Are Are Creek Catchment Baseline Water Resource Report

Prepared for

Marlborough District Council

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Executive Summary

Are Are Creek is a northern tributary of Wairau River, with its upper reaches near Okaramio and its confluence with the Wairau River at Kaituna. Surveys by MDC staff have identified Are Are Creek as supporting a diverse ecology. MDC staff have also indicated that this is likely to be an area of intensifying land use, which will need to be supported by irrigation. The purpose of this report is to provide an overview of existing water resources information in the catchment, with a particular focus on groundwater and it's interactions with surface flow in Are Are Creek.

The valley floor of Are Are Creek has been infilled with alluvial gravels, which were initially derived from the Pelorus River catchment (in the lower part of the valley floor sequence) and, at shallower depth from the locally derived schist rock that forms the valley sides. Many of these gravel deposit occur in a silty/clay matrix and are used by productive water supply bores, which are mostly less than 25m deep and provide yields ranging as high as 140m^3/hour (but mostly around 5-20 m^3/hour). The groundwater in the valley floor gravels provides base flow to Are Are Creek, which increases in flow downstream, even during dry periods when there is no surface inflow from tributary streams .

Groundwater chemistry analyses indicate that the groundwater is derived primarily from local rainfall infiltration, with no significant input from Wairau River seepage, even in the lower part of the valley.

There are no laterally extensive aquifer or aquitard layers that are evident throughout the valley, with the exception of a shallow clay layer that may occur near the ground surface and would be consistent with earlier aerial photos indicating swampy areas with the valley floor. Below this the strata is probably best characterised as a variable mixture of lenses dominated by either gravel or clay.

The Are Are Creek channel is slightly incised into the valley floor and measurements made by MDC and from private pumping test indicates that it has a reasonable degree of hydraulic connection with the shallow groundwater, with a measured streambed conductance of around 7m/day. Pumping tests indicate that the gravel strata has transmissivties of a few hundred to a few thousand m^2/day.

Based on this information there is potential for groundwater abstractions to affect streamflow however the exact magnitude of these potential effects need to be assessed on a case by case basis. The size of abstraction rate, the separation distance to the stream channel and the permeability of the intervening strata are all factors that affect the magnitude of any groundwater pumping effects on streamflow.

The key water management issues for the Are Are Creek catchment are:

- Defining an instream flow regime to protect the ecological values of Are Are Creek.
- Defining an allowable abstraction value and reliability of supply to meet abstraction needs .

- To consider changes in land cover within the catchment and how they impact on infiltration and surface runoff within the catchment

The balance between these facts should ideally be determined by the sharing of technical information on water resources and consultation with interested parties to determine the most appropriate water management regime for the Are Are Creek Catchment.

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1.0 Introduction

Are Are Creek is a northern tributary of the Wairau River, with its upper reaches near Okaramio and its confluence with the Wairau River at Kaituna, downstream of the State Highway 6 bridge. Figure 1 shows the Are Are creek catchment boundary. Surveys by Marlborough District Council (MDC) have identified Are Are Creek as supporting a diverse ecology, particularly in its lower reaches. It is also an area of intensifying land use, which will need to be supported by irrigation. Because of the demand for water abstraction, MDC have engaged Pattle Delamore Partners Ltd (PDP) to compile the existing information on the water resources of the Are Are Creek catchment, with a particular focus on groundwater, and to provide a preliminary assessment of the potential effects of groundwater abstraction on the surface water resource.

This report has been prepared to provide the following information:

- a description of the geological setting (Section 2);
- a description of the surface water resource (Section 3);
- a description of the groundwater resource (Section 4);
- a discussion of the water resources issues that occur within the Are Are Creek catchment (Section 5).

2.0 Geological Setting

Figure 2 shows a geologic map of the Are Are catchment and surrounding area. The basement rocks for the area comprise low permeability schist that forms the Richmond Ranges and underlie alluvial quaternary deposits that fill the valley floor. In the Okaramio-Kenningtons Road area, boreholes have drilled through the total thickness of alluvial strata and encountered schist at a depth of around 60m. These deeper boreholes identified ultra-mafic gravels from the upper Pelorus catchment at depths greater than around 40m, indicating that in earlier geologic time the Pelorus River flowed southwards into the Wairau River and would have initially eroded the valley into the schist basement that now contains both the northward flowing Kaituna River and the southward flowing Are Are Creek. This has resulted in a considerably wider and deeper valley (formed by the relatively large Pelorus River), compared to the relatively small sized waterways (Kaituna River and Are Are Creek) that currently occupy it. Figure 3 shows the location of the Pelorus River, Kaituna River and Are Are Creek, and Figure 4 is a schematic diagram showing the location of the two deep boreholes that provide this evidence (boreholes K1 and K2). Figure 5 is a simplified record of the strata encountered in these two drill holes, indicating the rounded Pelorus River gravels deposited above the schist basement. The Pelorus River gravels are overlain by units of more angular, locally derived schist gravels inter-layered with muddy silty deposits.

A contributing factor to these changing drainage patterns are the tectonic influences of the Wairau Fault (Figure 3), which has its surface trace running sub-parallel and just to the south of the Wairau River through this area. The strata on the northern side of the fault is being pushed upwards and to the north-east, relative to the southern side of the fault. Craw et al (2007) report that the strata on the north side of the Wairau fault is moving laterally to the north-east at an average rate of about 4mm/year towards a zone of subsidence. This subsidence and tilting, coupled with the build up of alluvial sedimentary deposits, both within the Kaituna-Are Are corridor and in the Wairau River has caused this reversal in drainage patterns, although such changes are very slight, creating very low gradient streams and the creation of fine grained swamp deposits within both the Kaituna River valley and the Are Are Creek catchment. Figure 6 shows the changing elevation profiles of the waterways, and the resulting elevation of these drainage patterns is shown schematically in Figure 7. Craw et al (2007) note that the drainage reversal most likely occurred when ponding of sediment in the south allowed overtopping of a low drainage divide to the north in what is now Pelorus Sound. The creation of this divide would have caused important ecological changes as it created a barrier to the previous migration of freshwater species between the Wairau and Pelorus Rivers. Figures 4 and 5 contain references to the remnants of older alluvial terrace surfaces that were formed during times of colder climates and enhanced sediment transport and deposition. These tend to be more silty, poorly sorted strata and are identified as follows:

- Q6a – 128,000-186,000 years ago (Pelorus River flowing south, drainage reversal occurs);
- Q4a – 59,000-71,000 years ago;
- Q2a- 14,000-24,000 years ago.

In the intervening warmer periods, some erosion and re-working of these deposits has occurred.

This sequence of geological formation suggests that the most permeable gravel strata is likely to occur in the lower sequence of alluvial deposits, formed by the Pelorus River, just above the schist basement. However, these deposits are not extensive throughout the valley, as evidenced by a deep exploratory well for the Havelock water supply in the Kaituna valley which was drilled to a depth of 62.3m and found only low yielding alluvial strata. Furthermore, whilst the Pelorus gravels are likely to be permeable, whether or not they form a productive aquifer will depend on a connection to a reliable source of recharge.

The overlying gravels will tend to be more poorly sorted, with a greater proportion of fine grained sediments creating lower permeability alluvial deposits.

2.1 Soils

Figure 8 shows the soil map for the Are Are creek catchment. The soils mimic the geology. The valley floor is predominately compromised of Kaituna soils. At the southern end of the valley a terrace of the Wairau River occurs. To the south of the terrace Waimakariri soils are present. The steeper valley sides comprise Tuamarina soils on the lower slopes and Onamalutu soils at higher elevations. The General Survey of the Soils of South Island, New Zealand (Soil Bureau Bulletin 27) provides the following notes on these soil types:

- **Kaituna Soils**: Drainage generally free; but impeded in places. Suitable for more intensive pasture management. Water supply adequate;
- **Waimakariri Soils**: Soils variable in texture, but mainly stony; all are droughty. Suitable for improved dryland farming; some parts are suitable for irrigation. Water supply inadequate; few streams;
- **Tuamarina Hill Soils**: Rainfall generally adequate. Tends to revert to scrub. Suitable for rough grazing or afforestation in present state, but capable of much improvement by oversowing and topdressing. Water supply inadequate; streams dry in summer;
- **Onamalutu Steepland Soils**: Rainfall adequate. Many very steep slopes and rocky bluffs. Cleared slopes sheet eroded; slips common in deeper soils on lower slopes. Considerable pasture improvement possible in parts, but no further clearing of forest advisable. Exotic production forests possible on lower slopes. Water supply adequate.

3.0 Surface Water Resource

Figure 1 shows the outline of the surface water catchment that drains into Are Are Creek. It comprises an area of 2,243 ha of elevated hillside area and 939ha of relatively flat valley flow, ranging in elevation from 543 m down to an elevation of around 31 m, where it discharges into the Wairau River.

The valley floor is relatively flat, with the catchment divide to the Kaituna River occurring at an elevation of around 61 m above mean sea level. Are Are Creek is slightly incised into the valley floor sediments by around 1-3 m.

A 1958 aerial photograph held by MDC shows the pattern of a very low gradient meandering channel and indications of swamp deposits in the middle reaches of the valley floor. Part of this aerial photo is reproduced in Figure 9b. In contrast to the meandering creek pattern, the current channel of the creek follows a very straight alignment for most of its course, having been constructed as a drain to enable farming of the adjacent land. Mr John Wratt, a local farmer, has reported that the drain was first constructed around 1945-47 and upgraded in the early 1960s. He has described how the creation of the drain has enabled productive use of the valley floor, without the need for any field tiles to be installed.

A series of gaugings have been carried out by MDC in summer and autumn of 2004 and 2007/08 at sites plotted in Figure 10. Figure 11 shows how the pattern of flow generally increases in a downstream direction, with an average increase in flow of around 80L/s between Long Gully Bridge and the Kaituna – Tuamarina Track. However on some occasions this pattern of increasing flow downstream may be disrupted by irrigation pumping abstractions.

Mr Wratt expressed the view that during summer months there is no tributary inflow to Are Are Creek, but the creek flow appears visually to be very steady and stable. He also has observed that the pine plantations on the catchment sides has significantly reduced any surface runoff from those areas.

The MDC gaugings indicate that at times of low stable baseflow, the Are Are Creek baseflow increases along the creek bed. The source of this increase is expected to be due to groundwater seepage into the streambed. The creekbed is comprised of sandy gravel material in many places, indicating a reasonable hydraulic connection with the surrounding gravels, although more silty strata may occur beneath this. There is no indication of discrete springs discharging through fissures in any low permeability strata. MDC have a brief period of continuous stage height recording in Are Are Creek at a location near the Opawa Rivervines well. This is plotted in Figure 12 and shows a sharp response to three rainfall events, due to rainfall runoff. However, not all rainfall events show a response, most likely due to the localised variability between the rainfall recorder site, which is located near Havelock, and the Are Are Creek catchment. Figure 12 also shows a smaller range of fluctuations, on the order of 20-30mm, which are likely to be due to the irrigation abstraction from the creek. Table 1 shows some isolated gauging measurements at the Kaituna-Tuamarina Road bridge. The more recent gaugings have occurred more regularly and are plotted in Figure 12a. The lowest recorded flow is 78 L/s on 1 March 1973, which is one of three recorded measurements below 100 L/s.

3.1 Abstractions of Surface Water

MDC have reported that the main abstraction of surface water from Are Are Creek is carried out by John Wratt who is currently seeking a new replacement resource consent U070878 for the abstraction of 29.6 L/s (1,560 m^3/day) to irrigate 40 ha of crops and pasture. MDC have recently granted this application but included a condition requiring abstraction to cease when the surface flow at the Kaituna-Tuamarina Road bridge is below 100 L/s. This flow approximately corresponds to the five year seven day low flow of 8 m^3/s, which is set as the sustainable flow regime (SFR) for the Wairau River. The imposition of this low flow condition has been appealed by the Wratts. This appeal is currently waiting to be resolved.

Two other consents are listed by MDC as occurring from the surface waterway. These are:

- Peter Jackson Family Trust– U011418 – 3.7 L/s; (317m^3/day);
- Zaccarat – U011391 – 2.3 L/s. (200m^3/day).

The location of these three surface water abstraction points is shown in Figure 13.

In 2004, three consent applications (U040239 Smart, U040792 Okaramio Partnership, U041081 Maitland) applied to MDC to take water either directly from Are Are Creek or from nearby wells. A hearing for the first of these applications (U040239) declined the application on the grounds that there was insufficient information about the effects of the abstraction on the in-stream flora and fauna, and on the reliability of supply to the consented downstream users. The other applications were subsequently withdrawn.

Table 1: Are Are Creek Gauged Flows at Kaituna-Tuamarina Track

Date	Flow (litres per second)
4 May 1960	118
29 January 1970	154
13 February 1970	129
5 March 1970	104
15 February 1973	95
1 March 1973	78
3 May 1988	211
14 May 1992	149
8 March 2001	102
21 January 2004	138
7 April 2004	157
9 February 2006	168
3 May 2006	234
20 June 2006	433
18 July 2006	302
29 August 2006	341
26 September 2006	274
7 November 2006	334
20 February 2007	156
6 March 2007	103
3 April 2007	98
17 May 2007	116
16 October 2007	651
23 October 2007	396
31 October 2007	253
7 November 2007	244
22 November 2007	188
27 November 2007	170
30 November 2007	151
7 December 2007	137
15 December 2007	112
19 December 2007	395
26 December 2007	182
1 January 2008	163
9 January 2008	148
14 January 2008	135
21 January 2008	121
30 January 2008	128

Table 1: Are Are Creek Gauged Flows at Kaituna-Tuamarina Track	
Date	**Flow (litres per second)**
31 January 2008	126
4 February 2008	113
11 February 2008	142
21 February 2008	120
25 February 2008	112
3 March 2008	171
19 March 2008	126
27 March 2008	117
31 March 2008	219
7 April 2008	214
18 April 2008	443
30 May 2008	223
21 June 2008	191

4.0 Groundwater

Figure 14 presents a plot of wells located in, or close to, the Are Are catchment. This amounts to 94 wells located within the Are Are Creek area to the north of the terrace that forms the northern boundary of the Wairau River gravels.

Figure 15 shows the depths of the mid-point of the wells indicating that most bores abstract water from less than 20m deep. A review of the drillers logs indicates that the strata is predominately described as gravelly, with varying proportions of sand, silt and clay. There are indications of a near surface clay layer over the first few metres along part of the valley floor. Figure 16 shows the recorded thickness of low permeability strata at the ground surface (i.e. the thickness of strata before any description of “gravel” or “shingle” was encountered). This indicates that fine grained strata overlying more permeable gravels is highly variable.

Figure 17 shows a schematic hydro geologic section from north-south along the Kaituna River valley and the Are Are Creek valley. The section has a significantly exaggerated vertical scale and shows the drillers description of the strata from each borehole along with the position of the well screen, which indicates the most permeable water bearing zone in each well.

The cross-section indicates the variable nature of the strata, the predominance of clay and gravels but the absence of any consistent layering of permeable gravel layers and intervening low permeability aquitards, with the exception of a possible surface fine grained clay strata along Are Are Creek. Below this the strata is probably best characterised as a variable mixture of lenses dominated by either gravel or clay.

Figure 18 shows a plot of well yields versus depth indicating that the highest yields have been achieved at depths less than 20m.

Figure 19 shows a plot of specific capacity versus depth. Specific capacity is calculated from the well yield divided by the drawdown that occurred in the pumped well. It again indicates a pattern of more productive wells at shallower depths (less than 20m) with the strata either becoming less permeable and/or more separated from a source of recharge (namely surface flow in Are Are Creek) with increasing depth. No yield data is available for any depths greater than 40m.

4.1 Abstractions of Groundwater

Groundwater within and adjacent to Are Are Creek is reportedly used for domestic, stockwater and irrigation supply The location of the consented groundwater abstractions is shown in Figure 13 and the details of all consented abstraction that have been provided by MDC are summarised in Table 2. These details also include the consent that is currently being sought for a portion of the original Wratt surface water irrigation consent by Opawa Rivervines Ltd (consent application U070972), who propose to utilise a well located around 28 m away from the creek.

Based on the evidence of the groundwater contribution to surface flows during summer months, MDC is interested in trying to better quantify the relationship between groundwater and surface flow, the effect that groundwater abstractions may have on surface flow regime and what, if any, restrictions on groundwater abstraction might help in the management of these water resources.

Table 2: Consented Abstractions (information provided by MDC)

Source of Water	MDC Resource Consent and Holder	Daily Volume (m^3/day)	Well Number
Surface Take – Are Are Creek	U011418 (Jackson)	317	-
Surface Take – Are Are Creek	U011391 (Zaccarat)	200	-
Surface Take – Are Are Creek	U971166/U070353 (Wratt)	2,000	-
Underground Take	U021144 (Forrest)	112	P28w/4103
Underground Take	U020903 (Zaccarat)	180	P28w/3792
Underground Take	U030854 (Jackson)	600	P28w/4132
Underground Take	U030679 (Jackson)	1,728	P28w/4059
Underground Take	U051128 (Wooding)	229	P28/4587
Underground Take*	U041445 (Maher/Delegats)	2,000	P28w/1284
Underground Take*	U040373 (Maher)	721	P28w/3923
Underground Take*	U020689 (Leslie)	325	Infiltration gallery
Underground Take*	U051201 (King Salmon)	30,240 (re-circulated)	P28w/1679, 1680, 1797, 1798
Underground Take*	U010460 (Heinemann)	176	P28/3809
Underground Take	U070972 (Opawa Rivervines)	440	P28w/4732

* These wells are located some distance from Are Are Creek and have other surface waterways that are closer to them. As a result, they are best to be managed in terms of

other groundwater and surface water systems and are not considered further in this study.

4.2 Groundwater Surface Water Interaction

The lack of surface water inflow during dry periods and the increase in surface flow down the catchment, as shown in Figure 11, indicates that groundwater contributes to the surface water flow along the length of the valley.

MDC have carried out some isolated measurements of water levels at surveyed points in the mid-valley area at three locations:

- bore P28/4732, screened from 13.4 – 16.5m deep and located around 28m from the stream bed;
- the elevation of water in the stream near to bore P28/4732;
- the elevation of groundwater in a piezometer driven to a depth of about 1m beneath the stream bed.

Figure 20a shows the location of the monitoring points and Figure 20b shows the water level measurements. This indicates that groundwater levels are higher than the stream level, thereby creating a hydraulic gradient towards the stream, which will cause groundwater to seep into the stream.

Two measurements were made on 27 March which showed a drop in stream level of 35mm which corresponded to Mr John Wratt's irrigation abstraction and a corresponding drop in the groundwater level of 5mm.

