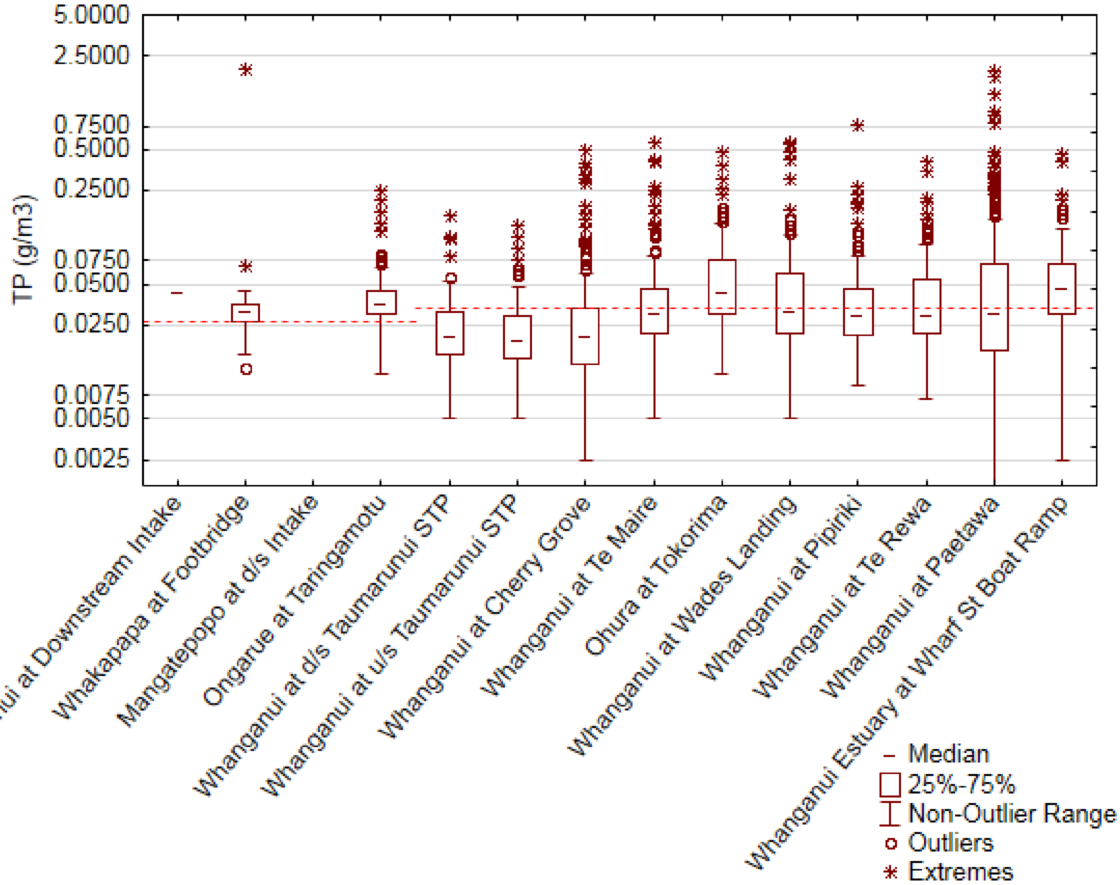

Figure 81: Total phosphorus measured at 14 monitoring sites in the Whanganui catchment, 1989–2016. Red dashed lines denote ANZECC trigger values for TP (80th percentile). Note the logarithmic scale on the y axis.

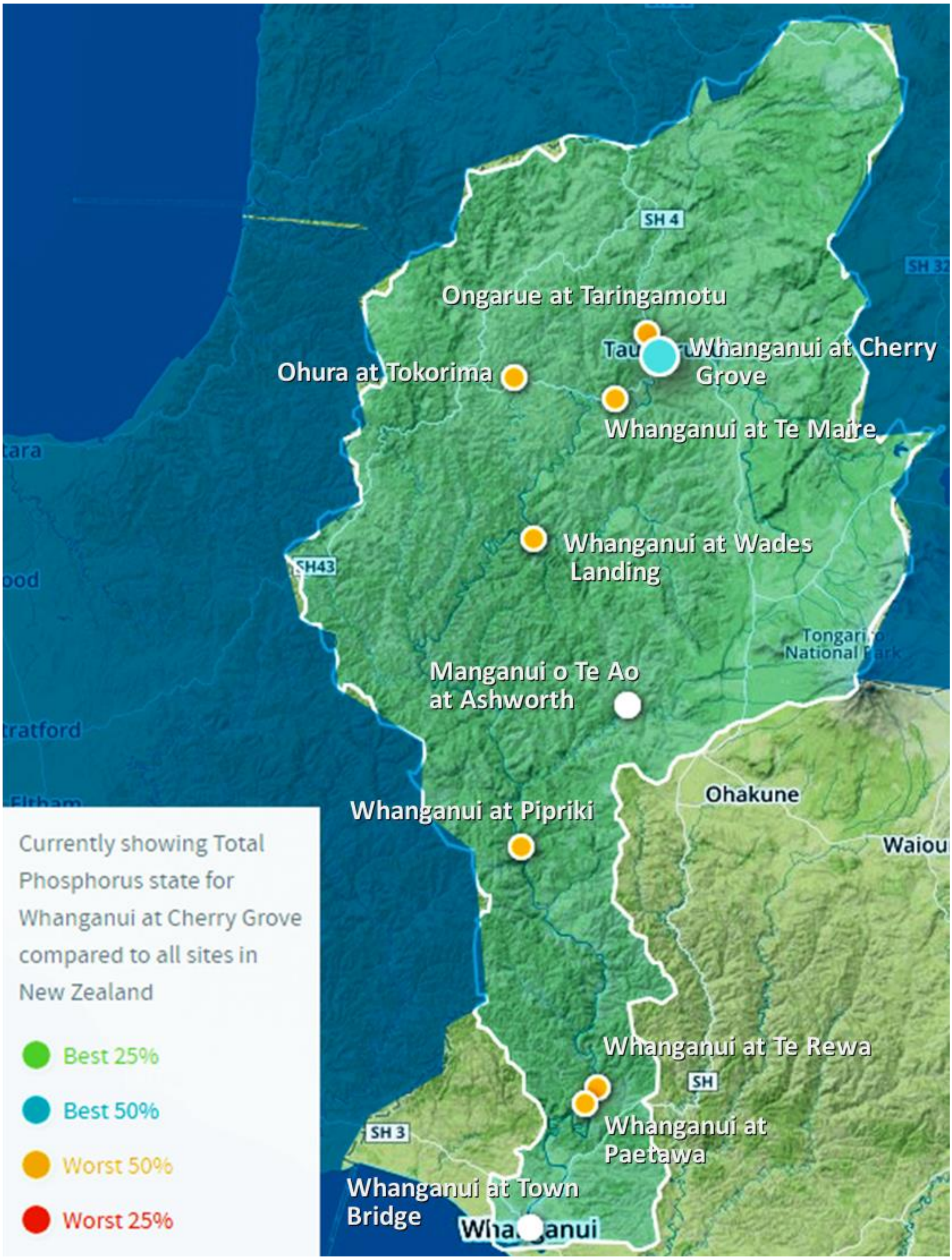

Figure 82: Total phosphorous of Whanganui River catchment sites.

Dissolved reactive phosphorus is also measured in the Whanganui catchment as part of Horizons Regional Council's monitoring programme, 1989–2016. Horizons sets a target that DRP remains below 0.006 g/m^3 in streams in the upper reaches of the catchment, and then incrementally increases through 0.01 g/m^3 through the mid reaches, to 0.015 g/m^3 in the lower reaches. While insufficient data exist to make statements with any certainty, DRP concentrations actually decline from the upper to lower reaches of the catchment (Fig. 83). This may be due to several reasons, including dilution from more forested tributaries, or uptake by periphyton.

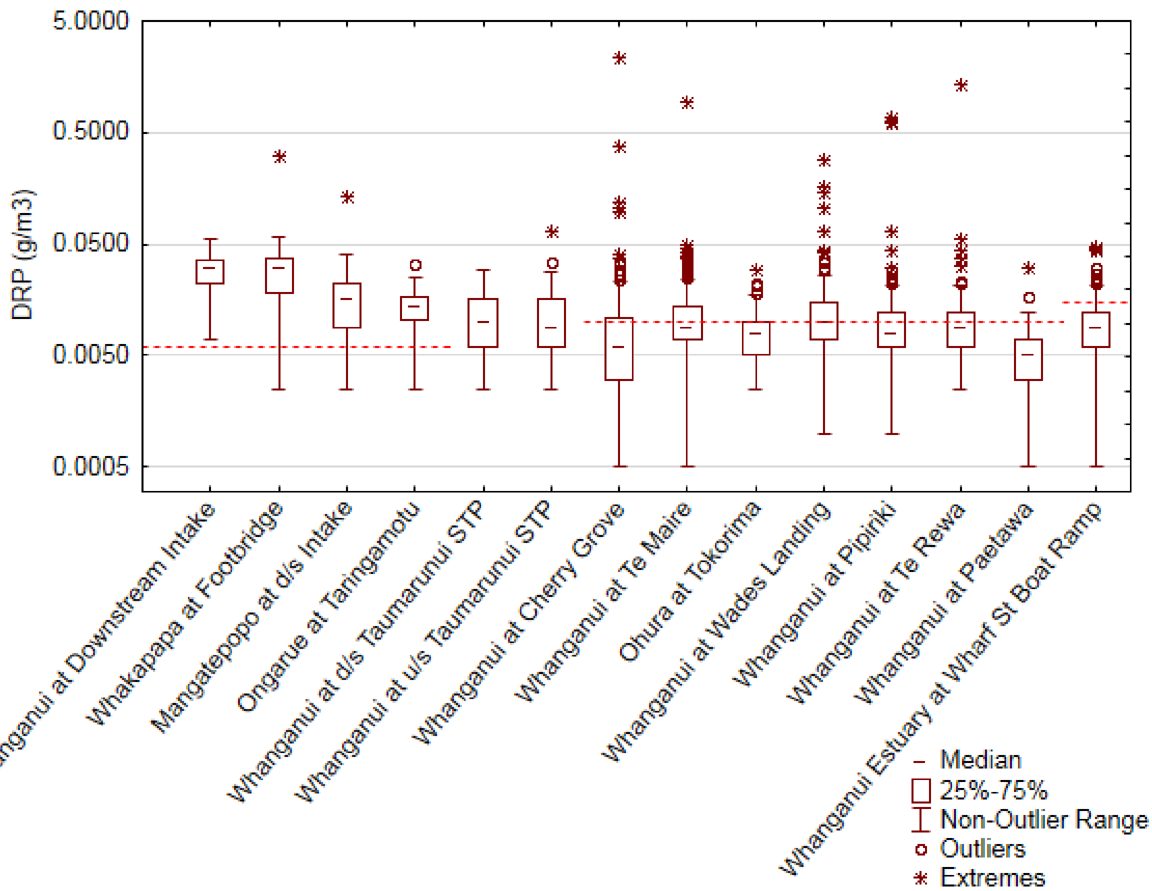

Figure 83: Dissolved reactive phosphorus at 14 monitoring sites in the Whanganui catchment. The red dashed line denotes Horizons Regional Council's target that the annual average concentration of DRP when the river flow is at or below the 20th flow exceedance percentile, must not exceed the target value (red dashed line, unless natural levels already exceed this). Monitoring sites are ordered left-right on the x axis, upstream-downstream.

pH

pH is a measure of water quality representing the acidity of a water sample. The pH scale ranges from 0 to 14, with 7.0 considered neutral, below 7.0 acidic, and above 7 alkaline or basic. Streams affected by volcanic eruptions can have very low pH water. pH is an important measure of water quality given that low pH levels can be toxic for aquatic life, and it can also be corrosive to metals. Similarly, high pH may exacerbate the toxic effects of ammonia to fish and aquatic insects. Accordingly, Horizons Regional Council sets a target pH band for waterways in the Whanganui catchment of 7–8.5.

pH has been measured by Horizons Regional Council as part of their 1989–2016 environmental monitoring programme. pH levels at each of the monitoring sites sit within Horizons' target band, with the exception of some outliers and extreme outliers (Fig. 84). Note that measurements are spot measurements, and therefore do not record the daily fluctuations of pH levels that occur throughout a 24-hour period.

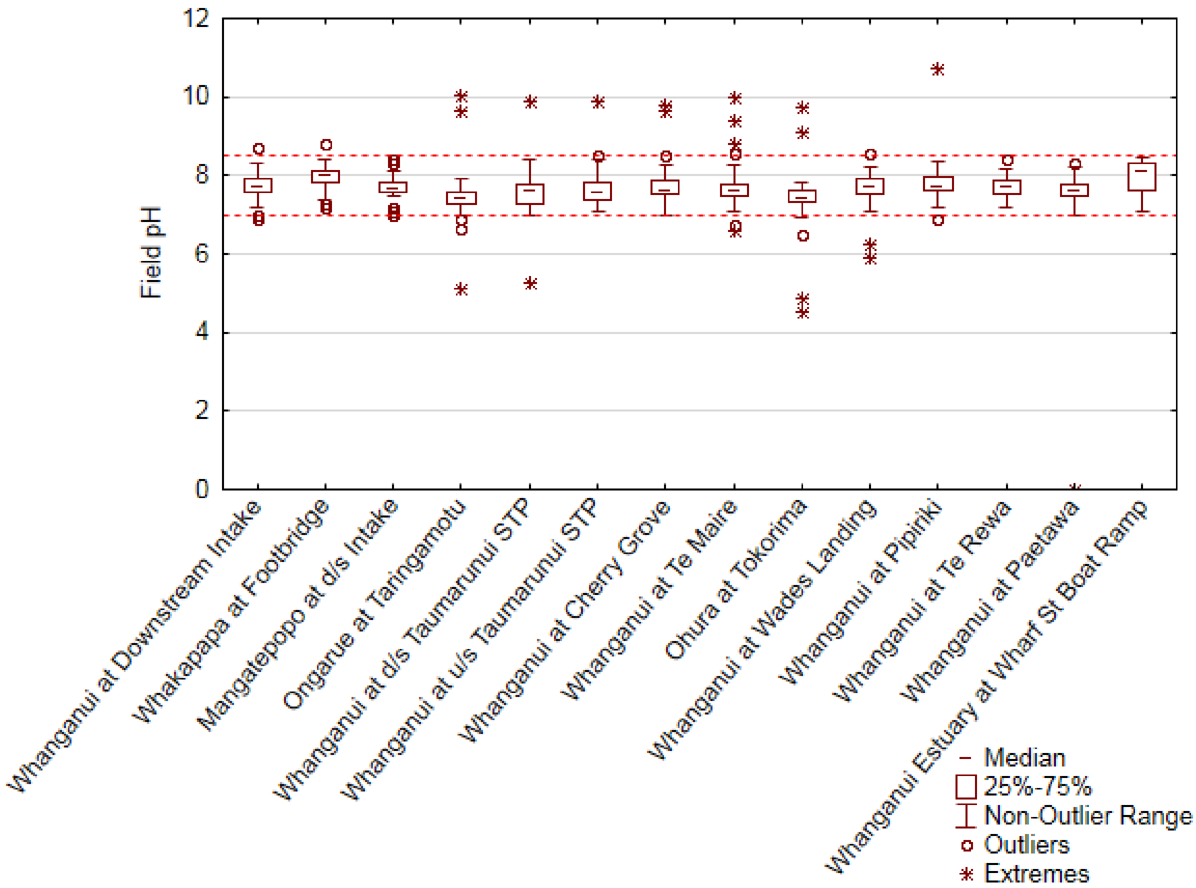

Figure 84: Field pH levels at 14 monitoring sites in the Whanganui catchment. Note that the area within the red dashed lines denotes Horizons Regional Council's pH target for rivers in the Whanganui catchment. Monitoring sites are ordered left-right on the x axis, upstream-downstream.

Dissolved Oxygen

Dissolved oxygen (DO) is the amount of oxygen that is dissolved in water. Concentrations of DO in the water are a critical component affecting the life supporting capacity of a river system. DO concentrations are affected by three key processes: 1) oxygen production associated with photosynthesis of algae and other aquatic plants, which raises the oxygen concentrations within the water; 2) oxygen uptake associated with respiration of all river life including fish, invertebrates, algae, aquatic plants and microbes, which lowers the oxygen concentrations in the water; and 3) oxygen diffusion through the water surface, which can either raise or lower oxygen concentrations. DO concentrations rise during the daytime when sunlight facilitates photosynthesis, and then decline during the night when only respiration is occurring. The size of the daily fluctuations depends on the amount of photosynthesis and respiration occurring within the river and also on the flux of oxygen through the river surface. Low DO concentrations cause stress on aquatic life. According to the NPSFM, DO concentrations must exceed a 7-day mean minimum of 8 mg/L in summer to ensure that there is no stress on any aquatic organisms resulting from low concentrations (A-band river).

Spot measurements of dissolved oxygen in the Whanganui catchment are measured by Horizons Regional Council monthly as part of their State of the Environment monitoring program. Monitoring has occurred at 13 sites in the Whanganui catchment from 1999 to 2016. While it is not possible to determine compliance with NPSFM levels due to the absence of continuous monitoring data, most sites appear to achieve A- or B-band status based on available data (Fig. 85). The upper reaches of the catchment around the Western Diversion of the Tongariro Power Scheme have consistently high DO concentrations, and have not dropped below the A-band threshold on any occasion during the monitoring period. Median and minimum DO concentrations generally show a slight decline with distance downstream, and a noticeably lower concentration occurs in the Ohura River (Fig. 85).

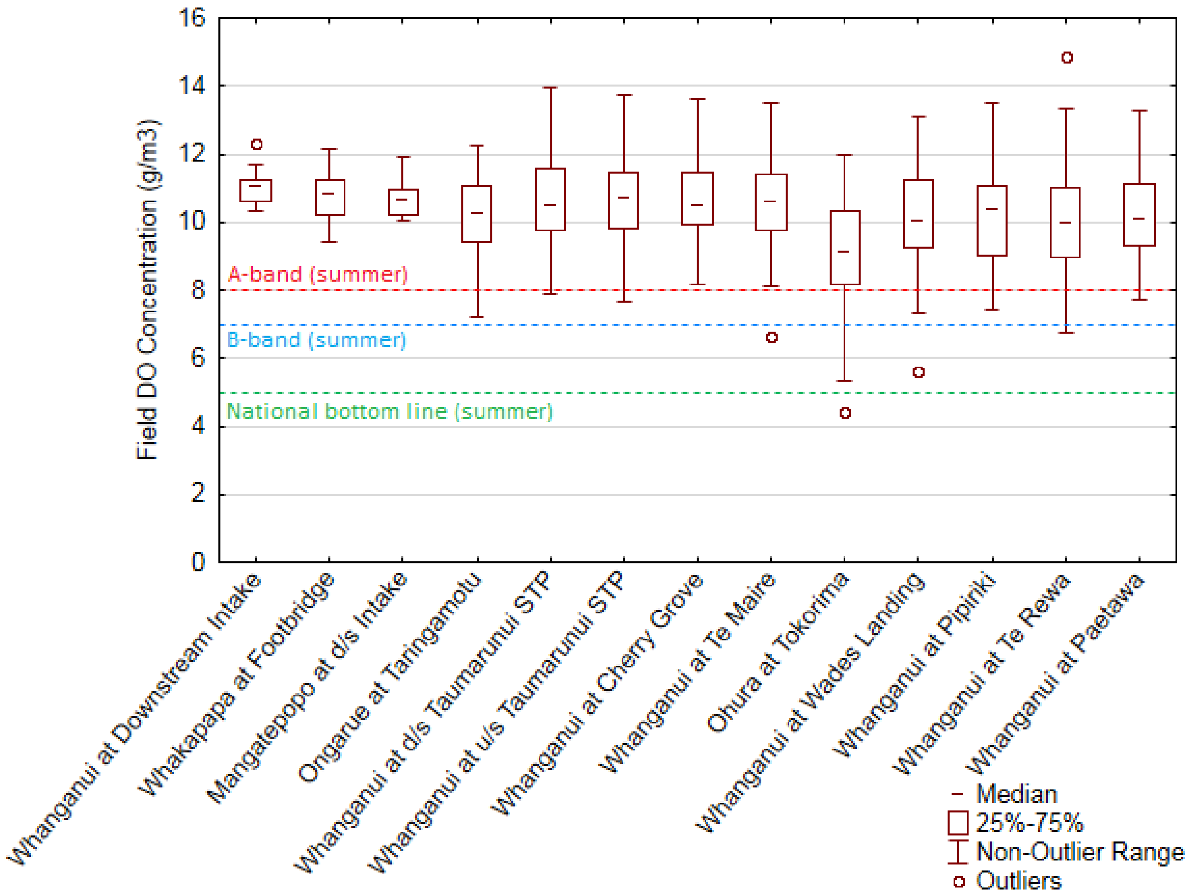

Figure 85: Dissolved oxygen concentrations at 13 monitoring locations in the Whanganui catchment, 1999–2016. A-band (red dashed line), b-band (blue dashed line), and national bottom line (green dashed line) derive from the National Objectives Framework in the NPSFM and denote the 7-day mean minimum for the summer period 1 November to 30 April. However, note that monitoring data are more complete for some monitoring sites than for others, and that the most frequently collected data are monthly – not instantaneously, as required to ascertain 7-day mean minimums under the National Objectives Framework. As such, comparison with National Objectives Framework values is approximate. Monitoring sites are ordered left-right on the x axis, upstream-downstream.

Dissolved oxygen saturation is also measured as part of Horizons Regional Council's State of the Environment monitoring programme. Dissolved oxygen saturation is the percentage of dissolved oxygen measured in the water relative to the equilibrium amount of oxygen possible in the water at a given temperature. Horizons sets a target of 80% DO saturation as a minimum for most waterways in the Whanganui catchment, and 70% for the Ohura River and the four monitoring stations downstream of Pipiriki. ANZECC trigger values for DO saturation are also provided in the ANZECC guidelines, which sets values of >98% and <105% DO saturation for lowland rivers, and >98% to <103% for upland rivers.

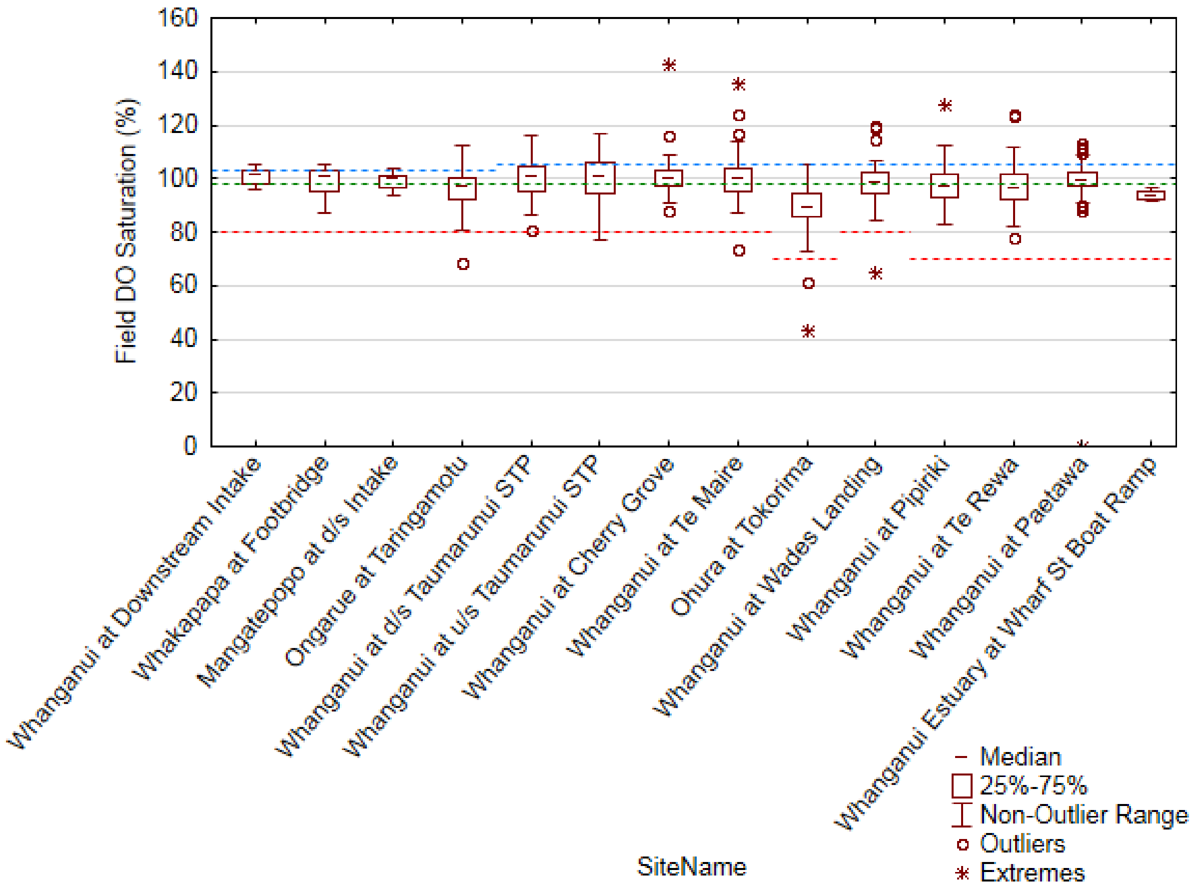

Figure 86: Field DO saturation (%) at 14 monitoring sites in the Whanganui catchment, 1989–2016. Note that red dashed line denotes Horizons Regional Council target minimum level for % DO saturation. Green dashed lines denote ANZECC guidelines lower limit for %DO saturation for upland and lowland waterways, and blue dashed line denotes upper limit. Monitoring sites are ordered left-right on the x axis, upstream-downstream.

Temperature

Temperature affects aquatic plants and animals both indirectly through its effect on chemical processes, and also directly in that the growth and physiology of organisms are strongly influenced by temperature. Lower temperatures are tolerated by most aquatic organisms, but many aquatic organisms are sensitive to warm temperatures.

Horizons Regional Council sets targets for waterways in the Whanganui catchment. For waterways upstream of Te Maire, water temperature must not exceed 19°C (Horizons Regional Council 2014). Downstream of Te Maire, including the Ohura River, Horizons' target is that water temperature must not exceed 22°C. Horizons Regional Council has made spot measurements of water temperature monthly at 14 sites in the catchment over the period from 1989 to 2016. Water temperature is lowest in the upper reaches, and increases with distance downstream (Fig. 87). Temperatures are within guideline levels most of the time, although there were occasional higher measurements at all monitoring sites except at three monitoring locations in the upper-most reaches of the catchment.

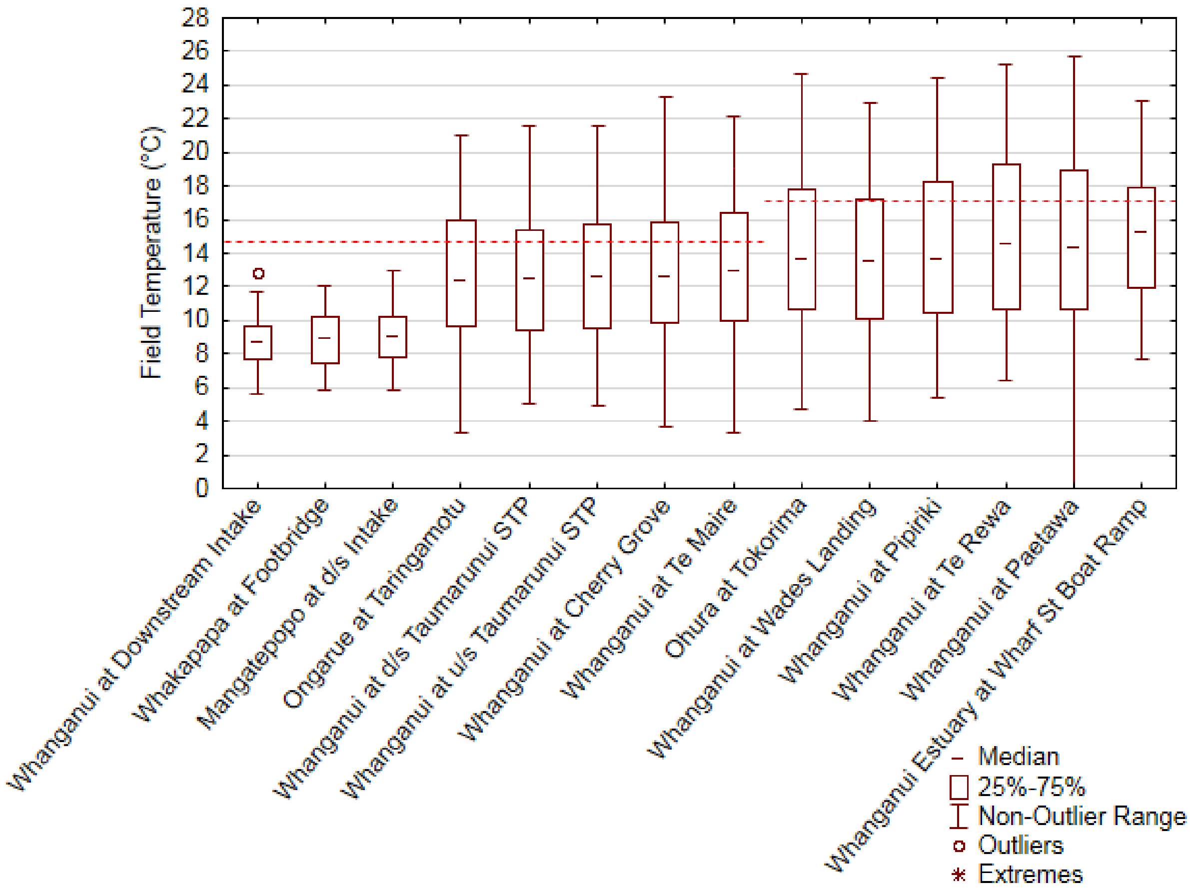

Figure 87: Water temperature at 14 monitoring sites in the Whanganui catchment, 1989–2016. Red dashed line denotes Horizons Regional Council's target temperature for waterways in the Whanganui catchment. That is, that the temperature must not exceed the target value. Monitoring sites are ordered left-right on the x axis, upstream-downstream.

Macroinvertebrate Community Index (MCI)

The macroinvertebrate community index (MCI) is a general measure of river health. Macroinvertebrates make the ideal basis for a biotic index, in that biological communities are a product of their environment, and different kinds of organisms have different habitat preferences and pollution tolerances (Stark & Maxted 2007). Under the index, sensitive macroinvertebrate species get high scores while tolerant species get low scores. The presence and abundance of macroinvertebrate species combine to make a single MCI score that provides an indication of overall river health, where >119 = excellent; 100–119 = good; 80–99 = fair; and <80 = poor for hard-bottomed (e.g. gravel bedded) streams.

Horrox (1999) studied the effect of land use and geology on macroinvertebrate communities in Te Awa Tupua during 1996–1997, finding that sub-catchments with high pastoral agriculture land use had lower diversity and abundance of pollution sensitive taxa compared to forested catchments and, further, that both geology and land use affected macroinvertebrate community structure.

