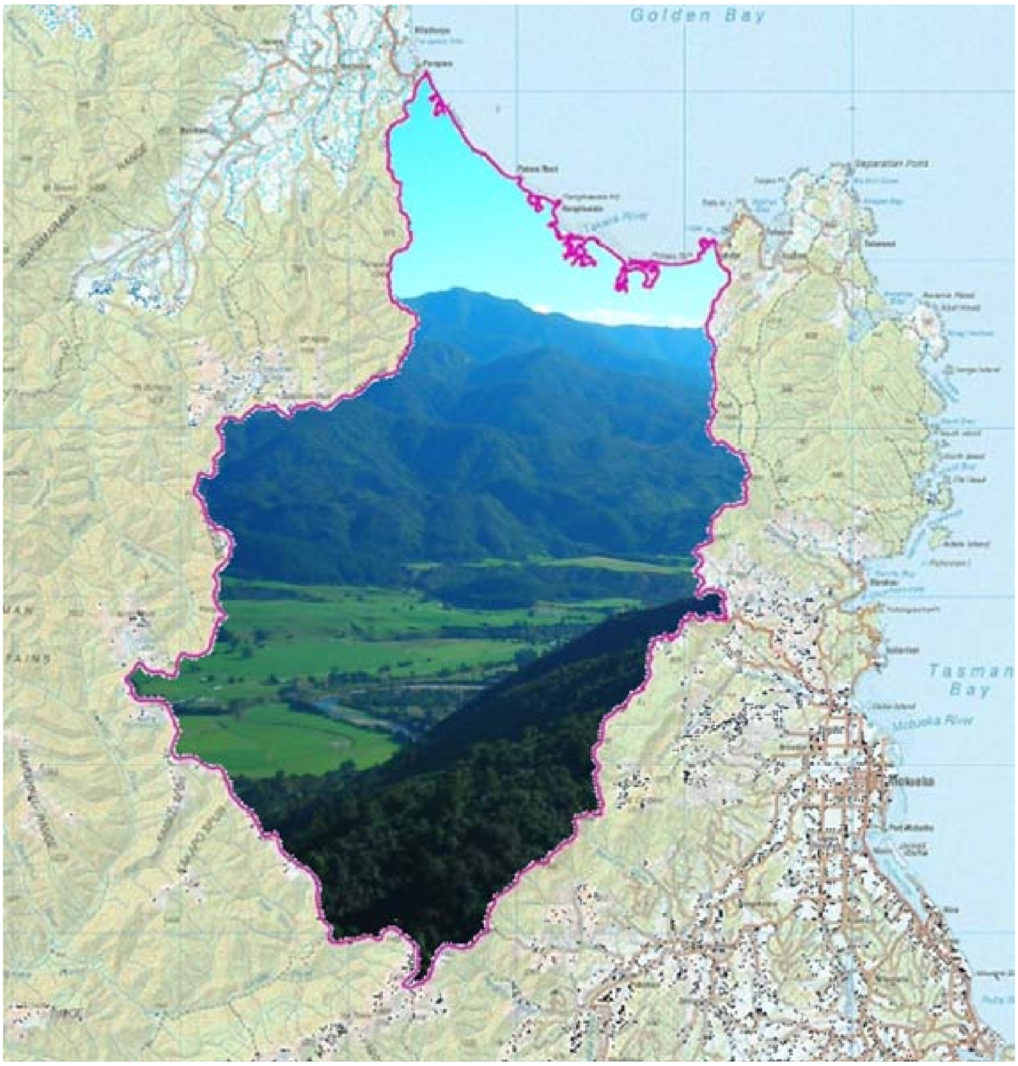
Water Resources of the Takaka Water Management Area



J T Thomas
M M Harvey

July 2013

Table of Contents

List of Figures

List of Tables

List of Appendices

1. Introduction

The Takaka Water Management Area (Figure 1) covers an area of about 1013 km^2. This area can be broadly split into two; the much larger Takaka catchment (940 km^2) and the smaller Takaka North (73 km^2) Catchments. The Takaka catchment includes the main river catchments of the Takaka, Waingaro, Anatoki, the smaller catchments around Pohara, Motupipi and Waikoropupu and the alluvial plains which include Takaka township and Rototai. The Takaka North catchments include all the smaller rivers/creeks north of the Takaka River between Waitapu and Tukurua i.e. the Onahau, Puremahaia, Pariwhakaoho, Onekaka and Tukurua. Dairying is the predominant land use in much of the flat land in the valley floors and Takaka North catchments. Takaka Township lies on the floodplain in the lower reaches of the valley. Smaller settlements occur in Central Takaka, Clifton and Pohara with small beach communities located in the Takaka North catchment, such as Patons Rock and Tukurua.

2. Geography

2.1 Topography

The area is of rugged topography with steep ranges to the east, south and southwest with narrow valleys that broaden out towards Takaka. The high ridges to the south are at elevations of between 1500 to 1650 m and to the east on the Pikikiruna range just over 1000 m. The high ridges to the west of the Takaka North Catchments have elevations of between 1250 m to 560 m. Takaka township itself lies at an elevation range of about between 8.5 to 10 m with the coastal margins along Waitapu and Rototai between 1.5 to 2.0 m and the coastal margins of Pohara between 4 to 5 m.

2.2 Land Cover

The land cover statistics for the area were obtained from Teralink's Land Cover Database 2 (LCDB2, 2004). Figure 2 shows the land cover and areas under each classification as obtained from the LCDB2. A large amount of the Takaka Water Management Area comprises the Kahurangi National Park and the Takaka Hill Forest Park which are administrated by the Department of Conservation (DOC). The national park and forest park comprises 63.5% of the total area (635 km^2). Indigenous forest (Manuka-Kanuka) outside the DOC administered land comprises 14.9% of the catchment (150 km^2).

Land classified as high producing exotic grasslands amount to 14.9% (i.e. 151 km^2) of the catchment. If the grassland area below the 160 m elevation contour is considered the total area of high producing exotic grassland drops to 12.1% (i.e. 123 km^2). This statistic is provided because the grasslands at higher elevation (i.e. Takaka Hill) are classified as high producing grasslands but do not have perennial flowing rivers or streams. Only a small area within the Takaka Water Management Area is in pine forest and orchard i.e. 1.9% and 0.2% respectively.

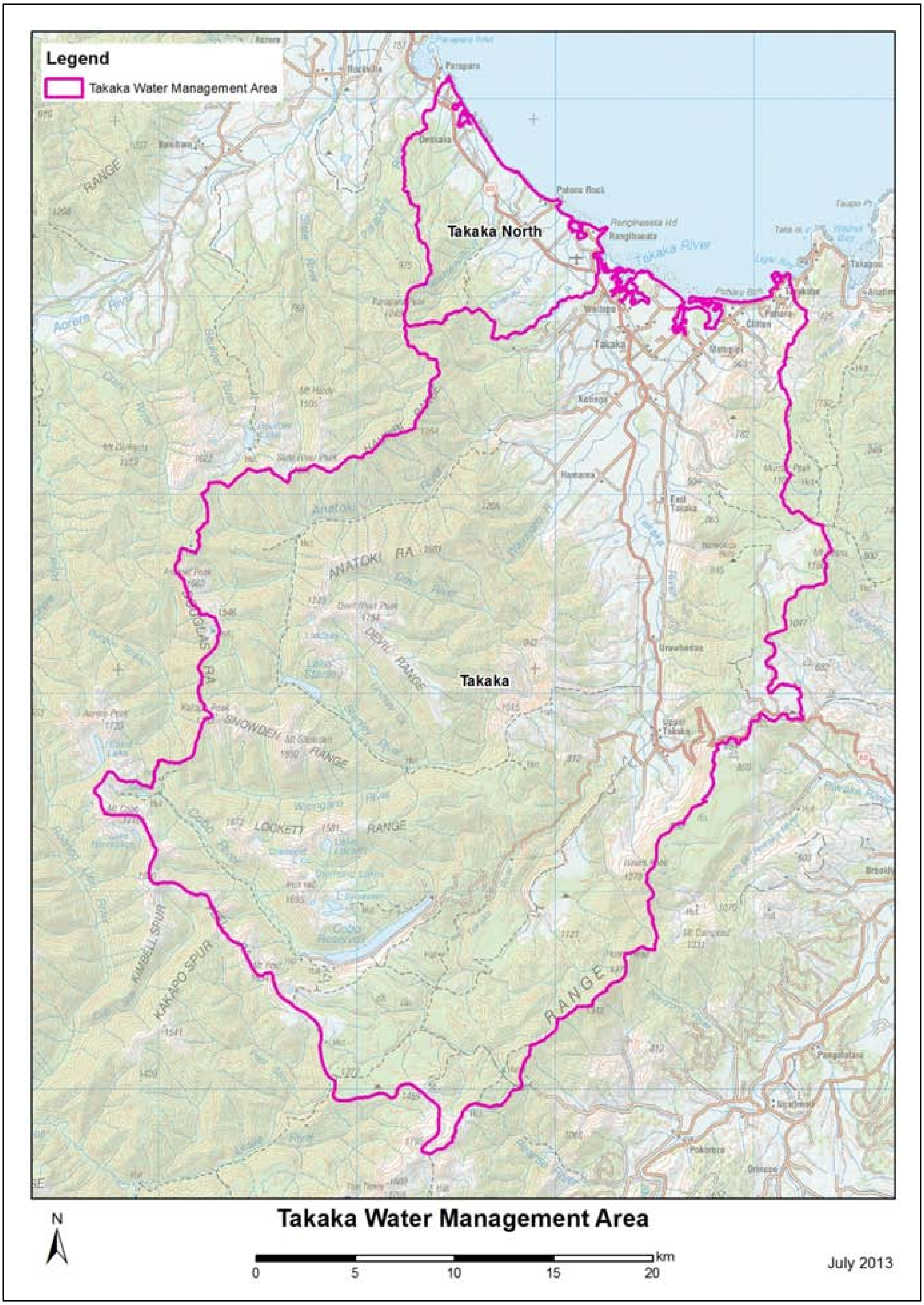


Figure 1: Map of the Takaka Water Management Area

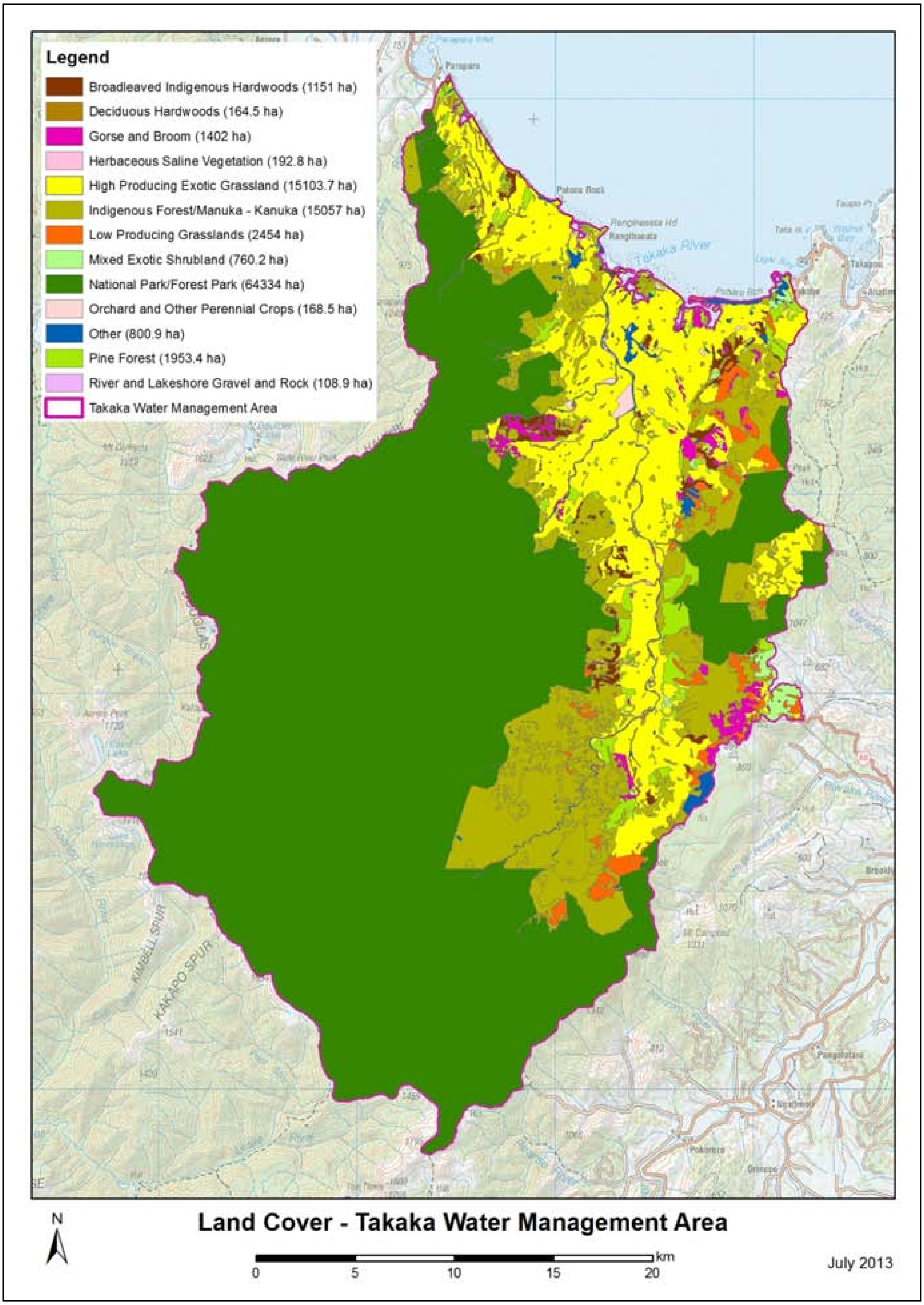


Figure 2: Land Cover Map - Takaka Water Management Area

2.3 Geology

This area comprises rocks of varied and complex geology. The ages of the rocks vary as does the rock type. The key geological groups that occur in the area can be broadly categorised as schist, igneous intrusive rocks (granite and diorite), Arthur Marble, metamorphic rocks of various types including quartzite and argillite's, tertiary sediments which includes the Tarakohe Mudstone, Takaka Limestone and Motupipi Coal Measures and Quaternary (recent) sands, gravels and coastal deposits. Much of the Takaka valley floor is covered by alluvial gravels with higher aggradational and fan gravels occurring to the east and west of the Takaka Valley floor downstream of Upper Takaka. Aggradational terrace gravels also occur east and west of the State Highway north of the Takaka River at Waitapu. Figure 3 shows a simplified geology map of the area with the youngest geology shown at the top of the legend.

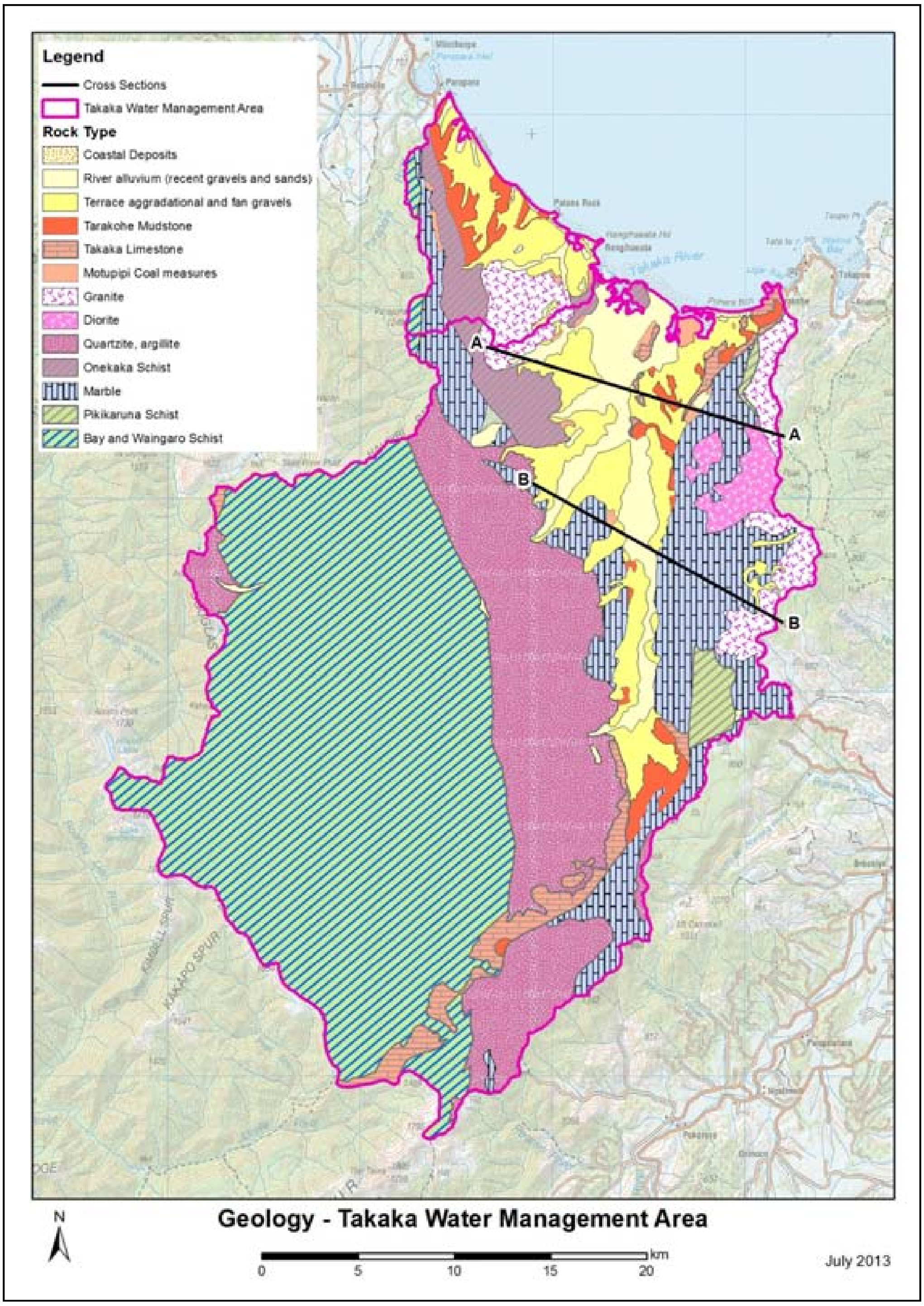


Figure 3: Geology Map - Takaka Water Management Area

Figure 3 also includes two cross-section profiles for the mid and lower Takaka Valley. Figure 4 shows the schematic geological cross sections for the profiles between AA and BB.

