Tasman District Council

State of the Environment Report

Groundwater Quality in the MOTUPIPI RIVER HEADWATERS

June 2008

GROUNDWATER QUALITY IN THE MOTUPIPI RIVER HEADWATERS

Document Status: Final Report

September 2008

The purpose of this report is to provide information about groundwater quality in the Motupipi catchment, particularly around the headwaters, and the likely influence of this water on the water quality of the upper Motupipi River.

Prepared By:	**Reviewed by:**
Glenn Stevens and Trevor James	Rob Smith

Cover Photos: Motupipi River upstream Watercress Creek near Fonterra's Takaka Dairy Factory.

Tasman District Council Report Ref: 07004

Tasman District Council
189 Queen Street
Private Bag 4
RICHMOND

Executive Summary

Water quality in the Motupipi River is characterised by concentrations of nutrients (N and P) and faecal bacteria that are regularly above national guidelines. The river also has prolific growth of aquatic plants, and in February, filamentous green algae, and low dissolved oxygen concentrations at times. Macro-invertebrate condition in the river also indicates poor water quality.

Much of the flow in the Motupipi River is derived from groundwater (which includes spring discharges). This investigation attempts to identify the characteristics of this surrounding groundwater and whether there exists a relationship between groundwater quality and the surface water quality of upper Motupipi River. To this end a number of groundwater sites were sampled on two occasions (February and June 2007).

Results of this investigation, and other water quality monitoring programmes, indicate two distinct groundwater types, one very similar to Takaka River water and the other with a geochemical signature (in particular, hardness) reflecting its origins in limestone geology. Groundwater comprising a mixture of these was also present in places. The highest nitrate concentrations were encountered in the karst dominated groundwater which in general, had higher nitrate concentrations than the river dominated groundwater.

Long term monitoring of nitrate concentrations in karst dominated groundwater near the Takaka Hospital (and Rameka Creek) show similar concentrations (~2 g/m^3-N) to the karst springs discharging to the Motupipi River. It is unlikely that this represents natural background concentrations given groundwater from the Takaka limestone in East Takaka (and outside of the Motupipi River catchment) show low nitrate concentrations (<1 g/m^3-N).

In general, faecal indicator concentrations are low in karst derived groundwater suggesting that the source of nutrients is unlikely to be of sewage or animal effluent origin. Some relatively high faecal bacteria concentrations were measured at some of the springs feeding the Motupipi headwaters. However at present it is not possible to completely exclude a surface source despite these spring sources being fenced to exclude stock for 150m upstream of the point where water regularly starts to flow.

There is much uncertainty about the specific groundwater flow paths within the karst aquifer, largely due to the more complex nature of the limestone hydrogeology. As a consequence, the ability to accurately identify the specific source catchments for the karst spring discharges is limited.

TABLE OF CONTENTS

Acknowledgements:
Tasman District Council wishes to thank the farmers of the Motupipi River catchment who have provided access for this investigation and to Fonterra for supplying data to supplement that collected by Tasman District Council.

1. INTRODUCTION

Tasman District Council undertakes regular monitoring of water quality in representative rivers and streams within the District as part of its State of the Environment river water quality monitoring programme. This has identified a level of degradation to the water quality in the lower reaches of the Motupipi River, primarily indicated by the presence of elevated concentrations of nutrients, fine sediment and disease-causing organisms. Macro-invertebrate condition in the river also indicates poor water quality.

The Motupipi River is spring fed resulting in very stable base flows. This, combined with elevated nutrient and fine sediment concentrations and the limited shading of the waterway, has led to prolific growth of aquatic plants. This in turn, has given rise to large dissolved oxygen fluxes down to as low as 35% saturation. There has also been widespread public concern for algal blooms in the lower Motupipi River.

A number of investigations have been initiated in the past two years to try to determine the causes of this condition and obtain better baseline information. The upper Motupipi River is known to be fed by groundwater discharging from alluvial gravels recharged by the Takaka River as well as from karst aquifers systems present in the Tertiary limestones. This investigation was undertaken to determine the contribution of the surrounding groundwater quality to surface water quality issues in the upper Motupipi River. The concentration of various nutrients and indicator bacteria was measured at various locations in the Motupipi headwaters.

A number of potential causes of elevated nutrient concentration exist in the Motupipi catchment:

1. Sewage from failing septic tanks or sewerage networks
2. Farm effluent discharges
3. Silage pit leachate, fertiliser or other farm practice
4. Historic wastewater discharges from the Takaka dairy factory
5. Historic dumping of waste onto or into karst (limestone) areas
6. Possible natural weathering of karst or mudstone rock in the catchments recharging groundwaters

Faecal contamination could arise from potential causes 2,3 or 6.

2. SITE DESCRIPTION

The Motupipi River headwaters are located immediately to the west and southwest of the Takaka township (see Figure 2)

Figure 1: The spring sources of the Motupipi River.__**Fig 1a** Watercress Ck u-s dairy factory **Fig 1b** Watercress Ck Spring source, **Fig 1c** Motupipi Rv u-s Watercress Ck, **Fig 1d** Motupipi trib 10m u-s Factory Farm Br, **Fig 1e** Motupipi trib 310m d-s Factory Farm Br (near Motupipi confluence), **Fig 1f** Motupipi trib 310m d-s Factory Farm Br source (170m upstream Fig 1e)

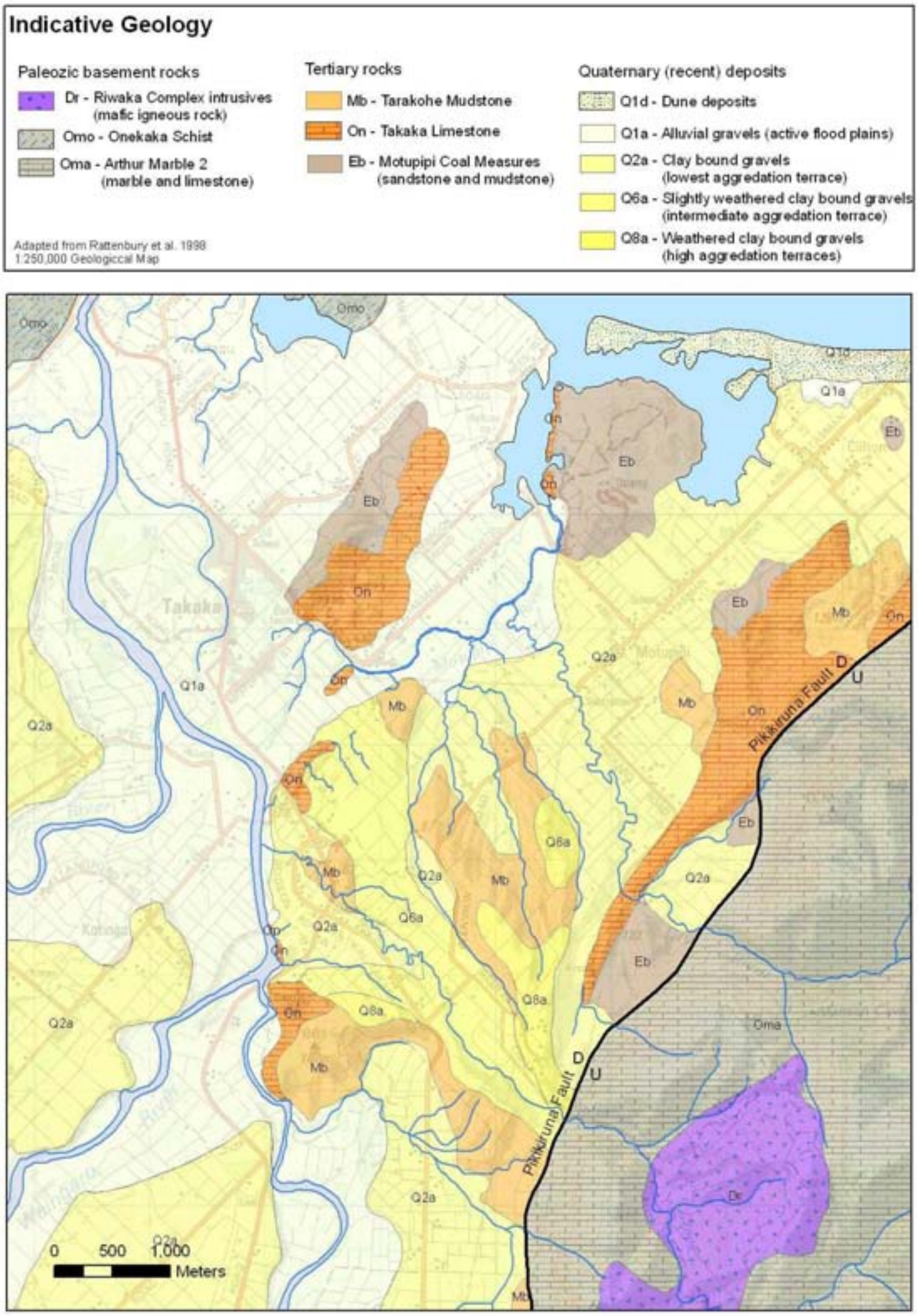

Figure 2: Indicative geology of the Motupipi River headwaters area.

2.1 Geology

Figure 2 shows the generalised geology of the Motupipi River headwaters area. It is adapted from the 1:250,000 scale geological map (Rattenbury *et al*. 1998) and the boundaries of the rock units are approximate only.

At depth across much of the headwaters catchment is Arthur Marble, which only outcrops to the southeast beyond the Pikikirunga Fault in the steep hill-country of the catchment. Whilst this formation contains the extensive Waikorupupu Arthur Marble aquifer system (which includes Waikorupupu Springs) it is largely separated from the surface strata by the overlying impermeable Motupipi Coal Measures (course sandstone and carbonaceous shale with thin coal seams) (Grindley 1971, Mueller 1991, Edgar 1998, Thomas 2001).

Overlying the Motupipi Coal Measures is the Takaka Limestone. This is the grey flaggy (“layered”) limestone seen as the bluffs at Paynes Ford, The Labyrinth and surrounding Port Tarakoe, for example. However, over much of the headwaters catchment this limestone is present at shallow depths though outcropping in places. The Takaka Limestone has been folded, forming the Motupipi syncline, with the fold axis trending in a general northeast/southwest direction (Mueller 1991).