MCI was first monitored by Stark at three locations along the river in 1989. MCI monitoring has occurred annually since 1999 by Horizons Regional Council at four sites: Cherry Grove, Te Maire, downstream of the Retaruke confluence, and Pipiriki. Monitoring has also occurred annually in the Mangatepopo, Whanganui, and Whakapapa rivers upstream and downstream of the Western Diversion intake since 2011. These data are held by Horizons Regional Council and Genesis Energy, and are presented in Figure 88. The graphs show aquatic habitat quality to be in the excellent range in the upper reaches of the catchment around the Western Diversion, with an apparent decline with distance downstream. All median MCI values for the four monitoring sites – Cherry Grove, Te Maire, Wades Landing, and Pipiriki – are within the 'good' range. Further, since 1999, there has been no statistically significant increasing or decreasing trend at any of the four sites. However, if the unpublished data from 1989 are included in the calculations, statistically significant improvements in MCI occurred at Cherry Grove ($P = 0.013$), Te Maire ($P < 0.001$), and Pipiriki ($P < 0.001$) (Stark 2014) (Figs 89, 90, 91, and 92).

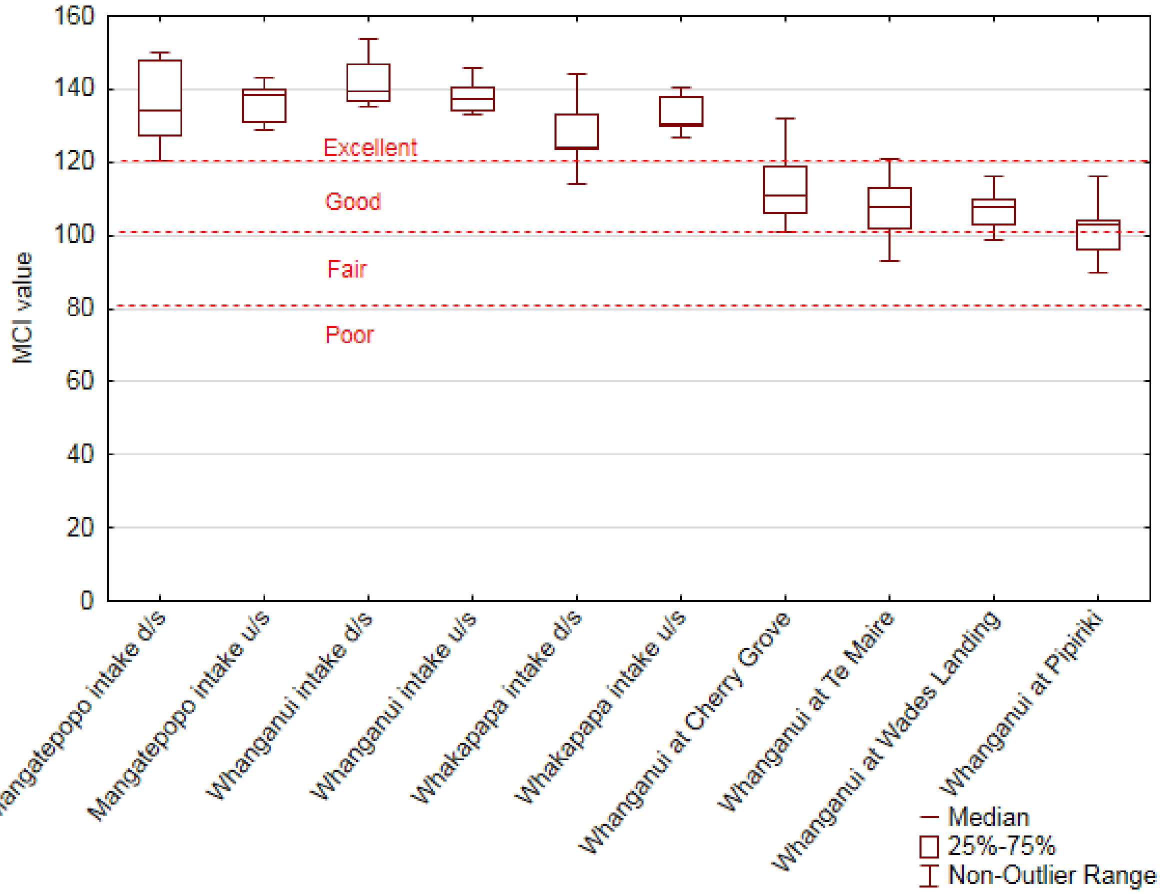

Figure 88: Boxplot of MCI monitoring at 10 sites in the Whanganui catchment, 2005–2016. Red dashed lines denote water quality (aquatic habitat) bands as defined by Stark & Maxted 2007. Monitoring sites are ordered left-right on the x axis, upstream-downstream

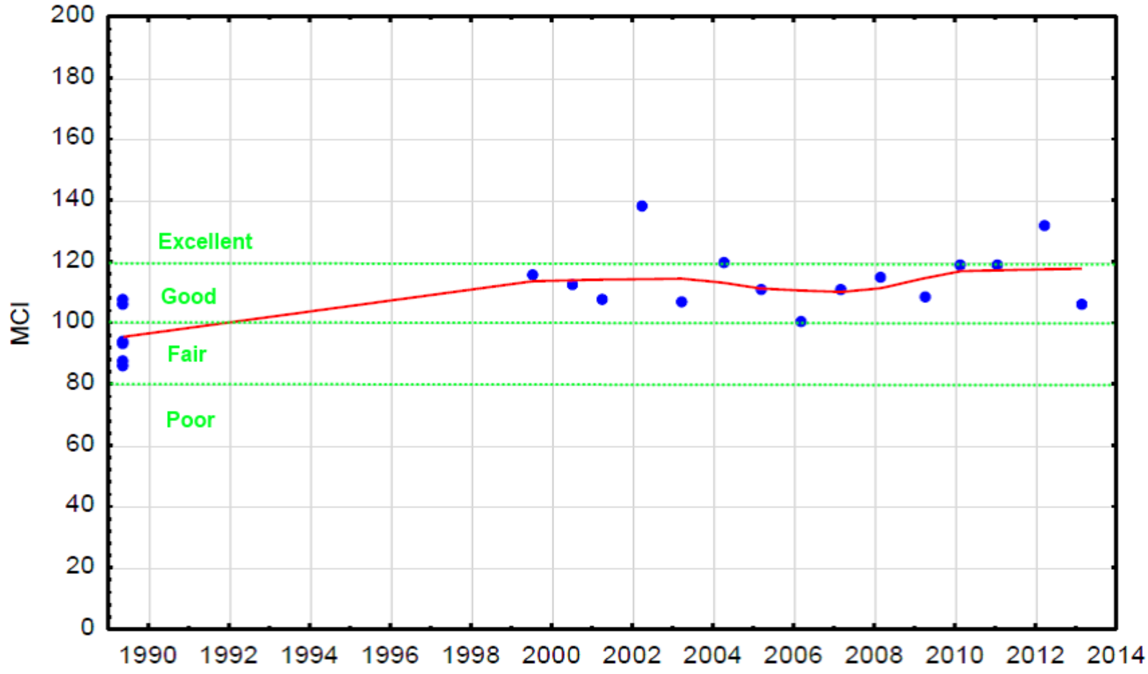

Figure 89: Trend in MCI in the Whanganui River at Cherry Grove in the Whanganui catchment. The positive trend was statistically significant (*P* = 0.013) at face value with data from 1989 included but was deemed non-significant by the Benjamini-Hochberg FDR procedure. Without data from 1989 the trend was not significant (*P* = 0.961) (adapted from Stark 2014, p. 56).

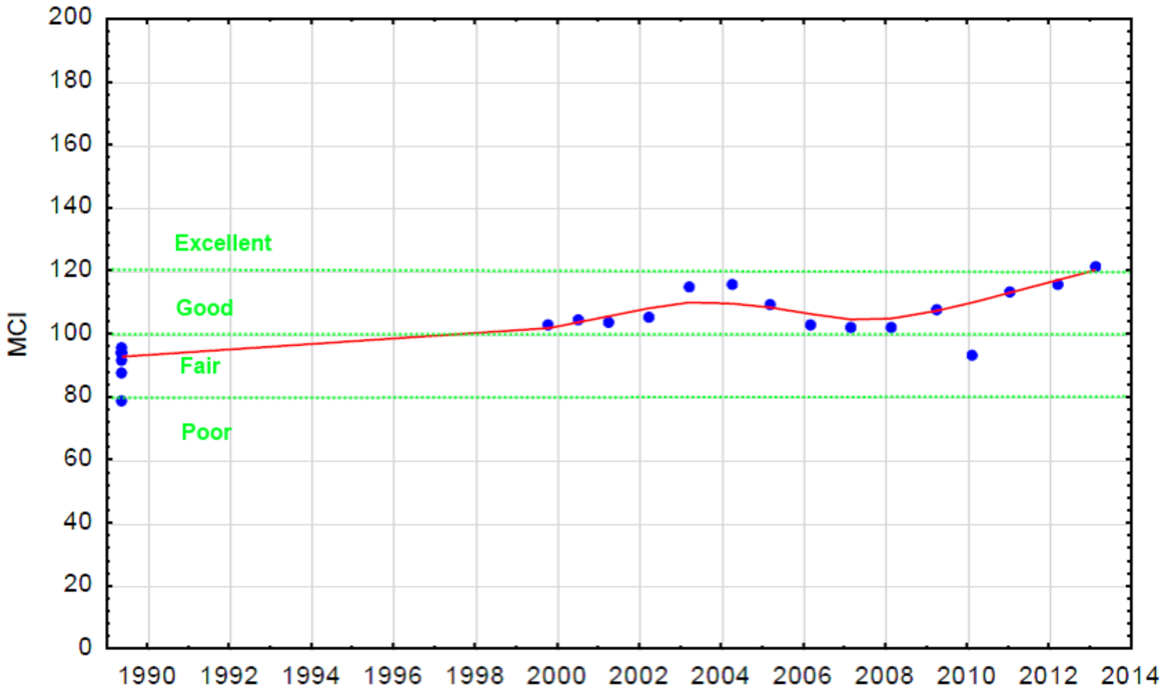

Figure 90: Trend in MCI in the Whanganui River at Te Maire in the Whanganui catchment. The positive trend was statistically significant (P < 0.001) at face value with data from 1989 included and remained significant following the Benjamini-Hochberg FDR procedure. Without data from 1989 the trend was not significant (*P* = 0.294) (adapted from Stark 2014, p. 56).

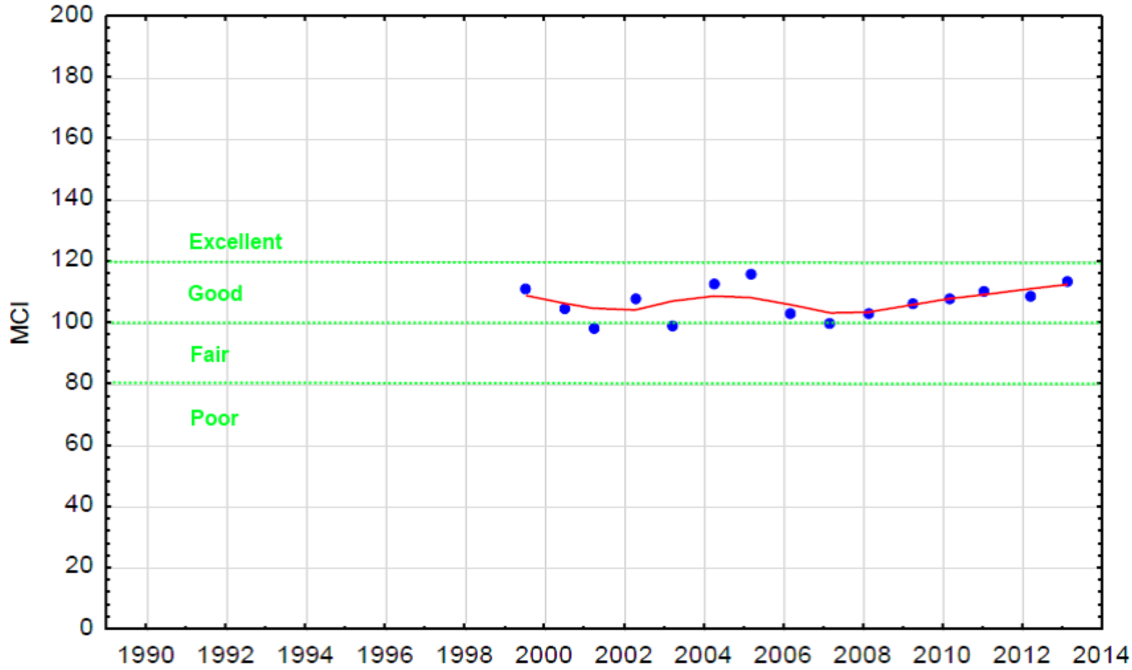

Figure 91: Trend in MCI in the Whanganui River downstream of the Retaruke confluence in the Whanganui catchment. The trend was not statistically significant (*P* = 0.164) (adapted from Stark 2014, p. 57).

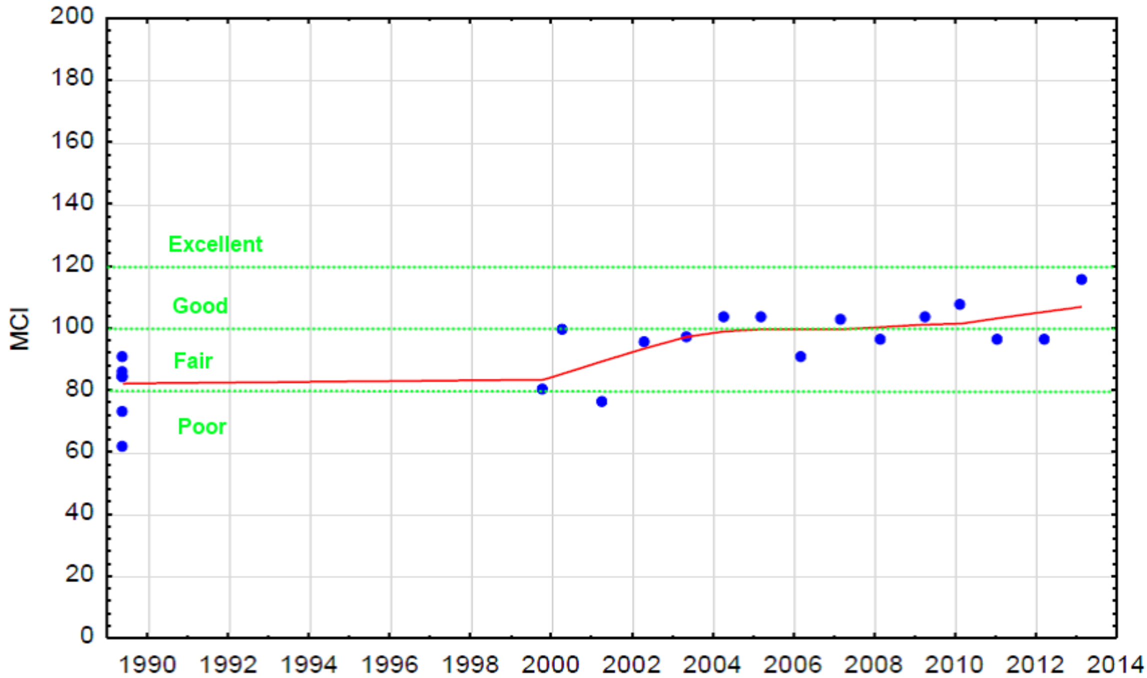

Figure 92: Trend in MCI in the Whanganui River at Pipiriki in the Whanganui catchment. The positive trend was statistically significant ($P < 0.001$) at face value with data from 1989 included and remained significant following the Benjamini-Hochberg FDR procedure. Without data from 1989 the trend was significant ($P = 0.047$) but not strong enough to avoid elimination by the Benjamini-Hochberg FDR procedure (adapted from Stark 2014, p. 57).

%EPT

The %EPT metric refers to the percentage of three invertebrate types – Ephemeroptera (May flies), Trichoptera (Caddis flies) and Plecoptera (Stone flies) – out of all invertebrate species present in a sample. The %EPT decreases with increasing stress.

%EPT decreases from upstream to downstream in the Whanganui River, indicating increasingly unfavourable instream conditions for EPT taxa in the downstream reaches. In the upper reaches of the catchment, data provided by Genesis Energy cover the upstream and downstream monitoring sites at Mangatepopo, Whanganui, and Whakapapa intakes of the Western Diversion, 2011–2016. Monitoring occurs five times per year at each monitoring site. Median %EPT is between 80% and 100% across these sites (Fig. 93). Data provided by Horizons Regional Council cover five monitoring sites further downstream – Ongarue at Taringamotu, Whanganui at Cherry Grove, Te Maire, Wades Landing, and Pipiriki (Fig. 93). Each of these monitoring stations has been monitored once per year, from 2005 to 2015, except for Ongarue at Taringamotu, which has been monitored once annually since 2013. Median values are 54 %EPT at Cherry Grove, 52 %EPT at Te Maire, 49 %EPT at Wades Landing, and 45 %EPT at Pipiriki.

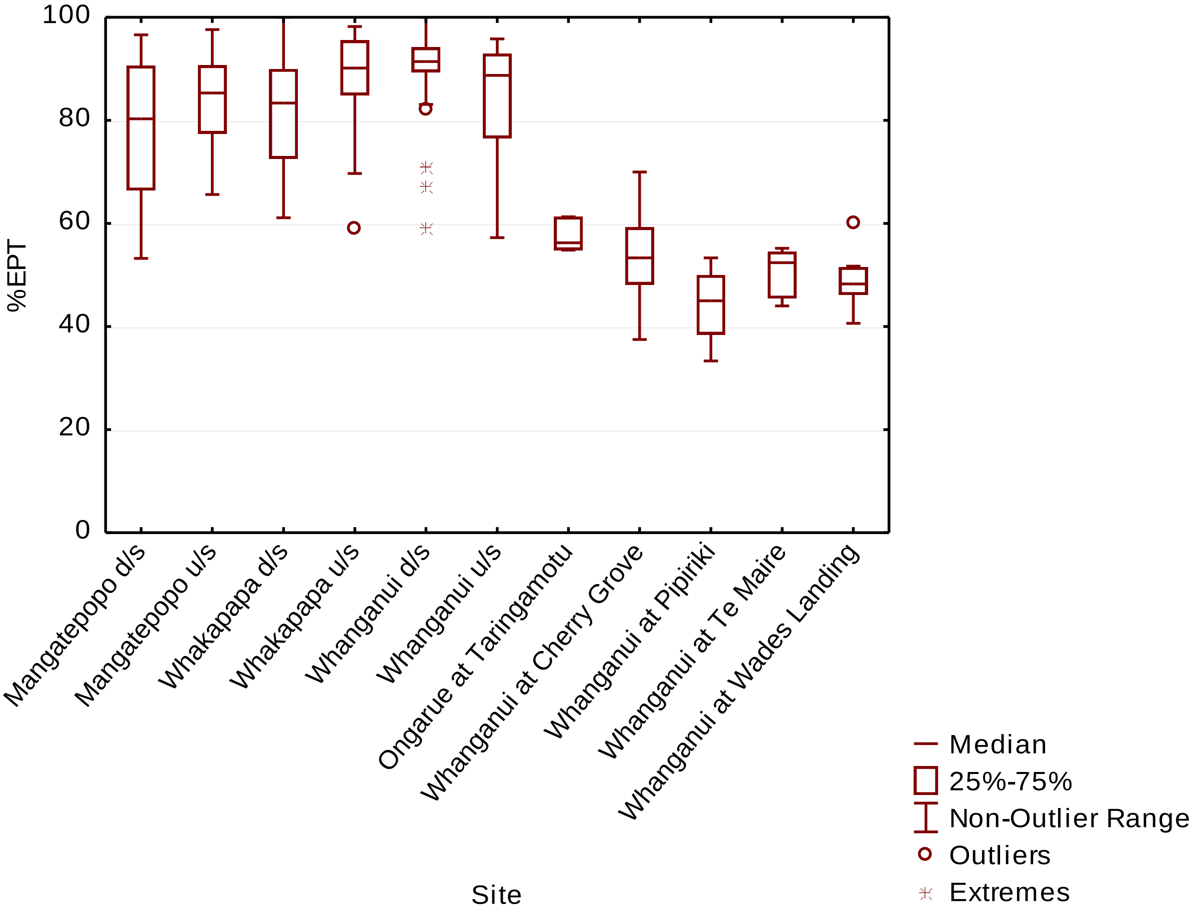

Figure 93: %EPT at eleven monitoring locations in the Whanganui Catchment, 2005–2016. Monitoring sites are ordered left-right on the x axis, upstream-downstream. Data provided by Horizons Regional Council.

Periphyton

Periphyton is algae (and some other organisms) that grow attached to or associated with the rocks or sediment covering the beds of rivers and lakes. Periphyton is integral to a functioning ecosystem, but too much of it can become problematic by, for example, degrading swimming and fishing spots, clogging irrigation and water supply intakes and degrading habitat for stream life on and within the riverbed (Biggs 2000) (see Table 24).

Genesis Energy has monitored periphyton annually around the Western Diversion of the Tongariro Power Scheme, 2010–2016. Periphyton monitoring occurs at sites upstream and downstream of the Whakapapa, Mangatepopo and Whanganui intakes of the Western Diversion on one occasion per year in late summer/autumn.

Table 24: Instream values that can be compromised and associated problems that may arise as a result of periphyton proliferations (Biggs 2000, p. 28)

Instream Value	Problem
Aesthetics	Degradation of scenery, odour problems
Biodiversity	Loss of sensitive invertebrate taxa through habitat alteration, possible reduction in benthic biodiversity
Contact recreation	Impairment of swimming, odour problems, dangerous for wading
Industrial use	Taste and odour problems, clogging intakes
Irrigation	Clogging intakes
Monitoring structures	Fouling of sensor surfaces, interferes with flow
Potable supply	Taste and odour problems, clogging intakes
Native fish conservation	Impairment of spawning and living habitat
Stock and domestic animal health	Toxic blooms of cyanobacteria
Trout habitats/angling	Reduction in fish activity/populations, fouling lures, dangerous for wading
Waste assimilation	Reduces stream flow, reduces ability to absorb ammonia, reduces ability to process organics without excessive DO depletion
Water quality	Increased suspended detritus, interstitial anoxia in stream bed, increased DO and pH fluctuations, increased ammonia toxicity, very high pH
Whitebait fishing	Clogging nets

Periphyton levels in the upper reaches of the catchment around the Western Diversion are consistently within MfE guideline values and Horizons Regional Council targets since monitoring began in 2011. The highest recorded level of chlorophyll *a* has never exceeded 50mg Chl *a* m^{-2} (which is the MfE guideline value for benthic biodiversity), and is well below the MfE guideline for trout habitat of 200 mg Chl *a* m^{-2} (Fig. 94).

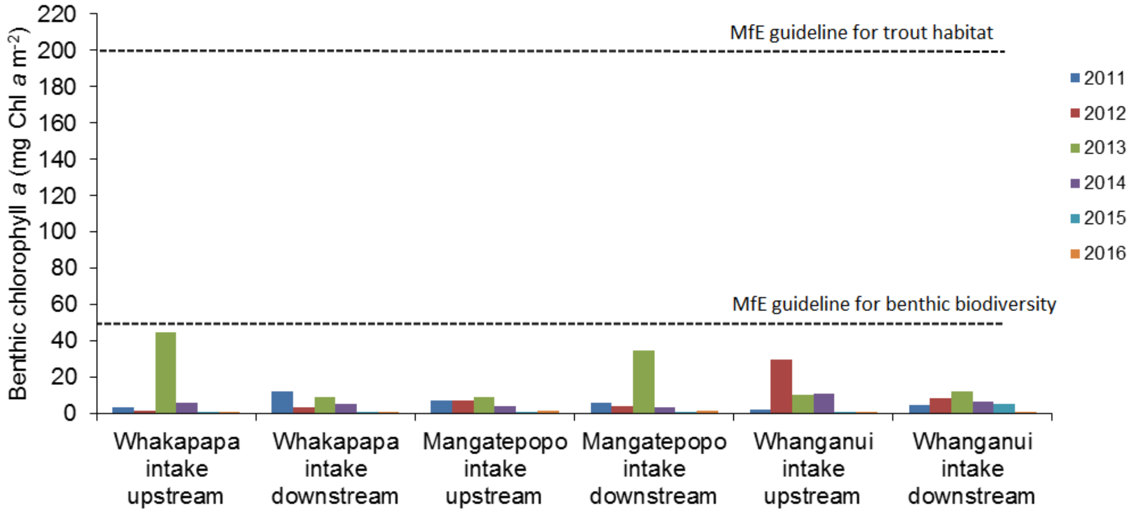

Figure 94: Benthic chlorophyll *a* upstream and downstream of three intakes along the Western Diversion of the Tongariro Power Scheme (adapted from Tonkin & Taylor 2015, p. 58).

Ash free dry mass is also consistently within MfE guideline levels for trout habitat (35 g m^{-2}). The highest recorded level of AFDM recorded was 21g m^{-2}, and this was upstream of the Whakapapa intake in 2013 (Fig. 95).

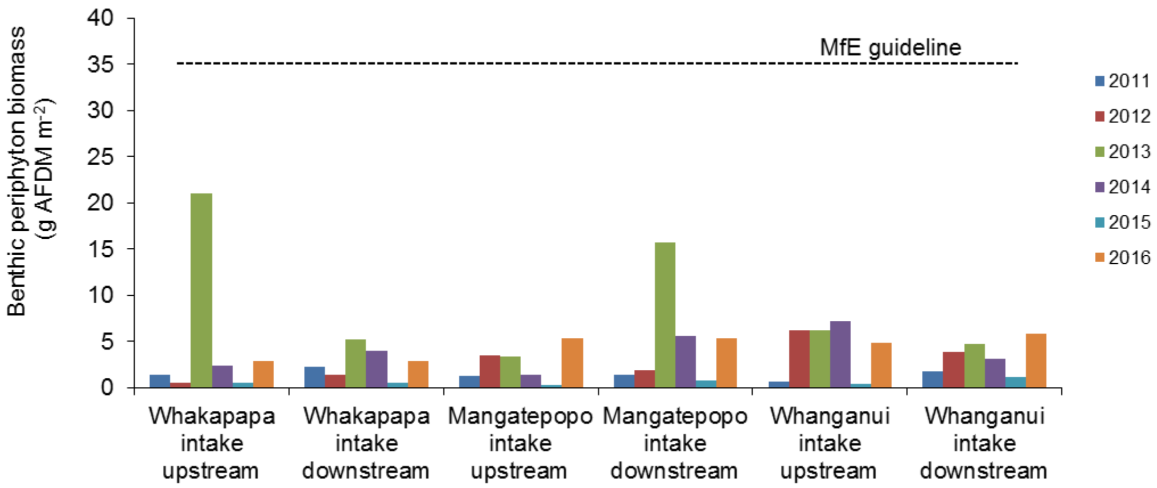

Figure 95: Benthic periphyton upstream and downstream of three intakes along the Western Diversion of the Tongariro Power Scheme (Tonkin & Taylor 2015. P. 58).

Horizons Regional Council also sets a target of 50mg Chl *a* m^{-2} in the upper reaches of the Whanganui catchment (i.e. around the Western Diversion), and 120–200 mg Chl *a* m^{-2} further downstream (Horizons Regional Council 2014).

Horizons Regional Council has monitored periphyton in the Whanganui River annually since 2011, although no data were provided for 2014. Monitoring occurs at four locations: Cherry Grove, Pipiriki, Te Maire, and Retaruke. Data exist for percent coverage of different types of periphyton, but not for Chl *a* and AFDM. Given that MfE only provides guidelines for filamentous algae and not for other types of periphyton, filamentous algae are the only type of periphyton reported here. A filamentous algae cover of 30% has been suggested as a guideline value in order to provide suitable instream conditions for contact recreation activities (e.g. swimming and bathing) (Biggs 2000).

Filamentous algae in the Whanganui River increase with distance downstream. The uppermost of Horizons Regional Council's monitoring stations, Cherry Grove, has never exceeded MfE's guideline value of 30% filamentous algae coverage during the monitoring period (Fig. 96). On the other hand, at the lower-most monitoring station, Pipiriki, filamentous algae have exceeded the guideline value on all but one occasion, 2011. The monitoring station downstream of the Retaruke confluence has the same exceedances. These results suggest that instream recreational activities may be impacted by the presence of filamentous algae during summer months downstream of the Retaruke confluence.

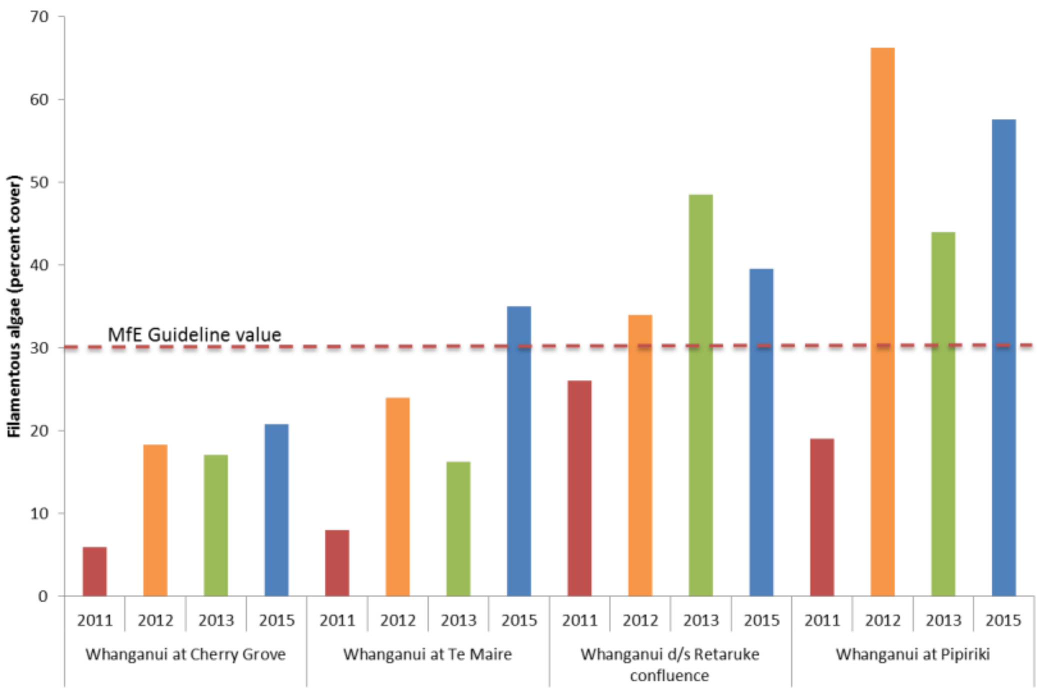

Figure 96: Filamentous algae percentage cover at four sampling locations on the Whanganui River, 2011–2015 (source: LAWA). Note that the values were derived by combining data for 'coarse filamentous' and 'slimy filamentous' longer than 2 cm.

5.5.3 Aquatic ecosystems biodiversity and taonga species

Introduction

Fish monitoring data for the Whanganui catchment is held in the New Zealand Freshwater Fisheries Database.[5] Information contained in the database includes the location of sample sites (Fig. 97), the fish species present, their abundance and size, as well as sampling methods, and a physical description of each site. Data for the Whanganui catchment span 1948 to 2016, and cover more than 170 streams, rivers, and lakes over the nearly 1,600 monitoring occasions within the catchment. Many sites have only been monitored once while others, such as the Whanganui River, have been sampled more than 100 times over the course of many more than five decades. Eighteen species of native fish inhabit the Whanganui River, which includes taonga species such as tuna, kōaro, piharau, koura, and kōkopu (DOC, 2006). Two introduced fish species are also present in the river – rainbow trout and brown trout.