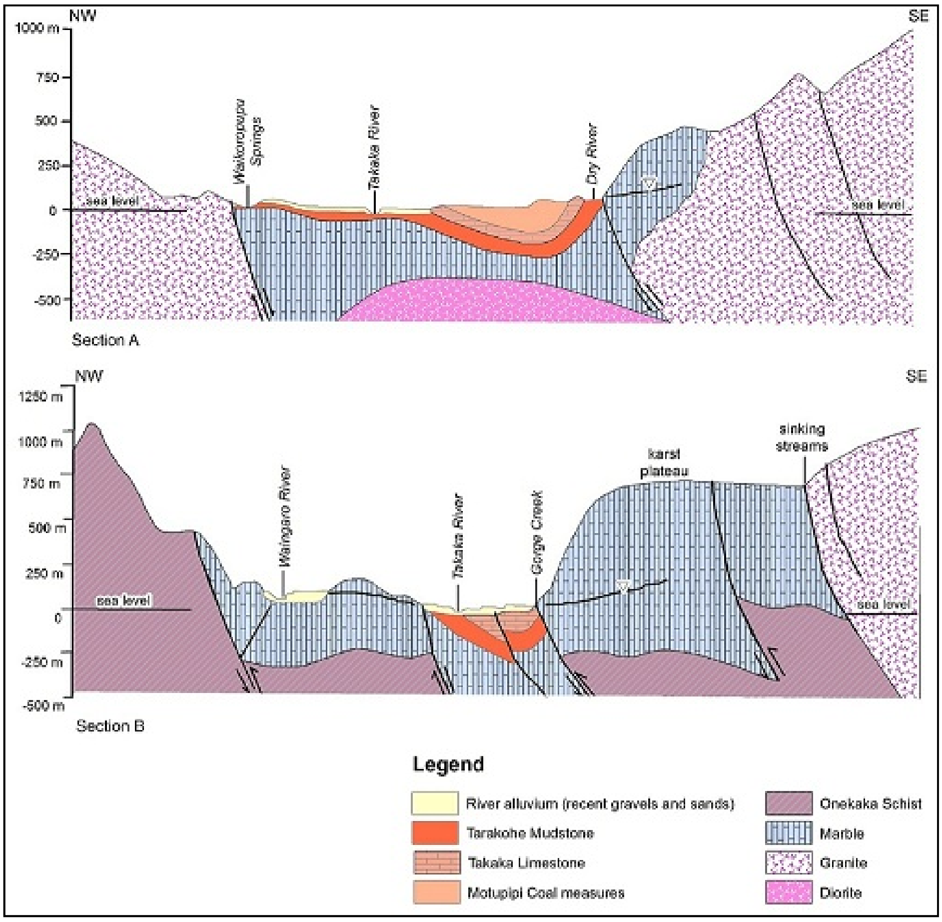


Figure 4: Geological Cross-Sections of the Takaka Valley

A distinctive feature of this area is the distinct karst landscape. This is largely shaped by the dissolving action of water on carbonate rock in this area i.e. the Takaka Limestone and Arthur Marble. As rain falls through the atmosphere it picks up carbon dioxide (CO^2) which dissolves in the droplets. Once rain hits the ground it percolates through the ground and picks up more CO^2 to form a weak solution of carbonic acid. This water over long periods dissolves the carbonate rocks. This geological process, occurring over many thousands of years, results in the unusual surface and subsurface features ranging from sinkholes, vertical shafts, disappearing streams and springs to complex underground drainage systems and caves.

2.4 Climate/Rainfall

The area experiences a generally mild climate with average to high sunshine hours. Rainfall is variable with the rainfall gradient declining from the west to east and towards the coast. Local weather is affected by elevation which also affects temperatures and rainfall. Orographic precipitation due to westerly and northerly winds can generate heavy rainfall in the western and north-western ranges. Figure 5 shows rainfall in the catchment from several Council monitored sites. Takaka Hill at Canaan has an annual average of 3,484 mm of rain, Cobb 2,575 mm, Waingaro 3,128 mm and Takaka at Kotinga 1,978 mm. Site rainfall figures show a slight increase in rainfall in the winter months from May to October.

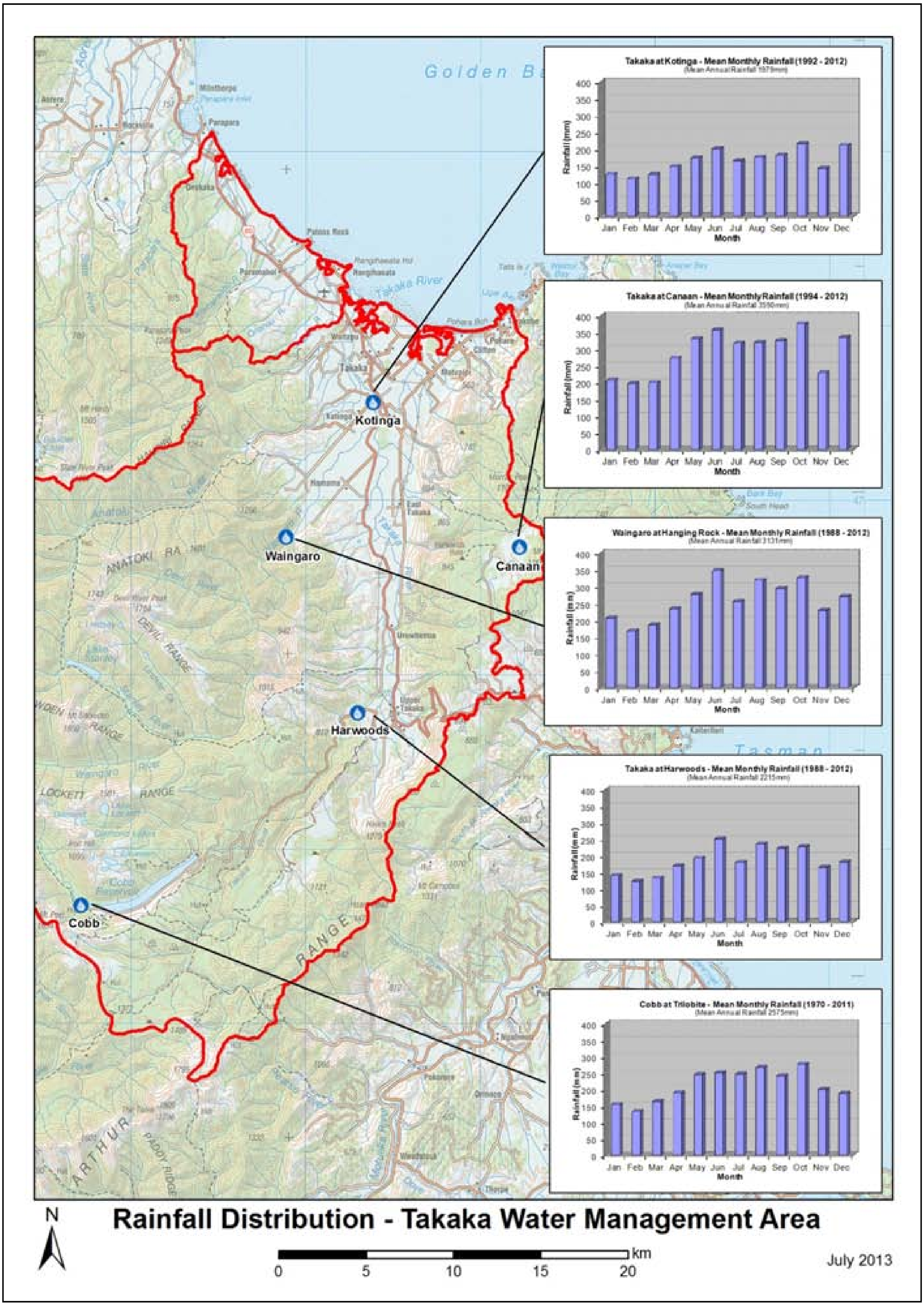


Figure 5: Rainfall Distribution - Takaka Water Management Area

3. Water Resources

3.1 Physical Water Resources Monitoring - Flow/Levels/Rainfall/Quality

To understand the physical nature of water resources in any area a key aspect is monitoring the water resource. In relation to water quantity key components that are monitored are rainfall, surface water flows (rivers and springs) and groundwater levels. These provide critical information of where, how much and how it moves. Continuous monitoring of rainfall, river/spring flows and groundwater provides baseline information on water availability and variability. Figure 6 shows the current rainfall, flow and groundwater sites in the area and includes the sea level site at Port Tarakohe.

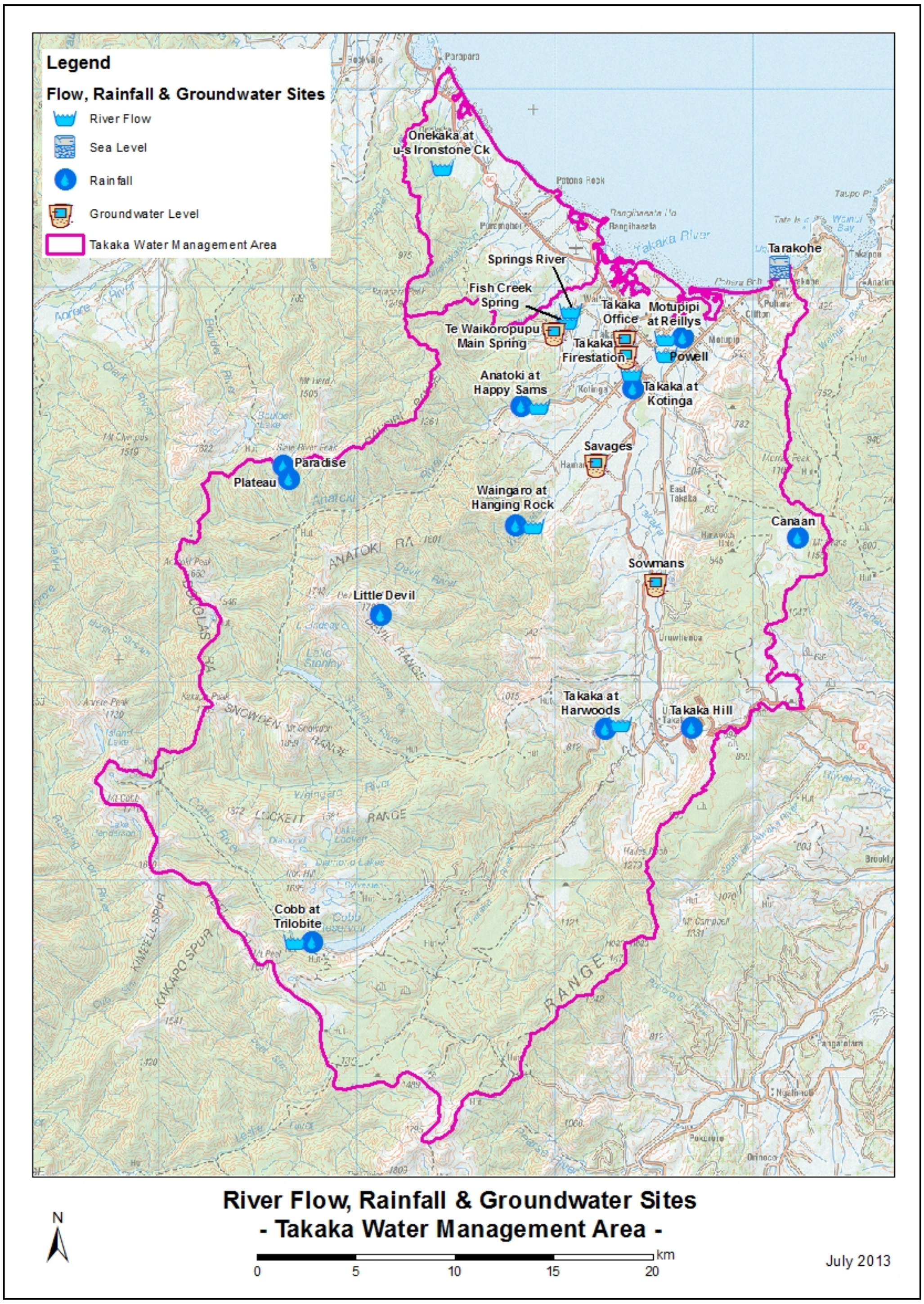


Figure 6: Current Environmental Monitoring Sites - Takaka Water Management Area

In addition to collection of data from the sites above, Council has over the years also collected significant flow data from various parts of the main rivers, streams and springs. These include numerous low flow concurrent flow measurements carried out in the rivers and streams in the area. Groundwater levels have also been monitored in various bores and wells from the area. Several flow tests have been conducted on bores to determine hydraulic properties and yields. Surface water and groundwater quality is also monitored in the area.

3.2 Surface Water Resources

3.2.1 Takaka River

The Takaka River is the principal river that drains the Takaka Valley which flows into Golden Bay. Major tributaries of this river include the Cobb, Waingaro, Anatoki and Waikoropupu rivers. The flow characteristics of each of the major rivers are described in the following sections.

The Cobb Dam is a hydro dam located in the upper part of the catchment and dams the upper Cobb River. The earth dam was built between 1949 and 1954 with the reservoir being filled in 1955. Prior to construction of the dam there was a run of the river hydro operation which was constructed in the early 1940's, producing power in mid 1944. Parts of the Cobb River just below the dam are dry due to impoundment, and the remnant Cobb River flows into the Takaka River just above where the Cobb power station is located. The Cobb Dam operation significantly affects flow in the Takaka River, this is more pronounced during lower flow periods in the catchment. There are hydrological records and evaluations of flows from contributing catchments to the Takaka River above the Harwood's site (Figure 7). However as much of the area above Harwoods flow site is very rugged country and is in the Kahurangi National Park - flows below the Harwoods recorder will be the one more relevant to water resources management. A significant amount of hydrological data was collected and widespread consultation was undertaken for the renewal of the Cobb Dam permits in early 2000. The Cobb Dam permits received final approval from the Environment Court in 2004.

Table 1 shows flow statistics from Harwood's recorder site and several downstream sites (Figure 7) for which correlations have been developed. As mentioned earlier these statistics incorporate the flow generation regime over the period as well.

Recorder Site	**Mean**	**Median**	**1 day low flow (l/s)**				**Analysis Period**
			MALF	**5 yr**	**10 yr**	**20 yr**	
Takaka at Harwoods	14333	9970	1669	1127	943	808	1976 -2013
Takaka at Kotinga	31351	15038	3111	2472	2254	2095	1986 - 2012

Gauging Site	**Mean**	**Median**	**1 day low flow (l/s)**				**Correlated With**
			MALF	**5 yr**	**10 yr**	**20 yr**	
Takaka at Pages Cut	N/A*	N/A*	3749	3109	2891	2732	Takaka at Kotinga
Takaka at Paynes Ford	N/A*	N/A*	243	181	159	144	Takaka at Kotinga

Flows from Harwoods recorder site and Paynes Ford gauging site are highly influenced by the Cobb Dam and releases from there. The recorder site at Kotinga and gauging site at Pages Cut are less influenced by the Cobb Dam as at lower flows this influence is masked by the Waingaro and Anatoki rivers. Low flow statistics are only given here for 1 day at these sites, not 7 days as with other less influenced rivers (7 day statistics are in the Appendix of this report).