These measurements occur in a section of stream, where flow in the creek has been measured to increase from around 21 L/s between Wratts Bridge and the Weyerhauser site at Mahers Road (a distance of 1,490m). The stream is around 3m wide at this point. The average difference in water levels between the piezometer 1m below the stream bed and the water level in the stream is 0.16m. If the gradient in the streambed measurements is typical of the gradient throughout that reach it allows the following indicative calculation of the streambed conductance, as shown schematically in Figure 21. The resulting calculation for Are Are Creek is:

$$\text{Streambed conductance} = \lambda = \frac{0.021\text{m}^3/\text{s}}{1490\text{m} \times 0.16\text{m}} = 7.6\text{m/day}$$

$$\text{Hydraulic conductivity of streambed} = K' = \frac{7.6\text{m/day} \times 1\text{m}}{3\text{m}} = 2.5\text{m/day}$$

A similar pair of measurements were made on 11 March 2008, which recorded the following flows:

- Wratts Bridge – 78 L/s;
- Piezometer near Opawa River vines well – 85 L/s.

This shows:

$$\text{Streambed conductance} = \lambda = \frac{0.007\text{m}^3/\text{s}}{560 \times 0.16\text{m}} = 6.8\text{m/day}$$

Hydraulic conductivity of streambed = K' = $\frac{6.8\text{m/day} \times 1\text{m}}{3\text{m}}$ = 2.3m/day.

These are relatively high values, indicating a good degree of hydraulic connection between the groundwater and the creek bed. Therefore, whilst the drillers' bore logs indicate the possibility of a surface clay layer (Figures 16 and 17), it is likely to be variable in nature and the incised channel of Are Are Creek will cut thorugh the top few metres of this fine grained strata.

4.3 Pumping Test Information

To properly determine aquifer parameters and potential groundwater pumping effects on surface flows requires carefully monitored pumping tests carried out over several days with monitoring of effects in the surface waterway. One such test from the upper valley occurred in a bore screened from 41.5 – 44.5m deep in the vicinity of the Okaramio Hotel. This relatively deep bore was pumped at a rate of 21.6 L/s for four days and the resulting drawdown effects are summarised in Table 3.

Table 3: Summary of Aquifer Test Wells, Near Okaramio Hotel

Well ID	Depth (mbgl)	Easting	Northing	Screen Interval (mbgl)	Distance from Pumped Well (m)	Direction from Pumped Well	Drawdown Constant rate test pumping 21.6 L/s for five days
Pumped Well	45	2573895	5976107	41.5 – 44.5	-	-	2.34m
0B1	5	2573942	5976202	?	~100	N	0.18m
0B2	18	2573582	5976638	?	~500	NW	~0.03m

The drillers log indicates that the permeable water bearing strata comprised of schist gravels which were overlain by some finer grained sediments including fine sand (3.7-4.1m deep) and silty clay (4.1-5.7 and 15.1-18.3m deep). Despite this fine gravel strata the pumping test indicated that pumping did cause a drawdown effect extending right up to the water table (monitoring bore 0B1) which is the water table that provides seepage into Are Are Creek. This indicates that groundwater abstraction in the upper catchment area can affect surface flow.

Several other pumping tests have occurred in the lower valley area. The available information from these tests has been reviewed and the results are summarised in Table 3. The location of these pump tested bores is shown in Figure 22. Many of the tests were at low abstraction rates or of short duration and do not show signs of any stream depletion effects, particularly where they are located at large distances from the stream. Tests in Table 3 that fall into that category are Heinemann and Mountain View. However other tests that occurred at higher rates and or in closer proximity to a stream did show a drawdown pattern that is consistent with a stream depletion effect. Tests in Table 4 that fall into that category are both the Jackson bores, Zaccarat and the test near the Okaramio Hotel.

It is interesting to note that whilst the valley sides are comprised of low permeability strata, none of the pumping tests show any indication of a low permeability lateral boundary effect. Therefore the dominant boundary demonstrated by the tests is a recharge effect, most likely due to Are Are Creek, and/or, at the southern end of the valley, the Wairau River.

Due to the low pumping rates and small drawdown effects there is an absence of well defined aquifer parameters for this area. The indications are that aquifer transmissivity (T) is in the range of a few hundred to a few thousand m^2/day. Storage coefficients are not well defined but it is expected that most drawdown effects will transmit through to the water table which is expected to have a storage coefficient in the range of 0.02-0.2. Based on the available data it is also to be expected that groundwater abstractions within the valley strata have the potential to cause a stream depletion effect. However whether or not such an effect is significant depends on the magnitude of the abstraction rate, the separation distance to the nearest stream and the hydraulic conductivity of the strata that occurs between the well screen and the streambed.

Table 4: Summary of Pumping Test Information Provided by MDC

Bore Owner	Bore Number	Screened Depth	Distance to Are Are Creek (m)	Other Nearby River	Distance to Other River	Aquifer Parameters	Comments
K.G. Heinemann	P28w/3809	12.9-16.9m	500	Wairau	400	T = 320m²/day No obvious stream depletion pattern, probably due to low pumping rate and large distance to streams.	Small abstraction rate of 3.6 L/s located below northern terrace. Unconfined aquifer behaviour, no sign of stream depletion due to low abstraction rate. Stream depletion most likely to affect Wairau River if a large pumping rate used.
Mountain View Wines	P28w/2061	11.5-15.5m	550	Wairau	460	No reliable aquifer parameters from step drawdown test	Small abstraction rate of 2.1 L/s located above northern Wairau terrace. Relatively large separation distance from surface waterways so unlikely to cause adverse stream depletion effect.
Jackson	P28w/4059	8.7-12.3m	240	Wairau	240	No reliable aquifer parameters, but drawdown pattern is consistent with a stream depletion effect	Abstraction rate of 20 L/s below northern terrace is likely to have a stream depletion effect on the lower reaches of Are Are Creek.
Zaccarat	P28w/3792	20.5-24.08m	100	-	-	T=670m²/day Drawdown pattern is consistent with a stream depletion effect	Small abstraction rate of 2.1 L/s, but stream depletion effect is likely with prolonged pumping at a higher abstraction rate.

Table 4: Summary of Pumping Test Information Provided by MDC

Bore Owner	Bore Number	Screened Depth	Distance to Are Are Creek (m)	Other Nearby River	Distance to Other River	Aquifer Parameters	Comments
Pitts	P28w/4132	15.64-21.24m	55			No reliable aquifer parameters but drawdown pattern is consistent with a stream depletion effect	Medium abstraction rate of 6.9 L/s is likely to have a stream depletion effect on Are Are Creek due to its close proximity.
Near Okaramio Hotel	-	41.5-44.5m	90	-	-	$T = 3456 m^2/day$ $S = 3410^{-3}$ $\sigma = 0.02$ $K^1/B^1 = 0.13 day^{-1}$	Drawdown at water table observation bore indicates a stream depletion effect.

4.2 Groundwater Chemistry

Groundwater quality from most bores screened in the gravel strata of Are Are Creek are expected to be of generally good quality with low concentrations of most chemicals. pH values may sometimes be lower than the aesthetic guideline criteria specified in the Drinking Water Standards for New Zealand (2005), however that is a natural characteristic of groundwater that receives recharge via infiltration through the land surface.

One unusual groundwater chemistry analysis in this general area has been recorded from well P28w/3791 located at the eastern end of Kenningtons Road, which is outside of the top end of the Are Are Creek catchment. This well is reportedly screened from 16.7-20.4m deep in low yielding clayey gravels. The water has a high salinity with an electrical conductivity of 609ms/m and a chloride concentration of 1900g/m³ which can be compared with values of 8mS/m and 5g/m³ for groundwater within the main Are Are Creek gravels The eastern end of Kenningtons Road occurs in a narrow valley bounded by low permeability schist basement rock and presumably reflects groundwater where there has been a lack of throughflow, to provide fresh recharge water into the strata. Whilst similar areas of poor water quality could occur in zones of very low permeability strata, particularly near the schist basement, it is unlikely to occur in the more permeable gravel strata within the valley floor.

MDC undertook a sampling survey in May 2004 to assess recharge sources for groundwater on the northern side of the Wairau River in the vicinity of Kaituna and Are Are Creek, compared to groundwater on the south side of the Wairau River. The general water chemistry results are summarised in Figures 23 and 24. The results fall into two clear groupings. The Wairau River and Wairau Aquifer wells (i.e. south side of the Wairau river) show a similar pattern which is most noticeably distinguished by lower concentrations of sodium (Na), Chloride (Cl), nitrate (NO_3) and silica (SiO_2). In contrast, the northern wells and streams show generally higher concentrations for most of the analysed parameters, with the exception of calcium (Ca).

This same patterns is reinforced by oxygen isotope ratio surveys ($^{18}O/^{16}O$) which are shown at three different sampling dates in Figures 25a, b and c. This shows a consistent pattern with Wairau River water and Wairau Aquifer water (south side of the river) having more negative values (<-8.0) whereas all the northern wells and streams have less negative values (>-7.3). Dr Claude Taylor prepared a note on these results (dated August 2004) stating that the average ($^{18}O/^{16}O$) ratio for Wairau River water is -8.9 and for local precipitation is around -6 to -7. The results indicate that Are Are Creek groundwater is recharged predominately from local rainfall with very little influence from Wairau River seepage, even for wells located within the Wairau River gravels on the south side of the northern terrace scarp.

4.3 Conceptual Hydrogeologic Model

Figure 26 provides a schematic diagram of the conceptual hydrogeologic model of the Are Are Creek groundwater system. This diagram has been prepared by Peter Davidson the MDC's Groundwater Scientist and correctly reflects the key aspects of our understanding of this groundwater system, namely:

- the alluvial gravels have infilled a valley that has been eroded into the schist basement rock;
- the valley was originally formed by the Pelorus River and the lower gravels are of an ultra-mafic geology derived from that catchment (diagrams a and b in Figure 7);
- subsequent uplift of the valley strata caused the Pelorus River to be shut off from the catchment (diagrams c and d in Figure 7). As a result, the upper part of the valley floor strata is derived from the local schist gravels, but due to the small size of the valley they are relatively poorly sorted and contain a large proportion of clay in amongst the schist gravels;
- all the currently used abstraction wells are screened within the shallower schist gravels;
- there is an indication of a low permeability surface layer of around 3-6m thick in some places, although the thickness of this strata is quite variable and is dissected by the incised channel of Are Are Creek;
- beneath that surface layer there is no evidence of laterally extensive consistent aquifer layers or low permeability clay aquitards layers. It is more likely to be a variable mix of strata with differing lenses where either gravels or clay predominate;
- the groundwater system is likely to receive most of its recharge from local rainfall draining off the valley side. Even at the lower end of the valley in the Wairau River gravels the water chemistry suggests rainfall recharge predominates, with no significant recharge from the Wairau River;
- Are Are Creek increases in flow downstream. During drier times, when there is no rainfall runoff, this increase in flow is expected to be derived from groundwater seepage into the stream channel;
- discharge from the gravel aquifer system will occur via three main mechanisms:
  - seepage into Are Are Creek;
  - abstraction via pumping bores;
  - down valley groundwater flow towards Wairau River.

5.0 Groundwater-Surface Water Management Issues

MDC staff have reported that historically the valley flats of the Are Are Creek catchment have been used for dairy farming or arable cropping and the hill country for plantation forestry or semi-extensive grazing. However, vineyards are now replacing the traditional land uses at the southern end of the valley and if that trend were to continue it could see an increase in the number of abstraction points. Vineyard water use occurs at a lower rate than dairy and crop farming so in areas where that change in land use occurs there may be a decrease in abstraction rate. Conversely, if vineyard development occurs on currently unirrigated areas there will be an increase in water demand.

Irrespective of those changes, the development of new abstractions allows a consideration of the most appropriate water management strategies to be put in place on new consent applications.

Based on the reported ecological values in the lower reaches of Are Are Creek, a balance will need to be struck between the amount of water that is allowed for abstraction and the way in which it is controlled relative to the amount of water that is required to be left in the stream.

Surface water abstractions cause a direct abstraction on surface flow which is a direct and immediate reduction in flow.

The information in this report demonstrates that groundwater seepage contributes to surface flow and therefore it is to be expected that abstractions from groundwater will cause some depletion of the surface flow. However the surface water depletion effect that is caused by groundwater pumping is not direct and tends to build up gradually depending on the duration of pumping, the proximity of the abstraction well to the stream (both laterally and vertically) and the degree of hydraulic connection between the abstraction well and the stream bed.

From a management perspective the following issues require consideration:

- what are the critical values of Are Are Creek that require protection;
- which reaches of the Creek require protection;
- what surface water flow regime provides that protection.

Those surface water values then need to be balanced against the needs for water abstraction to occur at a reasonable level of reliability to allow a range of diversified land uses.

A third factor to consider is catchment land use activities and their impact on both the quantity of water available (i.e. surface run off and infiltration rates) and water quality impacts. Modifications to, and controls on, land use activities can alter the availability of water within the catchment.

Ideally all these three factors (in-stream requirements, abstraction requirements and land use impacts) should be considered via a community consultation process to determine where the most appropriate management balance should be struck.

In considering any consent applications it is helpful to consider the change in land use that is occurring and its associated impact on the water resources, which might be greater, or smaller, than what the Creek has experienced to date.

For surface water abstractions the implementation of a consistent allocation regime is relatively straightforward, although some allowance (and dispensation) for existing abstractions may sometimes be required. For groundwater abstractions their key allocation restrictions are likely to be based on their effect on surface water flows. However it is important to recognise that the estimation of stream depletion effects caused by groundwater pumping is not a precise science and that the effects often develop gradually. Therefore it may be appropriate to have a threshold below which no surface water restrictions should apply. This threshold is partly in recognition of the uncertainties associated with estimating the magnitude of stream depletion effects.

As stated in section 4.3 there is an absence of reliable pumping information. However, as an initial indication of potential stream depletion effects, Table 4 has been prepared to provide an initial generic indication of potential stream depletion effects from existing consented groundwater abstractions.

The assessment is based on the following assumed aquifer parameters:

- transmissivity = T = 500 m^2/day;
- storage coefficient = S = 0.1;
- stream bed conductance = λ = 7m/day.

The last column in Table 4 indicates the proportion of the depletion effect that could be subject to surface flow restrictions if a threshold cut off of 5L/s was adopted.

It is important to recognise that this is a very simplified and indicative assessment and site specific testing should be undertaken to more precisely define this potential effect.

Table 5: Indicative Estimate of Stream Depletion Effect

MDC Resource Consent and Holder	Abstraction Rate (L/s)	Nearest Stream	Distance to Nearest Stream (m)	Estimated Stream Depletion Rate After 30 Days (L/s)	Estimated Stream Depletion Rate That May Require Management Restrictions (L/s)
U021144 (Forrest)	1.3	Are Are Creek	200	0.7	Small abstraction, below management threshold
U020903 (Zaccarat)	2.1	Are Are Creek	100	1.4	Small abstraction, below management threshold
U030854 (Jackson)	6.9	Are Are Creek	50	5.1	0.1
U030679 (Jackson)	20	Wairau River	240	10.0	5.0
U051128 (Wooding)	2.7	Are Are Creek	420	0.9	Small abstraction, below management threshold
U020460 (Heinemann)	2.0	Wairau River	500	0.5	Small abstraction, below management threshold
U070972 (Opawa River Vines)	8.1	Are Are Creek	28	6.2	1.2

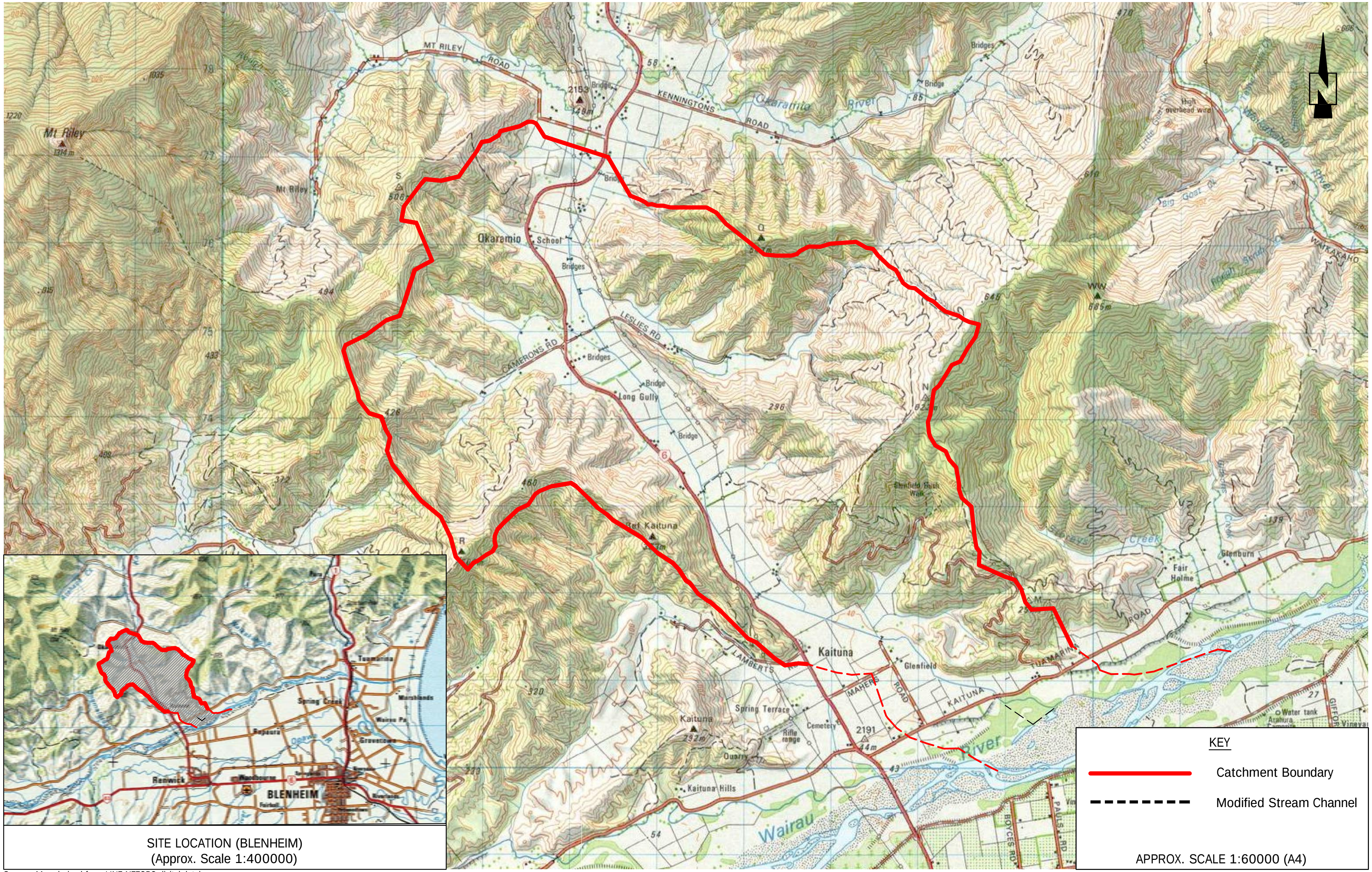
6.0 Conclusion

Are Are Creek is a small and highly modified stream which drains surface runoff from the local catchment (totalling around 3,200ha) and groundwater from the former swampy soils which have now been drained to allow productive farming. The basement schist strata was initially eroded by the Pelorus River, which flowed south-wards during earlier geologic times and infilled the valley floor with gravels derived from its catchment. However, tectonic uplift changed that river's course and the upper part of the valley floor infill comprises poorly sorted schist gravels in a sandy/clayey matrix. This has provided a productive aquifer that is used to meet local water supply needs, however pumping at high rates and/or a prolonged period is likely to cause an indirect depletion effect on surface flow in Are Are Creek.

