Gravel Management Plan

Gravel Resource Inventory (Issue 3)

For

Hawke's Bay Regional Council

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EXECUTIVE SUMMARY

This report covers Issue 3 "Gravel Resource Inventory" identified as one of 13 key issues by Hawke's Bay Regional Council into ways of improving the council's gravel management plan for the Region. The key objectives of the study are;

- Identification of resource locations, resource volumes available for potential extraction and aggregate quality.
- To identify and assess risks in gravel supply and quality.
- Assist in determining the sustainability of the river based gravel resource.
- Provide input into the gravel management plan.

The study methodology involved site visits to extraction sites and the main operations, compilation of river production data from HBRC records and reports, compilation into a GIS, interviews with various stakeholder groups including Hawke's Bay Regional Council (HBRC), District Councils, the main producers, individual roading contractors, contracting companies and a wider literature search into aspects of the geology and aggregate quality.

The Hawke's Bay region can be broadly divided into several physiographic regions that have distinct features reflecting their underlying geology. The main physiographic regions that are of relevance to the river gravel aggregate resources are the Ruataniwha and Heretaunga Plains and the North Island axial greywacke ranges that lie to the west of the outwash gravels that form the plains.

The source rocks from the axial ranges belong mainly to the Torlesse type quartzofeldspathic greywackes of the Kaweka Terrane as well as lesser contributions from the Pahau Terrane and Waioeka Petrofacies that become more prevalent to the north. Kaweka Terrane greywackes in general produce premium aggregates by the time they have been naturally abraded through fluvial processes in the main river systems. They invariably have some laumontite veining which can have adverse effects on aggregate if present in large quantities. Other gravels from the Pahau Terrane and Waioeka Petrofacies are likely to have higher quantities of deleterious minerals.

Estimates of gravel sitting above the grade line in the **Ngaruroro River** show in the 2013-2014 year there is an average net gravel resource availability of 2.56 million m^3. Of this total there is approximately 519,000m^3 above grade line within the areas where the main extraction is occurring. Assuming, based on gravel transport modelling an average addition of 170,000m^3 per annum of new gravel to the catchment and flowing through the extraction reaches suggests the areas of extraction could reach grade line in 3.5 to 5 years. An additional 7 to 10 years of resource would be available further upstream of current main extraction sites.

This scenario is at variance to other observations over time. Similar analyses based on gravel volume data undertaken at particular time periods since 1977 produce similar results that show gravel supplies would have run out by now.

Clearly this has not occurred and estimates are roughly the same now as in the past. This suggests there are other inputs and refinements to the river modelling required to get an accurate estimate of the sustainable extractable yield of gravel from the river.

It is essential that further study is carried out to determine the sustainable gravel extraction rate, gravel transport rates and depositional site variation and grainsize variability over time.

If the scenario under the current analysis is correct then the implication is that aggregate supplies could reach an unsustainable level in 3.5 to 5 years at the current sites with adverse implications for aggregate producers and for flood control.

It is recommended that further detailed modelling is conducted to determine the drivers for gravel supply and a more robust supply model developed.

To obtain more detailed data it is recommended:

- To use lidar data and closely spaced survey sections, (250m apart) to generate a more accurate model of the resource along with updated gravel size analysis on the surface and in depth profiles to the depth limits that extractors are allowed to excavate to.
- Assess the impact of hydrological and weather pattern changes on gravel transport. There is a suggestion that there may be a decadal downward trend in volumes above grade line, possibly due to changes in flood frequency and climate change.
- Assess the geomorphology and geology of gravel source areas which may have changed since the last survey was done in 1997.

Another issue is the conclusion there is or will be a gradual fining of gravel over time at the current extraction sites due to selective targeting of coarser gravel in the river by extractors, possibly compounded by reduced flood event frequency. There is a minimum size limit of around 30mm in order achieve around 75% broken faces for sealing chip and premium base-course products. Currently only approximately 50% to 60% of raw gravel extracted is utilised as saleable product for at least one of the major producers.

Total net gravel resource above the grade line in the **Upper Tukituki River** are around 881,981m^3 for the 2013/2014 year. Actual recorded production of gravel from the Upper Tukituki has ranged between 60,000 m^3 in 2000 to a low of around 10,000 m^3 in 2013. Current production is impacted by one of the main producers ceasing gravel extraction.

Assuming production levels increase again to the average over the last 10 years of around 41,000 m^3 and assuming that addition of new gravel to the system at least equivalent to that modelled for the Ruataniwha Dam of between 140,000 m^3 and 180,000 m^3 for the other catchments feeding into the Upper Tukituki then there should be adequate supplies for the long term in this portion of the river.

There is likely to be an issue with the build-up of gravel above grade line over time with dependency on extraction, rate of movement of gravel through the system to lower reaches, flood event frequency, aggradation rates etc.

The **Middle Tukituki River** potentially has large resources of gravel. Sectional data is available however HBRC at this stage have not determined an appropriate grade line for this reach of the river. Using estimates based on the most conservative scenario of using the 0.5m above Thalweg it can be seen that there is potentially **14 million m^3 of gravel available.**

Morphological modelling is in progress for the whole Tukituki River utilising the GRATE simulation programme. Once complete this will provide information on gravel supply and sustainability.

There is currently 9,246m^3 of gravel above grade line at the design level in the **Lower Tukituki River**.

HBRC policy is to manage the resource sustainably taking into account that there has historically been over extraction in the Lower Tukituki River. It is the only major river system delivering gravel to the coast where northward longshore drift helps replenish gravel on the coast up to Napier and there is still a deficit of gravel in what is effectively a sink.

The currently surveyed design volumes for the **Waipawa River** show a net volume of gravel above grade line of 1,509,935 m^3. The lower reaches of the Waipawa River are at or just below grade line, while between Section lines 17 and 39 there is some 1,455,000m^3 of gravel available.

Average recorded production between 2003 and 2011 has been around 102,000m^3 per annum. Allocations for 2013-2014 are similar however the major operator here, has gone out of business.

Estimates of sustainability of supply at the average of 100,000m^3 per annum would see enough resource to last a minimum of at least 16 years before the grade line level is reached for the Waipawa River.

Encouraging the aggregate industry to extract gravel from the Waipawa River at around the estimated sustainable rate is considered important for flood control management.

Past over extraction of gravel on the **Tutaekuri River** now means only small volumes are available. To remain sustainable the current HBRC allocations of around 20,500m^3 are appropriate.

The **Esk** River has in the past been heavily over extracted. No major extraction is warranted here.

Current (2013-2014) allocations for the **Mohaka River** (upper and lower) total approx. 100,000m^3. Actual recorded production returns have averaged approx. 47,000m^3 for the period 2003 to 2013.

The majority of current production from fixed/mobile plant is in the lower reaches of the river and near the river mouth, and from the relatively small volumes involved it is concluded that there are no issues with the current extraction rates.

The **Waiau River** produces generally small volumes which averaged 17,350m^3 per annum from 2003 to 2013. Much of the gravel is used for general road maintenance, forestry and by local contractors. Given the small volumes extracted and the likely subdued demand it is concluded there will no issue with sustainability of supply.

Industry sources who extract gravel from this river also describe difficulties in obtaining premium product due to the presence of pumiceous silt and 'papa rock' where the gravel bed is thin above the Tertiary sedimentary basement.

Recent gravels that lie outside the active river channels are potentially an important source of gravel in the future should extraction from the active river channels become restricted due to sustainability or other issues.

At present there is thought to be only one consented land based extraction operation based near Maraekakaho on the Ngaruroro River, which is mining recent river gravels as opposed to the gravel pits in the raised terraces.

Land based **gravel pits** form an important part of the overall aggregate supply to the region. Sourced from Quaternary aged gravel terraces of the Kidnappers Group, these are sometimes referred to colloquially as red rock pits, and are typically slight to moderately weathered river terrace gravels uplifted above the main active river channels.

They are used by the local construction industry, forestry roading, maintenance metal on unsealed roads and general roading maintenance and could represent about 25% of total gravel extraction for the region.

Observations and industry feedback indicates that, for the large producers in particular on the Ngaruroro, with one exception**,** approximately 60% of the gravel, sand and silt excavated ends up as useable product. Minimum grain size for crushing is around 30mm to 40mm to ensure enough broken faces for chip and base course products. A certain amount of undersize is used for concrete aggregates, drainage products, fill etc, however, the large percentage that can't be used for premium aggregate is stockpiled.

Selective targeting coarser material is likely to result in a long term reduction in gravel grain size and could adversely impact on the economics of extracting from the lower reaches.

It is recommended that in the areas of active gravel extraction a programme of pitting and/or shallow drilling be conducted to establish grainsize distribution through the resource areas in 3 dimensions.

The gravel source rocks are mainly highly indurated zeolite facies metamorphosed quartzofeldspathic greywacke sandstones and argillites. Some elements of these are strongly veined with deleterious minerals such as the zeolite laumontite and some smectite, (swelling) clay minerals.

Natural abrasion from gravel movement downstream winnows out most of the softer material. However zeolite and clay minerals or high sulphides can persist. Processing can remove these less desirable minerals however in some products such as GAP (general all passing) products the fines can concentrate deleterious minerals. Geotechnical testing usually detects issues however there is a lack of petrological data to establish baseline variability in the constituent rock types that make up the gravel resources from the different river catchments. It is recommended that baseline petrological and X-Ray diffraction studies be carried out on representative samples from each of the major extraction areas on each river.

In terms of aggregate quality the gravels in the Hawke's Bay region, being derived from Torlesse Terrane greywackes, are at the higher end of the range in performance.

In terms of encouraging extractors to move some operations to other rivers where HBRC want extraction for flood control it would worth considering obtaining some independent geotechnical test data to demonstrate compliance with aggregate specifications.

As discussed in the sister report "Gravel Demand Forecast (Issue 5) the HBRC allocates gravel extraction volumes on an annual basis, commencing 1 July each year. Feedback from most extractors is that this process works well, however some of the larger extractors have said that a one year time frame is too short for strategic business planning and investment purposes.

This business risk may be even more pronounced if further studies show that the supply risk on the Ngaruroro River is real and HBRC needs to take action to reduce production here.

1.0 BACKGROUND

This report covers one of the key issues identified in a scoping report instigated by Hawke's Bay Regional Council (HBRC) and prepared by Tonkin and Taylor in 2010 into ways of improving the Council gravel management plan for the Region.

There has been recognition by stakeholders including gravel extractors, district councils, and HBRC for better information on gravel resources in the Hawke's Bay Region to enable more informed decisions on resource allocation, the needs of industry for security of supply and business planning and HBRC's responsibilities to manage the river catchments and gravel resources sustainably.

Some 13 main issues were identified, two of which required the input from 'independents' with experience in the aggregates industry. These are the Gravel Resource Inventory, (Issue 3), the subject of this study and Gravel Demand Forecast (Issue 5), the latter which was completed in February 2015.

The other issues identified are either completed or at various stages of study with the ultimate aim of incorporating all into a Riverbed Gravel Management Plan.

2.0 SCOPE AND OBJECTIVES

The Gravel Resource Inventory Study has the following key objectives;

- Identification of resource locations, resource volumes available for potential extraction and aggregate quality.
- Identify and assess risks in gravel supply and quality.
- Assist in determining the sustainability of the river based gravel resource.
- Provide input into the gravel management plan

The preliminary scope of work outlined by HBRC details the following requirements:

- Identification and mapping of gravel source locations (maps to be produced on GIS base).
- Incorporate information from Gravel Supply and Transport study (Issue 2)
- Estimate of available volumes (from Gravel Supply and Transport study (Issue 2))
- Assessment of material type (quality and mineralogy) and size (including in context of industry requirements)
- Land-use zoning and constraints in district plans
- Assessment of capacity of current and potential land-based quarries
- River access mapping (excluded from this report)
- Input on environmentally sensitive areas from Ecological Effects studies (Issues 7 and 8) (Excluded from this report)
- Gain input from industry representatives

The inventory is to also cover land based gravel resources as there are a number of operators using these resources of varying quality for specific purposes, while they could be a future source of aggregate if river gravel supply is limited in some catchments.

3.0 METHODOLOGY

3.1 Site Visits

Preliminary site visits were carried out in conjunction with the Gravel Demand study (Issue 5) on 14 and 15 October, 2014 and again on 12 to 14 November, 2014. This involved brief site visits with HBRC personnel to several representative river extraction sites, particularly on the Tukituki and Waipawa Rivers. Site visits were undertaken to the three main river gravel extraction operating sites on the Ngaruroro, being Holcim and Higgins plus the Winstones/Firth site on the coast at Awatoto. In addition the site of Infracon extraction on the Waipawa River near Waipukurau was examined and Higgins' land based operation at Maraekakaho.

3.2 Programmes/GIS

Databases were prepared from HBRC raw data, cross sectional survey data and volume estimates calculated by HBRC using their Xsection programme on volumes of aggregate available for each of the main river systems and plotted using the GIS programme MapInfo Version 12.5.2/Discover 2014.0.2 and plots produced as detailed throughout this document. Raster imagery and vector data were obtained from LINZ and GNS Science.

3.3 Interviews

A series of interviews and meetings were held with various stakeholder groups including HBRC staff Engineering Section and of industry representatives from the main producers including Winstone Aggregates, Holcim, Higgins Aggregates, and Wairoa Metal Supplies. QRS, Infracon and the 4 local authorities (Napier City, Hastings District, Central Hawke's Bay District and Wairoa District Councils).

In addition valuable information was gathered from discussions with a number of the main road maintenance contractors from the region.

3.4 Literature research

Data and reports were provided by HBRC as detailed in the references at the rear of the document. In addition the GERM database of New Zealand mineral occurrences and all inactive and active quarries and mines was reviewed. This database was current up until 1999 but does provide a useful guide to quarrying operations throughout the region.

The geological discussion is derived from researching the available literature much of which is summarised in the QMAP 1:250,000 Geological Map series produced by GNS Science.

Other sources of information included the work being carried out by Professor Philippa Black of Auckland University and the FRST funded "Geologic Inventory of North Island Aggregate Resources".

4.0 RIVER CATCHMENTS AND GEOMORPHOLGY

4.1 General

The Hawke's Bay area can be broadly divided into several physiographic regions that have distinct features reflecting their underlying geology. The main physiographic regions that are of relevance to the aggregate resources are discussed as follows. Figure 1 shows the main physiographic regions.

4.2 Ruataniwha Plains

The Ruataniwha Plains between Dannevirke and Tikokino are underlain by Quaternary alluvial gravels eroded from the adjacent Ruahine Range. The oldest terraces, of early Quaternary age, are folded and warped by surface and sub-surface reverse faults (Lillie 1953; Melhuish 1990; Beanland *et al*. 1998). Along the Ruahine Range front, terraces between Wakarara and Norsewood reach elevations of circa 500 m. South of Takapau, rivers drain south into the Manawatu River, which flows west through the axial ranges via the Manawatu Gorge and drains to the west coast. North of Takapau, rivers including the Tukipo, Waipawa, Makaroro and Makaretu Rivers drain into the Tukituki River, which flows into Hawke Bay.

4.3 Heretaunga Plains

Napier, Hastings and Havelock North are sited on an extensive alluvial plain deposited adjacent to southern Hawke Bay where the Tukituki, Ngaruroro and Tutaekuri rivers converge. These rivers have a catchment area of 5,900 km2. Within about five kilometres of the coast near Clive, estuarine, lagoon and beach sediments underlie surficial alluvial gravels and were deposited before progradation of the coastline began about 6,500 years ago (Dravid & Brown 1997). Part of the coastal area between the Napier harbour entrance and the Esk River mouth, formerly known as the Ahuriri Lagoon, was uplifted by at least one metre (Hull 1986, 1990; Litchfield *et al*. 2005) during the 1931 Hawke's Bay Earthquake.

Figure 1: Main catchments and geomorphic features of Hawke's Bay (Lee et al 2011)

4.4 Northern Hawke's Bay Hill Country

Northeast-trending strike ridges of Neogene sandstone, limestone and conglomerate are prominent features of the landscape of northern Hawke's Bay, and in general, bedding dips gently to the southeast. The Mohaka, Ngaruroro, Tutaekuri and Waiau rivers that begin in the axial ranges, cut through the hill country to the coast.

4.5 North Island Axial Ranges

The southwest-northeast trending axial ranges of the North Island, pass through the Hawke's Bay on the western side of the region. They include the Ruahine, Wakarara, Kaweka, Ahimanawa ranges and Kaimanawa Mountains. These are mostly composed of greywacke and are the main source rock for the gravel resources in the Heretaunga and Ruataniwha Plains. They are onlapped by Paleogene and Neogene sedimentary rocks or, in the northwest, mantled by Quaternary volcanic rocks. Major, sometimes active, faults within the ranges control the drainage pattern, as seen with the Ruahine and Mohaka Faults in the Ruahine Range. Localised remnants of Neogene rocks found hundreds of metres above sea level in the Ruahine Range imply that the erosion surface was formed before the Pliocene (Beu *et al*. 1981; Browne 2004a).

5.0 GEOLOGY

5.1 Hawke's Bay Regional Geology

The regional geology of the Hawke's Bay comprises Jurassic to Cretaceous aged greywacke rocks that form the Ruahine, Kaweka, Kaimanawa and Ahimanawa north-east trending axial ranges in the western part of the region. Uplift and erosion of these rocks over time has produced the primary source rocks of the gravels that are extracted in Hawke's Bay region.

Figure 2 shows a generalised geological map of Hawke's Bay region.

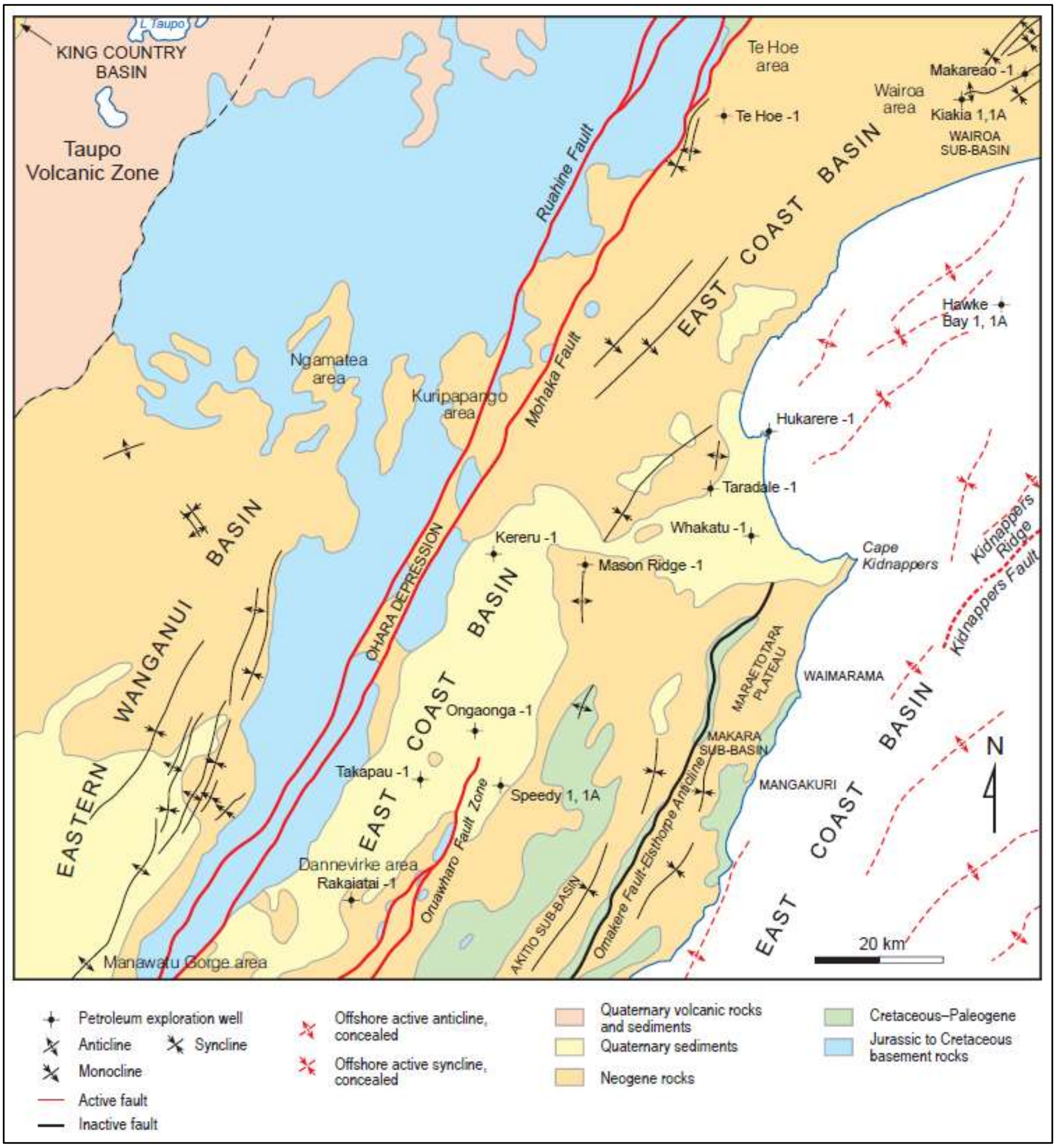

Figure 2: Generalised geology of Hawke's Bay (Lee et al 2011)

These rocks are separated by several NE trending major active faults, namely the Ruahine and Mohaka Faults, from the East Coast Basin comprised of Cretaceous to Plio-Pleistocene aged (Neogene) sequences of marine to terrestrial sediments that include significant mudstone, sandstone and limestone deposits. In terms of source rocks for aggregate these are of minor importance apart from some conglomeratic units that get eroded and reworked into the active river systems.

Within the Hawke's Bay region the youngest rocks of Quaternary age have been divided based on age and stratigraphy. The main groups recognised are:

Kidnappers Group - mid to late Quaternary sediments in the East Coast Basin**, (**Fleming 1959; Kingma 1971) and its correlatives, of Pleistocene age, are up to 600 m thick and unconformably overlie Pliocene Mangaheia Group. The deposits crop out in the Ruataniwha area, to the east of the Ruahine and Wakarara ranges, in the Waipawa and Waipukurau areas, at Cape Kidnappers and locally in the Napier area. These sediments are less pumiceous in the east, where they are mainly conglomeratic.

At the type section at Cape Kidnappers, basal fossiliferous sandstone, unconformably overlying Late Pliocene rocks, passes upward into thick-bedded conglomerate, sandstone and carbonaceous mudstone, with intercalated tephra and ignimbrite beds. In the Napier area, Kidnappers Group deposits are mostly poorly sorted greywacke gravels with interbedded sand and silt (Bland *et al*. 2007). Thinly layered sandstone and siltstone, with locally abundant plant material, are probably lake deposits (Kingma 1971).

Landslide deposits -Landslide deposits comprise a variety of rock and soil debris, depending on source area rock types. Landslides are common in hilly and mountainous areas, although most are small. Major landslides within the axial ranges are shown in Figure 3 and are an important source of greywacke for the river catchments of the Ruataniwha and Heretaunga Plains as well as the more northerly rivers such as the Mohaka and Waiau.

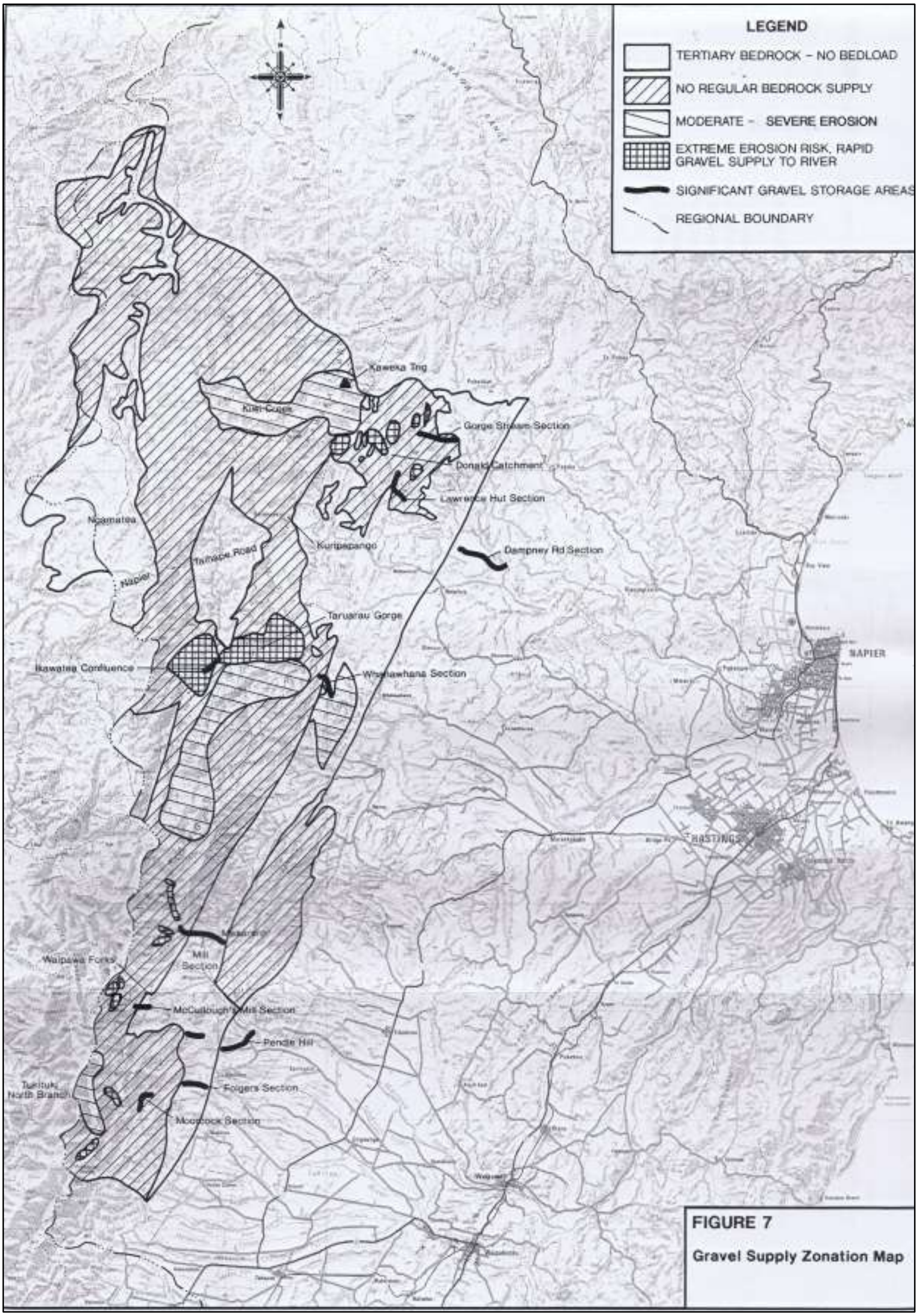

Figure 3: Areas of major land slides and erosion in the axial ranges. (Source Black, 1992)

Alluvial fan, scree and colluvial deposits

Alluvial fan, scree and colluvial deposits are present in areas with steep topography. They commonly contain a higher proportion of silt and clay than alluvial terrace deposits. The deposits consist of unconsolidated, locally derived, angular to sub-rounded pebbles, cobbles and boulders.