**The correlation values for this site do not cover a high enough range of flows to accurately provide a figure for mean and median flow.*

Table 1: Flow Statistics for Takaka River at Harwoods and Downstream Sites

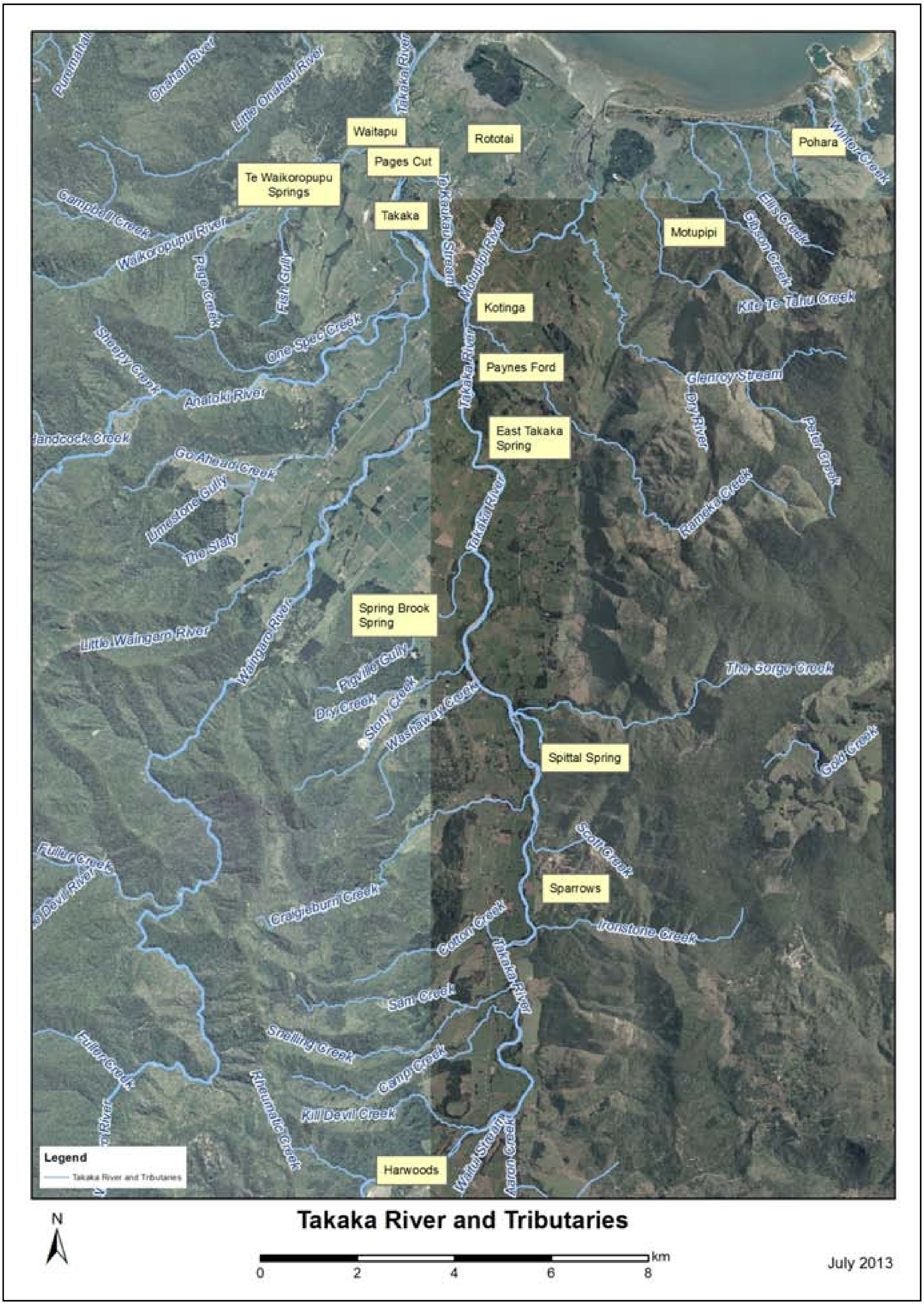


Figure 7: Takaka River and Tributaries

The Takaka River regularly dries up downstream of Lindsay's Bridge. Figure 8 shows the flow losses between Harwoods and Sparrows flow measurement sites. The threshold flows at Harwoods (when parts of the Takaka River would be dry), is significantly affected by groundwater levels in the Takaka valley. This drying phenomenon is not new and there is recorded data on this from the late 1800's. The upper reaches of the drying zone occurs from below the Takaka River/Ironstone Creek confluence. The lower reaches of the drying zone occurs around the Takaka River just north of Loop Road in East Takaka. Generally the lower end of the drying section can be anticipated to be dry when the flows at Harwood's drops below 7000 l/s, with the upper end being dry when flows drop below 3500 l/s. During low groundwater levels drying at the lower end could happen when flows are much higher at Harwoods (i.e. 15,000 - 20,000 l/s). Resource information and studies as part of the Cobb Dam permit renewals concluded that the historical operation of the Cobb Dam has increased the natural flows in the Takaka River, and also reduced the amount of time the Takaka River would naturally be dry below Lindsay's Bridge.

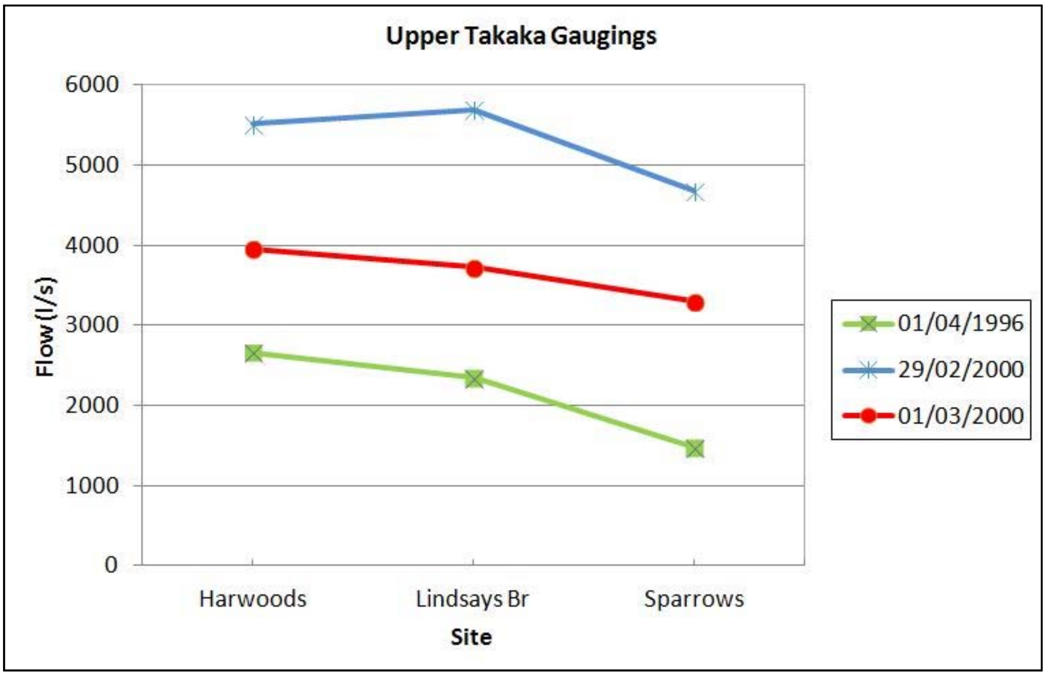


Figure 8: Flow Losses Between Harwoods and Sparrows

There are numerous smaller streams (Figure 7) that flow into the Takaka River between Harwood's and Kotinga. Many of these are dry in the lower reaches, i.e. upstream of where they meet the Takaka River, due to flow loss to the underlying karst. Ironstone Creek is one that flows all year round due to the geology of the catchment only partly being underlain by karst.

Apart from the rivers and creeks there are also spring discharges that emanate from the valley which are related to Arthur Marble. One is Spring Brook Springs in the mid Takaka Valley upstream of the Waingaro Road turnoff. These springs also go dry in dry periods. The other spring is along East Takaka, upstream of the Gorge Creek confluence with the Takaka River and is called Spittal Spring. Flows in this spring get very low in dry periods with the water disappearing into the valley gravels below the point it emerges from the foothills. There are also a series of seeps/springs in East Takaka above Payne's Ford and these flow all year round due to the water source more tied to the shallower Takaka Limestone Aquifer discharge. This base flow is what is normally measured at Payne's Ford during dry conditions.

3.2.2 Waingaro River

The Waingaro River is the second largest river in the area and flows into the Takaka River just below the State Highway 60 Bridge at Payne's Ford. A significant part of the catchment is rugged steep country and part of the Kahurangi National Park. Lake Stanley (a landslide lake formed in 1929) is located in the upper part of the Waingaro Catchment. The lower part of the catchment from the end of Hamama Road opens up into alluvial and aggradational terrace gravels. Council has had reliable flow records from the Waingaro River since 1986. Table 2 shows the flow statistics for the recorder site at Hanging Rock and a flow gauging site located upstream of the Takaka River confluence. This site upstream of the Takaka River confluence is a correlated site, which was derived from numerous concurrent downstream flow gaugings. Figure 9 shows the pattern of flow variations from the flow recorder site downstream. A series of sinkholes are obvious along the upper ends of Hamama and Long Plain Road and this ties in with the known extent of the Arthur Marble outcrop. Some of the flow loses in parts of the Waingaro River contributes water to both the local gravel and deeper underlying marble aquifer geology.

Recorder Site	**Mean**	**Median**	**7 day low flow (l/s)**				**Analysis Period**
			MALF	**5 yr**	**10 yr**	**20 yr**	
Waingaro at Hanging Rock	17841	10055	3576	3070	2897	2771	1986 - 2013

Correlated Gauging Site	**Mean**	**Median**	**7 day low flow (l/s)**				**Correlated With**
			MALF	**5 yr**	**10 yr**	**20 yr**	
Waingaro at u-s Takaka Confl	N/A*	N/A*	2730	2132	1928	1779	Waingaro at Hanging Rock

**The correlation values for this site do not cover a high enough range of flows to accurately provide a figure for mean and median flow.*

Table 2: Flow Statistics for the Waingaro River

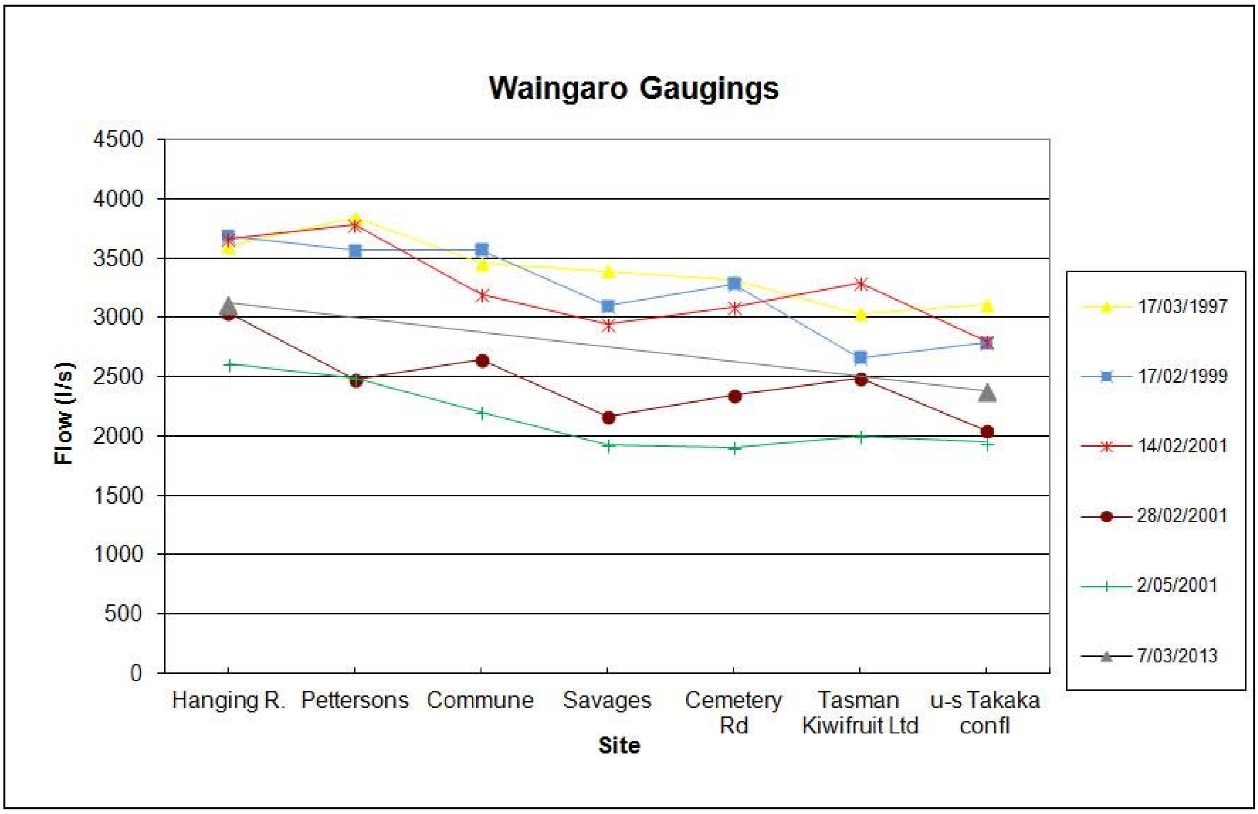


Figure 9: Concurrent Flow Gaugings on the Waingaro River (for flows less than 4000 l/s)

3.2.3 Anatoki River

The Anatoki River is the third largest river in the area and flows into the Takaka River east of the main Takaka township. A significant part of the upper catchment is rugged steep country and is part of the Kahurangi National park. The lower part of the valley below the McCallum Road turn-off, beside the river's edge, opens up into flatter land being flanked by alluvial and aggradational terrace gravels. Council has had flow records on the Anatoki River at Happy Sams for 34 years. Numerous concurrent flow gaugings have been carried out along the Anatoki River to its confluence with the Takaka River. Figure 10 shows the pattern of flow from the flow recorder site downstream. Table 3 shows the flow statistics for the Anatoki recorder site and a correlated site upstream of the Takaka confluence.

Go-Ahead Creek flows into the Anatoki River below Langford Road. Reaches of the river from below the foothills of The Slaty, Limestone Gully and Go-Ahead Ck to above the McCallum Road culvert can be dry in summer and this is related to the underlying marble aquifer geology. Low flows measured at McCallum Road range between 17 and 98 l/s.

Recorder Site	**Mean**	**Median**	**7 day low flow (l/s)**				**Analysis Period**
			MALF	**5 yr**	**10 yr**	**20 yr**	
Anatoki at Happy Sams	12315	6027	2186	1813	1686	1593	1987 - 2013

Correlated Gauging Site	**Mean**	**Median**	**7 day low flow (l/s)**				**Correlated With**
			MALF	**5 yr**	**10 yr**	**20 yr**	
Anatoki at One Spec Road	N/A*	N/A*	1757	1331	1185	1079	Anatoki at Happy Sams

**The correlation values for this site do not cover a high enough range of flows to accurately provide a figure for mean and median flow.*

Table 3: Flow Statistics for the Anatoki River

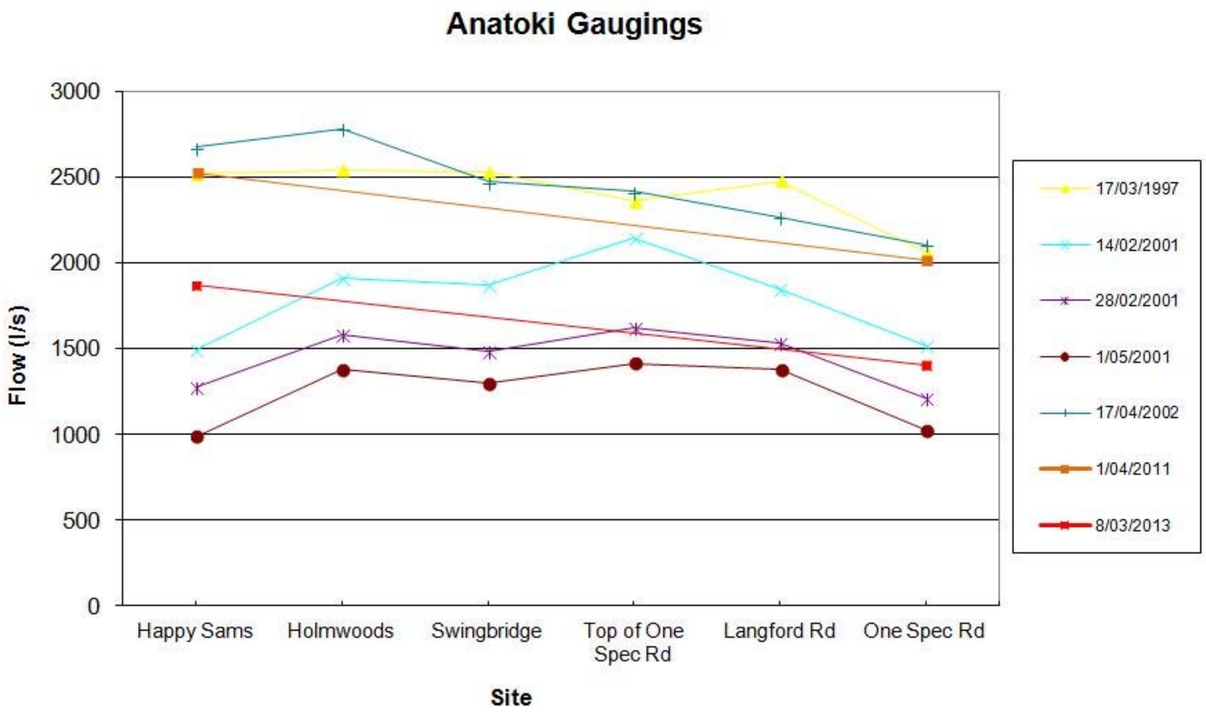


Figure 10: Concurrent Flow Gaugings on the Anatoki River (for flows less than 3000 l/s)

3.2.4 Waikoropupu River

The Waikoropupu River flows into the Takaka River upstream of the Waitapu Bridge. There is a small hydro station which diverts water from Campbell Creek, which is a tributary of the Waikoropupu in the higher reaches. Toward the lower reaches a substantial amount of water emanates from the Te Waikoropupu Springs and flows via Springs River into the Waikoropupu River. Table 4 provides the flow statistics for a correlated site upstream of the Takaka confluence.

Correlated Site	Mean	Median	7 day low flow (l/s)			
			MALF	5 yr	10 yr	20 yr
Waikoropupu at u-s Takaka Confl	14630	14030	8683	7101	6563	6168

Table 4: Flow Statistics for the Waikoropupu River

3.2.5 Motupipi River and Te Kaukau Stream

The Motupipi River doesn't have a properly defined geographical catchment. It is mainly a spring fed lowland stream, with the exception of Takaka River water getting into the upper reaches by State Highway 60 during flood events. During non flood events the Motupipi River is fed by Takaka River source-fed springs in the upper reaches i.e. Watercress Creek and creeks that drain from a farm south-east of the Takaka Milk Factory. Downstream along Sunbelt Crescent the Motupipi River gains water from discharges from the underlying Takaka Limestone Aquifer. Further downstream north-east of Sunbelt Crescent, unnamed creeks that drain the Glenview Road area contribute water to the Motupipi during wetter periods, as does Dry Creek. Monitoring of Motupipi Stream prior to any direct abstractions shows for a 7 day period, a 5 year return period flow of 220 l/s.