In the southeast part of the Motupipi headwaters catchment the limestone is observed outcropping at the surface and, in places, is overlain by the impermeable Tarakohe Mudstone. These strata extend to the east where they are bounded by the Pikikirunga Fault and Arthur Marble of the Pikikirunga range beyond.

In the northwest part of the Motupipi headwaters catchment (i.e. the Takaka township area), which includes the zone where several springs discharge, the surface strata comprises alluvial gravels largely overly the impermeable Tarakohe Mudstone, which in turn overlies the Takaka Limestone. Edgar (1998) notes that there may be areas on the periphery (for example at Motupipi) where mudstone is thin or not present such that the gravels are hydraulically connected to the limestone. These gravels extend to the quaternary terrace scarp southeast of the Moutpipi River. Limited bore log data indicate a thickness for the gravels to the southeast of the Motupipi headwaters of less than 10 m. Whereas to the northwest (i.e. the vicinity of the Takaka township) several bores have been sunk to at least 20 metres and are still within the gravels (WWD6535, 30 m; WWD6339, 20 m; and WWD6355, 21 m).

2.2 Hydrogeology

The Motupipi River has a significant proportion of its flow is derived from discharging groundwater. Three principal groundwater bearing formations (aquifers) have previously been described in the Motupipi headwaters area by Edgar (1998), Thomas (2001) and White *et al*. (2001). These are:

- Central Takaka Motupipi sub-aquifer (CTM)[1],
- Takaka Township Gravel aquifer (TTG)
- Waikoropupu Arthur Marble aquifer (WAM).

Of these aquifer systems in the headwaters area, the CTM sub-aquifer is present in the southeast and TTG aquifer to the northwest where the alluvial gravels are present. Both aquifer systems discharge to the Motupipi River headwaters.

The WAM aquifer is only located at depth in the vicinity of the Motupipi headwaters. Nevertheless, it is postulated by some (Edgar 1998) to possibly discharge to the CTM sub-aquifer via inter-aquifer leakage, potentially via the Pikikiruna Fault and East Takaka Fault systems and/or where the Motupipi Coal Measures are thin or absent. However, it is considered that even should such a connection be present, other sources of recharge to the CTM sub-aquifer will dominate.

Therefore hydrogeologically, the Motupipi headwaters area can be considered to comprise of two distinct components. To the northwest are the recent alluvial gravels and its aquifer system. The main stem of the Motupipi River headwaters and Watercress Creek are located within these gravels. To the southeast is the Takaka Limestone and the karst aquifer it supports. The boundary between these differing aquifer systems is not well understood, but is located in the Motupipi catchment and likely to be dynamic (i.e. vary depending on the prevailing groundwater levels in the two aquifer systems). Both aquifer systems interact and contribute to surface flows in the Moutpipi River resulting in a relatively complex hydrological system.

2.3 Aquifer Recharge and Discharge

Edgar (1998), Mueller (1991) and White *et al*. (2001) list the following recharge sources and discharges from the CTM sub-aquifer and TTG aquifer.

Central Takaka Motupipi Sub-aquifer

Recharge

- Incident rainfall on outcropping limestone
- Infiltration of rainfall along the eastern boundary of the CTM sub-aquifer via the Pikikiruna Fault
- Runoff lost to groundwater via stream sinks (such as in Dry River and Rameka Creek.
- Leakage from the Takaka River (particularly where outcropping Takaka Limestone intersects the Takaka River immediately downstream of the confluence of the Anatoki and Takaka rivers.
- Possible upwards leakage from the underlying WAM aquifer.

Discharge

[1] Naming of aquifers follows that used in White *et al*. (2001).

- Various springs
- Discharge to the TTG aquifer (between Bridger's Hollow and the factory farm bridge).
- Possibly other springs/vents (including submarine) to the northeast, however, such discharges will not influence the Motupipi headwaters area.

The precise location of the recharge areas for the karst aquifer is poorly understood. It is likely that recharge is uneven (i.e. greater in some places and not at all in others). The potential catchment of the karst aquifer (i.e. the surface expression of the recharge area) for the Motupipi headwaters area extends to the Pikikirunga ranges and probably includes Rameka Creek and possibly Dry Creek. However, surface flows from the upper catchments of these two creeks are first captured to the WAM aquifer where it flows underground into outcropping Arthur Marble east of the Pikikiruna Fault. Surface flows are only able to reach the Takaka Limestone west of the Pikikiruna Fault further down the catchment during periods of prolonged and/or intense rainfalls resulting in sufficient flow to make it past the marble.

Takaka Township Gravel Aquifer

Recharge

- Leakage from the Takaka River
- Incident rainfall
- Flow loss from the Motupipi River (upstream of Watercress Creek). This will only occur during periods of high groundwater levels in karst aquifer.

Anecdotal evidence points to a lowering of the Takaka River bed level over recent decades from the TTG aquifer. The associated lowering of river levels is anticipated to have some affect on recharge rates (lowering), however, this has not been quantified.

Discharge

- Springs (such as Watercress Creek) and diffuse discharge to the channel of the Motupipi headwaters.

Discharges from the TTG aquifer also occur outside of the Motupipi catchment, namely:

- the lower reaches of the Takaka River below the confluence of the Anatoki and Takaka rivers,
- to the Te Kakau Stream
- to Golden Bay.

3. SAMPLING METHODOLOGY

Samples were collected from groundwater (3 sites), spring discharges (4 sites) and surface water flows (3 sites) in February and June 2007. Figure 4 shows the locations of these sites.

The groundwater samples from bores WWD6317 and WWD6321.1 were collected via a motorised surface pump. These bores were purged of a volume of water at least three times the casing volume immediately prior to sampling. The sample from WWD6324, which is a continuously used farm supply bore, was collected from the existing reticulation after running a tap for 10 minutes to flush any standing water within the pipe work.

All samples were analysed for: nutrients, bacteriological contamination and major anions and cations. The appended laboratory results detail the complete list of parameters. The results of the two sampling rounds are attached as Appendix I.

Additional data is available for WWD6601 and WWD6342 which have been part of Council's quarterly groundwater quality monitoring programme since 1990 and 2000 respectively. Summary data for nitrate-nitrogen and hardness for these two quarterly monitored sites are included in Appendix II.

Council also has various miscellaneous groundwater quality data collected previously. Primarily these comprise of nitrate data but a significant number also include hardness. This data is included in Appendix III.

Data was analysed and compared with relevant water quality guidelines (see Table 1).

Table 1: Guideline water quality values for protection of river ecosystem and human health.

Parameter	Guideline value	Reference
Nitrate-N in drinking water	<11.3 g/m^3-N	Ministry of Health (2005)
Nitrate-N toxicity in natural waters	<7.2 g/m^3-N for 95% level of protection	Hickey, C. (Recalculated from ANZECC & ARMCANZ(2000))
Nitrate-N periphyton growth in natural waters	<0.444 g/m^3-N	ANZECC & ARMCANZ(2000)
Dissolved reactive phosphorus	<0.01 g/m^3-N	ANZECC & ARMCANZ(2000)

4. WATER QUALITY RESULTS AND DISCUSSION

4.1 Source Characterisation

The particular geology that groundwater comes into contact with and the length of time it remains in contact will influence the chemistry of that groundwater. As previously noted there are two principal hydrogeological environments influencing in the headwaters (namely the gravel aquifer to the west and the karst aquifer to the east).

The different water chemistry, and hence different source waters, present in the Motupipi headwaters can be can be shown graphically with Stiff Diagrams (Figure 3). When plotted this way, water of a similar chemical composition will have a similar shape. Two distinct groundwater geochemical groups have been identified (with a third being a mixture of these two). These are:

- Sites dominated from recharge from the Takaka River via the fluvial aquifers (TTG aquifer)
- Sites dominated by the karst aquifer
- Sites that show a mixture of these two geochemistries

The locations of the sampling points for these Stiff diagrams are shown in Figure 4.

When compared to the sites dominated by alluvial gravels recharged primarily from the Takaka River, the groundwater from the karst aquifers (i.e. the Takaka Limestone) typically have higher calcium, magnesium and bicarbonate/carbonate concentrations, which is reflected in the elevated hardness of the groundwater. Typically groundwaters from the alluvial aquifers have hardness values in the range of 40 to 60 g/m^3 (as $CaCO_3$). In contrast, groundwaters in the karst aquifers are typically in the range of 80 to 150 g/m^3 (as $CaCO_3$).

All the available groundwater hardness data held by Council for the Motupipi catchment is presented in Figure 5. This correlates well with the known extent of the limestone. Also shown in Figures 3 and 5 are Waikorupupu Springs and two bores in East Takaka that penetrate down to the underlying Takaka Limestone for comparison.

Whilst two distinct areas of groundwater can be identified relatively easily, the boundary between the two is less distinct. In part, this is a result of the limited distribution of sampling sites. Also the boundary will comprise of a mixing zone that moves to an extent over time reflecting the relative recharge rates (and hence groundwater levels) of the respective aquifer systems. Likewise the relative contribution of these sources is uncertain, however, the portion derived from the karst aquifers has been estimated to be about 60% (J Thomas, *pers comm.*).

Bores WWD6324 and WWD6317 are located close to where the boundary between the two groundwater types would be expected to lie in the headwaters area. WWD6324 is the Windle farm supply bore and is located approximately

750 m south of the main channel of the Motupipi River. Groundwater from this bore is characteristic of a mixed source from both the alluvial and karst aquifers. The July 2007 sampling demonstrates the expected variability where a greater component of karst sourced groundwater was present than when sampled in February 2007. This difference can be clearly seen in Figure 3.

WWD6317 is located a further 180 m to the southeast of WWD6324 and located adjacent to outcropping limestone and within a shallow depression with internal drainage. The sampled groundwater was characteristic of a predominantly karst groundwater source. This would infer that at the time of sampling the boundary between the two groundwater sources is located close to, but northwest of, WWD6324. The mixed karst source water signature of the Motupipi tributary that enters at the Factory Farm bridge and limestone outcrops to the northeast help delineate the boundary's location further.