Alluvial terrace and floodplain deposits

Alluvial terrace and floodplain gravel, sand, silt and mud, deposited by rivers and streams, occur in large areas along river edges and in the Heretaunga and Ruataniwha plains. They typically comprise moderately to well-sorted, sandy, rounded greywacke gravel. Deposits are up to several metres thick in river valleys, tens of metres thick beneath the Ruataniwha Plains, or hundreds of metres thick beneath the Heretaunga Plains (Dravid & Brown 1997; Francis 2001). Loess, paleosols and tephra are common constituents. Terraces east of the ranges are poorly dated, particularly in the Ruataniwha Plains.

Slightly weathered grey brown alluvium forms low terraces, typically only a few metres above a broader aggradational plain built from Last Glacial Stage outwash gravels. Unweathered Holocene alluvium covers the floors of entrenched stream valleys and is extensive in the Ruataniwha and Heretaunga plains.

Other Deposits – There are a variety of other deposits recognised in the region that are of Holocene age and these include swamp deposits, frequently formed as a result of Quaternary fault movement impeding drainage.

There are coastal dune deposits including those approx. 7km south of Cape Kidnappers and beach and estuarine deposits. These include the dominantly gravel beaches at Awatoto and the estuarine deposits that underlie the former Ahuriri Lagoon at Napier, which was uplifted by 1–2 m during the 1931 Hawke's Bay Earthquake (Hull 1990).

There are deposits of human origin particularly in the urban areas, these include fill, reclaimed land, along roads and railways, under bridge abutments, and stop banks.

Pliocene to Holocene sediments of the **Tauranga Group** are exposed mostly in the north of the region, and consist of mainly alluvial volcanoclastic sediments (see Leonard *et al*. 2010). The Taupo Pumice Formation (see below) was fluvially reworked to form extensive, low-level terraces of pumiceous alluvium in the northwest and in the headwaters of the Ngaruroro River (Segschneider 2000; Segschneider *et al*. 2002).

5.2 Source Rock Geology

The source rocks for the gravel deposits in the Ruataniwha and Heretaunga Plains all are originally derived from the axial ranges. There is some reworking of gravel material from the Kidnappers Group and the gravels forming the low terraces of post glacial aggradational outwash.

The main elements of the greywackes are shown in Figure 4 which is a generalised geological map of New Zealand that highlights the Hawke's Bay region. This shows that the main source rocks in the axial ranges are described as Torlesse type rocks now ascribed to the Kaweka Terrane, (Adams et al, 2009). This is equivalent to the Rakaia Terrane as used by Black, 2009.

Kaweka Terrane rocks are dominantly composed of massive fine to medium grained quartzofeldspathic sandstone and well bedded indurated mudstone and sandstone with quartz and zeolite veining.

Minor components include conglomerate, limestone, chert and volcanics.

Most of the Kaweka Terrane is metamorphosed to zeolite facies which can have implications for aggregate quality in some instances.

To the east of the Kaweka Terrane rocks lies a relatively narrow southwest-northeast trending belt of rocks along the eastern Ruahine Range that have been classified as Pahau Terrane within which there is a distinctive petrofacies described and known as the Waioeka Petrofacies.

This belt is bisected by the Mohaka Fault. Undifferentiated Pahau Terrane rocks lie west of the fault, whereas Waioeka petrofacies rocks are found only east of it. The undifferentiated Pahau Terrane rocks are mostly thinly bedded, alternating sandstone and mudstone, massive sandstone and concretionary mudstone.

Sandstones are fine to medium grained quartzofeldspathic arenites, with carbonaceous material present. Areas of mélange, and basalt, limestone and chert are unknown in the map area. Undifferentiated Pahau Terrane rocks are inferred to be of prehnite-pumpellyite metamorphic facies (Spörli & Bell 1976).

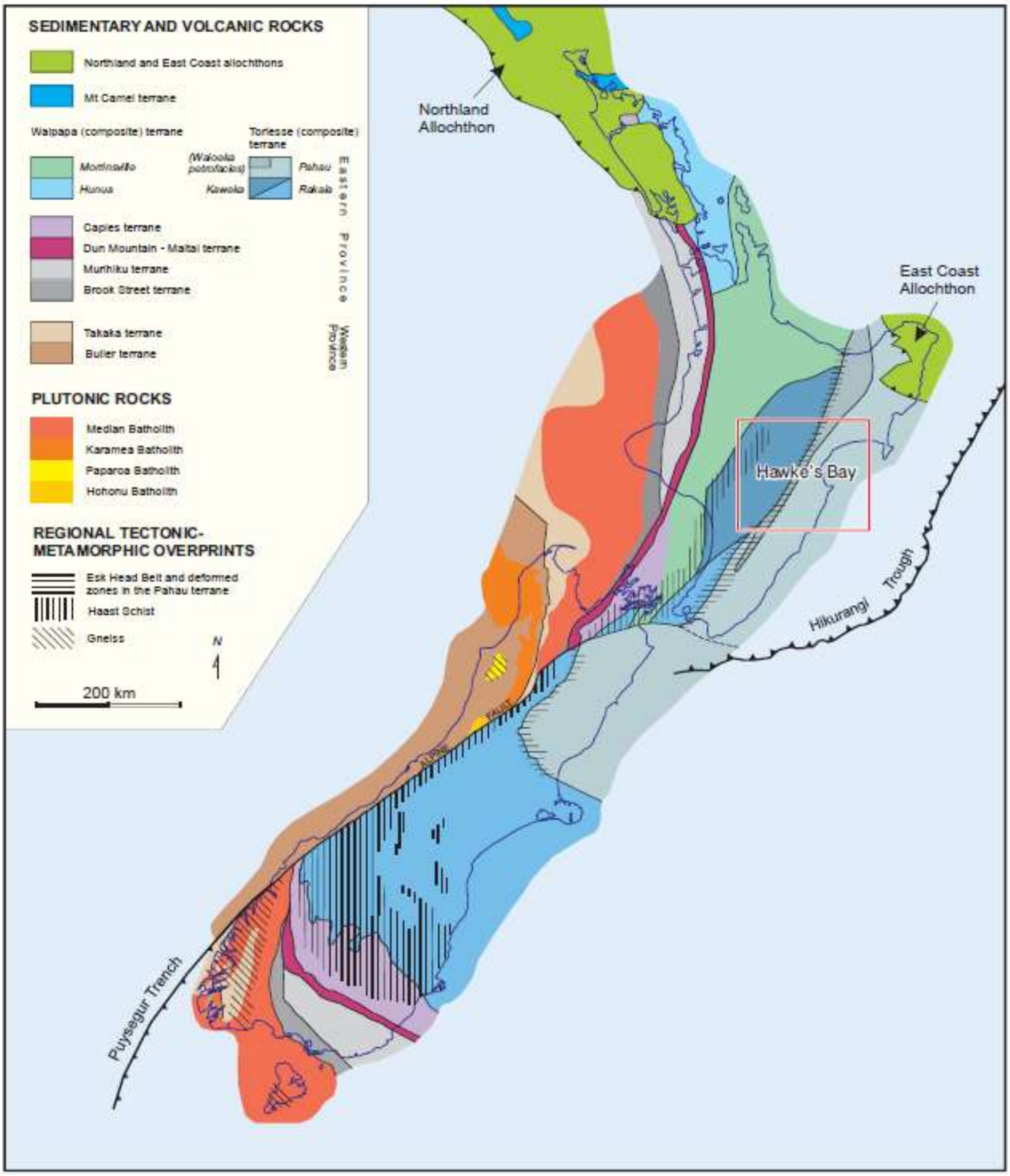

Figure 4: Main geological terranes in New Zealand. Hawke's Bay highlighted, (Lee et al, 2011)

The Waioeka petrofacies rocks crop out discontinuously east of the Mohaka Fault from northwest of Dannevirke to the Wakarara Range (Mortimer 1995). The easternmost exposures are faulted slivers along the Oruawharo Fault Zone, near Takapau. The Waioeka petrofacies differs from the other Kaweka Terrane and Pahau Terrane rocks in that the thin bedded fine to medium grained sandstones and mudstones and more thick bedded sandstones have a higher abundance of carbonised plant fragments and are distinctly more volcaniclastic in their mineralogy.

Black, 2009 identifies the Pahau Terrane rocks as having the potential to have the zeolite laumontite present plus smectite and other swelling clays. It is also notable that the Kaweka terrane is metamorphosed to zeolite facies and again zeolite veins are recorded in these rocks.

6.0 RESOURCE INVENTORY

6.1 General

The inventory of aggregate resources focuses on those resources in the active river systems that are currently forming the main supply of aggregate for the Hawke's Bay region. Commentary is also made on the so called "red rock" aggregates that form the terraces of the post glacial outflow deposits and kidnappers group deposits as well as and the potential for aggregate resources in the margins of the main river channels where river channels have migrated over time.

6.2 Assumptions, modelling parameters, limitations

Following major reviews by the Hawke's Bay Catchment Board and Regional Water Board in 1987 and prepared by G J Williams plus additional studies for the Hawke's Bay Regional Council (HBRC) on the Ngaruroro River by G J Williams in 1997 lead to defining a set of parameters to sustainably manage the river systems and control aggregate extraction.

More recently NIWA in conjunction with HBRC developed modelling software known as GRATE to model gravel transport, extraction and bed level change in the Ngaruroro River. This model was refined using the cross-sectional database on aggregate volumes since 1961. This modelling software is now being applied to model the gravel transport in the other major river systems in the region.

The HBRC have established a series of cross sections at regular intervals on all major river systems in the region. These range from approximately 500m to 1.3km apart and are surveyed approximately every two years and volume changes measured. This sectional data has been used to determine a grade line for each major river based on a 2 year return flood event.

HBRC policy has been to manage extraction so that it, in general, is only allowed in parts of the rivers where gravel accumulations are above grade line. This is the base case for determining available gravel supplies for extraction.

The evaluation of aggregate resource available was also determined using a 0.5m below grade line and a 1.0m below grade line.

G. Edmondson from HBRC estimated the volumes based on the cross-sectional areas of contiguous sections estimating the volumes between as either above or below grade line for the active river channel only.

Resource estimates have been calculated for the sections for which there are data. There are a number of other sections where volumetric data is not available and where grade line has not been determined, for instance the Middle Tukituki.

It is evident from HBRC records that the volume of aggregate supply to the river catchments is episodic and driven primarily by flood events.

For the purposes of this inventory compilation the 2013-2014 year has been used as a representative base case. This will vary both in volume of new supply to the catchments and where the resource occurs as the sediment load moves down stream.

7.0 RIVER BASED GRAVEL INVENTORY

7.1 Ngaruroro River

7.1.1 Base Case Grade Line

The current extraction sites on the Ngaruroro River cover an approximate river length of 32km starting around 5km from the coast at Section line 14 near Chesterhope and upstream to the confluence of the Mangatahi Stream and the Ngaruroro River at Section line 57 west of Maraekakahoe.

The bulk of the allocated extraction comes from three main producers between Section lines 36 to 51, a distance of around 12.4km.

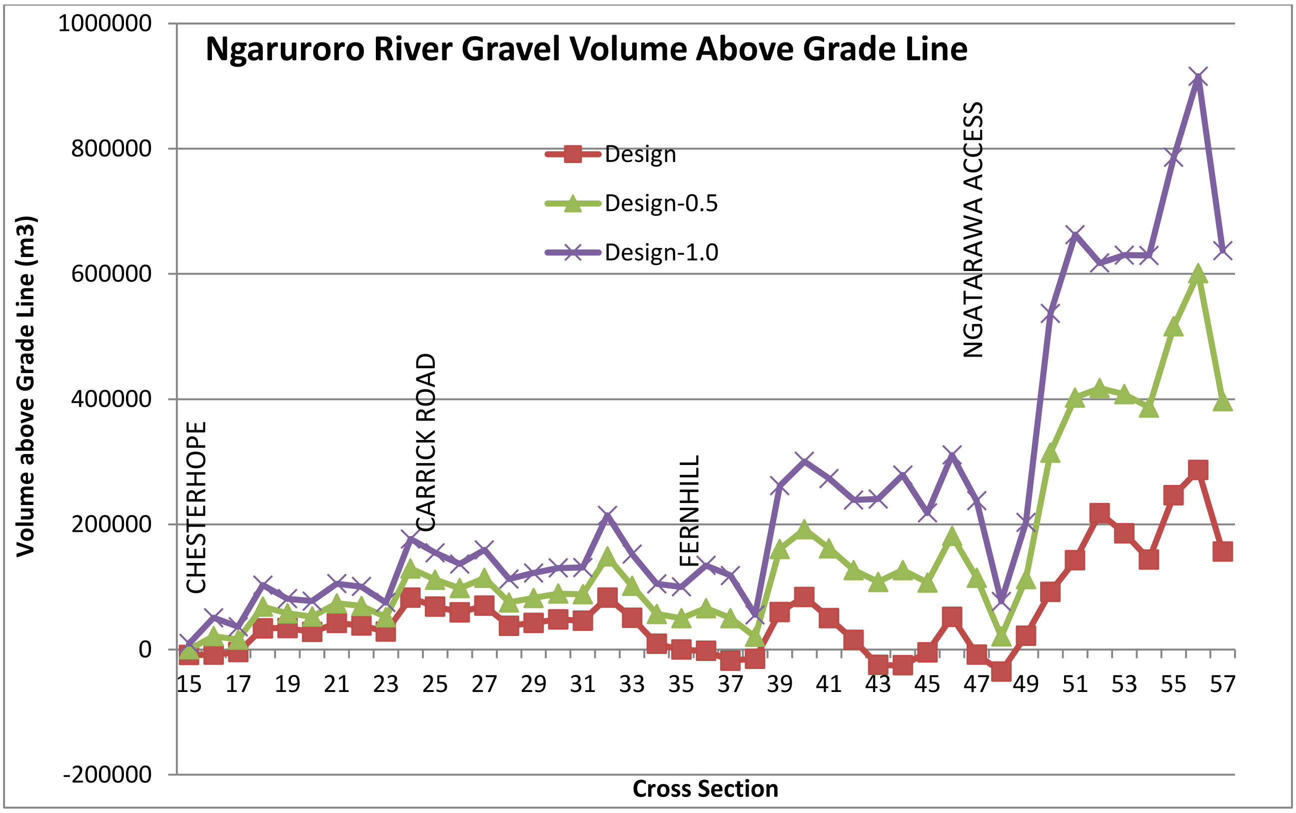

Figure 5: Ngaruroro River sectional gravel volumes

Figure 5 shows graphically the volumes currently available at each section line. Table 1 shows the calculated volumes by section line and the net total volume above the base case grade line.

CROSS SECT NO	CROSS SECT DIST FROM COAST (KM)	CROSS SECT WIDTH (M)	MBL CHANNEL (MASL)	GRADE LINE DESIGN (MASL)	VOLUME DESIGN (M3)	VOLUME DESIGN (-0.5M) (M3)	VOLUME DESIGN (-1.0M) (M3)
14	5.78	47	10.91	11.40			
15	6.15	52	11.31	11.77	- 8,686	472	9,629
16	6.84	118	12.48	12.47	- 7,845	21,480	50,805
17	7.29	62	12.62	12.93	- 4,059	16,191	36,441
18	7.86	180	14.28	13.51	34,023	68,508	102,993
19	8.27	48	14.52	13.90	34,514	57,884	81,254
20	8.72	172	15.09	14.54	27,981	52,731	77,481
21	9.08	178	15.85	15.06	42,340	73,840	105,340
22	9.48	132	16.00	15.60	38,684	69,684	100,684
23	9.77	189	16.81	16.05	28,484	51,756	75,029
24	10.26	194	17.75	16.75	82,722	129,639	176,557
25	10.75	157	18.00	17.45	68,686	111,683	154,681
26	11.20	187	19.05	18.10	59,400	98,100	136,800
27	11.71	162	19.63	19.03	70,087	114,584	159,082
28	12.19	149	20.31	19.90	37,990	75,310	112,630
29	12.67	183	21.42	20.78	42,770	82,610	122,450
30	13.11	190	22.12	21.58	48,338	89,368	130,398
31	13.56	188	22.94	22.40	45,927	88,452	130,977
32	14.26	188	24.74	24.02	82,908	148,708	214,508
33	14.81	182	25.56	25.29	50,737	101,613	152,488
34	15.34	179	26.44	26.52	9,227	57,060	104,892
35	15.87	199	27.82	27.75	- 103	49,982	100,067
36	16.55	203	29.22	29.32	- 2,166	66,174	134,514
37	17.21	209	30.69	30.85	- 17,734	50,246	118,226
38	17.58	169	31.35	31.62	- 14,628	20,337	55,302
39	18.41	317	34.10	33.50	59,997	160,842	261,687
40	19.07	339	35.83	35.64	84,021	192,261	300,501
41	19.72	347	38.00	37.74	50,255	161,730	273,205
42	20.42	292	39.84	40.00	15,225	127,050	238,875
43	21.29	317	42.79	42.82	- 24,460	107,997	240,455
44	22.29	291	45.92	46.06	- 25,125	126,875	278,875
45	23.02	319	48.49	48.40	- 4,391	106,934	218,259
46	23.88	282	51.84	51.51	52,361	181,576	310,791
47	24.95	177	54.79	55.40	- 7,977	114,806	237,588
48	25.48	246	56.74	56.84	- 35,131	20,916	76,964
49	26.13	310	58.90	58.60	22,230	112,580	202,930
50	27.44	369	63.60	63.47	92,335	314,708	537,080
51	28.95	320	69.52	69.08	142,521	402,619	662,716
52	30.24	299	74.56	73.90	218,100	417,728	617,355
53	31.65	331	80.00	79.80	185,796	407,871	629,946
54	33.10	339	85.72	85.33	143,847	386,722	629,597

CROSS SECT NO	CROSS SECT DIST FROM COAST (KM)	CROSS SECT WIDT H (M)	MBL CHANNEL (MASL)	GRADE LINE DESIGN (MASL)	VOLUME DESIGN (M3)	VOLUME DESIGN (-0.5M) (M3)	VOLUME DESIGN (-1.0M) (M3)
55	34.66	353	91.81	91.29	246,301	516,181	786,061
56	36.46	346	98.55	98.16	286,650	601,200	915,750
57	37.85	346	103.76	103.50	156,306	396,776	637,246
Total Resource above Grade Line					**2,560,763**	**6,553,783**	**10,699,108**
Net Total Resource					**2,408,458**	**6,553,783**	**10,699,108**

Table 1: Ngaruroro base case volumes by section line

The volume of gravel for each section line is also shown on the aerial photograph in Figure 6.

The estimates show in the 2013-2014 year that there is an average gravel resource availability of 2.56 million m^3 above grade line.

Importantly, the **available gravel for extraction** where the main producers operate between **Section lines 36 to 51 amounts to 518,945.0 m^3.**

Williams 1997 estimated using a gravel balance approach that an average addition of 170,000 m^3 of gravel is added to the system annually. Williams 1997 and Measures 2012 using the GRATE model note wide variability on an annual basis dependant largely on frequency of storm and flood events.

Current and future demand forecasts indicate production for the Ngaruroro is estimated at 270,000 m^3 in the low case scenario and 315,000 m^3 for a medium to high case demand growth forecast over the next 5 years.

Assuming the natural average addition of aggregate estimated by Williams, 1997 at 170,000 m^3 and available supplies (assuming the 2013-2014 volumes are representative) leads to the conclusion that over extraction of between 100,000 m^3 and 145,000 m^3 is or will occur at the projected extraction rates.

This implies that with an **average of 518,945 m^3 of gravel in the main extraction areas** available above grade line for extraction there is likely to be a 3.5 to 5 year time period before gravel resources in the main extraction areas fall below grade line. (See discussion below in Section 7.1.4).

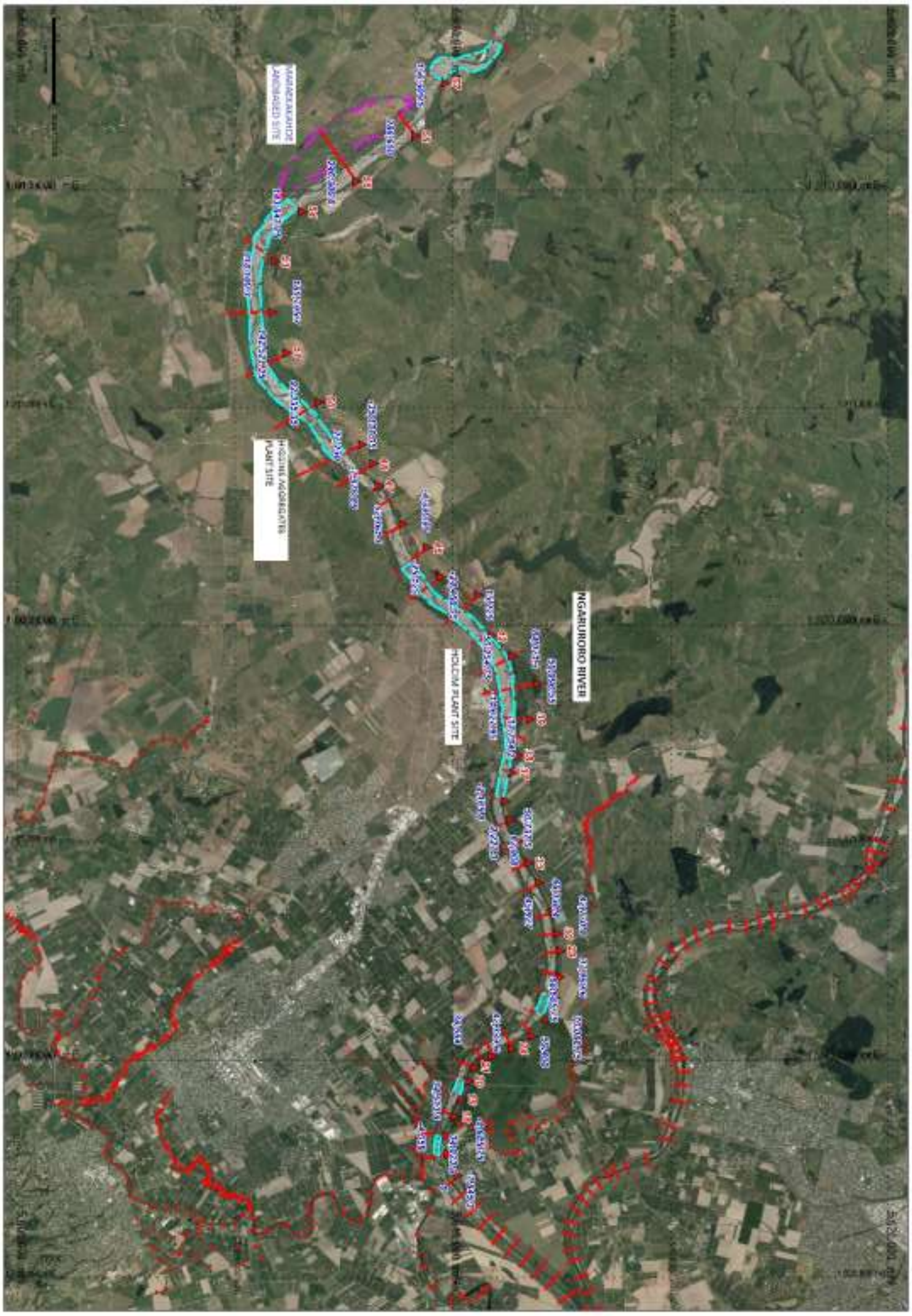

Figure 6: Plan of sectional volumes at grade line for Ngaruroro River and extraction areas.