[5] Access the database at https://www.niwa.co.nz/our-services/online-services/freshwater-fish-database

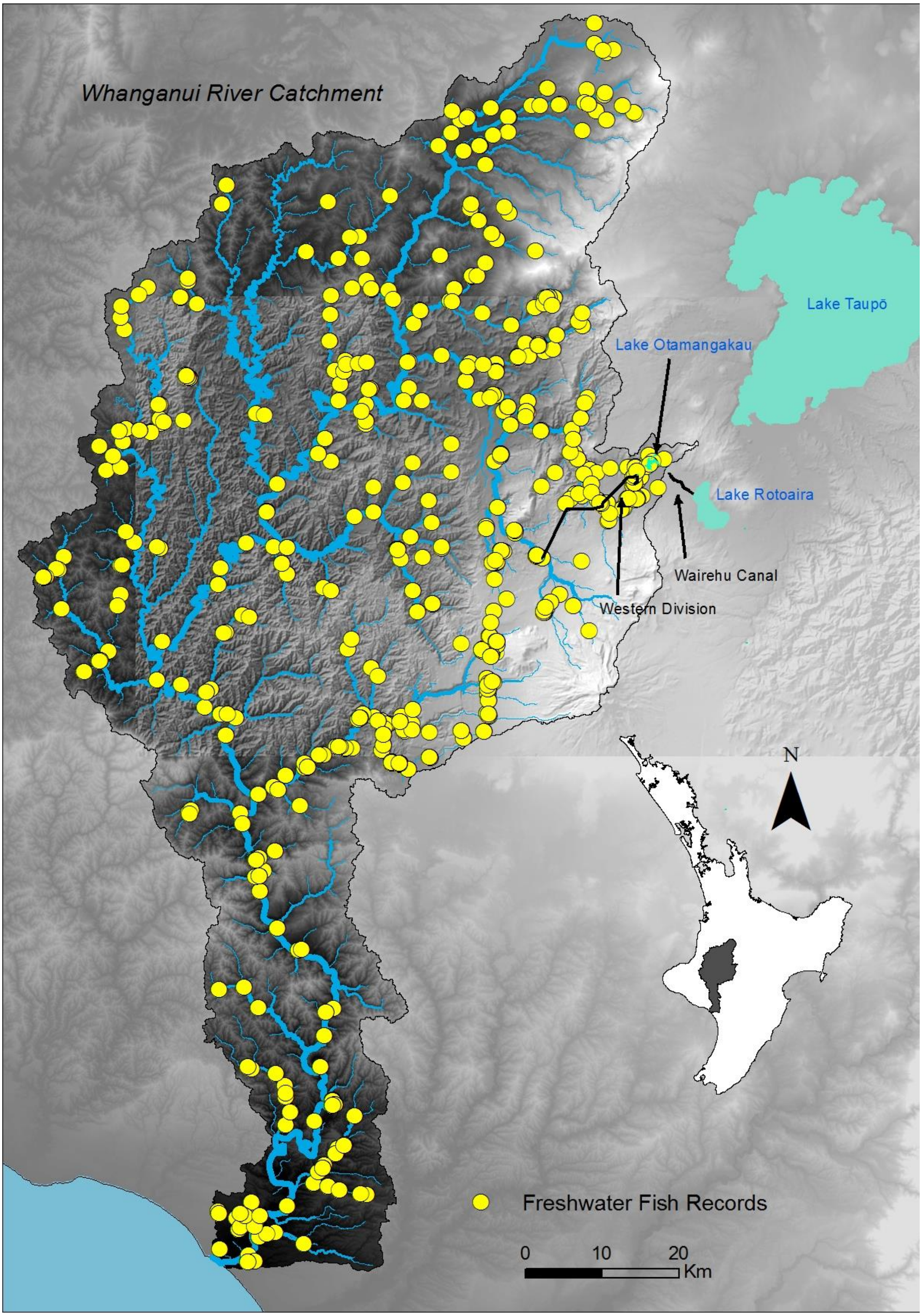

Figure 97: Freshwater fish records as recorded in the New Zealand Freshwater Fish Database, 1948–2016. Each yellow dot represents the location of one or more monitoring occasions.

Documented fish monitoring studies and observations are numerous. For example, Mair (1879) recorded papanoko, toitoi, inanga, atutahi, upokororo, and “a peculiar kind of eel called tunaheke” in the upper Whanganui River in the mid-late 19th century. Rowe et al. (1989) studied the diversity of species in the Whanganui River by conducting a synoptic survey of 35 sites along the river in 1989, finding that the middle catchments (Retaruke River, Tangarakau River, and Whangamomona River) were lacking fish numbers and species diversity. Possible reasons included both land use and geological processes affecting streambed sediment in the middle reaches, as well as the possibility of seasonal effects due to the timing of the study. Jowett and Richardson (1996) included the Whanganui River in a study of 38 medium to large New Zealand rivers to compare fish communities between rivers on a national scale.

Fish monitoring has also been undertaken by Genesis Energy around the Western Diversion of the Tongariro Power Scheme. A summary of the key fish monitoring details, and other environmental outcomes, are presented in Genesis’ Annual Environmental Reports (see e.g. Genesis Energy 2015).

Tuna

There are three species of tuna in New Zealand, and two of these – the longfin eel (*Anguilla dieffenbachia*) and shortfin eel (*Anguilla australis*) – are present in the waterways of the Whanganui catchment.

Longfin eel are widely dispersed throughout New Zealand, and may be found in lowland rivers and up to as high as 1150 m and 350 km inland. Their wide dispersal is in part due to their climbing capability of large and steep falls – particularly in the early stages of their life. Habitats of longfin eel include rivers, lakes, streams, and wetlands. They prefer to live under instream cover such as logs and boulder piles, and emerge at night to feed. Their diet includes insects, fish, and even small birds. While widely abundant throughout New Zealand, numbers have declined through exploitation and commercial fisheries (McDowall 2000). Longfin eel are classified as at risk, declining, under the New Zealand Threat Classification System (Goodman et al. 2014).

Shortfin eels are also widely distributed around New Zealand, but less so than the longfin eel. They may be found up to as high as 835 m and inland as far as 292 km in streams, rivers, lakes, and wetlands. Their diet includes aquatic insects, snails, crustaceans, and fish. As with the longfin eel, shortfin eels have been impacted by exploitation and commercial fishing (McDowall 2000). However, shortfin eel are classed as not threatened under the New Zealand Threat Classification System, indicating large, stable populations nationally (Goodman et al. 2014).

Fish monitoring in the Whanganui catchment recorded in the New Zealand Freshwater Fisheries Database provides data for longfin eel and shortfin eel. Longfin eels are the most frequently observed of the two and are widespread throughout the Whanganui catchment, having been observed on 332 monitoring occasions at 148 different waterways in the catchment, 1961–2016. They are observed throughout the catchment including in the upper reaches upstream of the Western Diversion. The maximum number of longfin eels observed on one occasion was 100, and this occurred in the Orautoha Stream tributary in 1979. The highest altitude at which longfin eels were recorded is 890 m, and this occurred in the Mangahuia Stream, upstream of the Western Diversion, in 1980. The most recently recorded observation of longfin eel above the Western Diversion was 2012 (Fig. 99).

In contrast, shortfin eels have been observed on 90 monitoring occasions at 52 different waterways in the Whanganui catchment, 1966–2016. The maximum number of shortfin eels observed in a single monitoring occasion was 59, and this occurred in the Taringamotu River in 2005. Shortfin eels are most frequently distributed on the eastern side of the catchment, including in the upper reaches around the volcanoes (Fig. 98).

There is not enough evidence to determine the extent to which the presence of shortfin and longfin eels in the upper reaches of the catchment have been impacted by the construction of the Western Diversion. While shortfin eels have been observed in the upper reaches of the Whanganui and Whakapapa Rivers and their tributaries above the Western Diversion after construction, for many records, fish sizes are not documented and so it is not possible to determine whether the recorded eels are a pre-construction remnant population. For those records that do have size classes the NZFFD states that shortfin eel size around Lake Okamagakau are 110–273 mm. These sizes mean the eels are juveniles and not adults.

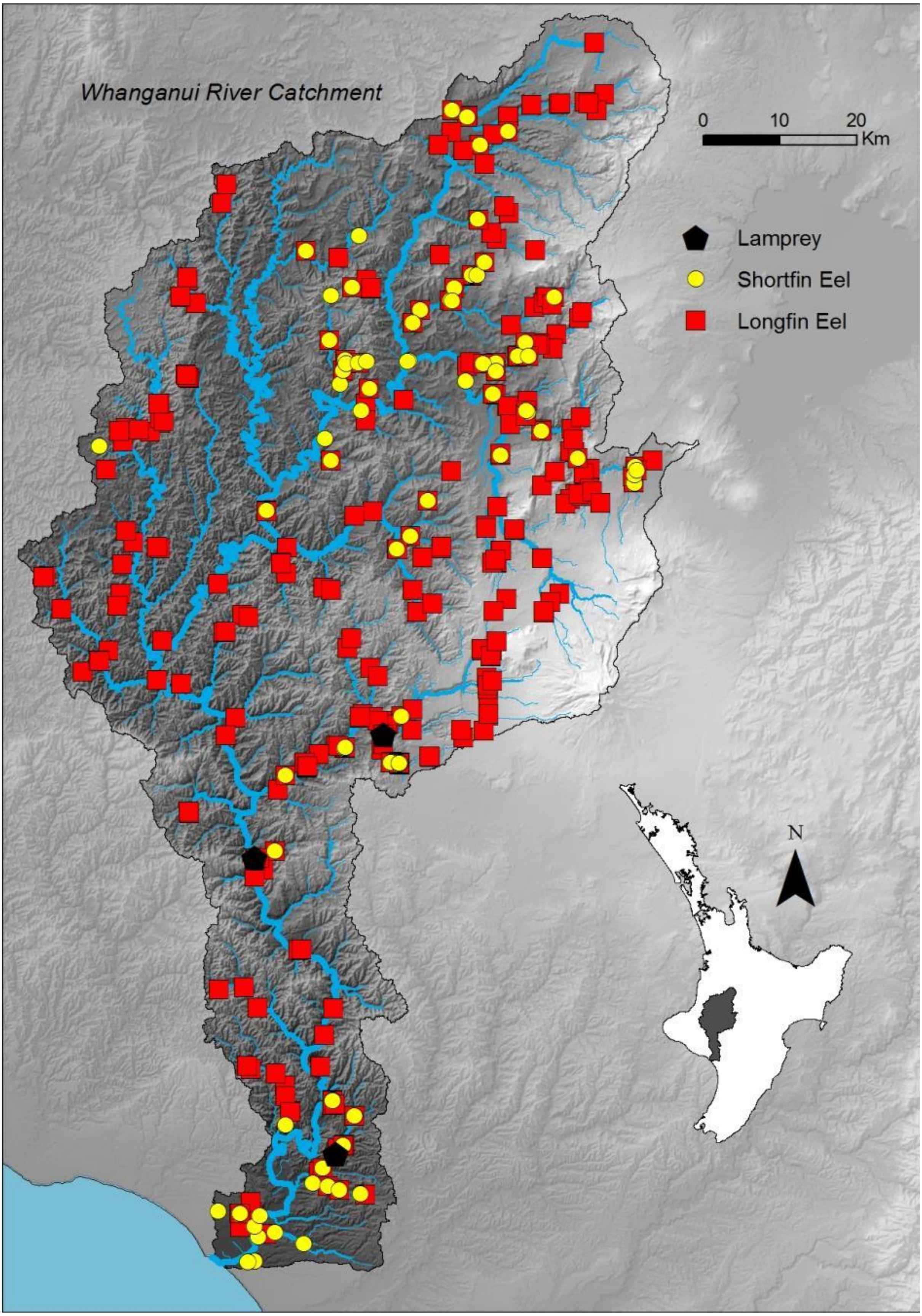

Figure 98: Distribution of longfin eel (1961–2016), shortfin eel (1966–2016), and piharau (1978–2000) in the Whanganui catchment.

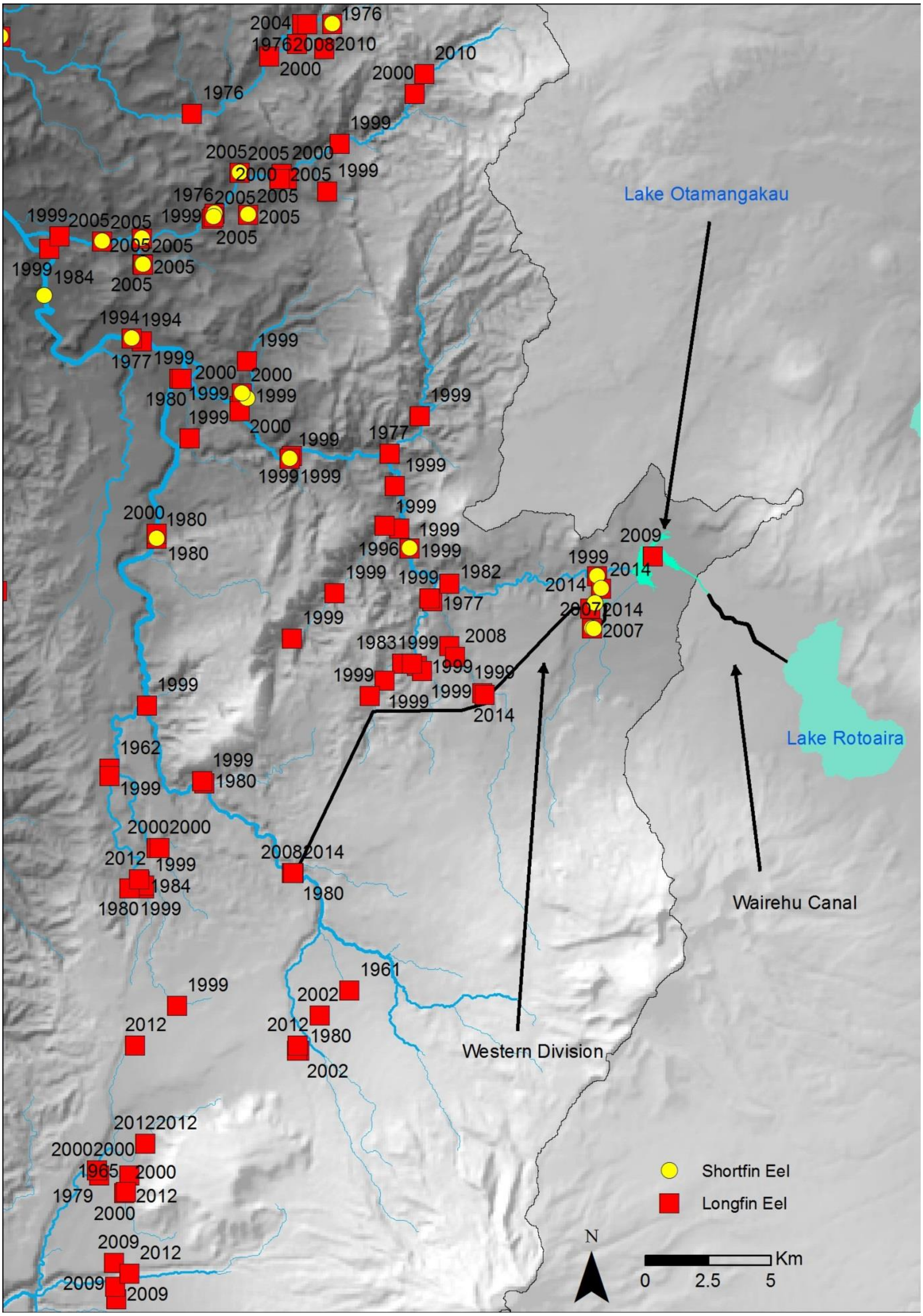

Figure 99: Distribution map showing dates of observed instances of shortfin and longfin eels in the upper reaches of the Whanganui River catchment, 1961–2016. Additionally, while not displayed on the map, Genesis Energy monitoring in 2015 and 2016 found shortfin eels in Lake Otamangakau at Wairehu Canal.

The effects of the Western Diversion on shortfin and longfin eel numbers downstream of the Western Diversion are assessed by Genesis Energy's environmental monitoring programme. Under the programme, fish monitoring is conducted every 3 years at three locations downstream of the Western Diversion: the Whanganui, Mangatepopo, and Whakapapa Rivers. While acknowledging that eel numbers were impacted before the implementation of low flow conditions, Genesis Energy's monitoring programme has found "…the reaches that were dry prior to the establishment of minimum flows [in 2004] had been recolonised by the fish communities present in the upper Western Diversion tributaries", and further "no significant adverse ecological effects as a result of the diversions in the three rivers of the Western Diversion" (Genesis Energy 2015, p. 29).

Tuna in the Whanganui River have been the subject of several studies. In their synoptic survey, Rowe et al. (1989) found longfin and shortfin eels the most common species. Juvenile longfin eels were only present downstream of Pipiriki, while juvenile shortfins were found throughout the river where suitable habitat existed. By contrast juvenile inanga, kōkopu, and koaro were relatively sparse.

Piharau

Piharau (*Geotria australis* – lamprey) begin their lifecycle as filter feeders in freshwater rivers before migrating to the ocean where they become parasites on other fish. Later in life they migrate back upstream the river to spawn. Sometimes they can travel long distances upstream, for example, Best (1929) found Piharau some 240 km upstream at Taumarunui. In 2014, Piharau were classified as a nationally threatened species (Goodman et al. 2014).

Piharau have rarely been observed by monitoring in the Whanganui catchment. As documented in the New Zealand Freshwater Fisheries Database, Piharau have been observed on only three sampling occasions, out of the total 1600. These three occasions occurred in the Whanganui River in 1978 (600 individuals), the Orautoha Stream in 1979 (two individuals), and the Mangotai Stream in 2000 (two individuals).

There has been one study of piharau in the Whanganui catchment. Baker et al. (2016) used Polar Organic Chemical Integrative Samplers (POCIS) to examine the distribution of larval piharau and provide a semi-quantitative estimate of their abundance. POCIS detect the pheromone petromyzonol sulphate that is released by upstream resident larval piharau. The amount of the pheromone can be used to infer larvae populations upstream of the sampling point. Detection of larval populations helps identify important spawning and larval rearing streams, as the pheromone signature of larvae is used by migratory adults to select spawning streams. The study found that the larger Ohura River and Manganui o te Ao River catchments have a higher abundance of larval piharau relative to other sites sampled and these systems could, therefore, be important spawning and larval rearing habitats. Also, larval piharau pheromones were more commonly detected in streams of the eastern side of the catchment, with the exception of two streams on the Western side – the Ohura River and Waikaka Stream (Baker et al. 2016) (Figs 100, 101).

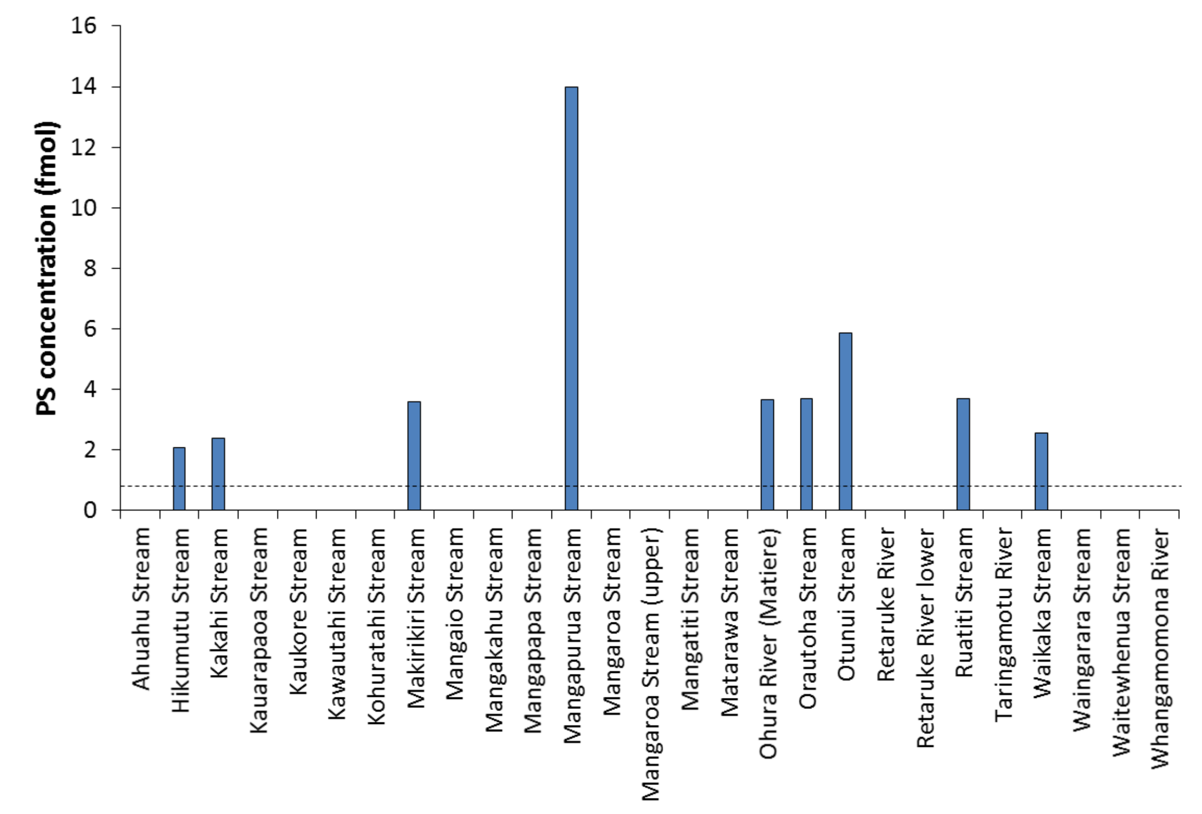

Figure 100: Calculated time averaged water concentrations (fmol) of petromyzonol sulphate (PS) in the 27 Whanganui River sites successfully sampled with POCIS. Note: fmol is 10^{-15} M. Dashed line indicates the detection threshold of 0.8 fmol.

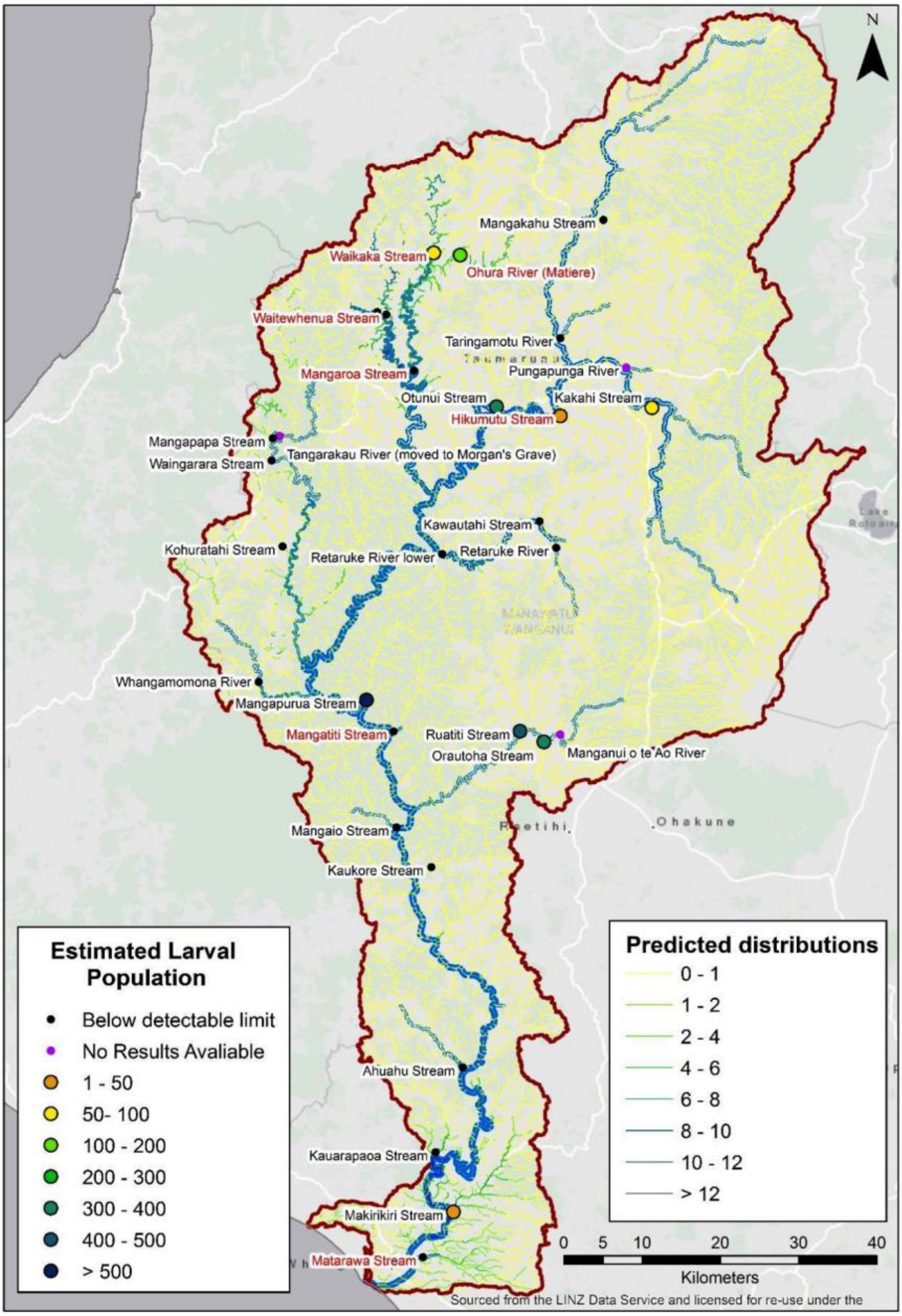

Figure 101: Estimated larval abundance based on POCIS deployment in the Whanganui River catchment. The Whanganui River is indicated by the thick blue line, with other main rivers indicated by thinner blue lines. Site names in red indicate samplers affected by heavy fouling or being out of the water when retrieved so they will be underestimating larval abundance. The predicted probability of piharau occurrence is also displayed for all stream segments. For graphical clarity, the probability of occurrence is displayed as a % ranging between 0 and 12, and greater than 12.

Kōaro

Kōaro (*Galaxias brevipinnis*) are a diadromous species, but may also spend their entire lifecycle landlocked by using lakes for juvenile rearing. They prefer clear, swift, cool water less than 13°C and are known as good climbers (McDowall 2000). Kōaro are declining nationally (Goodman et al. 2014), and in the Whanganui River (Rainforth 2008). There are many possible reasons for the decline, including land use change from forest cover to farming and horticulture, and being outcompeted by introduced trout and smelt (McDowall 2000; Rowe et al. 2002).

Kōaro have been observed at 18 different sites on 29 monitoring occasions in the Whanganui catchment between 1948 and 2016. The greatest recorded number observed in a single monitoring occasion was 20, and this occurred in the Makomiko Stream in 2000. Other notable observations were at a tributary to the Makatote River where 14 individuals were recorded in 2009; and the Ngahuina Stream where eight individuals were observed, also in 2009. The distribution of Kōaro in the Whanganui catchment is predominantly in the upper reaches of the eastern side of the catchment (Fig. 102). The highest altitude at which Kōaro have been recorded is 860 m, and this occurred in 1969. The median altitude over the monitoring period is 732 m. Their distribution in the higher reaches of the catchment may be expected given their preference for colder temperatures, and their strength as climbers.

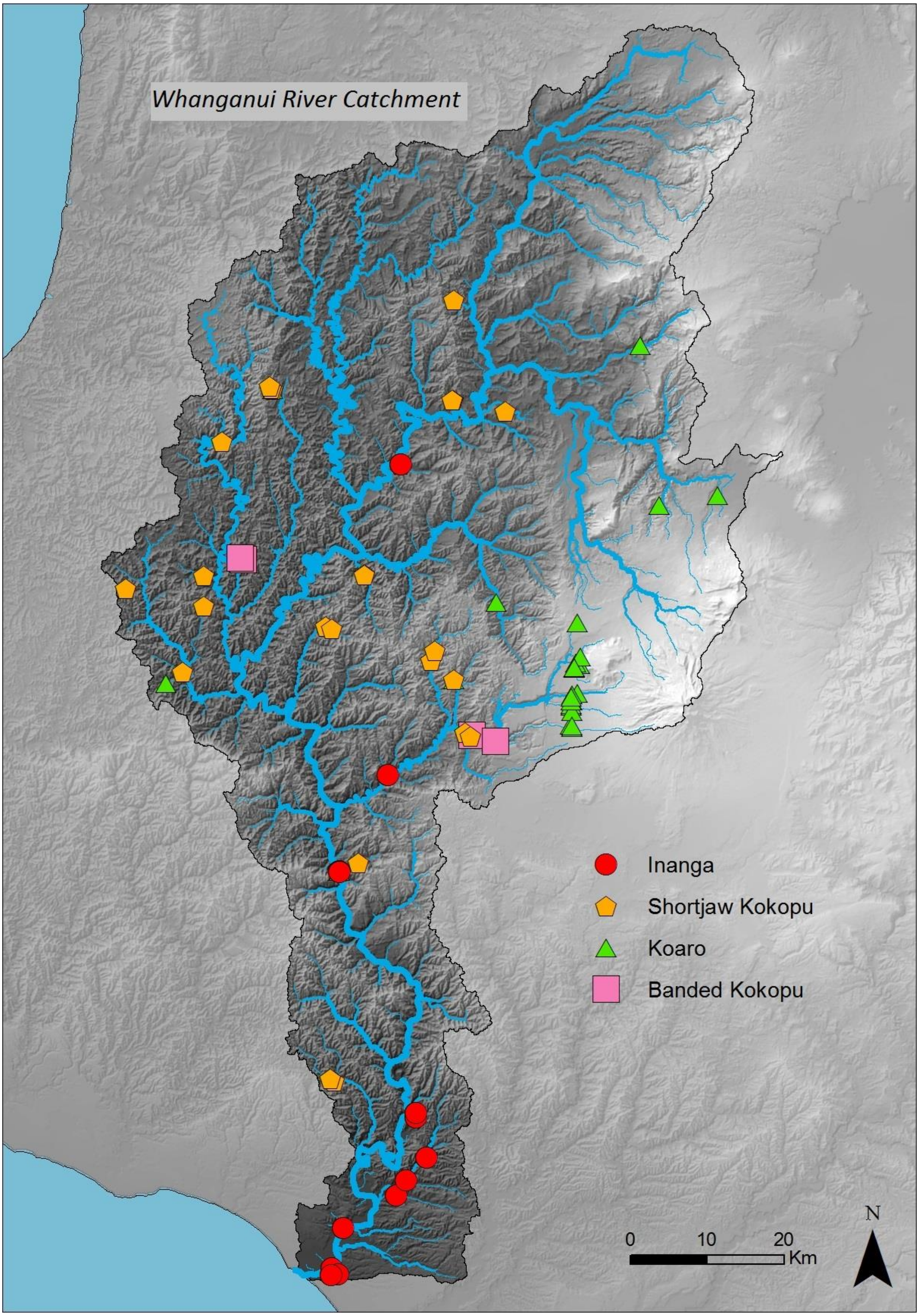

Figure 102: Distribution map of four galaxiids – inanga, shortjaw kōkopu, kōaro, and banded kōkopu – identified in the Whanganui catchment, 1948–2016.

While kōaro had been recorded on one occasion upstream of the Western Diversion of the Tongariro Power Scheme before its construction, there have been no recorded sightings since. However, this single observed instance of kōaro tells us that numbers have always been low in those upper reaches. As such, the reason kōaro have not been observed upstream of the Western Diversion since construction is unclear.