Te Kaukau Stream is a spring fed stream which emanates from an old river channel behind the Junction Hotel in Takaka. It flows into the Takaka River upstream of Waitapu Bridge. The source of the spring water is groundwater emergence fed from the Takaka River. The flow of the springs generally increases towards Haldane Road during high Takaka River flows and then flow reduces downstream from there. Changes in flow are due to losses to groundwater because of the level differences between the adjacent Takaka River, the bed of Te Kaukau Stream, and the underlying groundwater. Flow gaugings in the Te Kaukau Stream indicate for a 7 day period, a 5 year return period flow of 10 l/s as an estimate at Haldane Road. In extremely dry periods it is likely Te Kaukau stream will be dry in its lower reaches. Flows as low as 2 l/s have been measured in the lower reaches.

3.2.6 Creeks/Streams between Packard's Road and Pohara

Figure 7 also shows creeks/streams between Packard's Road and Pohara, many of which are small. These creeks/streams can carry a lot of water during rain events, however in low flow periods many will go dry or are barely flowing in their lower reaches. The exceptions are Ellis Creek and Winter Creek which are perennial streams. Although it is difficult to obtain flow statistics in this area, Table 5 shows the lowest flows gauged at some of the creeks/streams.

Creek/Stream	Location	Lowest Gauged Flow (l/s)
Te Kaukau	Haldane Road	16
Ellis	Main Road	29
Winter	Pohara Valley	25
Kite Te Tahu	Main Road	6
Gibson	Main Road	31

Table 5: Lowest Gauged Flow for Creeks/Streams in Pohara Area

3.2.7 Takaka North Catchments

The Takaka North Catchments have been broadly divided into five smaller catchments - Onahau, Puremahaia, Pariwhakaoho, Onekaka and Tukurua. These are shown in Figure 11. Figure 11 also shows the numerous creeks that drain into these five catchments. Areas to the east of the State Highway rise steeply, with much of the area being in the Kahurangi National Park. Aggradational terraces form the flat land immediately adjacent to the State Highway and towards the coast.

Figure 11: Map of Takaka North Rivers and Tributaries

Table 6 shows estimated flows for the main rivers in the Takaka North Catchments.

River	Site	Total Catchment Area (km2)	Estimated Low Flows (l/s)			
			Mean	Median	1 day MALF	7 day MALF
Onekaka	Shambala	19.4	833	394	113	126
Pariwhakaoho	SH60	15.7	830	428	170	182
Puremahaia	SH60	8.5	223	98	18	21
Onahau	Onahau Road	21.3	477	223	60	67
Tukurua	SH60	7.6	N/A	N/A	41	45

NOTE: Gaugings at sites in this table have been correlated with flows from the Anatoki at Happy Sams hydrology recorder site to give estimated flow statistics.

Table 6: Flow Statistics for Takaka North Rivers

4. Surface Water Quality and Ecology

The Takaka Water Management Area has some of the best and worst features of water quality and aquatic ecology in Tasman District:

The best:

- Te Waikoropupu Springs has the highest water clarity outside of Antarctica with a median of 62 m.
- Waingaro River has the highest water clarity for a river in Tasman District Council's River Water Quality Monitoring Programme - median of 12.1 m with a maximum of 30.5 m.
- Fish biodiversity - the Onekaka River has the highest number of native species of fish in one reach in NZ - 12 species (with trout there are 13 species in the lower river).
- Safe and attractive water for swimming - swimming holes on the Takaka River at Paynes Ford are regularly sampled and very rarely breach microbiological guidelines for recreational waters (<3% of samples are above). However, this site can have coverage of filamentous green algae above guidelines during extended low-flow periods in summer.

The worst:

- Daily minimum dissolved oxygen levels in the Motupipi River and Te Kaukau Stream were among the lowest ever recorded in the district. Aquatic plant growth rates in Te KauKau Stream were over double the median for streams draining intensive agriculture in New Zealand.
- Disease-causing organisms in several small streams in intensive pastoral land use have been well over stock drinking water guidelines e.g. Onahau and Motupipi catchments.
- Limited flood-flow samples indicate that during flood events the loading of faecal indicator bacteria to the coast is as high as the Aorere catchment.
- Nitrate-nitrogen in the Motupipi River is near guidelines for toxicity to fish and is part of the reason why filamentous green algae coverage of the bed is above guidelines and the unsightly bloom of the pelagic *Crytomonas* in the lower Motupipi River. These are the highest levels known in streams in the district after spring-fed streams in the Waimea Plains.

Water temperatures are acceptable in most rivers but there are a few smaller streams with little shade from riparian trees that have water temperatures above guidelines for protection of aquatic life. Examples include Powell Creek in the Motupipi catchment.

Flushing flood flows are really important for the ecological condition of the Motupipi and Te Kaukau. Provision should be made with the stopbank design along the Takaka River to let a certain amount of flood flows from the Takaka River into these systems. It was obvious that for 2-3 years after the November 2008 flood overflow into the Motupipi from the Takaka River, the water was clearer and there was less algae either attached or in the water column.

While good progress has been made in assessing and remediating fish passage barriers on land that is publicly accessible, very little progress has been made in this respect on private land. In Golden Bay it is estimated that >90% of these structures have been assessed and >70% of these have been remediated, whereas only about 10% of structures on private land have been assessed and remediated.

It is important to recognise the high ecological values of small creeks to moderate-sized streams that flow either directly to the sea or to a river close to the sea. The number of fish per unit area and the species diversity in these streams is high. Slow-flowing wetland-fed streams with depths over 1 m are known to support giant kokopu which is now rare in Tasman District. Eighteen species of native fish are known to occur in the Takaka Water Management Zone.

The following Figures 12 and 13 provide a rating for monitoring sites sampled by Tasman District Council in the Takaka Management Zone. The rating is based on the key below.

🟢	Excellent:	<5% of a site’s records exceed relevant guidelines. All key processes are functional and all critical habitats are in near pristine condition.
🟡	Good:	>5 to <10% of a site’s records exceed relevant guidelines. Most key processes are functional and most critical habitats are intact.
🟠	Fair:	>10 to <30% of a site’s records exceed relevant guidelines. Some key processes are functional but some critical habitats are impacted.
🔴	Poor:	>30% of a site’s record exceed relevant guidelines. Many key processes are not functional and many critical habitats are impacted.

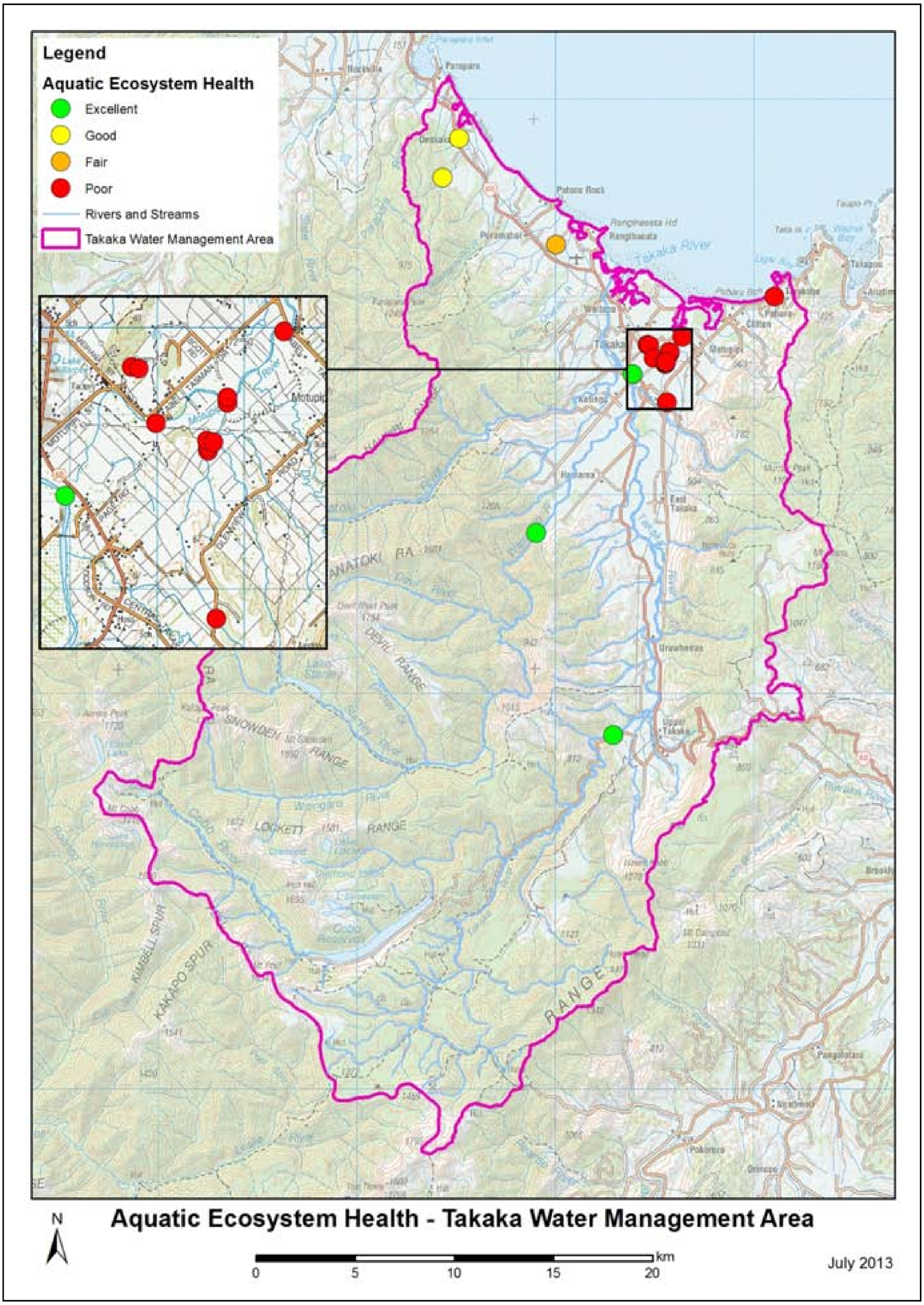


Figure 12: Surface Water Quality Rating in Takaka Water Management Area

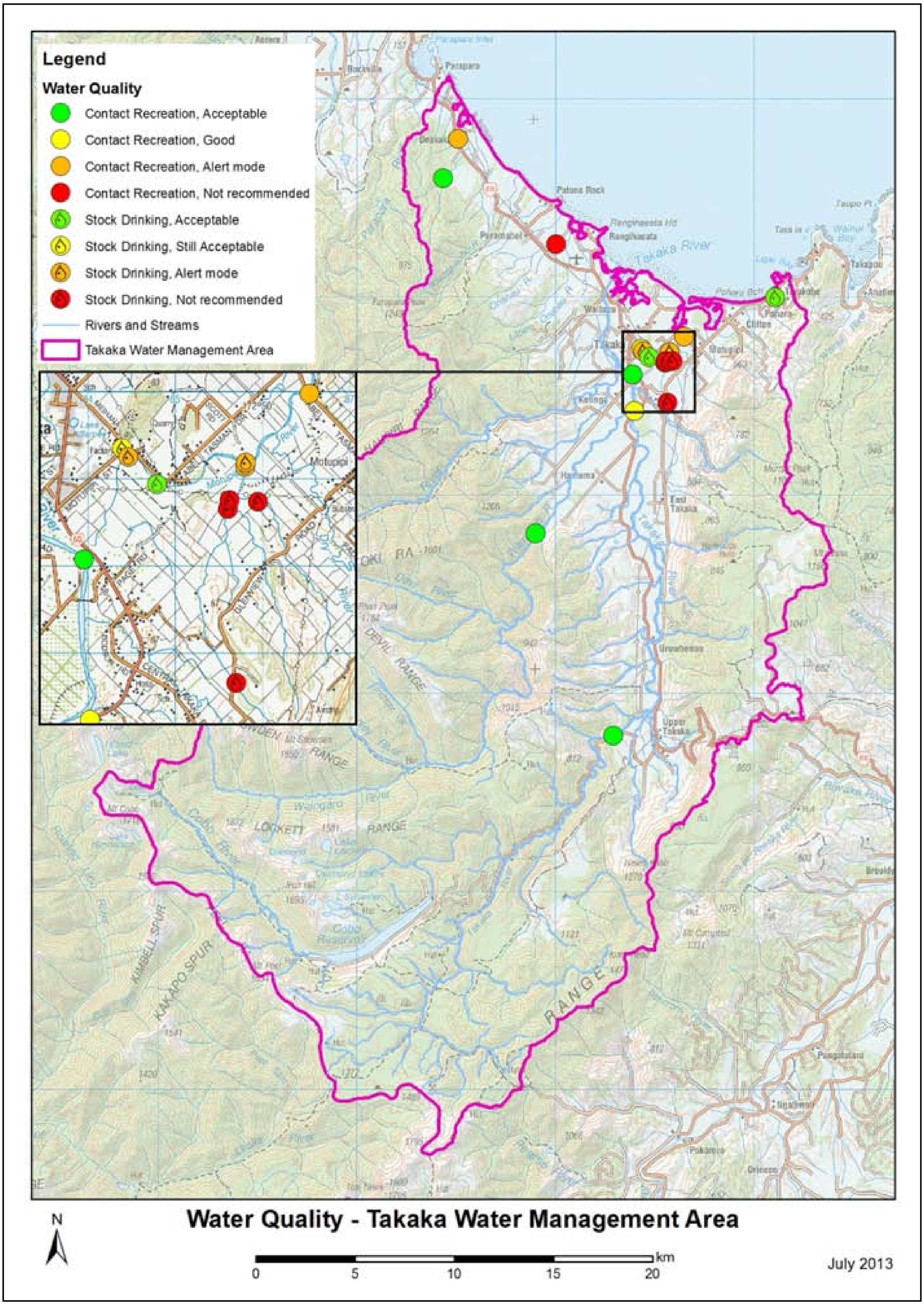


Figure 13: Surface Water Quality Assessments in Takaka Water Management Area

5. Groundwater Resources

There are three main water bearing units (aquifers) in the area. These are directly related to lithology (rock characteristics) and geology**.** The three main aquifers are the Arthur Marble Aquifer, Takaka Limestone Aquifer and the Takaka Unconfined Gravel Aquifer. There are complex interactions/connections between the various aquifers and the rivers and streams in the area including their recharge and discharge, and their nature i.e. unconfined* and confined*. Limited and localised groundwater may occur in some areas especially in the coastal deposits and aggradational terraces shown in Figure 3.

**Unconfined Aquifer is one where the permeable rock units are open to receive water from the surface i.e. in direct contact with the atmosphere.*

**Confined Aquifer is one where the permeable rock units are overlain by impermeable rock.*

5.1 Arthur Marble Aquifer (AMA) and Te Waikoropupu Springs

The Arthur Marble Aquifer (AMA) is the principal karstic aquifer that occurs in the Takaka Valley, and is an aquifer in the Arthur Marble. The Arthur Marble in the Takaka catchment is found underneath the Takaka Valley floor, and from Upper Takaka to the Golden Bay coast, and in the mountain ranges parallel to the Takaka Valley section. Arthur Marble covers an area of about 180 km^2 in the central and lower Takaka sub-catchments. Under the central Takaka Valley floor the marble is covered by tens of metres of alluvial gravel and in the lower Takaka catchment it is additionally covered by impervious Tertiary formations - i.e. the Motupipi Coal measures and Tarakohe Mudstone. The thickness of the marble is variable and is considered to be at least 500 m and possibly 1000 m.

Dissolution of the marble has caused the formation of a significant surface karstic landscape, with features such as sinkholes (karren, dolines, swallow holes) and strong serrated relief, and a significant subterranean aquifer system.

The AMA is unconfined from Upper Takaka to about Hamama. In the unconfined area Arthur Marble is overlain by cavernous Takaka Limestone and/or permeable alluvial gravels. The lithological boundary between marble and limestone has no distinguishable influence on groundwater flows in these unconfined areas. North of Hamama the AMA becomes confined by impervious Motupipi Coal Measures that overlie the Arthur Marble. Figure 14 shows the extent of the AMA and the unconfined and confined parts of it.

Figure 15 shows a cross section from Lindsay's Bridge to Te Waikoropupu Springs and out to sea. Figure 3 also shows two further cross sections for the area. The aquifer surface in the unconfined area is defined by the water table, which may be above the surface of the marble body and found within overlying Takaka Limestone or Quaternary Gravels. In the confined area the surface of the aquifer is defined by the presence and elevation of impervious Motupipi Coal Measures.

Aquifer depth is controlled by the thickness of the marble and the penetration depth of dissolution. In East Takaka, and upstream of the Te Waikoropupu Springs area, deep bores reveal karstification to be more than 100 m deep. Geological data indicates the marble depth to be several hundred metres below the valley floor and karstification could well extend to these depths, although the exact depth of karstification into the marble body is unknown.