The management of water resources in this catchment needs to focus on finding a balance between the following three factors:

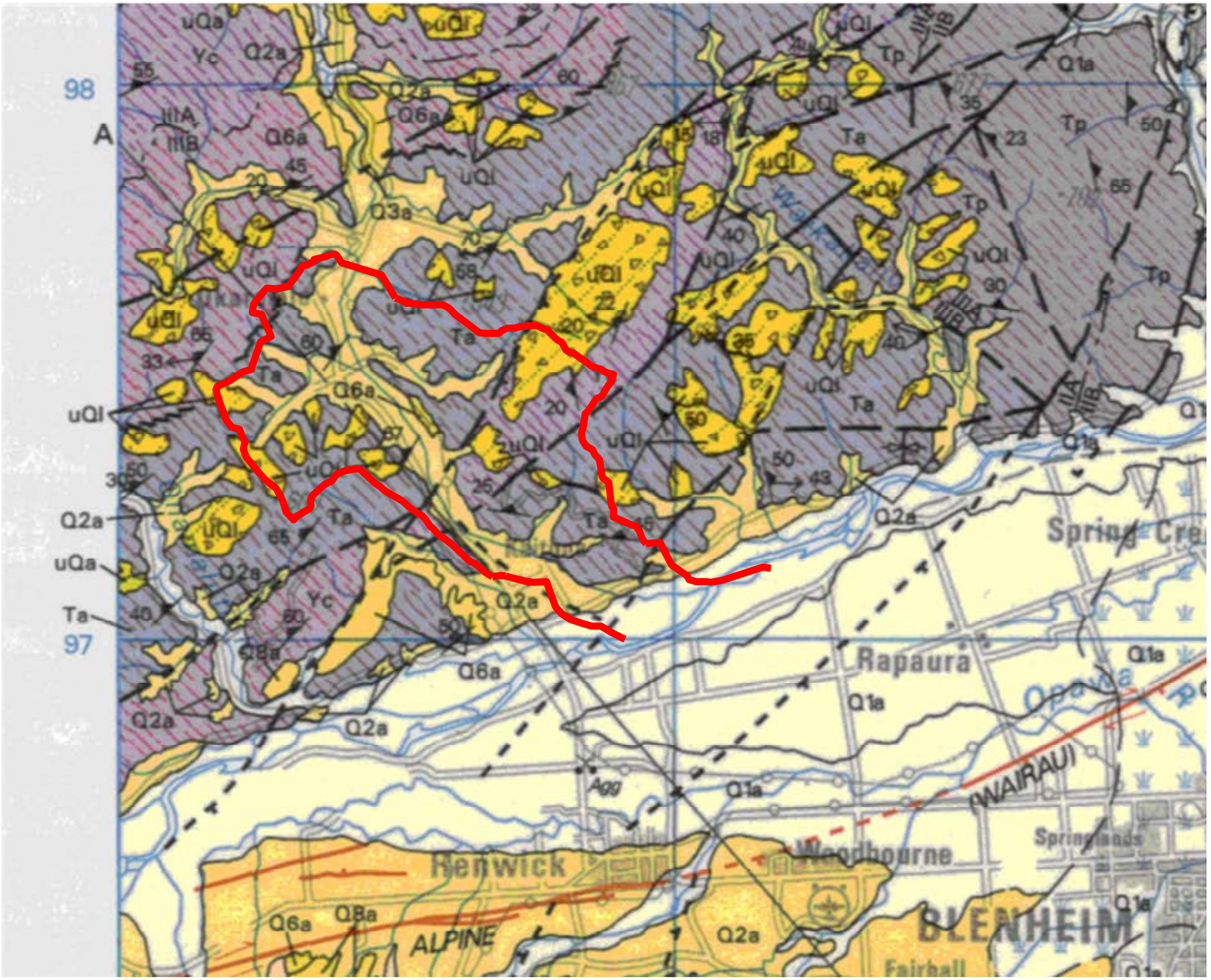
- the flow requirements of important reaches of Are Are Creek for the protection of stream ecology;
- the likely needs of abstraction, both in terms of quantity and reliability;
- land use activities and their impact on infiltration and surface runoff.

The technical information in this report provides an initial basis for understanding the water resources issues for future water development in the Are Are Creek catchment. This information should be shared with interested parties and further developed in a consultative manner to develop the most appropriate water resources management regime to be implemented.



Source: Map derived from LINZ NZTOPO digital database

Figure 1 : ARE ARE CREEK CATCHMENT



Holocene & Quaternary	
	Landside Deposits
uQ1	Undifferentiated landslide deposits ranging from coherent shattered masses of rock to unsorted angular rock fragments in a fine grained matrix
	Fan Deposits
Q1a	Alluvial fan, scree, and colluvial deposits consisting of poorly sorted gravels
Q2a Q3a Q6a	Poorly sorted steep fan gravel deposits
uQa	Undifferentiated poorly sorted steep fan gravel deposits
	Alluvial Deposits
Q1a	Well sorted floodplain gravels
Q2a	Poorly to moderately sorted gravel with minor sand or silt underlying aggradational and degradational terraces; includes minor fan gravel
Q3a Q4a Q6a	Weathered, poorly to moderately sorted gravel underlying loesscovered, commonly eroded aggradtional surfaces
uQa	Undifferentiated weathered, poorly sorted loess covered alluvial gravel deposits
	Swamp Deposits
Q1a	Swamp deposits consisting of poorly consolidated silt, mud , peat, and sand - Estuarine deposits consisting of poorly consolidated silt, peat, sand, and minor gravel
Q2a	Swamp deposits consisting of peat, sand and mud
Jurassic / Triassic	
	Marborough Schist

Figure 2 : GEOLOGY MAP
(the geologic data included here is provided by the institute of geological sciences.)
Image files from QMAP Wellington - Begg, J.G.; Johnston, M.R.
(compilers) 2000: Geology of the Wellington area.
Institute of Geological & Nuclear Sciences

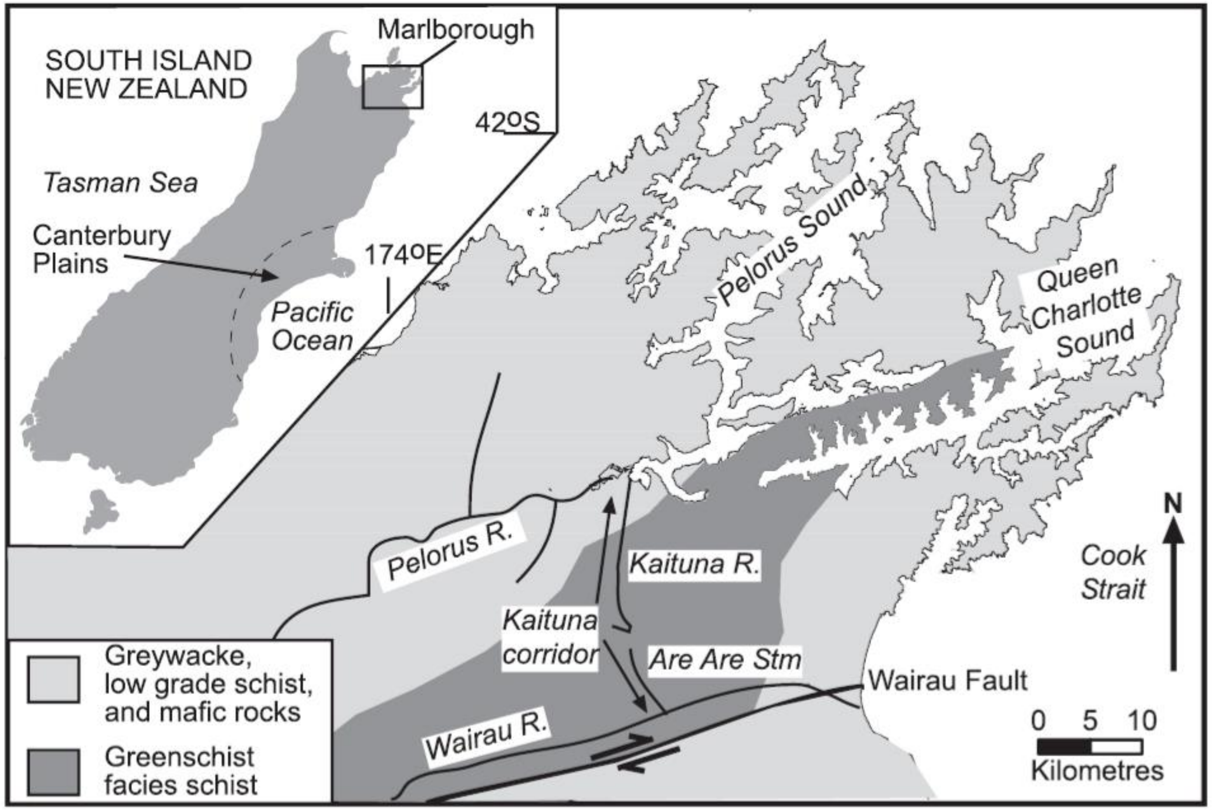


Fig. 1 Geological and locality maps (after Begg & Johnston 2000), showing the Marlborough Sounds area and major rivers, and the Kaituna corridor (valleys of Kaituna River and Are Are Stream) that is the focus of this study.

Figure 3 : (From Craw et al, 2007)

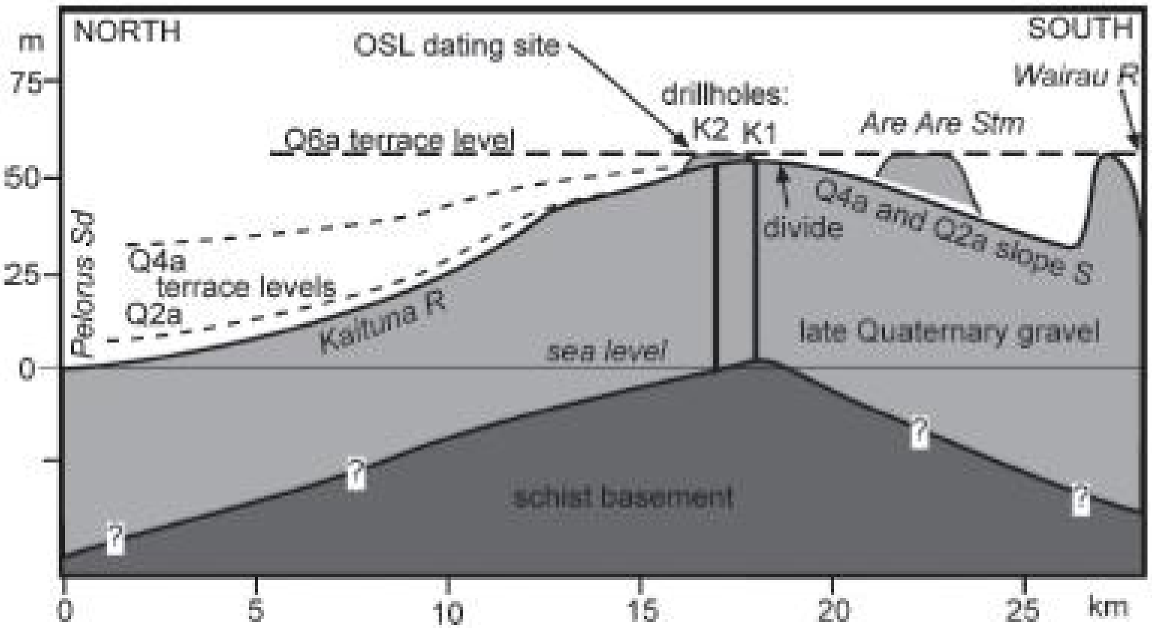


Fig. 2 Sketch cross-section through the Kaituna valley from Pelorus Sound (left) to the Wairau River (Fig. 1). Schist basement boundary is projected from valley walls, and constrained by drillholes K1 and K2 (Wopereis 1999). The topographic profile follows Kaituna River and the Are Are Stream. Locations of Q6a terrace remnants, above the rivers, are indicated. 100× vertical exaggeration.

Figure 4 : (From Craw et al, 2007)

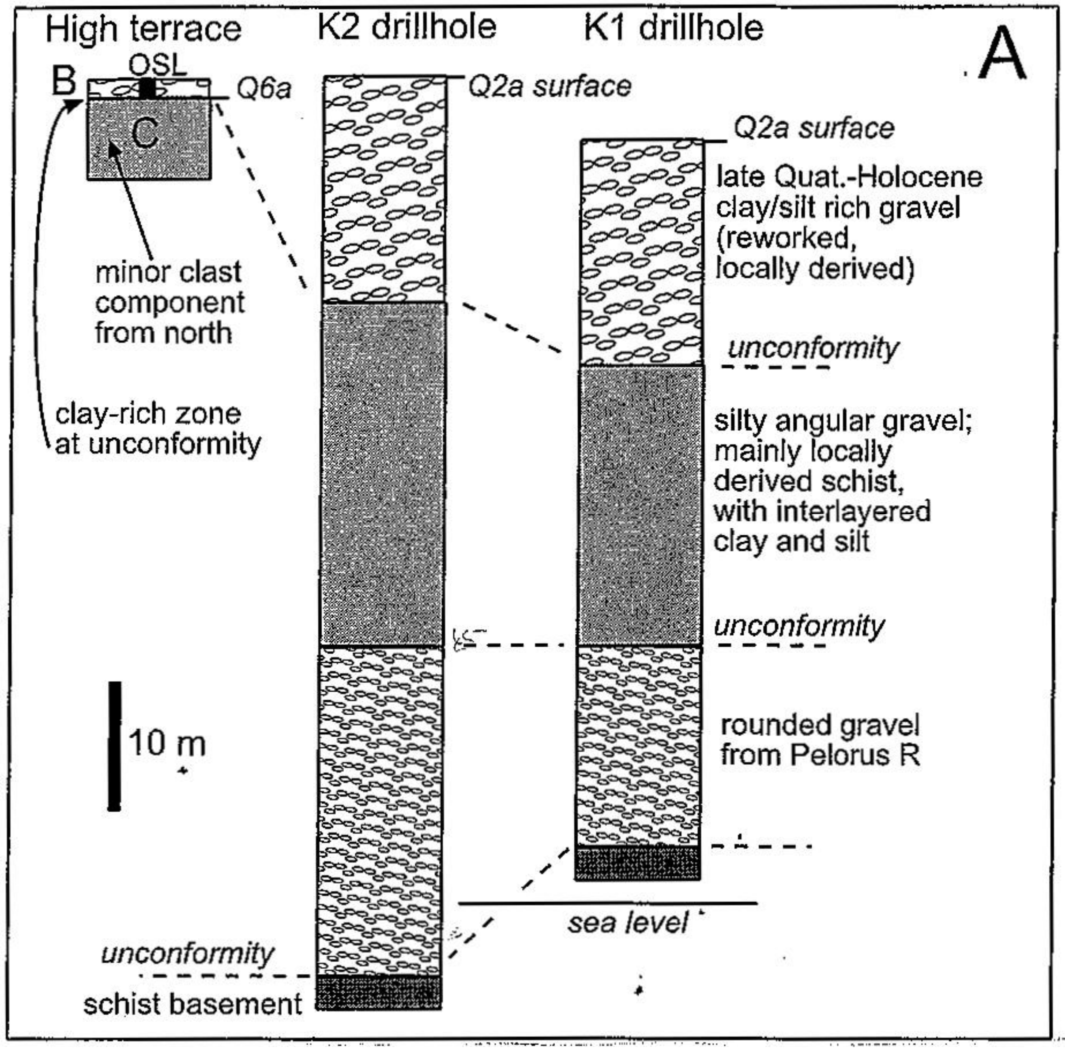


Fig. 3 Stratigraphy of Kaituna valley Quaternary sediments. **A**, Left-hand stratigraphic column is from outcrops of the high Q6a terrace in the middle Kaituna valley. The black square shows the relative position of OSL dates. The centre and right columns were compiled from drillhole data (Wopereis 1999). Dashed lines show suggested correlations (see text). **B**, **C**, Azimuths of dip directions (15° class intervals) of schist clasts in gravel in exposures near the top of high Q6a terrace in A. B = near-surface deposits; C = underlying deposits.