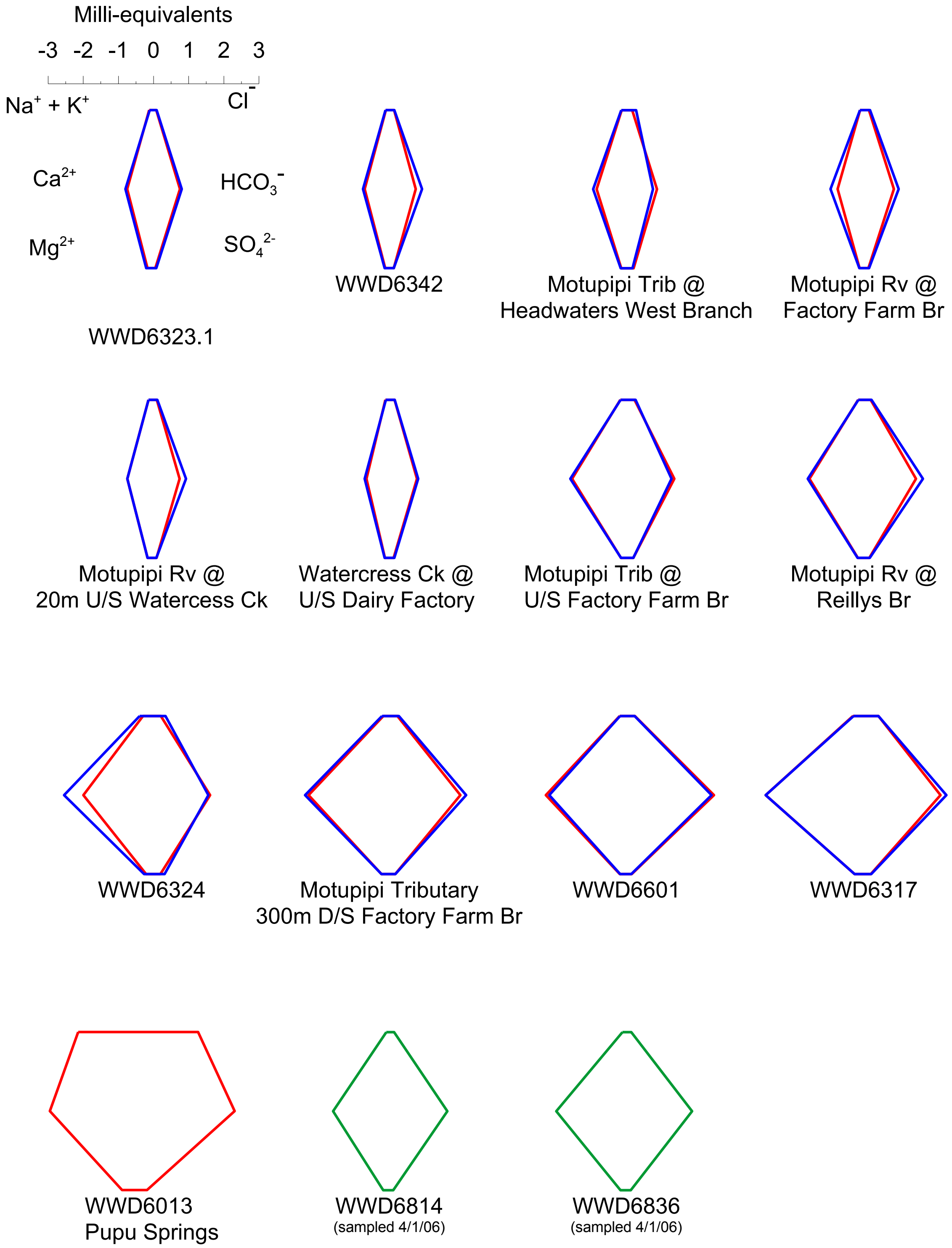

Figure 3: Stiff Diagrams for sampled sites in the Motupipi headwaters catchment (red Feb 2007, blue July 2007). Also included are two East Takaka bores (WWD6841 and WWD 6342) which draw from the underlying limestone geology and Waikorupupu Springs.

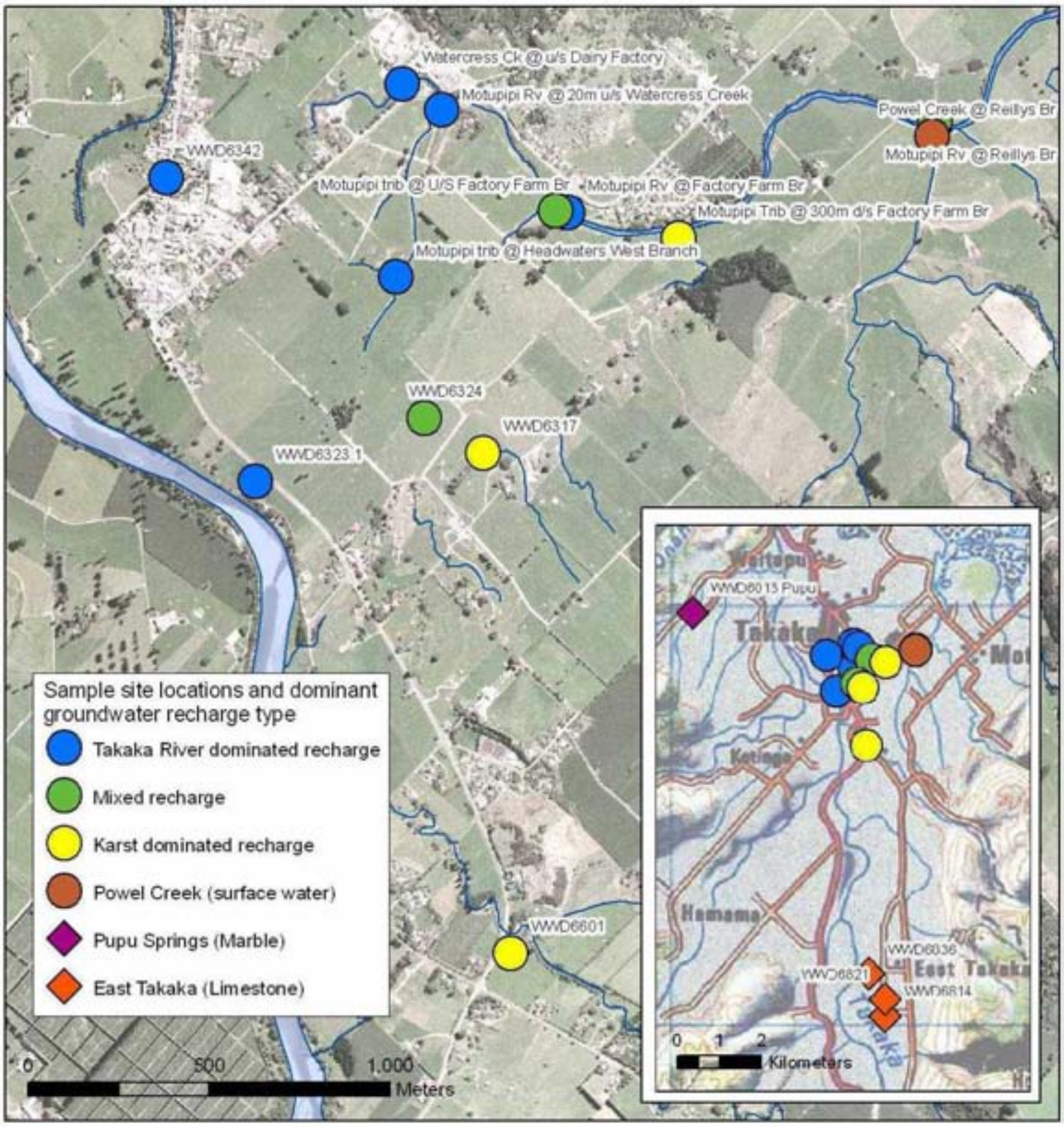

Figure 4: Sites sampled during February and July 2007 showing the dominant groundwater type present. The locations of some additional sites of interest are shown in the inset.