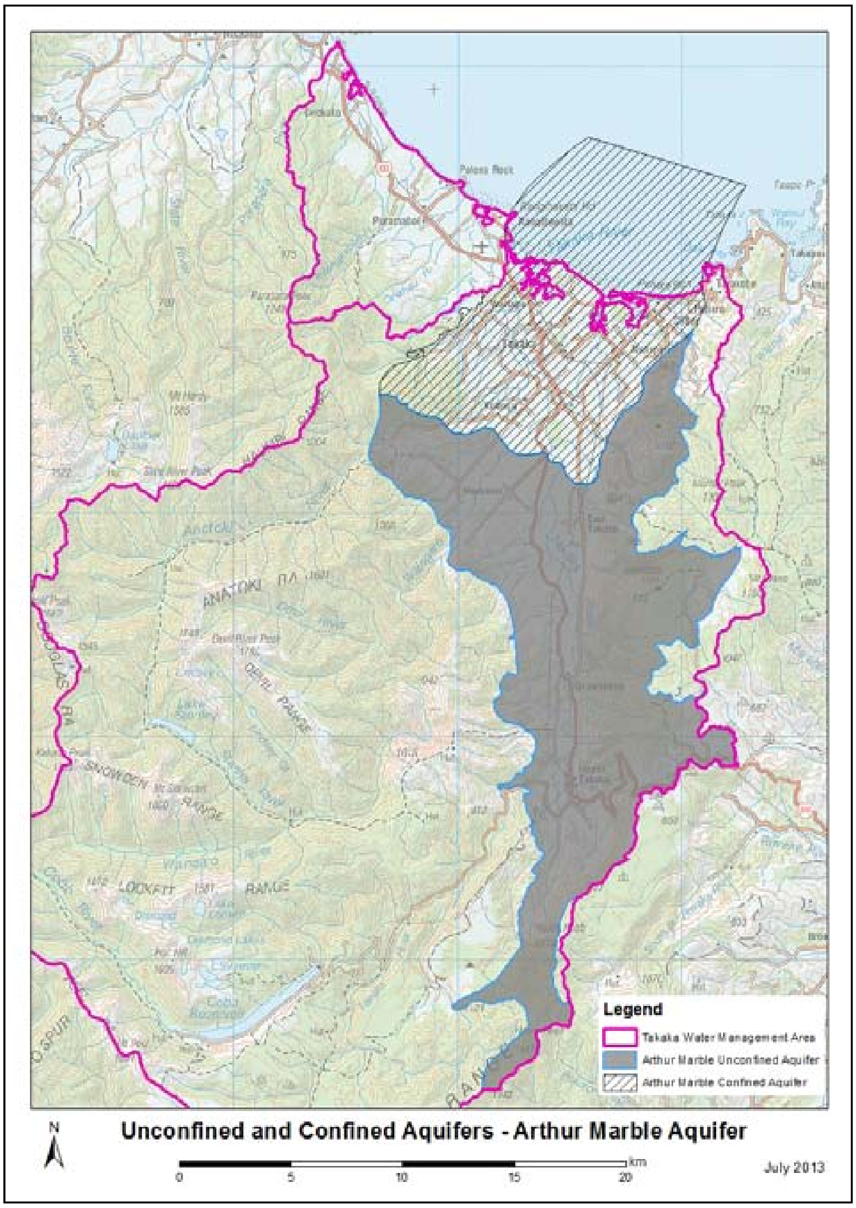


Figure 14: Arthur Marble Aquifer - Extent of Unconfined and Confined Aquifers

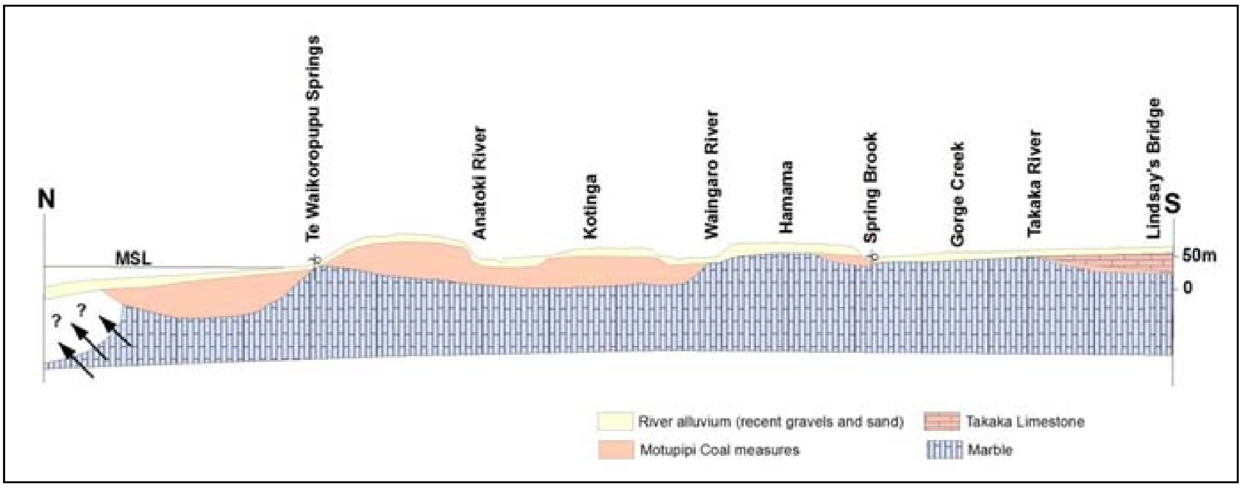
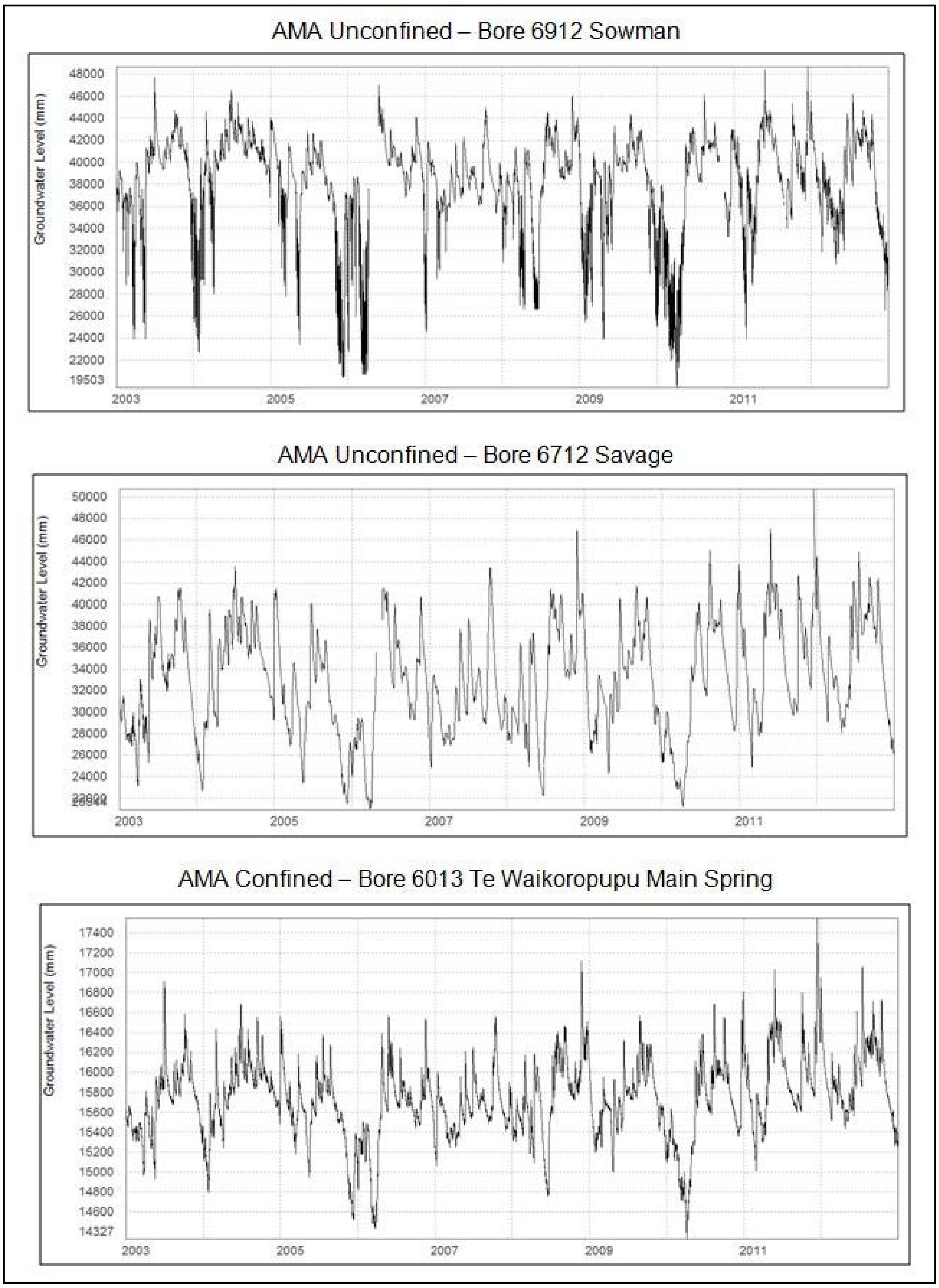


Figure 15: Geological Cross Section from Lindsay's Bridge to Te Waikoropupu Springs

Aquifer recharge locations are spread over areas where Arthur Marble is either outcropping, or from the unconfined aquifer in the central Takaka Valley. Recharge is both through rainfall in the areas where the marble is outcropping, as well as flow loss from the main rivers i.e. the Takaka and parts of the Waingaro, as well as all the creeks draining into the Takaka Valley. Many of these creeks flow in their upper reaches but upon reaching the underlying marble geology go dry. The Takaka River on average loses 8000 l/s through the gravel of the riverbed into the karst aquifer system below Lindsay's Bridge. As noted in the surface water section when the flows at Harwood's drops below 7000 l/s the Takaka River can be anticipated to be dry in its lower reaches (East Takaka). The underlying groundwater levels influence the river flow losses. Figure 16 shows water levels (from 2003 to 2012) from three bores, two in the unconfined and one in the confined parts of the AMA. The location of these bores is shown in earlier Figure 6. All groundwater levels are above mean sea level (AMSL). The large variations in bores 6912 and 6712 are due to elevation, low river flows, and Cobb Dam generation.


AMA Unconfined – Bore 6912 Sowman

AMA Unconfined – Bore 6712 Savage

AMA Confined – Bore 6013 Te Waikoropupu Main Spring

Figure 16: Water Levels in Unconfined and Confined Parts of the AMA (2003 to 2012)

Te Waikoropupu Springs (Figure 17) is a large karst resurgence consisting of a main spring with mean discharge of 10,000 l/s, and a number of smaller springs known as Fish Creek Springs with mean discharge of 3,300 l/s. Figure 18 shows the average flow at Te Waikoropupu main springs since 1991. Fish Creek Springs goes dry during extended drought periods. Table 7 shows flow statistics for Te Waikoropupu main spring and Fish Creek springs.

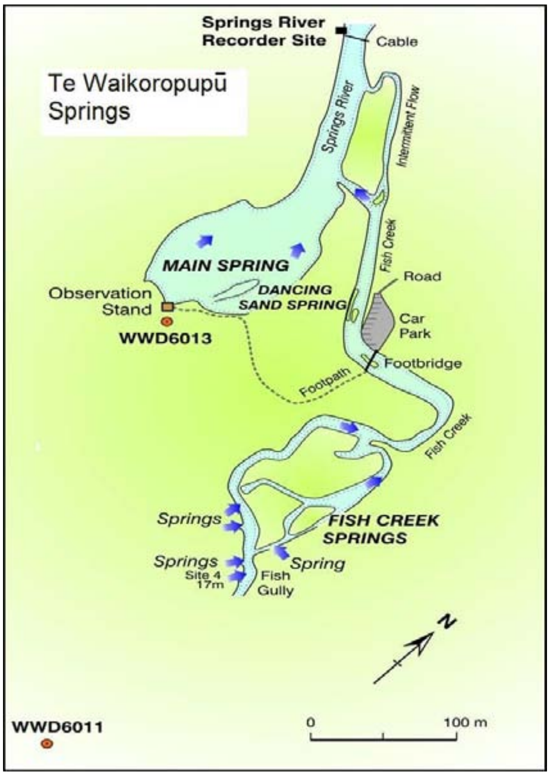


Figure 17: Plan of the Te Waikoropupu Springs and nearby Bores WWD 6011 and WWD 6013

The springs are the main discharge zone for the AMA, which underlies much of the Takaka Valley. Arthur Marble also outcrops in karst uplands to east (Takaka Hill) and west of the valley. Hydrogeological and water balance studies show that water from the AMA also discharges out to Golden Bay. There is no proof to date of any discreet offshore springs, even though numerous comments have been made about their presence. Several investigations to locate these offshore springs have been unsuccessful. Hydraulic and hydrogeological information suggest that water from the AMA is likely diffusing out in the bay over a wide area and hence not obvious.

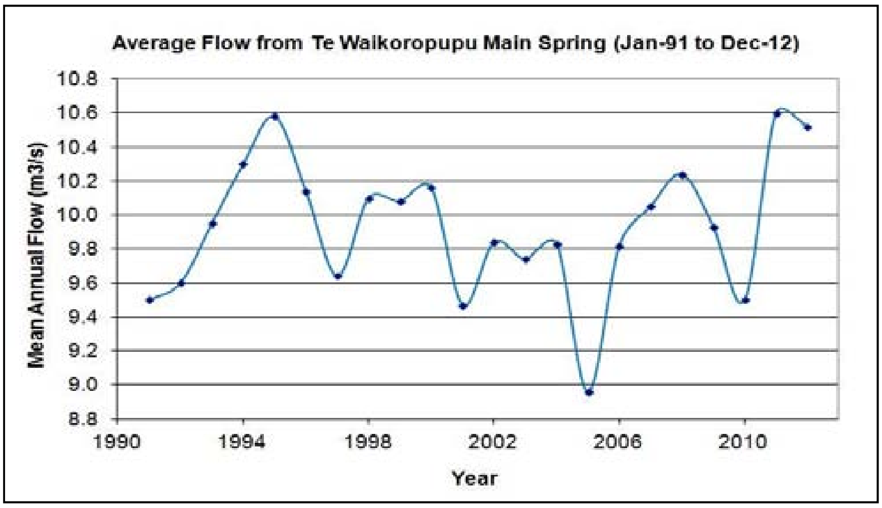


Figure 18: Average Flows Te Waikoropupu Main Spring

Recorder Site	Mean	Median	7 day low flow (l/s)				Analysis Period
			MALF	5 yr	10 yr	20 yr	
Fish Creek Spring	3476	3546	665	127	-	-	1985-2013
GW 6013 Te Waikoropupu Spring	9890	9940	7717	6718	6379	6129	1999-2013

Table 7: Flow Statistics for Fish Creek and Te Waikoropupu Springs

Several interpretations of the source water (recharge) to the AMA and Te Waikoropupu Springs have been made in the past. Table 8 below provides the latest interpretation (Stewart & Thomas 2008) combining information from isotopic analysis (age), chemical analysis, flow measurements, water balance and isotopic mixing models of these sources.

	Mean Flow (l/s)				
Recharge Source	**Main Spring**	**Fish Springs**	**Offshore Springs**	**Total**	**% of Total Flow**
Karst Uplands	7,400	830	970	9,200	46.6%
Upper Takaka River	1,850	1,650	4,850	8,350	42.3%
Takaka Valley Rain	750	820	630	2,200	11.1%
Total mean flow	10,000	3,300	6,450	19,750	

Table 8: Recharge Sources of AMA

One source of water for recharge to the AMA identified is the Takaka River. The Takaka River contribution to the main springs of Te Waikoropupu is about 18.5% compared with 74% for the Karst uplands. In the case of Fish Creek the proportions are 50% and 25% respectively. The flow fluctuations observed in the Te Waikoropupu show a hydraulic connection to the Takaka River and this hydraulic connection is important to the discharge of water from the springs. Figure 19 shows the hydraulic effect of Takaka River flows on the Te Waikoropupu Springs. Increases or decreases in flows at Te Waikoropupu Springs corresponds with an increase or decrease in flow in the Takaka River. Figure 19 also shows the tidal fluctuations at Te Waikoropupu Springs. Similar patterns to those shown in Figure 19 are also observed in Fish Creek Springs.

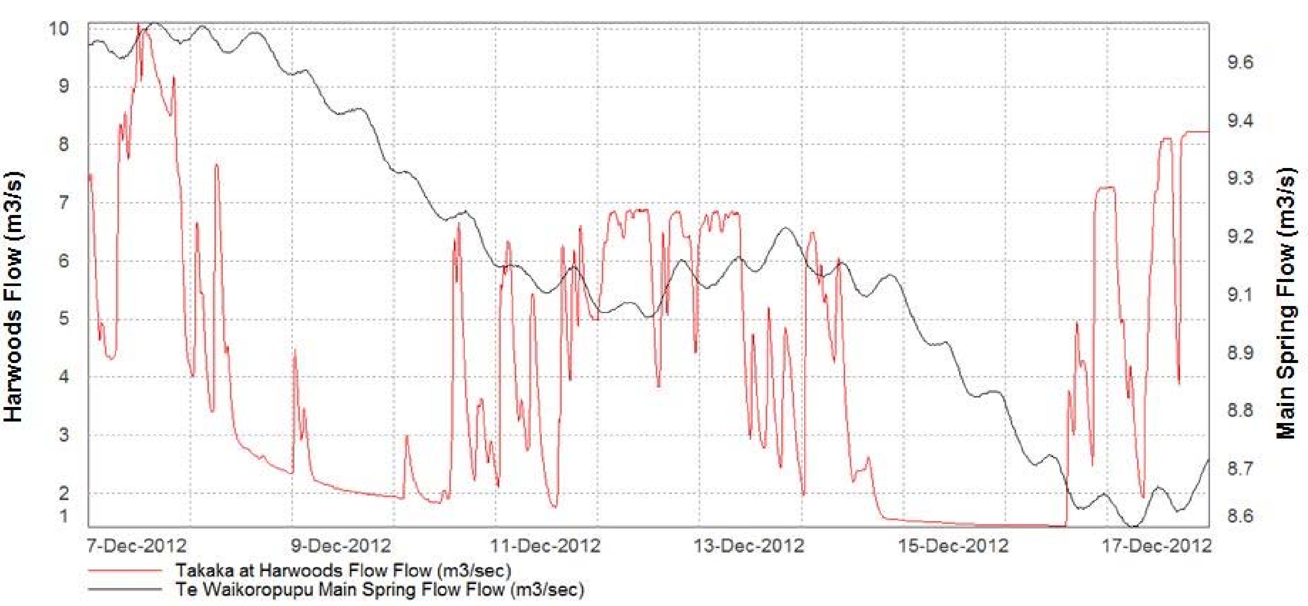


Figure 19: Graph of Takaka River Flows versus Te Waikoropupu Spring Flows

The chemical concentrations of the Te Waikoropupu Main Spring show input of 0.5% of sea water on average, but varying with flow. Figure 20 shows the correlation between chloride (an indicator of sea water) and flow at the Te Waikoropupu Main Spring.