Figure 5 : (From Craw et al, 2007)

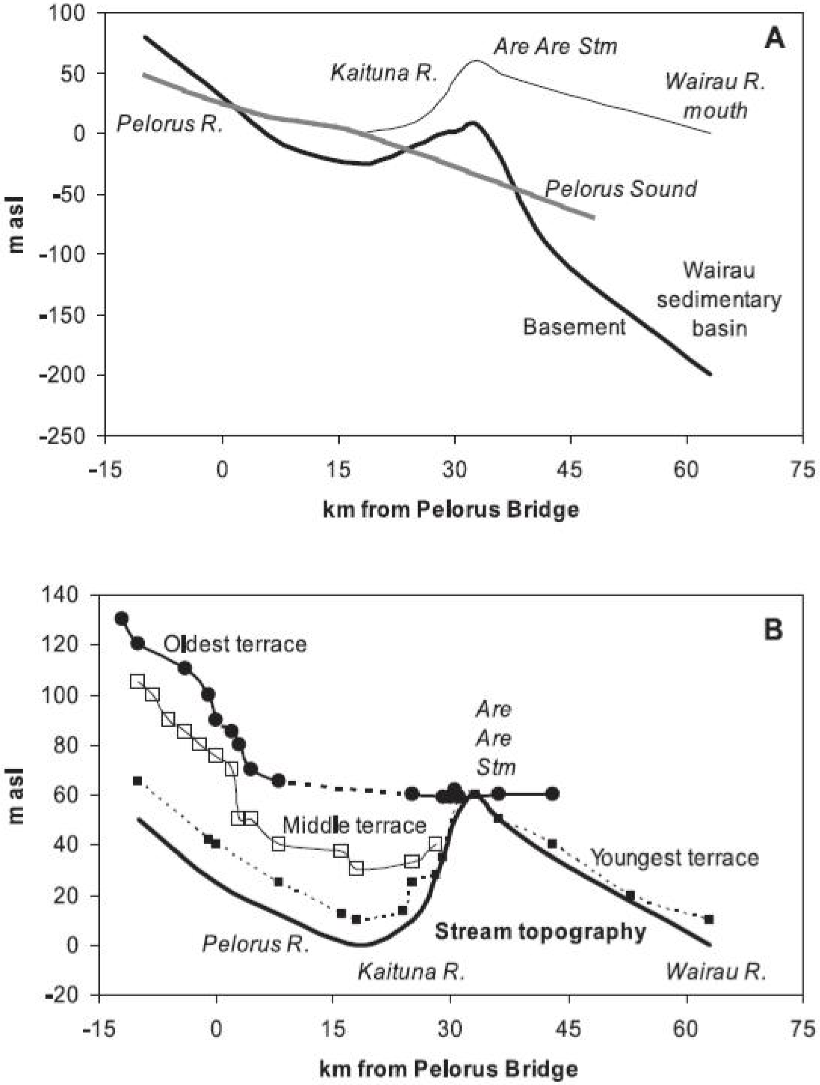


Fig. 4. Topographic profiles of rivers and terraces described in this study, with heights (in metres) above sea level (m asl) plotted with distance from Pelorus Bridge (Fig. 2a) (**a**) Present profiles of Pelorus River (extended down Pelorus Sound, after Singh 1994), and Kaituna valley to the sea via the Wairau River. Bedrock profile down Pelorus River and through the Kaituna valley is estimated from field observations and drillhole data of Mortimer & Wopereis (1997). (**b**) Terrace profiles for the three terraces mapped in this study in the Pelorus and Kaituna valleys (see text for details), in comparison with the present topographic profile along the valleys. Symbols on profiles represent observation sites.

Figure 6 : (From CRAW & J WATERS, 2007)

Fig. 5 A–D Serial sketches of evolving draining geometry in Marlborough at indicated times. Arrows show flow directions; dark shading is Q6a sediment; light shading is schist basement. **A**, Early in Oxygen Isotope Stage 6 with drainage to south. **B**, At end of Oxygen Isotope Stage 6. **C**, After the Last Interglacial, at beginning of Oxygen Isotope Stage 4. **D**, Present geometry with most drainage to north.

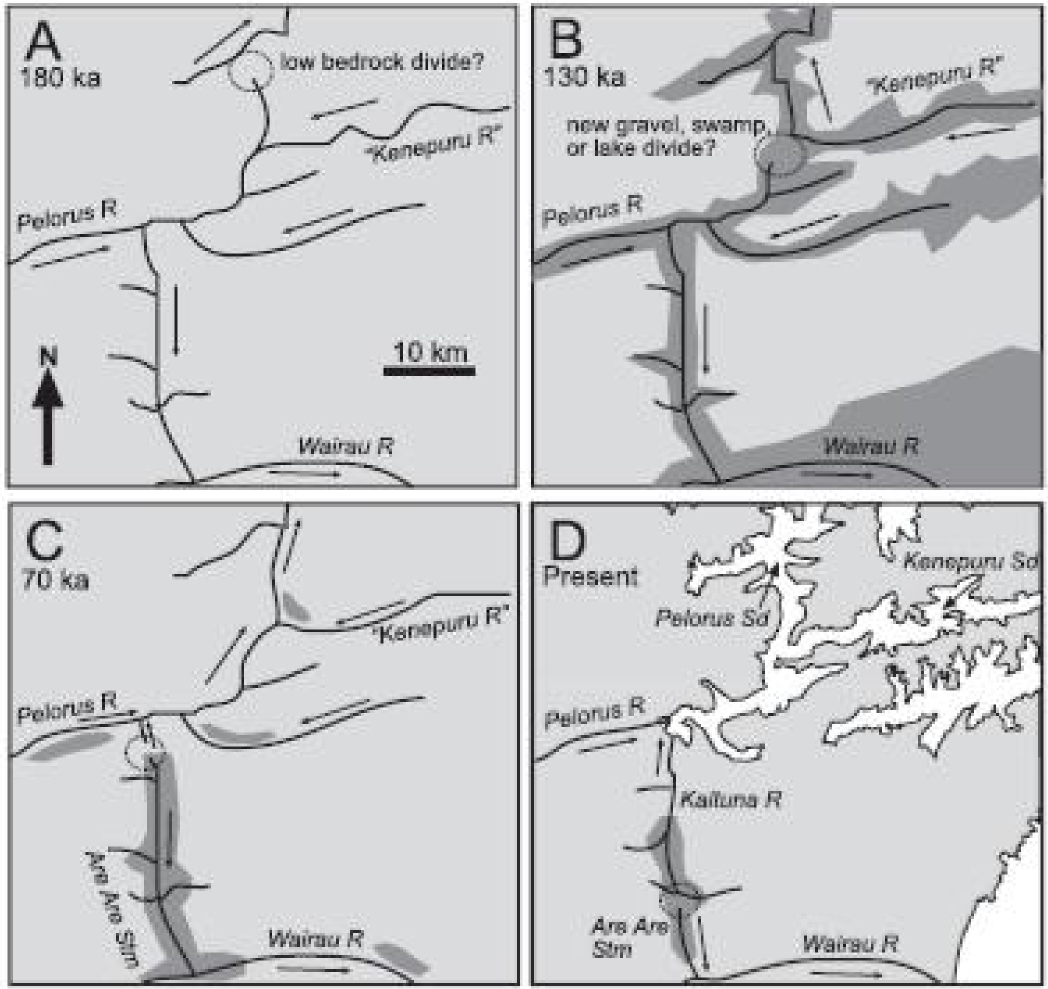


Figure 7 : (From Craw et al, 2007)

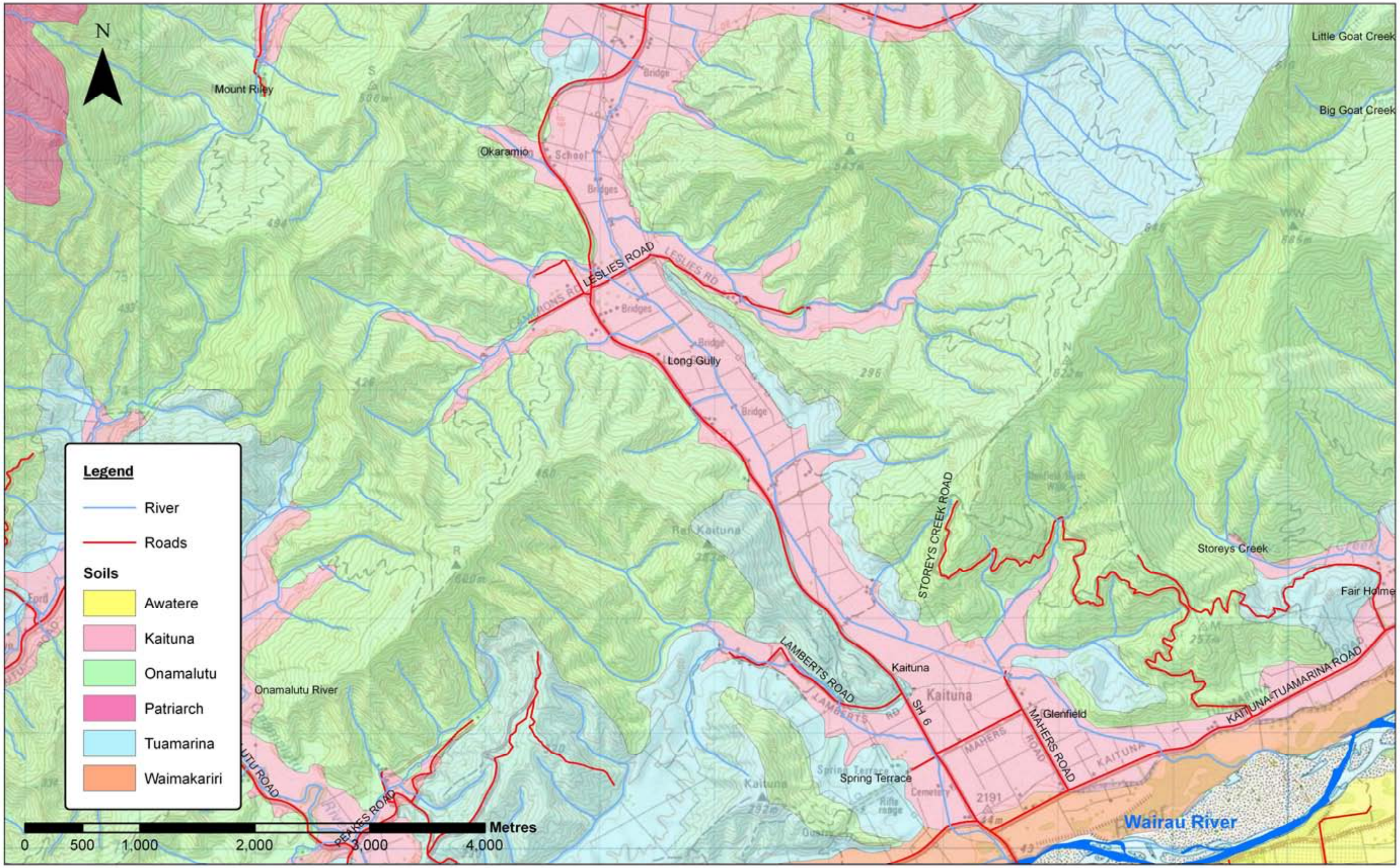
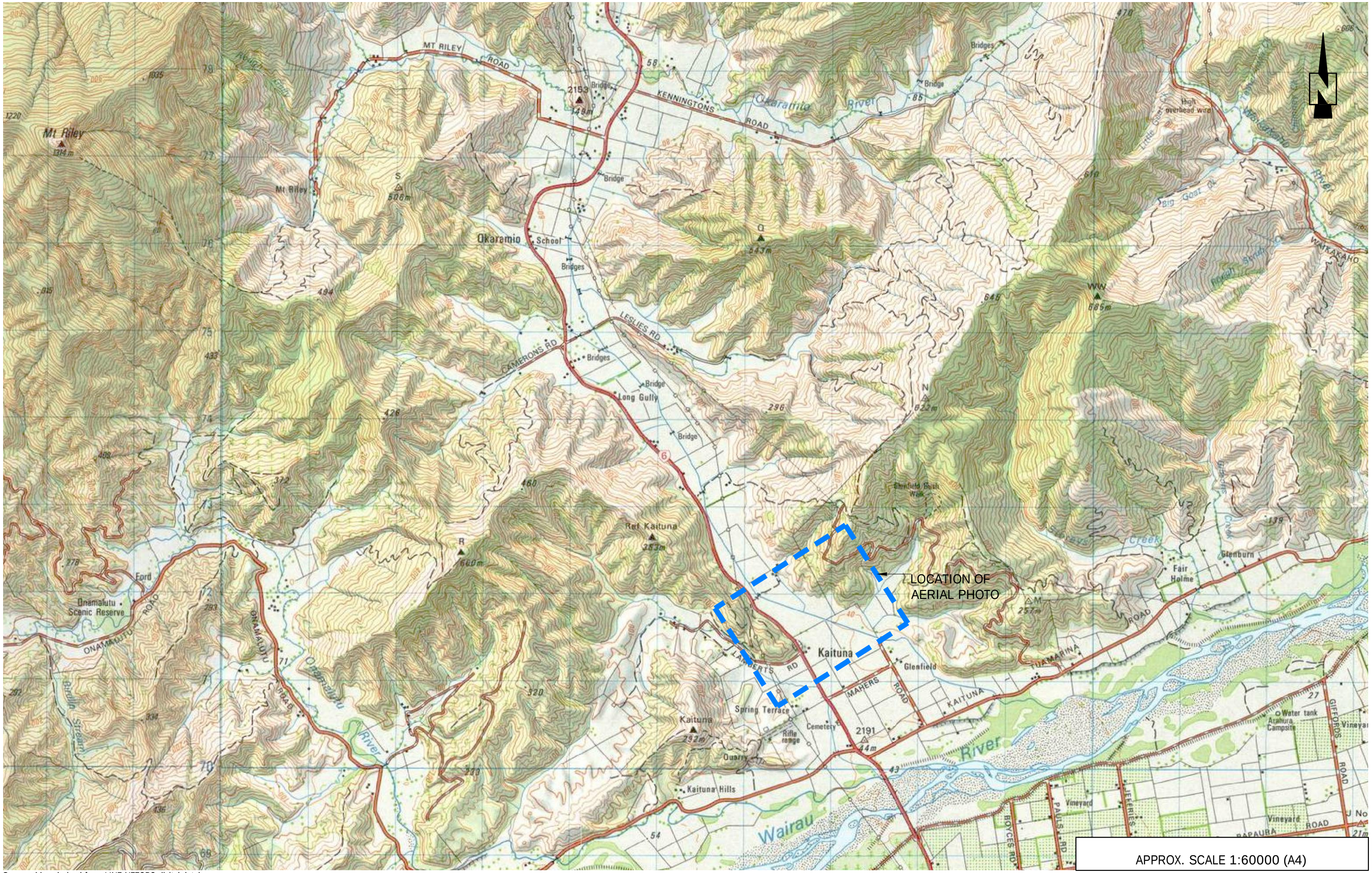


Figure 8 : SOIL MAP



Source: Map derived from LINZ NZTOPO digital database

Figure 9a : LOCATION OF HISTORICAL AERIAL PHOTO OF ARE ARE CREEK

Figure 9b : 1958 AERIAL PHOTO OF ARE ARE CREEK
(from MDC records)