Red lines are survey section lines, blue numbers are volumes by section, cyan = current extraction areas, magenta = current and possible future land based recent gravel potential resource

As observed by Williams there are considerable volumes of gravel above grade line upstream of Section line 51 to 57 amounting to 1,237,000 m^3. Also of note are similar areas upstream of Section 57 to Section line 70, a distance of over 20km of river bed.

A critical issue alluded to in Williams, 1997 and Measures, 2012 is the rate of gravel transport through the system. Options include:

- Active beach raking upstream of Section line 57 to increase gravel transport rates.
- Moving the major extraction sites further upstream.
- Trucking from up stream sites to current processing sites

If some of the major extraction moved from Section lines 50 to 57 then there would be nominally 1.47 million m^3 available above grade line. Allowing for the recommended 30% buffer (Williams, 1997) this would make available approximately 1.02 million m^3 for extraction.

On this basis at the upper and lower case production scenarios of 270,000 m^3 and 315,000 m^3 there would potentially be a further 7 to 10 years supply above grade line, beyond the 3 to 5 year time horizon. This would expand the resource available out to 2024-2028. See figure 7 and 8 below.

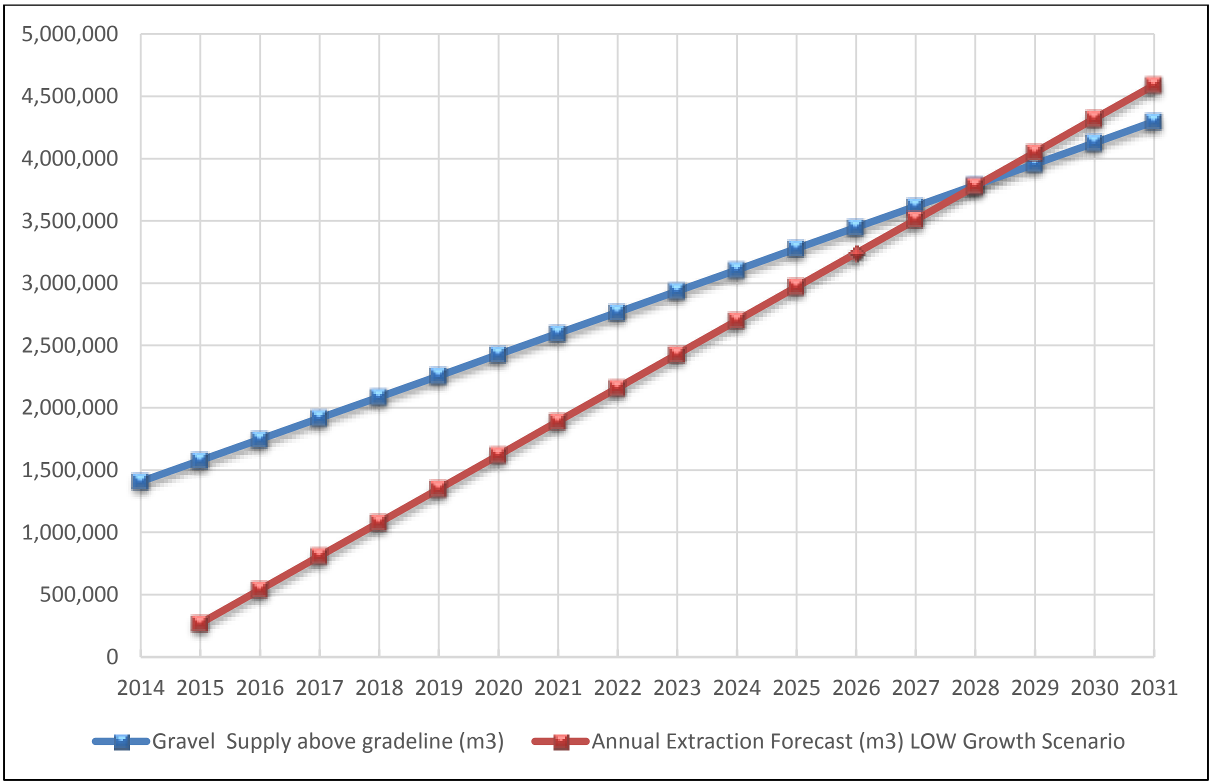

Figure 7: Low Growth scenario if additional resource extracted upstream of current locations.

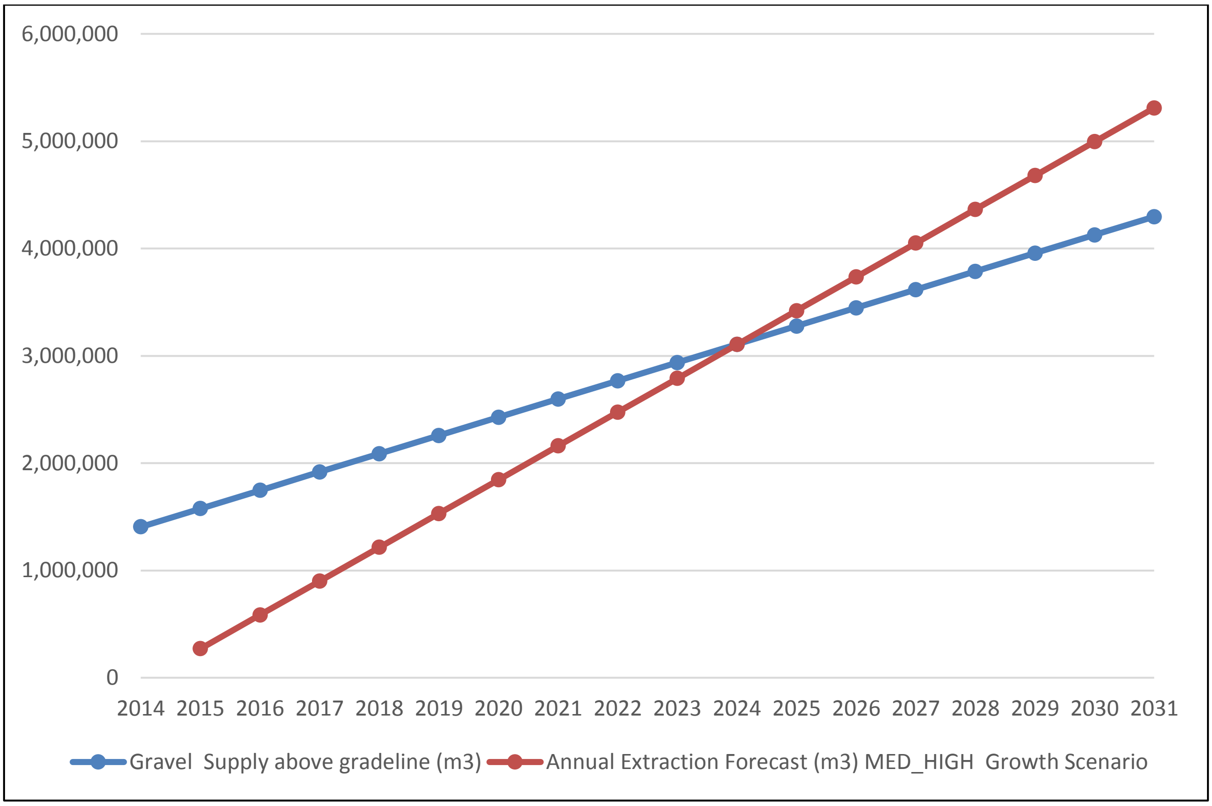

Figure 8: Medium to high growth scenario if additional resource extracted upstream of current locations.

It should be noted that the demand forecast figures available are only for the next 5 years, as provided in the Gravel Demand Forecast Report. In the absence of longer term demand forecast data at this stage, we have utilised similar demand levels. As recommended in the other report, this forecast should be updated annually on a rolling 5 year basis.

The morphological modelling undertaken by Measures, 2012 acknowledged the variability in supply rates from year on year. His modelling used Williams's gravel balance approach for calibration purposes. In his scenario the model demonstrated that actual gravel supply may be up to 30 to 40% less than modelled.

The estimates of duration and sustainability are averages and may vary in actuality due to natural variation in supply due to flood/fresh frequency, modelled lower gravel supply with climate change, supply of new material, rate of movement through the river system and depositional areas.

7.1.2 0.5m below Base Case Grade Line

Referring to Figure 5 and the scenario where extraction could occur up to 0.5m below grade line it can be seen that there is a total resource of around 6,554,000 m^3. The gravel resources in the extraction areas where the main producers are operating between Section Lines 36 to 51 amounts to 2,268,000 m^3.

At the low production growth (270,000 m^3) and mid to high production growth (315,000 m^3) scenarios and natural gravel accumulation of 170,000 m^3, available resource in those reaches would be enough for around 15 to 22 years (Note: this assumes using the current forecast extraction rate in the absence of other longer term forecasts).

Any consideration for allowing additional extraction to this level would require careful investigation to model what the likely impacts would be on infrastructure, river bank and flood protection, upstream depositional patterns.

7.1.3 1.0m below Base Case Grade Line

In considering the scenario where extraction could occur up to 1.0m, below grade line it can be seen that there is a total resource of around 10,699,000 m^3. The gravel resources in the extraction areas where the main producers are operating between Section Lines 36 to 51 amounts to 4,148,000 m^3.

At the low production growth (270,000 m^3) and mid to high production growth (315,000 m^3) scenarios and natural gravel accumulation of 170,000 m^3, available resource in those reaches would be enough for around 28 to 41 years. Again, note the demand forecasts are based on the next 5 years only.

Any consideration for allowing additional extraction to this level would require careful investigation to model what the likely impacts would be on infrastructure, river bank and flood protection and upstream depositional patterns.

7.1.4 Discussion on Sustainability of Supply Issues

7.1.4.1 Current Analysis

The above grade line volumes of gravel in the current Ngaruroro extraction sites at end of 2014 year are estimated to be in the order of 519,000 m^3.

The forecast extraction rate for the next 5 years is on average **270,000m ^{3} in the low growth scenario.** For simplicity we have used these average figures in the supply vs. extraction graphs. Note, anecdotal industry feedback, indicates that the current volumes going out seem to be tracking closer to the low growth forecast rather than the medium to high growth forecasts. This of course could change in the coming years and should be tracked with annual updates of the forecast in June each year, which is when the Infometrics 5-year rolling forecasts can be sourced. This can be done quite easily, based on the work the writers have done to date**.**

It is assumed for the purpose of the forecast that extraction by the three main extractors continues in the current locations and at the same level beyond the 5 year forecast period in the absence of other information on growth demand beyond this time frame.

The following graph attempts to demonstrate the changing supply and demand balance if extraction and supply continues on basis of the above assumptions and from the existing extraction sites on the Ngaruroro River.

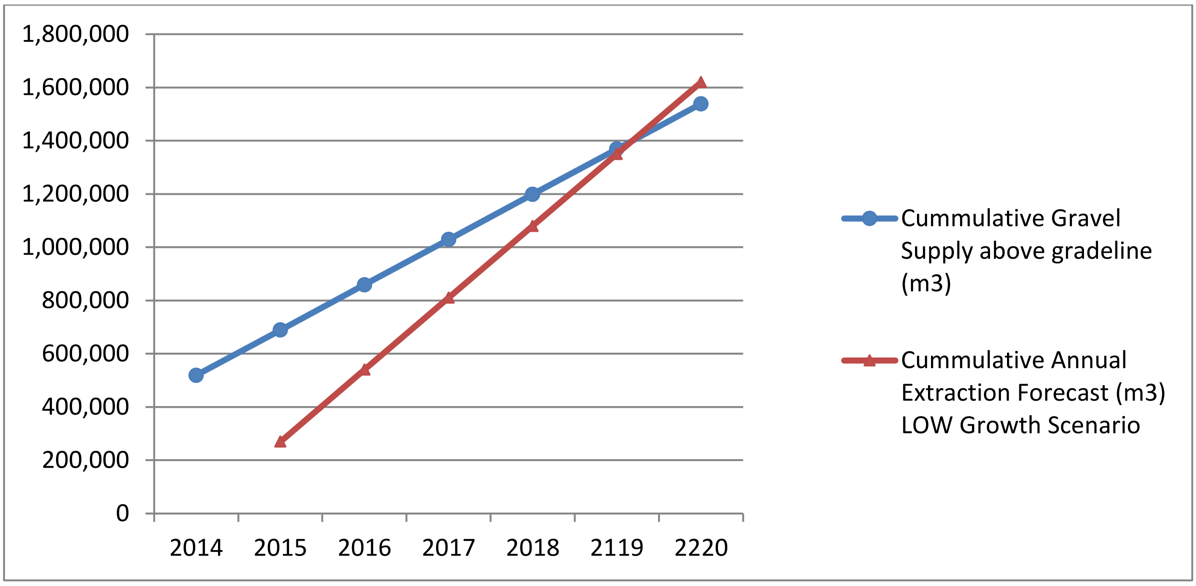

Figure 9: Cummulative Gravel Supply (above grade line) vs. Cummulative Annual Extraction Rates in low growth demand forecast

The above graph in Figure 9 indicates the Ngaruroro River gravel could potentially be at 'grade line' towards the end of 2018 calendar year, based on forecast extraction rates.

In this low growth scenario, in order to maintain the river at grade level beyond 2018, extraction rates would need to reduce to equal the supply rate, estimated to be 170,000 m^3 per annum. This equates to around 63% of the forecast extraction rate, or a 37% reduction in assumed extraction volumes, (270,000 m^3). Growth forecasts in 2018-19 could also be different, and would need to be updated as discussed.

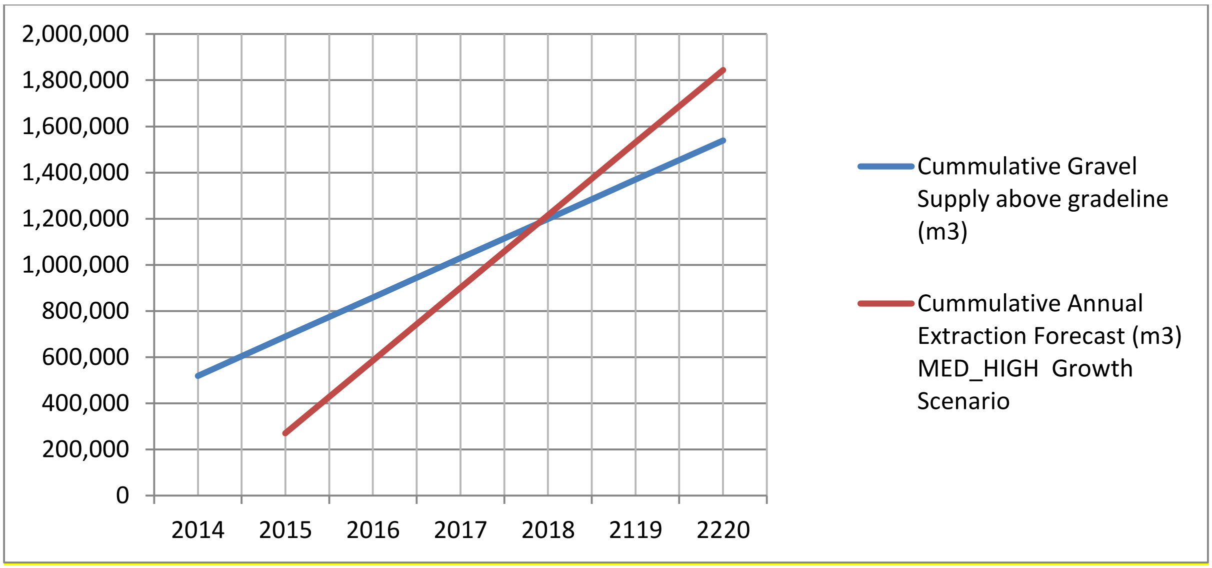

Figure 10: Cummulative Gravel Supply (above grade line) vs.Cummulative Annual Extraction Rates in medium-high growth demand forecast

The above graph Figure 10 indicates the Ngaruroro River gravel could be at 'grade line' in the early 2018 calendar year, based on medium-high growth forecast extraction rates.

In this medium-high growth scenario, in order to maintain the river at grade level beyond 2018, extraction rates would need to reduce to equal the supply rate, estimated to be 170,000 m^3 per annum. This equates to around 54%of the forecast extraction rate, or a 46% reduction in extraction volumes

7.1.4.2 Observations on Historic Estimates and mitigation options on the Ngaruroro River

The analysis using the current data 2013-2014 to estimate sustainability of supply is at variance to other observations over time. Undertaking similar analyses based on gravel volume data at particular time periods since 1977 produce similar results that show gravel supplies should have run out by now.

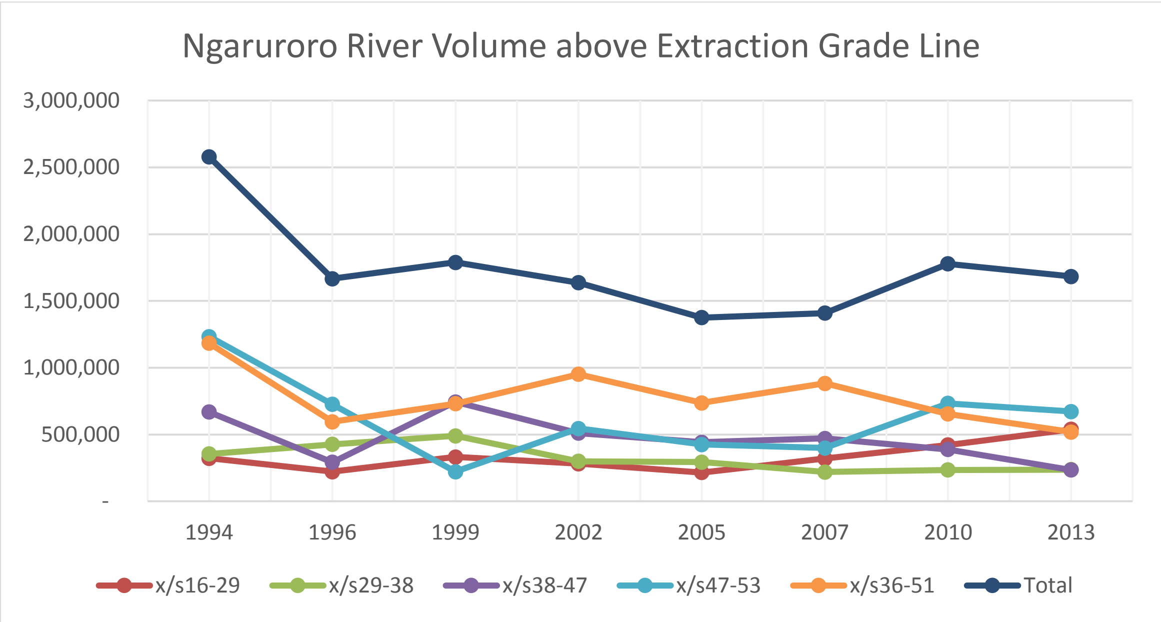

Figure 11: Graph showing volumes above the extraction line for different reaches over time

Using reaches 36 to 51 as an example under the above analysis there is a 3.5 to 5 year supply remaining, however Gary Clode of HBRC looked at data going back to 1994 where it can be seen that the volume above the extraction grade line was 1,183,115 m^3. At an extraction rate of 270,000 m^3pa and aggradation of 170,000 m^3 pa the implication would be that the supply would runout in 11.8 years, around 2006 and this is did not happen.

The variance in the analysis and what has actually been observed over time can be attributed to an under estimate in transport rates in the modelling used.

Survey periods are generally at three yearly intervals during which time sediment can move through the reach and not be recorded. Additionally, other factors such as long term trends and variation in climate may have an impact that if factored in would improve sustainability modelling.

7.2 Upper Tukituki

7.2.1 Base Case Grade Line

The current extraction sites on the Upper Tukituki River cover an approximate river length of 30km starting at Section Line 1, around 5km below the confluence of the Tukituki and Waipawa rivers and approximately 13km east of Waipukurau Township. The western upstream extent for the sectional resource data is section line 75 approximately 2.5km up stream of SH50. The majority of the allocated extraction which totals 108,500m^3 in the 2013-2014 year was from two larger extractors, one of whom has since gone out of business. The bulk of this allocation comes from section lines 51 to 62 where individual allocations range from 10,000 to 30,000 m^3. A number of other allocations to smaller users in the range of 500 to 2000 m^3 are distributed over the length of the reach.

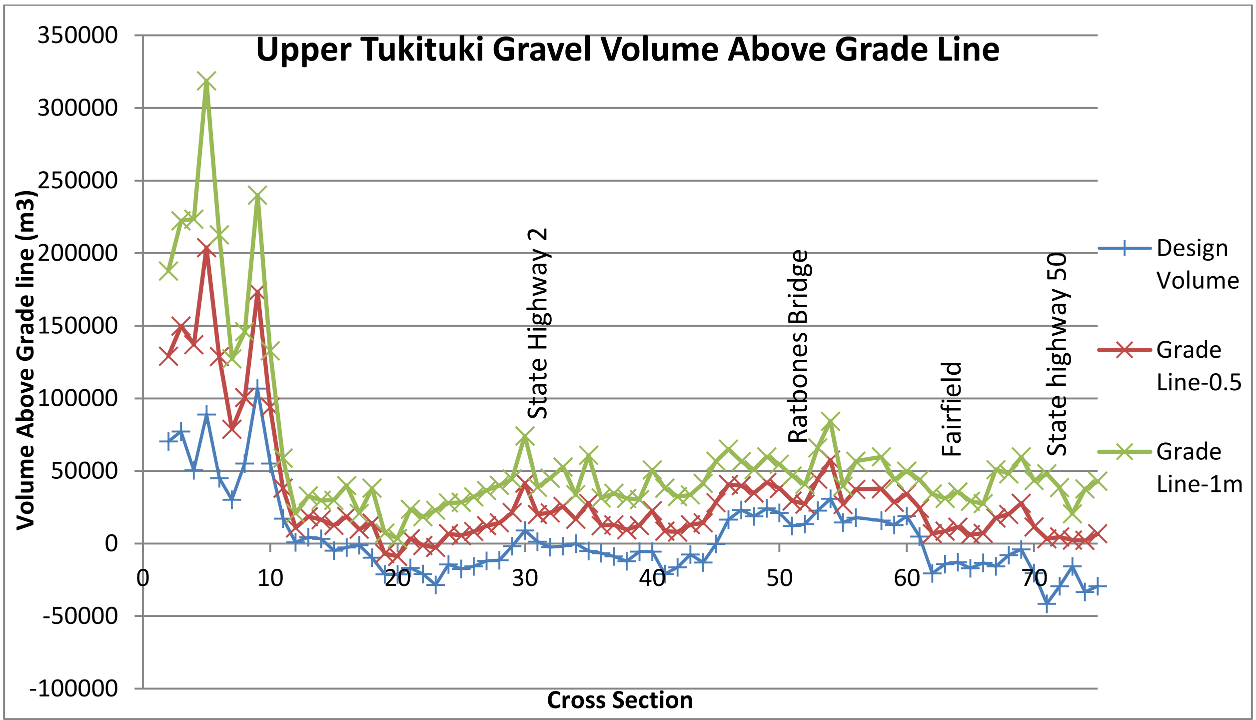

Figure 12: Upper Tukituki Sectional Gravel Volumes

CROSS SECT NO	CROSS SECT DIST FROM START (KM)	CROSS SECT WIDTH (M)	MBL_CHANNEL (MASL)	GRADE LINE DESIGN (MASL)	VOLUME DESIGN (M3)	VOLUME DESIGN (-0.5M) (M3)	VOLUME DESIGN (-1.0M) (M3)
1		217	108.39	108.2			
2	590	181	110.56	109.47	70,363	129,068	187,773
3	760	201	111.14	111.11	77,262	149,842	222,422
4	620	357	112.89	112.45	50,564	137,054	223,544
5	830	197	114.52	114.23	88,897	203,852	318,807