Shortjaw Kōkopu

Shortjaw kōkopu (*Galaxias postvectis*) are generally found in western areas of New Zealand in low to moderate elevations of lower than 520 m. Their habitat is small, stable, bouldery streams enclosed by podocarp/broadleaf forest. Shortjaw kōkopu are found among instream cover that includes logs, overhanging banks, and large boulders (McDowall 2000).

Sightings of shortjaw kōkopu in the Whanganui Catchment were first recorded in the New Zealand Freshwater Fish Database in 1979, and they have been observed at 18 different sites on 27 sampling occasions since then. Their distribution is in the lower to middle reaches of the catchment to a maximum altitude of 380 m (Fig. 102). There are no records of shortjaw kōkopu in the Whanganui River itself, nor do they reach as far inland as the Western Diversion. The highest number of shortjaw kōkopu recorded on a sampling occasion between 1979 and 2016 was nine and this occurred in a 234-m reach of the Mototara Stream in 2003.

Banded Kōkopu

Banded kōkopu (*Galaxias fasciatus*) are widespread around New Zealand, but sparser on the East Coast of the North Island from East Cape to Otago Peninsula, with the exception of Banks Peninsula (McDowall 2000). The habitat of banded kōkopu includes cool, small boulder/rocky, pool/riffle streams with low pH, and brown-stained water. They prefer forested streams – usually broadleaf/podocarp – or streams heavily overgrown with pasture. The range and abundance of banded kōkopu has decreased dramatically throughout New Zealand due to habitat destruction driven primarily by deforestation (McDowall 2000).

Banded kōkopu are recorded in the New Zealand Freshwater Fish Database as having been observed on four sampling occasions at four different rivers in the catchment (Fig. 102): Manganui o te Ao River in 1979, Mangatururutu River in 2000, Marangae Stream in 1998, and a Marangae Stream tributary in 1998. In each instance, just one individual was observed.

Kōkopu have been the subject of several studies in the Whanganui catchment. Rowe et al. (2000) observed that banded kōkopu are more sensitive to turbid water than other species of native fish when measured in terms of abundance – probably due to the reduced recruitment of juveniles in turbid rivers.

Inanga

Inanga (*Galaxias maculatus*) are widely distributed around New Zealand. They are found in lowland waterways with elevations lower than 230 m, and have been found as far as 215 km inland. Inanga prefer slow moving or stationary waters including lagoons, streams, rivers, and estuaries. In faster moving waterways they tend to disperse from their shoals and become solitary. Habitat deterioration has been responsible for a national reduction in inanga abundance (Allibone et al. 2010; McDowall 2000).

Inanga are present in the Whanganui River, and have been recorded on 13 monitoring occasions in the New Zealand Freshwater Fish Database, 1959–2016. They are found in the lower reaches of the catchment to a maximum elevation of 120 m. The furthest inland inanga have been recorded is 211 km, in a tributary to the Whanganui River (Fig. 102). This is 4 km short of the furthest inland recording of inanga in the whole New Zealand Freshwater Fish Database.

Kākaki

Kākaki (*Echyridella menziesii*) are freshwater shellfish, and have always been an important food source for local Māori. Kākahi are widespread throughout New Zealand, and may be found in diverse habitats from small streams through to lakes. Kākahi populations are in decline nationally (Grainger et al. 2014), generally attributed to loss of habitat resulting from altered flow, eutrophication, pollution, and possibly the loss of host fish that are required to complete the life cycle (McDowall 2002).

There have been few specific studies of kākaki in the Whanganui catchment. Horrox (1999) studied the effect of land use and geology on benthic communities of the Whanganui River. For kākahi, Horrox looked specifically at the influence of habitat and environmental characteristics on shell morphology, finding that shell morphology was not related to physicochemical and habitat variation, but geographical isolation from tectonic activity was a possibility. Rainforth (2008) analysed the mātauranga of kākaki, which recorded a decline of kākahi in the Whanganui River. Rainforth noted that kākaki were once so abundant throughout the Whanganui River that they provided a food source for local hapū, yet now numbers are so low that even locating them is difficult. Several possibilities are suggested for the decline, including changed flow and desiccation following the hydropower scheme, sedimentation, domestic and agricultural pollution, gravel extraction, and channel modification.

Kākahi monitoring data for the Whanganui catchment are recorded in the New Zealand Freshwater Fish database, 2005–2009. During this period, kākahi have been observed at one site in the Whanganui Catchment (Fig. 103). This observation occurred in 2009 in the Otamaewa Stream, at an elevation of 740 m. Between 2005 and 2009, there were 32 monitoring occasions where no kākahi were observed.

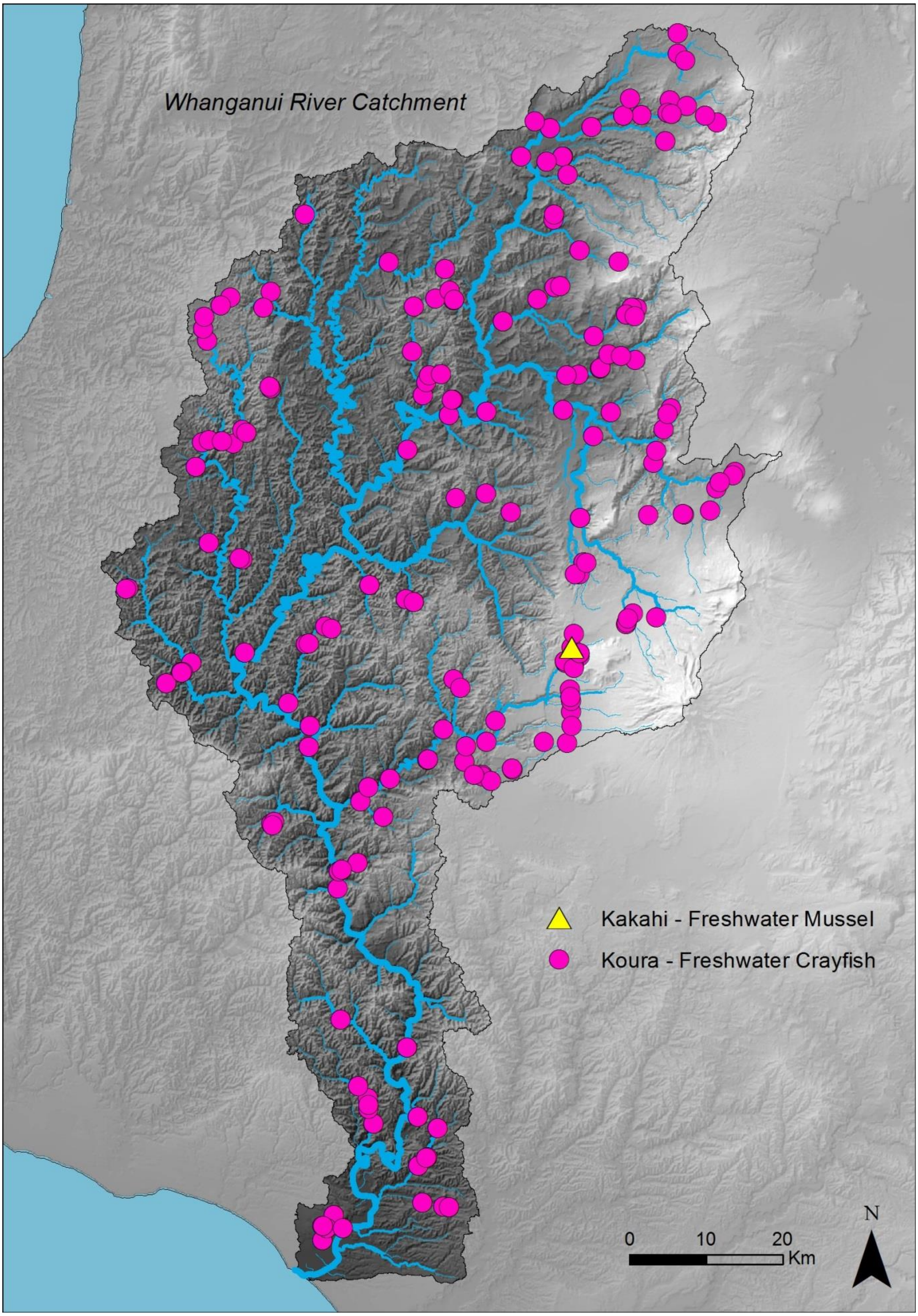

Figure 103: Distribution map of koura and kākahi in the Whanganui River catchment, 1948–2016, as recorded in the New Zealand Freshwater Fish Database.

Koura (freshwater crayfish)

Two species of koura are found in New Zealand: *Paranephrops planifrons* is found in the North Island and upper South Island, and *Paranephrops zealandicus* is found in eastern regions of the South Island and Stewart Island. *P. planifrons* is found in the waterways of the Whanganui River catchment. Koura are found in native forest, exotic forest, and pastoral waterways; however, their sensitivity to chemical pollutants means they are often absent from urban waterways. Koura habitat includes instream features such as boulders, overhanging bands, and logs, which provide cover from predators. Koura prefer low calcium waters, with optimum water temperatures less than 23^{o}C. Introduced species such as trout and perch – both present in the Whanganui River catchment – pose threats to koura, which have not had time to adapt.

Koura are widespread throughout the Whanganui River catchment. They are found in the pastoral waterways of the west, and the forested catchments of the east (Fig. 103). They are present at high altitudes, having been recorded at a maximum elevation of 927 m in the Whakapapa Stream. Their lowest recorded elevation is 10 m above sea level. Koura are also found immediately upstream and downstream of the Western Diversion of the Tongariro Power Scheme. Recorded sightings of koura in 2014 occurred in the Whanganui and Mangatepopo Rivers downstream of the Western Diversion, but not downstream of the Whakapapa River. Upstream monitoring efforts found koura in 2002 and 2007 in the Whanganui and Mangatepopo Rivers, as well as upstream in the Whakapapa River in 2012 (Fig. 104).

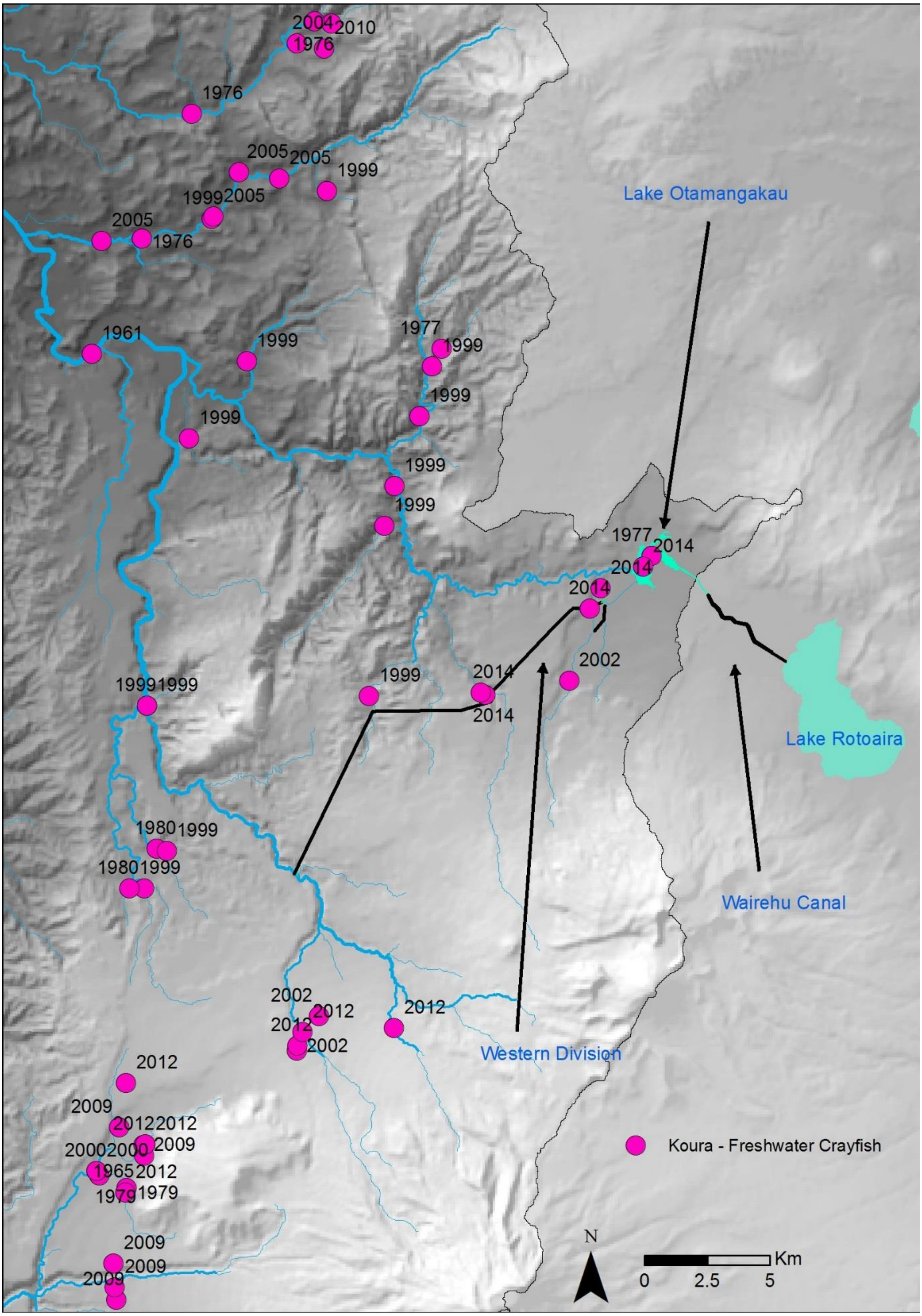

Figure 104: Distribution map and year of koura sightings upstream and downstream of the Western Diversion of the Tongariro Power Scheme.

5.5.4 Introduced and invasive species, water quality/quantity, and threats to aquatic ecosystems

The following excerpts[6] relate to Whanganui National Park but are probably relevant to the wider Whanganui catchment.

Results of DOC pest fish surveillance and other research suggest that threats to indigenous freshwater plants and animals from introduced species (including trout and aquatic plant pests) are not on a scale that warrants immediate action. However, there have been unconfirmed sightings of koi carp (*Cyprinus carpio*) in the catchment, and catfish are also thought to be present in the lower reaches of the Whanganui River. A more active monitoring and eradication programme may be necessary if the presence of these species further upstream where the river flows through the National Park is confirmed.

The introduction and spread of trout in the Whanganui River over the past century may have influenced native fish populations, particularly galaxiids. Removal of introduced trout from some of the streams in the Park is proposed as a possible ecological restoration measure. This would not have a significant impact on the regional trout fishery, but would enable some of the natural values of the Park's aquatic ecosystem to be restored and reduce competition over food sources for native fish species and whio (blue duck).

Biosecurity risks also arise from the passage of watercraft along the river. Potential for the spread of invasive plant pests such as hornwort (*Certophyllum demersum*) via boat hulls is a concern and requires continuing vigilance. The Whanganui catchment is at risk from invasion by *didymo*, particularly through its rocky and fast-flowing tributaries. DOC has a surveillance programme in place and is also a participant in multi-agency working groups that have been established to manage the risks associated with the spread of *didymo*.

5.6 Recommendations

Recommendations relate to improving both the monitoring of water quality aspects of the entire catchment and the links between available data on land use, including land management practices, and water quality and habitat outcomes:

- A regular and consistent fish monitoring programme for the entire Whanganui river catchment would be a significant benefit by providing information for the long-term health of river system. This would focus specifically on taonga such as tuna and piharau and include studies on climate events and land use changes for long-term understanding.

[6] http://www.doc.govt.nz/about-us/our-policies-and-plans/national-park-management/whanganui-national-park-management-plan/4-preservation-of-indigenous-species-habitats-ecosystems-and-natural-features/4_7-freshwater-ecosystems/

- A dedicated quantitative study on the historical suspended sediment regimes for the Whanganui Catchment would greatly benefit understanding of the natural sediment conditions of the catchment and long-term trends of land use change.
- Climate variability (storms and droughts) obscure the longer-term trends in river and habitat quality as affected by land use practices. Monitoring attributes such as Macroinvertebrate Community Index (MCI) provide a more integrated picture of aquatic habitat change than other water quality attributes summarised in this report.

6 The human and built environment

Today's Whanganui catchment is typical of rural New Zealand. Its two service centres, Taumarunui and Whanganui, were established in the days of land clearance and settlement, and developed in an economic environment that, more often than not, favoured the rural economy. These centres remain, but no longer enjoy a robust economy, and in the last two decades have declined. Both are now trying to re-focus on opportunities other than traditional pastoral agriculture.

The land in the catchment includes some of the most challenging for agricultural production and much of the hill-country that was rashly cleared for pasture is now in an advanced state of reversion. New, more sympathetic, and sustainable uses are developing, including bush honey production and ecotourism. So, while some small rural settlements, such as Matiere, Ohura and Ruatiti are "closing down" (RDC 2015), others, such as Taumarunui, National Park, Whakahoro, Pipiriki (and nearby Raetahi), are noticing a modest boost from river tourism, bush walking, and the Mountain to Sea Cycleway. Whanganui National Park and the large Stewardship areas and Forest Parks make the Department of Conservation the catchment's largest land manager.

The districts struggle, not only with a slowly declining population, but with a population that is changing in its nature. Ruapehu District Council (2015) contends not only with a declining permanent population but an increasing holiday home population, as well as a "missing cohort" of those between 20 and 40 years who have moved to the cities for education and employment.

6.1 Population and Infrastructure

6.1.1 Population

Published statistics are usually aggregated and reported for administrative areas like Regional Councils and District Councils. Even a superficial analysis of the Whanganui catchment proved elusive, so a statistical set was assembled from scratch for this study.

Our analysis of population was undertaken using national census data for 2001, 2006, and 2013. Statistics New Zealand data tables and census boundaries were downloaded and merged at the level of meshblock – the smallest geographic unit for which statistical data are reported by Statistics New Zealand (Statistics New Zealand 2016). Meshblocks are a flexible unit generally aligning with cadastre, road or railway centrelines and geographic features that ideally contain 30–60 dwellings. Rural meshblocks are therefore considerably larger than those in urban areas.

We imported Statistics NZ statistical areas and census tables into ArcGIS and used a relational join to merge them with meshblocks selected to best approximate the Whanganui catchment.

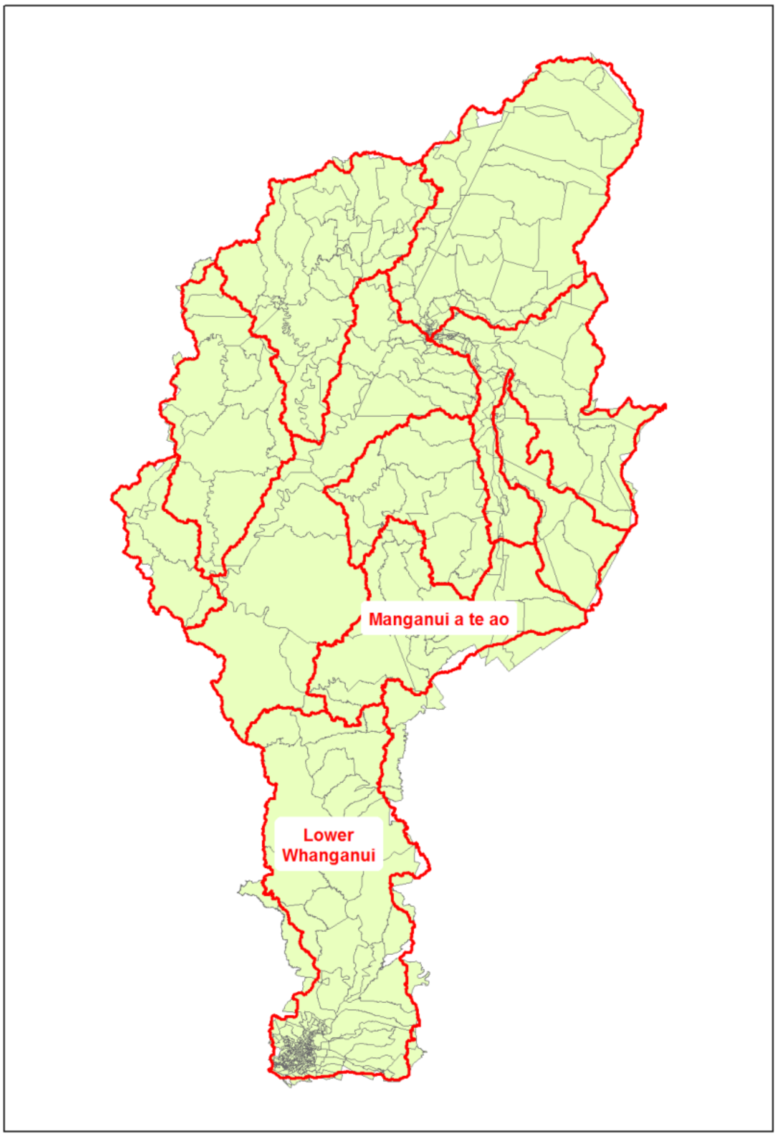

Figure 105: Statistics New Zealand meshblock boundaries (grey), aggregating to the geographic area analysed in this study (green). This area aligns quite closely to the Whanganui catchment (red) except in the Manganui a te ao and Lower Whanganui sub-catchments, where deviations of 3–4 kilometres occur.

For the purposes of this analysis, meshblocks whose centroid fell within the Whanganui catchment were used to build the statistical set (Fig. 105). This geographic selection was considered adequate and more defensible than tightly clipping meshblocks with the catchment boundary and undertaking a, possibly tenuous, resampling of statistics within dissected meshblocks. In reality, this statistical set aligns geographically to within a few hundred metres of the catchment boundary over most of its periphery. Deviations of as much as three or four kilometres occur, however, in a few sections of generally low population in the Manganui a te ao and Lower Whanganui sub-catchments.

At 2013, the resident population in the 7,118 km^2 catchment was about 44,700. This is concentrated in the two major urban centres of Whanganui (35,000 in the city and its immediate environs) and Taumarunui (4,300 in the town and its immediate environs). The remaining 5,400 people are dispersed among the few small settlements, including Ohura, Owhango, and National Park, the numerous, even smaller, hamlets, and over the extensive rural hinterland of the catchment.

Some 44 meshblocks, occupying 13% of the catchment area, report zero resident population – these are mainly in the national parks and forest parks in the middle and upper catchment. Unsurprisingly then, over most of the populous area of the catchment, densities are low – and in 74% of the catchment population densities are one-or-fewer people per square kilometre (Fig. 106).

At these low densities, mapping the density of people claiming Māori descent appears, at first, proportionate with the wider population (Fig. 106). But reality is quite different. Among the resident population, a quarter of all people (11,200) claim Māori descent, significantly higher than the NZ average of 15%. Examining the varying proportions of Māori to non-Māori across geographic space is revealing. The distribution of Māori to non-Māori shows a distinct skewing of Māori in rural areas and a notable concentration along the main stem of the River in its lower reaches (Fig. 106).

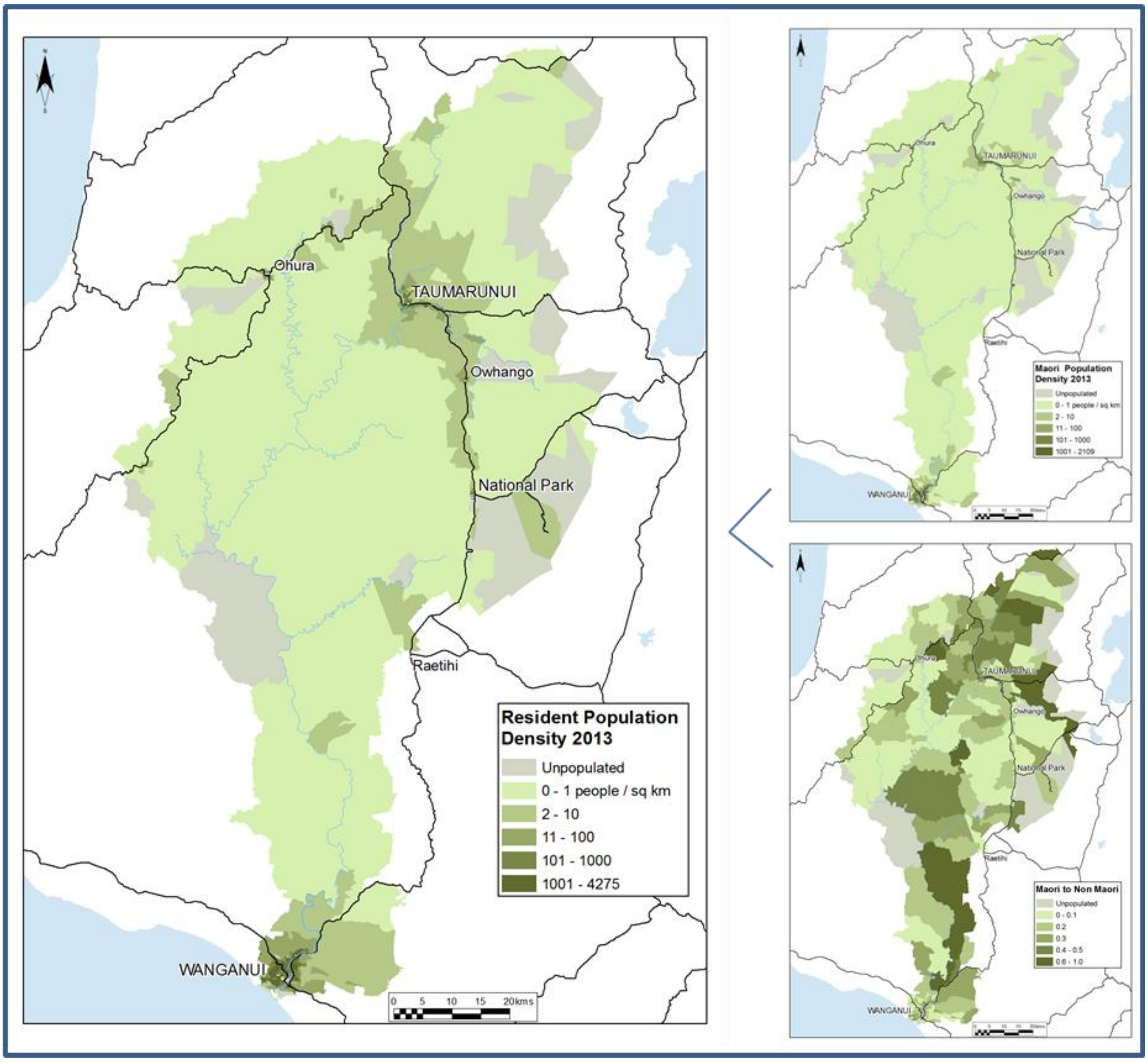

Figure 106: 2013 Resident Population Density, Māori Population Density, and proportion of Māori to non-Māori at 2013.

The population in the catchment as a whole peaked in the mid-1990s and since then has been in gradual decline (Table 25). The general population fell almost 5% in the period 2001–2013, while those claiming Māori descent fell by just under 2%. This decline occurred in both urban centres (Whanganui and Taumarunui), and generally over both districts within which most of the catchment lies (Ruapehu and Whanganui), though it was more marked in Ruapehu District.

Table 25: Resident population at 2001, 2006, and 2013 for the general population (Māori and Non-Māori) and those claiming Māori descent

Census	2001	2006	2013
General population	46,956	46,326	44,697
Māori descent	11,430	11,304	11,232

Interpreting the geographic distribution of population change, from census-to-census, and over a longer interval is fraught. Temporal fluctuations occur at the meshblock level between each census and these are not always indicative of a general trend. Instead, it points to the difficulty of interpreting trend based on census-to-census change in small sample sizes. Significant increases and decreases in population density have occurred in urban localities suggesting a relatively mobile population obscures the general downward trend in both urban centres. Gradual increases and decreases in many rural areas suggest greater stability (as well as their sensitivity to small population movements) but the gradual decline is a little more evident when viewed overall (Fig. 107). The few areas of consistent (albeit modest) growth can, in some cases, be explained by the growth in tourism (e.g. parts of the volcanic plateau) but elsewhere, other factors may contribute.

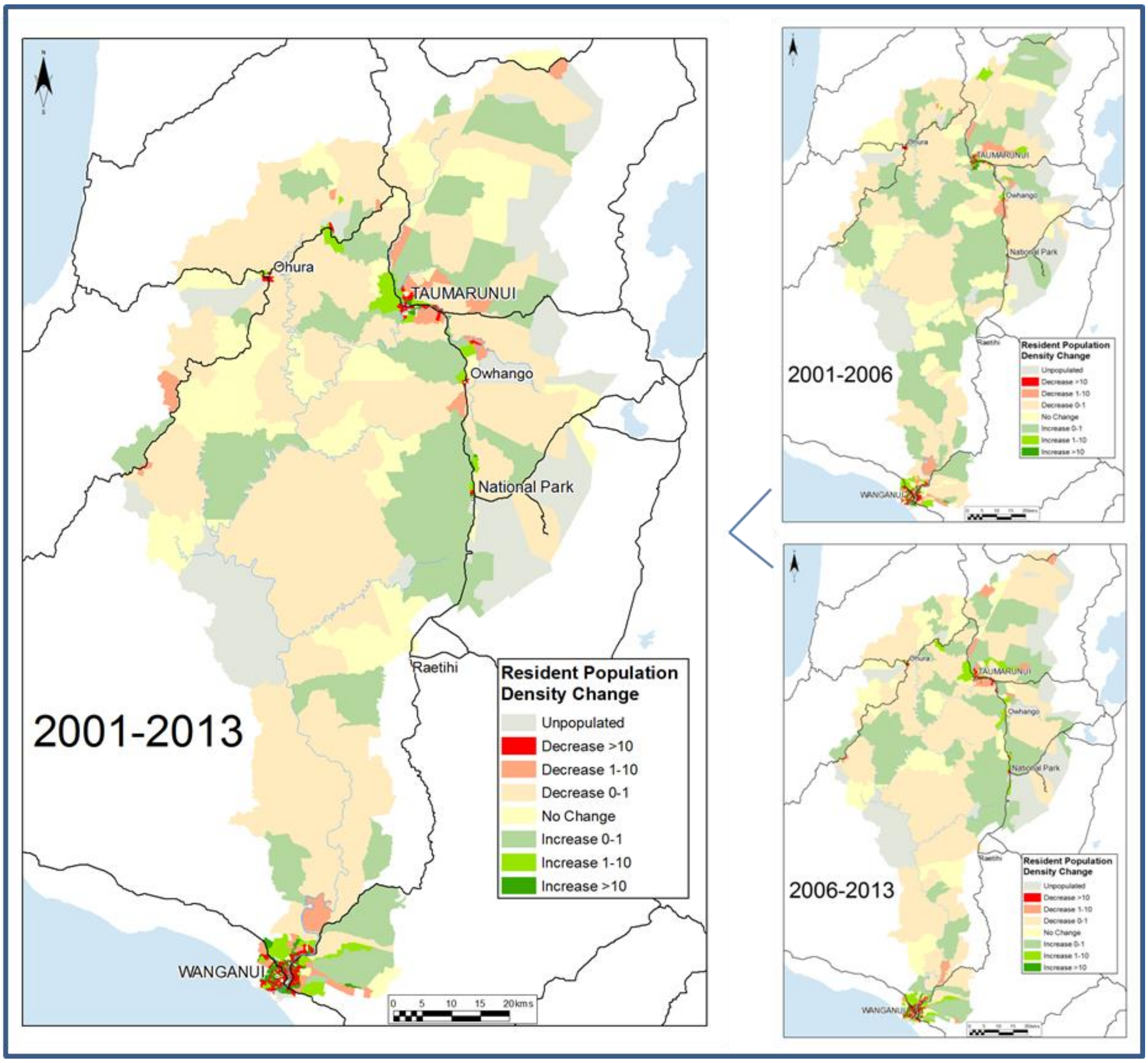

Figure 107: Change in resident population density over the full (2001-2013) census span, and between each individual census (2001–2006 and 2006-2013).