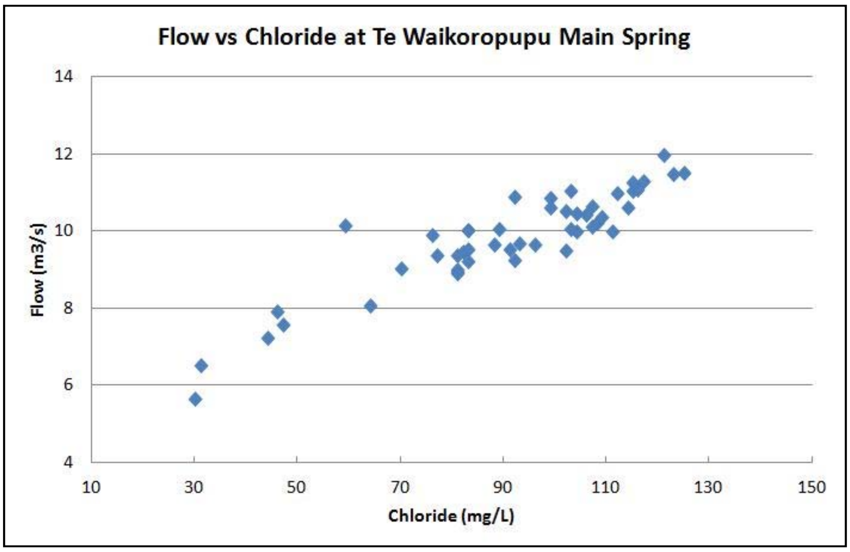


Figure 20: Correlation Between Flow and Chloride at Te Waikoropupu Main Spring

The variation shows that two water components (sea-water-bearing and non-sea-water-bearing) contribute to the flow. Isotopic measurements give a mean residence time of 8 years for the Te Waikoropupu Main Spring water using the preferred two-component model.

A conceptual flow model, based on the flow, chloride and isotopic measurements, shows two different flow systems with different recharge sources to explain the flow within the AMA. Figure 21 shows the conceptual model of flow in AMA. One system contains deeply penetrating old water with a mean age of 10.2 years and water volume 3 km^3, recharged from the karst uplands on the sides of the valley. The other, at shallow levels below the valley floor, has much younger water, with mean age of 1.2 years and water volume 0.4 km^3, recharged by Upper Takaka River and valley rainfall. The two flow systems contribute in different average proportions to the Main Spring (74% deep, 26% shallow), Fish Creek Springs (25% deep, 75% shallow) and offshore springs (15% deep, 85% shallow).

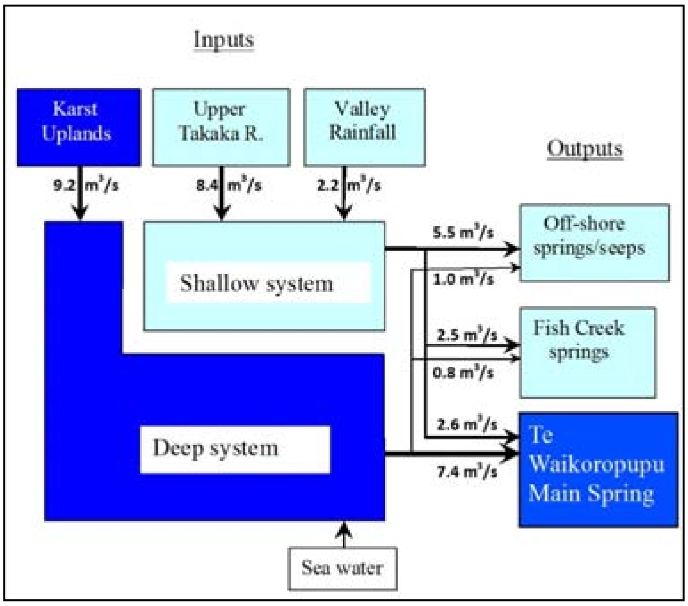


Figure 21: Conceptual Model of Flow in the AMA

The very different behaviour of the two systems, despite being in the same aquifer, is attributed to the presence of a diorite intrusion below the surface of the lower Takaka Valley (Figure 22), which diverts the deep system flow towards the Te Waikoropupu Springs, and allows much of the shallow system flow to pass over the intrusion and escape via offshore springs.

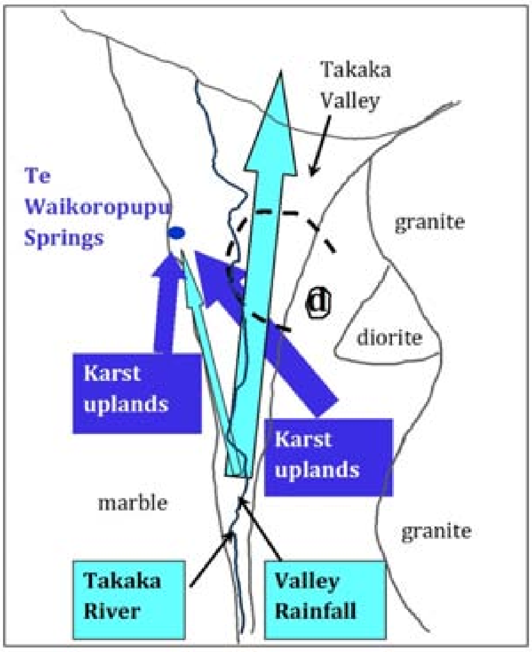


Figure 22: AMA Deep and Shallow Flow Systems

5.2 Takaka Limestone Aquifer (TLA)

The Takaka Limestone Aquifer (TLA) occurs between East Takaka and Tarakohe (Figure 23) and is a result of karstification processes on the Takaka Limestone. The TLA in the northern half of the Valley (north of Hamama and East Takaka) is underlain by an aquiclude (impermeable rock/geology i.e. Motupipi Coal Measures). To the south of Hamama and East Takaka the aquiclude is absent and the AMA and TLA are indistinguishable. The Takaka Limestone is gently folded into a series of low amplitude synclines and anticlines. Several bores tap into the aquifer in East Takaka, where the depth to limestone ranges from 60 - 120 m. In the Motupipi area bores have encountered the aquifer from depth of about 20 - 60 m below ground level. The TLA thickness varies between 30 - 60 m.

Groundwater levels in the TLA vary depending on their elevation. In the Takaka Valley floor from East Takaka to along the Motupipi River the groundwater levels range between 1 - 4 m, depending on locality. In areas where the Takaka Limestone underlies the overlying gravels the water levels can be indistinguishable from those in the gravel. Water level fluctuations of about 8 m have been measured in the TLA along the western margins from Central Takaka to Clifton. Depth to water table in these areas is affected by elevation with water tables varying from the western margins toward Motupipi and the sea. Water table depth below ground could be 10 - 18 m deep in the western margins along Clifton in summer, whilst around Motupipi the depths would be 6 - 9 m. Recharge to the aquifer is mainly from rainfall and seepage from creeks draining the eastern boundary. Recharge also occurs from the southern end via Takaka River flow seepage into the underlying gravel and then into limestone. Whilst Takaka Limestone geology occurs in the upper parts of the Takaka catchment west of the Cobb Reservoir, not much about groundwater occurrence is known as these outcrops lie at high elevation, rugged terrain and are in the Kahurangi National Park. The elevation data and geology indicates that any drainage from this formation would be into the Takaka Catchment.

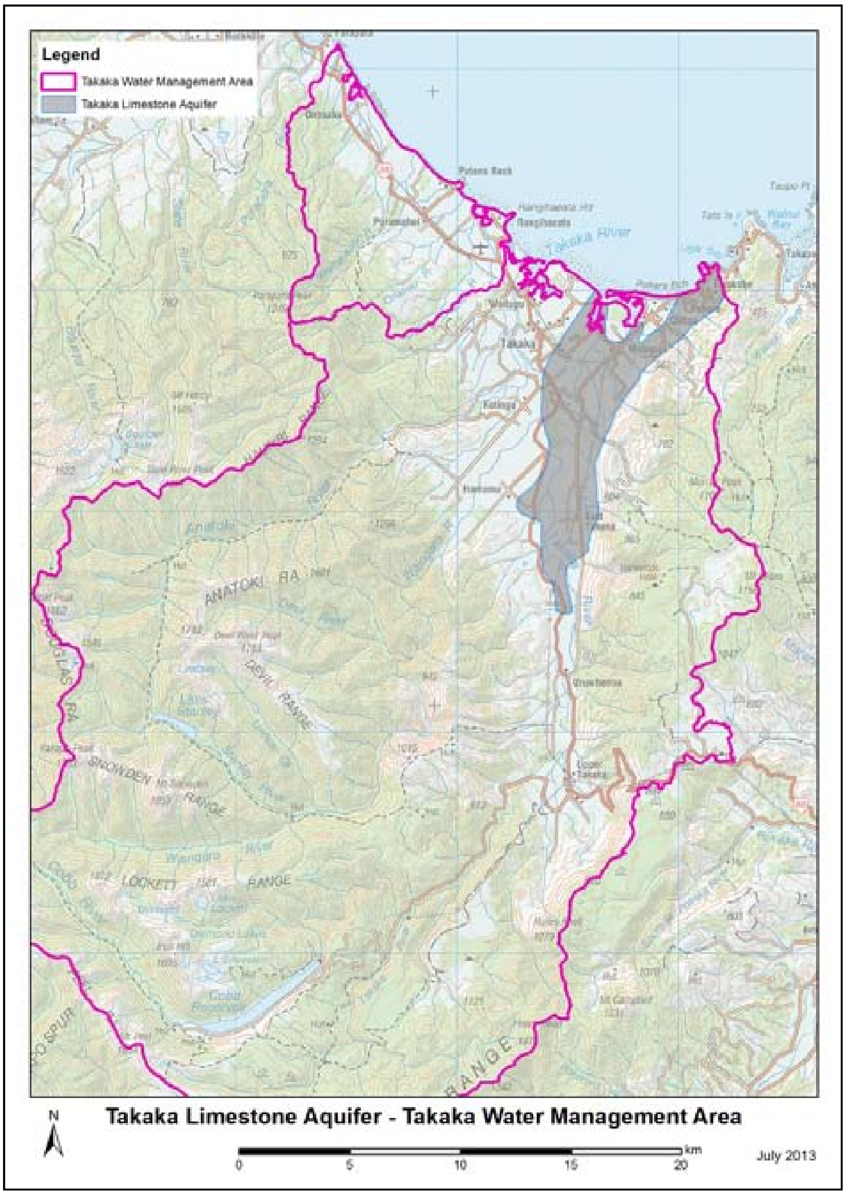


Figure 23: Takaka Limestone Aquifer - Takaka Water Management Area

Currently there is no groundwater monitoring bores in the TLA due to the limited nature of the extent of the aquifer. Historic data was collected from a bore in the TLA at Motupipi. Figure 24 shows groundwater level fluctuations at this bore.

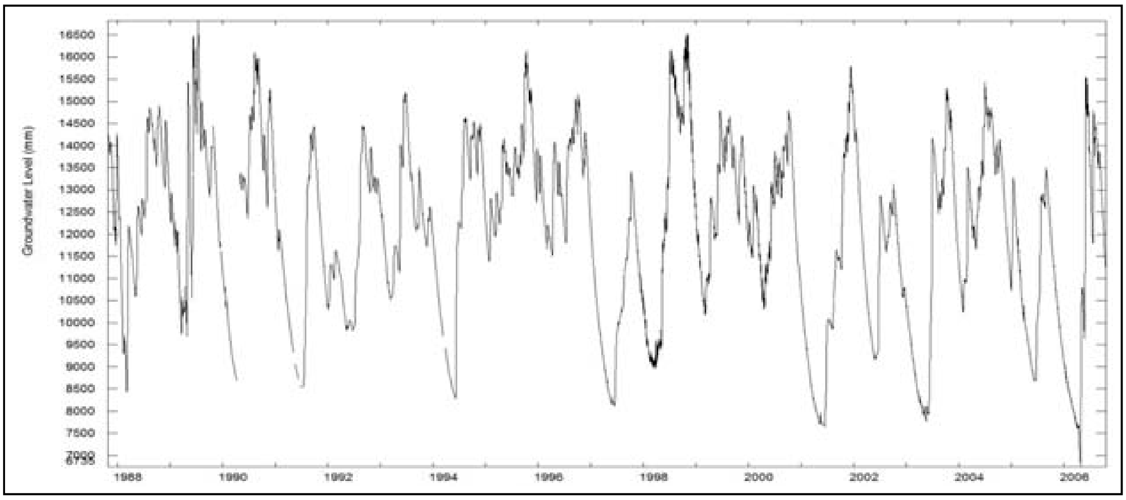


Figure 24: Historic Water Levels in the TLA at Motupipi

5.3 Takaka Unconfined Gravel Aquifer (TUGA)

Quaternary (recent river) gravel and sand deposits cover most of the Takaka Valley from Upper Takaka to the sea. The major water bearing gravels are the ones underlying the lowest river terraces of the Takaka Valley and gravels underlying the Takaka township (Figure 25). The thickness of the gravels varies considerably down valley.

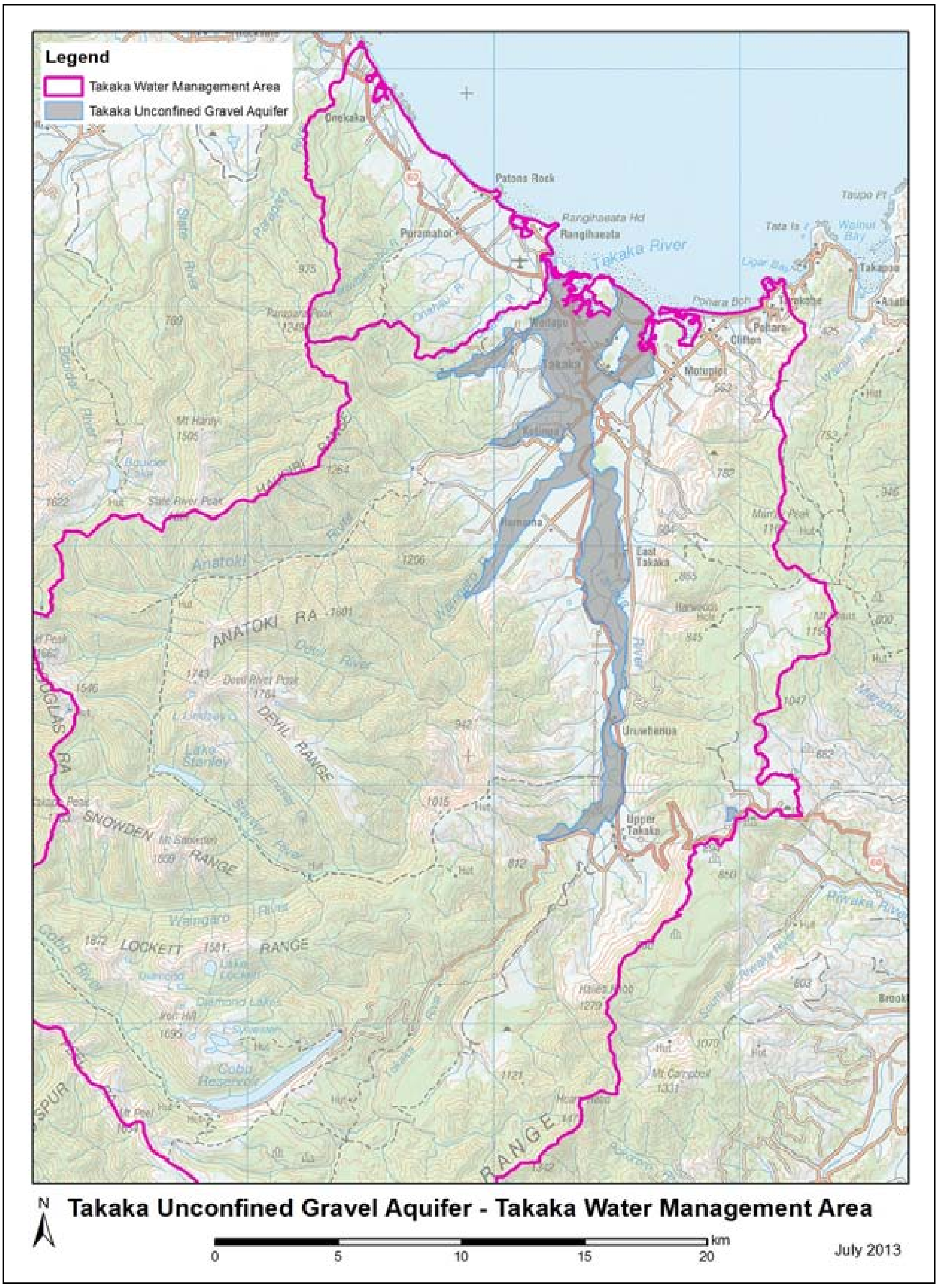


Figure 25: Takaka Unconfined Gravel Aquifer

Around Lindsay's Bridge the gravels are about 10 m thick. Drilling upstream of the Craigieburn Creek confluence with Takaka River revealed a gravel thickness of 59 m. Here the gravel is underlain directly by the Arthur Marble. The gravel is generally between 5 -12 m thick in East Takaka, with it generally being underlain by Tarakohe Mudstone to the west and directly over limestone closer to the Takaka River and Kotinga.