CROSS SECT NO	CROSS SECT DIST FROM START (KM)	CROSS SECT WIDTH (M)	MBL_CHANNEL (MASL)	GRADE LINE DESIGN (MASL)	VOLUME DESIGN (M3)	VOLUME DESIGN (- 0.5M) (M3)	VOLUME DESIGN (- 1.0M) (M3)
6	800	222	116.21	115.96	45,052	128,852	212,652
7	470	191	117.35	116.97	30,099	78,626	127,154
8	440	222	118.72	117.92	55,040	100,470	145,900
9	550	263	119.9	119.1	106,700	173,388	240,075
10	430	99	120.44	119.98	55,027	93,942	132,857
11	490	71	121.34	120.99	17,246	38,071	58,896
12	350	44	121.23	121.7	730	10,792	20,855
13	370	110	122.86	122.46	4,314	18,559	32,804
14	330	50	122.66	123.14	3,300	16,500	29,700
15	470	98	124.13	124.1	- 4,949	12,441	29,831
16	470	83	124.89	125.06	- 2,625	18,643	39,910
17	280	73	125.73	125.64	- 1,056	9,864	20,784
18	610	84	126.42	126.88	- 9,781	14,161	38,104
19	470	37	126.46	127.85	- 21,166	- 6,949	7,269
20	360	100	127.93	128.59	- 21,137	- 8,807	3,523
21	390	107	129.2	129.39	- 16,834	3,348	23,531
22	430	77	129.26	130.27	- 21,092	- 1,312	18,468
23	480	138	130.95	131.25	- 28,601	- 2,801	22,999
24	380	85	131.62	132.03	- 14,488	6,697	27,882
25	420	133	132.53	132.89	- 17,373	5,517	28,407
26	390	113	133.41	133.7	- 15,727	8,258	32,243
27	400	130	134.4	134.61	- 12,014	12,286	36,586
28	420	116	135.34	135.5	- 11,579	14,251	40,081
29	350	148	136.5	136.38	- 1,764	21,336	44,436
30	460	135	137.6	137.44	9,053	41,598	74,143
31	290	124	138	138.1	1,334	20,112	38,889
32	370	133	138.94	138.95	- 2,540	21,232	45,005
33	430	121	139.88	139.94	- 1,847	25,458	52,763
34	290	112	140.66	140.6	- 78	16,814	33,707
35	550	128	141.88	142.08	- 5,192	27,808	60,808
36	310	118	142.77	142.92	- 6,711	12,354	31,419
37	380	110	143.69	143.95	- 8,797	12,863	34,523
38	400	106	144.73	145.03	- 12,080	9,520	31,120
39	320	117	145.87	145.89	- 5,462	12,378	30,218
40	420	151	146.87	147.03	- 5,565	22,575	50,715
41	450	112	147.63	148.25	- 21,060	8,528	38,115
42	410	125	149.28	149.36	- 16,285	8,007	32,300
43	330	123	149.96	150.25	- 7,536	12,924	33,384
44	430	130	151.22	151.41	- 12,980	14,218	41,415
45	380	169	152.58	152.44	- 198	28,207	56,612
46	400	73	154.31	153.5	16,558	40,758	64,958

CROSS SECT NO	CROSS SECT DIST FROM START (KM)	CROSS SECT WIDTH (M)	MBL_CHANNEL (MASL)	GRADE LINE DESIGN (MASL)	VOLUME DESIGN (M3)	VOLUME DESIGN (-0.5M) (M3)	VOLUME DESIGN (-1.0M) (M3)
47	470	69	156.23	155.66	23,138	39,823	56,508
48	450	74	158.33	157.74	18,673	34,760	50,848
49	460	81	160.62	159.86	24,201	42,026	59,851
50	440	71	162.38	161.89	21,197	37,917	54,637
51	480	73	164.31	164.1	12,029	29,309	46,589
52	370	74	166.58	165.8	13,514	27,112	40,709
53	590	72	169.31	169.04	22,762	44,297	65,832
54	690	83	172.94	172.1	30,760	57,498	84,235
55	310	78	174.84	174.54	14,434	26,911	39,389
56	500	78	177.89	177.28	17,745	37,245	56,745
58	560	79	180.47	180.36	15,756	37,736	59,716
59	400	78	183.26	182.56	12,658	28,358	44,058
60	370	89	185.73	185.2	18,827	34,275	49,722
61	480	74	188.53	188.9	4,750	24,310	43,870
62	670	89	193.72	194.1	- 20,502	6,801	34,103
63	530	82	197.96	198.2	- 14,177	8,480	31,138
64	550	94	202.21	202.5	- 12,908	11,292	35,492
65	530	80	206.14	206.6	- 16,976	6,079	29,134
66	480	90	210.09	210.3	- 13,368	7,032	27,432
67	740	90	215.84	216.1	- 15,651	17,649	50,949
68	630	88	220.88	220.9	- 7,925	20,110	48,145
69	750	82	226.59	226.7	- 4,042	27,833	59,708
70	740	90	231.99	232.5	- 20,320	11,500	43,320
71	980	93	239.68	240.1	- 41,630	3,205	48,040
72	820	73	246.55	247	- 29,483	4,547	38,577
73	430	95	250.18	250.6	- 15,641	2,419	20,479
74	660	120	255.59	256.1	- 33,363	2,112	37,587
75	790	63	262.49	262.7	- 29,400	6,743	42,885
Resource above Grade Line					**881,981**	**2,378,546**	**4,417,280**
Net Total Resource					**300,075**	**2,358,677**	**4,417,280**

Table 2: Upper Tukituki River Gravel Volumes By section at grade line, -0.5m and -1.0m below grade line

Figure 12 and Table 2 shows that the there is a surplus of gravel above grade line of approximately 882,000 m^3 in the 2013-2014 year. The main areas of the river where gravel deposits lie above grade line are between Section lines 2 to 14, (600,000 m^3) and Section lines 46 to 61, (267,000 m^3). See Figure 12.

While the total allocation for the 2013-2014 year was 108,000 m^3 it is apparent that not all allocation has been used. In recent times this is mainly due to a local significant extractor ceasing operations in the region. From examining HBRC records of reported production from 1961 to 2013 (see graph in section 11.2.2) this shows average production of around 60,000 m^3 with a general decline since 2011.

HBRC are currently modelling the Tukituki River gravel transport. Part of this will enable estimation of the volumes of new gravel added to the system on an average annual basis.

At this stage HBRC's principal considerations are around flood control and ensuring gravel volumes reaching the sea are adequate to ensure no adverse effects occur in the coastal zone. The Tukituki River is the only major river still delivering gravel to the foreshore in Hawke's Bay between Cape Kidnappers and Napier.

Actual recorded production of gravel from the Upper Tukituki as shown in Figure 22 has ranged between 60,000 m^3 in 2000 to a low of around 10,000 m^3 in 2013. On the assumption that production levels rise back to the average over the last 10 years of around 41,000 m^3 and assuming that addition of new gravel to the system at least equivalent to that modelled for the Ruataniwha Dam of between 140,000 m^3 and 180,000 m^3 for the other catchments feeding into the Upper Tukituki then there should be adequate supplies for the long term in this portion of the river.

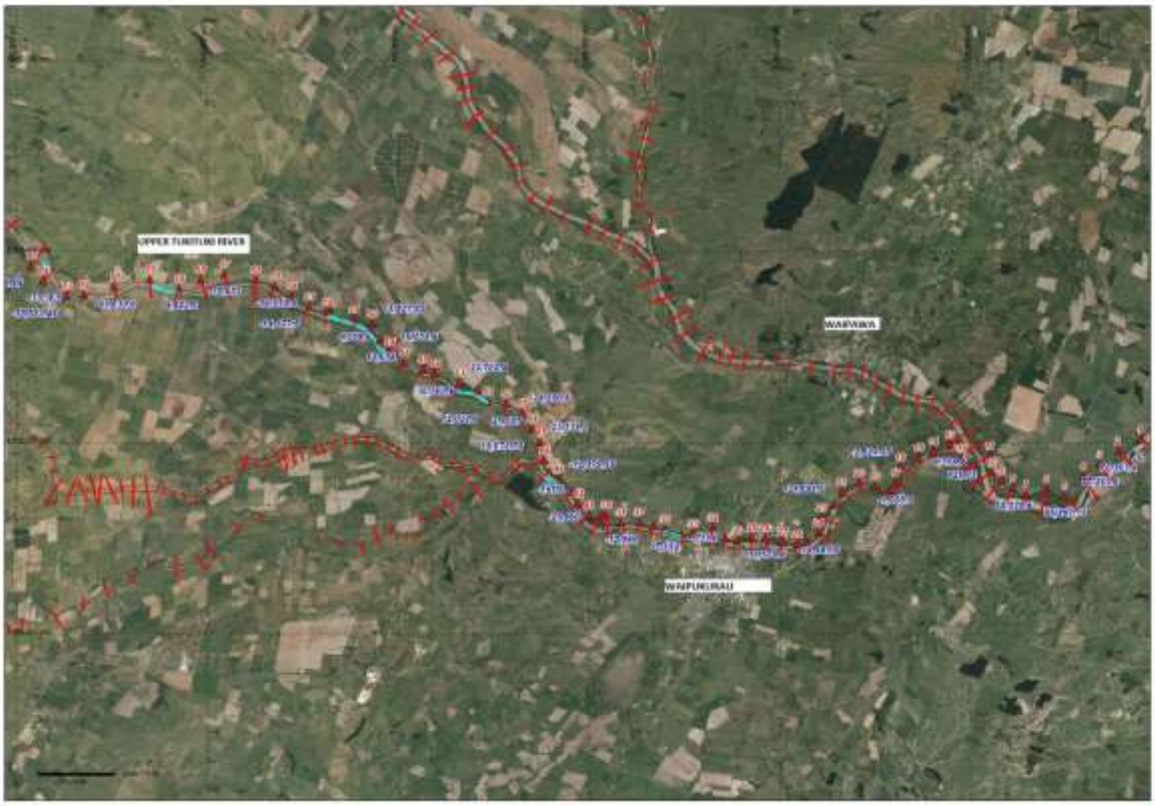

Figure 13: Map of Upper Tukituki River showing sectional resource volumes above grade line and resource extraction areas.

Red lines are survey section lines, blue numbers are volumes by section, cyan = current extraction areas.

There is likely to be an issue however with the build-up of gravel above grade line over time with an adverse effect on flood control. This is dependent on the rate of movement of gravel through the system to lower reaches, flood event frequency, aggradation rates and extraction. The situation for flood control is likely to be exacerbated if extraction does not increase back to average levels.

Estimates of gravel volumes 0.5m and 1.0 m below grade line show some 2.6 million m^3 and 4.4 million m^3 respectively potentially available. Any decisions to extract below the grade line would need to be made with full knowledge of what the potential effects on river bank stability and infrastructure are likely to be.

7.3 Middle Tukituki River

The Middle Tukituki River is defined by an upstream extent to Tamamu Bridge and to a downstream limit of Red Bridge as shown in Figure 14.

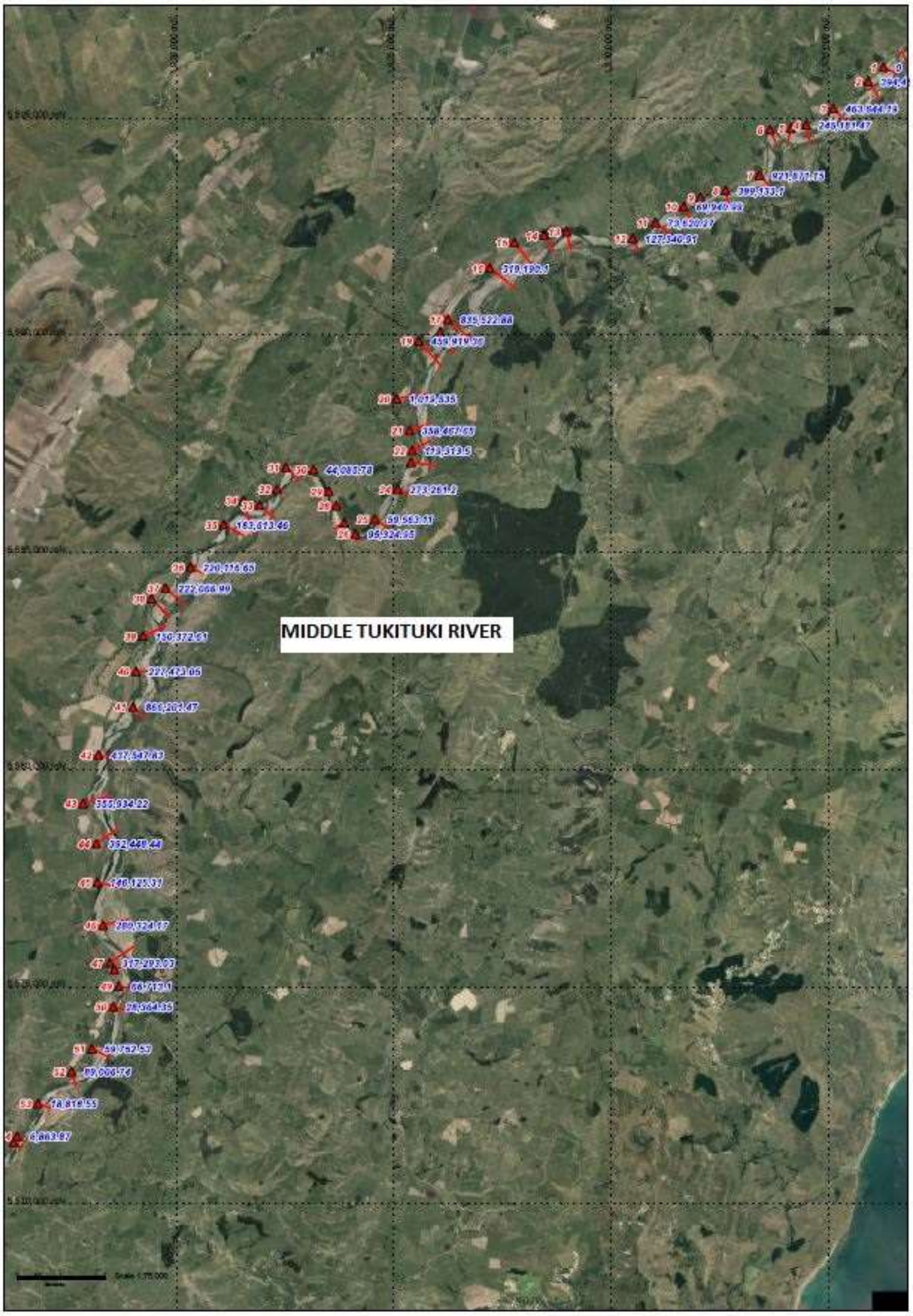

Figure 14: Aerial photograph plan of Tukituki River showing resource areas and section lines.

Red lines are survey section lines, blue numbers are volumes by section, cyan = current extraction areas.

HBRC have sectional data for the Middle Tukituki with the most recent survey in 2011. HBRC currently have not determined a grade line for this section of river.

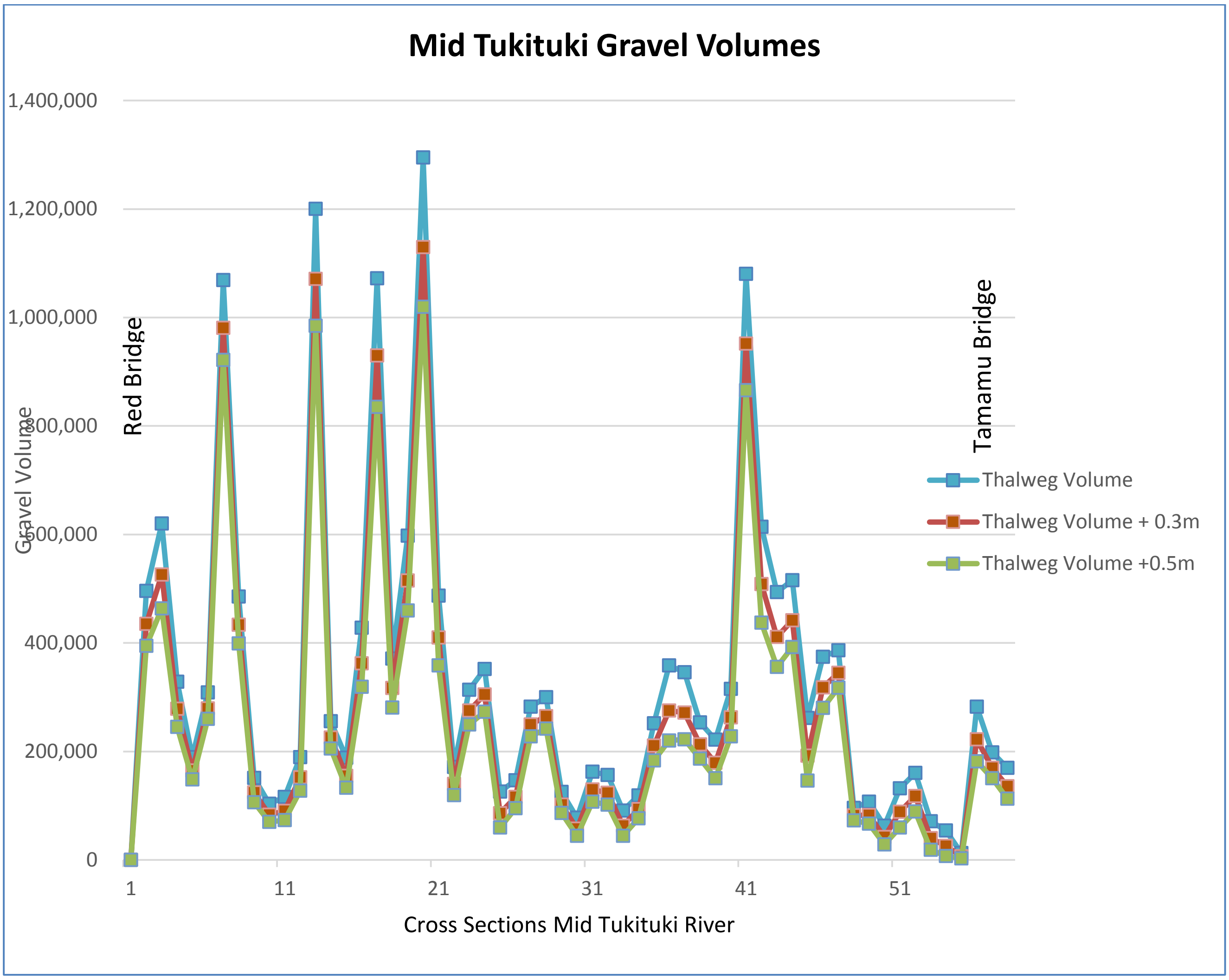

Figure 15: Middle Tukituki River Gravel Volumes

HBRC have provided figures based on the RL of the Thalweg (centre line of the deepest part of the active river channel) and the average of the surveyed profiles and used this to determine gravel volumes. These are shown graphically in Figure 15 and in Table 3.

Three estimates are shown. Firstly with the estimate of the total volume of gravel from Thalweg to the median survey channel RL, secondly an estimate of gravel volumes 0.3m above the Thalweg and thirdly, 0.5m above the Thalweg.

CROSS SECT NO	CROSS SECT DISTANCE (KM)	CROSS SECT WIDTH (M)	MBL CHANNEL 2011 (MASL)	THALWEG (MASL)	THALWEG +0.3M (MASL)	THALWEG +0.5M (MASL)	THALWEG VOLUME (M3)	THALWEG VOLUME +0.3M (M3)	THALWEG VOLUME +0.5M (M3)
1			35.0	32.0	32.3	32.5			
2	0.6	333.5	36.5	34.6	34.9	35.1	496,178	435,147	394,460
3	1.0	322.2	37.5	35.5	35.8	36.0	619,911	526,151	463,644
4	0.9	187.2	37.9	36.0	36.3	36.5	328,463	278,494	245,181

CROSS SECT NO	CROSS SECT DISTANCE (KM)	CROSS SECT WIDTH (M)	MBL CHANNEL 2011 (MASL)	THALWEG (MASL)	THALWEG +0.3M (MASL)	THALWEG +0.5M (MASL)	THALWEG VOLUME (M3)	THALWEG VOLUME +0.3M (M3)	THALWEG VOLUME +0.5M (M3)
5	0.5	170.7	39.7	37.0	37.3	37.5	189,272	164,691	148,304
6	0.4	264.0	41.1	37.5	37.8	38.0	308,708	279,410	259,877
7	0.1	270.0	42.7	39.0	39.3	39.5	1,068,994	980,720	921,871
8	0.9	185.8	43.4	41.5	41.8	42.0	485,507	433,683	399,133
9	0.6	159.5	45.0	43.5	43.8	44.0	150,951	124,155	106,291
10	0.5	146.6	44.1	42.5	42.8	43.0	103,647	83,424	69,941
11	0.7	126.3	45.8	44.7	45.0	45.2	115,931	90,544	73,620
12	0.7	181.9	48.2	46.2	46.5	46.7	189,187	152,079	127,341
13	0.2	269.5	51.5	47.9	48.2	48.4	1,200,461	1,071,101	984,861
14	0.5	224.6	50.7	49.3	49.6	49.8	255,808	225,487	205,273
15	0.6	180.6	53.0	51.0	51.3	51.5	188,108	155,059	133,025
16	0.7	310.3	53.9	52.0	52.3	52.5	427,795	362,632	319,190
17	0.2	315.5	56.7	54.2	54.5	54.7	1,072,148	930,173	835,523
18	0.5	392.2	58.1	56.6	56.9	57.1	371,017	316,894	280,811
19	0.5	529.3	59.2	56.4	56.7	56.9	597,537	514,967	459,919
20	0.1	501.0	60.5	58.6	58.9	59.1	1,295,085	1,129,755	1,019,535
21	0.7	368.2	61.4	59.5	59.8	60.0	487,320	410,009	358,468
22	0.4	235.9	61.6	60.2	60.5	60.7	171,212	140,073	119,314
23	0.5	256.8	63.1	59.6	59.9	60.1	313,874	275,354	249,674
24	0.7	218.6	63.1	62.1	62.4	62.6	351,943	304,734	273,261
25	0.9	152.3	65.3	64.4	64.7	64.9	125,818	86,065	59,563
26	0.7	151.6	65.8	63.9	64.2	64.4	146,852	115,936	95,325
27	0.6	192.4	68.0	64.8	65.1	65.3	282,431	249,540	227,612
28	0.5	260.1	68.3	66.4	66.7	66.9	300,221	265,114	241,710
29	0.4	188.5	67.9	66.6	66.9	67.1	125,168	101,989	86,536
30	0.5	128.7	68.9	67.9	68.2	68.4	77,535	57,465	44,086
31	0.5	215.6	70.8	68.8	69.1	69.3	162,515	129,528	107,537
32	0.5	202.4	70.2	69.2	69.5	69.7	156,567	123,778	101,919
33	0.6	165.6	71.5	70.5	70.8	71.0	90,807	62,995	44,453
34	0.4	224.1	72.5	70.7	71.0	71.2	118,982	93,440	76,412
35	0.6	244.1	73.8	71.8	72.1	72.3	251,947	210,947	183,613
36	1.3	213.3	74.4	73.8	74.1	74.3	358,729	275,562	220,117
37	0.8	313.9	77.9	75.8	76.1	76.3	346,057	271,663	222,067
38	0.4	319.2	78.7	77.0	77.3	77.5	253,408	213,195	186,387
39	0.8	187.9	79.0	77.6	77.9	78.1	221,775	178,933	150,373
40	0.9	199.3	81.3	79.2	79.5	79.7	315,165	262,550	227,473
41	1.3	327.5	83.5	80.6	80.9	81.1	1,080,714	952,006	866,201
42	1.2	302.2	85.2	84.6	84.9	85.1	614,335	508,263	437,548
43	1.1	260.3	88.8	85.8	86.1	86.3	493,893	411,118	355,934
44	0.9	276.2	88.9	87.7	88.0	88.2	515,357	441,612	392,448
45	1.3	182.2	91.0	89.9	90.2	90.4	261,822	192,404	146,125
46	1.1	179.6	92.6	89.7	90.0	90.2	374,614	318,040	280,324

CROSS SECT NO	CROSS SECT DISTANCE (KM)	CROSS SECT WIDTH (M)	MBL CHANNEL 2011 (MASL)	THALWEG (MASL)	THALWEG +0.3M (MASL)	THALWEG +0.5M (MASL)	THALWEG VOLUME (M3)	THALWEG VOLUME +0.3M (M3)	THALWEG VOLUME +0.5M (M3)
47	0.8	165.2	93.6	90.9	91.2	91.4	386,677	345,047	317,293
48	0.3	157.2	94.1	92.6	92.9	93.1	95,666	81,990	72,872
49	0.5	158.8	94.9	93.7	94.0	94.2	107,194	82,906	66,713
50	0.5	130.9	95.4	94.7	95.0	95.2	63,040	42,234	28,364
51	1.1	126.3	97.6	96.4	96.7	96.9	131,744	88,549	59,753
52	1.0	145.6	99.3	98.2	98.5	98.7	160,326	117,535	89,007
53	1.0	110.1	101.1	100.9	101.2	101.4	71,092	39,728	18,819
54	0.9	101.8	103.0	102.2	102.5	102.7	54,201	25,799	6,864
55	0.2	120.9	103.4	103.0	103.3	103.5	12,501	6,700	2,833
56	1.0	195.9	106.2	103.8	104.1	104.3	282,718	222,201	181,856
57	0.5	197.5	106.1	104.4	104.7	104.9	198,037	169,597	150,637
58	0.7	171.0	107.9	106.7	107.0	107.2	169,907	135,536	112,622
Total	**37.7**						**19,196,876**	**16,264,699**	**14,309,915**

Table 3: Middle Tukituki gravel volumes by section line

These estimates were used to approximate the methodology used for the other river gravel estimates. It can be seen in Table 3 that there are large total volumes of gravel potentially available for extraction. Taking the most conservative scenario of using the 0.5m above Thalweg estimate it can be seen that there is potentially **14 million m^3 of gravel available.**

Modelling of new gravel added to the system annually from the Ruahine Ranges and other reworking of terrace gravel sources is in progress. Existing potential resources are large and if it is assumed that the 0.5m above Thalweg is near to grade line then the conclusion is that there is a long term resource available for extraction at the current levels allocated of approximately 15,000 m^3annually.