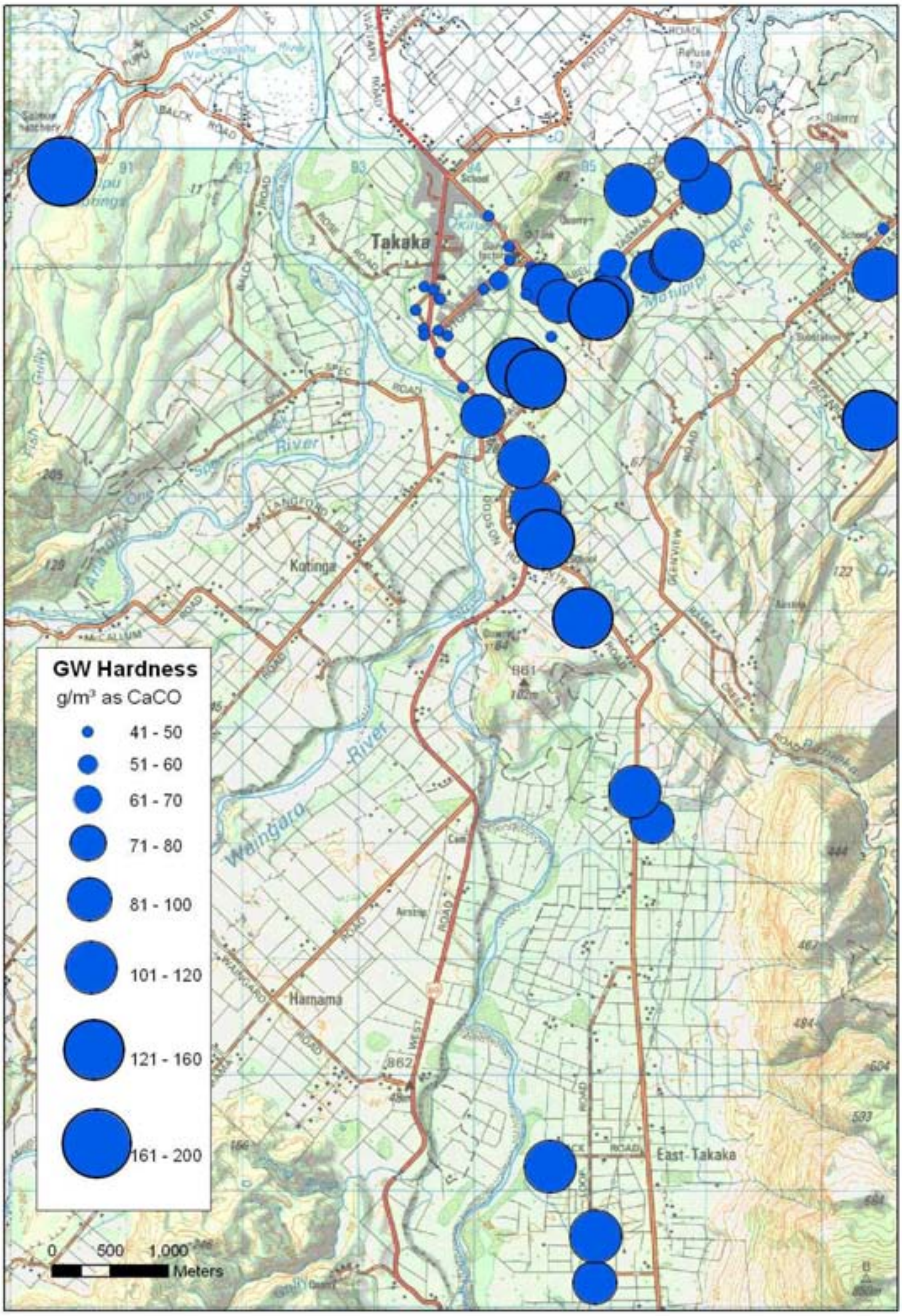

Figure 5: Groundwater hardness in the wider Motupipi catchment (g/m^3 as $CaCO_3$)

4.2 Nutrients

4.2.1 Nitrate

The distribution of nitrate concentrations within the groundwater collected specifically for this investigation during February and July 2007 is shown in Figure 6. Groundwater sites are shown as lighter coloured symbols and surface water sites as darker symbols. Sites that represent spring discharges are shown as groundwater sites. The size of the symbols reflects the nitrate and phosphorus concentrations (refer to map legend for scale). It is important to note that the site at Motupipi River @ Factory Farm Bridge is upstream of the Motupipi trib @ u-s Factory Farm Br and that the first sample point for these combined waters is down at Reilly's Bridge. However, the Reilly's Bridge site will also be substantially influenced by the tributary that comes in 300m d-s Factory Farm Bridge. Figure 8 is similar to Figure 6, but also includes additional nitrate data Council has collected previously.

All of the inputs and the main stem of the Motupipi at the head of the catchment generally had low (0.4 to 1.5 g/m^3-N) nitrate concentrations. The exception being the July 2007 sample from the town tributary which was sampled following some rainfall the previous day and surface runoff from the township area is likely to have contributed to the elevated concentrations of 4.3 g/m^3-N (as opposed to reflecting only the underlying groundwater).

Generally, higher nutrient concentrations were encountered in the remaining samples, with variable nitrate concentrations ranging up to 10 g/m^3-N and a median value of 2.7 g/m^3-N. These samples all had groundwater hardness' that reflect varying components of a karst source. Figure 9 shows nitrate concentrations plotted against hardness for all available groundwater data in the wider headwaters catchment.

There are two sites from within the Motupipi catchment (WWD6323.3 and WWD6615) with hardness values suggesting a karst groundwater source that had nitrate concentrations less than 1 g/m^3-N. Both of these are single samples and were collected in 1996. WWD6323.3 is a shallow monitoring bore located where it is more likely to reflect groundwater from the Takaka Township Gravel aquifer. In other words, the nitrate concentration is consistent with other nearby data but its hardness is higher than would be expected. WWD6615 is located in Takaka Limestone and its nitrate concentration is low compared to other nearby and more recent data.

The identified karst sources to the Motupipi River that were sampled, namely the spring fed tributaries at the factory farm bridge and 300 m downstream of the factory farm bridge, had nitrate concentrations of 2.1 to 4.0 g/m^3-N. These values are well above levels required to control undesirable algal growth (see Table 1).

The highest nitrate concentrations were encountered at WWD6317 and WWD6324 (7.5 and 9.8 g/m^3-N respectively), above ANZECC toxicity guidelines for 95% level of protection (see Table 1). WWD6317 is located within a low lying area of outcropping limestone (karst) which appears to have internal drainage. WWD6324 located slightly to further to the west.

There would appear to be some correlation between the groundwater source and nitrate concentration. All of the sampled groundwaters that are predominantly derived from the Takaka Township Gravel aquifer (and hence recharged primarily via leakage from the Takaka River) had low nitrate-N concentrations (i.e. <1.5 g/m^3-N). This is also supported by other miscellaneous groundwater quality data held by Council (Appendix II). This includes WWD6342 which has been monitored on a quarterly basis since 2000. Surface water nitrate concentrations measured in the Takaka River (at Kotinga Bridge) are typically less than 0.5 g/m^3-N.

Winter nitrate concentrations were substantially higher than in summer. This is expected due to higher nutrient uptake by plants and higher plant growth rates in summer. In addition, infiltration of rainwater through the soil to the underlying groundwater is greater in winter, leading to higher rates of transport of soluble nitrogen species to groundwater and on to the river.

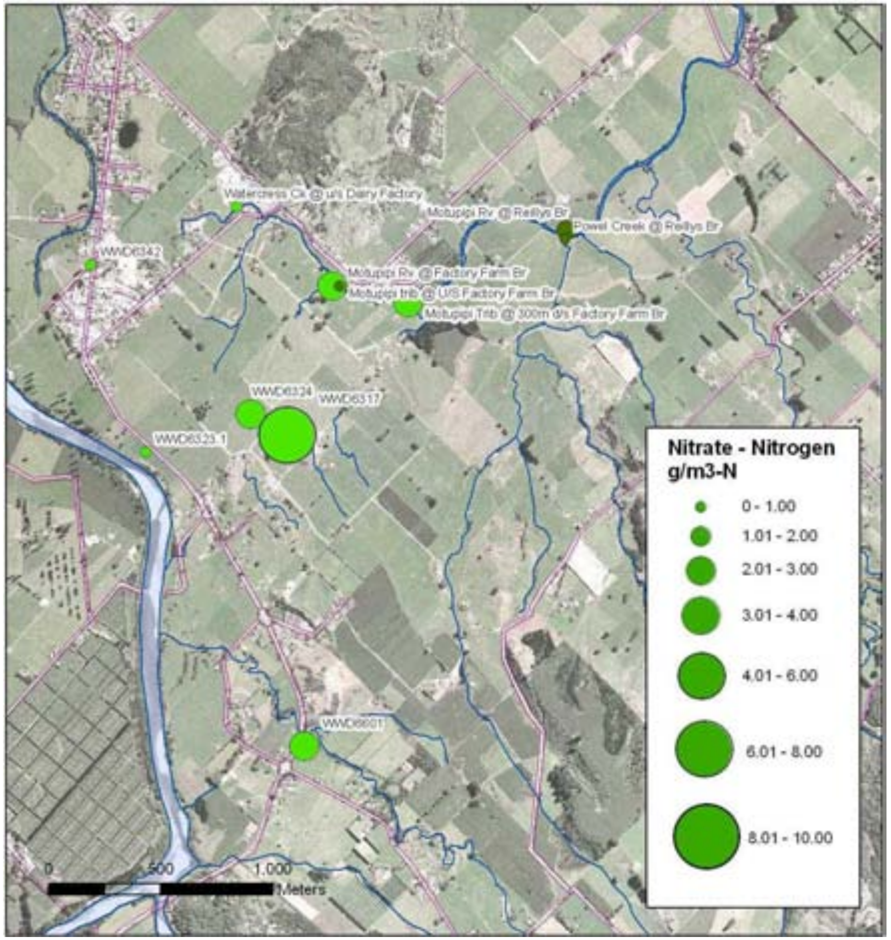

Figure 6a: Nitrate-nitrogen concentrations for sites sampled during February 2007 (surface water is shown as dark green).

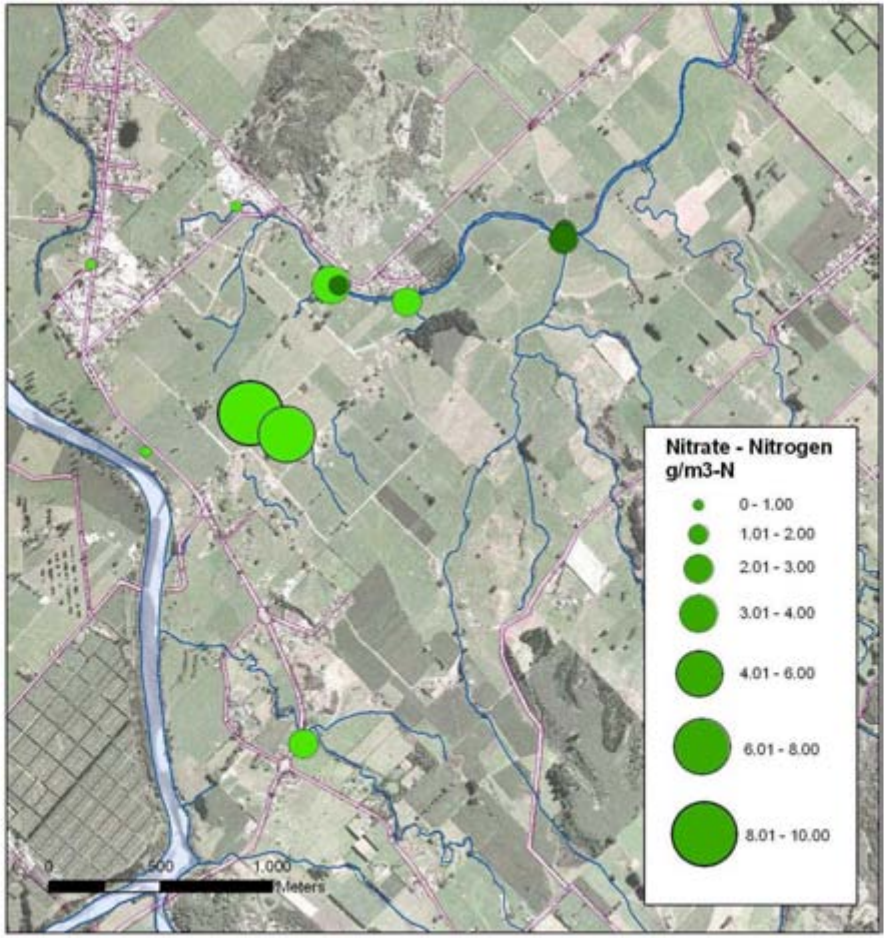

Figure 6b: Nitrate-nitrogen concentrations - July 2007.