In the central part of Takaka township the gravels are estimated to be about 30 - 50 m thick. Drilling information at the eastern end of Roses Road shows a gravel thickness of 8 m, near the coast by Waitapu the gravel thickness is 18 m and at Rototai it is about 15 m. Within the Takaka township the gravel appears to be thickest between Willow Street to Reilly Street and indicates an old deep river channel. Basement rock has not been encountered in the central part of the Takaka township but drilling shows Motupipi Coal Measures to underlie the gravel at the end of Roses Road and at Waitapu Road.

Lake Killarney which is located in Takaka township (on the TUGA), and Blue Lake (local name), which is located off Rototai Road (about 1 km from Golden Bay High school), are karstic collapse features (sinkholes) in the underlying AMA. The AMA here is overlain by Motupipi Coal Measures. The Motupipi Coal Measures are impermeable and hence water in these two sink holes are not directly connected to the AMA. Lake Killarney is connected to localised shallow groundwater and runoff and Blue Lake mainly localised runoff.

Based on information available from drill logs and geological interpretation it is thought that the Motupipi Coal Measures underlie the area between Willow Street to Waitapu, and to Tangmere Road. In the area between Sunbelt Crescent to the Motupipi River mouth the gravel thickness is between 6 - 10 m, and here the gravel is underlain by Takaka Limestone. Takaka Limestone is also known to underlie the area along Rototai Road and Nees Road by the Motupipi estuary.

Residents of the whole Takaka township obtain water from private individual domestic bores that are generally between 5 - 8 m deep. These bores are mainly driven pipes as groundwater is easily accessed by surface pumps. The water table is not far below ground level (2 - 3 m) and within easy suction reach for the surface pumps. Figure 26 shows water levels in bore WWD 6339, (Figure 6) located in the TUGA in Takaka township. The plot shows seasonal variability with maximum fluctuation of approximately 3.7 m. The lowest recorded groundwater level in WWD 6339 was about 3.3 m below ground level. The average summer groundwater level here is about 3 to 3.1 m below ground level.

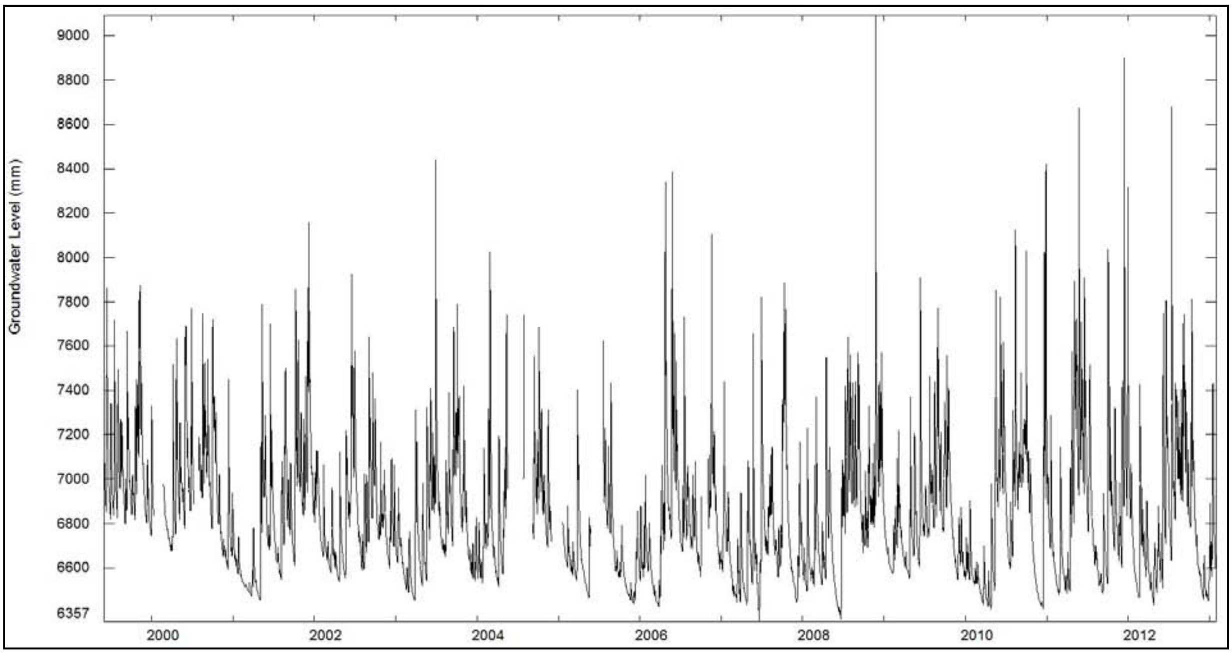


Figure 26: Water levels in the TGUA

Several pump tests on bores in the TGUA from around the Takaka township show the gravels to have very high transmissivity (>5000 m2/day), indicating the high permeability of the aquifer. Well constructed bores into good parts of the aquifer provide high yields (e.g. 300 mm bores can yield > 100 m^3/hr), with low drawdown's. Principal recharge to the aquifer is the Takaka River and rainfall in its catchment. As outlined in the surface water section, discharge from the TUGA contributes water to Watercress Creek behind the Fonterra Milk factory and to the springs emanating from farm land east of Motupipi Street. The groundwater discharges feed the upper parts of the Motupipi River. In the area adjacent to Abel Tasman Drive between Sunbelt Crescent and the Motupipi River mouth the TGUA is underlain by the TLA and discharges (upwelling) from the TLA are also a source of recharge for the aquifer.

The TUGA area between Nees Road and Tangmere Road does not get any direct recharge from the Takaka River, as the Takaka Limestone Syncline escarpment underlain by the impermeable Motupipi Coal Measures abuts between the Takaka Milk Factory and along Rototai Road. This area gets localised recharge from rainfall and from runoff from the hills along Tangmere Road and the south of Rototai Road. Historic work and information from the Catchment Board days in the late 1980's, noted the coastal area along Tangmere Road and Nees Road to have seawater intrusion risk if significant groundwater extraction were to occur.

The awareness of this issue in Tangmere Road area arose due to extensive kiwifruit orcharding and groundwater pumping in the 1980's. However there is no major kiwifruit orchards in this area now and no seawater was found then in the wells. Seawater intrusion has occurred in the coastal area of the Motupipi River mouth due to pumping in the past, as has been in the area along the coastal margins of Nees Road. The area along Nees Road is right at the margins of the aquifer and because of its location and tidal effects would be prone to seawater intrusion risk. There are also small springs that emanate between Maori Road and the Takaka River mouth, these springs are remnants of old Takaka River channels. The flows in these springs are dependent on the flow in the Takaka River (recharge) and are discharges from the TGUA.

5.4 Other Groundwater

There are other minor groundwater sources in the Takaka Water Management Area. In the Takaka North catchments small amounts of groundwater can be found in the terrace gravels. These gravels are only several metres thick (~ 5 - 7 m) and are underlain by the impermeable Motupipi Coal Measure called "Papa" locally. Generally yields from these sources are better near the rivers that transect these areas.

Small amounts of groundwater are also found in the terrace gravels along Motupipi and in coastal deposits (coastal/dune sands) between Pohara to Tangmere and around the coastal settlement of Patons Rock. Groundwater is generally abstracted from dug concrete lined wells that are between 3 - 4 m deep. Water availability from these sources is localised with generally low yields as the permeability is also low in these formations. Recharge to these minor aquifers is mainly direct rainfall and if near streams, seepages from these also contribute.

6. Groundwater Quality

Groundwater quality in the Takaka Water Management Area is highly influenced by the geology and the interactions or otherwise between the three main aquifers in the area i.e. AMA, TLA and the TUGA. Groundwater quality has been monitored through synoptic surveys and specific sampling covering a range of groundwater sources. This testing is also complemented by long term monitoring of groundwater quality in each aquifer at three monthly intervals.

The groundwater in both the AMA and TLA is hard due to the dissolution of calcium from the Arthur Marble and Takaka Limestone geology which are naturally calcium rich rock. Generally the calcium levels increase in the TLA from East Takaka to Motupipi and in the AMA they increase from the Upper Takaka Valley towards Te Waikoropupu Springs.

There are variations in calcium content between the Te Waikoropupu Main Spring and the smaller Fish Creek springs, and this is due to the complex mixing and variations in sources of recharge which were outlined in the section on the AMA. The TUGA has much lower hardness and calcium content due to recharge mainly from the rivers and rainfall.

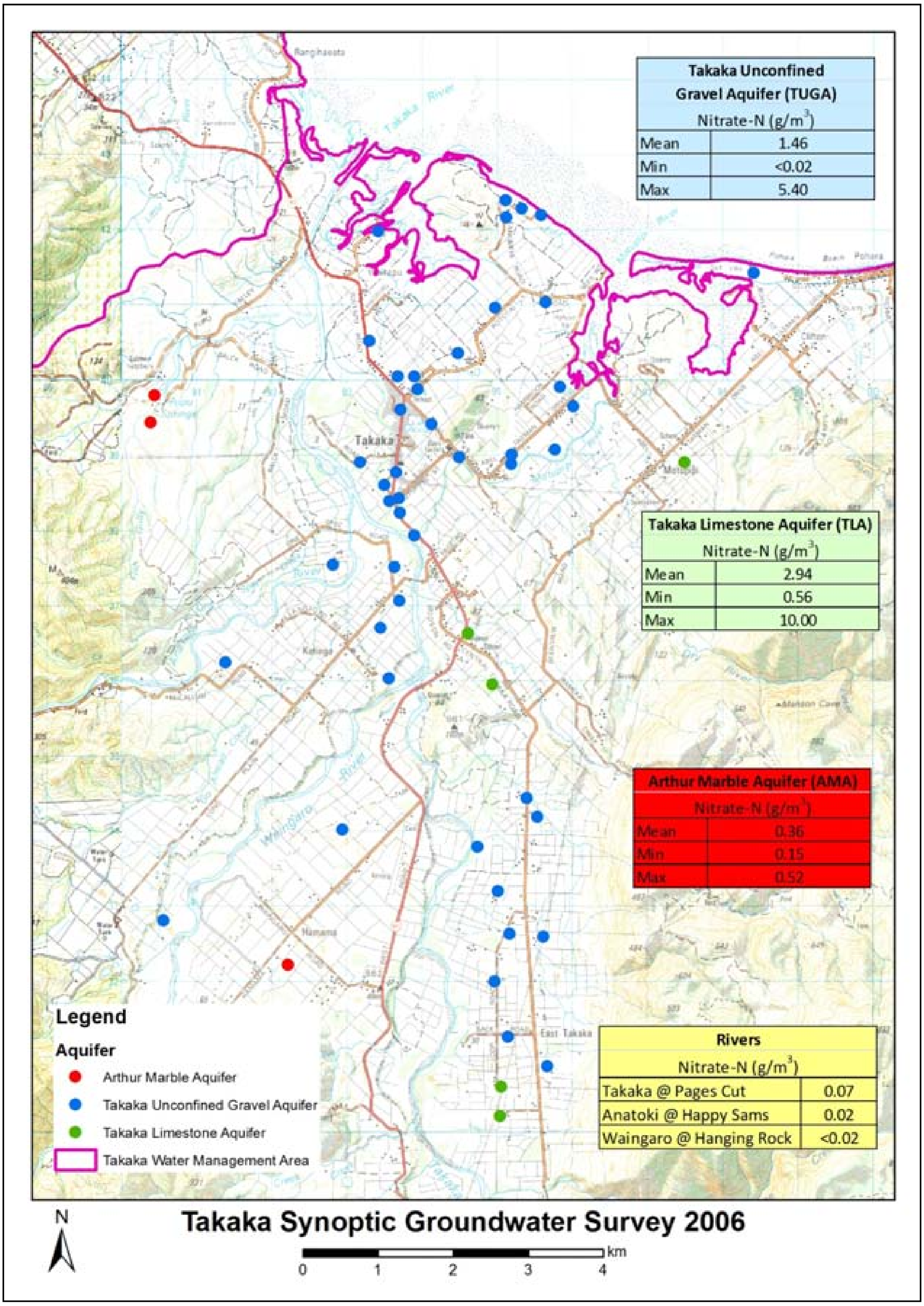
Generally the quality of groundwater in both the AMA and the TLA is high apart from the water being hard. Water from Te Waikoropupu Main Spring has higher chloride level (~ 90 g/m^3) than Fish Creek Springs (20 g/m^3) water. This again is the reflection of the recharge sources and the variable mixing effect of the deep marble water and the shallower marble water. Chloride levels are low (i.e. generally less than 10 g/m^3) in both the TLA and the TGUA.

The groundwater quality is generally high in the TUGA with low concentrations of dissolved minerals and nutrients. Groundwater, particularly in the gravel aquifer in the Takaka Valley and the Takaka Township is of good quality and extensively used for private domestic supplies.

There are localised areas (due to organic matter) within the TGUA where the water can have some swampy characteristics, being hard and sometimes irony e.g. in the area around Hiawatha Lane and Lake Killarney. Groundwater in the TGUA in the area between Sunbelt Crescent and the Motupipi River mouth is harder than that in the Takaka Township due to underlying discharge of groundwater from the TLA in this area.

Figure 27 shows a summary of the Nitrate-Nitrogen levels from aquifers in the Takaka Valley area that were monitored in the 2006 synoptic survey. Nitrate-Nitrogen is a nutrient and is a chemical constituent in fertiliser and also is found in wastewater. The drinking water standard for Nitrate-Nitrogen is 11.3 gm/^{3}.

Overall the Nitrate-Nitrogen levels are low in comparison to the drinking water standards. Figure 28 shows long term nitrate trends from samples collected three monthly from Te Waikoropupu Springs (AMA), a bore in Central Takaka off the Takaka Valley Highway near Dodson Road (TLA bore WWD 6601) and a fire bore right in Takaka township (by the corner of Commercial and Reilly Street, bore WWD6342). Nitrate-Nitrogen levels in both the AMA and the TUGA are much lower than that in the TLA although none of these sites have ever exceeded the drinking water limits (aquatic systems have different limits).



Takaka Unconfined Gravel Aquifer (TUGA) Nitrate-N (g/m^3)	
Mean	1.46
Min	<0.02
Max	5.40

Takaka Limestone Aquifer (TLA) Nitrate-N (g/m^3)	
Mean	2.94
Min	0.56
Max	10.00

Arthur Marble Aquifer (AMA) Nitrate-N (g/m^3)	
Mean	0.36
Min	0.15
Max	0.52

Rivers Nitrate-N (g/m^3)	
Takaka @ Pages Cut	0.07
Anatoki @ Happy Sams	0.02
Waingaro @ Hanging Rock	<0.02

Figure 27: Takaka Synoptic Survey Nitrate-Nitrogen Results

The TLA discharges into the TUGA in the area between Sunbelt Crescent and the Motupipi River Mouth, and also into the Motupipi River itself. The Nitrate-Nitrogen levels occurring in the TLA are believed to be due to a combination of land use practices in the recharge areas of the TLA and also inherent geochemistry within the recharge catchment.

Levels of Chloride in the three bores are shown in Figure 29, which clearly shows higher levels in Te Waikoropupu Springs (AMA) than the others. This is due to the effect of sea water mixing with the freshwater recharge in the AMA.

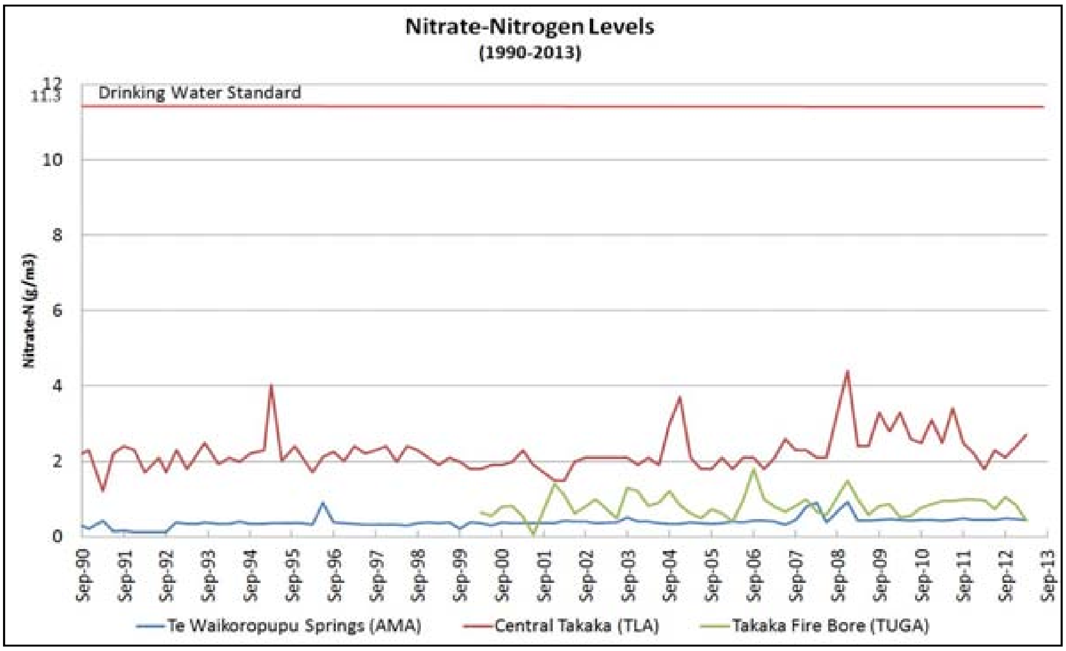


Figure 28: Nitrate-Nitrogen Levels in AMA, TLA and TUGA

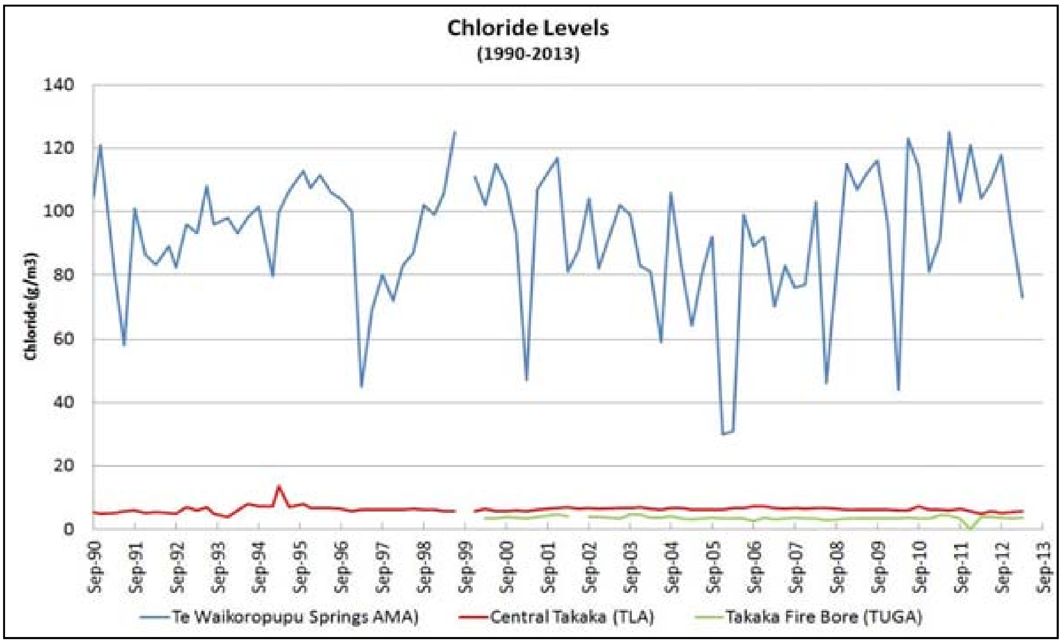


Figure 29: Chloride Levels in AMA, TLA and TUGA

Groundwater quality in the coastal deposits along Pohara and Patons Rock are variable. Generally the water has high iron content in these areas due to the overlying geology and local recharge.