Subject to determination of the actual grade line, modelling of gravel added to the system and gravel through flow, gravel extraction could be increased significantly here.

Issues include accessibility to the resources, volumes moving through the system to the Lower Tukituki to replenish over extracted resources and ensure gravel continues to reach the sea in adequate volumes for beach protection, travel distances to processing plant and the main contract areas for producers, (economics and market demands). It is recognised that this location is further away for the main aggregate urban markets and the main producers on the Ngaruroro. Transport costs being a significant cost factor.

7.4 Lower Tukituki River

The Lower Tukituki gravel supply and sustainable annual extraction was assessed in 2001 by Edmondson. His analysis demonstrated that the long term annual supply to the Lower Tukituki reaches averaged approx. 45,000m^3 noting that an unquantified volume passed through the Lower Tukituki to the sea dependant on the frequency and intensity of flood events.

In looking at the 2013-2014 data in Figure 16 below and in Table 4 it is clear that at the grade line design the majority of the gravel resource lies below grade line.

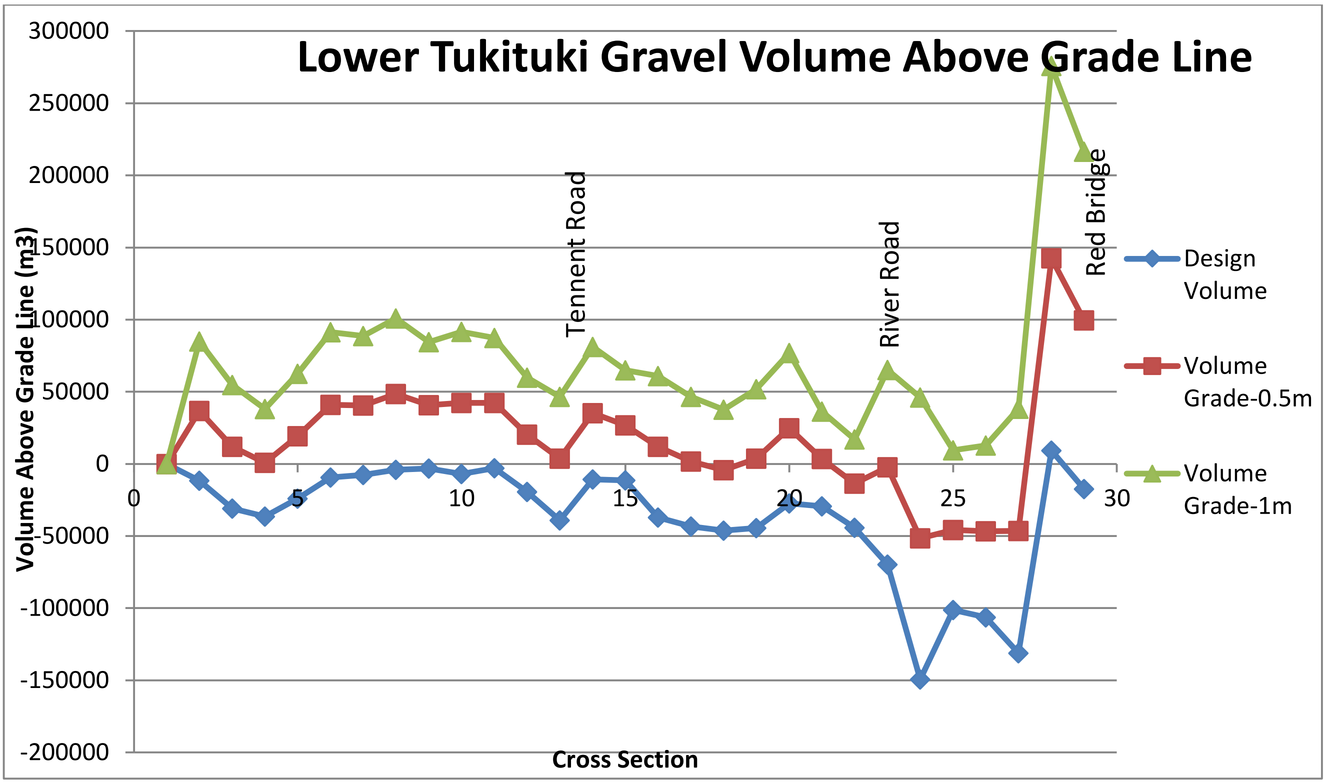

Figure 16: Lower Tukituki gravel volumes by section line

CROSS SECT NO	CROSS SECT SPACING (KM)	CROSS SECT WIDTH (M)	MBL_CHANNEL (MASL)	GRADE LINE DESIGN (MASL)	VOLUME DESIGN (M3)	VOLUME DESIGN (-0.5M) (M3)	VOLUME DESIGN (-1.0M) (M3)
1		253	9.45	9.4	-	-	-
2	0.430	196	9.77	10.11	- 11,608	36,660	84,927
3	0.420	211	10.42	10.8	- 30,832	11,903	54,638
4	0.360	203	10.8	11.4	- 36,356	904	38,164
5	0.370	264	11.98	12.01	- 23,998	19,199	62,397
6	0.390	253	12.49	12.65	- 9,438	40,970	91,377
7	0.380	254	13.28	13.28	- 7,691	40,474	88,639
8	0.430	234	13.91	13.99	- 4,025	48,435	100,895
9	0.390	216	14.64	14.63	- 3,229	40,646	84,521
10	0.450	222	15.22	15.37	- 7,006	42,269	91,544
11	0.400	230	16.11	16.03	- 2,980	42,220	87,420
12	0.370	198	16.02	16.64	- 19,307	20,283	59,873
13	0.410	220	17.01	17.32	- 39,147	3,698	46,543
14	0.400	239	18.04	17.98	- 10,772	35,128	81,028
15	0.350	197	18.16	18.56	- 11,281	26,870	65,020
16	0.470	220	18.97	19.33	- 37,130	11,868	60,865
17	0.420	208	19.42	20.03	- 43,277	1,663	46,603
18	0.410	201	20.21	20.7	- 46,201	- 4,278	37,644
19	0.430	247	21	21.44	- 44,542	3,618	51,778
20	0.430	238	22.11	22.19	- 27,460	24,678	76,815

CROSS SECT NO	CROSS SECT SPACING (KM)	CROSS SECT WIDTH (M)	MBL_CHANNEL (MASL)	GRADE LINE DESIGN (MASL)	VOLUME DESIGN (M3)	VOLUME DESIGN (-0.5M) (M3)	VOLUME DESIGN (- 1.0M) (M3)
21	0.350	138	21.71	22.79	- 29,414	3,486	36,386
22	0.360	202	22.94	23.42	- 44,280	- 13,680	16,920
23	0.630	226	23.96	24.51	- 69,697	- 2,287	65,123
24	1.080	136	25.25	26.37	- 149,375	- 51,635	46,105
25	0.510	298	26.44	27.26	- 101,153	- 45,818	9,517
26	0.510	169	27.12	28.14	- 106,269	- 46,726	12,816
27	1.000	170	29.31	29.84	- 131,240	- 46,490	38,260
28	1.190	278	32.24	31.86	9,246	142,526	275,806
29	1.140	132	32.77	33.8	- 17,282	99,568	216,418
Resource above Grade Line					9,246	697,064	2,028,042
Net Total resource	**14,480**				**- 1,055,743**	**486,149**	**2,028,042**

Table 4: Lower Tukituki gravel volumes by section line

In the 2013-2014 year HBRC allocated 35,000 m^3 to a number of small users, with a third to Winstone Aggregates. Actual recorded production based on returns was around 26,000 m^3 in 2013 and according to HBRC records from 1962 to 2013 has averaged approx. 45,000m^3. Figure 17 shows the current sectional data and gravel volumes plus extraction sites.

There is currently a net deficit of 1,055,000m^3 at the design level and just over 9,200 m^3 of this gravel lies above the gradeline. The volumes estimated at 0.5m below the grade line volume design and at 1.0m below volume design are 697,064 m^3 and 2,028,000m^3 respectively.

HBRC policy is to manage the resource sustainably taking into account that while there has historically been over extraction in the Lower Tukituki River, it is the only major river system delivering gravel to the coast where northward longshore drift helps replenish gravel on the coast up to Napier and there is still a deficit of gravel in what is effectively a sink. Consideration of the impact of a reduced volume of gravel moving through the river system will be required if the Ruataniwha Water Storage project goes ahead.

Options include;

- Allow minimal extraction until gravel resources build up to grade line and then allow extraction to the estimated average gravel passing through the reach.
- Keep the status quo which allows gravel to reach the sea but increases the time for the gravel sink to replenish and aggrade.

Figure 17: Lower Tukituki River sections and resource volumes.

Red lines are survey section lines, blue numbers are volumes by section, cyan = current extraction areas.

7.5 Waipawa River

The Waipawa River is a major True Left Hand (TLH) fork of the Tukituki River. The Makororo River is a TLH branch of the Waipawa and is the location for the proposed dam as part of the Ruataniwha Water Storage Project.

As part of the assessment for the Ruataniwha Water Storage Project HBRC carried out an assessment of gravel transport changes that could occur with the development of the Scheme. Clode et al, 2012 estimated that some 38,185m^3 of gravel as flowing through the Waipawa River as measured on an average annual at Section line 14 upstream of Waipawa Township.

Clode et al 2012 also estimated that when the dam is constructed on Makaroro River there could be up to an 18% reduction in gravel supply at that section of the Waipawa River and around 5% overall to the Tukituki River gravel supply.

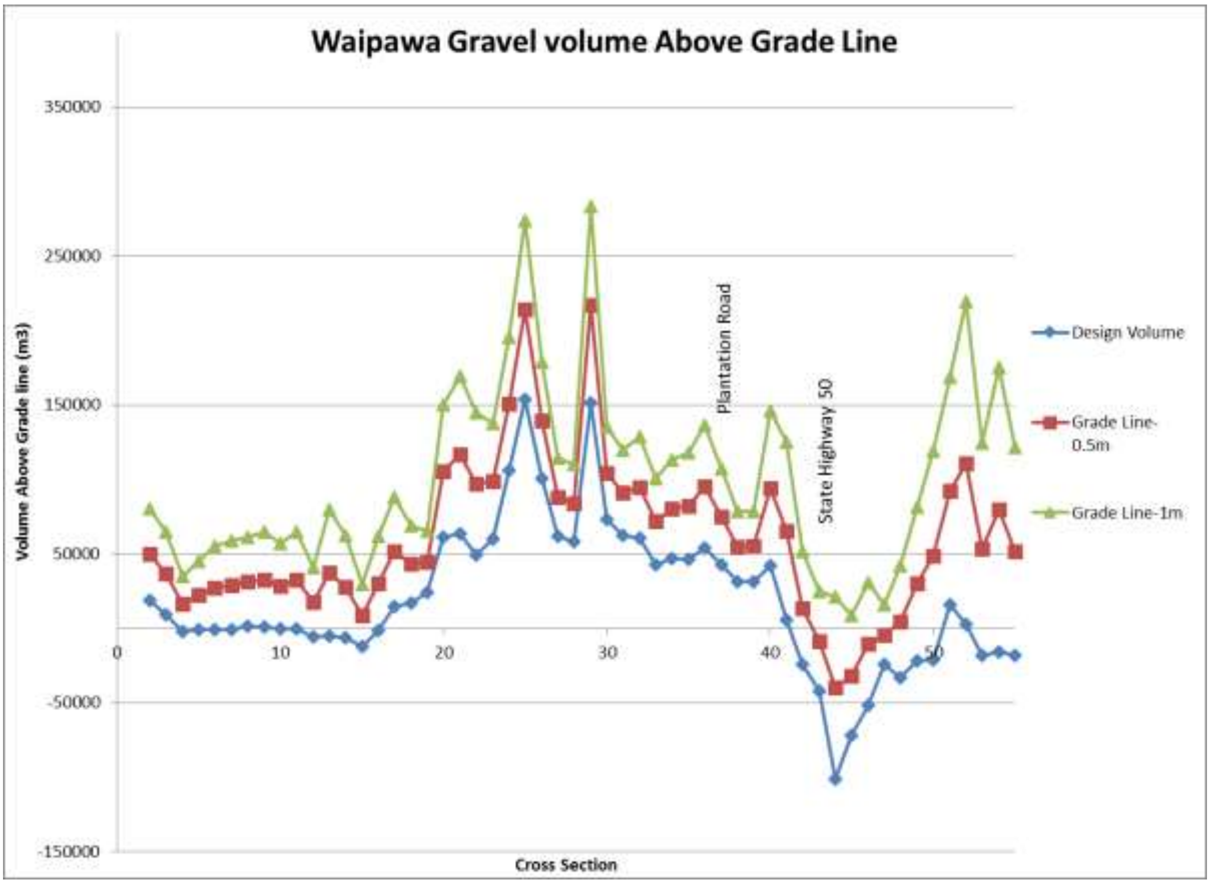

Figure 18: Waipawa River gravel volumes by section line

Current volumes by section are shown in Figure 18 and in Table 5. The currently surveyed design volumes show a volume of gravel above grade line of 1,509,622 m^3. The lower reaches of the Waipawa River are at or just below grade line, while between Section lines 17 and 39 there is some 1,455,000m^3 of gravel available. Figure 19 shows section line location, gravel volumes at design and extraction areas.

Figure 19: Waipawa River section lines, design volumes and extraction areas

Red lines are survey section lines, blue numbers are volumes by section, cyan = current extraction areas.

CROSS SECT NO	CROSS SECT SPACING (KM)	CROSS SECT WIDTH (M)	MBL_CHANNEL (MASL)	GRADE LINE DESIGN (MASL)	VOLUME DESIGN (M3)	VOLUME DESIGN -0.5M (M3)	VOLUME DESIGN -1.0M (M3)
1		154	124.52	124.20			
2	0.42	138	125.89	125.59	19,043	49,703	80,363
3	0.45	110	127.06	127.07	9,068	36,968	64,868
4	0.38	85	128.21	128.33	- 2,147	16,378	34,903
5	0.39	150	129.66	129.62	- 819	22,093	45,006
6	0.37	154	130.76	130.84	- 1,169	26,951	55,071
7	0.40	144	132.21	132.16	- 1,024	28,776	58,576
8	0.39	160	133.46	133.45	1,716	31,356	60,996
9	0.42	143	134.86	134.84	937	32,752	64,567
10	0.39	150	136.10	136.13	- 320	28,248	56,815
11	0.44	147	137.60	137.58	- 343	32,327	64,997
12	0.31	152	138.34	138.60	- 5,670	17,503	40,675
13	0.61	125	140.81	140.62	- 4,810	37,433	79,675
14	0.59	109	142.15	142.57	- 6,499	28,016	62,531
15	0.36	123	143.57	143.76	- 12,447	8,433	29,313
16	0.43	172	145.27	145.18	- 1,696	30,016	61,729
17	0.43	168	146.92	146.60	14,887	51,437	87,987
18	0.32	158	148.16	147.83	16,944	43,024	69,104

CROSS SECT NO	CROSS SECT SPACING (KM)	CROSS SECT WIDTH (M)	MBL_CHANNEL (MASL)	GRADE LINE DESIGN (MASL)	VOLUME DESIGN (M3)	VOLUME DESIGN -0.5M (M3)	VOLUME DESIGN -1.0M (M3)
19	0.24	189	149.53	148.75	23,947	44,767	65,587
20	0.53	145	151.36	150.78	61,353	105,608	149,863
21	0.69	160	154.05	153.42	63,791	116,403	169,016
22	0.58	169	156.05	155.64	49,326	97,031	144,736
23	0.46	168	158.54	157.40	59,986	98,741	137,496
24	0.51	182	160.59	159.36	105,922	150,547	195,172
25	0.61	211	163.03	161.70	153,869	213,802	273,734
26	0.48	113	166.15	164.92	100,709	139,589	178,469
27	0.47	112	168.58	167.48	61,615	88,052	114,490
27A	0.44	124	171.01	169.88	57,930	83,890	109,850
28	1.14	107	177.27	176.10	151,227	217,062	282,897
29	0.53	126	180.41	179.21	73,243	104,116	134,988
30	0.43	141	182.73	181.74	62,520	91,222	119,925
31	0.52	120	185.57	184.79	60,629	94,559	128,489
32	0.45	138	188.13	187.43	42,795	71,820	100,845
33	0.49	133	191.02	190.31	46,802	80,000	113,197
34	0.57	118	194.24	193.66	46,418	82,185	117,953
35	0.64	139	198.14	197.42	53,926	95,046	136,166
36	0.45	148	200.66	200.06	42,498	74,785	107,073
37	0.33	138	202.73	202.00	31,274	54,869	78,464
38	0.33	146	204.76	204.14	31,558	54,988	78,418
39	0.68	159	208.76	208.55	42,129	93,979	145,829
40	0.74	164	213.23	213.34	5,679	65,434	125,189
41	0.52	127	216.12	216.71	- 24,172	13,658	51,488
42	0.45	171	218.97	219.63	- 42,253	- 8,728	24,797
43	0.67	195	223.00	223.97	- 101,173	- 39,868	21,437
44	0.48	139	226.29	227.08	- 71,750	- 31,670	8,410
45	0.54	166	229.38	229.87	- 51,611	- 10,436	30,739
46	0.23	181	231.35	232.07	- 24,341	- 4,388	15,564
47	0.42	177	234.64	234.79	- 32,943	4,647	42,237
48	0.59	172	238.35	238.62	- 21,532	29,945	81,423
49	0.80	179	243.76	243.80	- 21,440	48,760	118,960
50	0.74	235	248.81	248.60	15,610	92,200	168,790
51	0.77	328	253.46	253.59	2,583	110,961	219,338
52	0.74	58	256.89	257.00	- 18,137	53,273	124,683
53	0.84	397	262.88	262.96	- 16,019	79,531	175,081
54	0.59	75	265.78	266.17	- 17,998	51,622	121,242
Resource above Grade Line					**1,509,935**	**3,324,507**	**5,429,212**
Total	**27.79**				**1,029,622**	**3,229,417**	**5,429,212**

Table 5: Waipawa River gravel volumes by section line

Between 2003 and 2011 recorded aggregate production averaged around 102,000m^3 per annum. This figure dropped off considerably from 2012 to 2014 to a low of 7000m^3.

Allocations for the 2013-2014 year were 101,500m^3 and it is apparent that much of this has not been used but this could in part be a reflection of differences in timing for allocating gravel extraction and reporting extraction returns. Moreover the main extractor Infracon went out of business and this reduced extraction.

Assuming that the gravel added to the system each year above grade line is in the range of 31,000m^3 and 38,000m^3 per annum and a net available supply of gravel above grade line is approximately 1,000,000 million m^3 then there is, if extraction gets back to the 100,000m^3 per annum average as for the 2003 to 2011 years, likely to be a minimum of at least 16 years supply before the grade line level is reached for the Waipawa River.

If the extraction rate stays at the current minimum levels then there is an issue with gravel accretion and potential adverse effects in terms of flood control.

When taking the modelled figures of Clode et al, 2012 for the volumes of gravel entering the system in the Makaroro River and where the main accumulations are in the Waipawa, section lines 17 to 39 it would appear that the river is aggrading and the gravel is not moving downstream as fast as it is accumulating. HBRC recognise in their 2013-2014 allocation document that there is a looming issue where the stopbank freeboard above the 100 year flood event is less than the 0.6m design.

In essence, there would not appear to be any issue with allocating at least 100,000m^3 per annum for extraction. In fact encouraging more extraction is warranted in the short term. The issue is the lack of demand by extractors currently. It is unknown what the extraction intentions of Higgins are, who have acquired the assets of the Infracon business.

The estimates for gravel available for extraction at 0.5m less than grade line and 1.0m below grade line show estimated volumes of 3.3 to 5.4 million m^3 respectively. It is unlikely that in the short to medium term that extraction below grade line is likely to be necessary and if it were to be contemplated then should only be undertaken with a full understanding of effects on river bank stability and impacts on infrastructure.

7.6 Tutaekuri River

The Tutaekuri River gravel resources were assessed in terms of sustainable supply by HBRC in 2001, (Edmondson, 2001). In his report he shows that during the 1960's and 1970's there was considerable over extraction from the river which lead to rapid entrenchment of the river channel around Taradale, river bank instability and foundation instability at Waiohiki Bridge. The proximity to the urban area and stop bank stability has seen extraction reduce significantly over the years.

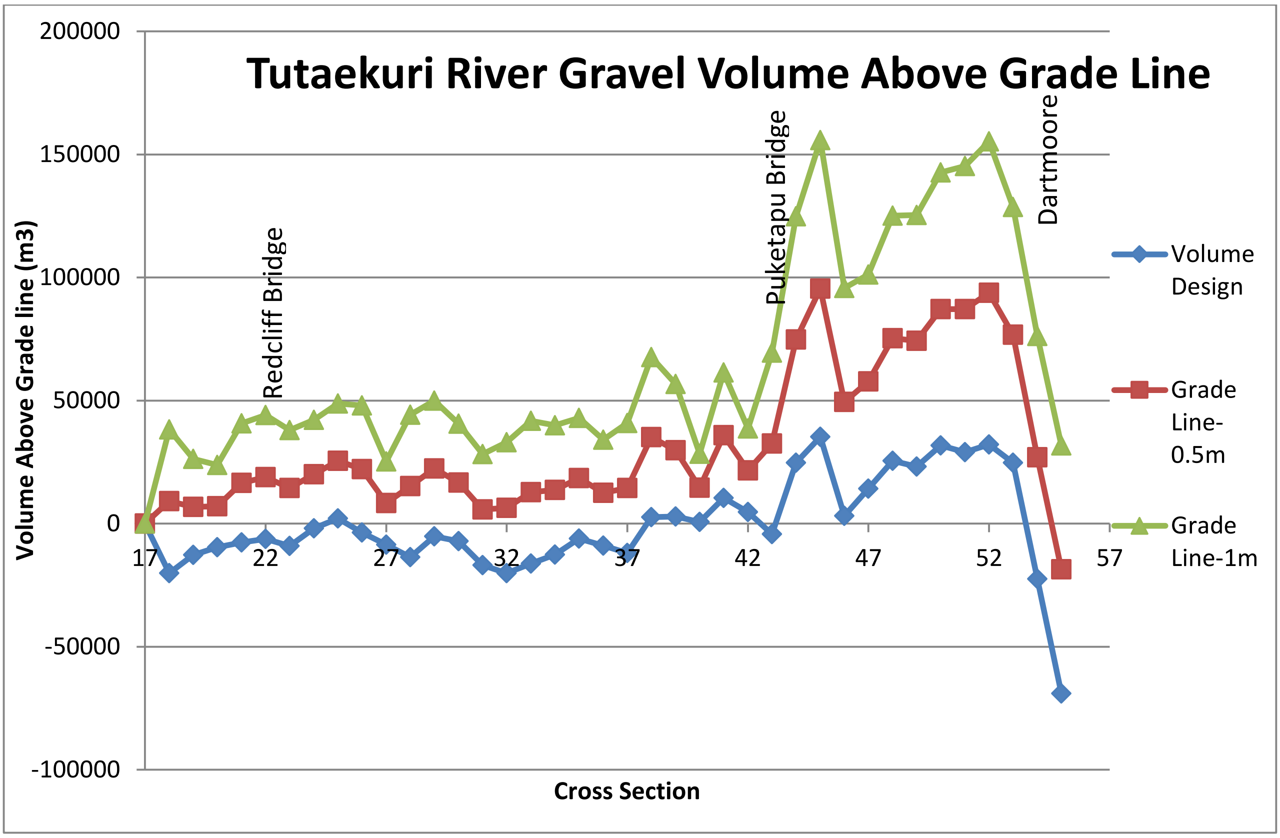

Figure 20: Tutaekuri River gravel volumes by section line.

Further Edmondson assessed the long term sustainable yield from the Tutaekuri at 28,000 m^3 as compared to the assessed long term yield of 36,000 m^3 in the Heretaunga Plains Gravel management Plan 1989.

Figure 20 and Table 6 show the 2013/2014 gravel volumes at grade line and at 0.5m and 1.0m below grade line respectively. Figure 21 shows gravel volumes and extraction areas in the Tutaekuri River.

