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Knapdale Groundwater Zone Technical Report#

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Report for Environment Southland#

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June 2012

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Report Prepared for Environment Southland

June 2012

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Executive Summary

The Knapdale groundwater zone is an important water resource for the Southland Region, providing a majority of the municipal water supply for Gore. In addition, extensive use is made of the groundwater resource for irrigation, dairy and domestic water supply. This report provides a summary of information available to characterise the hydrogeology of the Knapdale groundwater zone and provides recommendations to assist future resource management and monitoring.

The Knapdale groundwater zone contains a spatially extensive unconfined aquifer system hosted in a thin layer of Quaternary alluvium which overlies Tertiary lignite measure sediments. The aquifer system is predominantly recharged by infiltration of rainfall and runoff from elevated terrace areas along the margins of the Mataura Valley. Aquifer permeability appears to increase along the riparian margin of the Mataura River where aquifer water balance is increasingly influenced by groundwater/surface water interaction.

Available data indicate groundwater quality in the Knapdale groundwater zone is vulnerable to contamination resulting from overlying land use. This vulnerability is particularly elevated in areas away from the Mataura River where recharge is predominantly sourced from soil moisture infiltration, the water table is shallow and aquifer permeability is relatively low. This combination of factors increases the potential for accumulation of anthropogenic contaminants in the underlying aquifer.

In order to effectively manage future groundwater allocation it is recommended that Environment Southland consider dividing the existing Knapdale groundwater zone into two separate management zones situated on either side of the river. This division would reflect the hydraulic connection to the Mataura River which effectively divides the current management zone into two separate groundwater flow systems. Under the proposed boundary changes it is recommended the ‘Croydon’ groundwater zone on the south (true right) bank of the Mataura River is classified as a Riparian aquifer (under Policy 30 of the Regional Water Plan).

It is further suggested that Environment Southland consider expansion of the existing groundwater level and groundwater quality monitoring networks to include sites located in the Croydon zone. In addition it is recommended Environment Southland consider undertaking a one-off groundwater quality investigation in the Knapdale groundwater zone. Data from such a survey would be useful to improve understanding of the existing groundwater quality state and ensure SOE monitoring provides a ‘representative’ indication of overall groundwater quality.

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1. Introduction

In response to increasing pressure on groundwater resources, Environment Southland formally commenced a state of the environment (SOE) groundwater monitoring programme in 2000. The purpose of the program was to provide a regional perspective to:

- quantify the current state of the groundwater resources;
- identify trends in the ambient condition of groundwater resources;
- determine the cumulative effect of pressures including those from human activities;
- provide a basis for assessing environmental effects;
- identify resource management issues; and
- assist in monitoring the effectiveness of regional plans.

Over the subsequent period a significant amount of data has been collected to enable characterisation of the quantity and quality of Southlands groundwater resources.

In addition to the long-term SOE monitoring program, Environment Southland also developed a groundwater investigations programme designed to improve characterisation of the hydrogeological environments hosting the regions aquifer systems. Applications of this work include the establishment of sustainable allocation limits, improved understanding of the inter-relationship between groundwater and surface water resources and characterisation of potential linkages between land use change and impacts on groundwater quality. As a result of these programmes, knowledge and understanding of Southland's groundwater resources has increased considerably over the past ten years, particularly in those areas which have experienced higher levels of resource development.

The Knapdale groundwater zone is an important water resource for the Southland Region, providing a majority of the municipal water supply for Gore. In addition, extensive use is made of the groundwater resource for irrigation, dairy and domestic water supply. This report provides a summary of information available to characterise the hydrogeology of the Knapdale groundwater zone and provides recommendations to assist future resource management and monitoring.

1.1 Objectives

The purpose of this report is to document the current state of knowledge of the groundwater resource in the Knapdale groundwater management zone and provide recommendations for the future monitoring and management of the resource.

2. Physical Characteristics

2.1 Location

The Knapdale groundwater zone extends across an area of approximately 8,200 Ha immediately upstream of Gore in the mid-Mataura catchment. The area is bounded to the north by the rolling hills of the Chatton area and to the south by the Hokonui Hills. As currently mapped, the Knapdale groundwater zone encompasses the floodplain and associated lower alluvial terraces on the north (true left) bank of the Mataura River between Pyramid and East Gore and on the south (true right) bank between Otamita and Jacobstown. The downstream boundary marks the area where the Mataura River turns southward to flow through a narrow gorge eroded through the Murihiku Escarpment. The Knapdale groundwater zone is bounded by the Chatton groundwater zone to the north and the Hokonui groundwater zone to the south.

Figure 1 shows a map of the spatial extent of the Knapdale groundwater zone

Figure 1. Spatial extent of the Knapdale groundwater zone

A majority of the land area comprising the Knapdale groundwater zone is occupied by flat to gently rolling agricultural land (predominantly dairy and mixed sheep/beef) with a small area of urban development along the southern margin at Gore

2.2 Geology

The Knapdale groundwater zone occupies the south-eastern section of the mid-Mataura catchment. This area contains a complex assemblage of basement rocks from three distinct geological terranes which are sequentially overlain by Tertiary lignite measure sediments and a thin layer of late Quaternary alluvium. **Figure 2** shows a simplified geological map of the Knapdale groundwater zone based on the GNS Murihiku coverage (Turnbull and Allibone, 2003).

Extensively deformed rocks of the Murihiku Terrane form the steeply dipping strike ridges of the Southland syncline which can be traced from the east coast at Nugget Point to the North Range near Mossburn. This structure forms the southern boundary of the Mataura catchment between Gore and Josephville. To the north, semi-schist and schistose rocks of the Caples Terrane form the rolling foothills and mountains of the Black Umbrella and Mataura Ranges. Central areas of the Waimea Plain are underlain by rocks of the Dun Mountain-Matai Terrane. Surface outcrop of these materials is largely restricted to the footslopes of the Hokonui Hills and the southern margin of the Lintley Range near Lumsden.

Extensive faulting and structural deformation during the Mesozoic Period resulted in significant lateral displacement of the various basement terranes culminating in the formation of the basin structure currently occupied by the Waimea Plain. During the early Tertiary Period relative sea levels were significantly higher than at present resulting in the deposition of a thick sequence of marine and marginal marine sediments across flat-lying areas of coastal Southland, extending northwards through the Waimea Plain and Oreti Basin. These sediments predominately consist of fine-grained mudstone (often carbonaceous) and limestone of the East Southland Group.

During the late Quaternary Period the ancestral Mataura River (which for a time also drained the upper reaches of the present-day Oreti catchment) deposited and subsequently reworked extensive deposits of fluvioglacial outwash materials during successive glacial and interglacial cycles. Entrenchment of the Mataura River during the current (Aranuian) interglacial period resulted in the formation of the present day geomorphology which consists of a broad river terrace flanked by progressively older alluvial terraces along the valley margins.