6.1.2 Transport

Roading is probably the catchment's most important and, in many respects, most tenuous, infrastructural asset. There are 2,570 km of roads transecting the catchment, including 306 km of State Highway (Table 26). While these provide a respectable network in the upper half of the catchment and in the very lower catchment, they provide poor access in the remainder (Fig. 108). Most of the traffic flow is carried by the state highways, for example, in 2015 average annual daily traffic counts were 9555 on Highway 3 at Cobham Bridge, 2025 on Highway 4 at Owhango, 1186 on Highway 47, and 642 on Highway 41 (NZTA 2015). The "Forgotten Highway" (Highway 43), linking Stratford with Taumarunui recorded 168 at Whangamomona and 352 at Te Maire. These roads are maintained with Central Government funding by the New Zealand Transport Agency (NZTA). The remainder are managed by local territorial authorities – in this case, in descending order of responsibility, by Ruapehu, Whanganui, Stratford, and Waitomo District Councils. Funding for these local roads comes from rates, with assistance from the NZTA. Ruapehu District Council sees little appetite among ratepayers for funding new infrastructure (RDC 2015) and both Ruapehu and Whanganui District Councils have adopted a strategy of maintaining legacy assets to an acceptable level and directing almost all capital expenditure on programmed renewal of existing assets. The integrity of the road network is vulnerable to extreme events such as that of June 2015 during which slips cut the Whanganui River Road below Pipiriki for several months, and river erosion remains an immediate threat to the road below Hiruhārama. Whanganui District Council assesses the average condition of its road assets as just 'fair' (WDC 2015). New rules introduced in 2010 to allow trucks up to 53 tonnes on public roads (formerly 44 tonnes) will undoubtedly exacerbate the road maintenance burden of these local authorities.

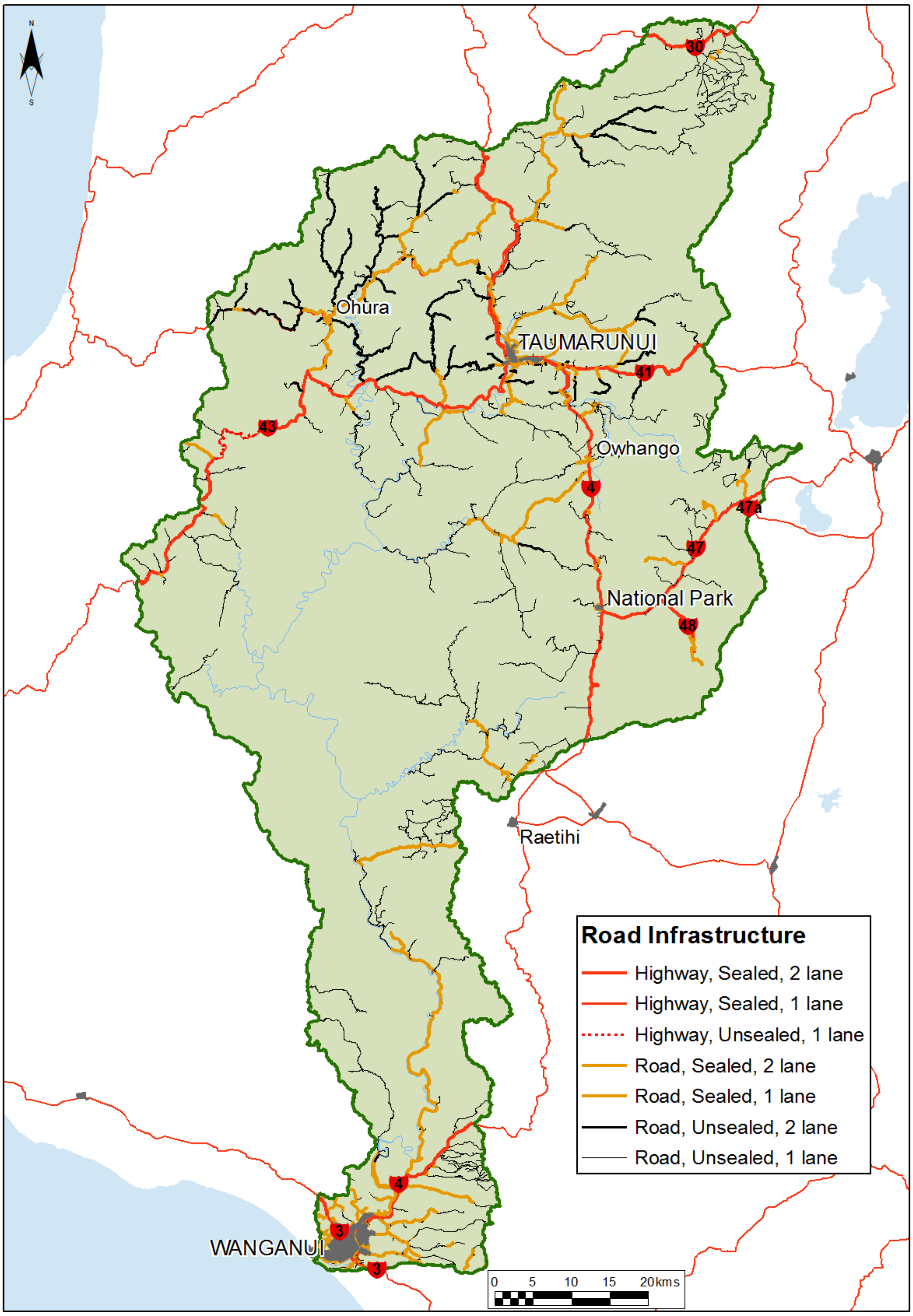

Figure 108: Whanganui Catchment Road Infrastructure.

Table 26: Whanganui Catchment Road Infrastructure

Type	Surface	Lanes	Length (km)		
			Rural	**Urban**	**Total**
Highway	Sealed	2	200	94	294
		1	1	0	1
	Unsealed	1	12	0	12
Road	Sealed	2	359	233	592
		1	133	11	144
	Unsealed	2	263	0	263
		1	1262	2	1264

6.1.3 Water supply

The urban centres of Taumarunui and Whanganui have well-developed filtered and treated water reticulation.

Water for Taumarunui is drawn from the Whanganui River at Mātāpuna, after which it is screened, filtered and treated.

Whanganui takes its water from six artesian bores – three at Kai-iwi, one at Aramoho and two at Westmere.

There are also rural schemes serving small communities including Ohura, Owhango, National Park, and Kawhaiki, the latter, a spring-fed system is currently undergoing an upgrade with improved collection, a new filtration system, expanded storage and new reticulation (Table 27). Outside the urban centres, and the few rural schemes, water supply is from individual or shared bores and rainwater collection.

Table 27: Water treatment levels for residential areas

Scheme	Filtered	Disinfection
Taumarunui	Yes	Chlorination
Ohura	Yes	Chlorination
Owhango	No	Chlorination
National Park	Yes	Chlorination
Kawhaiki	Yes	?
Whanganui	Yes	Chlorination

6.1.4 Wastewater

Community wastewater treatment in the catchment is restricted to the two urban centres and two rural schemes (Table 28).

Wastewater from Taumarunui is treated at the Hikumutu wastewater treatment plant. Treatment initially consists of inlet screening followed by primary and secondary oxidation via ponds in series. Tertiary wetland treatment and UV disinfection follows, before discharge through slotted pipes into the Whanganui River.

Table 28: Community wastewater treatment systems

Scheme	Type	Outfall
Taumarunui	Pond/aeration/UV/wetland	Whanganui River
National Park	Pond/aeration/wetland	Makaretu Stream
Pipiriki	Septic tank/sand filter	Land disposal
Whanganui	Screened /direct discharge	Ocean

Whanganui's wastewater is currently being screened to remove solids and then discharged directly through a 1.8-km-long ocean outfall under emergency provisions (Opus 2015). This situation arose from the failure (and shut-down in 2012) of a new 'optimised lagoon' wastewater treatment plant commissioned in mid-2007. In August 2016, the Whanganui District Council confirmed its approval for construction of a replacement plant (on the same site as the failed plant) based on a design that embodies aeration ponds in series, with UV sterilisation, foul air treatment, and sludge removal and drying. Disposal of dry sludge will be on land, and treated liquid discharged through the ocean outfall. The new plant is due to be in operation by the end of 2018.

National Park has a wastewater network that services 526 properties within the community and was commissioned in 1985. It is an entirely gravity-fed system feeding primary and secondary oxidation lagoons (in series), draining into a tertiary treatment wetland before the discharge of treated liquid into an unnamed tributary of the Makaretu Stream. The Makaretu Stream drains into the Whakapapa River about 7 km South of Owhango.

Pipiriki's wastewater treatment was installed in the 1980s to service 29 properties in the community. The network collects and treats discharge from individual septic tanks and pumps the effluent through two sand filters in series. Until 2014, treated effluent was discharged to the Kaukore Stream, but is now discharged to land via a sub-surface irrigation field adjacent to the Whanganui River.

In all other areas, wastewater treatment is owned and managed privately, by individuals or community collectives. The overwhelming majority of these will be septic tank-based systems.

6.1.5 Stormwater

Over most of the catchment, runoff from rainfall is via natural drainage, where it is also the predominant agency of erosion and flooding (a discussion that occurs elsewhere in this report). This short discussion focusses only on rainfall drainage from hard surfaces in the Whanganui urban area. Whanganui District Council manages 160 km of stormwater pipeline and a much greater length of open drains (many of them natural water courses) draining the Whanganui urban area (WDC 2015). Except for areas adjacent to the coast, all these drainageways discharge into the Whanganui River as it flows through the city, carrying whatever contaminants are picked up along the way.

Council performance is measured against two standards issued by the Department of Internal Affairs:

- To ensure a safe and operational stormwater drainage network for design events, and
- To monitor flood warnings and respond promptly during emergency management and flooding events.

Council also recognises its responsibility to manage stormwater to avoid adverse impacts on public health and public safety, and to protect the environment, property, and the economy. Council recognises that the quality of receiving waters are in large part influenced by the quality of stormwater and by adjacent land management but we have not established whether Council has set itself any performance standards to mitigate this environmental impact.

Discharges to the river from the Whanganui urban area have improved considerably since the time when there was a joint wastewater/stormwater system draining directly into the river. While wastewater and stormwater systems are now separate, cross-contamination is still noted by several sources (e.g. http://www.whanganui.govt.nz/our-services/water-services/Pages/default.aspx) – most commonly stormwater discharging to the sewerage system, but also the reverse, especially in adverse events.

6.2 Governance and oversight

6.2.1 Local government

New Zealand's local government system comprises two complementary sets of local authorities – regional councils and territorial authorities. The Whanganui Catchment falls effectively within one Regional Council (Manawatu-Whanganui Regional Council, operating under the name "Horizons Regional Council") and parts of four territorial authorities (Ruapehu, Whanganui, Stratford, and Waitomo District Councils) (Fig. 109).

The role of local authorities is to lead and represent their communities. They must encourage community participation in decision-making, and consider the needs of both people currently living in communities and those who will live there in the future.

Their purpose, as defined in the Local Government Act 2002, is:

- to enable democratic local decision-making and action by, and on behalf of, communities
- to meet the current and future needs of communities for good-quality local infrastructure, local public services and performance of regulatory functions in a way that is most cost-effective for households and businesses. (Local Government Act 2002, section 10 (1)).

The Act gives councils wide scope to do anything within the context of this purpose.

The Act requires all councils to:

- separate policy setting from operational functions as far as possible
- prepare long-term plans (LTPs), annual plans and budgets in consultation with their communities
- report annually on performance in relation to their plans
- prepare long-term financial strategies including funding, financial management and investment policies.

The Local Government Act 2002 also makes it clear that councils have a variety of other statutory responsibilities. These are mostly in other Acts such as the Resource Management Act 1991, the Building Act 2004, and the Biosecurity Act 1993.

Regional councils' responsibilities include:

- Sustainable regional well-being.
- Managing the effects of using freshwater, land, air, and coastal waters, by developing regional policy statements and the issuing of consents.
- Managing rivers, mitigating soil erosion and flood control.
- Regional emergency management and civil defence preparedness.
- Regional land transport planning and contracting passenger services.
- Harbour navigation and safety, oil spills and other marine pollution.

As for all regional councils, these multiple responsibilities are implemented through a regional policy statement and regional plans as required under the Resource Management Act 1991 (the RMA), and under specific management plans required under other statutes. In the case of Horizons Regional Council, most of these individual documents are embodied in a single regional regulatory planning document, "The One Plan" (Horizons Regional Council 2016). The One Plan 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.

At a high level, The One Plan focusses on four keystone environmental issues:

- Surface water quality degradation – recognising that run-off of nutrients, sediment, and bacteria from farms is now the single largest threat to water quality in the region. While the issue is a general one, it is being addressed in order of priority, and, currently, none of the water bodies identified as a priority under The One Plan lie in the Whanganui Catchment.
- Increasing water demand – recognising that the amount of water used from ground and surface water resources increases each year and at certain times of the year public water supply and irrigation demand exceed what some water bodies in the region can supply.
- Unsustainable hill country land use – recognising that damage to soil structure and accelerated erosion results in muddy rivers, increased river siltation downstream, and reduced protection level of flood control schemes, all principally caused by unsustainable pasture-based farming practices in the region’s steeper hill country. The Whanganui catchment with its extensive areas of highly-erodible land is cited in The One Plan as being particularly affected by this issue.
- Threatened indigenous biodiversity – recognising that after more than a century of landscape modification, the Manawatu/Whanganui Region has lost much of its indigenous habitat and, habitat remnants continue to be threatened by land development and by pest plants and pest animals.

The One Plan operates by recognising Issues, and addressing them through Objectives and Policies, which are implemented through Methods and Rules. The regulatory parts of the One Plan specify when resource consents are, and are not, required for activities such as taking, damming, and diverting water, discharging contaminants into water (including from farming and urban land use), and disturbing river beds and banks through gravel extraction and river control.

Issues not explicit above but still recognised by The One Plan include: energy efficiency; residential growth onto versatile soils; waste; hazardous substances and contaminated land; modifying the beds of rivers and lakes; managing outstanding natural features and historic heritage; maintaining air quality; management of the coastal environment; and recognising, adapting to, and mitigating natural hazards.

Two non-regulatory methods that presently exist to address the land and water issues are the Wanganui Catchment Strategy (Horizons Regional Council 1997, 2003), developed in 1997 and reviewed in 2003 and, SLUI – the Sustainable Land Use Initiative (Horizons Regional Council 2015). The former focusses specifically on improving water quality and sustainable land management in the Whanganui Catchment and the steps Council has committed to undertake. The Ohura sub-catchment has been identified as a high priority for erosion control, and, in conjunction with the Whanganui River Enhancement Trust, a local demonstration farm owned by Evan and Roseanne Parkes runs bi-annual field days to showcase environmentally sustainable practices on a working hill country farm (NZARM 2015). SLUI is a programme of work based on methodical, science-based, collaborative planning and on-farm works to optimise use of productive land and recognise (and retire) unsustainable and unprofitable land. The compilation of ‘whole-farm’ plans in partnership with land owners is central to this initiative.

The Biosecurity Act 1993 requires Horizons Regional Council to maintain a second regulatory document, the Regional Plant Pest Management Strategy (RPPMS). The current strategy took effect in 2007 for a 5-year period until 2012, but has rolled over, in the guise of annual operating plans (e.g. Horizons Regional Council 2015) until completion of the new Regional Pest Management Plan, which is currently in progress.

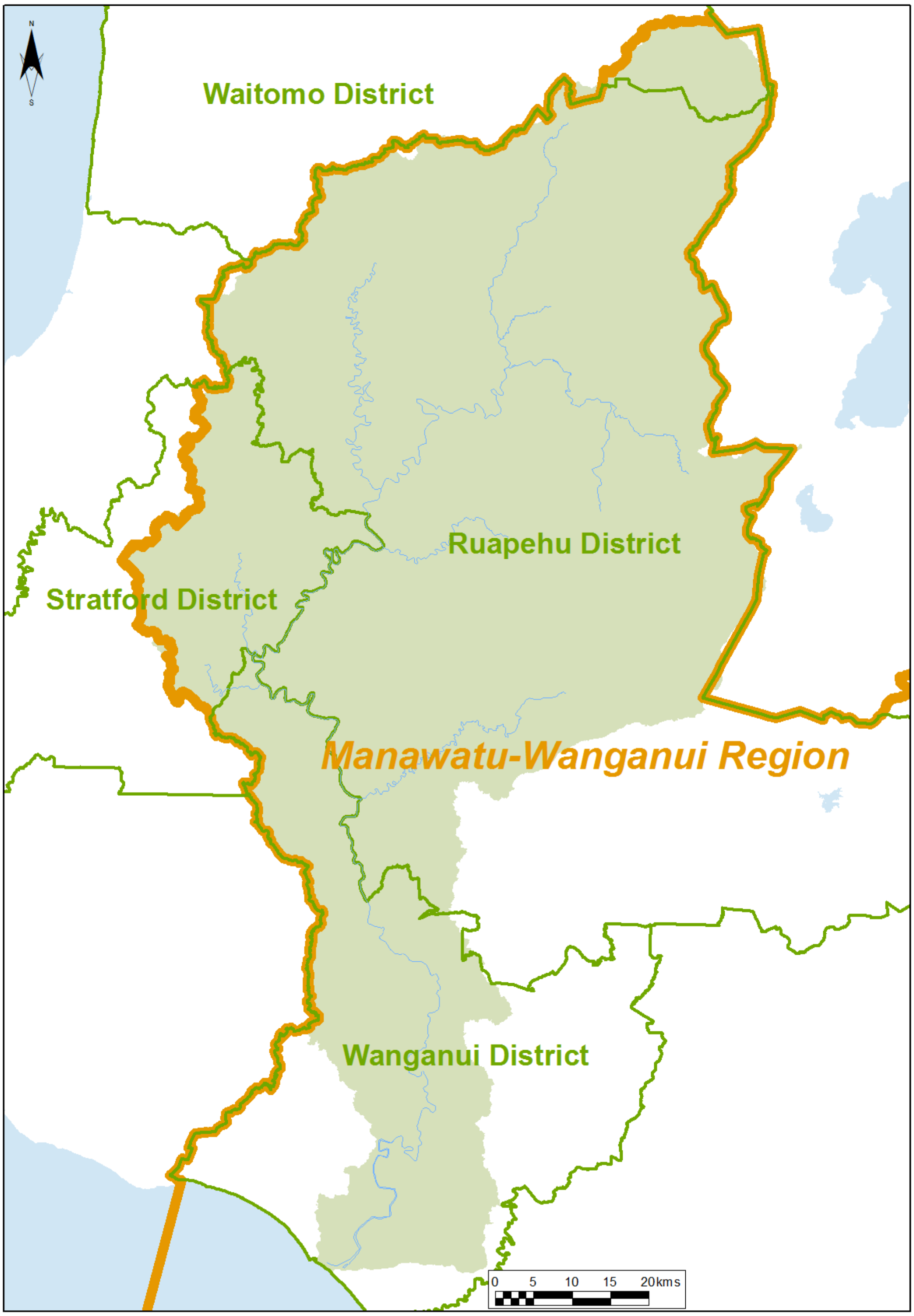

Figure 109: Manawatu-Whanganui (Horizons) Regional Council boundary (orange) and District Council boundaries (green) superimposed on the Whanganui Catchment (green shading).

Territorial authorities' responsibilities include:

- Sustainable district well-being.
- The provision of local infrastructure, including water, sewerage, stormwater, roads.
- Environmental safety and health, district emergency management and civil defence preparedness, building control, public health inspections and other environmental health matters.
- Controlling the effects of land use (including hazardous substances, natural hazards, and indigenous biodiversity), noise, and the effects of activities on the surface of lakes and rivers.

The powers and responsibilities of city and district councils are all the same - both are territorial authorities. The only difference is that city councils serve a population of more than 50,000 in a predominantly urban area.

Six territorial authorities in New Zealand also have the powers of a regional council. These unitary authorities are Auckland Council, Nelson City Council, Gisborne, Marlborough, Tasman District, and the Chatham Islands Council. In 2010, Ruapehu and Whanganui District Councils jointly reported on the case for repositioning themselves as unitary authorities to manage the Whanganui and adjoining catchments and local interests more efficiently and locally (RDC-WDC 2010). The report, recognising among other things, that in recent years Horizons Regional Council had spent almost $3 million more in Ruapehu and Wanganui than they had rated from those communities, recommended further investigation into the pros and cons of such an arrangement, and the mechanisms and legalities involved. This proposal does not appear to have been openly pursued in the 6 years following issue of the exploratory report.

6.2.2 Department of Conservation

The Department of Conservation (DOC) acting on behalf of The Crown has almost a quarter of a million hectares under management in the catchment, making it by far the largest land owner in the catchment (Fig. 110).

The Conservation Act 1987 sets out the majority of DOC's roles and responsibilities. In addition, DOC administers over two dozen Acts, among which are: Conservation Act 1987, Conservation Law Reform Act 1990, Marine Mammals Protection Act 1978, Marine Reserves Act 1971, National Parks Act 1980, Native Plants Protection Act 1934, Queen Elizabeth II National Trust Act 1977, Reserves Act 1977, Trade in Endangered Species Act 1989, Wild Animal Control Act 1977, Wildlife Act 1953. Land is vested in DOC principally under three articles of legislation: the National Parks Act 1980 (1,005 km^2 in the catchment), the Conservation Act 1987 (1,288 km^2 in the catchment), and the Reserves Act 1977 (160 km^2 in the catchment) (see land tenure discussion below).

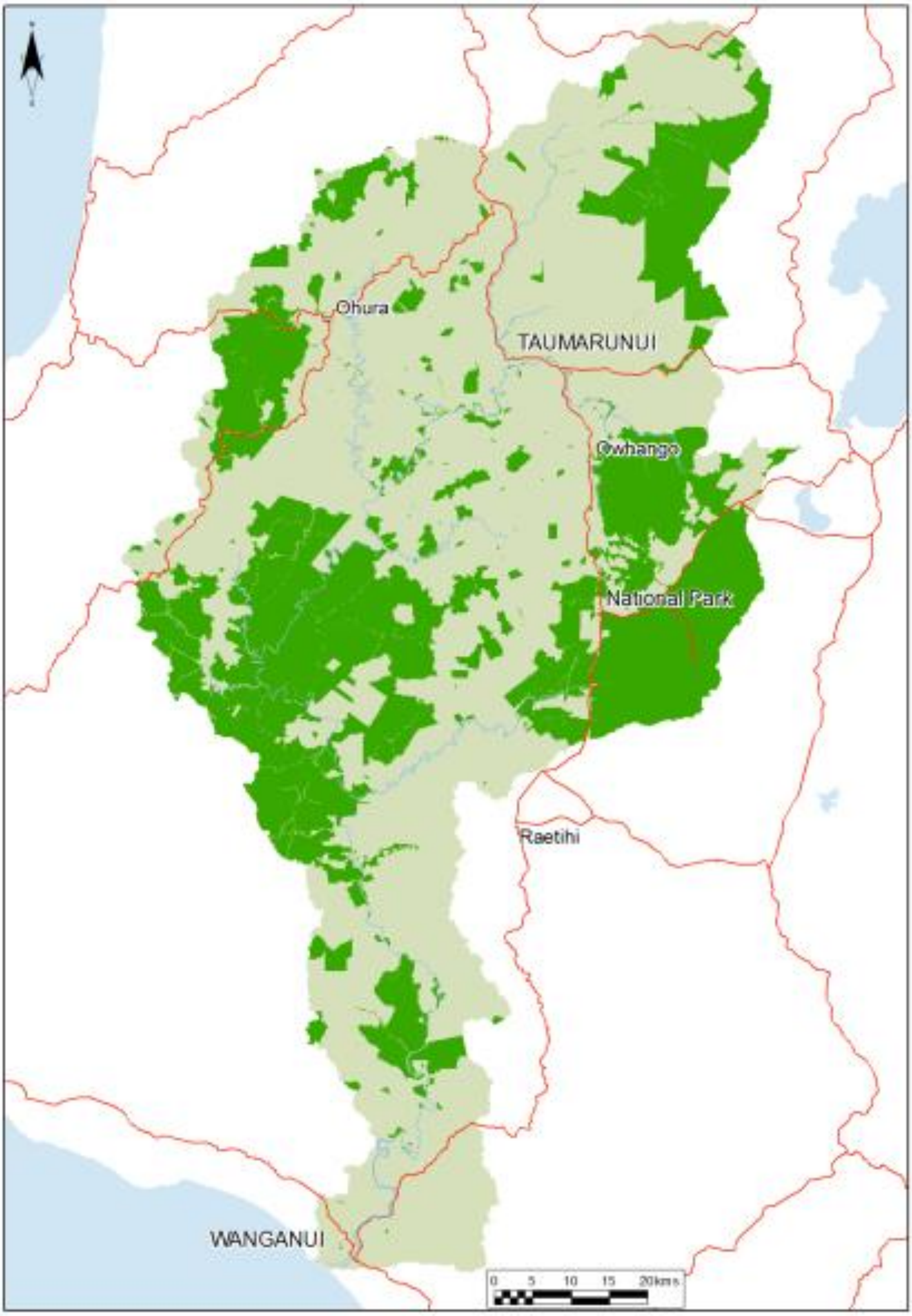

Figure 110: Land administered by the Department of Conservation (mid-green) superimposed upon the Whanganui Catchment (light green).

Under their current structure, the entire Whanganui Catchment falls into the Department's 'Central North Island' operations district but the policies and objectives for the Catchment are documented in three strategy documents (DOC 2014, DOC 2002, and DOC 1997) corresponding to the former Waikato, Tongariro/Taupō, and Wanganui Conservancies. These Conservation Management Strategies (CMS) are required under the Conservation Act 1987 and are 10-year regional strategies that identify the conservation objectives for the 10-year period and beyond, as well as the priorities, and how they will be achieved. The CMS for Waikato is still current, but those for Tongariro/Taupō and Wanganui are awaiting review. Although two of the strategies are 'expired' in their time focus, they remain in force as statutory documents of intent and activity until replaced. Additionally, there are Management Plans for the two National Parks in the Catchment – Tongariro National Park (DOC 2006) and Whanganui National Park (DOC 2012). These statutory documents are required under the National Parks Act 1980. They implement the respective Conservation Management Strategy(s) on the ground in accordance with the specific aims and character of each National Park and General Policy for National Parks.

6.2.3 Other agencies

The influence on land of other central government agencies is limited. These agencies (Landcorp New Zealand for state farms and Land Information New Zealand for land supporting infrastructure and special purpose reserves) are mentioned in the section below on Land Tenure.

6.3 Land tenure

Figure 111 and Table 29 present a general categorisation of land in the catchment and a breakdown of land tenure within these categories. The principal categories of land in New Zealand are usually considered to be "general land", Crown land, Māori freehold land, and Māori customary land. These categories are defined quite clearly in Section 129 of the Māori Land Act/Te Ture Whenua Māori 1993 (TTWM). "General land" is defined in TTWM as "land (other than Māori freehold land and general land owned by Māori) that has been alienated from the Crown for a subsisting estate in fee simple". This is a useful definition as it makes clear that all private titles in New Zealand originate from a Crown grant. Crown land, which nationally is about half New Zealand, is defined as "land … that has not been alienated from the Crown for a subsisting estate in fee simple". Underpinning both definitions is the concept that before European settlement all land in New Zealand was Māori under Māori customary law and such title had to be extinguished, by purchase or other means, before the Crown could acquire legal title itself, and subsequently enable private ownership. Māori customary land is now so uncommon that, for the purposes of this description, it is classified as part of Māori freehold land.

Table 29: Analysis of Land Tenure in the Whanganui Catchment

Land Category	Tenure type	Area (Km^2)	Percent
Māori	Māori Customary	<1	-
	Māori Freehold	892	12.5
	Māori Reserve	78	1.1
Crown	National Park	1,005	14.1
	Conservation Area	1,288	18.1
	Nature Reserve	160	2.3
	Crown Forest	18	0.3
	Crown Farm	103	1.5
	Māori Reserve	1	-
	Other Crown Land	246	3.5
General	Māori	37	0.5
	Private	3,290	46.2
TOTAL		**7,118**	**100**

Compared with most countries, New Zealand is unusual in having a high proportion of state-owned land (almost 50% nationally) and a high proportion of land owned by individuals (as opposed to corporates and collectives). And New Zealand is unique in recognising Māori freehold land as a tenure category (over 5% nationally).

Regionally, the respective weightings of Māori, Crown and General land vary, with Māori land grossly underrepresented in the South Island (where Crown land is heavily represented) and the reverse in some areas of the North Island like Gisborne-East Coast, Taupō-Rotorua, and Taranaki-Whanganui.

In the Whanganui catchment, Māori Freehold Land, at 13.6%, is more than twice the national average. Corporate farming by agencies such as Atihau-Whanganui Incorporation occupies a large proportion of this area. Māori land in the Ongarue sub-catchment operating under the, DOC-managed, Ngā Whenua Rāhui covenant scheme is identified separately (as Māori Reserve) in Figure 111 and Table 29. Māori Customary Land (occupying 52 Ha only) is almost unrepresented in the Catchment.

At a little under 40%, Crown land is a little under the national average, but still occupies a position of prominence in the catchment. Over a third of this lies in Tongariro and Whanganui National Parks, with almost a half occupied by Conservation and Stewardship areas reserved under the Conservation Act 1987. Virtually all the remaining conservation (i.e. DOC) land, comprising scenic reserves, marginal strips, and the like (amounting to a little over 2%), comes under the Reserves Act 1977. The State Owned Enterprise, Landcorp New Zealand, manages large farming blocks in the vicinities of Bennydale, Otangiwai, Maringa, and National Park, together covering more than 1% of the catchment. Remaining Crown land including numerous reserves (including some land reserved for Māori purposes), land dedicated to infrastructure, and some land-banked state exotic forests are mostly managed by Land Information New Zealand (altogether a little under 4% of the catchment).

Unsurprisingly, the catchment, as with most of New Zealand, is dominated by general land in private ownership (over 46%). We have identified a subcategory of this as General Land in private Māori ownership where this is evident in the land parcel data but this is not always obvious or implied.