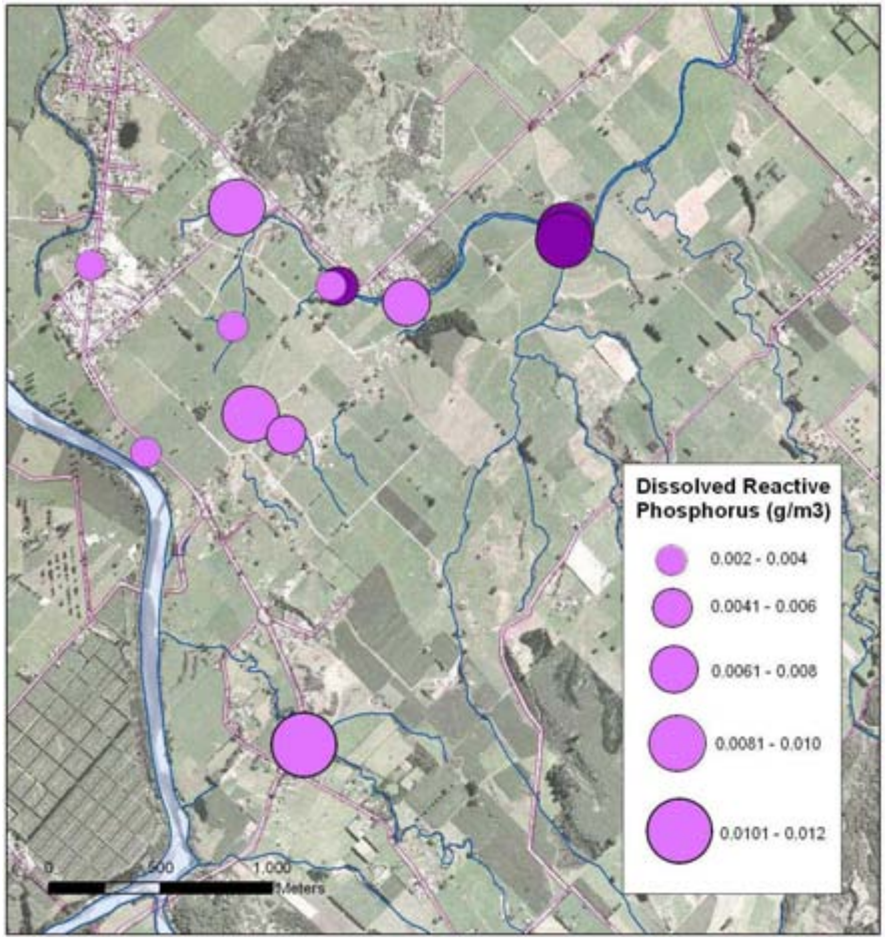

Figure 7a: Dissolved reactive phosphorus concentrations for sites sampled during February 2007 (surface water is shown as dark purple).

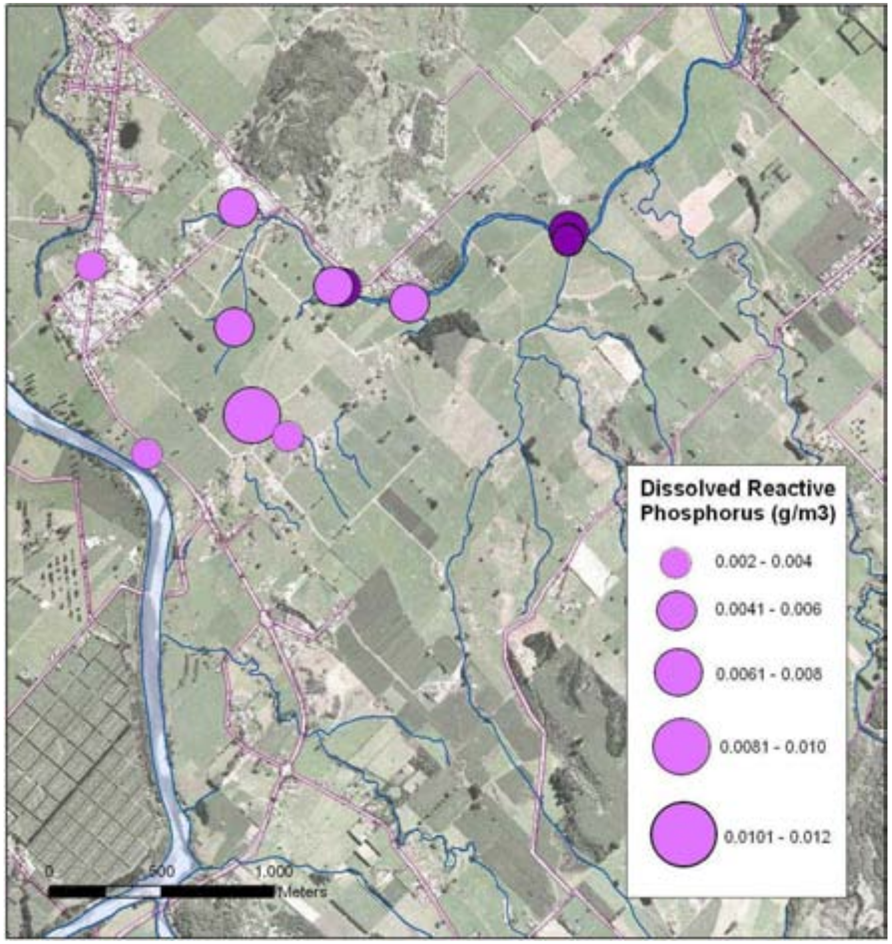

Figure 7b: Dissolved reactive phosphorus concentrations - July 2007

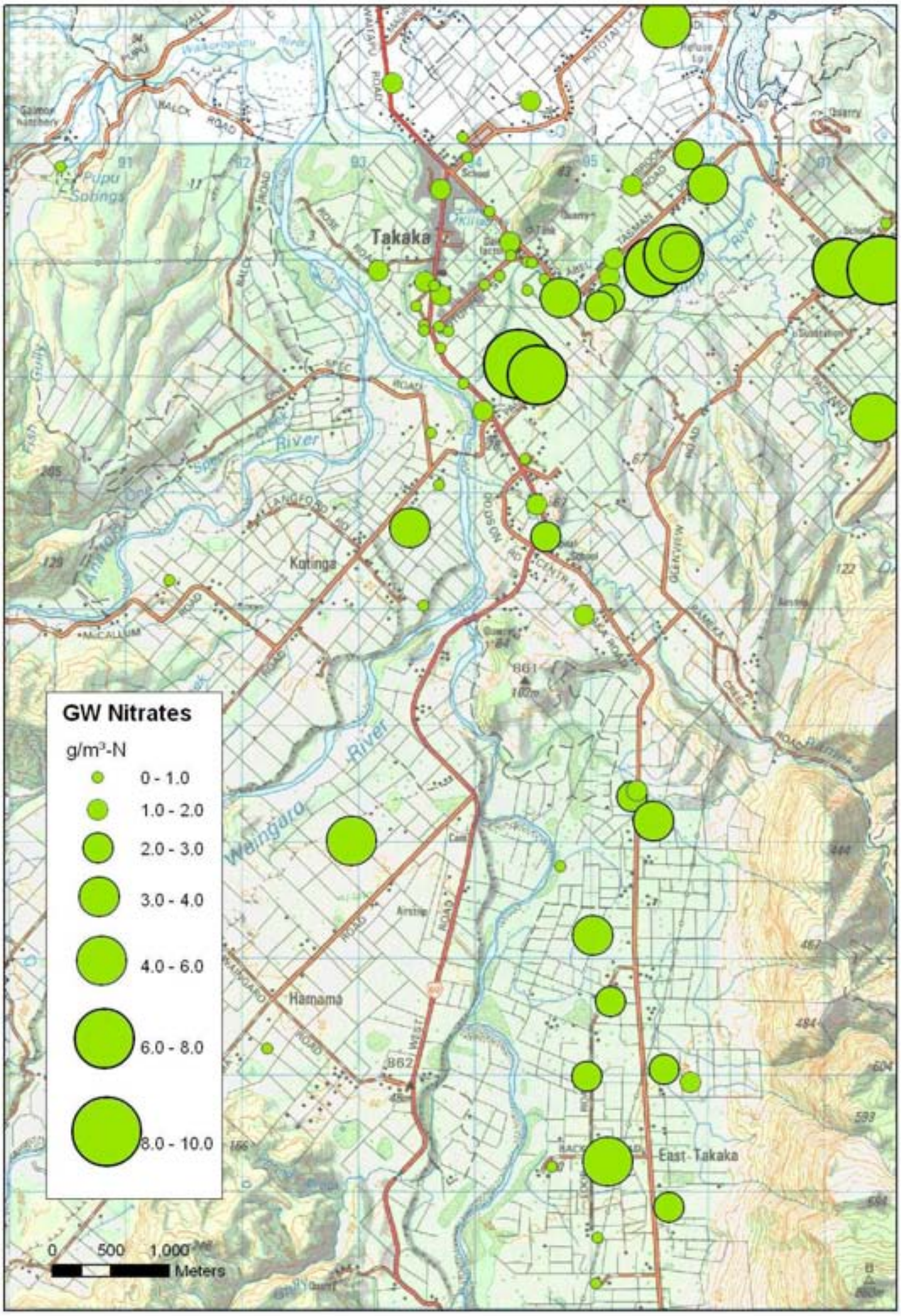

Figure 8: Nitrate-nitrogen concentrations for all available groundwater data (March 1986 to July 2007).