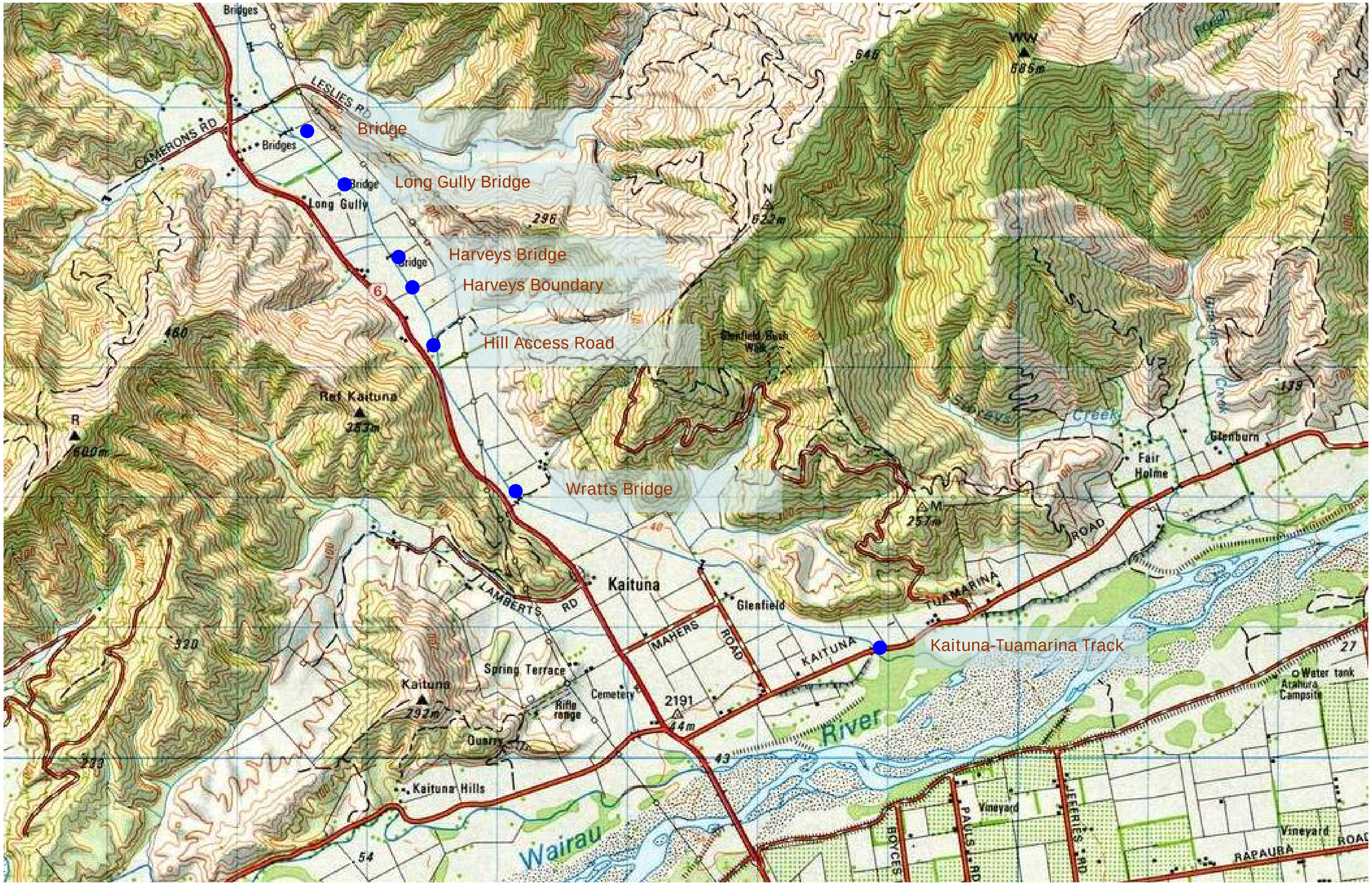


Figure 10 : SURFACE FLOW GAUGING LOCATIONS

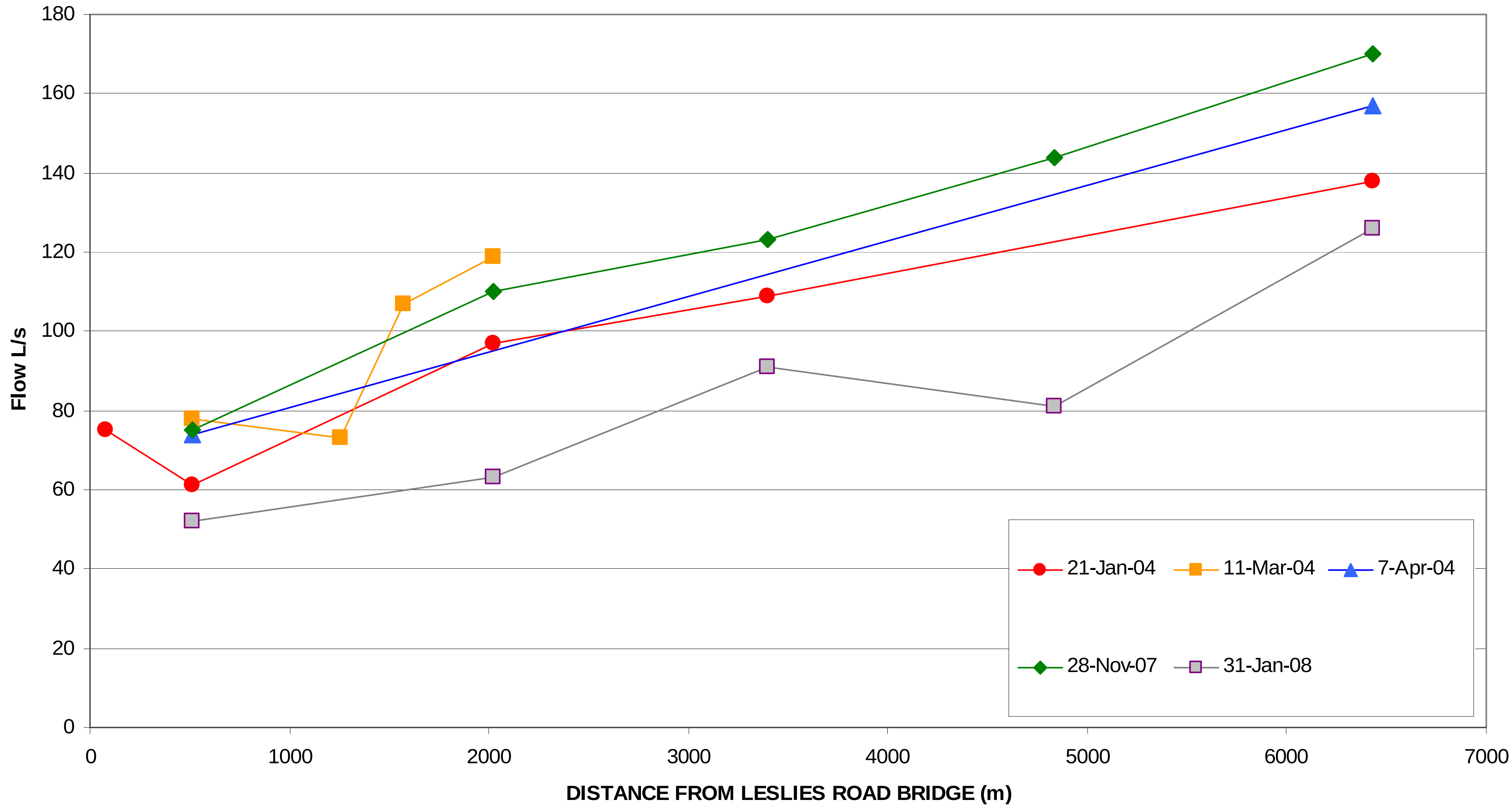


Figure 11 : ARE ARE CREEK FLOW GAUGINGS

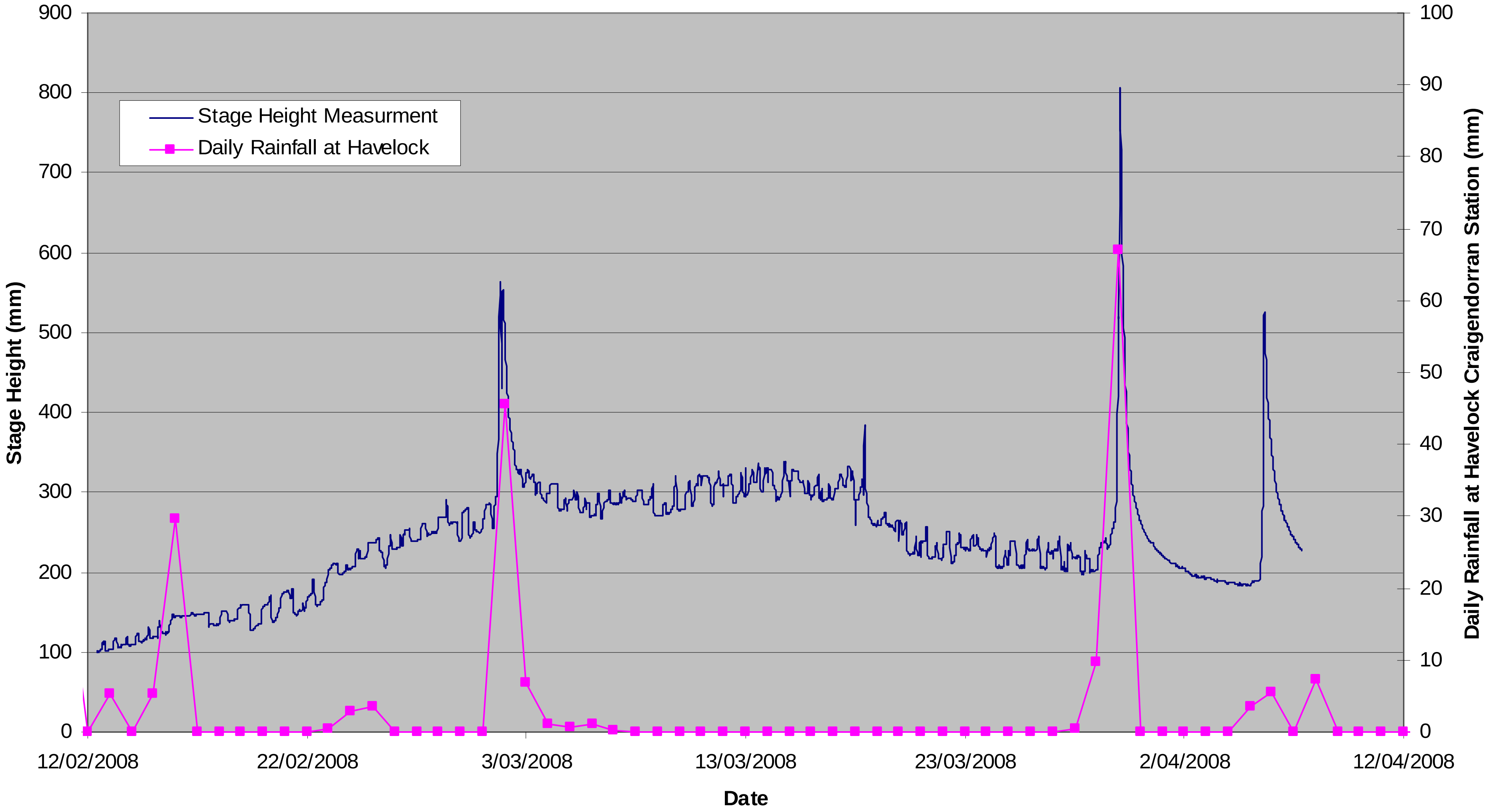


Figure 12: STAGE HEIGHT MEASUREMENTS AT OPAWA RIVERVINES

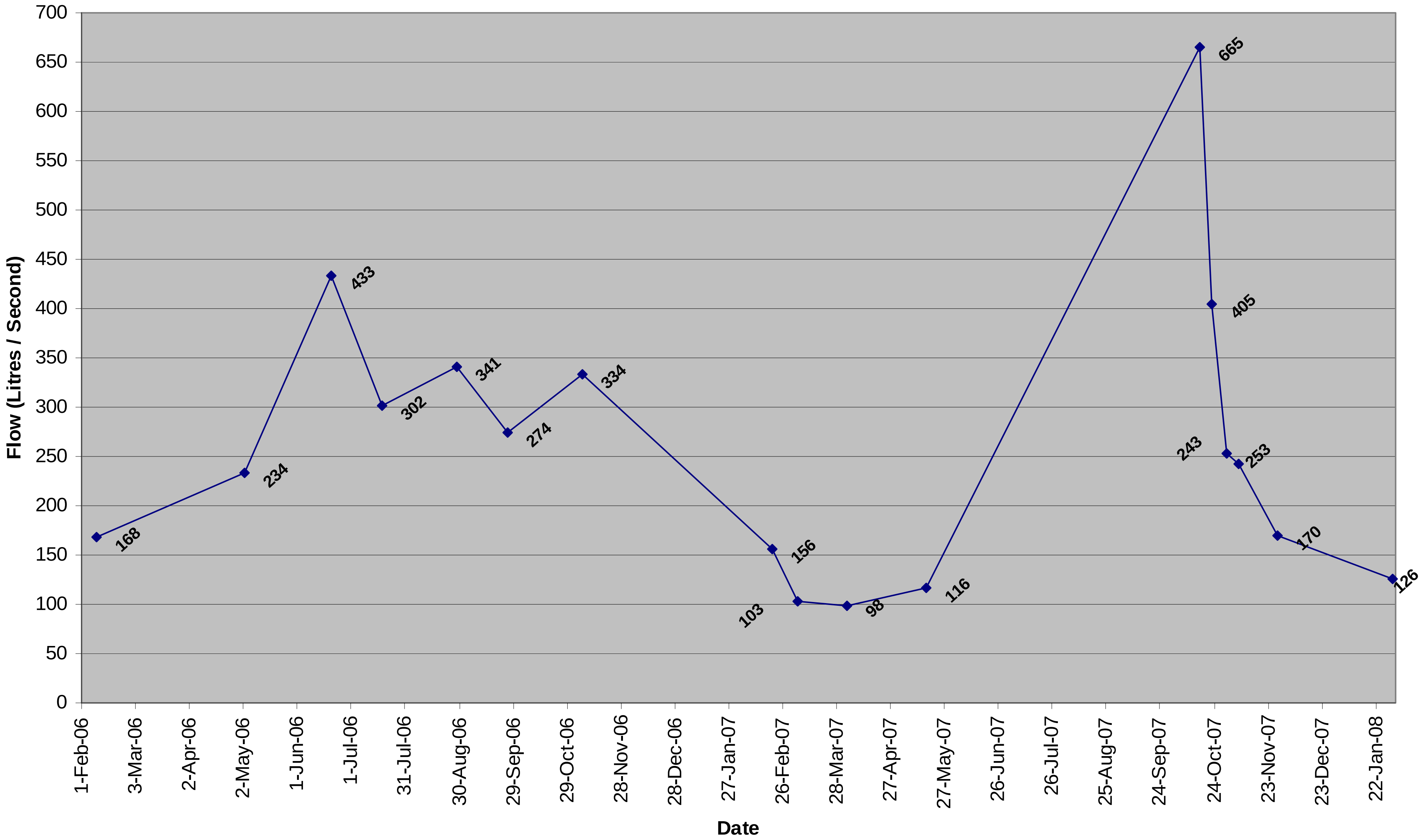
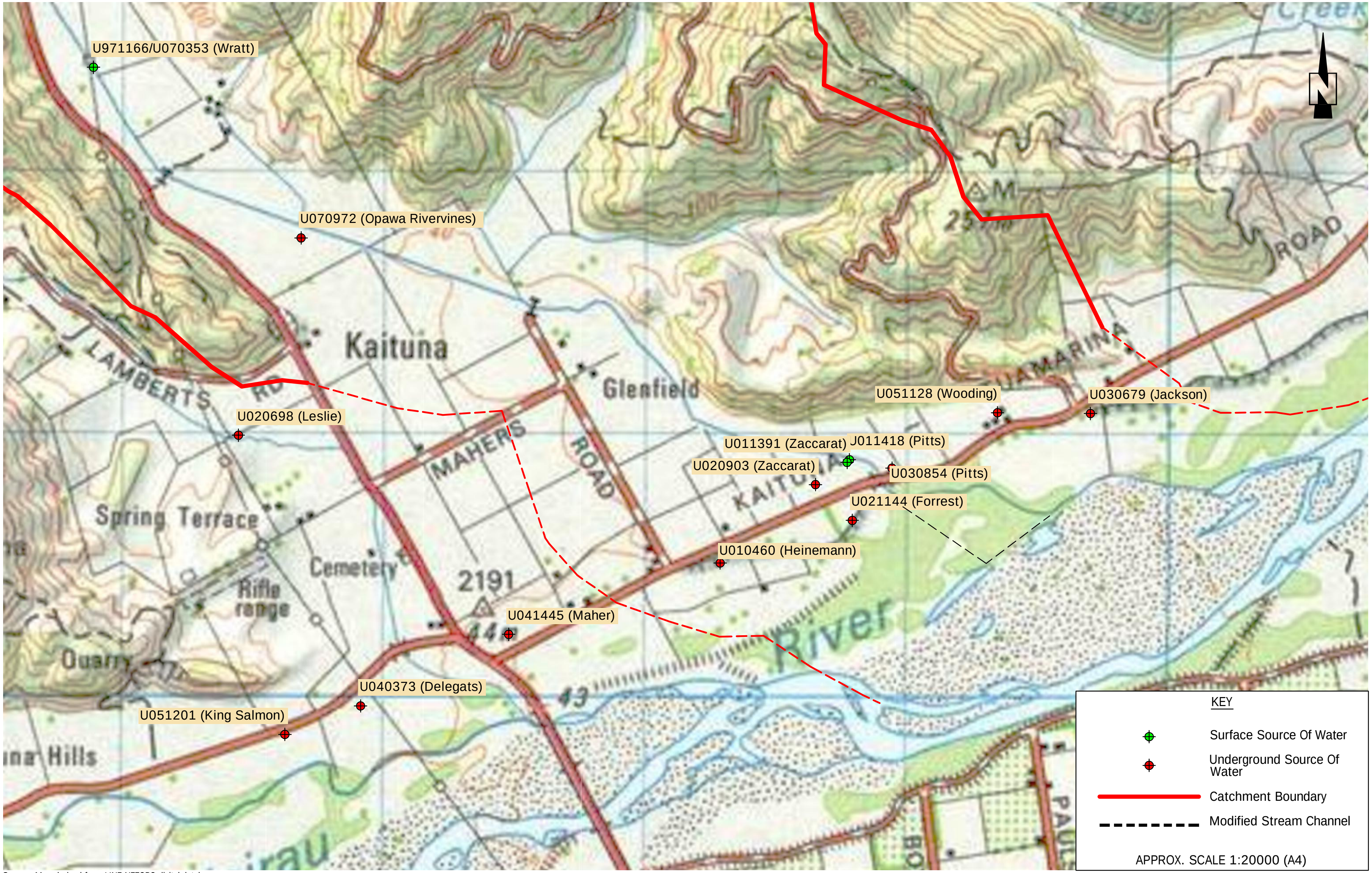
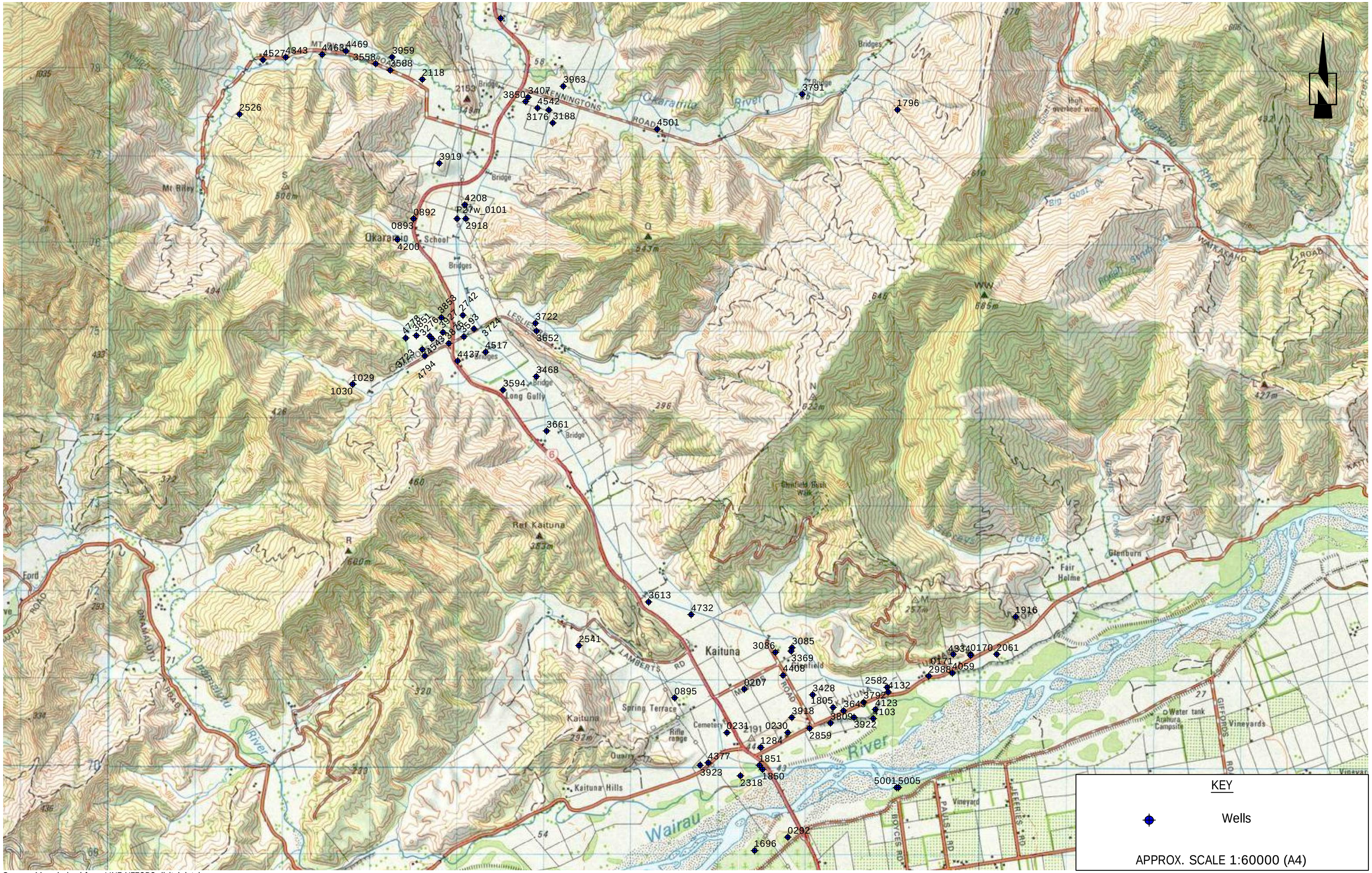