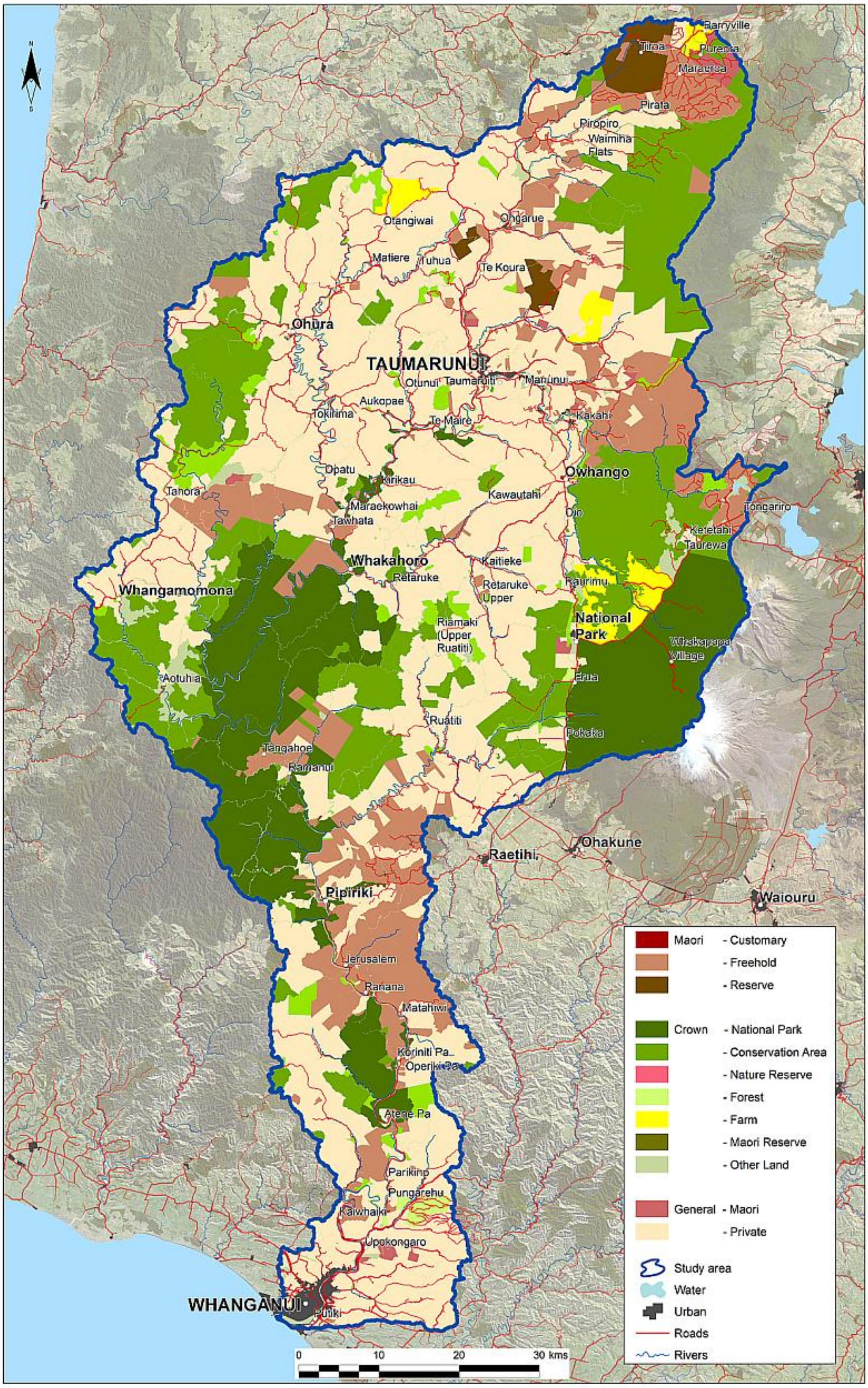

Figure 111: Distribution of Land Tenure in the Whanganui Catchment (classified from LINZ land parcels, DOC 'conservation units' database, LandCorp NZ (pers. comm.), and NZ Land Cover Database V4.1).

6.4 The Economy and Economic Development

The economies of Whanganui and Ruapehu Districts are still founded on pastoral agriculture, with tourism emerging as prominent in the central volcanic plateau and manufacturing/processing at the bottom of the catchment. None of these industries are thriving and instead, with some exceptions, are steadily contracting. The local constraints on business have remained largely unchanged – a geographically difficult area, relatively wanting in highly-productive land, dominated by hill country highly prone to erosion, quite poorly served by transport and communications infrastructure, and somewhat off the main routes of travel and commerce. All of which have required degrees of adaptation to make the best of the conditions presented and to stem the decline. But the bigger cause for decline lies in global trends, and impacts largely outside local control, and to the failure, thus far, to adapt quickly enough. Traditional job creators – agriculture and manufacturing – so significant to the Catchment, have become less labour intensive, and some activities have disappeared altogether.

Central Government's Manawatu-Whanganui Regional Growth Study (MPI 2015) was launched on 31 July 2015 by Economic Development Minister Steven Joyce, Primary Industries Minister Nathan Guy, and Māori Development Minister Te Ururoa Flavell. It recognises that these global trends have been gradual, have been happening for a very long time, are somewhat invisible on a day-by-day basis, but with impacts that, in aggregate, have been huge. "*The decline of manufacturing has been very severe and long term. Contemporary enterprises are not filling the gap in anything like sufficient numbers to offset the erosion of employment. The Region has been especially vulnerable because of its narrow range of enterprise. With its agricultural powerhouse not producing jobs and manufacturing in the same position, the Region has little to fall back on and growth has faltered as a result.*"

The report notes that the Manawatu-Whanganui Region, as a whole, is experiencing slow or static growth, ageing and declining populations, and declining employment due to declining jobs in traditional agriculture and manufacturing and a narrow range of other enterprises. It cites national employment growth as 11% over the decade to 2014, while employment in the wider Manawatu-Whanganui Region shrank by 1%. The same analysis focussing just on the Whanganui Catchment (falling predominantly in Whanganui and Ruapehu Districts) would make even more despondent reading.

By implication, a 'business-as-usual' future will see continued overall economic decline in the Manawatu-Whanganui Region, and particularly in the Whanganui Catchment. This is something that can only be reversed by recognising the region's advantages and deliberately developing them.

The report illustrates the region's business activity, areas of specialisation, and competitive advantage by business sector in Figure 112 below. Sectors showing comparative advantages greater than 1 are those in which the region exhibits a degree of specialisation, sectors above the 0% growth line are growing, while those below (comprising several of the regions traditional industries) are not. This figure illustrates how expanding the catchment's economy by growing traditional industries that are currently static or in decline (like primary production and manufacturing) will be difficult, unless niche markets are selected. It also identifies the opportunity to concentrate on sectors, like health, which are both growing and in which the region has a comparative advantage.

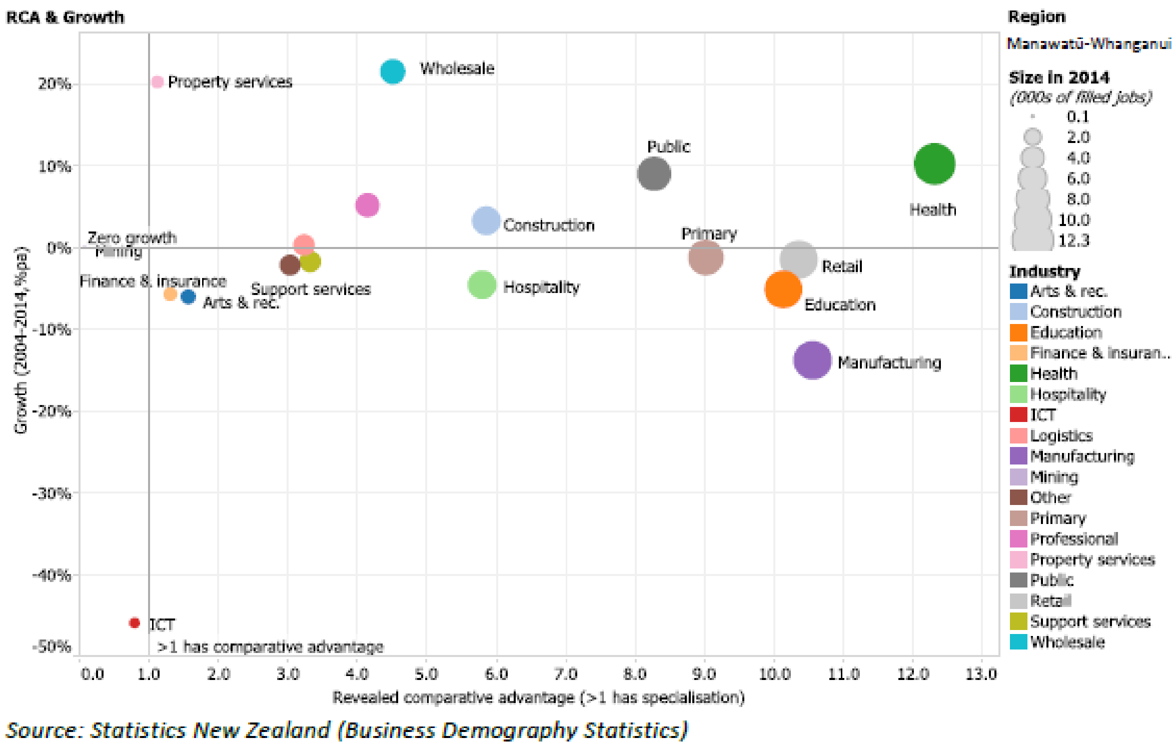

Figure 112: Manawatu-Whanganui Region, Competitive Advantage by Sector (Reproduced from MPI 2015).

The report identified eight opportunities for growing investment, incomes, and employment in the region. Its recommendations were used, in large measure, to inform **'Accelerate 25', the Manawatu-Whanganui Economic Action Plan** (Horizons Regional Council 2016) produced by a team of regional leaders appointed by the regional mayors. The Action Plan reviewed the recommendations of the Growth Strategy report and arrived at nine opportunities (and four enablers) for future implementation, as follows:

6.4.1 Tourism and Visitor Services

The opportunity here is to unlock the tourism potential (particularly of canoeing, biking, skiing and trekking) within and around the Tongariro and Whanganui national Parks. An increase in Manawatū-Whanganui GDP (above 2015 'business-as-usual' level) by 2025 of around $66 million and a corresponding rise in household spending of $32 million are hoped for from this initiative.

In the immediate term, the Accelerate 25 Action Plan targets work in destination marketing, development of the Tongariro Alpine Crossing, improving local water/wastewater and other infrastructure, developing the Mountains to Sea Cycle/Walking Trail (specifically the Tūroa-Ohakune and Horopito-National Park sections, and upgrading the Whanganui River Road).

This will likely stimulate supporting infrastructure and services in communities along the river, such as accommodation, eco-tours, and jet boat services. The use of jet boats on rivers has occasionally attracted comment. Remarks pertaining to noise, general disturbance, and endangerment of other river users are common on populous waterways. Vigourous debate, both for and against, resulted from proposals to exclude jet boats from a section of the Rangitikei River in 2012. Sutherland and Ogle (1975) found the passage of jet boats through spawning areas of the (shallow, braided) Ashley River, can kill salmon eggs buried in the river bed. Turbidity measurements at river banks, by Hill et al. (2002), found that boat wakes are capable of dislodging sediments from the banks, and that wakes are found to increase in amplitude with increasing boat size. They note, however, that because of the necessity to keep 'on-plane', jet boats tend to travel in a fairly narrow band of speed that is beneficial in minimizing wave heights at the banks, as is navigating in mid-channel of the river, wherever possible.

In the medium term, the Action Plan targets improving the range and adequacy of accommodation, establishing 'Gateways to National Parks', and extending the use and enjoyment of the Conservation Estate by increasing the range of (and upgrading) tracks, huts and other services.

The Action Plan sees a future in which the Tongariro World Heritage Park is paired with that of Hawai'i as a tourism destination, the Waiouru Army Museum includes a 'NZ Warrior' experience featuring pre-European conflict, and Whakapapa Village has an expanded role in delivering cultural, heritage, transport, and gateway functions to a year-round tourist market.

6.4.2 Land Use Optimisation

The opportunity here is to optimise, rather than expand, farming in the catchment, taking advantage of the sheer scale of productive hill country and the significant proportion of good quality soils. An increase in red meat export earnings (over the whole Manawatū-Whanganui Region) of around $76.8M by 2025 is considered possible by making small changes that multiply to major gains, developing areas of good soils, and becoming the 'first-mover' in innovations arising from research.

Māori, with their significant land holdings, current focus on fish, farm, and forestry, global 'indigenous-based' relationships, and integrated perspective on resource use, are seen as having advantages under this opportunity. And water, as both a resource to be utilised and a resource to be protected, is identified as a constraint under this initiative.

In the immediate term, the Accelerate 25 Action Plan targets information sharing to support land use decision making, commissioning an economic evaluation of stock water reticulation, documenting the Region's available water supply resources and, preparing project briefs focussed on high margin/low volume specialist and innovative crops and products (e.g. goat and sheep milk processing).

In the medium term, the Action Plan targets a programme to provide farmers with information on successful succession planning, research on the feasibility of community irrigation schemes and ‘shifting the bell curve’ of dairy farming to generate growth by farming-to-limits within a grass-based, low-input farming system.

The Action Plan sees a future characterised by provenance-aligned, ‘regionally-sourced’ value-added food production and branding.

Figure 113: Mixed land use, lower Whanganui River catchment below Parikino (2009).

Land use optimisation implies not only intensification but also retirement and conversion to other more sustainable uses than pastoral agriculture. After more than a century of land clearance, significant areas of highly erodible hill country (especially in the Ohura and Middle Whanganui, Retaruke subcatchments, and Whangamona and Ruatiti localities) are under agricultural management and exposed to the agencies of erosion (Fig. 40). Hillslope erosion not only affects livestock production and built infrastructure but it is the major source of sediment in the river. The Whanganui Catchment Study (Horizons Regional Council 1997) estimated that about 14,000 ha should be allowed to revert to forest (via Mānuka, see below) another 71,000 ha should be converted to production forestry, and a further 96,000 ha requires soil-conservation planting. Such changes do not come without a cost, over and above the initial cost of conversion. Woody vegetation, be it indigenous or exotic, creates habitat and dispersal corridors not only for desirable flora and fauna, but also for weeds and pests that threaten our environment. These threats must be managed both during and following any land use transition. So too must the move to erosion-control production forestry be carefully planned and managed. The siting, establishment, and maintenance of roads, tracks and landings are critical in this landscape, and management of the entire system during and after harvest is critical to avoid adverse impacts on the land and its waterways.

6.4.3 Mānuka Honey

Mānuka honey was identified by the regional leaders group as one of those opportunities that seldom occurs and breaks traditional moulds. Almost overnight, an under-used resource – Classes 6 and 7 hill country land – becomes a valuable and productive resource. Horizons Regional Council estimates there are 100,000 hectares of land in the Region suited for conversion to mānuka. A scenario where just 20,000 hectares are planted in mānuka would generate a value to the region of almost $28M above business-as-usual levels by 2025. Māori are identified as key players in this industry, as both land owners and workforce, with the challenges being those associated with growth rather than lack of growth.

In the immediate term, the Accelerate 25 Action Plan targets developing a draft regulatory standard defining what constitutes mānuka honey, collating existing information about the present extent of mānuka and the extent of land suitable for mānuka planting, processing applications for mānuka planting to assist with erosion management or climate control, and supporting other government and industry initiatives that encourage mānuka planting. The Action Plan examines the extent to which the Horizons One Plan provides for mānuka planting and whether it’s necessary to make enabling changes to that plan.

In the medium term, the Action Plan targets developing and implementing a case for a commodity levy to support mānuka research and advocacy and, contributing to discussions amongst land owners about opportunities for collaborative catchment approaches to honey production.

The Action Plan sees a future that might include a centralised processing, retailing and a honey tourism centre – possibly in Taihape or Whanganui.

6.4.4 Poultry Meat Production

This is seen primarily as an opportunity for Districts outside the Catchment (Horowhenua, Rangitikei and Manawatu), but some trickle-over effect could be felt (or sought) within the Catchment. The opportunity is to leverage domestic growth (currently over 50% of domestic meat consumption is poultry, and rising) and existing efficient industry capability and develop an emerging export market for high quality poultry meat production. This would take advantage of all the associations of New Zealand as a clean and disease-free environment.

In the immediate term, the Action Plan will focus on undertaking a market opportunity assessment to share information and support land use change, market focus and forming partnerships.

In the medium term, the plan will complete a poultry meat export feasibility study with a particular focus on exploring capital raising options, scale and processing location options, market entry and trade matters, and the structure of a likely business entity.

6.4.5 Quality care and lifestyle for older people

This is an opportunity in which Horowhenua District is showing leadership, but one which, if successful in Levin, could roll out across other parts of the Manawatu-Whanganui Region, notably Whanganui.

The opportunity involves a basic rethinking of how services are delivered to older people in a community setting. It addresses the quality and cost of ageing and how to make it more accessible for New Zealand, for the local community, and for the individuals involved. It involves integrating older people into communities so they can continue as net contributors to the immediate and wider community, in whatever forms that might take, well beyond retirement age.

This project will move through many phases. At present, it is at an 'ideas creation and conception' phase. It will then move to a feasibility phase where the viability of ideas can be tested for their operability. From there it will move to a 'planning and delivery' phase.

In the immediate term, the Action Plan will focus on developing a 10-year Master Plan model exploring the suitability of Levin as a location to invest and test new technologies, spatial planning, skills, facilities, and shared funding models.

In the medium term, the Action Plan will assist the development of an 'Innovation Hub' – a centrally located 'workshop' for prototyping and developing operational models. The Hub will develop and deliver projects to apply the prototypes to transform Levin and other suitable towns and cities into affordable and enjoyable places for meeting the quality care and lifestyle needs of older people.

6.4.6 Business Process Outsourcing – contact centres

This opportunity is not based on the utilisation of natural resources but, instead, is founded on the extended use of human resources, specifically targeting under-utilised labour in provincial towns and cities. It is also largely urban based, although it could provide employment for rural people who are prepared to travel. The competitive advantages of the region for this type of activity are the lower costs and the more stable (and available) workforce when compared to other regions.

In the immediate term, the Action Plan will; support and generally contribute to the success of the marketing efforts of the 'Lower North Island Contact Centre Cluster'– with a particular focus on the Australian and UK markets. It will allocate 86 training places to beneficiaries for potential inclusion in call centre and administration training programmes and align these programmes to meet sector demand.

In the medium term, the plan will assist project execution and reach by developing a pilot facility for use by potential customers and further development of the Lower North Island Contact Centre value proposition.

6.4.7 Business Process Outsourcing – Food HQ

This opportunity is centred outside the Catchment, in Palmerston North, where seven research organisations, two local territorial authorities, and a business incubator have formed an agri-food science and innovation partnership, Food HQ. This collaboration has an ambitious vision to double its scientists, researchers, and students to 4,000 – while attracting significant revenue in international food R&D.

The Accelerate 25 Plan intends to support Food HQ by co-funding R&D activity for an exemplar client, co-funding market penetration activities, helping develop the 'compelling value proposition' and, helping develop a refreshed Food HQ strategic plan.

6.4.8 Fresh Vegetables (Horowhenua, Rangitikei and Ruapehu)

The opportunity here is not to wastefully compete for greater share of an already saturated domestic market, but to seek opportunities for vegetable growers in the large and growing export market. Within, or adjacent to, the Catchment, Ruapehu is one of three Districts identified as having a long history of successful cultivation of vegetables and significant areas of high-quality soils to support an expanded horticultural industry. This is seen as an opportunity for iwi with incorporations in the area already at a scale and with labour on call to respond as functioning partners in a grower's collective.

The immediate priority under the Action Plan is to support a group of leading vegetable growers to engage with potential market partners, wholesalers, and other supply chain logistic experts to define a programme of activities – including a market exploration pilot to identify the vegetable products for which there is secure market demand.

In the medium term, the Action Plan will support a market study tour covering target markets to develop relationships with potential market partners and to learn more about how to avoid in-market pitfalls. The Plan will consider a business case for business assistance to secure an appropriate exporter and/or an in-market partner

Accelerate 25 sees a future where the Manawatu-Whanganui Region has a recognised brand reflecting the provenance of the region and providing a base for expanding the scale and attractiveness of regional-sourced vegetable produce to partners in international markets.

6.4.9 Realising Māori Potential

The Accelerate 25 Action Plan recognises the disproportionate weighting of those claiming Māori descent in the Manawatu-Whanganui Region (21% against a national average of 15–16%). In the Whanganui Catchment the proportion of Māori is even higher at 25%. The Plan also notes the wide mixture of Māori enterprise and some notably successful ventures, both by private individuals and especially through Māori incorporations, achieved with an indigenous perspective, a distinctive resource base, and under unique constraints. Māori view successful business and economic development as reflecting the integration of social, cultural, economic, environmental, and spiritual well-being. Success for Māori encompasses oranga tangata (human well-being), oranga whenua (well-being of the land), oranga wairua (spiritual well-being), and oranga whānau (family well-being) and endurance between generations. The Māori business model resonates strongly with many target markets nationally and globally, and is intrinsically sustainable. The cultural basis to their business gives Māori a unique branding position within sectors where they operate.

The plan recognises that realising Māori potential is not without its challenges, citing:

- Concerns about cultural mis-appropriation, loss of control and misuse of Māori cultural icons
- Involvement of all iwi and all hapū is not necessarily assured
- Māori are not always as visible as they should be in sectors where Māori already work
- While marae have an important role as a base for sharing understanding about culture, heritage, and world views, there are risks associated with their 'commercialised' use
- Issues of capability and capacity among Māori with the present workload, all too often, falling on a few individuals
- Raising capital, especially when utilising Māori land, is sometimes challenging

Notwithstanding, Accelerate 25 commits to a number of immediate priorities to realise this opportunity, as follows:

- To assess and assist the development of specific tourism business cases in the Whanganui River area
- To investigate ways of utilising Māori freehold land to optimise sustainable natural resource use and development. These include developing business cases that provide for the close cooperation of adjacent landholdings to enhance the viability of a commercial venture, and preparing business cases to attract investment for commercialisation of non-farm ventures (e.g. tourism and aquaculture)
- To support business cases that provide for Māori land owners to optimise their involvement in mānuka honey ventures
- To provide long-term job seekers with the opportunity to gain work experience in a not-for-profit or business organisation for 6 months, and, where possible, support the transition of these placements toward sustainable employment
- To support iwi to plan for and apply long-term development programmes which build financial literacy as a critical skill base for whānau
- To continue to promote the Māori Business Facilitation Service as a means to help Māori/iwi build their general capability and business acumen
- To provide resources to complete the regional Māori Economic Development Strategy – Te Pae Tawhiti. This strategy (MESG 2016) is now complete and was released in November 2016. It picks up the Māori-specific findings of the Manawatu-Whanganui Growth Study (MPI 2015) and Accelerate 25 (Horizons Regional Council 2016) in a far richer context to recognise ten priorities for Māori:

- Ahuwhenua (Land utilisation)
- Kaimoana (River and sea food)
- Mahi tāpoi (Tourism)
- Mīere (Honey)
- Te ngāhere (Forestry and plant-based products)
- Pakihi matahiko (Māori digital enterprise)
- Te piringa whānau (Whānau cooperatives)
- Whai ōhanga (Entrepreneurship and innovation)
- Oranga kaumātua (Older Māori vitality)
- Hanga whare (Housing)

The reader is referred to the Māori Economic Development Strategy – Te Pae Tawhiti for the details of these priorities (https://www.horizons.govt.nz/HRC/media/Media/Accelerate%2025/Te-Pae-Tawhiti-A4-Booklet-WEB.pdf?ext=.pdf).

6.4.10 Enablers – Growing business, Skills and Talent, Distribution and Transport, Digital Connectivity

To enhance the likelihood of success in the opportunities above, Accelerate 25 has resolved upon activities in four enabling areas:

- To encourage small business growth by:
    - seeking additional engagement with the Regional Business Partner Programme to provide support for tourism and other start-up businesses
    - advancing farmer discussion groups as a medium for effective knowledge and information transfer between members
    - accelerating support for performance improvement in 25 targeted companies in the Region
- To develop skills and talent by:
    - assisting the apiculture industry to develop an Apiculture Workforce Strategy
    - creating pathways for students to connect education and employment via the Primary Sector Scholarships programme
    - working with training providers to tailor training to suit the proposed new ‘Quality Care and Lifestyle’ model for older people
    - identifying gaps, priorities, and content in industry training for sheep and beef farmers
- To improve distribution and transport infrastructure by:

  - revitalising the Whanganui marine precinct and port area, initially by generating a Master Plan and Pre-feasibility Study followed by a full feasibility study
  - preparing a business case as a precursor to improving roads into and around the Palmerston North distribution hub
  - undertaking a feasibility study to identify demand and opportunities for more rail tourism to the Tongariro Whanganui area
  - giving further consideration to the particular transport needs of tourism and older people
  - preparing a proposal to explore options for transport of goods by air
- To facilitate better digital connectivity to support rural businesses, care, and lifestyle for older people and, tourism operators and visitors, by:
  - delivering the 'Rural Broadband Initiative' to 98 schools and a further 12 isolated schools in the Region as part of the 'Remote Schools Broadband Initiative'
  - rolling out the 'National Rural Broadband' and 'Mobile Black Spot Coverage Programme'
  - considering what more can be done to encourage people to use Ultra-Fast Broadband
  - determining how to prioritise investment in the 'Rural Broadband Initiative 2' programme.

7 Conclusion

Steady state is a condition rarely found in nature and it was not present in the Whanganui catchment when humans arrived 700 years ago. Although seemingly primeval, the landscape found was adapting to climatic warming after a period of glaciation, volcanic and tectonic events, and other processes. It was a young landscape, heavily dissected by streams and rivers, imbued with a complex sedimentary and volcanic geology, relatively intact under forest cover but inherently unstable in the face of extreme climatic and other natural events. Landscape change and adaptation is therefore a constant from before human arrival to the present day, but something that human intervention has greatly accelerated in historic times.

Apart from the foot-slopes of the central North Island volcanoes, the sea coast, and parts of alluvial floodplains, the Whanganui catchment was forested until the arrival of Māori in the 14th century. In the 500 years that followed, this forested landscape changed little, except in areas of easier topography in the upper catchment where fire was used to greater effect to foster bracken growth and in the very lower catchment where flat fertile land supported denser settlement. More profound during this period was the effect on fauna with extinction of moa and other species caused by hunting and the introduction of New Zealand's first mammalian predator, the kiore.

The environmental impact of Pākehā settlement from the 19th century onward occurred later in the Whanganui catchment than in other parts of the North Island. Comparative difficulties of access, the paucity of land attractive to farming, and the declaration (and the sometimes vigorous defense) of Tē Rohe Pōtae in the middle and upper catchment, meant that large-scale settlement and land clearance did not occur until around the establishment of the main trunk railway in the late 19th–early 20th century. The exception was the township of Petre, founded in 1840–42 by the New Zealand Company, reverting in name to Wanganui in 1854 following a petition to Government, and then to either Wanganui or Whanganui in 2009.

The locality of Whanganui offered the same attractions to Pākehā as it had to Māori – flat, fertile land, a harbour and, in the Whanganui River, a navigable waterway reaching far into the central North Island. In the first few decades of its existence, Whanganui's growth was slow, and at times tenuous, becoming more rapid from the 1870s as settlement spread along the coast to the north-west, and even more rapid from the 1880s to 1910s as farming spread into the inland hill country and Waimarino Plain, allowing Taumarunui and other centres to grow in significance.

It was to this period of forest clearance and settlement of the inland hill country from the late 1800s, that we attribute the far-reaching effects on the physical and living environments of the Whanganui catchment. The lowermost parts and most of the upper catchment are now deforested agricultural landscapes, supporting exotic grasses and clover and grazed by sheep and cattle that are the mainstay of the rural economy. Less than 40% of original forest remains, although this is a higher figure than across the rest of New Zealand. Across this deforested landscape fragments of original forest persist. In the logged-over forests and steeper hill-country (17% of the catchment) that proved unsuitable for farming, scrub and reverting forest is slowly re-claiming the land.

Many plants introduced by Pākehā have naturalised, many as invasive weeds, including gorse, which is widespread and persistent in the catchment, and old man's beard, which is less extensive but aggressively colonises forest margins, eventually overtopping and smothering the trees below. Other non-native plants that DOC ranks as high-priority species to control include African feather grass, Scotch broom, Japanese honeysuckle, Japanese spindle tree, common pampas grass, and tutsan. Controlling lodgepole pine and heather is a major focus in the tussock grasslands surrounding the volcanic peaks, and at the coast, gorse and marram grass compete with indigenous plants of the dunes.

Animals introduced by Pākehā such as ship rats and stoats are the most likely reason for extinctions of birds that were formerly widespread, including tieke, kākāpō, huia, hihi, and piopio. They are almost certainly the reason for extinction of populations of kōrure and other seabirds that formerly bred plentifully in the inland hills and ranges of the North Island and were an important source of food for Māori. They are largely responsible for declining numbers of some forest birds such as kākā, once widespread in the Whanganui River catchment.

Possums, pigs, rats, and mice are both predators and herbivores. Possums prey on native birds such as kererū and kōkako, and they also preferentially browse some native plant species, from the forest floor to forest canopies. Deer and goats browse forest understoreys, retarding recruitment of seedlings and saplings to the canopy, and slowing, or even preventing, regeneration in clearings and on pastures.

Nationally, while research to improve techniques and delivery has allowed more efficient use of limited funding (currently over $100M), pest-control programmes have served only to slow the decline in ecosystem health. Nonetheless, there exist examples of success in many parts of New Zealand, from community-led sanctuaries in which multi-species pest control has been achieved, to several intensively managed sites, covering hundreds to thousands of hectares, where DOC is effectively controlling predators to the benefit of indigenous vegetation, birds, and insects. Effective and sustained pest control in the forested landscape of the Whanganui catchment will be a challenge and one that may only be met through further research into improved techniques, increased funding, and partnerships between Government and the community to deliver positive results.

Our understanding of terrestrial ecology in the catchment is derived both from observation, survey, and sampling within the catchment, and from knowledge gleaned from studies outside the catchment. Ecological studies and biodiversity monitoring in the catchment are neither numerous nor representative. Information about some native species (including mosses, lichens, fungi, and insects) is haphazard. Knowledge of the state of and trend in biodiversity would be improved with more intensive study in the conservation estate and on privately-owned land.

Some 60% of land in the catchment is highly erodible. Fortunately, despite more than a century of land clearance, more than three-quarters of highly erodible land remains protected by forest or scrub. However, the remainder is under agricultural management and exposed to the agencies of erosion. The Whanganui Catchment Study (Horizons Regional Council 1997) estimated that about 14,000 ha should be allowed to revert to forest, another 71,000 ha should be converted to production forestry, and a further 96,000 ha require soil-conservation planting. Hillslope erosion not only affects livestock production and built infrastructure but it is the major source of sediment in waterways.

Annually, the Whanganui catchment delivers more than 3.3M tonnes of sediment to the sea. Much, but not all, of this sediment could be traced back to mass-movement erosion – some will have come with diffuse overland flow of water, some from stream and river banks, and some from re-mobilised bedload. Unsurprisingly then, much of the Whanganui river system scores poorly for turbidity – sites at Cherry Grove, Te Maire, and Taringamotu are in the worst 50% of rivers nationally, while all other monitored sites in the catchment are in the worst 25% nationally.

By other measures of quality (*E. coli*, nitrogen, and dissolved oxygen) the Whanganui waters are within (though sometimes close to) the limits set for 'lowest risk to human health' under the National Policy Statement for Freshwater Management (2014). Enrichment of waters by phosphorus is measurably greater in the upper catchment (where it reaches levels that could support nuisance algal growth) than lower downstream. The Ohura sub-catchment, by most measures (including turbidity) scores lowest among those sites monitored, supporting the assertion that land use in many areas here is beyond the inherent capability of the land.

Water quality monitoring records cannot support written and verbal accounts that the Whanganui River once ran clear over a stony bed all the way to the sea – they simply do not go back far enough to document that period of massive change following Pākehā settlement. But nor does the monitoring record refute such accounts.

Despite a mediocre water quality scorecard by many measures, there are grounds for optimism. The Macroinvertebrate Community Index (MCI, a general measure of river health based on presence and abundance of macroinvertebrates) shows a perceptible trend of improvement at some sites since monitoring began in 1990. Horizons Regional Council via The One Plan and initiatives like SLUI are targeting highly erodible land in an effort to 'shut down' the areas contributing the most sediment to waterways. Monitoring of taonga species in the Whanganui River (tuna, piharau, kōaro, kōkopu, inanga, kākahi, kōura) show that those species, so valued, are still there – perhaps in numbers much lower than they were, but with the capacity to increase. Good management to improve habitat quality is essential, combined with reducing the threats to their survival from introduced predators such as trout and perch.