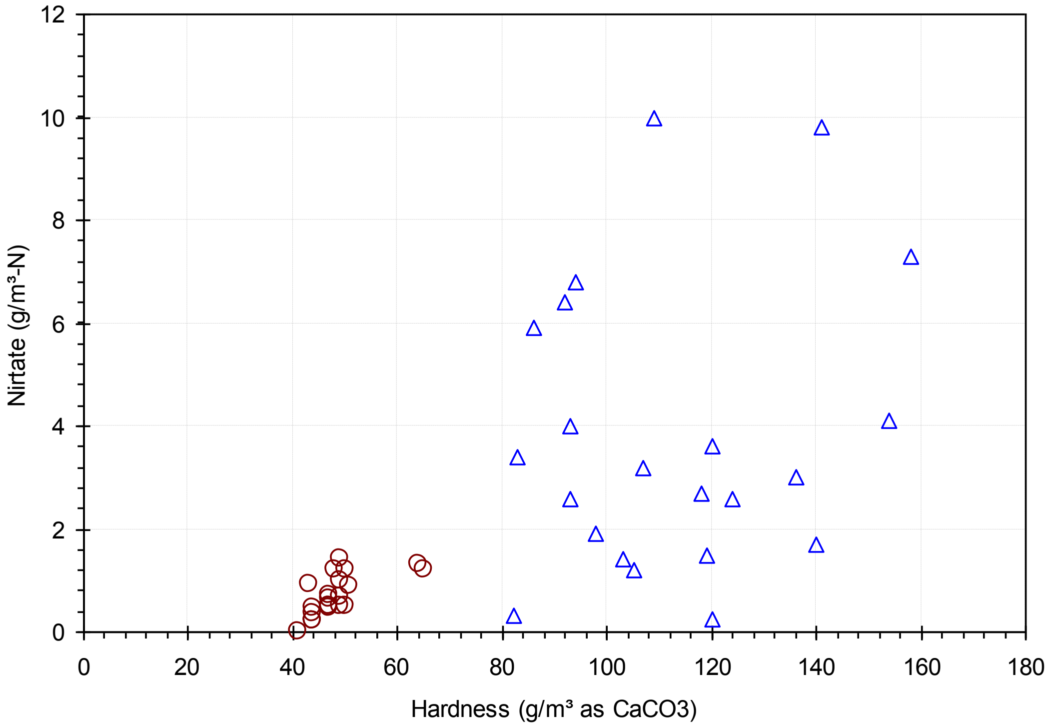

Figure 9: Nitrate concentrations and hardness in the wider Motupipi headwaters area. Brown circles indicate sites dominated by recharge from the Takaka River and the blue triangles are from karst dominated sites.

4.2.2 Phosphorus

Dissolved reactive phosphorus (DRP) concentrations were relatively low at all sites with guidelines (0.01 g/m^3-P; ANZECC 2000) being exceeded at only one site, and then, only by a small amount. The distribution of dissolved reactive phosphorus is shown in Figure 7. It is common for groundwaters to be low in DRP. It would appear that the freshwater part of the Motupipi catchment is phosphorus-limited. In the estuarine environment, however, phosphorus is naturally relatively abundant. The problem algal blooms in the upper estuary occur because neither nutrient is limiting.

4.3 Background nutrient concentrations

The available data suggests that the low nitrate concentrations encountered in groundwater of the alluvial aquifers (i.e. the TTG aquifer) represents largely natural background concentrations. This is consistent with natural groundwater nitrate concentrations from elsewhere in New Zealand which are noted as being rarely over 1 g/m^3-N (Close *et al*. 2001). Longer term data available from WWD6342 (Takaka township) reveals a median nitrate concentration of

0.8 g/m^3-N and a maximum concentration of 1.8 g/m^3-N (Figure 10). Surface water nitrate concentrations in the Takaka River (measured at Kotinga Bridge) are typically less than 0.5 g/m^3-N.

Where the groundwater has a karst source the expected background nitrate concentrations are less certain. As shown in Figure 9, nitrate concentrations in groundwaters with a significant karst component to their source (i.e. have hardness' greater than 80 g/m^3 as $CaCO_3$) showed considerable variation. Significantly, almost all of these sites had nitrate concentrations greater than 1 g/m^3-N. Long term groundwater quality data for the Takaka Limestone is available from WWD6601. Quarterly monitoring since 1991 (17 years) has shown a stable nitrate concentration with a median value of 2.1 g/m^3-N (Figure 10).

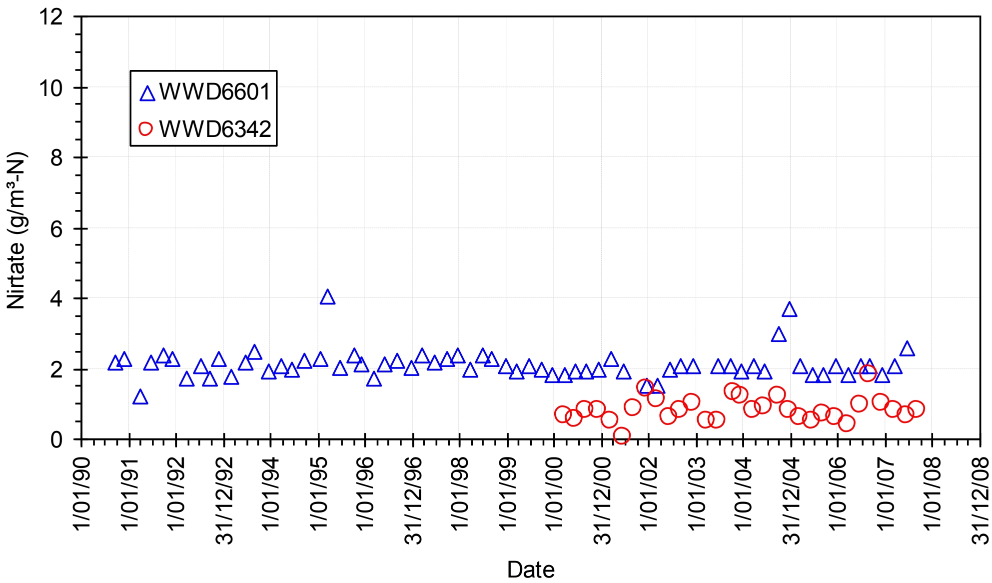

Figure 10: Nitrate-nitrogen concentrations, WWD6601 and WWD6342.

The relative stability of the observed nitrate concentrations in WWD6601, coupled with the absence of obvious seasonal variations, give the appearance stable background nitrate concentrations. However this is unlikely to be the case.

Three bores have been identified in East Takaka (approximately 7 km south of the Motupipi headwaters area) that penetrate the overlying mudstone and reach Takaka Limestone approximately 40 metres below ground level (see inset, Figure 4 for location). These three bores have previously been sampled in January 2006 and analysed for hardness and nitrates. The major cations and anions were also a measured in bores WWD6814 and WWD6836.

This water quality data confirms a significant karst influence on groundwater in these bores (Figures 3 and 5). However, the nitrate concentrations are all low

(<1 g/m^3-N). The other East Takaka groundwater sites with higher nitrate concentrations shown in Figure 8 are relatively shallow and do not reach the underlying limestone.

Whilst some distance from the Motupipi headwaters, these three East Takaka bores are considered to be a much closer representation of background groundwater quality from a karst aquifer. Largely due to the 40 metres or so of mudstone separating the limestone from direct surface activities and influences.

4.4 Nutrient and Faecal Sources

It is difficult to determine any particular source of nutrients in groundwater discharging to the Motupipi River headwaters based on the available data. It appears that septage or sewage discharges are not a factor in the groundwater quality given the low *E.coli* concentrations, however, this could be due to natural decay rates and filtering processes in the aquifer.

The presence of nitrate concentrations in the karst aquifer above what are considered to be natural background levels only emphasises the sensitivity of such areas to their respective land use activities. Where Takaka Limestone is present at or near the surface, particular care needs to be taken with nutrient sources.

One such area is Pages Road and south to WWD6601. There are a number of potential nutrient sources in this vicinity including domestic waste discharges, surface (stormwater) runoff and a silage pit located within a shallow karst depression near WWD6317. Whether any of these are actually contributing to nutrients entering the groundwater and Motupipi River is yet to be determined. Further testing and investigation are needed to confirm or refute potential sources in this area. However, even if a source is identified it is unlikely that this area is the sole contributor of nutrients entering the Motupipi River.

The legacy of wastewater discharges to land from the Takaka dairy factory may account for increased phosphorus concentrations in the river-dominated groundwater but there is little data to support this.

Silage leachate from a silage pit may be having some very localised effects on groundwater in the headwaters.

4.5 Degradation of the Takaka River bed

The bed of the Takaka River has degraded over recent decades. Changes to the stage-flow rating curve at the Kotinga Bridge flow recorder site (approximately 1 km south of Takaka) indicate that bed levels have dropped in the order of 1 m over the past 40 years. It would appear that the river bed has degraded similarly downstream from the Kotinga site, though adjacent to the Motupipi River headwaters and the Takaka township the decrease is more likely to be in the order of 0.5 m (P Drummond, *pers comm*.).

The impacts of this bed degradation on the local hydrogeology has not been specifically investigated or quantified to date. However, such a lowering of bed levels (and hence river water levels) can influence recharge rates from the river to the TTG aquifer. This in turn, may influence groundwater levels and flows within the aquifer. The lowering of groundwater levels can result in decreased discharges from the aquifer, both in the form of reduced flows in springs that feed Te Kakau, Motupipi and Watercress Creeks and reduced diffuse discharge along the river channels that intercept the aquifer. Wigo and Mason Creeks in the Waitapu area have completely dried up in the last 10-20 years.

There is some anecdotal evidence of such a decrease groundwater levels occurring, including reports of reduced flows in Te Kakau Stream, decreased discharges in Watercress Creek and reduced groundwater levels within Takaka (David Rose *pers comm*., Eric van der Stapp *pers comm*.). Unfortunately Council has only collected continuous water levels in the TTG aquifer since July 2004. There are no obvious trends apparent in this data to date, though there is insufficient length of record to draw any firm conclusions.