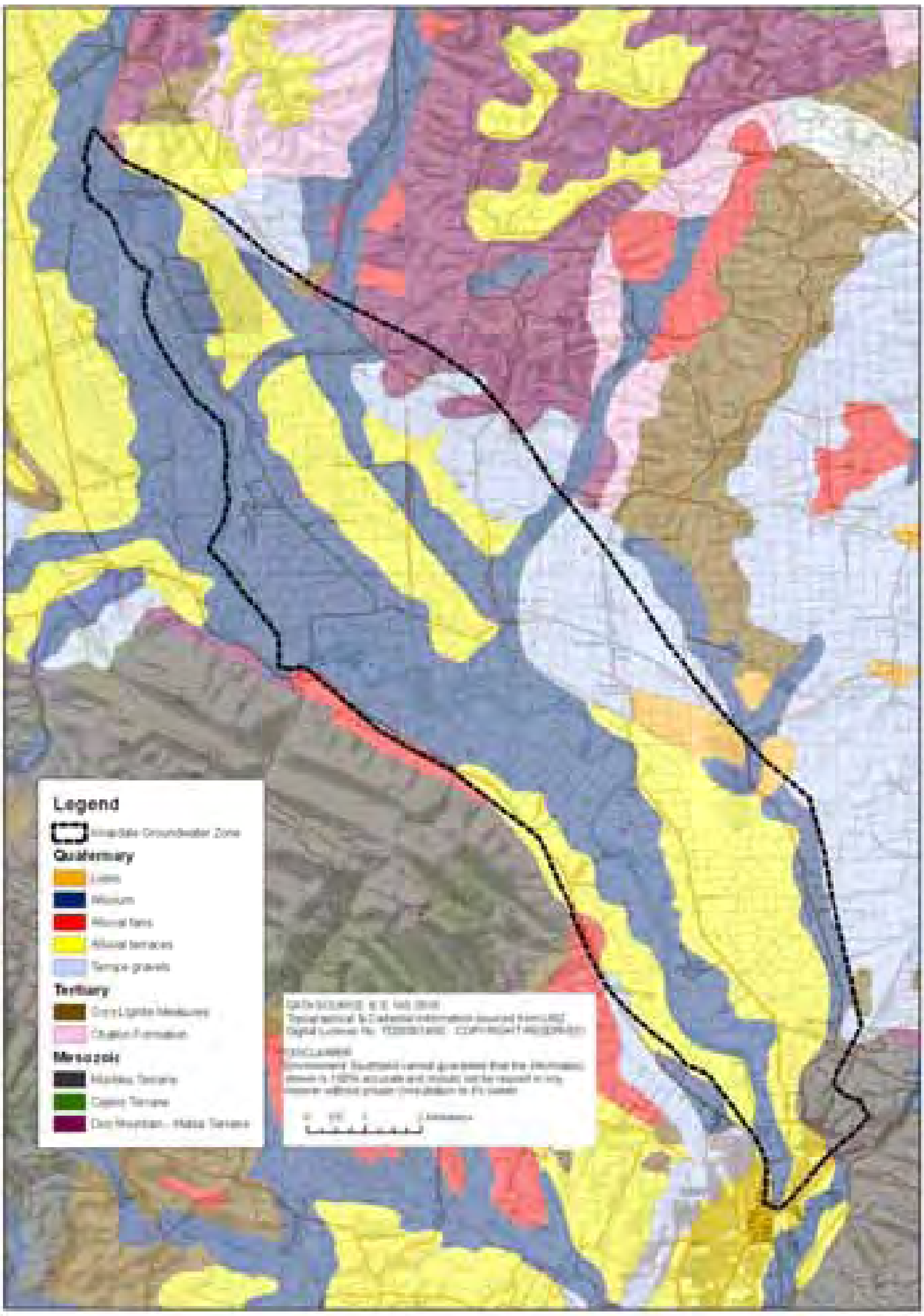

Figure 2. Simplified geological map of the Knapdale groundwater zone (modified from Turnbull and Allibone (2003))

Figure 3 shows a representative bore log from the central area of the Knapdale groundwater zone derived from Liquid Fuels Trust Board (LFTB) drilling investigations conducted in this area during the late-1970's. The log shows a thin (~10 metre) layer of Quaternary gravel underlain by a thick sequence of fine-grained mudstone and lignite sediments containing coarser-grained sand and gravel layers extending up to 200 metres below ground. Logs from bores located in the area between Gore and Waikaka indicate the Knapdale groundwater zone occupies the southern margin of an extensive sedimentary basin extending north of the Hokonui Hills from Pukurau in the east at least as far as Balfour in the west.

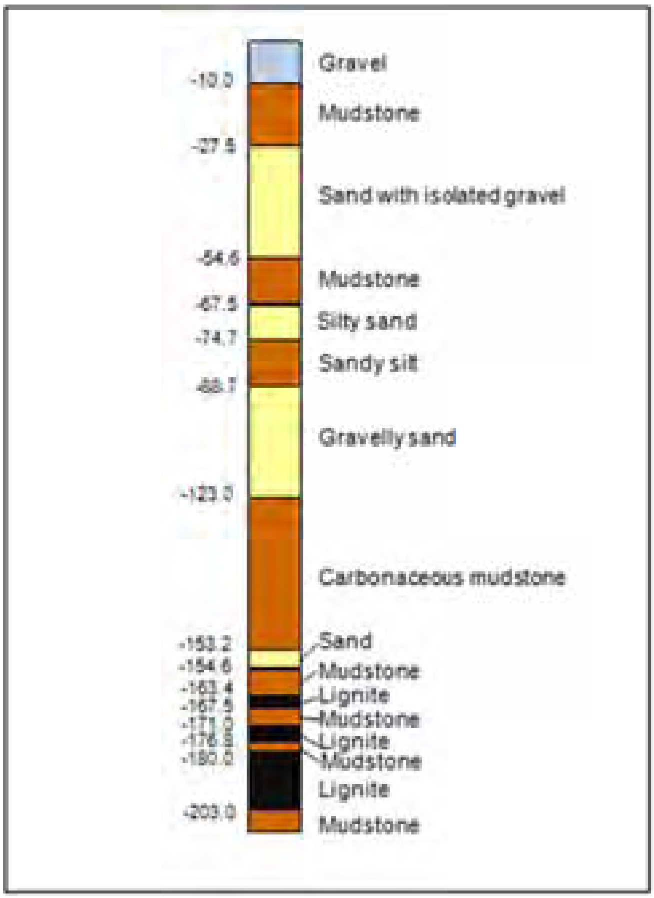

Figure 3. Schematic bore log from F45/0145 from the central area of the Knapdale groundwater zone

The Quaternary gravel deposits which extend across the Knapdale groundwater zone typically comprise quartz gravels containing varying amounts of sand and silt in the gravel matrix. **Figure 4** shows a plot of gravel thickness recorded from bore logs in the Knapdale groundwater zone. The data show the thickness of the alluvial materials generally increases to the west of Croydon with a maximum thickness of 43 metres recorded at the southern end of Wilsons Road. East of this area gravel thickness is generally less than 10 metres. Resistant sandstone beds within the lignite measure sequence are exposed in the Mataura River immediately south of the Knapdale Homestead. Lithified sandstone of the Murihiku Terrane is also exposed in the bed of the Mataura River immediately upstream of the SH1 bridge, illustrating the limited thickness of the alluvial materials where the Mataura River cuts through the Hokonui Hills.

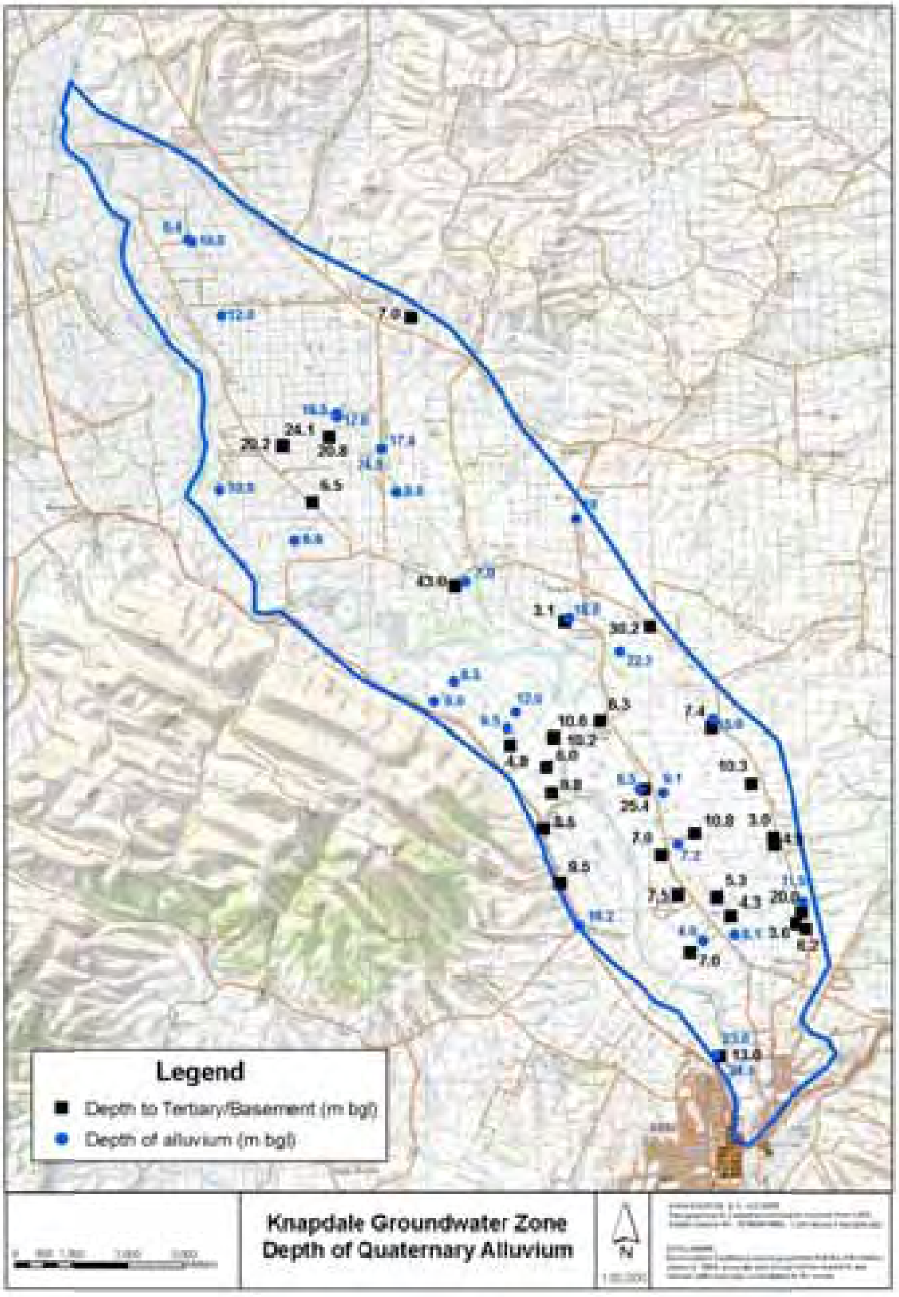

Figure 4. Thickness of alluvial gravel deposits in the Knapdale groundwater zone (Note: black markers denote the depth at which Tertiary sediments were intercepted, blue markers show the maximum thickness of alluvium in bores <u>not</u> intercepting Tertiary sediments)