Bacteria detected in groundwater (by Faecal and E Coli testing) indicate contamination from animal or human waste sources. Well/bore construction and security of the well/bore head is also important in alleviating potential bacterial contamination issues. Well constructed wells/bores with adequate separation distance from disposal systems are important in reducing bacterial contamination risk. Current bores in the AMA are deep and tap confined parts of the marble aquifer and do not show any bacterial contamination. Bacterial quality in the TLA can be variable and this is because some of the bores are close to recharge sources through the broken Limestone geology e.g. Motupipi. In the TGUA well constructed bores, tapping the deeper gravel layers are more secure from bacterial contamination then shallow wells or poorly constructed wells. In the case of the coastal deposits, due to the shallow nature of the wells and due to nearby wastewater disposal systems bacterial contamination has been detected e.g. Patons Rock.

7. Current Water Allocation Takaka Water Management Area (TWMA)

Figure 30 shows the location of water related consents in the TWMA as of April 2013.

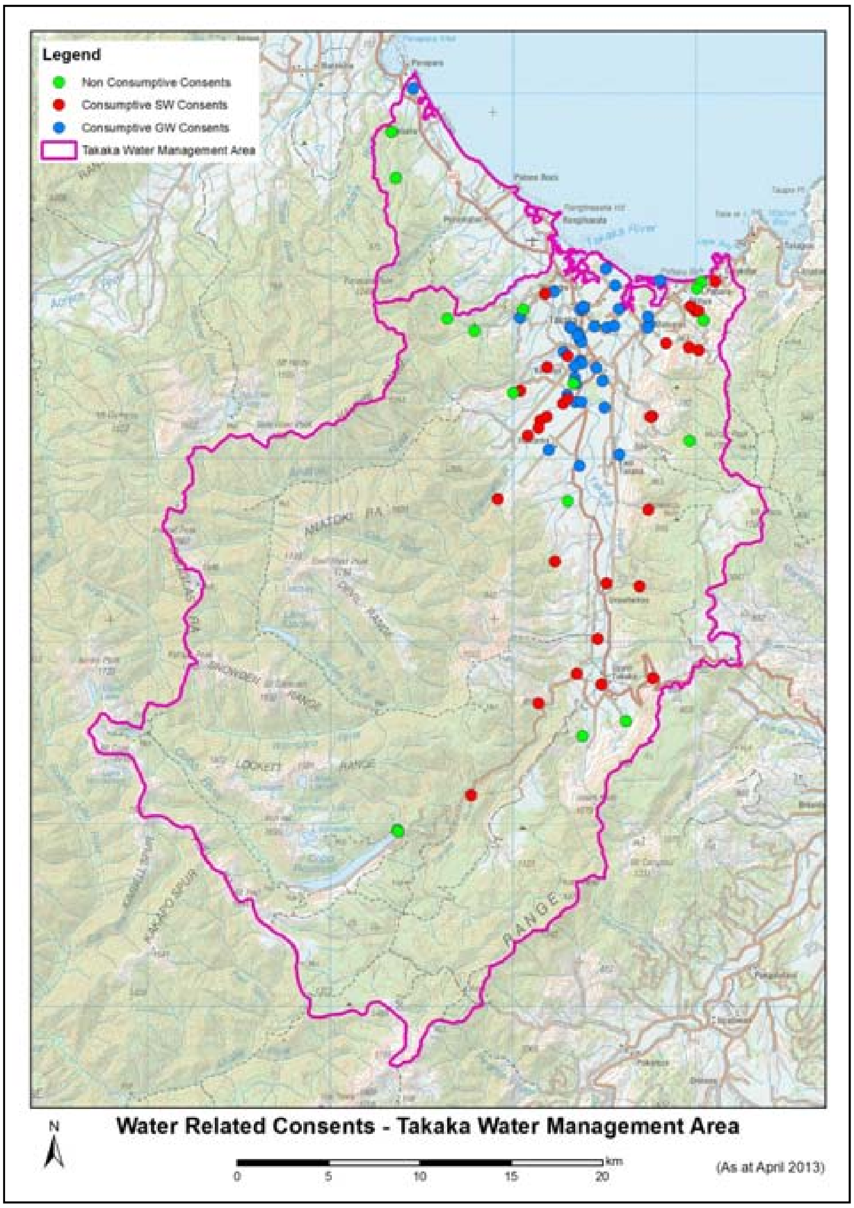


Figure 30: Water Related Consents - Takaka Water Management Area

Current water allocation in the TWMA has been based on generic default allocation policies specified in the Tasman Resource Management Plan (TRMP) for rivers. These policies provide for summer allocations (November to April inclusive) of either 10% or 33% of the 1:5 year low flow (7 day low flow), depending on significance of specified uses and values in Schedule 30A of the TRMP. Decisions on applications are guided by this policy and matters for discretion.

In terms of groundwater allocation, Council has administered the interim allocation of 500 l/s set by the Nelson Marlborough Regional Council in 1991 for the recharge zone of Te Waikoropupu Springs. This zone then was taken as the zone from which recharge to Te Waikoropupu Springs system originates from. Applications for water from other parts of the aquifer system have been based on aquifer testing, extraction drawdown and localised recharge effects.

As of April 2013 there were 80 consumptive water permits with a total allocation 1142 l/s. Of the 80 permits 40 permits were surface water permits with an allocation of 694 l/s, and 40 were groundwater permits with a total allocation of 448 l/s. Various breakdowns of the consumptive water permits are provided in Tables 9 to 12 by source, recharge zone, aquifers and main rivers.

Source	**Number of Permits**	**Total Allocated (l/s)**
Surface Water	40	694
Groundwater	40	448
Total	**80**	**1142**

Table 9: Total Allocated Consumptive Water Takes (as at April 2013)

Source	**Number of Permits**	**Total Allocated (l/s)**
Groundwater	3	41.0
Takaka River	3	239.4
Waingaro River	4	105.4
Other rivers	13	114.2
Total	**23**	**500.0**

Table 10: Recharge Zone - Allocated Consumptive Water Takes (as at April 2013)

Source	**Number of Permits**	**Total Allocated (l/s)**
Takaka Limestone Aquifer	6	50.3
Takaka Valley Unconfined Gravel Aquifer	30	359.7
Arthur Marble Aquifer	2	34.5
Takaka Misc (Takaka North & Coastal)	2	3.3
Total	**40**	**447.8**

Table 11: Aquifers - Allocated Consumptive Water Takes (as at April 2013)

River	**Number of Permits**	**Total Allocated (l/s)**
Anatoki	2	74.7
Takaka	3	239.4
Waingaro	6	221.1
Total	**11**	**535.2**

Table 12: Surface Water Consumptive Takes from Major Rivers (as at April 2013)

8. Water Allocation Management Zones

Currently there are no water allocation zones defined in the Council's TRMP for the Takaka Water Management Area. Based on the current knowledge of the water resources and geology, a water allocation zone map has been developed and is shown in Figure 31. Further refinement to these allocation zones, including water quality management need to be considered as development of the Takaka Water Management Plan progresses.

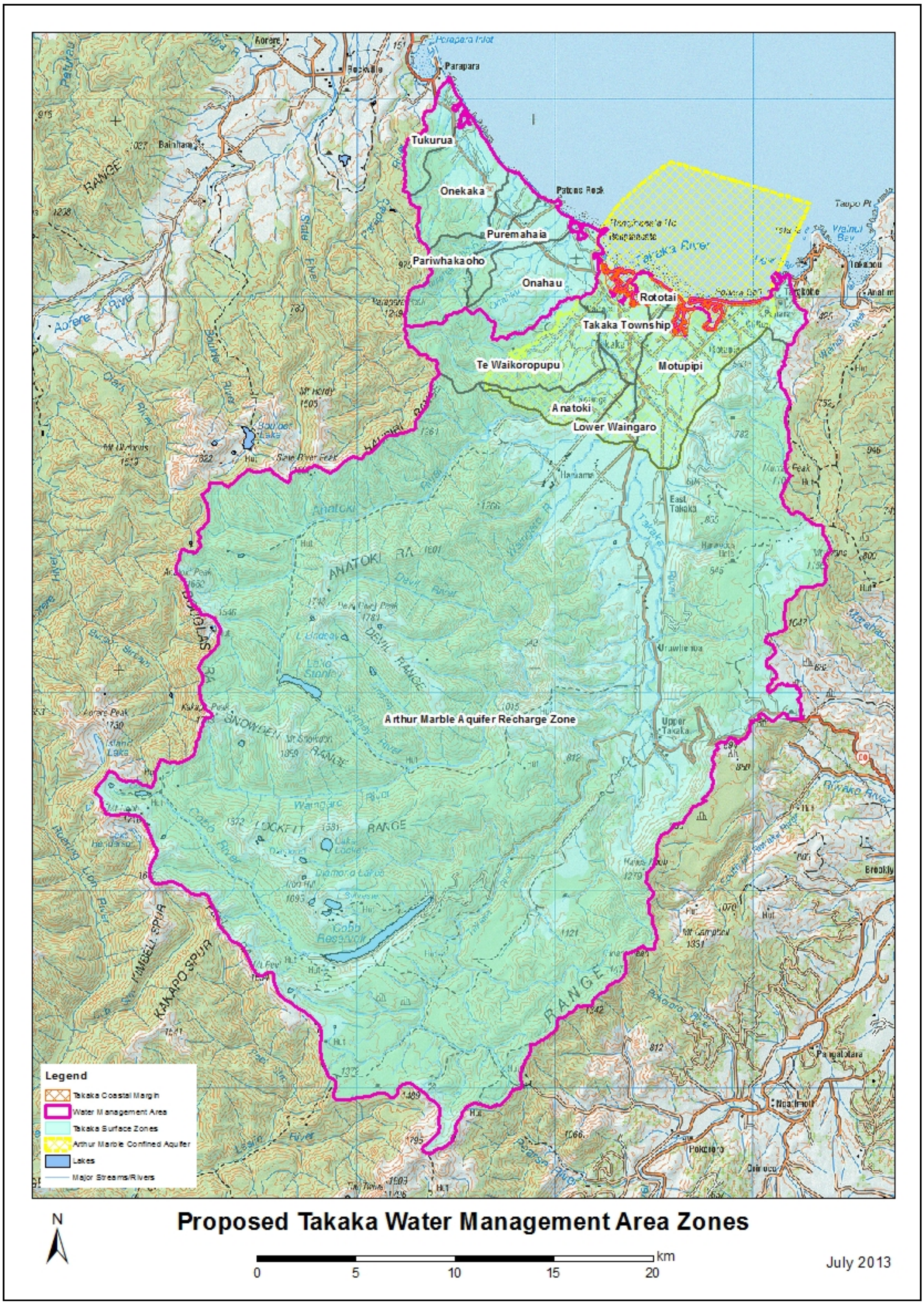


Figure 31: Proposed Takaka Water Management Area Zones

9. References

Edger, J.E. 1998: Hydrogeology of the Takaka Valley. Unpublished MSc thesis, University of Canterbury, Christchurch, New Zealand.

Mueller, M. 1987: Takaka Valley Hydrogeology (Preliminary Assessment) - Unpublished Report Prepared for the Nelson Catchment and Regional Water Board, Nelson, New Zealand, 70 pp.

Mueller, M. 1991: Karst hydrogeology of the Takaka valley, Golden bay, northwest Nelson. New Zealand Journal of Geology and Geophysics, 1991, Vol 34: 11-16.

Mueller, M. 1992: Geohydrology of the Takaka Valley. Unpublished Report Prepared for the Nelson-Marlborough Regional Council, Nelson, New Zealand, 32 pp.

Richards, D.T.W. 2003: Geomorphological and environmental studies of karst, northwest Nelson, New Zealand. Unpublished MSc thesis, University of Canterbury, Christchurch, New Zealand.

Roger, Y. et. al. 2001: Cobb Power Scheme - Takaka River Drying. Unpublished Report prepared for Natural Gas Corporation by Cawthron Institute in relation to renewal of consents in relation to the Cobb Power Scheme in Takaka 39 pp

Stewart, M.K., Thomas, J.T. 2008: A conceptual model of flow to the Waikoropupu Springs, NW Nelson, New Zealand, based on hydrometric and tracer (^{18}O, Cl, ^{2}H and CFC) evidence. Hydrology and Earth System Sciences 12, 1-19, 2008.

Thomas J.T. : In Groundwaters of New Zealand, Rosen M.R. and White P.A. (eds), New Zealand Hydrological Society Inc., Wellington, pp 411 - 425.

Waugh J. R. et al. 2000: Takaka Catchment River Flows 1945-1999. Unpublished Report prepared for TransAlta by Opus International Consultants in relation to renewal of consents in relation to the Cobb Power Scheme in Takaka 77 pp

White P.A. et al. 2001: Hydrogeology of the Takaka River Catchment and assessment of the effects of Cobb Power Station operation on groundwater in the catchment. Unpublished Report prepared for TransAlta by the Institute of Geological and Nuclear Sciences in relation to renewal of consents in relation to the Cobb Power Scheme in Takaka

10. Acknowledgements

Trevor James contributed the section on Surface Water Quality and Ecology.

The Environmental Monitoring team at Tasman District Council, who over the years have helped with the collection of a significant amount of hydrological data.

Pete Frew for drafting of figures and maps.

11. Appendices

Recorder Site	Mean	Median	1 day low flow (l/s)				Analysis Period
			MALF	5 yr	10 yr	20 yr	
Waingaro at Hanging Rock	17841	10055	3373	2934	2785	2675	1986 - 2013

Gauging Site	Mean	Median	1 day low flow (l/s)				Correlated With
			MALF	5 yr	10 yr	20 yr	
Waingaro at u-s Takaka Confl	N/A	N/A	2490	1971	1795	1665	Waingaro at Hanging Rock

Appendix 1: One Day Flow Statistics for the Waingaro River

Correlated Site	Mean	Median	1 day low flow (l/s)			
			MALF	5 yr	10 yr	20 yr
Waikoropupu at u-s Takaka Confl	14630	14030	8276	6782	6273	5900

Appendix 2: One Day Flow Statistics for the Waikoropupu River

Recorder Site	Mean	Median	1 day low flow (l/s)				Analysis Period
			MALF	5 yr	10 yr	20 yr	
Anatoki at Happy Sams	12315	6027	2005	1710	1585	1488	1987 - 2013

Gauging Site	Mean	Median	1 day low flow (l/s)				Correlated With
			MALF	5 yr	10 yr	20 yr	
Anatoki at One Spec Road	N/A	N/A	1550	1213	1070	959	Anatoki at Happy Sams

Appendix 3: One Day Flow Statistics for the Anatoki River

Recorder Site	Mean	Median	7 day low flow (l/s)				Analysis Period
			MALF	5 yr	10 yr	20 yr	
Takaka at Harwoods	14333	9970	2380	1646	1397	1213	1976 -2013
Takaka at Kotinga	31351	15038	3347	2626	2352	2147	1986 - 2012

Gauging Site	Mean	Median	7 day low flow (l/s)				Correlated With
			MALF	5 yr	10 yr	20 yr	
Takaka at Pages Cut	N/A	N/A	3986	3263	2989	2784	Takaka at Kotinga
Takaka at Paynes Ford	N/A	N/A	266	196	169	149	Takaka at Kotinga

Flows from Harwoods recorder site and Paynes Ford gauging site are highly influenced by the Cobb Dam and releases from there. The recorder site at Kotinga and gauging site at Pages Cut are less influenced by the Cobb Dam as at lower flows this influence is masked by the Waingaro and Anatoki rivers.

Appendix 4: Seven Day Flow Statistics for the Takaka River

Recorder Site	Mean	Median	1 day low flow (l/s)				Analysis Period
			MALF	5 yr	10 yr	20 yr	
Fish Creek Spring	3476	3546	499	62	-	-	1985-2013
GW 6013 Te Waikoropupu Spring	9890	9940	7508	6492	6147	5893	1999-2013

Appendix 5: One Day Groundwater Flow Statistics