Recharge to the CTM sub-aquifer is more complex, and is thought to include leakage from the Takaka River where Takaka Limestone outcrops in the bed of the Takaka River downstream of the confluence of the Takaka and Anatoki rivers (Edgar, 1998 and White *et al*., 2001). The more complex nature of the recharge to the karst aquifer, including the presence of other sources of recharge, means the component of recharge derived from the Takaka River (and hence potentially controlled by water levels in the river) is difficult to quantify. It is possible, that given the other potential recharge sources to the karst aquifers, that the karst aquifer is not as sensitive to changes in Takaka River levels as the TTG aquifer.

Variations to the recharge rate of the aquifer systems present in the Motupipi headwaters will have some impact on the base flows present in the Motupipi River. How this may affect nutrient concentrations is less certain. If nutrients are entering the system via the groundwater then changes to inflows can be expected to result in limited changes to nutrient concentrations but in variations to the total nutrient loading. As noted previously, the Takaka River has low nutrient concentrations (nitrate typically less than 0.5 g/m^3-N) and hence is not considered a source of nutrients to the Motupipi River. Alternatively if nutrients are not entering via the groundwater then a relatively stable total loading with variable nutrient concentrations in the Motupipi can be expected (i.e. concentrations varying as a result of changes to the available dilution capacity). It is likely that a combination of these is happening and that the changes are small compared to other variations (from rainfall events, seasonal changes etc.) and hence difficult to discern.

4.6 Flood flows

The biggest impact from the bed level decrease in the Takaka River is more likely to be the lack of flood flows over topping the bank, crossing Bridges Hollow, and continuing down the Motupipi. Historic flood pattern maps record that flows leaving the Takaka River and flowing down the Motupipi River generally occurred 2 to 3 times per year in the 1970's and 80's. This is certainly not what has been observed in recent years with flows from the Takaka River across Bridger's Hollow into the Motupipi having only occurred two times in the past 10 years or so.

Such flood flows are important in waterways for maintaining a healthy ecosystem. Floods scour the bank and bed creating greater morphological diversity in the bed profile (both cross-section and longitudinal section). In addition, floods 'clean out' fine sediments (either trapped in the cobbly bed matrix or in pools) and ream out the excessive growths of aquatic weed. The nutrients bound up in sediment and weeds will also be lost from the system, thereby reducing the potential growth of weeds and algae in the waterway. Once the bed sediment is cleaned out, greater habitat for a larger range of invertebrates will be available thereby improving food supplies for fish.

5. RECOMENDATIONS

5.1 Best Management Practice

Karst landscapes have a unique hydrogeology and the potential for rapid conduit flow of contaminants through subterraneous karst systems. Such interconnections are difficult to identify from surface features alone. As a consequence, there is a need to place greater emphasis and effort in such areas into sustainable farming and sewage/septage disposal practises, particularly where karst rocks either outcrop or are present near the surface.

5.2 Further monitoring

1. Further monitoring of key groundwater sites in the suspected recharge zone of WWD6601. Sampling of Rameka Creek in the zone where it permanently flows may also be useful. Rameka Creek as a potential source has the complexity that under normal flow conditions it is captured into the Arthur Marble before crossing the Pikikirunga Fault and only continues to the Tertiary mudstones and limestones during periods of elevated flows. Consideration may need to be given to sampling Rameka Creek when flows are elevated sufficiently to allow surface flows to extend to the vicinity of WWD6601 and beyond.

   The purpose of such monitoring is to determine whether the groundwater at WWD6601 is acting as a useful reference site for the groundwater in the Tertiary karst rocks or if is it influenced by sewerage or other discharges in the area. This includes along Takaka Central Road where the hospital and school are located. It would be important to include indicator faecal bacteria as well as nutrients in such sampling.

2. Regular sampling of groundwater for nutrients at long term monitoring bores (i.e. WWD6601, WWD6323.1 and WWD6342) should include faecal coliforms and *E.coli* as indicators of faecal contamination.

3. Repeat this investigation in February and July 2012. The characterisation of the full suite of anions and cations may not be necessary.

4. Isotopic fingerprinting of nutrient species to determine possible sources (effluent vs fertiliser) at key locations.

6. GLOSSARY

TTGA – Takaka Township Gravel Aquifer
CTM – Central Takaka Motupipi sub-aquifer
WAM – Waikoropupu Arthur Marble Aquifer

7. REFERENCES

ANZECC. 1999. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality 1999*, Australian and New Zealand Environment and Conservation Council.

Close, M.E., Rosen, M.R., and Smith, V. R. 2001: Fate and transport of nitrates in New Zealand's aquifers. In *Groundwaters of New Zealand*, M.R. Rosen and P.A. White (*eds*). New Zealand hydrological Society Inc., Wellington.

Edgar, J.E. 1998. Hydrogeology of the Takaka Valley. MSc thesis, University of Canterbury.

Grindley, G.W. 1971: Sheet S8 Takaka (1st ed.) Geological Map of New Zealand 1:63360. Department of Scientific and Industrial Research, Wellington, New Zealand.

James, T.I. 2007: Water Quality and Aquatic Ecology of the Motupipi Catchment. *Tasman District Council Report # 07001*

Ministry of Health. 2005. *Drinking Water Standards for New Zealand 2005*, Ministry of Heath.

Mueller, M. 1991: Karst hydrology of the Takaka Valley, Golden Bay, northwest Nelson. In *New Zealand Journal of Geology and Geophysics, 1991 Vol. 34.*

Rattenbury, M.S., Cooper, R.A., Johnston, M.R. (compilers) 1998: Geology of the Nelson area. Institute of Geological & Nuclear Sciences 1:250,000 geological map 9.

Thomas, J. 2001: Tasman. *In* Groundwaters of New Zealand, M.R. Rosen and P.A. White (*eds*). New Zealand Hydrological Society Inc.

White, P.A., Cameron, S., Hong, T., Read, S.A.L., and Stewart, M.K. 2001: Hydrogeology of the Takaka River catchment and assessment of the effects of Cobb Power Station operation on groundwater in the catchment, prepared for TRANSALTA NEW ZEALAND by Institute of Geological & Nuclear Sciences Limited. Client Report 2000/41.

Appendix I

Sampling results for the Motupipi headwaters sites sampled during February and July 2007.

Parameter	Unit	WWD6323.1		WWD6317		WWD6324		Motupipi trib @ U/S factory farm bridge		Motupipi Trib @ Headwaters west branch	
		13/02/2007	18/07/2007	13/02/2007	18/07/2007	13/02/2007	18/07/2007	13/02/2007	18/07/2007	13/02/2007	25/07/2007
Faecal coliforms	cfu/100mL	<5	<5	10	5	5	<5	197	10	10	10
E.coli	cfu/100mL	<5	<5	10	5	5	<5	197	10	10	10
pH	-	7.2	7	7	7.2	6.8	6.9	6.9	7.5	6.8	6.6
Acidity	g/m³ as $CaCO_3$	20	22	38	<1	40	34	29	13	32	23
Alkalinity	g/m³ as $CaCO_3$	46	49	130	140	98	95	80	75	50	43
Total Suspended Solids	g/m³	<1	-	3	-	<1	-	<1	-	2	-
Chloride	g/m³	2.9	3.2	13	13	7.3	12	6.4	7.4	4.1	8
Sulphate	g/m³	2.6	3.8	7.1	7.7	9.4	15	7	6.9	7.3	5.8
Ammonia-N	g/m³	0.008	0.007	0.016	0.012	0.013	0.013	0.018	0.018	0.01	0.009
Conductivity 25°C	mSm^{-1}	11	11	36	36	26	33	21	22	14	15
Dissolved Inorganic Nitrogen	g/m³	0.23	0.49	7.5	7.3	3	9.8	2.5	4	1.5	4.4
Dissolved Reactive Phosphorus	g/m³	0.004	0.003	0.006	0.003	0.009	0.009	0.004	0.006	0.003	0.005
Nitrate-N	g/m³	0.22	0.48	7.5	7.3	3	9.8	2.5	4	1.5	4.3
Total Nitrogen	g/m³	0.23	0.61	7.6	8	3.1	24	2.7	4.8	1.5	4.8
Total Phosphorus	g/m³	0.004	0.003	0.011	0.009	0.009	0.009	0.005	0.007	0.006	0.01
Turbidity	NTU	<0.1	1.1	3.3	6	0.1	0.1	0.2	0.2	0.2	0.7
Calcium	g/m³	15	16	57	57	40	51	32	33	18	20
Iron	g/m³	0.003	0.003	0.16	0.19	<0.002	0.002	0.008	0.031	0.026	0.021
Magnesium	g/m³	2.1	2.5	3.8	3.8	2.6	3.3	2.5	2.5	2.4	2.6
Manganese	g/m³	<0.001	0.002	0.012	0.011	<0.001	<0.001	0.006	0.013	0.018	0.011
Potassium	g/m³	0.3	<0.2	3.4	3.2	3.8	5.5	1.6	1.5	1.9	1.9
Sodium	g/m³	2.6	2.4	6.3	6	4.7	5.9	4.2	4.1	3.2	3.4
Hardness	g/m³ as $CaCO_3$	46	50	158	158	111	141	90	93	55	61