2.3 Soils

Figure 5 shows a map of soil types in the Knapdale groundwater zone based on data collected for the Topoclimate South project. The data indicate the presence of a range of soil types in the area including Riversdale and Mataura (recent), Gore, Ardlussa, Artherton, Kaweku and Oreti (brown), Fleming, Otamita, Hokonui, Dipton and Waikoikoi (Pallic), Jacobstown and Glenure (gley), Kaihiku (melanic) and Andrews (organic).

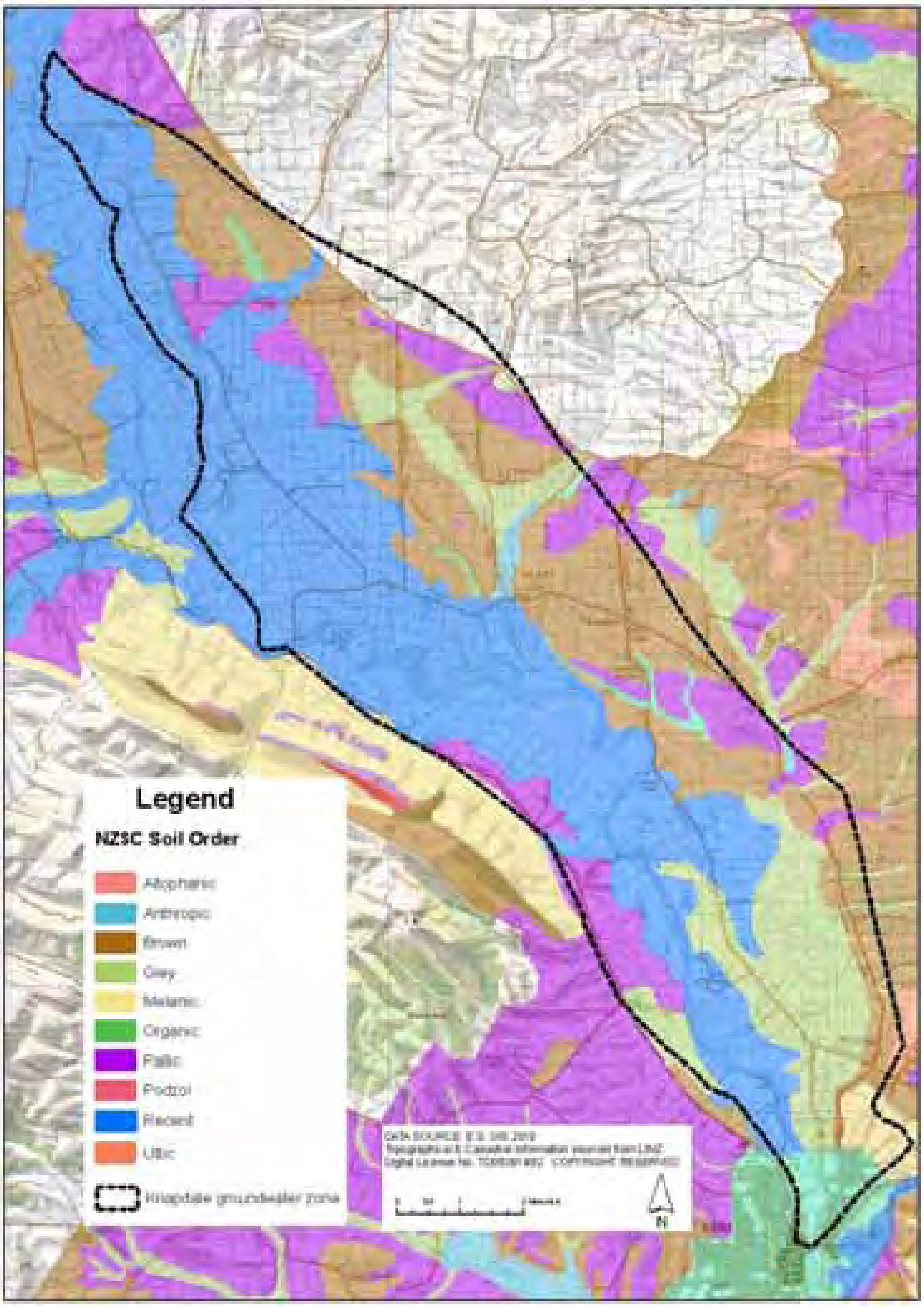

Figure 5. Soil map of the Knapdale groundwater zone (source Topoclimate South)

The major soil types in the Knapdale groundwater zone include Riversdale and Mataura soils which occur on the floodplain of the Mataura River. Riversdale soils are generally free draining with a limited B horizon reflecting their recent development. These soils typically have a high gravel content which results in a moderate to low water holding capacity and restricted plant rooting depth. Mataura soils also have a limited B horizon but are generally stoneless resulting in a moderate water holding capacity with no restriction on rooting depth. Relatively extensive areas of poorly drained, silty Jacobstown soils occur in the area immediately upstream of Gore. These soils have a deep rooting depth and high water holding capacity reflecting the accumulation of overbank silt deposits along the margin of the Mataura River floodplain.

Oreti, Gore and Kaweku soils are found on the intermediate terraces to the north of the Mataura River valley. These Brown soils are characterised as well drained with abundant gravel in the topsoil and subsoil which limits rooting depth and water holding capacity.

Imperfectly to poorly drained soils including Fleming, Otama, Dipton and Waikoikoi are found toward the margins of the older alluvial terraces. These soils typically contain a dense fragipan which restricts internal drainage.

2.4 Climate

Figure 6 shows a plot of mean monthly rainfall at four sites located between Gore and Balfour. The data show a distinct seasonal pattern with highest rainfall totals occurring in summer (December/January) and late autumn (May/June) and a pronounced decline during winter (July to September). While exhibiting a similar pattern of seasonal variation, the data show marked spatial differences in monthly rainfall totals with an appreciable decline evident in data from Riversdale and Mandeville. On an annual basis, average rainfall for the sites shown ranges from 941 mm at Gore and 868 mm at Balfour reducing across the intervening area to 848 mm at Mandeville and 714 mm at Riversdale. The decline in rainfall across the Riversdale area is interpreted to reflect a rain shadow effect in the central area of the mid-Mataura basin with orographic enhancement of rainfall toward the surrounding foothills.

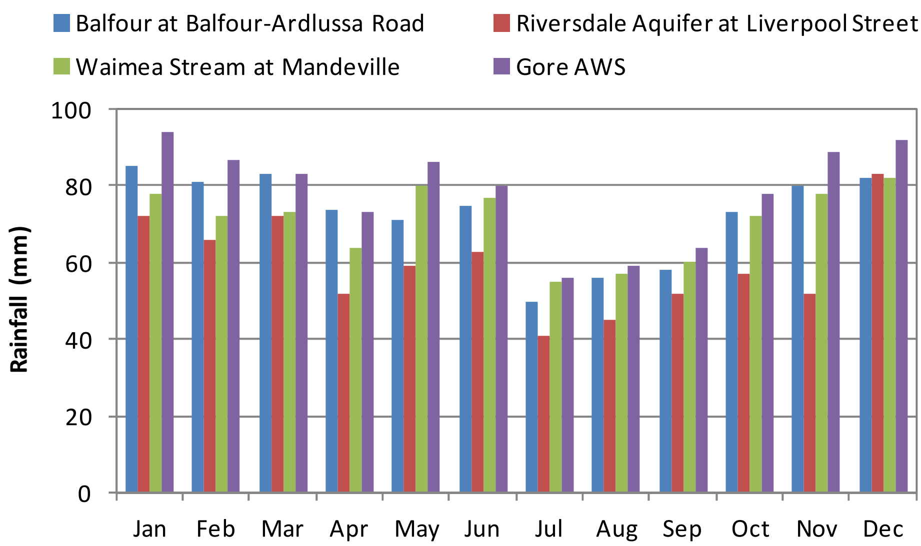

Figure 6. Monthly rainfall recorded in the mid-Mataura basin

While rainfall sites in the Knapdale area exhibit a relatively consistent pattern of seasonal variation, actual rainfall totals in this area may vary considerably on an inter-annual basis around the longer-term mean. For example, **Figure 7** shows a plot of long-term rainfall departure from the mean at the Mandeville rainfall site (I68081) recorded on the NIWA CliFlo database over the period 1950 to 2012. Although short-term variability is evident throughout the record, the plot shows that rainfall varies over time with extended periods of above average (positive slope on the graph) and below average (negative slope on the graph) rainfall clearly evident. The data clearly show an extended period of below average rainfall between 1950 and 1979 followed by above average rainfall between 1980 and 1998. Since 2000 rainfall has been closer to the long term average (i.e. limited slope) except for short duration 'wet' periods during 2004-05 and 2011. A similar pattern is observed in other long-term rainfall monitoring sites in the area[1].