Figure 12a : ARE ARE CREEK GAUGED FLOW AT KAITUNA - TUAMARINA TRACK



Source: Map derived from LINZ NZTOPO digital database

Figure 13 : MDC RESOURCE CONSENT NUMBER & HOLDER



Source: Map derived from LINZ NZTOPO digital database

Figure 14 : GROUNWATER ABSTRACTION WELLS (as recorded on MDC data base)

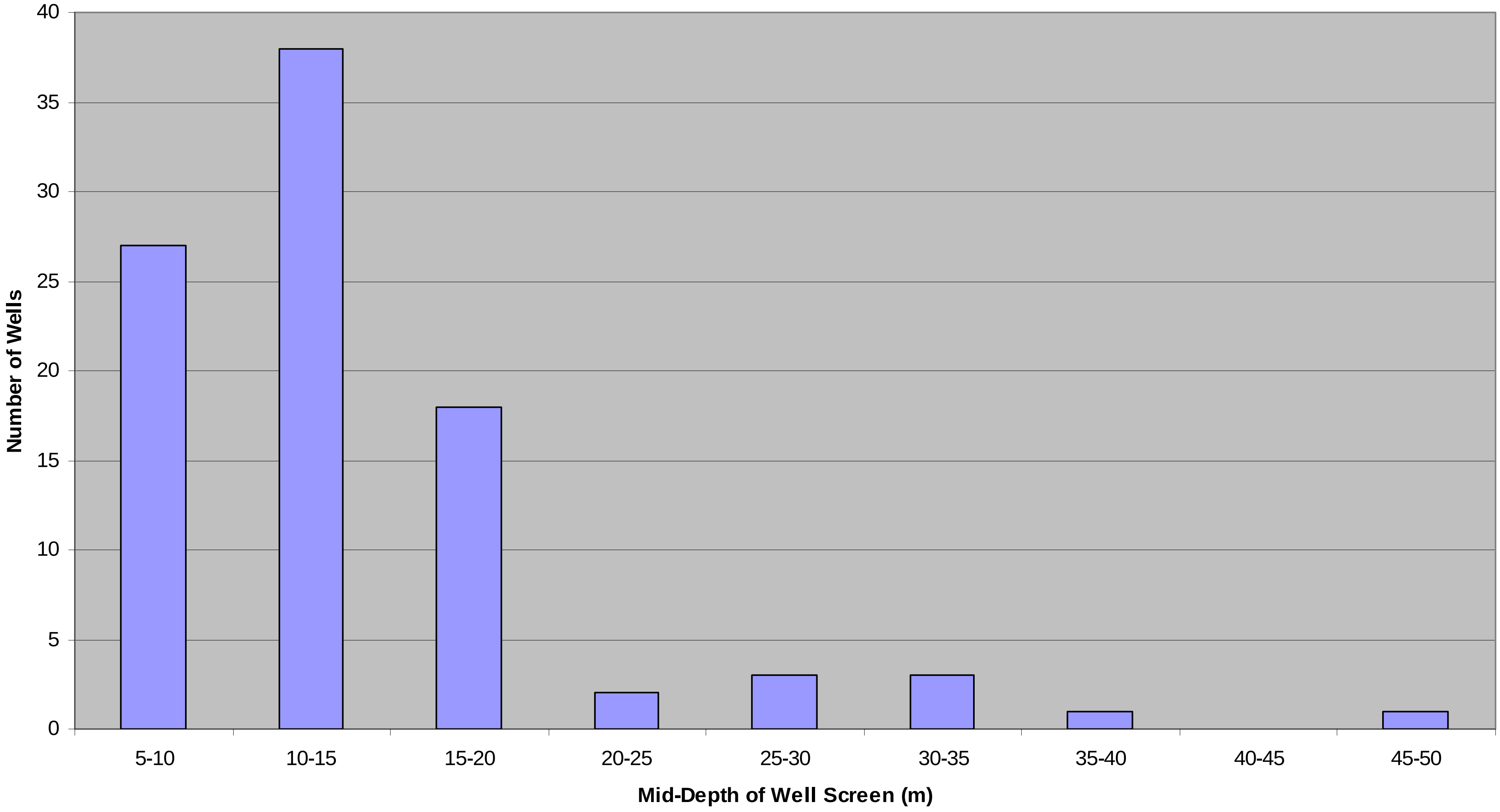
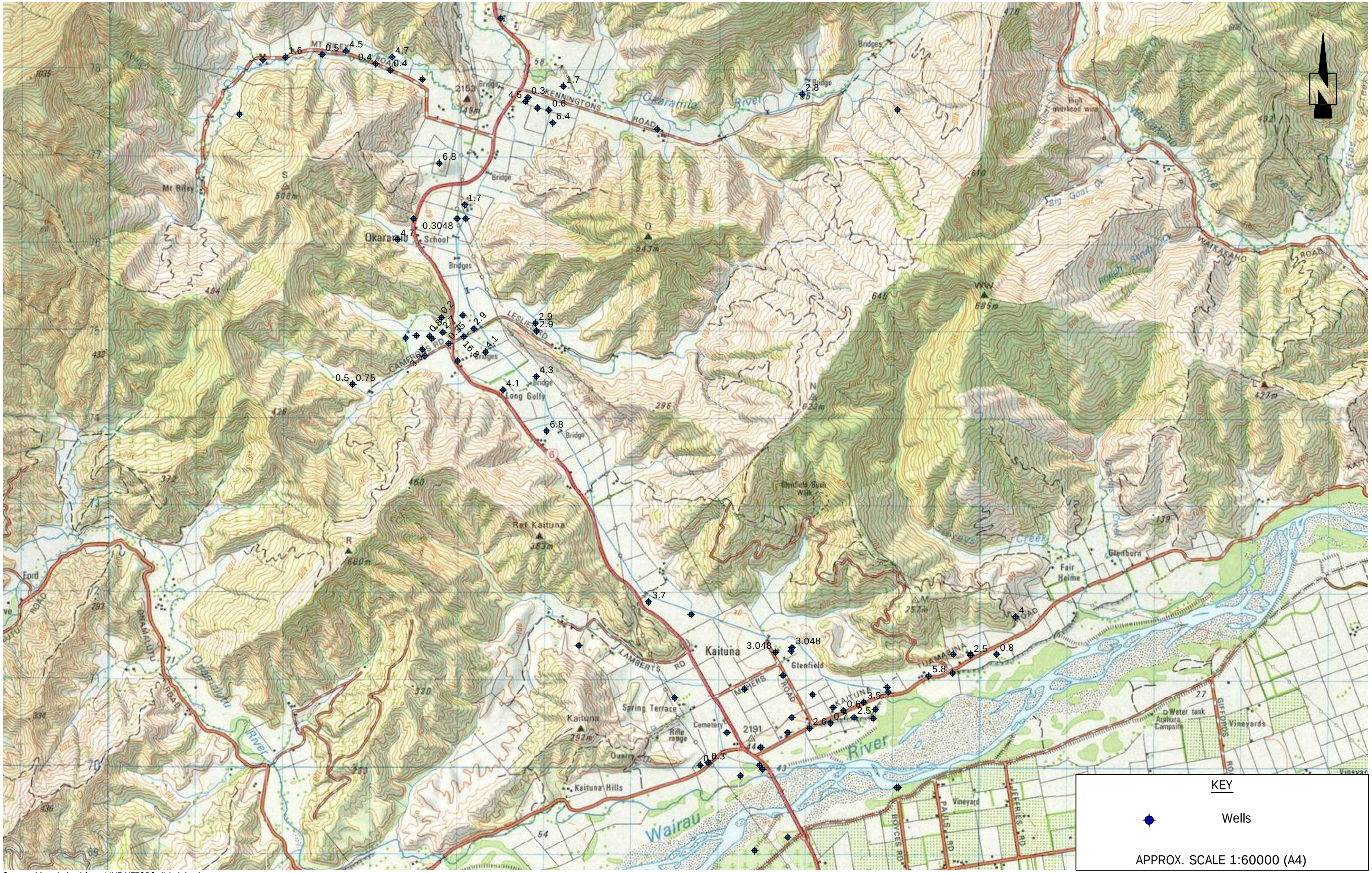


Figure 15 : WELL SCREEN DEPTHS



Source: Map derived from LINZ NZTOPO digital database

Figure 16 : THICKNESS OF FINE GRAINED STRATA OVERLYING WATER BEARING GRAVELS (m)