Parameter	Unit	Motupipi Trib @ 300m d/s factory bridge		Watercress Creek @ u/s dairy factory		Motupipi Rv @ 20m u/s Watercress Creek		Motupipi Rv @ Factory Farm Bridge		Motupipi Rv @ Reilly's Br	
		13/02/2007	18/07/2007	13/02/2007	18/07/2007	13/02/2007	18/07/2007	13/02/2007	18/07/2007	13/02/2007	19/07/2007
Faecal coliforms	cfu/100mL	420	<5	105	<5	265	10	169	40		70
E.coli	cfu/100mL	420	<5	84	<5	265	10	135	40		70
pH	-	7.6	7.7	7	7.8	7.3	7.6	7.3	7.9	7.7	7.7
Acidity	g/m³ as $CaCO_3$	9.6	5.6	26	8.2	15	7.8	12	5.2	7	5
Alkalinity	g/m³ as $CaCO_3$	120	130	45	47	45	56	49	57	87	99
Total Suspended Solids	g/m³	<1	-	<1	-	<1	-	<1	-	<1	-
Chloride	g/m³	6.5	8	3.6	3.8	3.2	3.8	3.4	4.4	5.2	6
Sulphate	g/m³	5.8	6	3.7	4.6	4.1	3.9	3.9	4.7	5.1	5.7
Ammonia-N	g/m³	0.016	0.015	0.064	0.032	0.012	0.013	0.022	0.018	0.015	0.032
Conductivity 25°C	mSm^{-1}	28	30	11	11	11	11	12	14	20	20
Dissolved Inorganic Nitrogen	g/m³	2.1	3	0.49	0.52	0.5	0.74	0.51	1.3	1.3	2
Dissolved Reactive Phosphorus	g/m³	0.008	0.005	0.009	0.006	0.003	0.003	0.005	0.005	0.01	0.005
Nitrate-N	g/m³	2.1	3	0.41	0.49	0.49	0.73	0.49	1.3	1.3	2
Total Nitrogen	g/m³	2.3	3.8	0.55	0.72	0.51	0.93	0.53	1.6	1.4	2.5
Total Phosphorus	g/m³	0.01	0.029	0.021	0.012	0.006	0.004	0.01	0.007	0.014	0.013
Turbidity	NTU	0.2	0.5	0.4	0.3	0.3	0.3	0.4	0.4	0.5	0.4
Calcium	g/m³	47	49	14	15	15	15	16	20	32	33
Iron	g/m³	0.031	0.058	0.15	0.085	0.051	0.023	0.11	0.056	0.072	0.032
Magnesium	g/m³	3.3	3.3	2.1	2.2	2.1	2.1	2.1	2.2	2.7	2.8
Manganese	g/m³	0.004	0.012	0.057	0.028	0.019	0.07	0.043	0.039	0.015	0.007
Potassium	g/m³	0.3	0.9	1	0.7	0.7	0.7	0.7	0.8	0.9	0.9
Sodium	g/m³	4.8	5.3	3.1	2.9	2.9	2.9	3.2	3.2	4.4	4.2
Hardness	g/m³ as $CaCO_3$	131	136	44	47	46	46	49	59	91	94

Appendix II Nitrate-nitrogen and hardness data for Council's State of the Environment groundwater monitoring undertaken near the Motupipi catchment.

	Nitrate-N	***Calcium***	***Magnesium***	***Hardness***
WWD6601	*g/m^3-N*	*g/m^3*	*g/m^3*	*g/m^3 as $CaCO_3$*
25/09/1990	2.2	40	2.6	111
28/11/1990	2.3	37.4	2.4	103
26/03/1991	1.2	42.3	2.6	116
20/06/1991	2.2	49.9	2.8	136
23/09/1991	2.4	40.5	2.8	113
3/12/1991	2.3	44	2.6	120
24/03/1992	1.7	42.8	2.8	118
13/07/1992	2.1	45.9	2.9	126
15/09/1992	1.7	38.3	2.4	105
2/12/1992	2.3	39	2.5	108
2/03/1993	1.79	43	2.7	118
21/06/1993	2.2	38	2.5	105
26/08/1993	2.5	37	2.7	103
13/12/1993	1.92	41	2.8	114
22/03/1994	2.1	47	3.1	130
7/06/1994	1.99	45.2	3.3	126
19/09/1994	2.21	46.8	2.9	129
16/01/1995	2.29	48	2.8	131
20/03/1995	4.04	39.1	2.7	109
21/06/1995	2.02	43.1	2.9	119
3/10/1995	2.4	38.8	2.5	107
5/12/1995	2.11	44.4	2.9	123
6/03/1996	1.7	45.8	3.1	127
5/06/1996	2.123	41.9	3.1	117
4/09/1996	2.24	42.1	2.6	116
17/12/1996	2.02	44.3	2.66	121
19/03/1997	2.4	46	2.85	127
17/06/1997	2.2	50	3	137
23/09/1997	2.3	44.4	2.8	122
10/12/1997	2.4	48.2	2.8	132
19/03/1998	2	49.8	3.1	137
23/06/1998	2.4	43.8	2.8	121
9/09/1998	2.3	44	2.7	121
15/12/1998	2.1	47	2.8	129
16/03/1999	1.9	50	3.1	138
15/06/1999	2.1	45	2.7	123
20/09/1999	2	46	2.9	127

WWD6601 (cont)	Nitrate-N g/m^3-N	Calcium g/m^3	Magnesium g/m^3	Hardness g/m^3 as $CaCO_3$
15/12/1999	1.8	44	2.8	121
20/03/2000	1.8	44	2.8	121
7/06/2000	1.9	43	2.7	118
6/09/2000	1.9	42	2.6	115
6/12/2000	2	47	3	130
13/03/2001	2.3	46	2.9	127
19/06/2001	1.9	49	3.2	135
18/12/2001	1.5	39	3	110
12/03/2002	1.5	41	3.1	115
12/06/2002	2	46	3	127
3/09/2002	2.1	40	2.6	111
3/12/2002	2.1	44	2.7	121
18/06/2003	2.1	44	2.9	122
23/09/2003	2.1	40	2.6	111
10/12/2003	1.9	43	2.7	118
17/03/2004	2.1	39	2.3	107
15/06/2004	1.9	37	2.2	101
21/09/2004	3	39	2.6	108
13/12/2004	3.7	44	2.9	122
15/03/2005	2.1	44	2.8	121
15/06/2005	1.8	45	2.8	124
13/09/2005	1.8	39	2.5	108
12/12/2005	2.1	48	3.2	133
count	60	60	60	60
minimum	1.2	37	2.2	101
median	2.1	44	2.8	121
average	2.1	43.4	2.8	120
maximum	4.04	50	3.3	138

WWD6342	***Nitrate-N*** *g/m^3-N*	***Calcium*** *g/m^3*	***Magnesium*** *g/m^3*	***Hardness*** *g/m^3 as $CaCO_3$*
22/03/2000	0.65	16	2.1	49
7/06/2000	0.56	16	2	48
6/09/2000	0.8	16	2.1	49
6/12/2000	0.81	14	1.9	43
13/03/2001	0.53	14	1.8	42
19/06/2001	0.05	15	2	46
11/09/2001	0.86	12	1.7	37
18/12/2001	1.4	16	2.1	49
12/03/2002	1.1	16.2	2.24	50
12/06/2002	0.62	15.9	2.21	49
3/09/2002	0.8	15	2.2	46
3/12/2002	1	16	2.1	49
24/03/2003	0.49	14	2	43
18/06/2003	0.49	15	2.1	46
20/10/2003	1.3	17	2.3	52
10/12/2003	1.2	15	2.1	46
17/03/2004	0.82	17	2.4	52
15/06/2004	0.91	17	2.3	52
21/09/2004	1.2	16	2.2	49
13/12/2004	0.83	15	2.2	46
15/03/2005	0.63	15	2	46
15/06/2005	0.5	15	1.9	45
13/09/2005	0.73	14	1.9	43
12/12/2005	0.61	14	2	43
21/03/2006	0.41	14	1.9	43
6/03/2007	0.8	15	2	46
12/06/2007	0.67	16	2.2	49
6/09/2007	0.81	16	2.2	49
count	28	28	28	28
minimum	0.05	12	1.7	37
median	0.8	15	2.1	46
average	0.8	15.3	2.1	47
maximum	1.4	17	2.4	52

Appendix III Additional nitrate-nitrogen and hardness data for the Motupipi catchment area.

Bore number	*sample date*	*Easting*	*Northing*	*Nitrate-N (g/m^3-N)*	*Hardness (g/m^3 as $CaCO_3$)*
WWD6013 Pupu	12/6/2007	2490442	6039799	0.32	179
WWD6207	25/03/1986	2499120	6040360	2.2	-
WWD6224	28/02/1996	2499590	6039990	5.9	86
WWD6306	25/03/1996	2494450	6038980	0.3	-
WWD6307	12/01/2006	2494491	6038974	0.37	44
WWD6308	13/03/1996	2494300	6039150	1.2	50
WWD6310	5/01/2006	2495150	6038860	1.2	65
WWD6311	13/03/1996	2493560	6038440	0.46	47
WWD6321	12/01/2006	2493566	6038390	0.22	44
WWD6323.11	23/10/1996	2494664	6038376	0.012	41
WWD6323.2	23/10/1996	2494210	6038860	0.88	51
WWD6323.3	23/10/1996	2494600	6038830	0.32	82
WWD6323.5	23/10/1996	2495150	6038670	2.7	118
WWD6323.7	23/10/1996	2495530	6038940	6.4	92
WWD6325	12/01/2006	2493705	6038241	0.72	47
WWD6326	13/01/2006	2494085	6038787	0.45	44
WWD6327	13/01/2006	2494125	6039416	0.65	47
WWD6328	14/03/1996	2493570	6038810	1.4	49
WWD6330	5/06/1996	2494451	6038737	0.5	49
WWD6331.1	17/02/2006	2495035	6039316	0.005	294
WWD6331.2	17/02/2006	2495350	6039640	1.2	105
WWD6339	24/08/1999	2493704	6038699	1.2	48
WWD6341	12/01/2006	2493493	6038604	0.49	47
WWD6350	5/01/2006	2495194	6039010	1.3	64
WWD6401	13/03/1996	2495700	6039050	6.8	94
WWD6402	5/01/2006	2495996	6039658	3.6	120
WWD6404	21/03/1986	2497436	6037655	4.1	154
WWD6419	25/03/1986	2497150	6038930	7.8	-
WWD6423	5/01/2006	2497489	6038911	10	109
WWD6424	15/04/1986	2497530	6039310	0.93	43
WWD6433	5/01/2006	2495831	6039913	2.6	93
WWD6434	18/01/2006	2495765	6039075	3.2	107
WWD6534	18/01/2006	2493689	6038426	0.21	44
WWD6535	13/04/2005	2493771	6038382	0.99	49
WWD6602	21/03/1986	2494530	6036900	1.4	103
WWD6605	5/01/2006	2494934	6035952	1.7	140
WWD6611	14/03/1996	2494070	6037700	1.9	98
WWD6615	5/06/1996	2494430	6037290	0.24	120
WWD6802	19/01/2006	2495530	6034190	3.4	83
WWD6814	19/01/2006	2495039	6030213	0.56	93
WWD6821	19/01/2006	2495050	6030606	0.68	104
WWD6824	4/01/2006	2495388	6034439	1.5	119
WWD6836	19/01/2006	2494659	6031210	0.75	113
WWD6824	4/01/2006	2495388	6034439	1.5	119