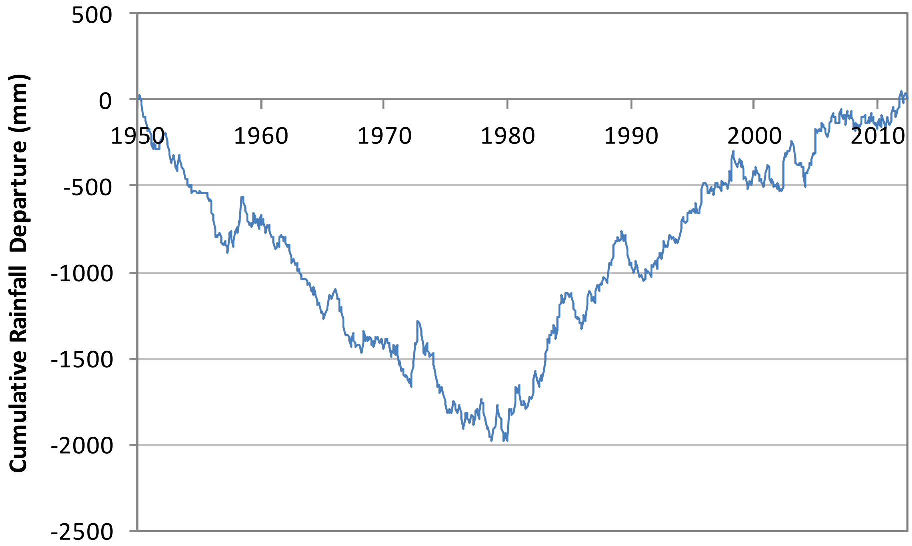

Figure 7. Cumulative rainfall departure recorded at Mandeville (I68081)

This long-term variation in rainfall patterns is interpreted to reflect the predominance of westerly airflows (with associated higher rainfall) over southern and western New Zealand in response to both inter-annual (e.g. El Nino/La Nina) and longer period (e.g. Interdecadal Pacific Oscillation or IPO) climate shifts across the Pacific Region. As described in Liquid Earth *et al* (2011) both phenomena appear to exert a significant influence on both seasonal and longer term rainfall patterns across Southland. Of particular significance is the relationship of rainfall to the IPO indices which, based on extrapolation of historical trends, may suggest an extended period of average to below average rainfall over the coming decade similar to that experienced during the 1950's to 1970's.

Figure 8 shows a plot of mean monthly rainfall recorded at the Environment Southland Waimea Stream at Mandeville rainfall site and calculated evapotranspiration (PET) at Gore. As illustrated, despite highest monthly rainfall totals being recorded during the summer months, PET typically exceeds rainfall between October and February resulting in an average seasonal water deficit of approximately 150 mm. Conversely, between late autumn and early spring rainfall exceeds PET resulting in an average water surplus of approximately 220 mm.

[1] e.g. sites with >60 years of rainfall data including Otama (I58981), Nithdale (I59101), Mokoreta (I69411) and Kaweku (I58961)

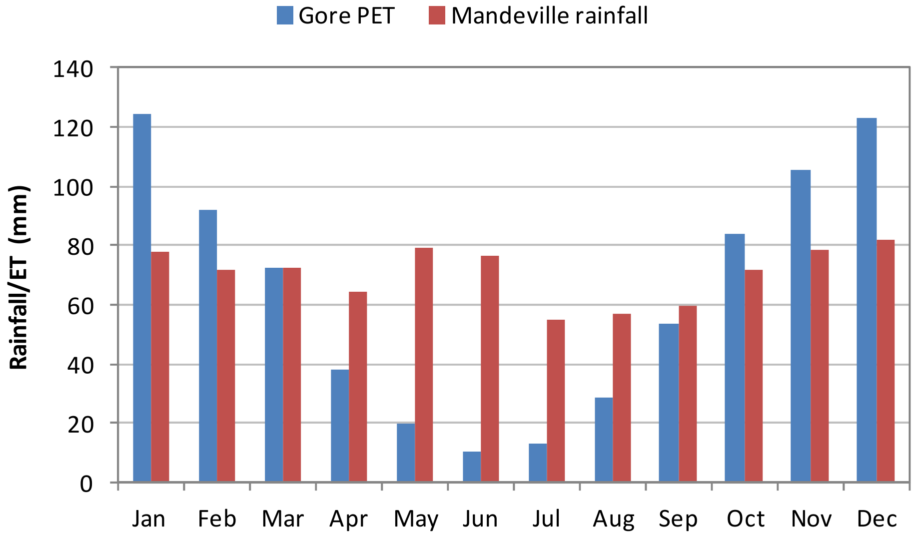

Figure 8. Mean monthly rainfall at Mandeville and PET at Gore

Due to the climate variability the Knapdale area can experience prolonged periods of moisture deficit during the summer months in response to extended periods of below average rainfall and/or relatively high PET due to high wind run (particularly during spring) and air temperatures**. Figure 9** shows a simple water balance (rainfall minus evapotranspiration) to illustrate potential seasonal water deficit in the Mandeville area in an 'average' year and under 'dry' conditions (represented by 20 percentile rainfall and 80 percentile evapotranspiration). The data indicate that during dry periods, monthly water deficits may exceed 80 millimetres between November and January with a potential cumulative seasonal water deficit of 390 millimetres across an entire growing season.

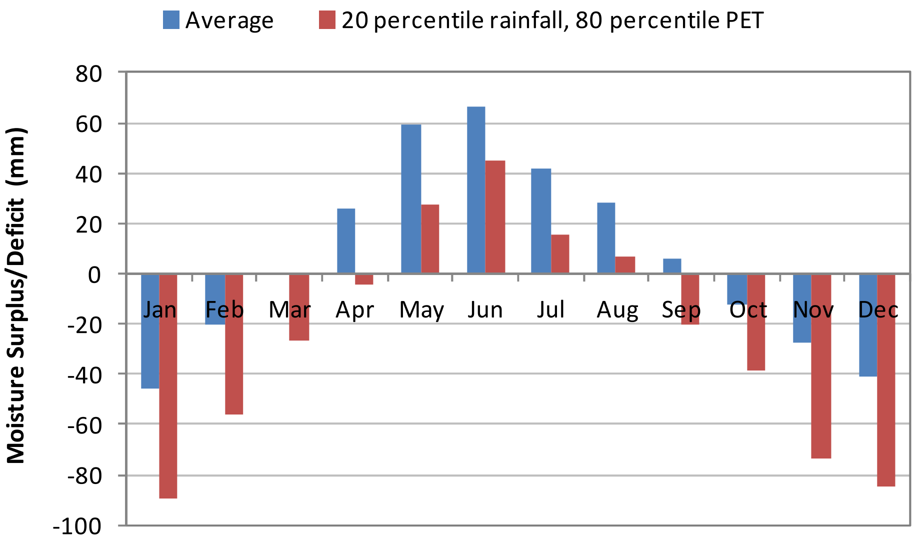

Figure 9. Monthly water balance in the Knapdale groundwater zone under 'average' and 'dry' conditions

However, while potential cumulative summer moisture deficits may be relatively significant, available climate data suggest the occurrence of such extended dry conditions are likely to be relatively rare with ‘dry’ spells more typically being of three to four month durations. For example, **Figure 10** shows a plot of calculated moisture deficit at Mandeville for the 1989/90 to 2011/12 seasons. These data indicate a maximum moisture deficit between October to March of 315 mm in 2007/08 with six years (~25% or 1 in 4 years) having a cumulative moisture deficit exceeding 250 mm. In is noted that the water balance data shown in the figure reflect the overall trend in rainfall departure discussed previously which an increase in average seasonal moisture deficit from 127 mm/year between 1989/90 and 1999/00 to 168 mm over the subsequent period (an increase of approximately 30 percent).