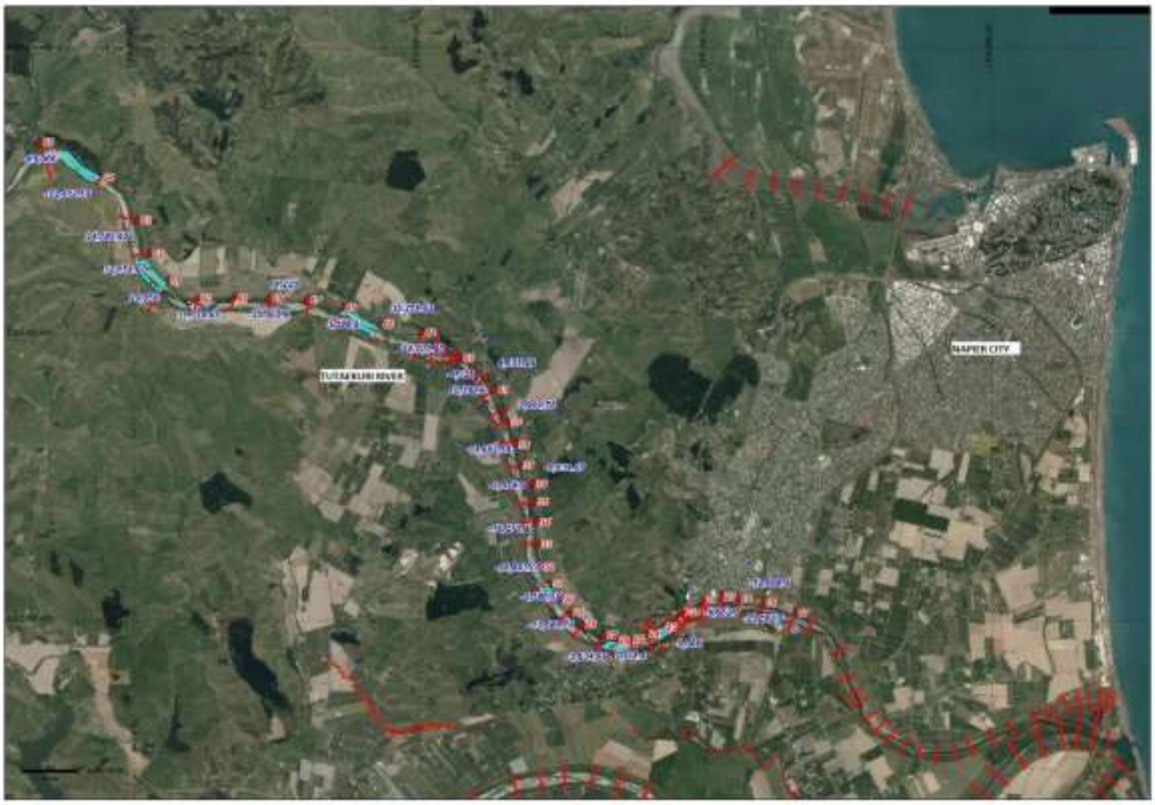

Figure 21: Tutaekuri River gravel volumes at design and extraction locations.

Red lines are survey section lines, blue numbers are volumes by section, cyan = current extraction areas.

Allocated extraction for the Tutaekuri for the 2013–2014 year was 20,500 m^3 with actual recorded production returns of straight haul averaging approximately 14,000 m^3 per annum from 2001 to 2013.

CROSS SECT NO	CROSS SECT SPACING (KM)	CROSS SECT WIDTH (M)	MBL_CHANNEL (MASL)	GRADE LINE DESIGN (MASL)	VOLUME DESIGN (M3)	VOLUME DESIGN -0.5M (M3)	VOLUME DESIGN - 1.0M (M3)
17		100	14.96	15.23			
18	0.59	100	15.67	16.09	- 20,183	9,068	38,318
19	0.37	111	16.4	16.64	- 12,698	6,819	26,337
20	0.31	105	16.75	17.09	- 9,663	7,077	23,817
21	0.34	179	17.54	17.59	- 7,591	16,550	40,690
22	0.33	126	17.85	18.08	- 6,258	18,904	44,067
23	0.40	109	18.52	18.67	- 9,066	14,434	37,934
24	0.36	136	19.24	19.20	- 1,964	20,086	42,136
25	0.32	156	19.95	19.9	2,118	25,478	48,838
26	0.33	157	20.52	20.71	- 3,635	22,188	48,010
27	0.25	113	20.96	21.30	- 8,531	8,344	25,219
28	0.44	153	22.15	22.31	- 13,681	15,247	44,174
29	0.36	158	23.11	23.14	- 5,187	22,415	50,016

CROSS SECT NO	CROSS SECT SPACING (KM)	CROSS SECT WIDTH (M)	MBL_CHANNEL (MASL)	GRADE LINE DESIGN (MASL)	VOLUME DESIGN (M3)	VOLUME DESIGN -0.5M (M3)	VOLUME DESIGN - 1.0M (M3)
30	0.33	136	23.61	23.90	- 7,179	16,708	40,596
31	0.32	150	24.18	24.63	- 16,843	5,679	28,202
32	0.37	137	25.19	25.49	- 20,091	6,457	33,004
33	0.43	133	26.24	26.50	- 16,271	12,754	41,779
34	0.38	147	27.15	27.37	- 12,548	13,702	39,952
35	0.33	150	28.11	28.14	- 6,079	18,424	42,926
36	0.31	132	28.44	28.85	- 8,940	12,563	34,065
37	0.37	157	29.63	29.70	- 11,883	14,489	40,860
38	0.41	160	30.81	30.66	2,667	35,160	67,652
39	0.37	135	31.45	31.51	2,902	29,820	56,739
40	0.21	135	32.1	31.99	692	14,529	28,367
41	0.36	148	33.11	32.82	10,399	35,869	61,339
42	0.23	154	33.33	33.34	4,655	21,643	38,630
43	0.60	92	34.34	34.48	- 4,326	32,574	69,474
44	0.75	175	36.65	36.20	24,701	74,764	124,826
45	0.78	136	38.37	38.28	35,259	95,515	155,771
46	0.68	138	40.09	40.11	3,200	49,437	95,675
47	0.60	152	42.05	41.72	14,220	57,720	101,220
48	0.66	150	43.67	43.49	25,463	75,293	125,123
49	0.66	162	45.51	45.24	23,167	74,257	125,347
50	0.65	182	47.3	47.00	31,715	87,185	142,655
51	0.64	181	48.96	48.76	29,056	87,136	145,216
52	0.72	161	51.02	50.69	32,159	93,719	155,279
53	0.67	149	52.63	52.49	24,787	76,712	128,637
54	0.87	79	54.17	55.09	- 22,412	26,893	76,198
55	0.11	113	57.38	57.90	- 69,006	- 18,606	31,794
Resource above gradeline					**267,159**	**1,255,609**	**2,500,881**
Total	**17.13**				**- 26,874**	**1,237,003**	**2,500,881**

Table 6: Tutaekuri River gravel volumes by section line

Section lines 44 to 53 from Puketapu Bridge to Dartmoore are the only areas where there is significant resource sitting above grade line of approximately 240,000 m^3. Given the HBRC policy of not extracting gravel to below grade line and the necessity for the overall gravel resource to replenish the areas of over extraction for long term bank stability and infrastructure protection it seems that the current extraction is sustainable at the levels allowed in the allocations.

Gravel resources estimates for the 0.5m and 1.0m below grade line scenarios show potential for long term supply, however decisions to utilise these would require full understanding of the risks and other ramifications to river flow, infrastructure impacts, etc.

7.7 Esk River

The Esk River is a relatively small catchment that underwent significant over extraction in the 1970's for the development of the Whirinaki Timber Processing plant. HBRC describe the lower reaches as having undergone massive degradation due to this over extraction and only allocate in the order of 5000m^3 per annum recently for minor works. Essentially the HBRC's view is that little or no meaningful extraction is likely in the foreseeable future.

7.8 Mokaha River

The Mohaka River has its headwaters in the Huiarau and Ahimanawa Ranges from where it sources the greywacke gravels of the Torlesse Kaweka Terrane and the Waioeka petrofacies. The river cuts through Tertiary sediments all the way to the coast without building up significant alluvial gravel terraces as compared to the rivers of the Ruataniwha and Heretaunga Plains.

Current (2013-2014) allocations for the Mohaka River (upper and lower) total approx. 100,000m^3. Actual recorded production returns have averaged approx. 47,000m^3 for the period 2003 to 2013 or roughly 50% of allocation.

HBRC's current view is that as most production from fixed or mobile plant is in the lower reaches of the river and near the river mouth, and the relatively small volumes involved mean there are no issues with the current extraction rates.

Overall gravel production for road maintenance is likely to remain similar to the present until at least 2018 when the next demand increase from forestry is likely to occur. On that basis it is concluded that the resource is sustainable at current rates.

7.9 Waiau River

The Waiau River drains the western greywacke ranges and has its confluence with the Wairoa River near Frasertown approx. 8km north of Wairoa.

While the river contains gravel from the western greywacke ranges it also has a significant proportion of the soft Tertiary aged sedimentary units through which it drains. Industry sources who extract gravel from this river also describe difficulties in obtaining premium product due to the presence of pumiceous silt, derived from the Central Volcanic Plateau and 'papa rock' which is most likely taken from areas of the river where the gravel bed is thin above the Tertiary sedimentary basement.

The 2013-2014 allocation is 28,200m^3. Average volumes used as recorded in HBRC files shows an average usage over the period 2003 to 2013 of 17,350m^3. Much of the gravel is used for general road maintenance, forestry and by local contractors. We are advised there have been issues on location of the extraction sites and private land so it is possible not all extraction has been recorded in the public domain. However given the small volumes extracted and the likely subdued demand it is concluded there will no issue with sustainability of supply.

7.10 Wairoa River

The Wairoa River drains the greywacke ranges in Northern Hawke's Bay region. HBRC production records show that any substantive production ceased on the Wairoa River in 1989. We are advised that there is limited public access to the river and some potential gravel resource is in private land ownership. There is currently no allocation for aggregate extraction from the Wairoa and the Northern regions needs are met from production from the Mohaka, Waiau and land based gravel pits.

7.11 Other Rivers

Other rivers, tributaries off the main rivers and several streams have small allocations issued on an annual basis dependant on local demand. For the Central region these include the Hautapau, Aropaoanui and Ohara Streams with a total allocation for 2013/2014 of 2,500m^3. In the Northern region from the Te Hoe Stream some 20,000m^3 was allocated in the 2013/2014 year for forestry roading.

Small allocations in the Southern Region have been given on the Makaretu River, Porangahau and Tukipo Rivers totalling around 10,500m^3 in 2013/2014.

Overall these are a small part of the total extraction. Resource volumes have not been evaluated in this study as they represent small volumes, often being ad hoc and dependant on local contractor requirements for road maintenance, forestry etc.

7.12 Estimates of Resources Available for Extraction

Table 7 below summarises the current estimates of resources in the main river systems based on cross sectional survey data. Details are discussed in the preceding sections.

River Name	Net Volume at Design Grade line	Net Volume at -0.5m below Design Grade Line	Net Volume at 1.0m below Design Grade Line	Current or Projected Average Annual Production	Years at Assumed Production Rate	Notes
Ngaruroro	2,560,763	6,553,783	10,699,108	270,000 - 315,000	3.5 to 5 at current sites or 10 to 15 if extraction moves upstream.	Assumes natural addition of 170,000m^3 pa
Upper Tukituki	881.981	2,378,546	4,417,280	40,000	Long term OK unless extraction increases	Assumes natural addition of 140,000 to 180,000 m^3 pa
Middle Tukituki	14,309,915	16,264,699	19,196,876	3000 - 5000	Could be increased significantly. Potentially large resource	Uses Thalweg. No grade line determined.
Lower Tukituki	9,246	697,064	2,028,042	26,000	Sustainable at low levels	Over extraction. No potential to increase.
Waipawa	1,509,935	3,324,507	5,429,212	102,000	Sustainable	
Tutaekuri	267,159	1,255,609	2,500,881	14,000	Sustainable at current low levels	Over extraction
Esk				5000	Minimal extraction	Over extraction
Mohaka				47,000	No constraints at current volumes	
Waiau				17,350	No constraints at current volumes	
Wairoa				Nil		

Table 7: Summary table of available river gravel resources

8.0 LAND BASED GRAVELS

8.1 Recent gravels

Recent gravels that lie outside the active river channels are potentially an important source of gravel in the future should extraction from the active river channels become restricted due to sustainability or other issues.

At present there is only one consented extraction operation based near Maraekakaho on the Ngaruroro River. This is owned by Higgins Aggregates Ltd and is designed to supplement their Roys Hill operations on the Ngaruroro River. It was consented for a 25 year term. The long term plan after extraction is complete is to develop recreational facilities at the site, based around a lake.

Considerations for selecting and evaluating other potential gravel resources in these recent gravels that have the same characteristics and quality as the premium aggregates that can be produced from the active river channels include;

- Competing land use, such as vineyard development, horticulture and other agricultural activities
- Impact on flood control infrastructure
- Proximity to market, travel distances
- Aggregate quality
- Long term supply
- Mitigation of adverse effects, visual, environmental
- Land and mineral ownership
- Land use planning zones
- Cultural aspects including iwi issues
- Final end use

Figure 22: Higgins Land based gravel resource at Maraekakaho.

At Maraekakoho where the Higgins land based deposit is located there is a large area of approximately 3.5km by 0.8km of recent gravel that, allowing for sufficient buffer zones from the active river, would warrant further investigation for future gravel resource.

Other opportunities maybe limited in the other catchments (see Figure 19) due to adequate supplies of gravel from the active river channel and distance to market. This could change but would be up to individual companies or operators to evaluate.

8.2 Terrace gravels

Land based **gravel pits** form an important part of the overall aggregate supply to the region. They are invariably sourced from Quaternary aged gravel terraces of the Kidnappers Group. These are sometimes referred to colloquially as red rock pits, and are typically slight to moderately weathered river terrace gravels uplifted above the main active river channels. They typically contain a portion of silt, red-brown fines and clay.

These gravels are used for the local construction industry, forestry roading, maintenance metal on unsealed roads and general roading maintenance.

There is no accurate data on the total annual volumes extracted for aggregate use from these land based pits. Preliminary research and anecdotal industry feedback suggests that the three districts, (Central Hawke's Bay, Hastings and Wairoa Districts) each produce in the order of 30,000m^3 per annum on average, while the main forestry companies usage depends on the forestry harvesting cycle. As indicated above, while there is no accurate data to support it, in total red rock quarries could represent about 25% of the total gravel volumes extracted.

From discussions with local contractors most of red metal gravel is screened to -40mm with only 1 to 2 percent above 40mm material. This means it is generally not large enough to process crushed aggregate with sufficient broken faces.

9.0 HARD ROCK QUARRIES

9.1 Limestone

There are several limestone quarries which typically service the agricultural industry and forestry, and one supplies crushed limestone for masonry block manufacture by Firth in Napier. However, minor volumes of limestone rock are occasionally used in road maintenance activities in the southern part of the Hawke's Bay region, where they are in close proximity to work contract areas. They are more frequently used in the Wairoa District Council area on road maintenance work.

As above, there is no accurate data on the volumes extracted or produced from these 'hard rock' quarry sources. The focus of this study has been on river and land based gravels

Again, more in depth detail on the above items are provided in the 'sister report' Gravel Demand Forecast Report (Issue 5), produced by the writers of this report.

9.2 Greywacke

A search of the GERM database shows there are no hardrock quarries in the region that exploit premium aggregate from greywacke or volcanic primary source rocks. Some of the "redrock" gravel pits are on elevated areas and benched but are still essentially gravel pits.

10.0 AGGREGATE PRODUCTION

10.1 Total Historic River Gravel Extraction Volumes

The HBRC and its forerunners have collected aggregate production records from rivers in the region since the early 1960's and this provides an excellent database to assist in managing the aggregate resources in the region from an aggregate production perspective as well as for general river management.

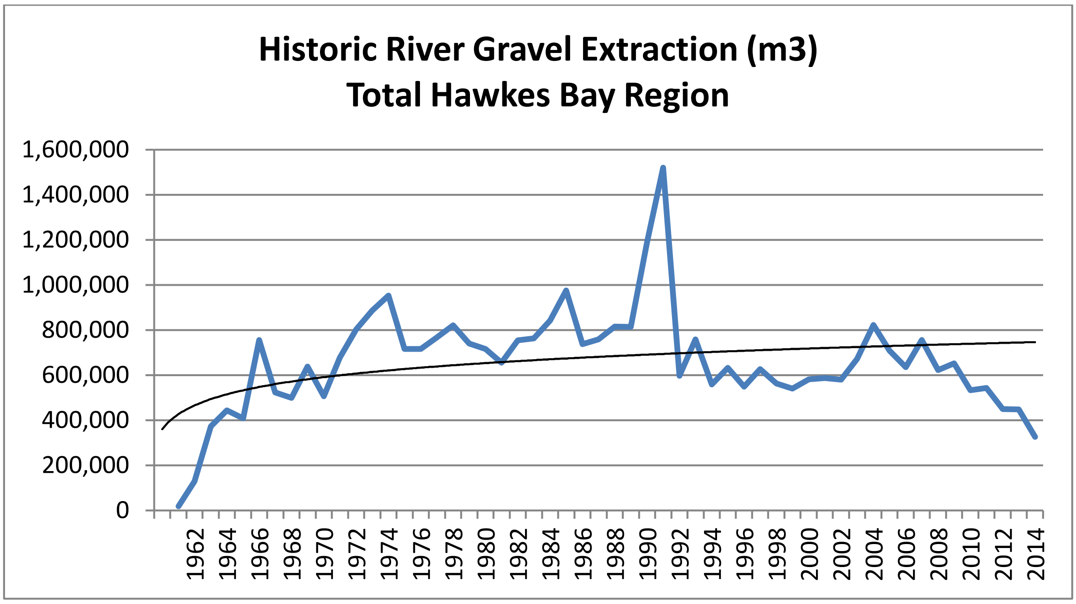

Figure 23: Total recorded production of river gravels for Hawke's Bay region

The graph shown in Figure 23 shows the gross recorded production from the Hawke's Bay region since 1961. The trend line shows an overall gradual increase over time with major peaks and troughs coinciding with economic cycles and major infrastructure projects. These include the construction of the flood control stop banking and major highway upgrades. Production levels peaked in 1990 with the construction of the Napier Expressway but have dropped regionally since the GFC in 2008, although production from the Ngaruroro River has more consistent volumes.

10.2 Current River based production by river

10.2.1 Ngaruroro River

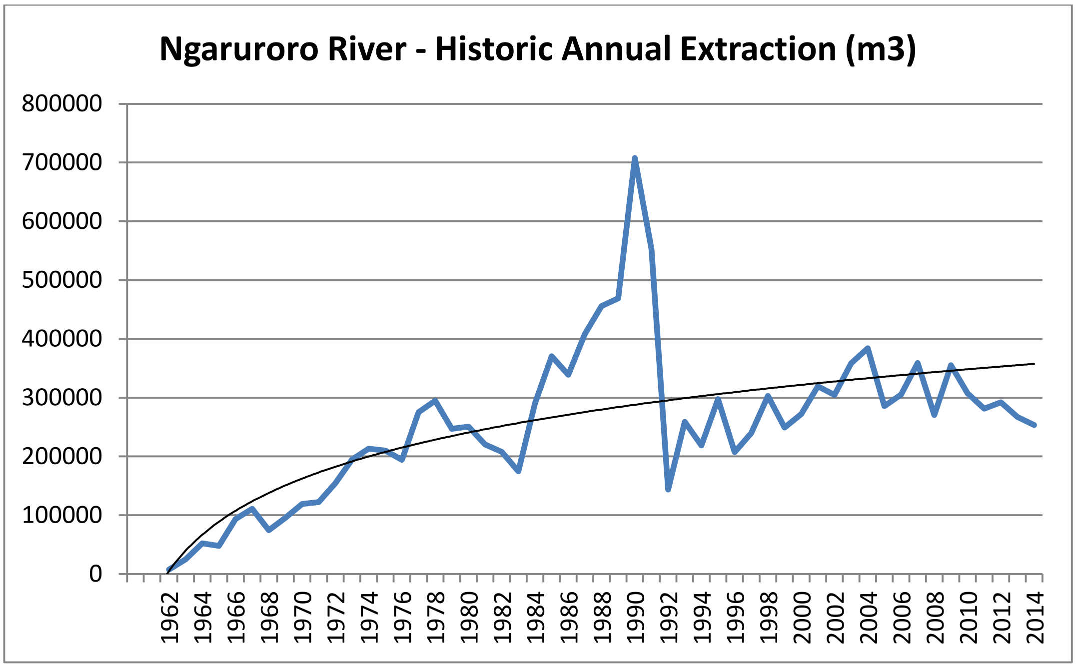

Figure 24: Ngaruroro River annual extraction

The Ngaruroro River has shown more production consistent volumes over time with a major spike in production in the early 1990's coinciding with the Napier Expressway construction.

This consistency is most likely to be due to there being three large permanent extraction companies operating on or near the Ngaruroro River: Winstone Aggregates, Holcim, and Higgins Aggregates. They are located there because they are close to the most densely populated urban areas of the Hawke's Bay with more concentrated industry and infrastructure. Hence the aggregate demand is more **consistent and the volumes are considerably larger than in other river locations.**

These three companies extract the large majority of the total Ngaruroro volumes. The Ngaruroro extraction volumes represent on average 60% of the total regional river gravel volumes in recent decades. In addition there is a more consistent demand level, supplying into many segments of the construction and aggregate market. This provides a more consistent level of production for the main extractors.

Many of the 'other' regional river extraction sites are temporary or mobile operations extracting when there is sufficient demand, or based on one off projects, including forestry.

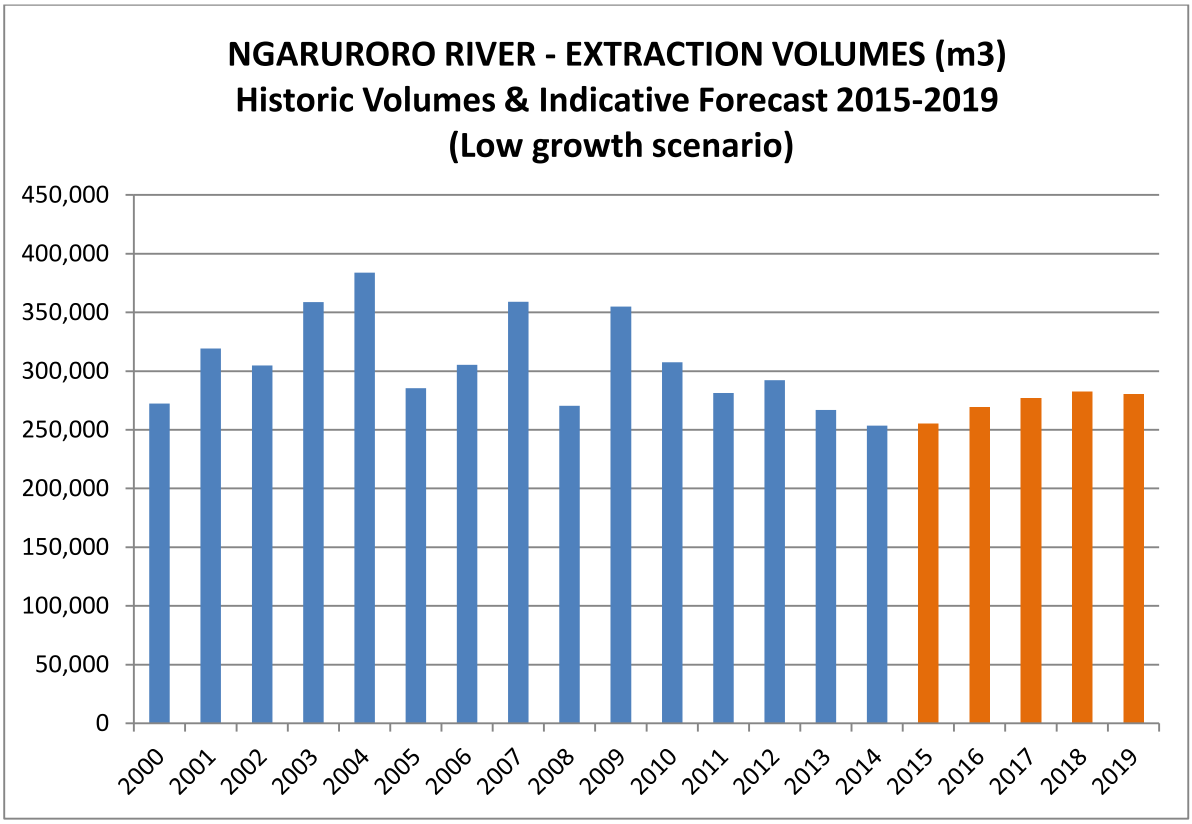

Figure 25: Ngaruroro River historic production and future demand growth, (low growth scenario) (source HBRC and Infometrics)

Low Growth Scenario

In this scenario the 'average' indicative extraction volumes forecast over the next 5 years is in the order of **270,000 cubic metres** annually.

Medium to high Growth Scenario

In Figure 26 below the average extraction over the forecast period is in the order of **315,000 cubic metres** annually.

Note that both of these scenarios <u>exclude</u> the impact of Ruataniwha Dam on downstream volumes. It is important to note, as written in the *Gravel Demand Report*, that the Ruataniwha Dam construction site plans to use local aggregates sourced and crushed from around the dam site and will not source these from the other downstream river extraction sites. It will be other related downstream 'on farm' and associated activity that will provide additional aggregate demand if the project goes ahead.