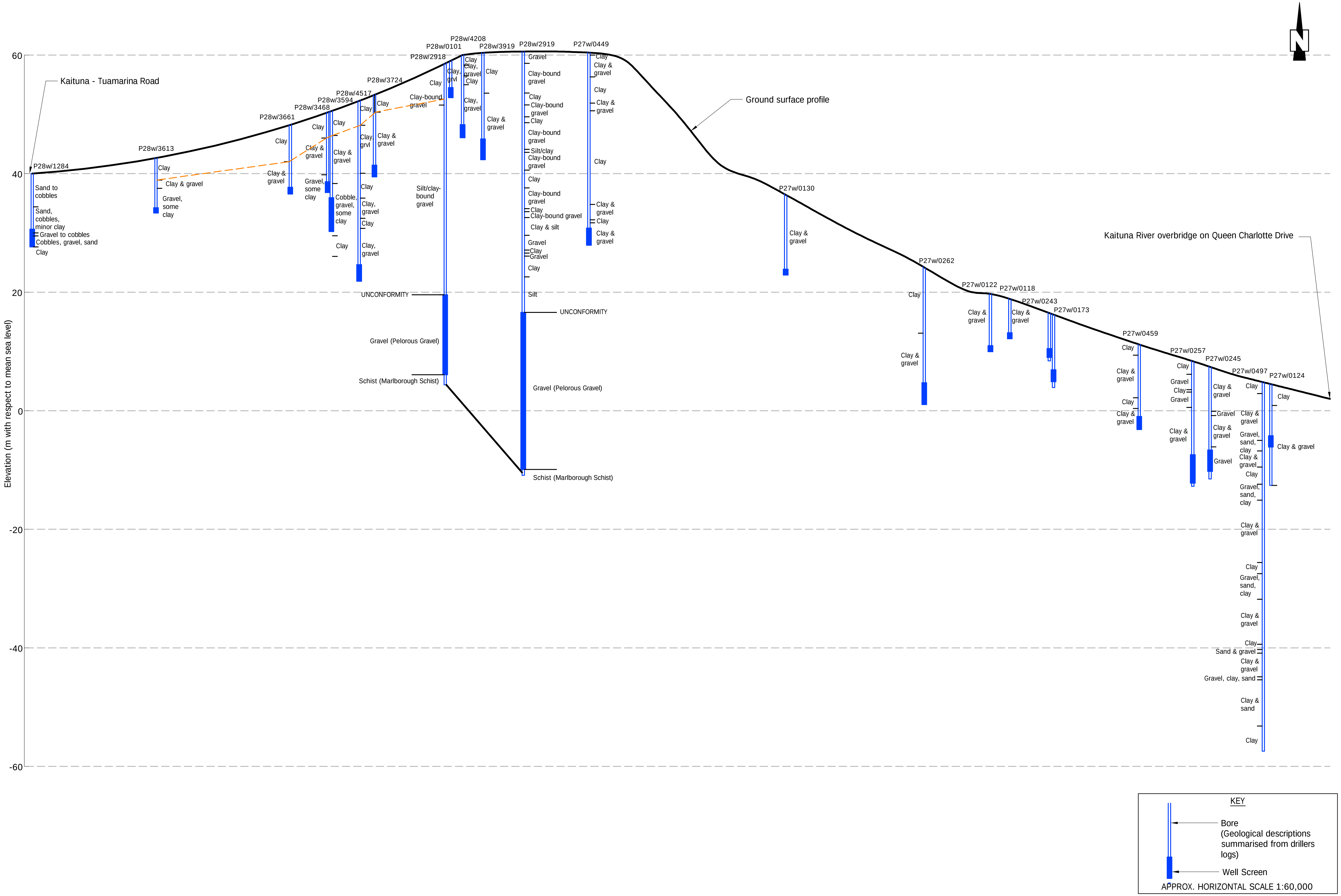


Figure 17 : HYDROGEOLOGICAL CROSS-SECTION

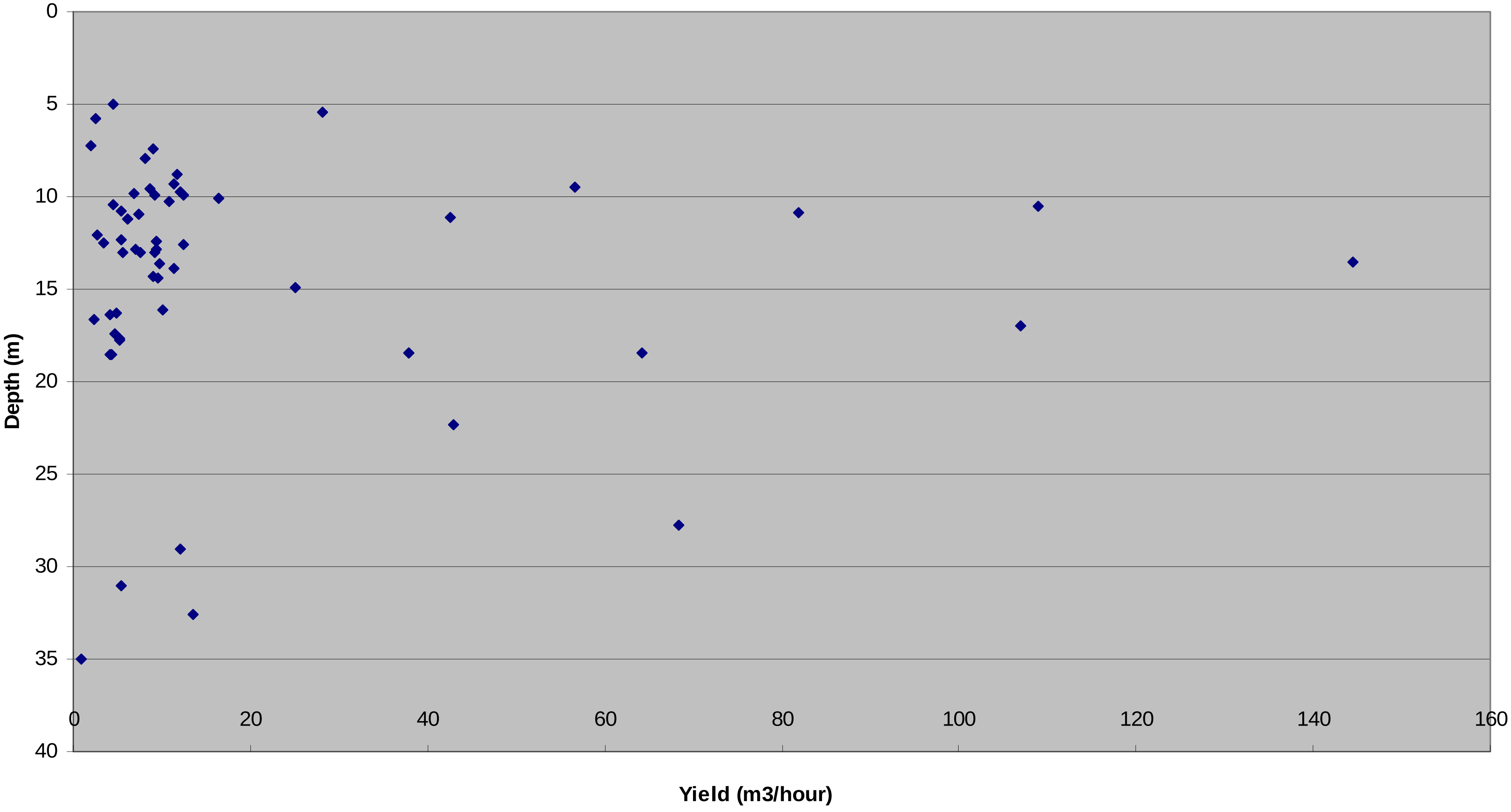


Figure 18 : WELL YIELDS

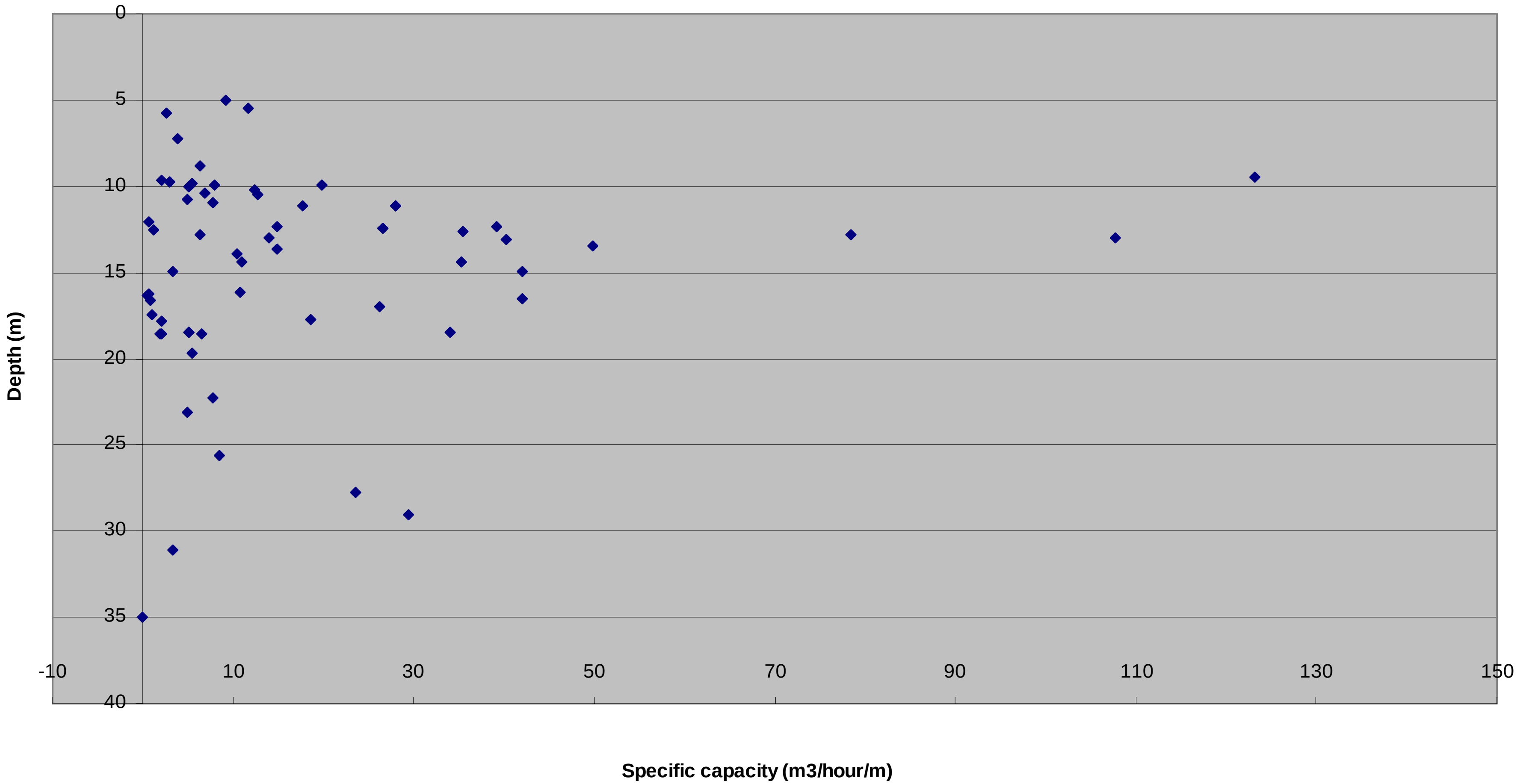
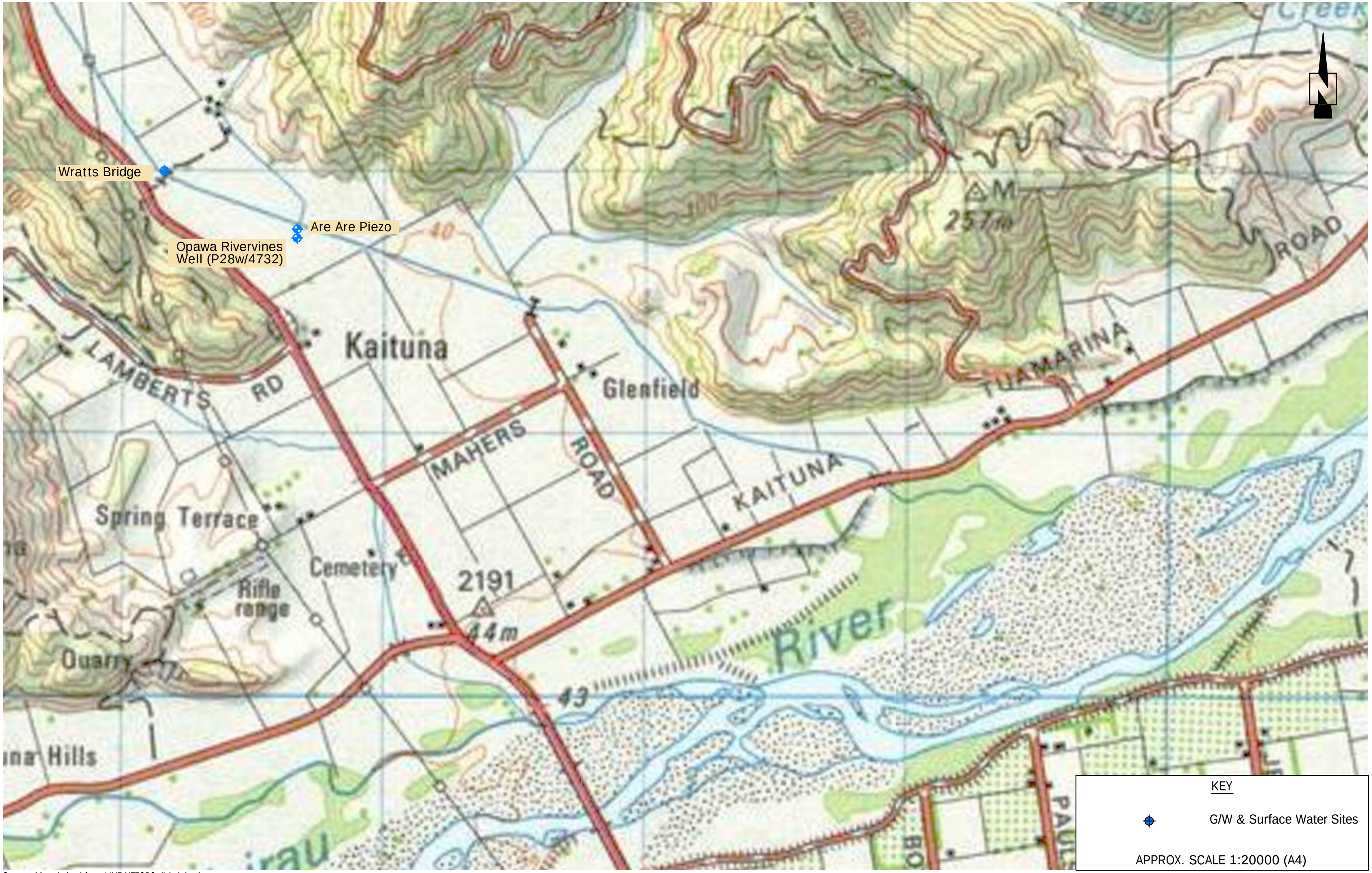


Figure 19 : SPECIFIC CAPACITY



Source: Map derived from LINZ NZTOPO digital database

Figure 20a : LOCATION OF GROUNDWATER AND SURFACE WATER ELEVATION SITES

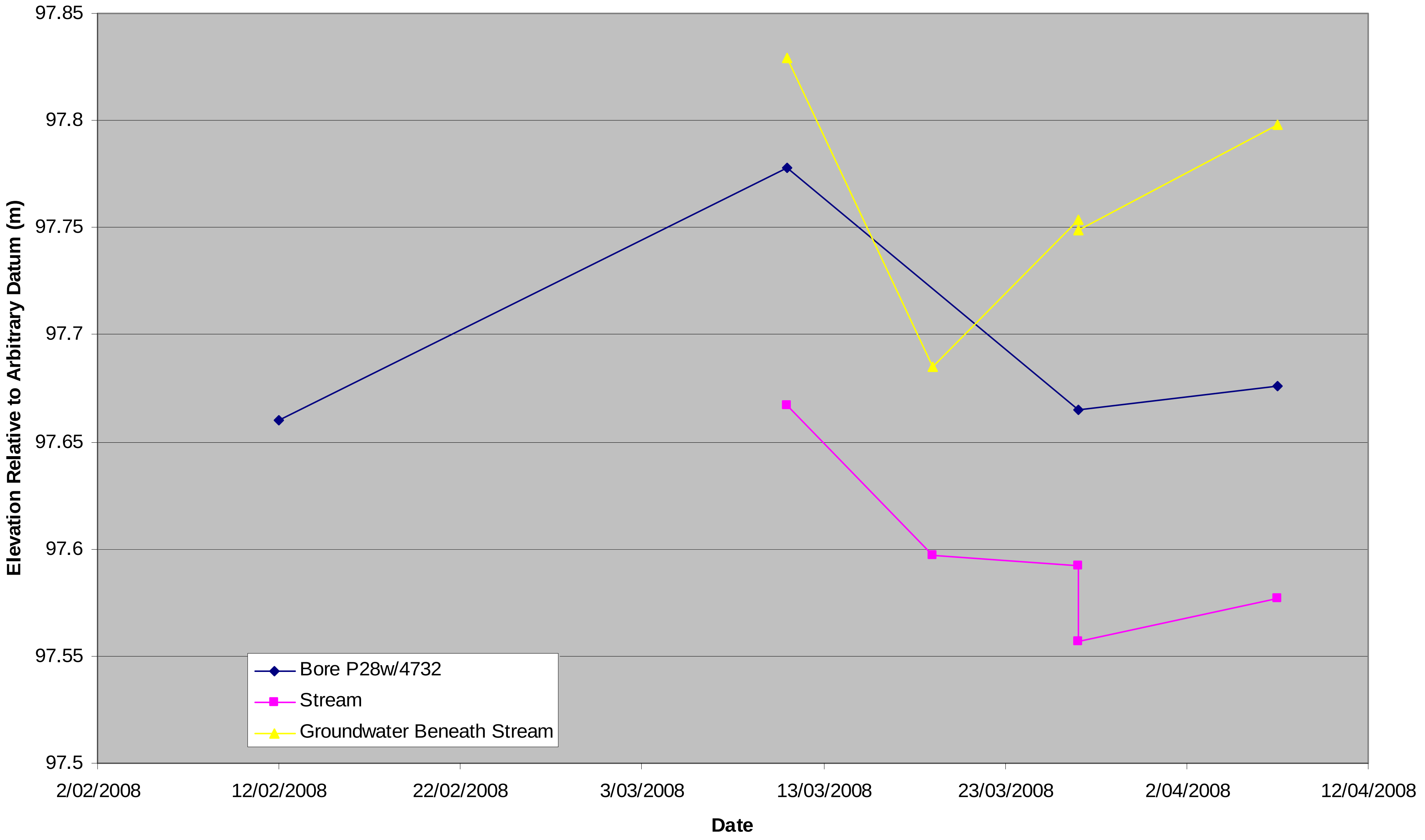
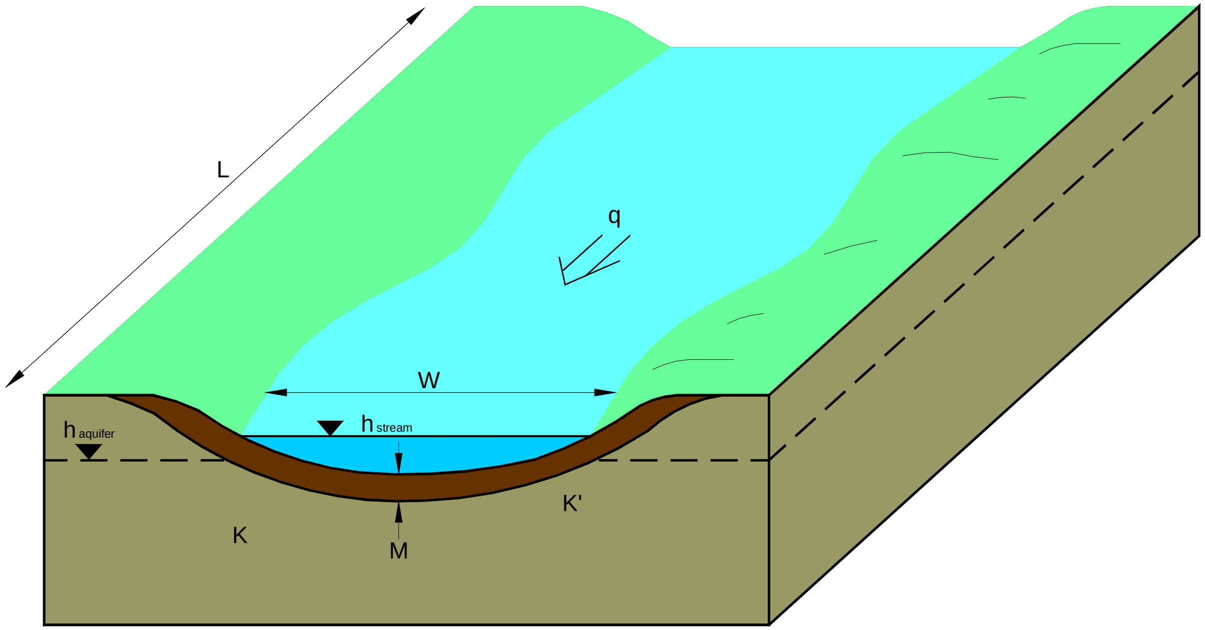


Figure 20b : ELEVATION OF GROUNDWATER LEVELS AND SURFACE WATER LEVELS

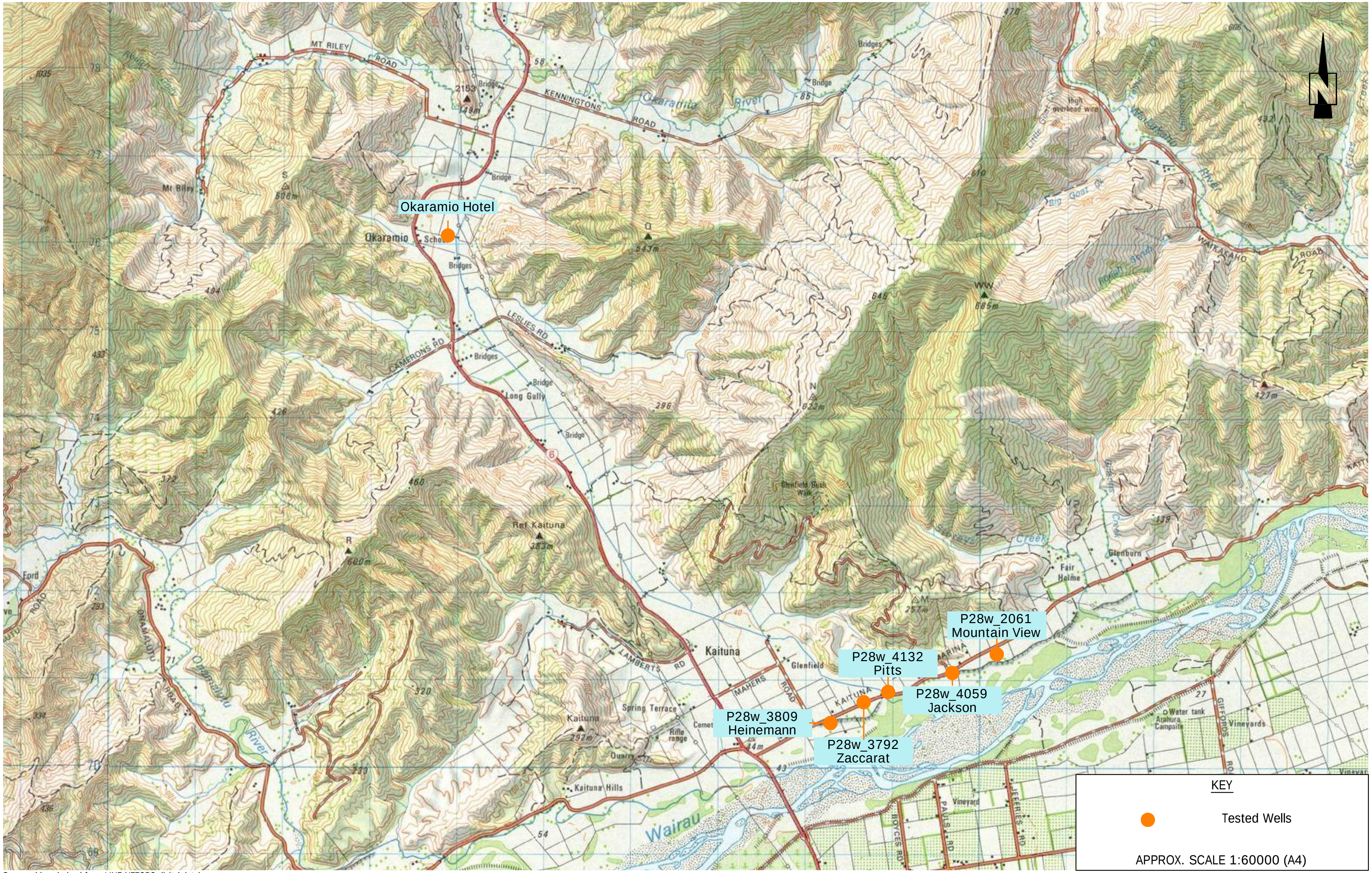


$$\lambda = \frac{\Delta q}{L\Delta h} = \frac{-K'W}{M}$$

Gauging and Piezometric surveys

Infiltration/Seepage measurements

Figure 21 : DEFINITION OF STREAMBED CONDUCTANCE (λ)



Source: Map derived from LINZ NZTOPO digital database

Figure 22 : LOCATION OF PUMP TESTED BORES

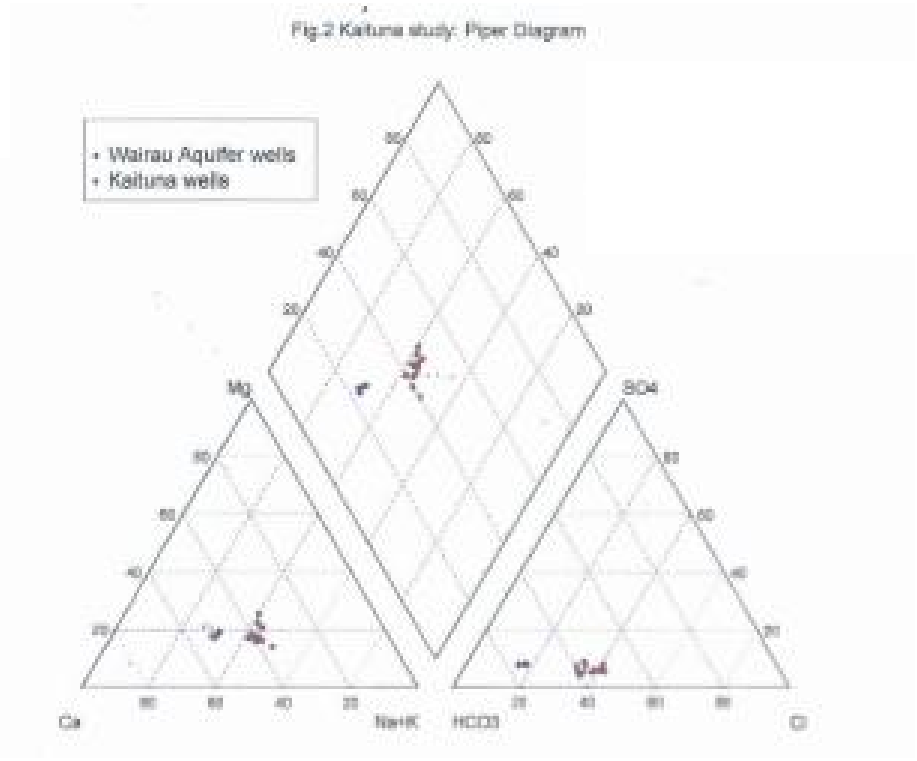


Figure 23 : (C.B Taylor , Report to MDC , August 2004)