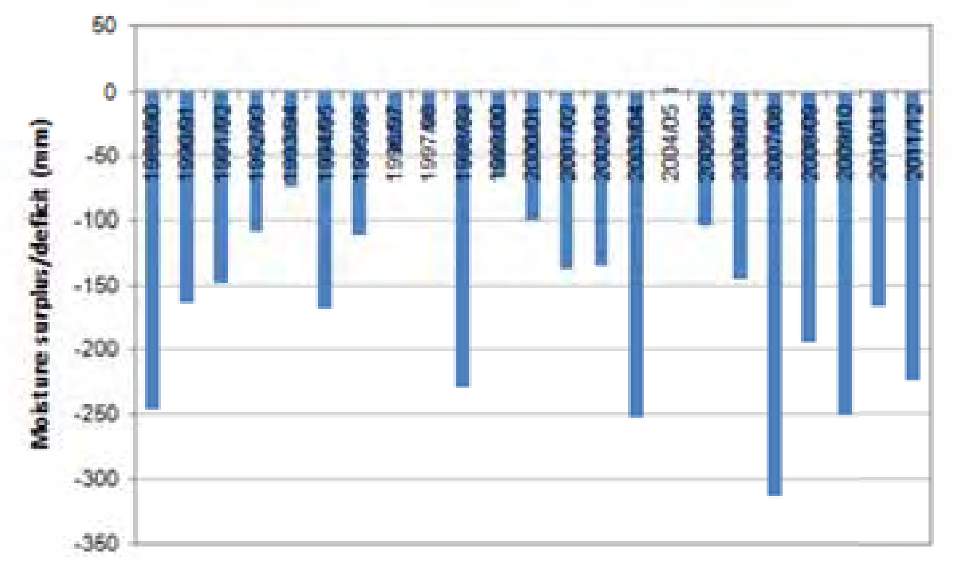

Figure 10. Estimated October to February water surplus/deficit in the Knapdale groundwater zone, 1989/90 to 2011/12

2.5 Hydrology

The higher terraces and rolling hills to the north of the Knapdale groundwater zone are drained by a network of small, partially incised streams which drain southward onto the Mataura River floodplain. The largest catchment draining the Knapdale groundwater zone is Otama Creek which flows from the rolling hills to the north of Otama into the Mataura River south of McBain Road. Other significant streams include Okapua Creek which drains from the Chatton area into the Mataura River at Knapdale and Gold Creek which flows from the higher terrace in the Whiterig area into the Mataura River approximately 2 kilometres upstream of Gore. Numerous small natural and artificial stream channels occur across the Mataura River floodplain in both the Knapdale and Croydon areas, many of which receive baseflow from the surrounding unconfined aquifer.

Limited information is available to quantify discharge in catchments draining the Knapdale groundwater zone with gauging information largely limited to isolated spot gaugings in the Otama, Okapua and Gold Creek catchments. **Table 1** summarises the available flow information for streams draining the Knapdale groundwater zone.

Table 1. Gauging information from the Knapdale groundwater zone

Catchment	Gauging location	Number of gaugings	Minimum gauged flow (L/s)	Maximum Gauged flow L/s
Gold Creek	Knapdale Road	1		39
Okapua Creek	Otamita Road	7	10	164
Otama Creek	McBain Road	3	128	249
	Otama Flat Road	5	20	261

A series of oxbows (abandoned channel meanders) occur on the true right bank of the Mataura River in the Croydon area. These features commonly contain standing water but in some cases also intercept groundwater throughflow which is discharged back to the river via surface drainage outlets.

3. Hydrogeology

The Quaternary gravels underlying the floodplain of the Mataura River and associated alluvial terraces host a thin, spatially extensive unconfined aquifer system. This aquifer system is recharged by local rainfall and infiltration of runoff from higher terraces along the margins of the Mataura Valley. Extensive groundwater/surface water interaction occurs along the riparian margins of the Mataura River, particularly in areas upstream of Otamita and in the Croydon area. The thick sequence of lignite measure sediments underlying the alluvial gravels is generally regarded as containing a limited groundwater resource although coarse-grained sediments may locally contain appreciable quantities of groundwater.

Due to the geometry of the mid-Mataura Basin the narrow channel of the Mataura River through the Murihiki Escarpment at Gore forms the single outlet for an extensive closed basin system. At this point the river essentially rests on indurated, low permeability bedrock resulting in the discharge of all water from the upstream catchment via surface flow at this point. As a consequence, gauging data show an overall gain in flow in the Mataura River as it traverses the Waimea Plain between Mandeville and Gore.

The following section described the primary hydrogeological characteristics of the Knapdale groundwater zone.

3.1 Groundwater Levels#

Environment Southland commenced regular monthly (manual) monitoring of groundwater levels in three bores (F45/0168, F45/0172 and F45/0173) in the Knapdale groundwater zone in late 2000. Over the subsequent period two additional bores (F45/0337 and F45/0422) have been included in the monthly monitoring network. In December 2009 an automatic water level recorder was installed in F45/0569 located adjacent to Otamita Road. **Figure 11** shows the location of groundwater level monitoring sites operated in the Knapdale groundwater zone. It is noted the monitoring network does not include any bores located on the southern side of the Mataura River[2].

Figure 12 shows a plot of groundwater levels recorded in the Knapdale groundwater zone over the period 2000 to 2012. The data show a relatively consistent seasonal variation with maximum levels occurring in winter (typically July/August) and minimum levels in early Autumn (March/April), reflecting the contribution of rainfall recharge to overall aquifer water balance. The magnitude of seasonal variation appears to decrease closer to the Mataura River reflecting the interaction between groundwater and surface water along the riparian margin. For example, the observed seasonal variation increases from around 0.2 metres at F45/0337 (located approximately 0.3 km from the river), to around 0.7 m at F45/0168 (~1.2 km), 1.2 m at F46/0172 (~2km) and 1.6 m at F56/0173 and F45/0422 (~2.5 km)[3].

The groundwater level data show little evidence of any significant temporal trends over the monitoring period (with the exception of F45/0173 and F45/0422 which are impacted by localised drawdown resulting from nearby pumping).

[2] i.e. in the proposed Croydon groundwater zone (see Section 5)