Ultimately, to succeed with environmental restoration, the present almost moribund demography and economy of the rohe need to be turned around, both to resource the necessary initiatives and to demonstrate their value for reclaiming the health and well-being of Te Awa Tupa.

8 Information Gaps

8.1 The land

Current information on the physical environment for the Whanganui catchment is reasonably comprehensive for regional scale analysis, and the establishment of the key elements determining its distinctive landscape features, with the exception of detailed soils data. This shortfall in detailed soils data could be rectified by Landcare Research's 'S-Map' programme (https://smap.landcareresearch.co.nz/), given sufficient regional demand and funding.

The catchment is characterised by a paucity of high quality land, a predominance of non-arable land, and a significant proportion of moderately steep to steep land with severe physical limitations to productive use. Over 45% of the catchment's soils are developed from volcanic ash, of variable natural fertility and susceptible to sheet and shallow landslide erosion. The steep to very steep, ash free, sandstone terrain is also very susceptible to shallow landslide and sheet erosion under pasture.

This highly erodible land has been identified and mapped. The application of the standard range of soil conservation techniques, space planting, afforestation, retirement, controlled grazing to maintain a vigorous vegetative cover, debris dams, sediment traps, revegetation, and riparian management would be expected to reduce the volumes of fine, suspended sediment generated and delivered to the waterways, and thus improve water quality. Because of the characteristics of the terrain, giving priority to controlling the areas and points of sediment generation at their source will yield the greatest benefit in the shortest time. This is the approach presently being implemented by Horizons Regional Council under their SLUI initiative and The One Plan.

It is also critical to match sustainable land use with land capability, establish best management practice guidelines, and to monitor these activities – another key activity under The One Plan.

8.2 Terrestrial ecosystems, biodiversity and taonga species

Current information, about the state of terrestrial ecosystems and their plants and animals, is best from public conservation land. The information about plant communities, birds, and pest mammals derive mostly from a coarse (8 km) monitoring grid. Finer scale resolution on public conservation land is patchy. Moreover, since most public conservation land is in the middle-to-upper reaches of the catchment, we have a geographically biased view of what we do know. On private land, including iwi-owned land, information about the state of terrestrial ecosystems and the plants and animals that they contain is very poor. Assessments of fragments of original native vegetation were conducted under the Protected Natural Areas programme up to the end of the 1990s, but there is little recent information. There are no data on the state of biodiversity from most private land where native plant cover is low or absent and non-native plant cover dominates (e.g. pastoral agriculture and plantation forests).

For taonga species, or geographic areas that may be of specific interest to tangata whenua, information available derives from small and often unrepresentative areas – building a view of the state of these species or areas at a whole-catchment level is not currently possible. Information about some native species (mosses, lichens, fungi, most insects) in the catchment is entirely haphazard and that which exists is not geographically comprehensive.

Although wetlands and some rare ecosystems (dunes, cliffs) are delineated and mapped, the state of these ecosystems is generally unknown.

If the state of terrestrial biodiversity in the Whanganui catchment is generally poorly known, defensible estimates of the trends in biodiversity are even more elusive. Much relies on oral history and reconstructions that cannot be verified by recorded measurement.

8.3 Water

For the catchment's water environments, there is a need for better linking of data on land use including land management practices, and water quality and habitat outcomes.

Climate variability (storms and droughts) obscures the longer-term trends in river and habitat quality as affected by land use practices. Monitoring attributes such as the Macroinvertebrate Community Index (MCI) provide a more integrated picture of aquatic habitat change than other water quality attributes summarised in this report.

A regular and consistent fish monitoring programme for the entire catchment would provide information on the long-term health of the river system, as well as the distribution of key species. Given the importance of some taonga species such as kakahi, for example, greater monitoring effort could enable a better understanding their distribution within the catchment. Similarly, a dedicated quantitative study on the historical suspended sediment regimes would greatly benefit understanding of the natural sediment conditions of the catchment and long-term trends of land use change.

More comprehensive monitoring of some water quality variables could provide better guidance for management. For example, because temperature and DO are presently measured periodically using spot measurements, data do not record daily fluctuations throughout the diurnal cycle. Further, the periodic nature of monitoring means that there are generally month-long gaps between records. More frequent monitoring, particularly over a number of summers, using continuous data loggers would provide a much richer dataset to highlight whether there is an issue with these parameters.

Above all, building a whole catchment understanding (and changes within the catchment) which links biophysical and social factors will enable more holistic management that truly reflects Tupua Te Kawa. Standard scientific measures of flow and water quality can be supplemented with mātauranga-based assessments of trends through both time and down-river between sites. (Fenemor et al. 2011; Harmsworth et al. 2016; Tipa et al. 2016). A range of cultural monitoring tools have been developed and used including:

- Cultural Health Index (CHI) (Tipa & Teirney 2003, 2006a, b)
- Taonga species measurement and monitoring (e.g. tuna – Williams et al. 2013, 2014; pihirau – Kitson et al. 2012)
- Cultural indicators of wetlands (Harmsworth 2002)
- State of Takiwā "toolbox" (iwi environmental monitoring and reporting tool; Pauling et al. 2007)
- Mauri assessment model and 'maurimeter' (Morgan 2006, 2007a, b)
- Significance assessment method for tangata whenua river values (Tipa 2010)
- KEIAR framework (Waikato case study) (Dixon & Harmsworth 2012)
- Cultural flow preference studies (Tipa & Nelson 2012; Rainforth 2014)

8.4 Social factors

In several respects, the human dimension of the Whanganui catchment is ailing as much as the natural and spiritual dimensions. Population is in decline and its demography is out of balance, the economy is languishing, infrastructure is only just being maintained, tourism is struggling, agriculture is retrenching, and processing and manufacturing are striving to remain viable. These are not conditions that attract innovation, engender vitality, and encourage investment in improving the health and well-being of a river and its catchment.

Opportunities exist to reverse this decline and to manage growth of the human environment in directions that benefit Te Awa Tupua and its people. Initiatives such as Accelerate 25, reinforced by the Māori-focused priorities delineated in Te Pae Tawhiti, will serve to unite the iwi/hapū of Te Awa Tupua (and the energy they can provide) behind a vision of a healthy and sustainable river and catchment.

9 Recommendations

9.1 Hui – priority setting

To further the development of Te Heke Ngahuru, our key recommendation is that the **main findings from this report are presented at a hui** attended by members of Te Kōpuka and other selected parties, with the aim of **setting priorities** for actions to restore the health of Te Awa Tupua.

Having identified priority catchment issues and actions, Te Kōpuka can consider potential research partnerships (e.g. in areas of sediment and erosion management, biodiversity measurement and monitoring, and integrated catchment management) and identify sources of funding additional to Te Korotete o Te Awa Tupua.

Specific recommendations that derive from this report are:

9.2 Land

- Support the activities of SLUI and The One Plan to shut down sediment generation from agricultural land at source, through measures like retirement, afforestation, and soil conservation planting and management.
- Rectify the shortfall in detailed soils data by investing in Landcare Research's 'S-Map' program (https://smap.landcareresearch.co.nz/) to extend regional coverage.
- Influence land owners always to manage land with the health of the river in mind, and with an aspirational goal of zero off-site impact rather than simple compliance with rules.

9.3 Terrestrial ecosystems, biodiversity and taonga species

- Develop a catchment-wide process to assess state and trend in terrestrial ecosystems. Support continued investment of DOC's Tier One monitoring programme on public conservation land, and encourage regional councils (principally Horizons Regional Council) to extend the same grid-based sampling to all other land.
- For those ecosystems selected as priority areas for management, commission a survey to establish a contemporary baseline against which future trends can be measured. As many attributes as thought necessary can be included – typically the surveys would include vegetation and bird communities. The baseline can be used to assess the effectiveness of any management or restoration activities.
- With tāngata whenua, develop specific methods (combining standard scientific methods with mātauranga-based assessments) to measure and monitor state and trend of taonga species, ecosystems, and geographic areas of importance. If these methods can be integrated, to the greatest extent possible, with those in use by DOC, then defensible comparisons can be made. Established protocols exist for monitoring

some species of concern (e.g. kiwi, pekapeka) and these could be adopted in the catchment.

- Invest in specific programmes to measure and monitor state and trends in rare ecosystems (wetlands, dunes) throughout the catchment.

9.4 Water

- Establish a holistic catchment-wide process, building on current hydrology and water quality monitoring programmes run by Horizons Regional Council, that incorporates mātauranga-based assessments and monitoring of taonga species (such as tuna and piharau) through both time and down-river between sites.
- Establish a regular and consistent aquatic monitoring programme for the entire Whanganui river catchment to provide information for the long-term health of river system.
- Set up a dedicated study on the historical suspended sediment regimes of the Whanganui catchment to benefit understanding of the natural sediment conditions in the catchment and long-term trends.

9.5 Social factors

- Engage to the fullest extent possible with initiatives under Accelerate 25 and Te Pae Tawhiti and facilitate inclusion of iwi/hapū of Te Awa Tupua in opportunities presented by these (and other) regional development plans. Māori are identified as both a resource and a beneficiary in these plans, and success (with flow-on benefits to Te Awa Tupua) cannot be achieved without their engagement.
- Above all, foster whole-catchment understanding that links biophysical and social factors to enable holistic management that truly reflects Tupua Te Kawa.

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Appendix 1: Vascular Plant species currently known from the Whanganui River catchment. (W) = Whanganui vernacular.

Native plant species

Māori, Pākehā Name	Latin Name
Piripiri, Hutiwai, Bidibid	*Acaena anserinifolia*
Red bidibid	*Acaena novae-zelandiae*
Heart-leaved orchid, Pixie cap	*Acianthus sinclairii*
Taramea, Papai, Speargrass	*Aciphylla species*
	Adenochilus gracilis
Cunninghams Maidenhair	*Adiantum cunninghamii*
Tuberous maidenhair, Small maidenhair	*Adiantum diaphanum*
Maidenhair fern, Huruhuru tapairu, Tawatawa, Makawe tapairu	*Adiantum species*
	Agrostis species
Titoki, NZ Ash	*Alectryon excelsus*
Pere, Matuku-roimata	*Alseuosmia banksii var. linariifolia*
Karapapa, Toropapa, Pere	*Alseuosmia macrophylla*
	Alseuosmia pusilla
Karapapa, Toropapa, Oak-leaved toropapa	*Alseuosmia quercifolia*
	Alseuosmia turneri
	Anaphalioides bellidioides
Puatea, Cudweed	*Anaphalioides trinervis*
	Androstoma empetrifolium
Kopoti, Aromatic aniseed	*Anisotome aromatica*
	Apium species
Odd-leaved orchid	*Aporostylis bifolia*
Mountain wineberry	*Aristotelia fruticosa*
Makomako, Mako, Wineberry	*Aristotelia serrata*
Rengarenga, Rengarenga-iti, Repehinapapa, Rock lily	*Arthropodium candidum*
Hutu	*Ascarina lucida*
Manamana, Mouku, Pikopiko, Hen and chicken fern, Mother spleenwort	*Asplenium bulbiferum*
Butterfly fern, necklace fern	*Asplenium flabellifolium*
Drooping spleenwort, Makawe, Raukatauri	*Asplenium flaccidum*
	Asplenium gracillimum
Colenso's spleenwort	*Asplenium hookerianum*
Hooker's spleenwort	*Asplenium hookerianum*
	Asplenium lamprophyllum
Lyall's spleenwort	*Asplenium lyallii*
Huruhuruwhenua, Pānako, Paretao, Shining spleenwort	*Asplenium oblongifolium*

Māori, Pākehā Name	Latin Name
Paranako, Paretao, Shore spleenwort	*Asplenium obtusatum*
Peretao, Petako, ParetaoSickle spleenwort	*Asplenium polyodon*
Wharawhara, Coastal astelia, shore kōwharawhara	*Astelia banksii*
Kakaha, Bush flax, bush lily	*Astelia fragrans*
Swamp astelia	*Astelia grandis*
Kahakaha, Tank lily	*Astelia hastata*
	Astelia microsperma
Kakaha, Mountain astelia	*Astelia nervosa*
Kōwharawhara, Kahakaha, kaiwharawhara, Perching astelia, perching lily	*Astelia solandri*
Kōkaha, Kauri grass	*Astelia trinervia*
Toetoe, toetoe-kākaho	*Austroderia fulvida*
Toetoe	*Austroderia richardii*
Toetoe	*Austroderia toetoe*
Mānawa	*Avicennia species*
Retoreto	*Azolla species*
Tawa	*Beilschmiedia tawa*
Rereti, Lance fern	*Blechnum chambersii*
Peretao, Petako, Colenso's hard fern	*Blechnum colensoi*
Piupiu, Petipeti, Crown fern	*Blechnum discolor*
Pānako, Thread fern	*Blechnum filiforme*
Kiwikiwi, kiwakiwa, kawakawa, Creek fern	*Blechnum fluviatile*
	Blechnum fraseri
	Blechnum membranaceum
Swamp kiokio	*Blechnum minus*
Black hard fern	*Blechnum nigrum*
Kiokio, horokio, Palm leaf fern	*Blechnum novae-zelandiae*
Little hard fern	*Blechnum penna-marina*
Small kiokio	*Blechnum procerum*
Korokio, Mountain hard fern	*Blechnum vulcanicum*
Pātōtara, Tī taranaki (W), Parsley fern	*Botrychium australe*
Fine-leaved parsley fern	*Botrychium biforme*
	Brachyglottis bidwillii
Hector's tree daisy	*Brachyglottis hectorii*
Kohurangi, Kōkohurangi (W), Kirk's daisy	*Brachyglottis kirkii*
Rangiora, Wharangi, Pukapuka, Bushman's friend, bushman's toilet paper	*Brachyglottis repanda*
Muttonbird scrub, Pūheretāiko	*Brachyglottis rotundifolia*
Tree daisy	*Brachyglottis turneri*
Pygmy tree orchid	*Bulbophyllum pygmaeum*
	Caladenia lyallii

Māori, Pākehā Name	Latin Name
	Caladenia minor
Mueller's starwort	*Callitriche muelleri*
Pōhue, Pāraha	*Calystegia species*
Panapana, NZ Bitter cress	*Cardamine debilis*
Bitter cress	*Cardamine depressa*
Bastard grass, Hook sedge	*Carex astricta*
Fine-leaved hook grass	*Carex banksiana*
	Carex breviculmis
Maurea, Longwood tussock	*Carex comans*
Rautahi, Cutty grass	*Carex coriacea*
Fish Hooks,Bastard grass	*Carex corynoidea*
Bastard grass, Hook sedge	*Carex crispa*
Forest sedge	*Carex dissita*
Bastard grass, Hook sedge	*Carex edura*
Lax Bastard Grass, Hook Sedge	*Carex erythrovaginata*
Yellow sedge	*Carex flaviformis*
Forster's Sedge	*Carex forsteri*
Rautahi, Cutty grass	*Carex geminata*
Harsh-leaved Bastard Grass, Hook Sedge	*Carex healyi*
Bastard grass, Hook sedge	*Carex horizontalis*
Feeble Bastard Grass, Hook Sedge	*Carex imbecilla*
Fine-leaved Bastard Grass, Hook Sedge	*Carex lectissima*
Rautahi, Cutty grass	*Carex lessoniana*
Māori Sedge	*Carex Māorica*
Matau, Bastard grass, Cavers beard	*Carex megalepis*
Bastard grass, Hook sedge	*Carex minor*
Bastard grass, Hook sedge	*Carex potens*
Red Bastard Grass, Frost Flat Hook Grass	*Carex punicea*
Pūrei, Pūkio	*Carex secta*
Forest Bastard Grass, Hook Sedge	*Carex silvestris*
Solander's Sedge	*Carex solandri*
Bastard grass, Hook sedge	*Carex subviridis*
Speckled Sedge, Trip Me Up	*Carex testacea*
Hook grass	*Carex uncinata*
Pūkio, toitoi, Swamp sedge	*Carex virgata*
Zotovs Bastard Grass, Zotovs Hook Sedge	*Carex zotovii*
Mākaka, NZ Broom	*Carmichaelia australis*
Desert broom	*Carmichaelia petriei*
	Carpha alpina
Putaputawētā, Marbleleaf	*Carpodetus serratus*

Māori, Pākehā Name	Latin Name
Bog Mountain Daisy	*Celmisia glandulosa*
Pekapeka, Common mountain daisy	*Celmisia gracilenta*
White mountain daisy	*Celmisia incana*
Tikumu, Puakaito, Common mountain daisy, cotton daisy	*Celmisia spectabilis subsp. spectabilis*
Bird orchid, ant orchid	*Chiloglottis cornuta*
Haunangāmoho, Broad-leaved bush tussock	*Chionochloa conspicua*
Mid-ribbed snow tussock	*Chionochloa pallens subsp. pallens*
	Chionochloa rubra
Red tussock, Wī kura	*Chionochloa rubra subsp. rubra var. rubra*
	Clematis cunninghamii
Clematis	*Clematis foetida*
Pōānanga, Pikiarero, Forster's clematis	*Clematis forsteri*
Puawhānanga, White clematis	*Clematis paniculata*
	Colobanthus species
	Convolvulus species
Māmāngi, Tree coprosma	*Coprosma arborea*
Thin-leaved coprosma	*Coprosma areolata*
	Coprosma cheesemanii
	Coprosma ciliata
	Coprosma colensoi
	Coprosma crassifolia
	Coprosma cuneata
	Coprosma dumosa
Stinkwood, hūpiro, pipiro	*Coprosma foetidissima*
Kanono, manono, raurēkau, Large-leaved coprosma	*Coprosma grandifolia*
Mikimiki, Karamū, Karangū, Yellow wood	*Coprosma linariifolia*
Karamū, Karangū, Shining karamu	*Coprosma lucida*
Large-seeded Coprosma	*Coprosma macrocarpa*
Small-seeded coprosma	*Coprosma microcarpa*
Leafy coprosma	*Coprosma parviflora*
	Coprosma perpusilla
Mingimingi	*Coprosma propinqua*
	Coprosma propinqua x robusta
	Coprosma pseudocuneata
Mingimingi	*Coprosma rhamnoides*
	Coprosma rigida
Karamū, Karangū, Glossy karamu	*Coprosma robusta*
	Coprosma rotundifolia
	Coprosma rubra
	Coprosma serrulata

Māori, Pākehā Name	Latin Name
	Coprosma spathulata
	Coprosma tayloriae
Hukihuki, Swamp Coprosma	*Coprosma tenuicaulis*
	Coprosma tenuifolia
	Coprosma xcunninghamii
Tī kōuka, Tī, Cabbage tree	*Cordyline australis*
Ti ngahere, ti rakau	*Cordyline banksii*
Tōī, Mountain cabbage tree	*Cordyline indivisa*
Tutu, Pūhou, TāwekuTree tutu	*Coriaria arborea*
Korokio, Wire-nettting bush	*Corokia cotoneaster*
Spider orchid	*Corybas acuminatus*
Spider Orchid	*Corybas macranthus*
Spider Orchid	*Corybas oblongus*
Spider Orchid	*Corybas orbiculatus*
Maikaika, Spider Orchid, Silverback	*Corybas rivularis*
Helmet Orchid	*Corybas rotundifolius*
Spider orchid	*Corybas trilobus*
Karaka	*Corynocarpus laevigatus*
Bachelor's button	*Cotula coronopifolia*
Pūnui, Gully tree fern	*Cyathea cunninghamii*
Ponga, Kāponga, Silver fern	*Cyathea dealbata*
Mamaku, Black tree fern	*Cyathea medullaris*
Kātote, Soft tree fern	*Cyathea smithii*
Coastal cutty grass, Giant umbrella sedge, Toetoe upoko-tangata	*Cyperus ustulatus*
Kahikatea, White pine	*Dacrycarpus dacrydioides*
Rimu, Red pine	*Dacrydium cupressinum*
Pua o te reinga, wood rose, flower of Hades	*Dactylanthus taylorii*
Winikā, pekapeka, Christmas orchid, bamboo orchid	*Dendrobium cunninghamii*
Mountain oat grass	*Deyeuxia avenoides*
Tūrutu, Rēua, Piopio, NZ blueberry	*Dianella nigra*
Long-hair plume grass	*Dichelachne crinita*
Whekī-ponga, wheki-kohoonga, Kurīpākā, Kōhunga, Golden Tree fern	*Dicksonia fibrosa*
Tūākura, Tree fern	*Dicksonia lanata*
Whekī, Tūākura, Rough Tree fern	*Dicksonia squarrosa*
	Diplazium australe
Akeake	*Dodonaea viscosa*
	Dracophyllum filifolium
Neinei, Needle-leaved neinei, spider wood	*Dracophyllum latifolium*
Inanga	*Dracophyllum longifolium*

Māori, Pākehā Name	Latin Name
Curled leaved neinei	*Dracophyllum recurvum*
Tōtorowhiti, Grass tree	*Dracophyllum strictum*
Sundew	*Drosera arcturi*
Sundew	*Drosera auriculata*
	Drymoanthus adversus
Raupeka, Easter orchid	*Earina autumnalis*
Peka-a-waka, Bamboo Orchid, Spring Earina	*Earina mucronata*
Forest hedgehog grass	*Echinopogon ovatus*
Hīnau	*Elaeocarpus dentatus*
Pōkākā	*Elaeocarpus hookerianus*
Parataniwha, NZ Begonia	*Elatostema rugosum*
Sharp spike sedge	*Eleocharis acuta*
Slender spike sedge	*Eleocharis gracilis*
Kuta, Paopao, Kutakuta, Spikes of doom, bamboo spike sedge, tall spike sedge	*Eleocharis sphacelata*
	Epacris alpina
Willowherb	*Epilobium alsinoides*
	Epilobium alsinoides subsp. alsinoides
	Epilobium alsinoides subsp. atriplicifolium
	Epilobium brunnescens subsp. brunnescens
Willowherb	*Epilobium nerteroides*
Creeping willowherb	*Epilobium nummulariifolium*
Willowherb	*Epilobium pallidiflorum*
Willowherb	*Epilobium pedunculare*
Willowherb	*Epilobium pubens*
Round-leaved willowherb	*Epilobium rotundifolium*
	Euchiton audax
	Euchiton collinus
	Euchiton delicatus
	Euchiton involucratus
	Euchiton japonicus
	Euchiton limosus
	Euchiton sphaericus
Tutumako, North Island Eyebright	*Euphrasia cuneata*
	Forstera tenella
Kiekie, Grass tree	*Freycinetia banksii*
Kōtukutuku, Tree fuchsia	*Fuchsia excorticata*
Tawhai rauriki, Mountain beech	*Fuscospora cliffortioides*
Tawai raunui,Tawhai, Red beech	*Fuscospora fusca*
Tawhai rauriki, Black beech	*Fuscospora solandri*
Hard beech	*Fuscospora truncata*

Māori, Pākehā Name	Latin Name
Cutting sedge	*Gahnia pauciflora*
Tātaki, Tūtaki, Giant sedge, Mountain Gahnia	*Gahnia procera*
Māpere, Cutty grass, Razor sedge	*Gahnia setifolia*
Tupari maunga, Mapere	*Gahnia xanthocarpa*
Māwe, Dwarf bedstraw	*Galium propinquum*
Perei, Hūperai, Māikaika, Māukuuku (honorific), Black orchid, black potato orchid	*Gastrodia cunninghamii*
Tāwiniwini, Bush Snowberry, Fool's beech, Koropuka	*Gaultheria antipoda*
	Gaultheria antipoda x oppositifolia
Mountain snowberry	*Gaultheria colensoi*
Snowberry, Tapuka	*Gaultheria depressa*
Snowberry, Niniwa, Waiūatua	*Gaultheria oppositifolia*
	Gaultheria paniculata
Hangehange	*Gaultheria rupestris*
	Gaultheria rupestris var. subcorymbosa
	Geniostoma ligustrifolium
Hangehange	*Geniostoma ligustrifolium var. ligustrifolium*
	Gentianella species
Short-flowered cranesbill	*Geranium sessiliflorum*
	Geum species
Tangle fern, Matua-rarauhe, Waewae-kākā (W)	*Gleichenia dicarpa*
	Gonocarpus aggregatus
Piripiri	*Gonocarpus micranthus*
Pāpāuma, Para, Kawariki, Paraparauma, Broadleaf	*Griselinia littoralis*
Akapuka, Puka	*Griselinia lucida*
	Gunnera monoica
Bog pine	*Halocarpus bidwillii*
Pink pine	*Halocarpus biformis*
Toatoa, Fire weed	*Haloragis erecta*
Porokaiwhiri, Pigeonwood	*Hedycarya arborea*
Slender everlasting daisy	*Helichrysum filicaule*
Niniao, Everlasting daisy	*Helichrysum lanceolatum*
Holy grass	*Hierochloe recurvata*
Kāretu, Scented grass	*Hierochloe redolens*
Matā, Mātātā, Water fern	*Histiopteris incisa*
Houhi, Narrow leaved lacebark	*Hoheria angustifolia*
	Hoheria angustifolia x sexstylosa
Houhere, Wheuhi (W), Lacebark	*Hoheria populnea*
Houhere, Lacebark	*Hoheria sexstylosa*
	Huperzia australiana
	Hydrocotyle dissecta

Māori, Pākehā Name	Latin Name
	Hydrocotyle elongata
Waxweed	*Hydrocotyle heteromeria*
	Hydrocotyle microphylla
Hairy pennywort	*Hydrocotyle moschata*
	Hydrocotyle novae-zeelandiae
	Hydrocotyle novae-zeelandiae var. montana
Filmy fern	*Hymenophyllum armstrongii*
Filmy fern	*Hymenophyllum australe*
Filmy fern	*Hymenophyllum bivalve*
Filmy fern	*Hymenophyllum cupressiforme*
Irirangi, Piripiri, Drooping filmy fern	*Hymenophyllum demissum*
Matua mauku, Filmy fern	*Hymenophyllum dilatatum*
Filmy fern	*Hymenophyllum flabellatum*
Wavy filmy fern	*Hymenophyllum flexuosum*
Rusty filmy fern	*Hymenophyllum frankliniae*
Filmy fern	*Hymenophyllum lyallii*
Filmy fern	*Hymenophyllum minimum*
Much-divided filmy fern	*Hymenophyllum multifidum*
Kopakopa, Konehu, Raurenga, Kidney fern	*Hymenophyllum nephrophyllum*
One-sided filmy fern	*Hymenophyllum peltatum*
Tufted filmy fern	*Hymenophyllum pulcherrimum*
Filmy fern	*Hymenophyllum rarum*
Filmy fern	*Hymenophyllum revolutum*
Filmy fern	*Hymenophyllum rufescens*
Piripiri, Scented fern	*Hymenophyllum sanguinolentum*
Rough filmy fern	*Hymenophyllum scabrum*
Hairy filmy fern	*Hymenophyllum villosum*
Swamp hypericum	*Hypericum pusillum*
	Hypolepis ambigua
	Hypolepis distans
	Hypolepis lactea
Thousand-leaved fern	*Hypolepis millefolium*
	Hypolepis rufobarbata
Pikirangi, Pirita, Pirinoa, Small-leaved mistletoe, Green mistletoe	*Ileostylus micranthus*
	Isolepis habra
	Isolepis pottsii
	Isolepis reticularis
Tawari, Whākou	*Ixerba brexioides*
	Jovellana repens
Two-storey rush	*Juncus distegus*

Māori, Pākehā Name	Latin Name
Wīwī, Edgar's rush	*Juncus edgariae*
Dwarf rush	*Juncus novae-zelandiae*
Wīwī, Giant rush	*Juncus pallidus*
Leafless rush	*Juncus pauciflorus*
Grass-leaved rush	*Juncus planifolius*
Fan-flowered rush	*Juncus sarophorus*
	Kelleria dieffenbachii
	Kelleria laxa
Rewarewa, NZ honeysuckle	*Knightia excelsa*
Kānuka, Mānuka, Makahikitoa, White Tea tree	*Kunzea ericoides*
Kaāuka,Kōpuka (W), Rawirinui, mānuka rauriki	*Kunzea robusta*
Mountain wind grass	*Lachnagrostis lyallii*
	Lagenifera species
Papatāniwhaniwha	*Lagenophora pumila*
Parani	*Lagenophora strangulata*
Smooth shield fern	*Lastreopsis glabella*
Hairy fern	*Lastreopsis hispida*
	Lastreopsis microsora
Velvet fern	*Lastreopsis velutina*
Pukatea	*Laurelia novae-zelandiae*
Kārearea	*Lemna species*
Nau, ngau (W)	*Lepidium species*
Square sedge	*Lepidosperma australe*
Yellow silver pine	*Lepidothamnus intermedius*
Pygmy pine	*Lepidothamnus laxifolius*
Mingimingi, Prickly mingimingi	*Leptecophylla juniperina*
Lace fern	*Leptolepia novae-zelandiae*
Heruheru, Crape fern	*Leptopteris hymenophylloides*
Heruheru, Prince of Wales feathers	*Leptopteris superba*
Mānuka, kahikatoa, Tea tree	*Leptospermum scoparium*
	Leptostigma setulosum
Mingimingi, Tall mingimingi	*Leucopogon fasciculatus*
Patotara, Dwarf mingimingi	*Leucopogon fraseri*
Mikoikoi, NZ iris	*Libertia grandiflora*
Mikoikoi, Tūrutu, Tūkāuki, NZ iris	*Libertia ixioides*
Mikoikoi, NZ iris	*Libertia micrantha*
Pāhautea, Kaikawaka, NZ Cedar	*Libocedrus bidwillii*
Kaikawaka, Kawaka, NZ Cedar	*Libocedrus plumosa*
	Lindsaea trichomanoides
	Lindsaea viridis

Māori, Pākehā Name	Latin Name
Mangeao, tangeao	*Litsea calicaris*
Pānakenake, Pratia, Pinakitere	*Lobelia angulata*
Sand lobelia	*Lobelia arenaria*
Ramarama, Bubble leaf	*Lophomyrtus bullata*
Rōhutu, NZ Myrtle	*Lophomyrtus obcordata*
Tawai, Tawhai, Silver beech	*Lophozonia menziesii*
Lance fern	*Loxogramme dictyopteris*
	Luzula banksiana
Woodrush	*Luzula banksiana var. migrata*
	Luzula picta
	Luzula picta var. pallida
	Luzula picta var. picta
	Luzuriaga parviflora
Club moss, Puakarimu, Waewae-koukou	*Lycopodium deuterodensum*
Alpine clubmoss, mountain clubmoss	*Lycopodium fastigiatum*
Creeping clubmoss	*Lycopodium scariosum*
Waewae-koukou, Waekāhu, Climbing club moss	*Lycopodium volubile*
Baumea	*Machaerina rubiginosa*
Tūhara	*Machaerina sinclairii*
	Machaerina tenax
Manoao, Silver Pine	*Manoao colensoi*
Poataniwha, Tātaka	*Melicope simplex*
Whārangi, Piro	*Melicope ternata*
Porcupine shrub	*Melicytus alpinus*
Māhoe-wao, Kai-wētā, Tāranga, Narrow-leaved mahoe	*Melicytus lanceolatus*
Swamp mahoe, Manakua	*Melicytus micranthus*
Māhoe, Moeahu, hinahina, Whiteywood	*Melicytus ramiflorus*
Aka, Akatea, White flowered rata	*Metrosideros albiflora*
Rātā	*Metrosideros colensoi*
White climbing rata, Rātā	*Metrosideros diffusa*
Akakura, akatawhiwhi, Rātā, Rata vine	*Metrosideros fulgens*
Akatea, Akatorotoro, White rata, Aka	*Metrosideros perforata*
Rātā, Nothern rata	*Metrosideros robusta*
Bush rice grass, oat grass	*Microlaena avenacea*
Pātītī, Meadow rice grass	*Microlaena stipoides*
	Microseris scapigera
Mountain Hounds tongue fern	*Microsorum novae-zealandiae*
Pāraharaha, Kōwaowao, Hounds tongue fern	*Microsorum pustulatum*
Mokimoki, Fragrant fern	*Microsorum scandens*
Onion-leaved orchid, Māikaika	*Microtis unifolia*