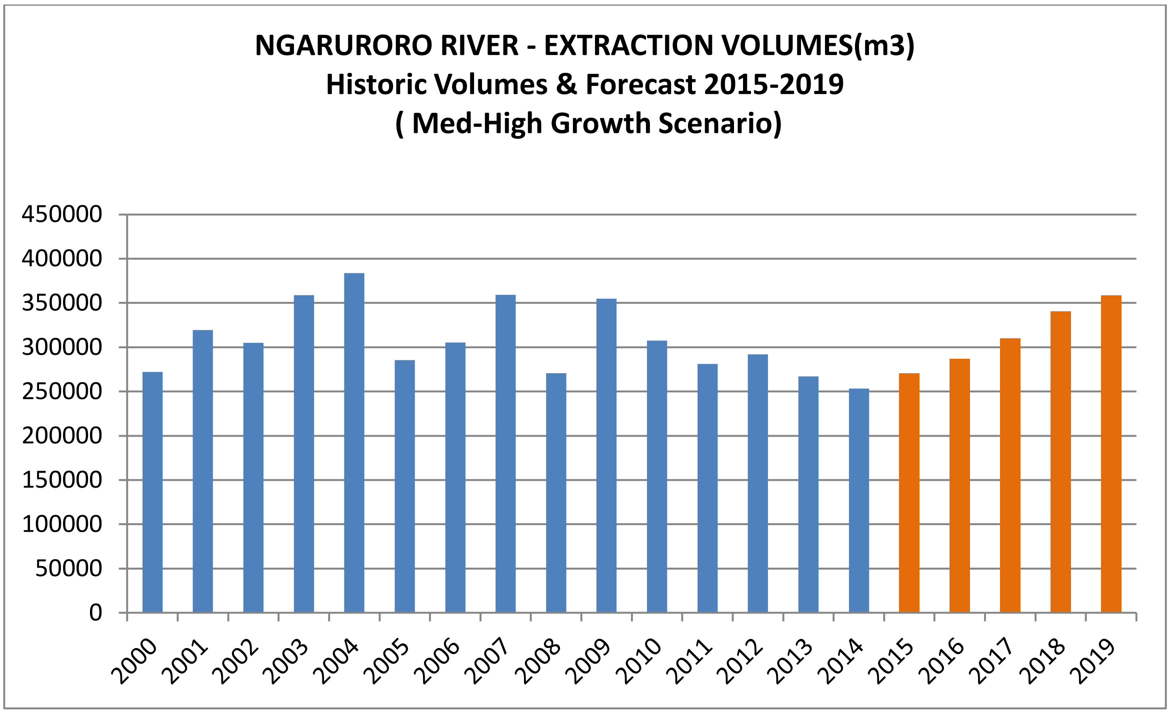

Figure 26: Ngaruroro River historic production and future demand growth, (medium to high growth scenario)

Figure 26 shows historic extraction based on annual gravel returns provided by HBRC, and projected <u>medium-high</u> growth demand based on extrapolation of Infometrics forecast growth in construction activity (residential, commercial and infrastructure)

11.2.2 Upper Tukituki River

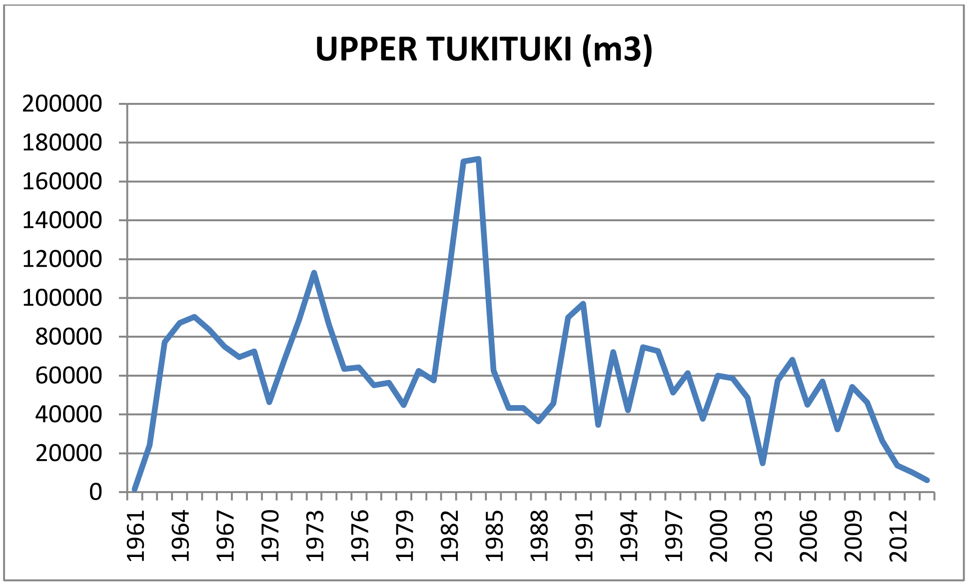

Figure 27: Historic gravel production from Upper Tukituki River

History: Peak production in the early 1980's (~170,000 m^3) (Figure 27) for construction of embankments for flood protection control scheme. Hurlstone and Calais extracted significant volumes, both businesses failed due to long transport distance and cost to get to market past closer extraction sites.

Recent Extraction Trends: Reduction in extraction policy due to need for gravel transport to Haumoana coast as mentioned above. Infracon business failure recently reduced extraction significantly.

Future Potential: Limited by policy of wanting gravel to transport to Haumoana coast and replenishment of gravel required to bring Lower Tukituki back to grade line.

11.2.3 Middle Tukituki River

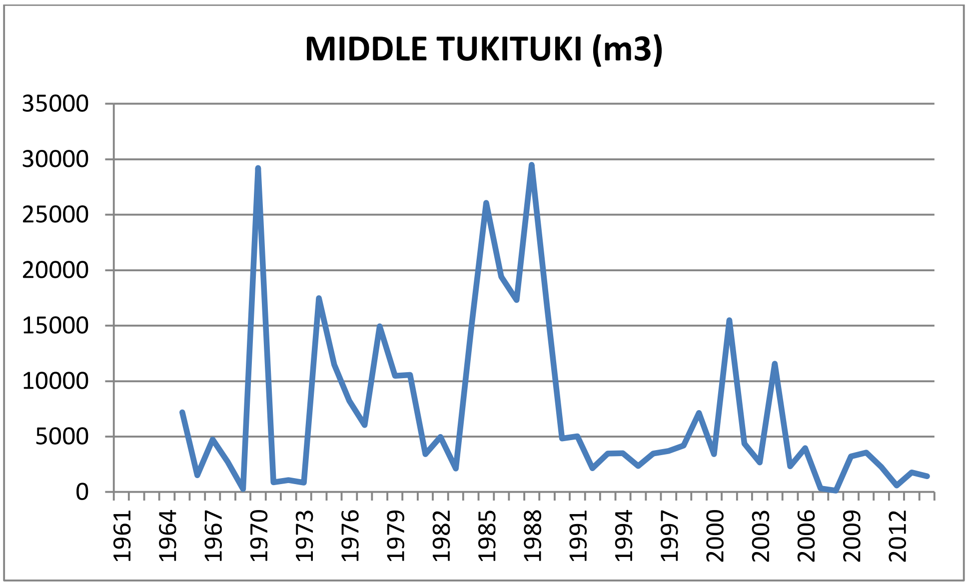

Figure 28: Historic gravel production from the Middle Tukituki River

History: Peak extraction 1970, 1988. (Figure 28).

Recent Extraction Trends: There are river access issues in the middle Tukituki, and subsequently extraction has dropped off.

Future Potential: Significant resources likely but dependent on further morphological modelling of this section of the river to determine grade line design and sustainable production scenario.

11.2.4 Lower Tukituki River

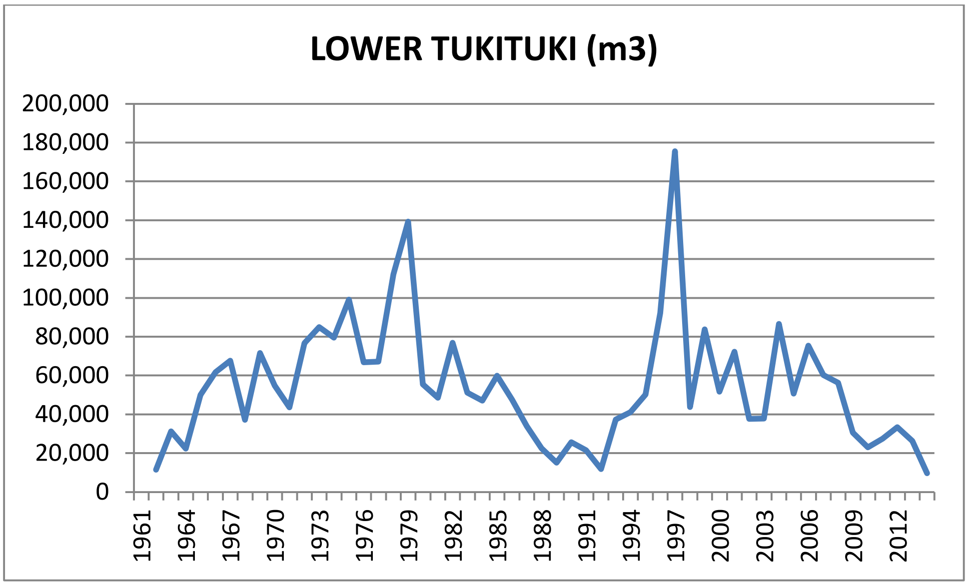

Figure 29: Historic gravel production from the Lower Tukituki River

History: Peak extractions 1979 and 1997 resulted in over extraction. (Figure 29).

Recent Extraction Trends: The Tukituki River is the only river that transports gravel to the Haumoana coast, which has foreshore erosion issues. HBRC policy has therefore been to reduce extraction to allow gravel to reach the coast. Currently around 26,000m^3 extraction in 2013.

Future Potential: Minimal gravel extraction likely for some time apart from sand and silt due to past over extraction.

11.2.5 Waipawa River

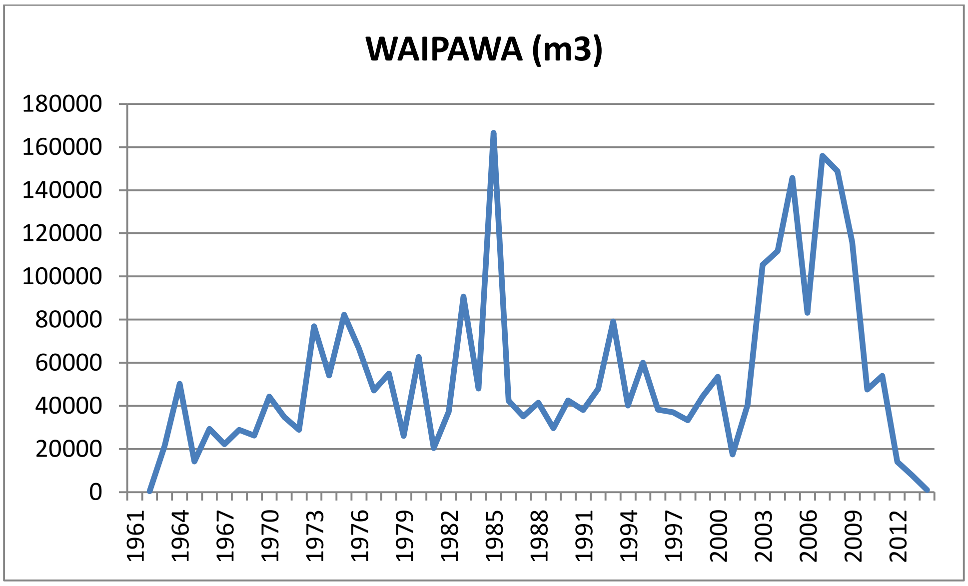

Figure 30: Historic gravel production from the Waipawa River

History: 1985 peak of more than 160,000 m^3. (Figure 30). Again in 2005 and 2008 ~150,000m^3 regular extraction by 2-3 contractors and operators being active across the region before going out of business.

Recent Extraction Trends: Infracon lost major roading contracts after these peaks, and dramatically reduced extraction, went into receivership and assets bought by Higgins, who haven't yet resumed extraction at those former levels. CHBDC road aggregate demand is understood to be changing with more emphasis on insitu stabilisation of roads, requiring less roading aggregate, and in addition land-based "red rock" gravel pits are being used more extensively.

Future Potential: Aggradation of gravel occurring. Gravel at similar volumes to past production required to alleviate potential flood risks.

11.2.6 Tutaekuri River

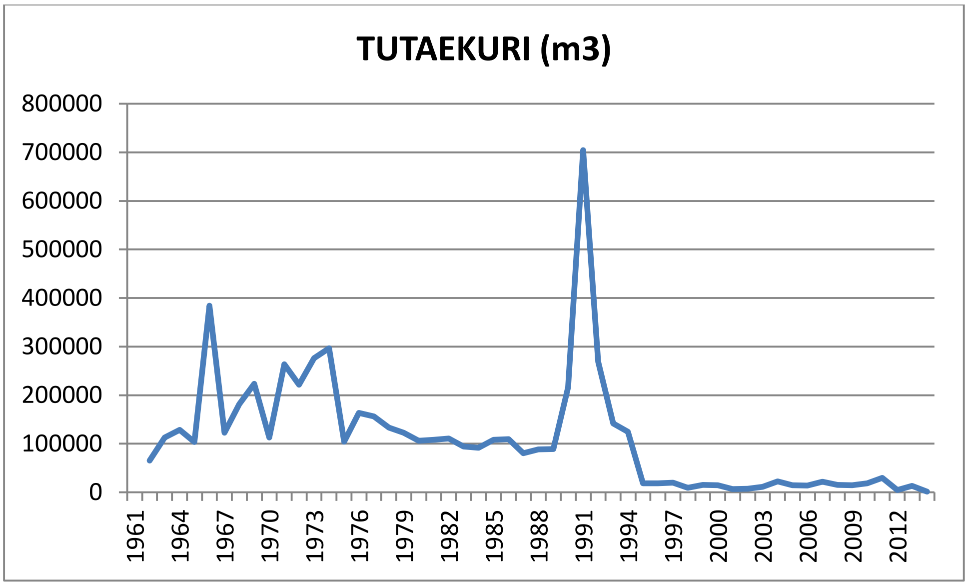

Figure 31: Historic gravel production from Tutaekuri River

History: 1991 peak of 700,000m^3 (Figure 31) due to the construction of the Napier Expressway. Earlier there was significant demand due to infrastructure and construction activity around Napier in 1960's and 1970's. Over extraction caused some rapid entrenchment around bridges and destabilisation of stop banks between Taradale and Puketapu Bridge and resulted in gravel extraction being discontinued.

Recent Extraction Trends: Extraction levels dropped dramatically since 1998 to around 10,000-15,000 m^3 per annum.

Future Potential: Similar volumes. Minimal volumes available according to HBRC allocation report of 2013/14

11.2.7 Esk River

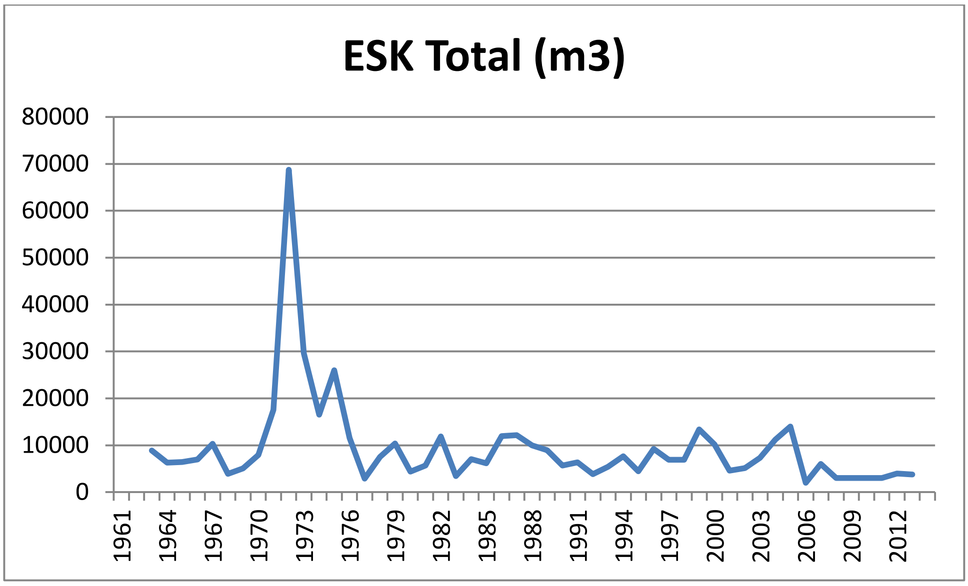

Figure 32: Historic gravel production from Esk River

History: Significant over extraction in the early 1970's for Whirinaki timber mill, to below the grade line has restricted subsequent extraction for many years. (Figure 32). Continual channel degradation and massive degradation reported by HBRC since 1970's in their 2013/14 allocation report.

Recent Extraction Trends/Issues: Small allocations, around 10,000 m^3 or less.

Future Potential: No significant change in foreseeable future.

11.2.8 Mohaka River

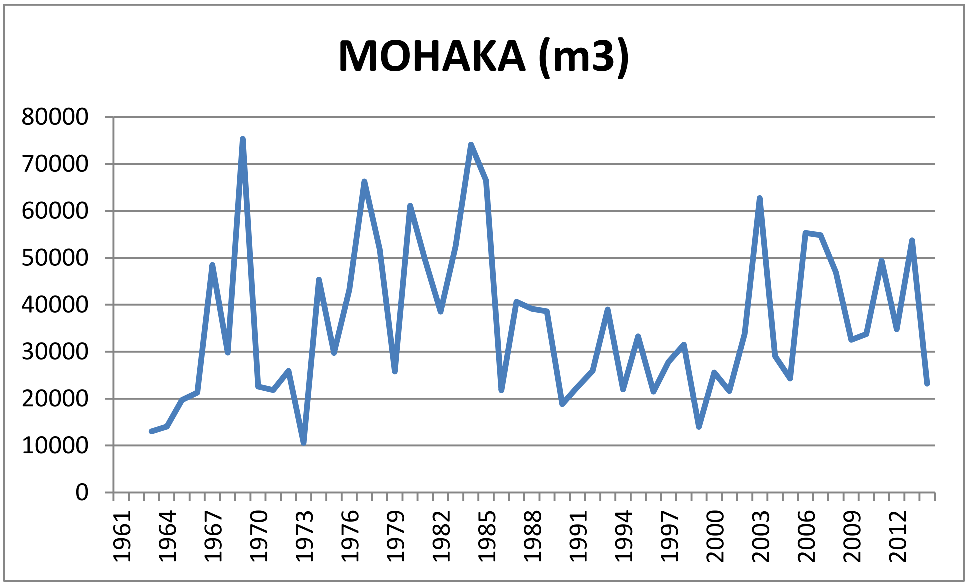

Figure 33: Historic gravel production from Mohaka River

History: Services local area needs, roading, forestry. River is deeply incised in Tertiary mudstone and sandstone with limited gravel terraces formed.

Recent Extraction Trends: Roading and Forestry key extractors. Annual figures can vary but averages around 48,000m^3 per annum over the last 10 years. (Figure 33).

Future Potential: Anecdotal feedback suggest demand likely to drop off a little with roading, and fluctuating forestry demand in short to medium term, with a pickup in demand likely in 2018.

11.2.9 Waiau River

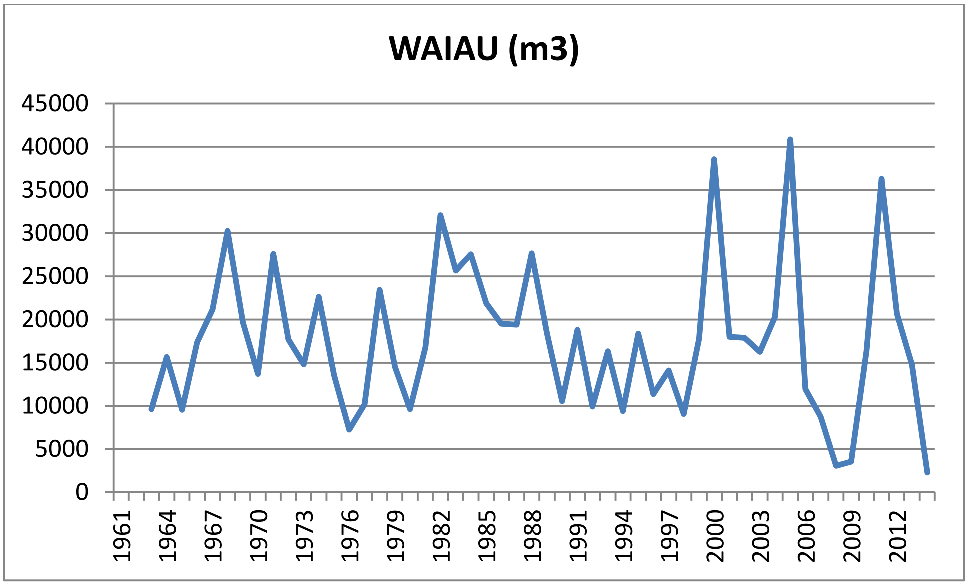

Figure 34: Historic gravel production from Waiau River

History: Note traditionally sourced for roading and forestry. Rock is understood to be generally softer and thought to be not suitable for quarry crushing and better quality aggregate production. Issues with mixing of soft bed rock when excavating requires additional processing to wash.

Recent Extraction Trends: Recent peaks in 2000, 2005, 2011 due to forestry demand. (Figure 34). Reduced extraction recorded by HBRC in last few years due to riverbed location and extraction sites being on private land, hence no returns provided. Extraction likely to resume and allocation/returns process will resume.

Future Potential: Yes, resource available. Difficult to quantify.

11.2.10 Wairoa River

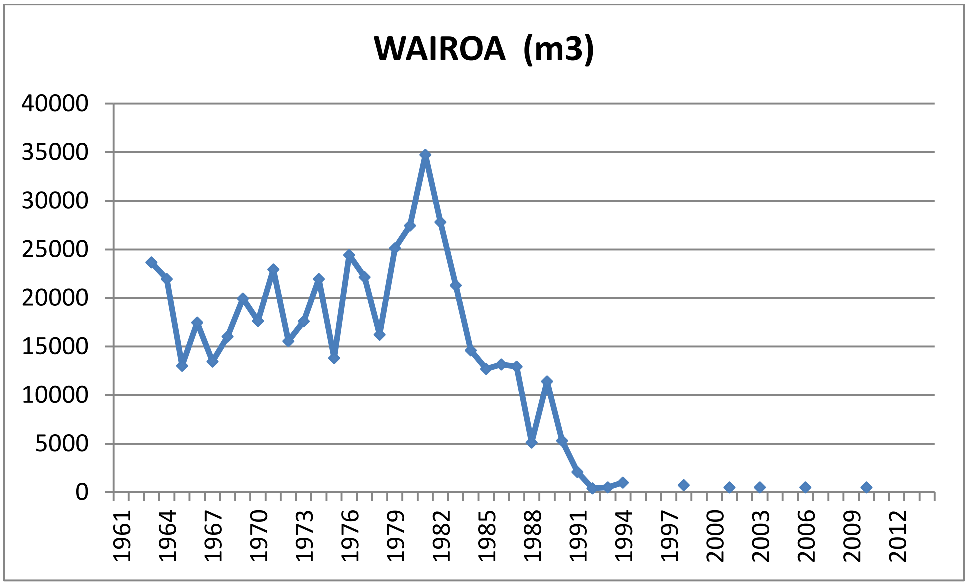

Figure 35: Historic gravel production from Wairoa River

History: Peak production in 1981. (Figure 35).

Recent Extraction Trends: Drop off in demand with forestry. Also, QRS using land based "red rock" pit sources. Since 1994 extraction has dropped to around 500m^3 every 3 or 4 years. Note these volumes are so small they do not show up on the above graph.

Future Potential: Resource available, though demand not currently there.

11.3 Current land based

Current land based gravel production is mainly from the red rock gravel pits of which there are several dozen, as indicated by local contractors, throughout the region. Contractors interviewed indicate that most pits produce in the order of several thousand m^3 per annum located on private land and accessed by private landowner agreement dependant on proximity to work location. It is estimated from anecdotal market information that total production for the region could be in the order of 100,000m^3 per annum.

11.4 Future demand

This is covered in detail in the *Gravel Demand Forecast Report,* as is the nature of the industry and the type of uses for the aggregate. As discussed elsewhere in this report, we believe there are two distinct parts to this.

First the Ngaruroro River with its three large extractors has consistent levels of production each year. As discussed there is a rationale to correlate demand with the rolling Infometrics Construction Industry demand forecast (5 year) demonstrated in the *Gravel Demand Forecast Report*.

Secondly, as a general observation the other rivers do not have consistent levels of production or demand like the Ngaruroro, and often have temporary satellite operations for contractors, based on proximity to contract or end use. As aggregate cartage costs are a key component of total delivered cost, it is critical to extract as close as practical to the end use site. Forestry can be a significant user of aggregate. Because of this there is not a strong case to correlate the Construction Industry Demand forecast to each of these rivers

Recommendation: Investigate the option of an industry working group to evaluate the practicality of establishing rolling forecasts for gravel allocations (or multiple years), rather than the current one year time frame. For example some of the larger forestry industry players have plans for higher levels of aggregate during the years 2018-2028 during their roading programmes. There are estimates available which indicate likely demand. Of course some of the gravel will come from land based pits as well as rivers. Proximity to forestry estate sections will be critical also.