[3] Allowing for localised interference effects

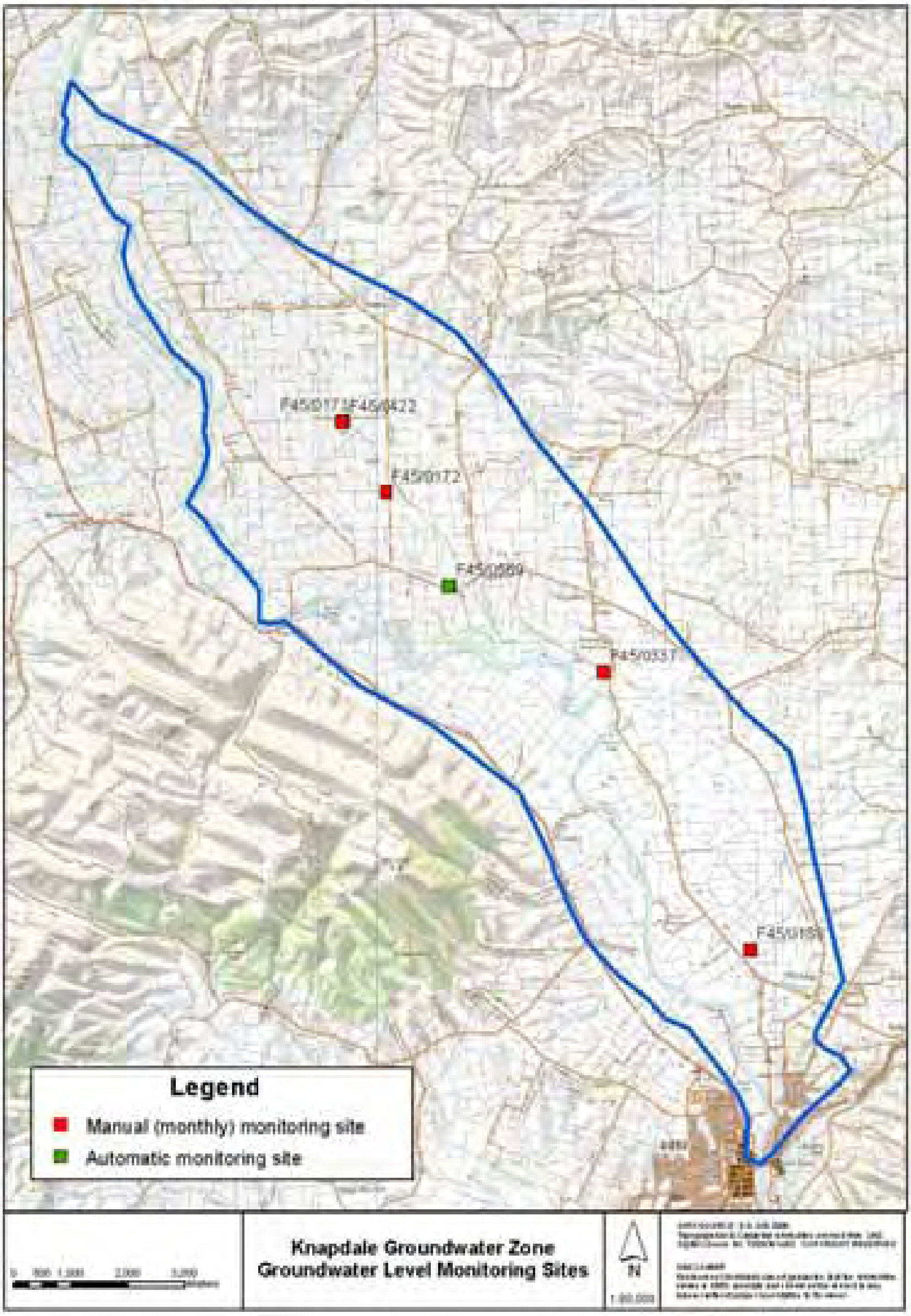

Figure 11. Groundwater level monitoring sites in the Knapdale groundwater zone

Figure 13 shows a plot of groundwater levels recorded in F45/0569, a 5 metre deep bore located along Otamita Road, approximately 850 metres from the Mataura River. The data indicate the groundwater levels at this site are commonly influenced local rainfall infiltration with temporal response commonly preceding variations in river stage during high flow events. However, at other times groundwater level response does not occur immediately following rainfall but appears to track subsequent increases in river stage. It therefore appears that temporal groundwater response at this site is influenced by a combination of both rainfall and groundwater/surface water interaction.

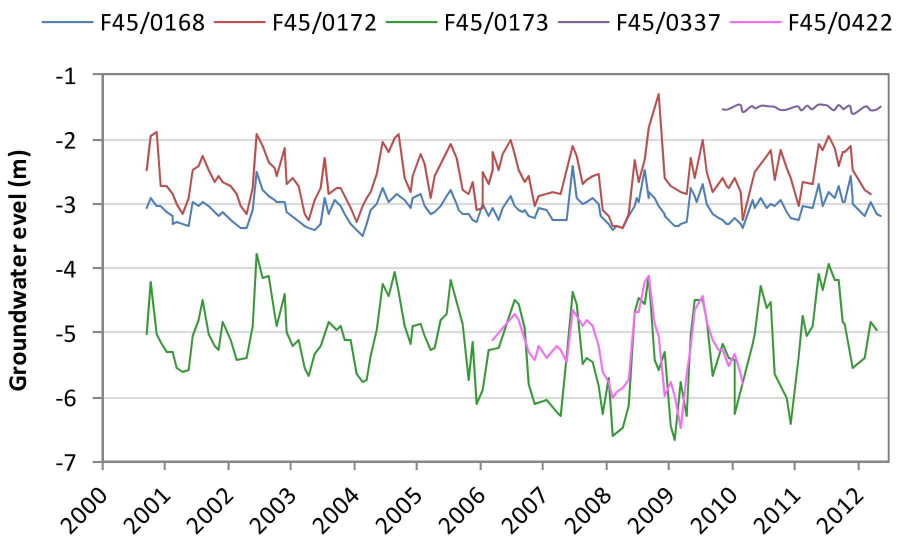

Figure 12. Groundwater levels recorded in the Knapdale groundwater zone, 2000 to 2012

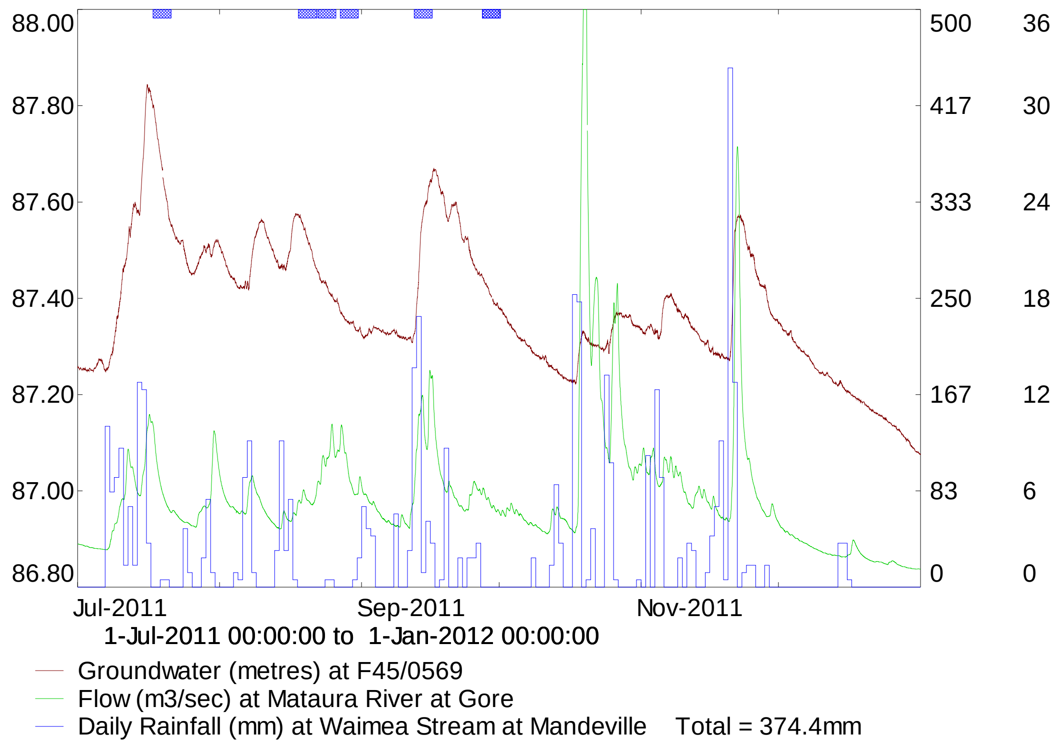

Figure 13. Graph of groundwater levels recorded in F45/0569, discharge in the Mataura River at Gore and rainfall at Mandeville, February to July 2011

Overall, available groundwater level monitoring data indicate that groundwater levels in the Knapdale groundwater zone are primarily controlled by seasonal rainfall recharge but become increasingly influenced by groundwater/surface water interaction along the riparian margin of the Mataura River.

In terms of groundwater flow directions and gradients, **Figure 14** shows a plot of composite piezometric contours for the Knapdale groundwater zone derived from results of the 2003 Waimea Plains piezometric survey (Hughes, 2003) combined with static water levels recorded on the Environment Southland Wells database, and wellhead elevations estimated from the GeographX digital elevation model (for bores where wellhead elevations have not been surveyed). The resulting coverage indicates concentric groundwater flow toward the Mataura River with the piezometric gradient steepening toward the Hokonui Hills to the south and the elevated terraces along the northern boundary of the Knapdale groundwater zone.