Māori, Pākehā Name	Latin Name
Maire taike, Willow-leaved maire	*Mida salicifolia*
	Montitega dealbata
Pohuehue, Puka, Heruna, Large-leaved muehlenbeckia	*Muehlenbeckia australis*
Pōhuehue, Creeping muehlenbeckia	*Muehlenbeckia axillaris*
Pōhuehue, Small-leaved pohuehue, scrub pohuehue, wire vine	*Muehlenbeckia complexa*
	Myosotis species
	Myriophyllum pedunculatum
Common water milfoil	*Myriophyllum propinquum*
Māpou, Māpau, Red matipo	*Myrsine australis*
Weeping matipo	*Myrsine divaricata*
Creeping matipo	*Myrsine nummularia*
Toro, Tīpau	*Myrsine salicina*
Rōhutu, Myrtle	*Neomyrtus pedunculata*
	Nertera ciliata
Bead plant, fruiting duckweed	*Nertera depressa*
	Nertera dichondrifolia
Hairy Forest Nertera	*Nertera villosa*
Black maire, Maire, Maire raunui	*Nestegis cunninghamii*
White maire, Maire, Maire rauriki	*Nestegis lanceolata*
Rororo, Narrow-leaved maire	*Nestegis montana*
	Notogrammitis angustifolia
	Notogrammitis angustifolia subsp. angustifolia
Common Strap fern	*Notogrammitis billardierei*
Strap fern	*Notogrammitis ciliata*
Comb fern	*Notogrammitis heterophylla*
Strap fern	*Notogrammitis pseudociliata*
Common tree daisy	*Olearia arborescens*
Akepiro, Tanguru, Pekapeka (W)	*Olearia furfuracea*
Mountain holly, hakeke, kōtara	*Olearia ilicifolia*
	Olearia nummulariifolia
Heketara, Scented tree daisy, taraheke, wharangi-piro	*Olearia rani*
Coromandel tree daisy	*Olearia townsonii*
Twiggy tree daisy	*Olearia virgata*
Adder's tongue	*Ophioglossum coriaceum*
	Oplismenus hirtellus aff. imbecillus
	Orchid
Comb sedge, cushion sedge, flat-leaved comb sedge	*Oreobolus pectinatus*
Comb sedge	*Oreobolus strictus*
Mountain foxglove, Hue-o-Raukatauri	*Ourisia macrophylla*
Mountain foxglove	*Ourisia vulcanica*

Māori, Pākehā Name	Latin Name
Creeping oxalis, yellow oxalis	*Oxalis exilis*
White oxalis	*Oxalis magellanica*
Lace fern, Ring fern, Scented fern, Mātā, Mātātā	*Paesia scaberula*
Kaiwhiria, Akakaikiore, Tōtoroene, Kaikū, NZ jasmine, small-flowered jasmine	*Parsonsia capsularis*
NZ jasmine, Poapoa tautaua (W), Kaiwhiria, Akakaikiore, Tōtoroene, Kaikū	*Parsonsia heterophylla*
Kōhia, Kāhia, PōwhiwhiNZ Passionfruit	*Passiflora tetrandra*
Tarawera, Round-leaved fern, NZ cliff brake	*Pellaea rotundifolia*
Kaikōmako	*Pennantia corymbosa*
	Pentachondra pumila
Korukoru, Pirita, Roeroe, Scarlett mistletoe	*Peraxilla colensoi*
Pirirangi ,pikirangi, pirita, roeroe, pirinoa, Red flowering mistletoe	*Peraxilla tetrapetala*
Clubmoss	*Phlegmariurus varius*
Wharariki, Mountain flax	*Phormium cookianum*
Harakeke, Flax	*Phormium tenax*
Toatoa, Mountain toatoa, Mountain celery pine	*Phyllocladus alpinus*
Toatoa	*Phyllocladus toatoa*
Tānekaha, Tāwaiwai, Nīko, Celery pine	*Phyllocladus trichomanoides*
Mountain hounds tongue fern	*Phymatosorus novae-zealandiae*
	Pimelea actea
	Pimelea buxifolia
	Pimelea oreophila subsp. ephaistica
Kawakawa, Pepper tree	*Piper excelsum*
	Pittosporum anomalum
Black mapou, Rautāwhiri	*Pittosporum colensoi*
Tawhirikaro, Karo, Wharewhareatua, Perching pittosporum	*Pittosporum cornifolium*
	Pittosporum crassicaule
	Pittosporum divaricatum
Tarata, Kīhihi, Lemonwood	*Pittosporum eugenioides*
	Pittosporum rigidum
Kōhūhū, Kohukohu, Tawiri, Kowhiwhi, Rautāwhiri, Black matipo	*Pittosporum tenuifolium*
Turner's kohuhu, tent pole tree	*Pittosporum turneri*
Haekaro ,Tātaka	*Pittosporum umbellatum*
Mānatu, Houhi ongaonga, Lowland ribbonwood	*Plagianthus regius subsp. regius*
Kopakopa, Kaupārerarera, Tukōrehu	*Plantago species*
Piupiu, Pākau, Pākau-roharohaGully fern, feather fern	*Pneumatopteris pennigera*
Broad-leaved poa	*Poa anceps*
Silver tussock, Wī, Pātītī	*Poa cita*
Blue tussock	*Poa colensoi*

Māori, Pākehā Name	Latin Name
Weak poa	*Poa imbecilla*
	Podocarpus cunninghamii x nivalis
Tōtara-kiri-kōtukutuku, Mountain totara, Hall's totara, Raunui, thin-barked totara	*Podocarpus laetus*
Tauhinu, Mountain totara, snow totara	*Podocarpus nivalis*
Tōtara	*Podocarpus totara*
Pikopiko, Shield fern	*Polystichum neozelandicum*
	Polystichum silvaticum
Puniū, Prickly shield fern	*Polystichum vestitum*
	Polystichum wawranum
	Potamogeton species
Leek orchid	*Prasophyllum colensoi*
Miro, Toromiro, Brown pine	*Prumnopitys ferruginea*
Mataī, Black pine	*Prumnopitys taxifolia*
Pukatea, Cudweed	*Pseudognaphalium luteoalbum*
Whauwhaupaku, Houhou, Puahou, Tauparapara, Five finger	*Pseudopanax arboreus*
Orihou, Mountain five finger	*Pseudopanax colensoi*
Horoeka, Lancewood	*Pseudopanax crassifolius*
Fierce lancewood	*Pseudopanax ferox*
	Pseudopanax laetus
	Pseudopanax linearis
Horopito, Puhikawa, Lowland pepper tree	*Pseudowintera axillaris*
Horopito, Ramarama, Mountain Pepper tree, Red horopito	*Pseudowintera colorata*
Rārahu, Rarauhe, Manehu, Bracken. Aruhe (root)	*Pteridium esculentum*
Sweet fern	*Pteris macilenta*
Turawera, Tender brake	*Pteris tremula*
Tutukiwi, Greenhood Orchid	*Pterostylis banksii*
	Pterostylis cardiostigma
Grass-leaved Greenhood	*Pterostylis graminea*
Swamp Greenhood	*Pterostylis micromega*
Greenhood	*Pterostylis montana*
Greenhood	*Pterostylis venosa*
Ota, Leather leaf fern	*Pyrrosia eleagnifolia*
	Quintinia acutifolia
Tāwheowheo	*Quintinia serrata*
Raoriki, waoriki, Water buttercup	*Ranunculus amphitrichus*
	Ranunculus recens
Maru, Mārūrū, Kōpukapuka, Pirikau, Hairy buttercup	*Ranunculus reflexus*
Tutāhuna	*Raoulia species*
	Raukaua anomalus
Raukawa, Kōtara, Koare, Rauraua	*Raukaua edgerleyi*

Māori, Pākehā Name	Latin Name
Haumakōroa	*Raukaua simplex*
	Raukaua simplex var. sinclairii
Taurepo, kaikaiatua, mātātā, waiūatua, NZ gloxinia	*Rhabdothamnus solandri*
Nīkau	*Rhopalostylis sapida*
Kareao, Supplejack	*Ripogonum scandens*
Tātarāmoa, Bush lawyer, Swamp lawyer	*Rubus australis*
Tātarāmoa, Bush lawyer	*Rubus cissoides*
Creeping lawyer	*Rubus parvus*
Tātarāmoa, Bush lawyer, white-leaved lawyer	*Rubus schmidelioides*
Leafless lawyer, yellow-prickled lawyer	*Rubus squarrosus*
Leathery shield fern, florists fern	*Rumohra adiantiformis*
Dainty bristle grass	*Rytidosperma gracile*
Bristle grass	*Rytidosperma nigricans*
Bristle tussock	*Rytidosperma setifolium*
Patē, Patetē, Kōtētē, Seven-finger	*Schefflera digitata*
	Schizaea bifida
	Schizeilema trifoliolatum
Dwarf bog rush	*Schoenus maschalinus*
Bog rush, sedge tussock	*Schoenus pauciflorus*
Remuremu	*Selliera radicans*
Selliera	*Selliera rotundifolia*
Australian fireweed	*Senecio bipinnatisectus*
Fireweed	*Senecio minimus*
Fireweed	*Senecio scaberulus*
Mountain fireweed	*Senecio wairauensis*
Poroporo	*Solanum aviculare*
Poroporo, Hōreto, Bullibulli	*Solanum laciniatum*
Small-flowered nightshade	*Solanum nodiflorum*
Rauriki, Pūhā	*Sonchus species*
Kōwhai, Kōwhai tāepa, Weeping kowhai	*Sophora microphylla*
Kōwhai, Large-leaved kowhai	*Sophora tetraptera*
Slender chickweed	*Stellaria gracilenta*
Kohukohu, NZ chickweed	*Stellaria parviflora*
Waekura, Tapuwae kōtuku, Umbrella fern	*Sticherus cunninghamii*
Tūrepo, Small-leaved milk tree	*Streblus heterophyllus*
Maire tawhake, waiwaka, Tuhuhi (W), Whawhakou (W), Swamp maire	*Syzygium maire*
Tohetaka	*Taraxacum species*
Māikaika, White Sun Orchid	*Thelymitra longifolia*
Māikaika, Striped Sun Orchid, Beautiful Sun Orchid	*Thelymitra pulchella*
Fork fern	*Tmesipteris elongata*

Māori, Pākehā Name	Latin Name
Fork fern	*Tmesipteris lanceolata*
Fork fern	*Tmesipteris tannensis*
Toro, toru (W)	*Toronia toru*
Bristle fern	*Trichomanes elongatum*
	Trichomanes endlicherianum
Erect bristle fern	*Trichomanes strictum*
Veined bristle fern	*Trichomanes venosum*
Raupō, Ngāwhā, Kōpūpūngāwhā, Bulrush	*Typha orientalis*
Ongaonga, Taraonga, Tree nettle	*Urtica ferox*
Red Hills hebe	*Veronica baylyi*
Fiordland Parahebe	*Veronica catarractae*
Hebe	*Veronica colensoi*
Hebe	*Veronica corriganii*
Koromiko	*Veronica salicifolia*
Koromiko	*Veronica stricta*
Whipcord hebe	*Veronica tetragona*
Mountain violet	*Viola cunninghamii*
Forest violet	*Viola filicaulis*
NZ harebell	*Wahlenbergia albomarginata*
North Island harebell	*Wahlenbergia pygmaea*
Rimuroa, Violet harebell	*Wahlenbergia violacea*
Kāmahi, tawhero, tōwai	*Weinmannia racemosa*
Water-meal	*Wolffia australiana*

Non-native plant species

Māori, Pākehā Name	Latin Name
	Acacia melanoxylon
	Acaena agnipila
	Achillea millefolium
	Agrostis capillaris
	Agrostis stolonifera
Pimpernel	*Anagallis arvensis*
Stinking mayweed	*Anthemis cotula*
Blue wheat grass	*Anthosachne scabra*
Sweet vernal	*Anthoxanthum odoratum*
Parsley piert	*Aphanes arvensis*
	Aphanes species
Burdock	*Arctium minus*
Climbing asparagus	*Asparagus scandens*
	Aster species

Māori, Pākehā Name	Latin Name
Barberry	*Berberis glaucocarpa*
	Blechnum patersonii
Soft brome	*Bromus hordeaceus*
Buddleia	*Buddleja davidii*
Water starwort	*Callitriche stagnalis*
Heather	*Calluna vulgaris*
Cannabis, marijuana	*Cannabis sativa*
	Carex leporina
Centuary	*Centaurium erythraea*
Mouse ear chickweed	*Cerastium fontanum*
	Cerastium fontanum subsp. vulgare
Annual mouse-ear chickweed	*Cerastium glomeratum*
Lawson's cypress	*Chamaecyparis lawsoniana*
Californian thistle	*Cirsium arvense*
Marsh thistle	*Cirsium palustre*
Scotch thistle	*Cirsium vulgare*
Old man's beard	*Clematis vitalba*
Hemlock	*Conium maculatum*
	Conyza albida
Broad-leaved flea-bane	*Conyza sumatrensis*
Pampas grass	*Cortaderia selloana*
Khasia berry	*Cotoneaster simonsii*
	Cotyledon species
Hawthorn	*Crataegus monogyna*
Hawksbeard	*Crepis capillaris*
Montbretia	*Crocosmia x crocosmiiflora*
Macrocarpa	*Cupressus macrocarpa*
Crested dogstail	*Cynosurus cristatus*
Broom	*Cytisus scoparius*
Cocksfoot	*Dactylis glomerata*
Wild carrot	*Daucus carota*
German ivy	*Delairea odorata*
Foxglove	*Digitalis purpurea*
	Dryopteris species
	Elytranthe species
Willowherb	*Epilobium ciliatum*
Spanish heath	*Erica lusitanica*
Alpine ash	*Eucalyptus delegatensis*
	Freycinetia baueriana
Cleavers	*Galium aparine*

Māori, Pākehā Name	Latin Name
Marsh bedstraw	*Galium palustre*
Purple Cudweed	*Gamochaeta coarctata*
	Geniostoma rupestre
	Gentiana species
Namunamu, Doves foot, cranesbill	*Geranium molle*
	Geranium robertianum
	Gnaphalium species
Tussock hawkweed	*Hieracium lepidulum*
Yorkshire fog	*Holcus lanatus*
	Hordeum species
	Hydrocotyle americana
	Hymenophyllum ferrugineum
St John's wort	*Hypericum perforatum*
Catsear	*Hypochaeris radicata*
	Isolepis fluitans
Ragwort	*Jacobaea vulgaris*
Leafless rush	*Juncus amabilis*
Jointed rush	*Juncus articulatus*
Toad rush	*Juncus bufonius*
	Juncus effusus
Leafless rush	*Juncus effusus var. effusus*
	Juncus gregiflorus
	Juncus tenuis
Track rush	*Juncus tenuis subsp. tenuis*
Acrid lettuce	*Lactuca virosa*
Nipplewort	*Lapsana communis*
Bay tree, Laurel	*Laurus nobilis*
	Leontodon saxatilis
Oxeye daisy	*Leucanthemum vulgare*
Himalayan honeysuckle	*Leycesteria formosa*
	Libertia pulchella
Pale flax	*Linum bienne*
Purging flax	*Linum catharticum*
Perennial rye grass	*Lolium perenne*
Japanese honeysuckle	*Lonicera japonica*
Lotus	*Lotus pedunculatus*
Hairy birdsfoot trefoil	*Lotus suaveolens*
Tree lupin	*Lupinus arboreus*
	Luzula multiflora
Hyssop loosestrife	*Lythrum hyssopifolia*

Māori, Pākehā Name	Latin Name
Horehound	*Marrubium vulgare*
	Melicytus dentatus
Pennyroyal	*Mentha pulegium*
Wall lettuce	*Mycelis muralis*
Catnip	*Nepeta cataria*
	Neslia paniculata
Broomrape	*Orobanche minor*
Tarweed	*Parentucellia viscosa*
Mercer grass	*Paspalum distichum*
Water pepper	*Persicaria hydropiper*
Timothy grass	*Phleum pratense*
Inkweed	*Phytolacca octandra*
Orange hawkweed	*Pilosella aurantiaca*
Radiata pine	*Pinus radiata*
Narrow-leaved plantain	*Plantago lanceolata*
Broad-leaved plantain	*Plantago major*
Annual poa	*Poa annua*
Rough-stalked meadow grass	*Poa trivialis*
	Polypodium species
Self-heal	*Prunella vulgaris*
	Prunus species
	Pseudotsuga menziesii
Buttercup	*Ranunculus repens*
Blackberry	*Rubus fruticosus*
Sheep's sorrel	*Rumex acetosella*
Clustered dock	*Rumex conglomeratus*
Broad-leaved dock	*Rumex obtusifolius*
Fiddle dock	*Rumex pulcher*
Pearlwort	*Sagina apetala*
Grey willow, pussy willow	*Salix cinerea*
Tall fescue	*Schedonorus arundinaceus*
	Selaginella kraussiana
Groundsel	*Senecio vulgaris*
Stone parsley	*Sison amomum*
	Sisyrinchium iridifolium
Bittersweet	*Solanum dulcamara*
Black nightshade	*Solanum nigrum*
Sea Sowthistle	*Sonchus maritimus*
Rauriki, Pūhā, Sow thistle	*Sonchus oleraceus*
Hedge woundwort	*Stachys sylvatica*

Māori, Pākehā Name	Latin Name
	Symphyotrichum subulatum
Dandelion	*Taraxacum officinale*
Yellow clover	*Trifolium aureum*
Suckling clover	*Trifolium dubium*
Lesser suckling clover	*Trifolium micranthum*
Red clover	*Trifolium pratense*
White clover	*Trifolium repens*
Gorse	*Ulex europaeus*
Stinging nettle	*Urtica incisa*
Woolly mullein	*Verbascum thapsus*
Moth mullein	*Verbascum virgatum*
Water speed-well	*Veronica anagallis-aquatica*
Field speedwell	*Veronica arvensis*

Appendix 2: Vegetation plots in the Whanganui catchment

The number of plots indicated for each survey includes those which are in the Whanganui catchment, not the total number of plots in the associated survey. Further information is available from NVS (http://nvs.landcareresearch.co.nz).

National surveys

LUCAS and Tier 1 monitoring

The Land Use and Carbon Analysis System (LUCAS) and the National Biodiversity Monitoring and Reporting System (Tier 1) measure and report on New Zealand's carbon storage and biodiversity. For native forest and shrubland vegetation a national grid-based network of permanent plots is measured to provide an unbiased estimate of carbon storage and plant biodiversity. Within the Whanganui catchment there are 48 of these permanent plots, of which 37 have been measured twice. Measurement began in 2002 and is ongoing. For more information visit (http://www.mfe.govt.nz/climate-change/tracking-greenhouse-gas-emissions/measuring-forest-carbon) and (http://www.doc.govt.nz/our-work/monitoring-and-reporting-system/)

National Forest Survey (NFS)

A nationwide survey and inventory of New Zealand's forests was carried out to underpin the recognised need for management of the nation's timber resource and to protect forest lands for other purposes.

- NFS Kaimanawa 1947–1962 (1 plot)
- NFS National Park 1947–1968 (389 plots)
- NFS Ruahine 1955–1968 (23 plots)
- NFS Taranaki 1948–1968 (327 plots)
- NFS West Taupo 1946–1959 (525 plots)

Protected Natural Are (PNA) surveys

These surveys provided an inventory of an Ecological Region's remaining natural areas and aimed to discover the extent of remaining native vegetation communities and faunal habitats. On the basis of this information proposals of representative examples suitable for conservation were made. The rohe contains parts of three ecological regions surveyed in the 1980s and 1990s:

- Rangitikei 1993 (4 plots)
- Taranaki North 1985–86 (67 plots)
- Matemateaonga 1995 (5 plots)

Regional surveys

Permanent vegetation plots

Permanent plots are where fixed area plots or transects have been established, and the vegetation has been measured precisely (e.g. tagged trees, sapling and seedling counts, species lists). These are ideal for monitoring vegetation changes and the effects of management. These surveys include:

- Pukepoto Forest survey. This was first measured in 1982. Eight plots fall within the catchment boundaries, and the survey has been partially or fully remeasured four times since establishment, the most recent being in 2011
- North Island Ecological Transects were measured three times between 1959 and 2006 with between 1 and 3 plots measured in the catchment during a given survey
- Tongariro Ex Tongariro 1984–1991 (2 plots). Remeasured in 1991–1996 and 2004
- Matemateaonga 1 Forest 2004 (10 plots)
- NZ Adaptive Management of Deer 2006–2008 (4 plots)
- Pureora Forest 1982-1983 (69 plots)
- Tangarakau Scenic Reserve 2006 (2 plots)
- Whakapapa Island Habitat Inventory 2006-2007 (6 plots)

Exclosure plots

A number of surveys have set up paired exclosure and control plots to look at the impact of deer and goat browsing on the vegetation, and also the impact of controlling these ungulate populations. These surveys include:

- Erua State Forest Exclosures 1994 (2 plots) and remeasured in 2006
- Hauhungatahi (Makatote) Exclosure 2000 (2 plots)
- Nihoniho Exclosure 2007 (2 plots)
- North Taranaki Exclosure Plots 2012 (1 plot)
- Pureora Sth Exclosures 1987 (3 plots) and partial remeasure in 1996 (2 plots)
- WACEM Project 2009–2010 (6 plots). This was a remeasure of existing exclosure plots from various projects
- Waitaanga Exclosure Plots 2002–2003 (4 plots) partially remeasured in 2007 (2 plots)
- Whanganui Nat. Park: Baldy's Clearing 2006 (2 plots)
- Whanganui Nat. Park: MANGAPURUA 2002 (2 plots)

- Whanganui Nat. Park: Mangawaiiti East 2006 (2 plots)
- Whanganui Nat. Park: Mangawaiiti Exclosure 2006 (2 plots)
- Whanganui Nat. Park: Tangahoe 2006 (3 plots)

Other surveys

A number of other surveys have been carried out in the area which quantify the vegetation within a fixed area at a given point in time but are not permanently marked. General vegetation survey data include reconnaissance descriptions ('Recces') and are suitable for vegetation descriptions, studies of species distributions, and studies needing only coarse measurement of changes in vegetation. These surveys include:

- Erua State Forest 1984 (73 plots)
- Erua/ Mangamingi 1999 (24 plots)
- Matiere Forest 1999 (34 plots)
- Taranaki, North Forest 1983–1984 (120 plots)
- Tongariro 1983–1984 (114 plots)
- Waitaanga 1994 (127 plots)
- Wanganui N.P. 1986–1987 (429 plots)

Appendix 3: Bird species currently known from the Whanganui River catchment

Native bird species

Māori, Pākehā Name	Scientific Name
Australian Coot	*Fulica atra australis*
Cape Petrel	*Daption capense*
Common Diving Petrel	*Pelecanoides urinatrix*
Fairy Prion	*Pachyptila turtur*
Flesh-footed Shearwater	*Ardenna carneipes*
Fluttering Shearwater	*Puffinus gavia*
Huahou, Red Knot	*Calidris canutus*
Hutton's Shearwater	*Puffinus huttoni*
Kāhu, Australasian Harrier	*Circus approximans*
Kākā, North Island Kākā	*Nestor meridionalis septentrionalis*
Kākāriki, Red-Crowned Parakeet	*Cyanoramphus novaezelandiae*
Kākāriki, Yellow-Crowned Parakeet	*Cyanoramphus auriceps*
Kārearea, Bush Falcoln	*Falco novaeseelandiae* "bush"
Karoro, South Black Backed Gull	*Larus dominicanus*
Kāruhiruhi, Pied Shag	*Phalacrocorax varius*
Kawau, Black Shag	*Phalacrocorax carbo*
Kawaupaka, Little Black Shag	*Phalacrocorax sulcirostris*
Kawaupaka, Little Pied Shag	*Microcarbo melanoleucos*
Kererū, New Zealand Pigeon	*Hemiphaga novaeseelandiae*
Koekoeā, Long-tailed Cuckoo	*Urodynamis taitensis*
Kōkako, North Island Kōkako	*Callaeas wilsoni*
Korimako, Bellbird	*Anthornis melanura*
Kōtare, Kingfisher	*Halcyon sancta vagans*
Kōtare, Sacred Kingfisher	*Todiramphus sanctus*
Kuaka, Eastern Bar-tailed Godwit	*Limosa lapponica baueri*
Little Penguin	*Eudyptula minor*
Mātātā/ Kōtātā, North Island Fernbird	*Bowdleria punctata vealeae*
Matuku-hūrepo, Australasian Bittern	*Botaurus poiciloptilus*
Miromiro, Tomtit	*Petroica macrocephala*
Nankeen Night-Heron	*Nycticorax caledonicus australasiae*
New Zealand Dotterel	*Charadrius obscurus*
New Zealand Shoveler	*Anas rhynchotis variegata*
Ngutu parore, Wrybill	*Anarhynchus frontalis*
North Island Brown Kiwi	*Apteryx mantelli*
Toutouwai, North Island Robin	*Petroica longipes*
Northern Giant Petrel	*Macronectes halli*

Māori, Pākehā Name	**Scientific Name**
Pāpango, also matapouri, titiporangi, raipo, New Zealand Scaup	*Aythya novaeseelandiae*
Pārekareka, Spotted Shag	*Phalacrocorax punctatus*
Pārera, Grey Duck	*Anas superciliosa*
Pīhoihoi, New Zealand Pipit	*Anthus novaeseelandiae novaeseelandiae*
Pīpīwharauroa, Shining Cuckoo	*Chrysococcyx lucidus*
Pīwakawaka/tīwaiwaka, Fantail	*Rhipidura fuliginosa*
Poaka, Pied Stilt	*Himantopus himantopus leucocephalus*
Pohowera, Banded Dotterel	*Charadrius bicinctus bicinctus*
Pōpokatea, Whitehead	*Mohoua albicilla*
Pūkeko	*Porphyrio melanotus*
Pūtangitangi, Paradise Shelduck	*Tadorna variegata*
Pūweto, Spotless Crake	*Zapornia tabuensis*
Riroriro, Grey Warbler	*Gerygone igata*
Royal Spoonbill	*Platalea regia*
Ruru, Morepork	*Ninox novaeseelandiae*
Spur-winged Plover	*Vanellus miles*
Tākapu, Australasian Gannet	*Morus serrator*
Tara piroe, Black-fronted Tern	*Chlidonias albostriatus*
Tara, White-fronted Tern	*Sterna striata striata*
Taranui, Caspian Tern	*Hydroprogne caspia*
Tarāpunga, Black-billed Gull	*Chroicocephalus bulleri*
Tarāpunga, Red-billed gull	*Larus novaehollandiae scopulinus*
Tauhou, Silvereye	*Zosterops lateralis*
Tete, Grey Teal	*Anas gracilis*
Tītī, Sooty Shearwater	*Ardenna grisea*
Tītitipounamu, North Island Rifleman	*Acanthisitta chloris granti*
Tōrea tuawhenua, South Island Pied Oystercatcher	*Haematopus finschi*
Tui	*Prosthemadera novaeseelandiae*
Variable Oystercatcher	*Haematopus unicolor*
Welcome Swallow	*Hirundo neoxena neoxena*
Weweia, New Zealand Dabchick	*Poliocephalus rufopectus*
Whio, Blue Duck	*Hymenolaimus malacorhynchos*
White-faced Heron	*Egretta novaehollandiae*

Non-Native bird species

Māori, Pākehā Name	Scientific Name
Black Swan	*Cygnus atratus*
Blackbird	*Turdus merula*
California Quail	*Callipepla californica*
Canada Goose	*Branta canadensis*
Cattle Egret	*Bubulcus ibis*
Chaffinch	*Fringilla coelebs*
Dunnock	*Prunella modularis*
Eastern Rosella	*Platycercus eximius*
Goldfinch	*Carduelis carduelis*
Greenfinch	*Chloris chloris*
Greylag Goose	*Anser anser*
Helmeted Guineafowl	*Numida meleagris*
House Sparrow	*Passer domesticus*
Indian Peafowl	*Pavo cristatus*
Magpie	*Gymnorhina tibicen*
Mallard	*Anas platyrhynchos*
Muscovy Duck	*Cairina moschata*
Mute Swan	*Cygnus olor*
Myna	*Acridotheres tristis*
Redpoll	*Acanthis flammea*
Ring-necked Pheasant	*Phasianus colchicus*
Rock Pigeon	*Columba livia*
Rook	*Corvus frugilegus*
Skylark	*Alauda arvensis*
Song Thrush	*Turdus philomelos*
Spotted Dove	*Streptopelia chinensis*
Starling	*Sturnus vulgaris*
Turkey	*Meleagris gallopavo*
White Heron	*Ardea alba*
Yellowhammer	*Emberiza citrinella*

Appendix 4: Names of tuna varieties recorded from Whanganui catchment by Downes (1918) and Best (1929)

Tuna varieties (Whanganui)	Description
Tunaheke – Migrating eel (Migrate from March-May)	
ngahuru First of tunaheke to go down rivers; from Mangawhio lake system?	Eel with thick, soft greeny-brown skin seemingly sprinkled with fine gold-dust Large eye, outer ring of blue, gold iris, black pupil. Difficult to skin.
hau (Whanganui name) or hao (Waitotara). Also called puhi and pango	Mud eel. Silvery belly. Blue-eyed, Best eating Difficult to skin.
riri (Whangaehu) rere (Whanganui) putairoe	Blue-black eel, large pectoral fins, rather small mouth and teeth, flat head, broad tail, blue eyes. Hard skin. Very lively. Finest of all eel flesh, resembling wild pork.
paranui	Black eel.
ruahine	Very large, but short.
arawaru	Not so thick but longer than ruahine
monanui	Small variety.
keke	"somewhat larger"
kuia	Largest of all, filled with roe, only seen and caught for 2-3 days per year.
riki	Eel fry going upstream. Fished at Ohura mouth.
Tunahoke or tarahe – Generic name for eels that remain in one place, taken with bait	
puharakeke	Large, yellowish-brown-skinned eel, common. Piharau used for bait if possible. Large head, small eyes with black pupil, ring of bright gold, outside ring of dull gold. Lower jaw protrudes, giving bull-dog appearance. Teeth sharp, set thickly, run back like a wedge. Under part of head whitish. Often grows to immense size.
pa	Always roasted overnight, a delicacy
iakaaka (hiakaaka). Perhaps same as taiaka	Light-green colour, considered inferior to tuna-pa, requires considerable boiling. Never grilled.
kaingara	Poor and lean, carries no fat, large head. Yellowish colour.
tuhoro	Black eel, long, very large head and small tail. Fast swimmer. No slime. Fish of ill omen. Never eaten.
piki	Pig-eared eel with hair or bristles on back. Black, with cream or pale yellow belly.
kohau	Mud eel
koiero, koiro, ngoiro	Conger eel (salt-water)
taiaka	Fine head, hard skin, will not boil tender.
ngahuru	
opuha or hopuha	
kopure	
tangaroa	
kaueri	