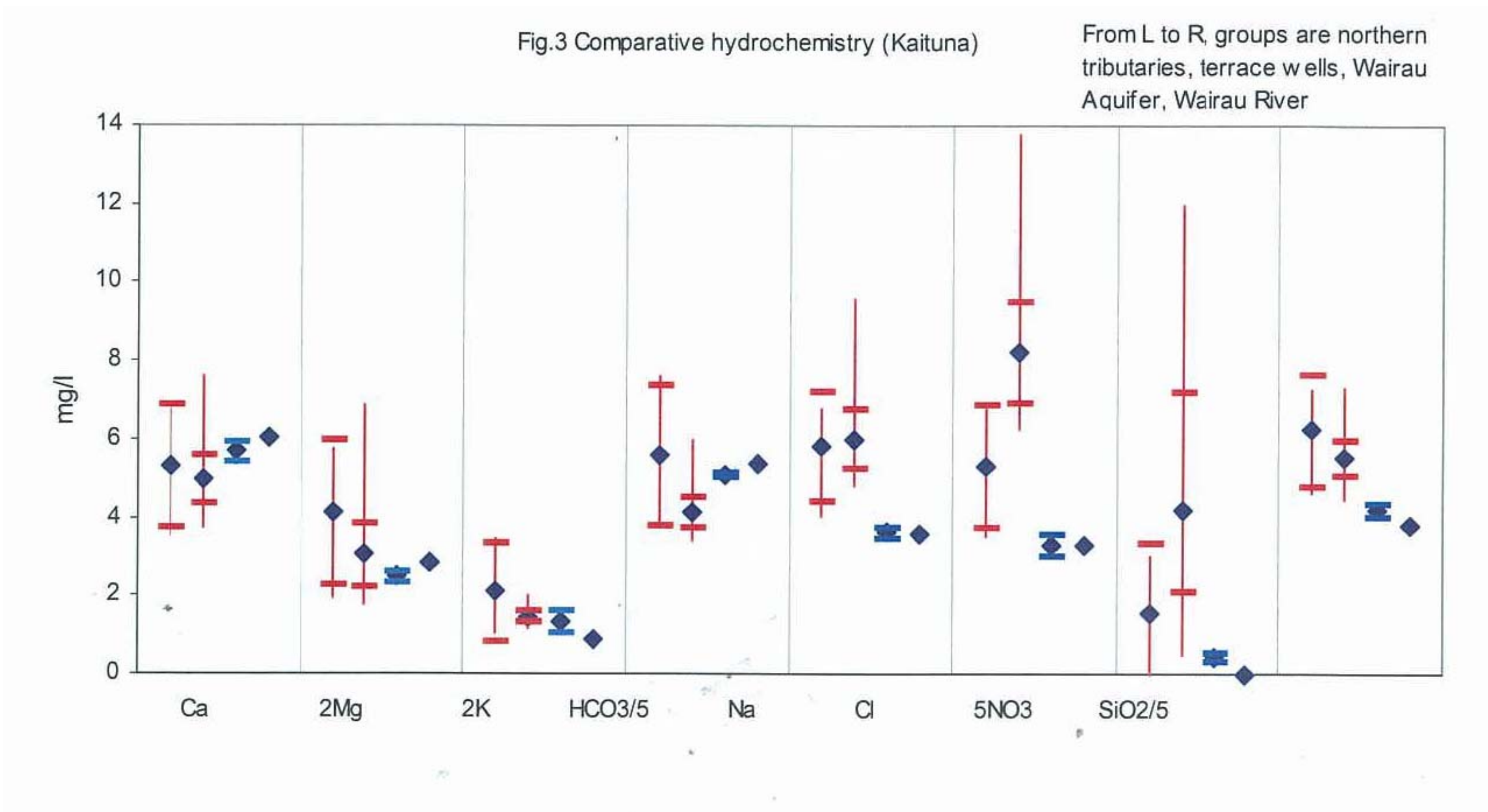


Figure 24 : (C.B Taylor , Report to MDC , August 2004)

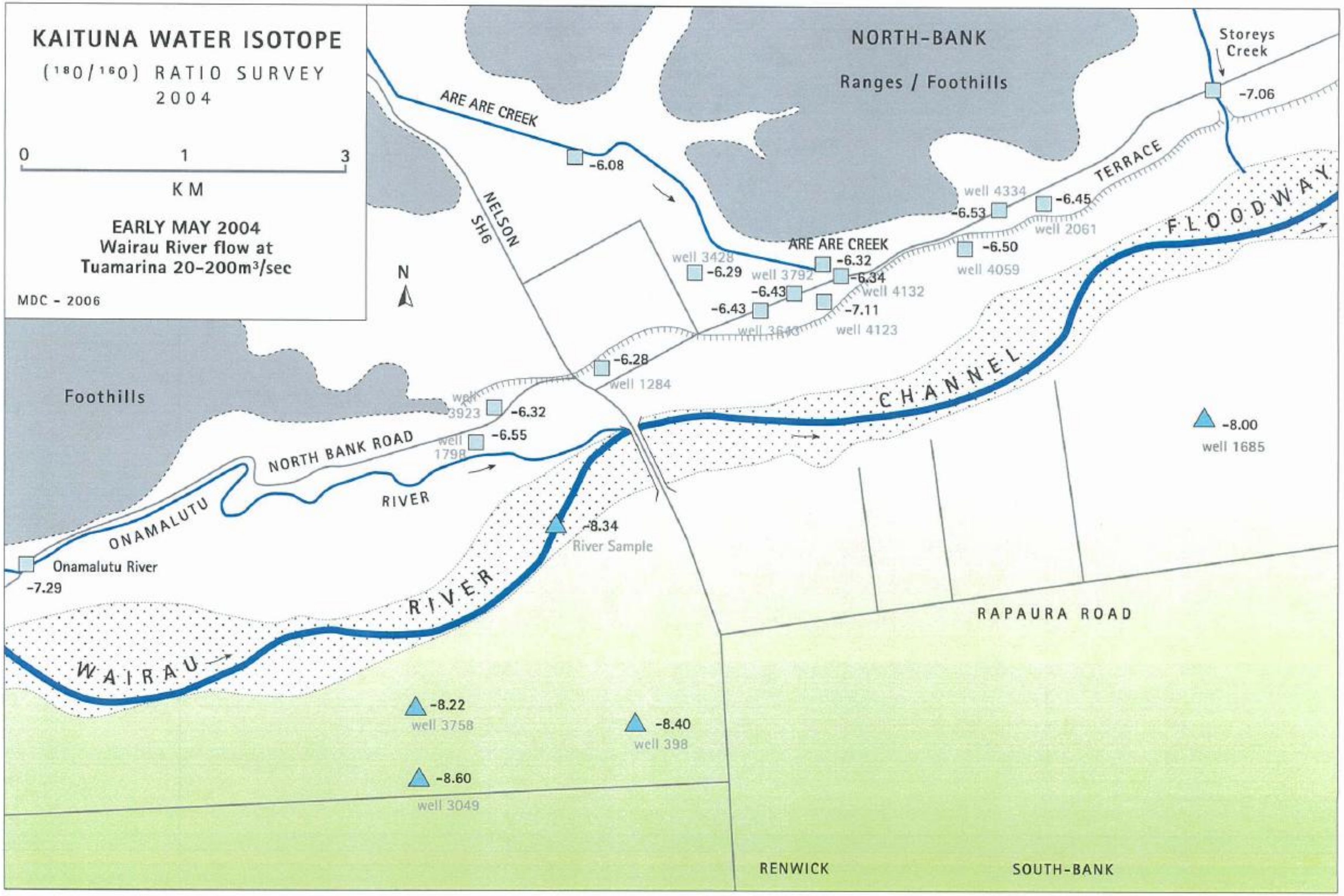


Figure 25a : PLOT OF OXYGEN ISOTOPE SAMPLING RESULTS FROM MAY 2004 (prepared by MDC)

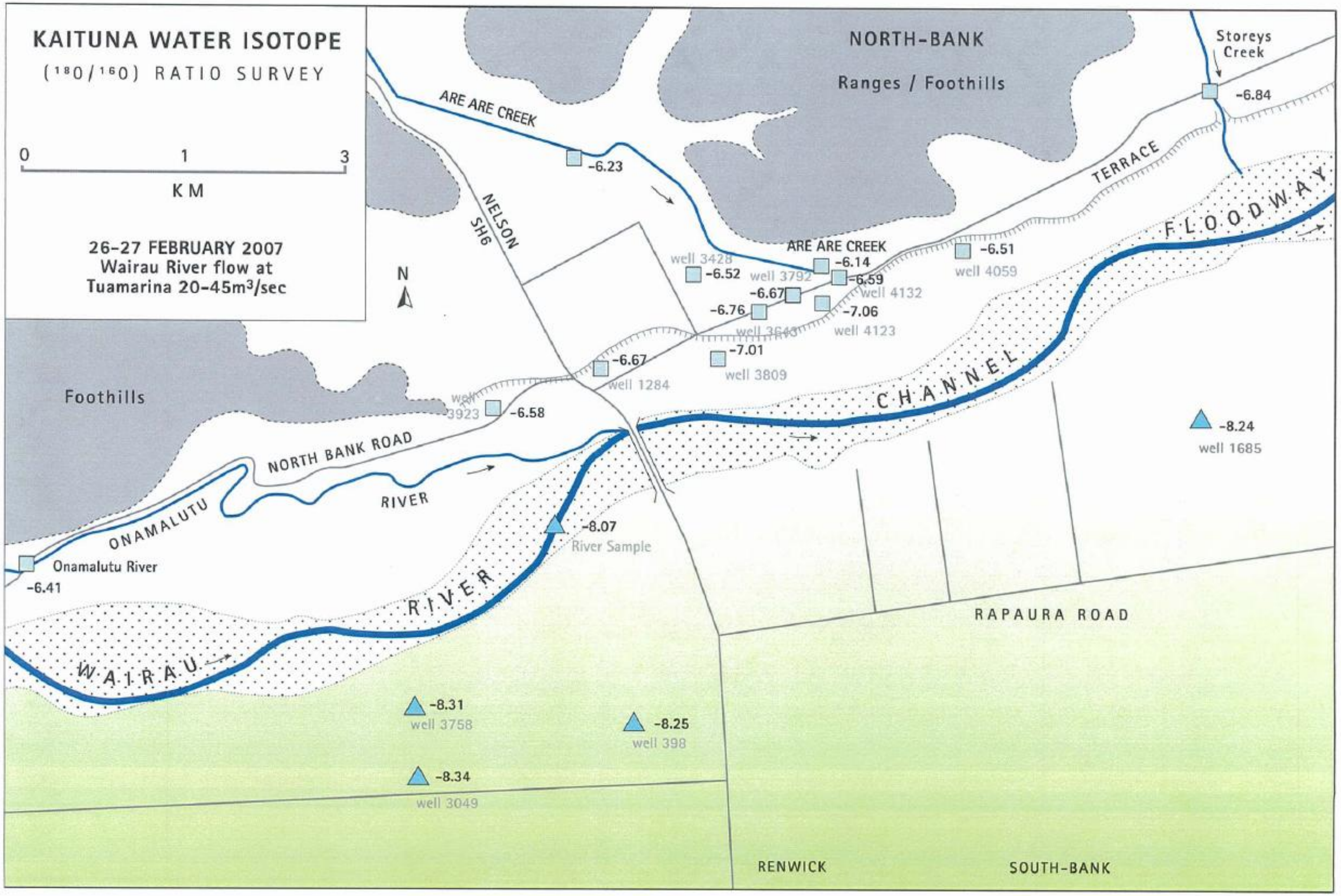


Figure 25b : PLOT OF OXYGEN ISOTOPE SAMPLING RESULTS FROM FEBRUARY 2007 (prepared by MDC)

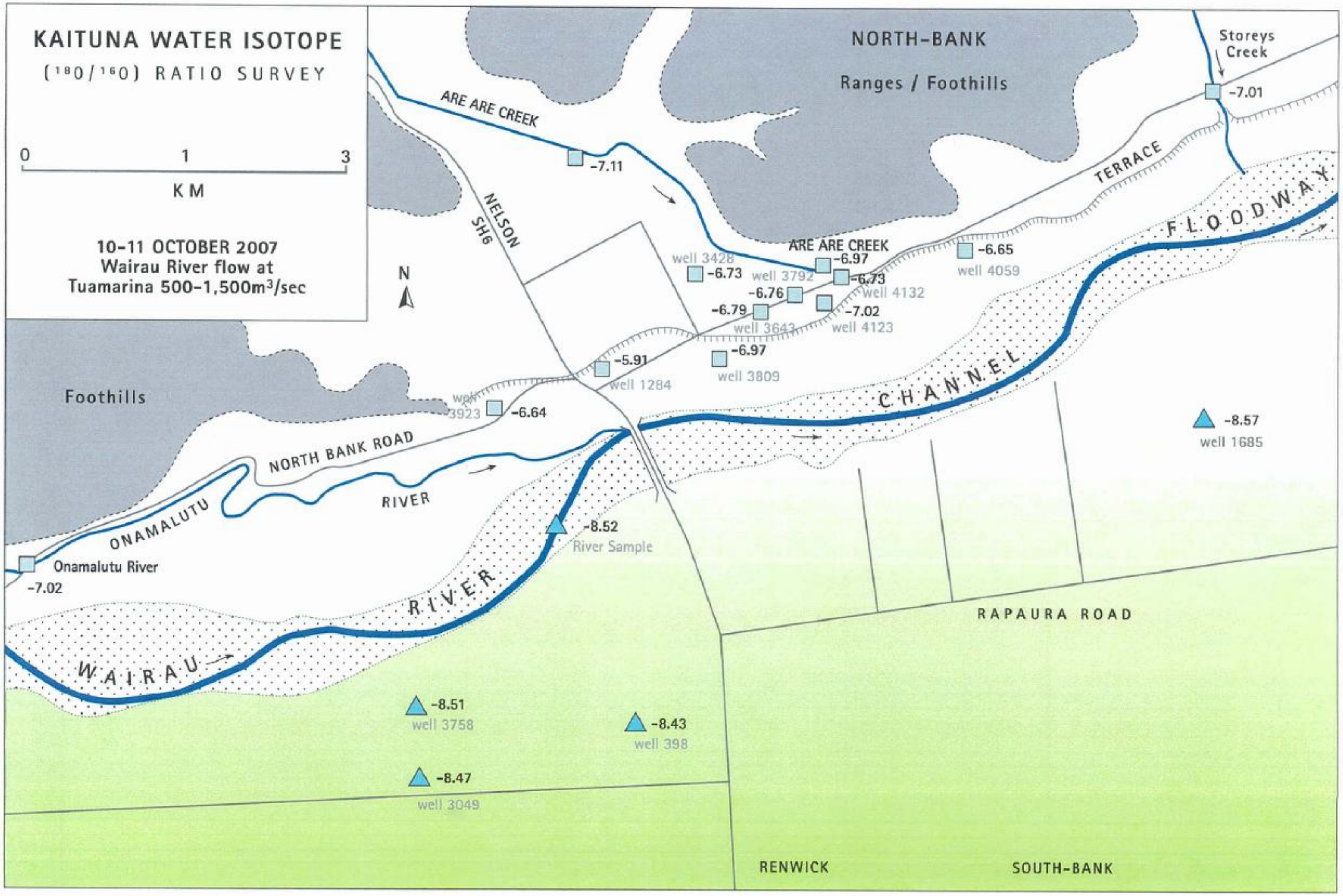


Figure 25c : PLOT OF OXYGEN ISOTOPE SAMPLING RESULTS FROM OCTOBER 2007 (prepared by MDC)

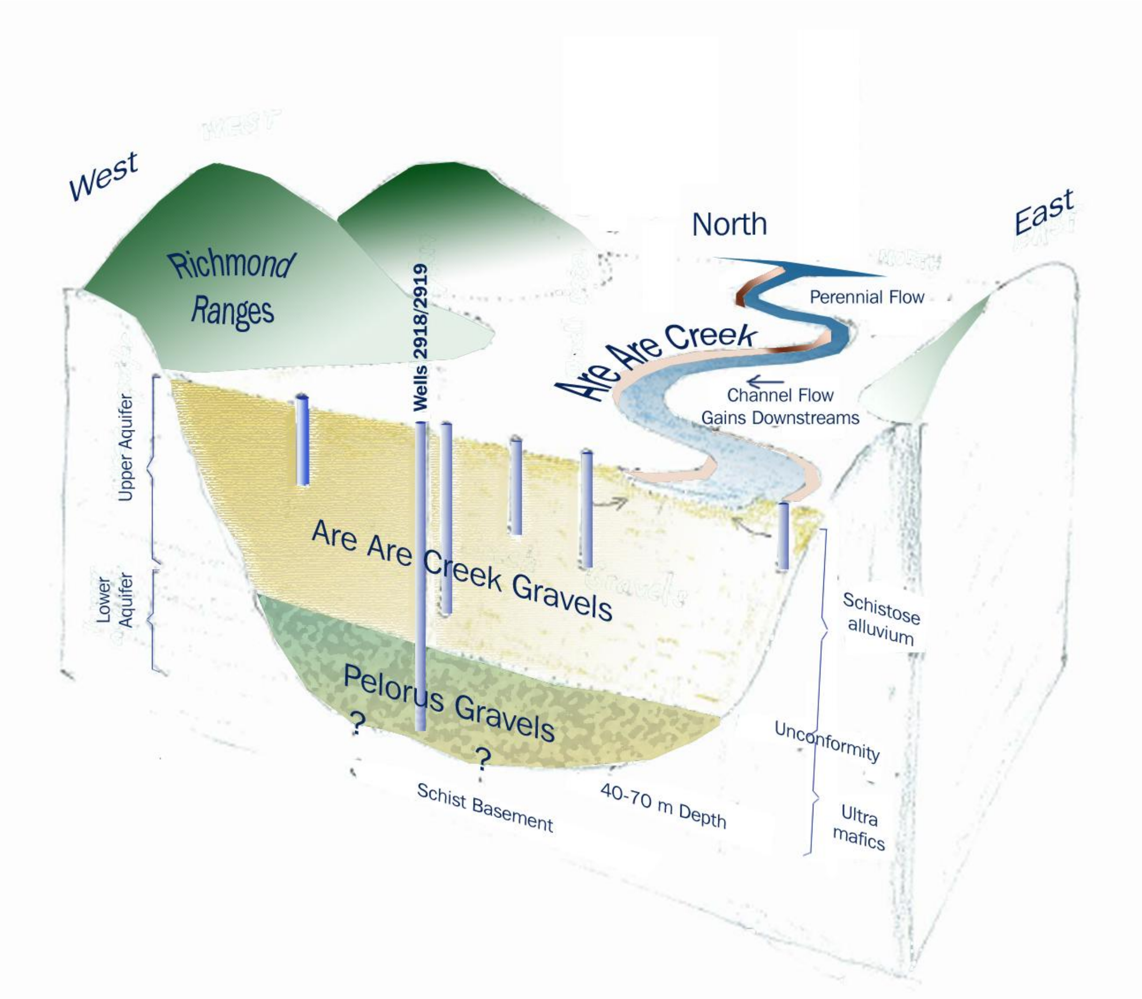


Figure 26 : SCHEMATIC DIAGRAM OF ARE ARE CREEK GROUNDWATER
(Prepared By Peter Davidson , Marbourgh District Council)