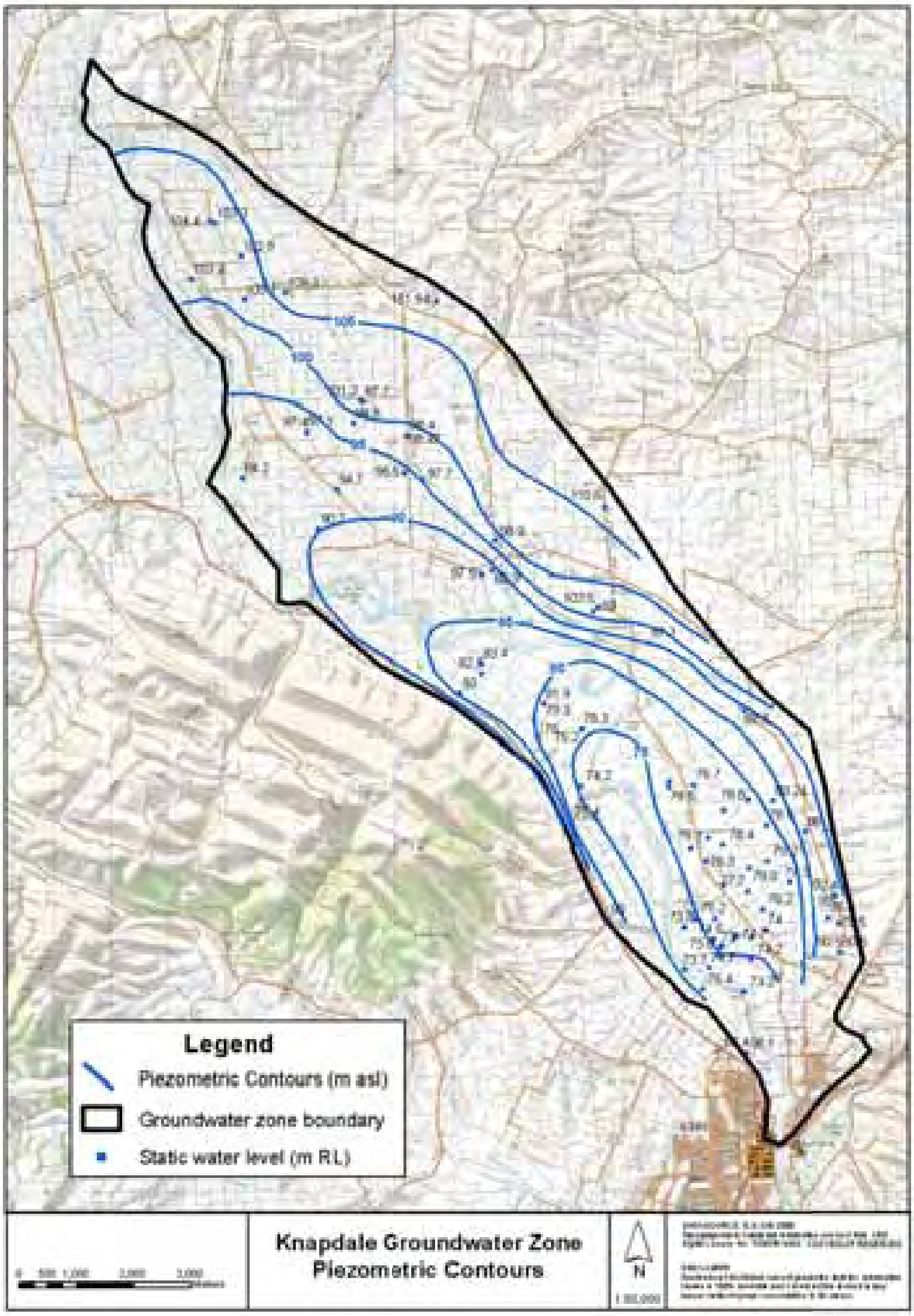

Figure 14. Composite piezometric contours for the Knapdale groundwater zone

3.2 Recharge and Discharge

The Knapdale groundwater zone is predominantly recharged via infiltration of local rainfall. Other potential recharge sources include groundwater throughflow from the Chatton groundwater zone to the north (both within Quaternary sediments as well as the underlying lignite measure sediments) and infiltration of runoff from the elevated areas to the north and south of the Knapdale groundwater zone as streams cross the Mataura River floodplain.

Table 2 provides a summary of rainfall recharge estimates for the Knapdale groundwater zone which range from 179 to 276 mm/year (with an average value of 230 mm/year). Across the 8,185 Ha area of the Knapdale groundwater zone this equates to an annual recharge volume of approximately 19 million m^3/year of which 17 percent (3.2 million m^3/year) occurs across the area of the existing Knapdale groundwater zone on the south (i.e. true right) bank of the Mataura River, with the balance occurring to the north of the river.

Table 2. Rainfall recharge estimates applicable to the Knapdale groundwater zone

Reference	Model	Rainfall recharge (mm/year)	% of mean annual rainfall
Lincoln Environmental (2003)	LEL irrigation model	254	30
SKM (2005)	SWMB model	211	24.9
Phreatos (2007)	Rushton	179 - 276	20 - 30
Average		***230***	***27***

Although limited gauging data is available to quantify infiltration from streams draining across the Knapdale groundwater zone, anecdotal information suggests many of these waterways lose flow as they traverse the outer margin of the Mataura floodplain and subsequently gain water toward their confluence with the Mataura River. For example, hydrogeological investigations undertaken at the Gore District Council (GDC) Coopers Wells supply by Rekker (1995) indicated that rainfall recharge and flow loss from Gold Creek were the primary sources of groundwater recharge in this area.

This local interaction with the unconfined aquifer is thought likely to occur in the catchments of the Otama Stream, Okapua Creek and Gold Creek as well as other smaller streams. Certainly, numerous small streams and artificial drains gain flow along the riparian margins of the Mataura River particularly in the area immediately downstream of the Otamita Bridge. The occurrence of these streams may be influenced by both variations in the saturated thickness of the alluvial materials with discharge occurring where the aquifer thins, as well as the occurrence of abandoned river channels (particularly in the Croydon area). Collection of additional concurrent gauging information would assist resolution of the spatial extent and magnitude of groundwater/surface water interaction in streams crossing the Knapdale groundwater zone.

Interaction between groundwater and surface water also occurs along the riparian margins of the Mataura River with seepage into or out of the unconfined aquifer occurring in response to spatial and temporal variations in relative groundwater level and river stage[4]. As further discussed in **Section 5**, due to the limited thickness of the alluvial gravels underlying the Knapdale groundwater zone, the hydraulic connection with the surrounding unconfined aquifer along the alignment of the Mataura River forms a hydraulic boundary which effectively divides the Knapdale groundwater zone (as currently delineated) into two separate groundwater flow systems. These aquifer systems essentially respond independently to variations in the local aquifer water balance, linked only by their common connection to the Mataura River.

As previously noted, available gauging data indicate an average flow gain of approximately 700 L/s between the Otamita Bridge and the Environment Southland Mataura River at Gore flow recorder site during periods of moderate to low flow (<30 m^3/s). Although ungaged, tributary inputs over this reach are relatively minor (<100 L/s) during low flows so a majority of the observed flow gain is attributed to progressive discharge from the surrounding unconfined aquifer upstream of the point (near East Gore) where the river becomes effectively perched on greywacke metasediments of the Murihiku Escarpment.

It is noted that the observed flow gain of approximately 600 L/s over this reach equates to an annual baseflow discharge of 19 million m^3/year. This total is equivalent to the estimated rainfall recharge across the entire Knapdale groundwater zone. However, given that approximately one-third of the total area of the Knapdale groundwater zone occurs upstream of Otamita the equivalence in recharge and discharge estimates may be coincidental and suggest either:

- Aquifer recharge is greater than the calculated 231 mm/year (possibly due to the contribution of infiltration of runoff from the surrounding alluvial terraces); or
- The Mataura River between Otamita and Gore receives discharge from outside of the defined area of the Knapdale groundwater zone (such as the underlying lignite measure sediments).

3.4 Hydraulic Characteristics

Limited information is available to reliably characterise the hydraulic properties of the Knapdale groundwater zone. Environment Southland consent files contain records aquifer of testing undertaken to support four individual resource consent applications (Consent No. 203151, 202868, 206057 and 207215). A review of these data indicate the tests are of variable quality, often providing a relatively wide range of aquifer transmissivity values from individual monitoring bores used in the same test. While this variability may in part reflect the overall heterogeneity of the alluvial gravel materials, in some instances it may also result from changes in antecedent conditions (e.g. rainfall, river stage and barometric pressure) which were not accounted for in the analysis undertaken.

Table 3 presents a listing of aquifer transmissivity values derived from aquifer testing undertaken to support individual resource consent applications in the Knapdale groundwater zone. It is noted that the data listed are derived from Assessment of Environmental Effects (AEE) reports and were not re-analysed for this report.

[4] This is illustrated by the response to a high stage event observed in F45/0529, located approximately 900 metres from the Mataura River, during aquifer testing undertaken to support Consent No. 206057

Table 3. Aquifer transmissivity values calculated in the Knapdale groundwater zone

Consent	Well No.	Transmissivity (m^2/day)
203151	F45/0424 F45/0422	450 - 900
206057	F45/0529	470 - 3,830
202868	F45/0424 F45/0458	950 - 1,300
207215	F45/0549	1,300

Three of the aquifer tests (Consents 202868, 206057, 207215) are located in the Croydon area (i.e. on the true right bank of the Mataura River) and indicate aquifer transmissivity values in the range of 1,000 to 1,500 m^2/day[5]. Results of the remaining test (Consent 203151) in the Croydon area suggest a slightly lower permeability with a median value of approximately 700 m^2/day[6].