11.5 Distances from plant and contract areas

Discussed elsewhere in this report. The following is an extract from the *Gravel Demand Forecast Report*

"*One of the key issues for the Gravel Management Plan is how does HBRC incentivise extractors to extract from other than their favoured locations (in particular the large semi-permanent locations on the Ngaruroro) which are generally in close proximity to their processing plants and/or their end market. The transport costs are key commercial issues.*

Recommendation: Investigate options to incentivise alternate extraction locations and consider a review of the HBRC regional extraction charges per cubic metre*. Consider increasing this rate in totality across the region to all extractors to make it equitable and reduce it in other more remote locations where HBRC wishes to extract, or propose a* ***transport subsidy****. There will be a number of scenarios to consider with this, and we suggest industry input will be valuable.*

When it is identified which southern river locations require gravel removal and the indicative volumes involved, it will be possible to estimate the potential cost differential to cart it by road to processing sites, over and above the cost of carting from current sites."

11.6 Aggregate product range

This topic has been discussed in detail within the *Gravel Demand Forecast Report (Issue 5*).

The three largest producers on the Ngaruroro River with more established production facilities produce the widest range of aggregates from premium to lower grade. These include concrete aggregates, sealing chip, asphalt aggregates, road base course at the premium end to a full range of other products, including sand and decorative pebbles. Aggregate is also exported to markets in other regions, including Taupo, Auckland, and Gisborne.

Most gravel extraction activity on other rivers is more project based, cyclic (forestry) or governed by one off demand. They are typically smaller volumes than the large operators extract from the Ngaruroro mentioned above.

12.0 EXTRACTION, MINERALOGICAL AND GEOTECHNICAL CHARACTERISTICS OF RIVER BASED AGGREGATES

12.1 River Gravel Extraction

The main operators extracting gravel use a variety of fixed and mobile plant dependant on scale and location of the operation.

Generally operators excavate gravel from the river beaches with limits placed on depth of extraction to around 1.0m depth or approximately 1 bucket depth. Excavations are designed to ensure no silt laden material escapes into the active river channel and operators work in with Regional Council to ensure river channels are entrained so as to minimise erosion of river banks.

Some waste material is used to stabilise river banks in some instances and to promote willow growth for bank protection.

We have been advised by some of the largest extractors that of the total material extracted from the river approximately less than 60% produces saleable products, but this can vary, depending on the products produced through the crushing and screening processes.

Producers of premium aggregates for sealing chip and base course products require gravel size fractions generally above 30mm in order to get the required 75% broken faces (from crushing) required for sealing chip.

One operator (Higgins Aggregates) sells their undersize (-30mm) to Winstones at their Awatoto Plant site to produce gravel for concrete aggregate. A good collaborative outcome is achieved, whilst maximising the use of the gravel resource.

Some of the issues related to the high volume of unsaleable product is that operators tend to selectively target those parts of the beaches where coarser material is located. **This selective mining is likely to result in a long term reduction in gravel grain size.** This is dependant to some extent on flood frequency, intensity and how much coarser gravel is mobilised from the higher reaches of the Ngaruroro in particular.

12.2 Mineralogical Characteristics

Aggregate quality is primarily dependant on the mineralogy of rocks being used for any particular aggregate product. These mineralogical characteristics determine the physical properties of the aggregate and ultimately the aggregates performance whether it be for roading, construction, concrete, etc.

Figure 36 below is a table of aggregate properties produced by Black, 2009 of various aggregates used in the North Island. This shows that the gravels derived from the Torlesse Rakaia Terrane, (equivalent to the Kaweka Terrane in Hawke's Bay) are generally less likely to have deleterious minerals present.

From hand specimen observation of gravels in the main river systems, the dominant lithologies are quartzofeldspathic sandstones, medium to fine grained. Individual grains appear angular to subangular. Some coarser pebbles are observed in hand specimen to have more veins that appear to be zeolite which, if it is the mineral laumontite, is a deleterious mineral in aggregate if present in large quantities.

Rare red and green chert as well as rare intrusive cobbles are present but generally not in large enough quantities to be an issue in the material that is processed.

In the northern rivers such as the Mohaka but more particularly the Wairoa and Waiau which drain areas containing the Pahau Terrane rocks and the Waioeka Petrofacies, there is likely to be more zeolite rich material and the rocks are more volcaniclastic sandstone, hence may have a higher proportion of gravel that could contain smectite clay.

It is important to establish the presence of deleterious minerals such as zeolite, in particular laumontite and smectite clays or high concentrations of pyrite (iron sulphide). A high proportion of argillite in the gravels could indicate the presence of smectite or high sulphide content.

Laumontite in particular has a high cation exchange capacity with dehydration and rehydration reactions causing volume changes in an aggregate and can cause popouts in concrete as well as aggregate degradation in basecourse and sealing chip in roading situations.

Similarly, the presence of high smectite clay content can lead to the breakdown of premium aggregate in roads. Fortunately it is not common in the Torlesse Terrane rocks that form the bulk of the Hawke's Bay gravels but is more likely in the more volcaniclastic sediments of the Pahau and Waioeka Petrofacies rocks which can be present in some rivers.

High sulphide content in greywacke aggregate can lead to formation of acidic fluids in the pavements and increased breakdown of constituent minerals such as calcium carbonate, feldspar, etc.

There is very little mineragraphic data in the public domain on the gravels themselves. A search of the Petlab database from GNS Science did not locate any petrographic descriptions of the gravels.

The gravels in the main rivers derived from the Axial Ranges have been naturally sorted and graded by fluvial processes. As such most have been broken down to sizes that reflect natural partings, joints and fractures in the primary rock. This has the effect of mechanically removing much of the potentially deleterious vein material such as zeolite, smectite swelling clays and sulphides.

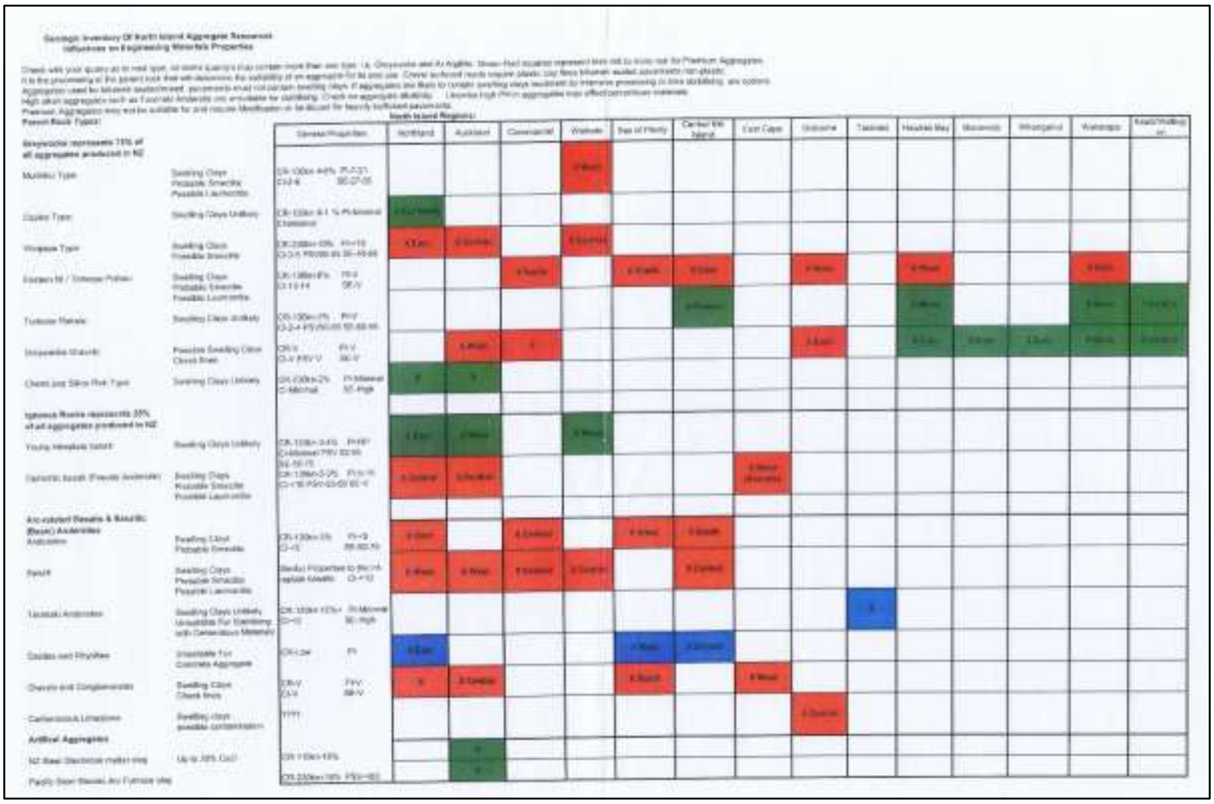

Figure 36: Diagram of Mineralogical Characteristics of North Island aggregates, (Black, 2009)

12.3 Geotechnical Properties

In general gravels derived from Torlesse Terrane greywackes produce an aggregate with properties at the higher end of the range for these lithologies. Typical properties described by Black, 2009 of primary Torlesse Terrane greywackes are:

Crushing Resistance (CR): 2% at 130 kN for GAP 65, 2.5% at 230kN for TNZ M/4 AP40.

Sand Equivalence (SE): in 60-65% range

Clay Index (CI): usually in the 2 to 4 range

Plasticity Index (PI): variable but may be high in GAP products.

Polished Stone Value (PSV): may exceed 55.

Several of the quarry industry operators extracting gravels from particularly the Ngaruroro River and the Mohaka River kindly provided test data on some of their products as part of this study.

Samples of AP40 from Ngaruroro River

Californian Bearing Ratio (CBR): 90 to 300

Weathering Index (WI): AA

Cleanliness Value (CV): 93

CI: 0.48

CR: 2.4% at 130kN

Samples of AP 40 TNZ M/4

Broken faces

37.5 – 19mm	69% - 83%
19.0 – 9.5mm	87% - 98%
9.5 – 4.74	94% - 98%

Grade 4 sealing chip PSV averaging 55.

Samples from the Mohaka River date from the 1990's have more limited data.

WI: AA

CV: 95

Grade 4 sealing chip PSV of 54 to 55.

This confirms the general observations that from the Ngaruroro and the Mohaka Rivers the aggregates produced have geotechnical properties consistent with other Torlesse Terrane greywacke aggregates and generally can produce premium products.

13.0 LAND USE ZONING, CONSENTING AND ALLOCATION

13.1 Land Use Zoning

We are advised by HBRC that they have secured all land required for flood protection and gravel extraction purposes. This includes 'right of way' access where required. (There is a possible exception on the Middle Tukituki River). Gravel is taken from within the river corridor and river access is typically via the nearest public road or state highway (under jurisdiction of NZTA or the local district council).

Where flood control stop banks exist along the rivers, this typically keeps the river within the 'river corridor'. Conversely where there are no stop banks, progressive gravel erosion or gravel accretion over time, can shift the physical river channels, sometimes outside the surveyed river corridor. Where this occurs, arrangements sometimes have to be made with private landowners, and as a rule if it is for flood protection purposes, or in the event of losing land to the river, then this is usually agreed to by the owner.

Where there is no 'public road' access to extraction sites, occasionally private extractors obtain approval from affected landowners to achieve access over their land, along with consents if required by the local district council. These extractors are required to provide evidence to HBRC that they have requisite legal access arrangements. Alternatively they may be redirected to other local sites where access does exist.

13.2 Consenting and Allocation – Current Process

The Asset Management Group of HBRC has an annual river gravel allocation process for the period 1st July- 30th June each year.

These cover the rivers in three sub-regional areas- northern, central and southern.

Extractors apply for a **gravel allocation** defined by the following – Contractor name, river, specific site name/location, and cross section number, volume required (m^3), indicated use of gravel, material type (typically straight haul).

Similarly requests are also made for **silt allocation**, which is typically used for blending with other material.

The Gravel and Silt requests are evaluated by HBRC and allocations are made, which may or may not be approved in the same volume or location, depending on gravel availability at the time.

The allocations do NOT constitute resource consent to extract gravel. Consent is required before extraction commences.

Each year extraction companies/contractors are required to furnish returns of the actual volumes extracted under the consented allocations. These data are collated by river and sub-region for planning and flood control purposes.

Rivers are surveyed approximately every 2-3 years by cross section to establish Gravel availability and levels

14.0 CONCLUSIONS AND RECOMMENDATIONS

- ***Source rock***
  - Update geology and geomorphology of source rock areas of the main river systems is required to gather up to date data on location of major slips within the axial ranges where greywacke rock is sourced that feeds the river catchments. This will be useful in locating more recent land slide activity that will be contributing to the gravel supply.
  - The last comprehensive survey of source rock gravel supply was completed by R Black in 1992 and data on landslide location is also presented in GNS geological mapping for the QMAP series but was not directed specifically at gravel supply to the main river catchments. There have been a number of major storm events since that time that will no doubt have led to reactivation of old landslides and the formation of new landslide areas contributing gravel to the river systems.
- ***Resource Inventory***
  - **Ngaruroro River**

    Estimates show in the 2013-2014 year that there is an average net gravel resource availability of 2.56 million m^3 above grade line. Of this total there is approximately 519,000m^3 above grade line within the areas where the main extraction is occurring. Taking into account the average addition of 170,000m^3 per annum of new gravel added to the catchment and flowing through the extraction reaches suggests the areas of extraction could reach grade line in 3 to 5 years. An additional 7 to 10 years of resource is available further upstream of current main extraction sites.

This scenario is at variance to other observations over time. Undertaking similar analyses based on gravel volume data at particular time periods since 1977 produce similar results that show gravel supplies would have run out by now.

Clearly this has not occurred and estimates are roughly the same now as in the past. This suggests there are other inputs and refinements to the river modelling required to get an accurate estimate of the sustainable extractable yield of gravel from the river.

It is essential that further study is carried out to determine the sustainable gravel extraction rate, gravel transport rates and depositional site variation and grainsize variability over time.

If the scenario under the current analysis is correct then the implication is that aggregate supplies could reach and unsustainable level in 3.5 to 5 years at the current sites with adverse implications for aggregate producers and for flood control.

It is recommended that further detailed modelling is conducted to determine the drivers for gravel supply and a more robust supply model developed.

To obtain more detailed data it is recommended:

- To use lidar data and closely spaced survey sections, (250m apart) to generate a more accurate model of the resource along with updated gravel size analysis on the surface and in depth profiles to the depth limits that extractors are allowed to excavate to.
- Assess the impact of hydrological and weather pattern changes on gravel transport. There is a suggestion that there may be a decadal downward trend in volumes above grade line, possibly due to changes in flood frequency and climate change.
- Assess the geomorphology and geology of gravel source areas which may have changed since the last survey was done in 1997.

We believe there is or will be a gradual fining of gravel over time at the current extraction sites due to selective targeting of coarser gravel in the river by extractors. There is a minimum size limit of around 30mm in order achieve a round 75% broken faces for sealing chip and premium base-course products. Currently only approximately 50% to 60% of raw gravel extracted is utilised as saleable product for at least one of the major producers.

It is recommended that gravel size analysis is conducted through the gravel profile by excavating pits to give an understanding of minimum depth to bed rock and variability in grain size distribution from a resource perspective. Producers could then target material that meets their size requirements more efficiently. Most of the current size analysis work has focussed on surface material for hydrological modelling.

- **Upper Tukituki River**

Actual recorded production of gravel from the Upper Tukituki has ranged between 60,000 m^3 in 2000 to a low of around 10,000 m^3 in 2013. On the assumption that production levels rise to the average over the last 10 years of around 41,000 m^3 and assuming that addition of new gravel to the system at least equivalent to that modelled for the Ruataniwha Dam of between 140,000 m^3 and 180,000 m^3 for the other catchments feeding into the Upper Tukituki then there should be adequate supplies for the long term in this portion of the river.

There is likely to be an issue however with the build-up of gravel above grade line over time with an adverse effect on flood control. This is dependent on the rate of movement of gravel through the system to lower reaches, flood event frequency, aggradation rates and extraction. The situation for flood control is likely to be exacerbated if extraction does not increase back to average levels.

We recommend looking at strategies to encourage production from the Upper Tukituki to alleviate flood risk.

- **Middle Tukituki**

The Middle Tukituki River potentially has large resources of gravel. Sectional data is available however HBRC at this stage have not determined an appropriate grade line for this reach of the river. Using estimates based on the most conservative scenario of using the 0.5m above Thalweg it can be seen that there is potentially **14 million m^3 of gravel available.**

Morphological modelling is in progress for the whole Tukituki River utilising the GRATE simulation programme. Once complete this will provide information on gravel supply and sustainability.

Issues include accessibility to the resources, volumes moving through the system to the Lower Tukituki to replenish over extracted resources and ensure gravel continues to reach the sea in adequate volumes for beach protection, travel distances to processing plant and the main contract areas for producers, (economics and market demands).

- **Lower Tukituki River**

There is currently a net deficit of 1,055,000m^3 below grade line at the design level. The volumes estimated at 0.5m below grade line volume design and at 1.0m below volume design are 486,000m^3 and 2,028,000m^3 respectively.

HBRC policy is to manage the resource sustainably taking into account that there has historically been over extraction in the Lower Tukituki River, it is the only major river system delivering gravel to the coast where northward longshore drift helps replenish gravel on the coast up to Napier and there is still a deficit of gravel in what is effectively a sink. Consideration of the impact of a reduced volume of gravel moving through the river system has been assessed in the event that the Ruataniwha Water Storage project goes ahead.

Recommended options include;

Allow minimal extraction until gravel resources build up to grade line and then allow extraction to the estimated average gravel passing through the reach.

Keep the status quo which allows gravel to reach the sea but increases the time for the gravel sink to replenish and aggrade.

- **Waipawa River**

The currently surveyed design volumes show a net volume of gravel above grade line of 1,029,000 m^3. The lower reaches of the Waipawa River are at or just below grade line, while between Section lines 17 and 39 there is some 1,455,000m^3 of gravel available.

Average recorded production between 2003 and 2011 has been around 102,000m^3 per annum. Allocations for 2013-2014 are similar however the major operator here, Infracon has gone out of business.

Estimates of sustainability of supply at the average of 100,000m^3 per annum would see enough resource to last a minimum of at least 16 years before the grade line level is reached for the Waipawa River.

If the extraction rate stays at the current minimum levels then there is an increasing issue with gravel build up and potential adverse effects in terms of flood control.

Recommended that contractors encouraged to supply out of the Waipawa. This may happen once Higgins Aggregates decide on their strategy with their acquisition of the Infracon assets, but is as yet unknown.

- **Tutaekuri River**

Allocated extraction for the Tutaekuri for the 2013 – 2014 year was 20,500 m^3 with actual recorded production returns of straight haul averaging approximately 14,000 m^3 per annum from 2001 to 2013.

Extraction currently from Puketapu Bridge to Dartmore where there is some resource above grade line, however the past over extraction means that increasing production here would not be sustainable in the medium to long term until gravel builds up to above grade line again.

Recommended that the current small volumes continue.

- **Esk River**

The Esk has in the past been heavily over extracted. No major extraction warranted here.

- **Mohaka River**

Current (2013-2014) allocations for the Mohaka River (upper and lower) total approx. 100,000m^3. Actual recorded production returns have averaged approx. 47,000m^3 for the period 2003 to 2013.

The majority of current production from fixed plant is in the lower reaches of the river and near the river mouth, and from the relatively small volumes involved it is concluded that there are no issues with the current extraction rates.

- **Waiau River**

The river contains gravel from the western greywacke ranges but also has a significant proportion of the soft Tertiary sedimentary units through which it drains. Industry sources who extract gravel from this river also describe difficulties in obtaining premium product due to the presence of pumiceous silt and 'papa rock' where the gravel bed is thin above the Tertiary sedimentary basement.

The 2013-2014 allocation is 28,200m^3. Average volumes used as recorded in HBRC files shows an average usage over the period 2003 to 2013 of 17,350m^3. Much of the gravel is used for general road maintenance, forestry and by local contractors. Given the small volumes extracted and the likely subdued demand it is concluded there will no issue with sustainability of supply.

- **Wairoa River**

Currently, little recorded production from this river. Some resource there but not essential for the long term supply of aggregates to the Wairoa District.

- ***Land based gravels***
  - **Recent Gravels**

Recent gravels that lie outside the active river channels are potentially an important source of gravel in the future should extraction from the active river channels become restricted due to sustainability or other issues.

At present it is understood that there is only one consented land based extraction operation based near Maraekakaho on the Ngaruroro River.

A number of considerations for selecting and evaluating other potential gravel resources in these recent gravels include; competing land use, impact on flood control infrastructure, proximity to market, aggregate quality, long term supply, mitigation of adverse effects, land and mineral ownership, land use planning zones, cultural aspects including iwi issues and final end use.

- **Terrace Gravels**

Land based **gravel pits** form an important part of the overall aggregate supply to the region. They are invariably sourced from Quaternary aged gravel terraces of the Kidnappers Group. These are sometimes referred to colloquially as red rock pits, and are typically slight to moderately weathered river terrace gravels uplifted above the main active river channels.
These gravels are used for the local construction industry, forestry roading, maintenance metal on unsealed roads and general roading maintenance.

In total "redrock" quarries could represent about 25% of total gravel extraction for the region.

While outside the current scope it is recommended that further study be conducted to establish the locations of the majority of these small quarries to improve overall knowledge of the regions aggregate resources to assist in long term planning.

- ***Extraction, Mineralogical and Geotechnical Characteristics of River Based Aggregates***
  - **Extraction Methods**

Generally operators excavate gravel from the river beaches with limits placed on depth of extraction to around 1.0m depth or approximately. 1 bucket depth.

Total useable gravel represents no more than 60% of gravel sand and silt excavated. Minimum grain size for crushing is around 30mm to 40mm to ensure enough broken faces for chip and base course products. A certain amount of undersize is used for concrete aggregates, drainage products, fill etc, however, the large percentage that can't be used for premium aggregate is stockpiled. This is not a particularly efficient utilisation of the resource.

Selective targeting coarser material is likely to result in a long term reduction in gravel grain size.

It is recommended that in the areas of active gravel extraction a programme of pitting and/or shallow drilling be conducted to establish grainsize distribution through the resource areas in 3 dimensions.

At present most grainsize data relates to the near surface for calibrating gravel flow modelling. Having grain size data with depth will give a better understanding of the resource and possible enable more efficient targeting of material that minimises wastage and over time provide a base for modelling grainsize variation over time.

It is also recommended that infill sections be surveyed in the critical areas where aggregate extraction is taking place to provide more data to model and manage the resource more precisely.

  - **Mineralogical Characteristics**

The source rocks are mainly highly indurated zeolite facies metamorphosed quartzofeldspathic greywacke sandstones and argillites. Some elements of these are strongly veined with deleterious minerals such as the zeolite laumontite and some smectite clay minerals.

Fortunately, the natural abrasion from gravel movement downstream winnows out most of the softer material. However zeolite and clay minerals or high sulphides can persist in some material. Processing can remove this less desirable material however in some products such as gap products the fines can concentrate minerals such as swelling clays etc. Any issue normally show up in geotechnical testing however there is a lack of petrological study to establish baseline variability in the constituent rock types that make up the gravel resources from the different river catchments.

Additional weathering can also occur in stockpiles that are left for long periods of time.

It is recommended that petrological studies be carried out on representative samples from each of the major extraction areas on each river to determine the baseline mineralogical characteristics. This should include as a minimum thin section petrography and X-Ray diffraction to determine presence of deleterious minerals.

- **Geotechnical Characteristics**

In general gravels derived from Torlesse Terrane greywackes produce an aggregate with properties at the higher end of the range for these lithologies. This is generally the case for the gravels derived from these lithologies in the Hawke's Bay.
However as there is some mixed sources from rock types less suitable for aggregate production particularly the Pahau Terrane and Waioeka petrofacies rocks regular testing is recommended to continue.
In some rivers issues arise from incorporation of muddy silt and the generally soft muddy substrate of Tertiary sediments being excavated with the gravels, requiring additional processing depending on the end use.

In terms of encouraging extractors to move some operations to other rivers where HBRC want extraction for flood control it would worth considering obtaining some independent geotechnical test data to demonstrate compliance with aggregate specifications.

- ***Land use zoning, consenting and allocation***

We are advised by HBRC that they have secured all land required for flood protection and gravel extraction purposes.

As discussed in the sister report "Gravel Demand Forecast (Issue 5) the HBRC allocates gravel extraction volumes on an annual basis, commencing 1 July each year. Feedback from most extractors is that this process works well, however some of the larger extractors have said that a one year time frame is too short for strategic business planning and investment purposes. These extractors believe longer time frames are required.

This business risk may be even more pronounced if further studies show that the supply risk on the Ngaruroro River is real and HBRC needs to take action to reduce production here.

The authors in their "Gravel Demand Forecast (Issue 5)" report recommended that HBRC work with the industry to consider extending the allocation out beyond one year with those specific extractors where requested and have suggested considering options such as a 5 year rolling allocation – that is reviewed annually. Possibly tied in with the 5 year rolling demand forecasts suggested in that report.

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16.0 DISCLAIMER

The statements, comments, conclusions and recommendations made in this report have been made in good faith and are based on the information that has been provided to the authors from various sources including HBRC records, HBRC staff, the authors' own research of public domain documents, discussions with stakeholder groups and the authors own observations. Except where disclosed in this report, we have not carried out an independent audit or confirmation of any of the facts presented to us from these sources, Our opinions and conclusions may be subject to qualification or modification as a result of information not provided to us, or of which we are not aware.

We do not make any representations or warranty, express or implied, as to the accuracy or completeness of the information provided to us on which this report is based.

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