The only other aquifer test data available in the Knapdale groundwater zone are associated with the GDC Coopers Wells installation. Records of well construction at this site indicate the large diameter bores were installed in an area of dredge tailings to increase well yield due to the low permeability of the native gravel materials. Analysis of the aquifer testing undertaken in 1979 (TH Jenkins and Associates, 1979 reported in SKM, 2006) yielded estimates of aquifer transmissivity ranging from approximately 300 m^2/day for the monitoring bore situated in reworked gravel materials to 55 m^2/day in the in-situ gravel materials. Groundwater level drawdown recorded in monitoring wells indicate the variable hydraulic properties of the surrounding materials with three distinct changes in slope observed on the drawdown curve. These changes in slope were inferred to represent expansion of the cone of depression around the pumping well, firstly through local fill materials, then an old dredged area and lastly the natural river gravels beyond.

Two further aquifer tests at this site in 1994 were undertaken at a rate of 31 L/s (2,678 m^3/day) over intervals of 3 and 7 days duration respectively utilising Well 1 as the pumped bore and Well 2 as the monitoring well (Rekker, 1994). Although hindered by a significant rainfall and high river flows during the initial pumping period, analysis of the test results yielded an aquifer transmissivity value of approximately 400 m^2/day, consistent with results of the original aquifer test for the reworked tailing materials.

Although influenced by well construction, in the absence of more detailed aquifer test data, specific capacity values can be utilised to provide a broad indication of relative aquifer permeability. **Figure 15** shows a plot of specific capacity data for the Knapdale groundwater zone based on basic yield and drawdown information provided on drillers logs.

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[5] The value of 3,830 m^2/day calculated for consent 206057 was estimated utilising the Theis recovery method and appears anomalously high compared to other analyses undertaken.

[6] It is noted two test bores drilled at this site were abandoned due to insufficient yield, suggesting appreciable spatial variability in aquifer permeability in this area.

These data show highest specific capacity values (>500 m^3/day/m) along the margins of the Mataura River reducing to less than 50 m^3/day/m under the older gravel terrace along the northern groundwater zone boundary. This is interpreted to reflect the greater degree of reworking of the gravel materials proximal to the main channel of the Mataura River (as well as the high specific capacity of large diameter municipal supply wells at Coopers and Jacobstown).

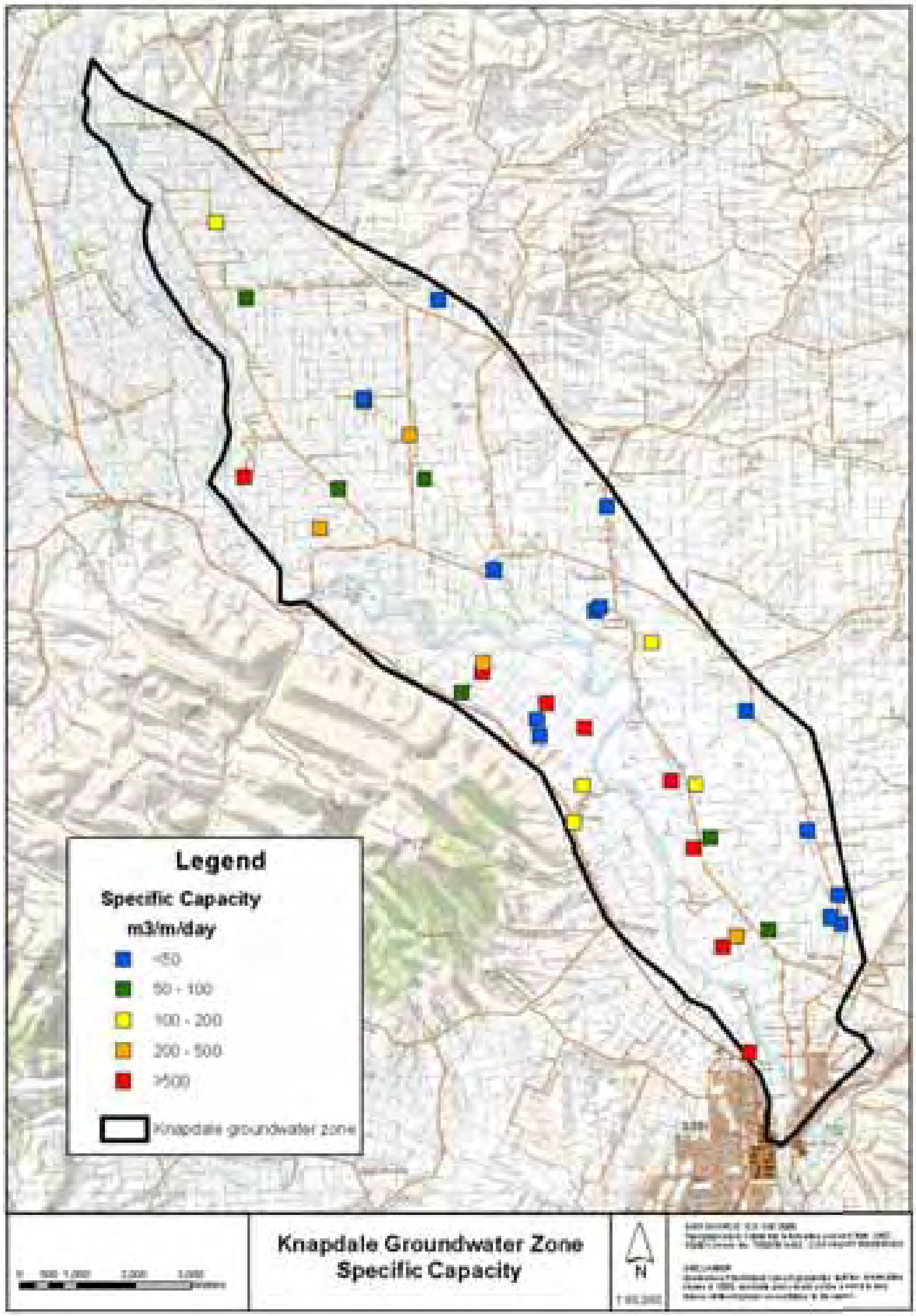

Figure 15. Specific capacity values recorded in the Knapdale groundwater zone

3.5 Groundwater Quality

Groundwater quality data the for the Knapdale groundwater zone stored on the Environment Southland groundwater quality database includes results of 262 individual samples collected from a total of 43 bores and wells since 1998. Of these samples, a majority have been analysed for basic water quality parameters (e.g. electrical conductivity (EC), Nitrate-N and indicator bacteria (*E.coli*)) as part of historical Environment Southland groundwater quality snapshot investigations or more recent resource consent compliance monitoring. Approximately 73 samples from a total of 3 bores have been analysed for a parameter suite including major cation and anion species (Calcium, Magnesium, Sodium, Potassium, Bicarbonate, Chloride and Sulphate) plus nutrients, trace ions and key physical parameters as part of the Environment Southland baseline groundwater quality monitoring network. **Table 4** provides a summary of the available groundwater quality data set.

Table 4. Summary of groundwater quality analyses from the Knapdale groundwater zone

Parameter	Units	No	Min	Max	Median	Comment
pH		104	5.4	7.4	6.1	
Electrical Conductivity	uS/cm	217	96	408	217	
Calcium	g/m^3	72	10	31	15	
Magnesium	g/m^3	72	3.3	13.1	5.2	
Sodium	g/m^3	72	10.3	19.8	14.0	
Potassium	g/m^3	72	1.5	3.7	2.6	
Iron	g/m^3	54	<0.02	0.07		33 samples < detection limit
Manganese	g/m^3	52	<0.001	0.42		6 samples < detection limit
Alkalinity	g/m^3 (as $CaCO_3$)	73	21	51	28	
Chloride	g/m^3	97	3	46	20.2	
Sulphate	g/m^3	72	4.7	38	17.0	
Nitrate-N	g/m^3	231	0.002	18	4.8	
Ammoniacal-N	g/m^3	87	<0.001	0.29		56 samples < detection limit
DRP	g/m^3	49	0.011	0.07	0.021	2 samples < detection limit
E. coli	MPN/ 100mL	178	<1	>2420		46 samples positive detection

In comparison with groundwater quality data recorded elsewhere in Southland (using data from Hughes, 2010), data from the Knapdale groundwater zone exhibit:

- Calcium, chloride, sodium and EC values close to the regional median;
- Median potassium (2.7 g/m^3) and sulphate (17.0 g/m^3) concentrations approximately three times the regional values (0.9 and 5.6 g/m^3 respectively);
- Median alkalinity values (28 g/m^3) equivalent to the regional value for Riparian aquifers and significantly lower than that calculated for Terrace and Lowland Aquifers (54 and 43 g/m^3 respectively)

- Median nitrate values (4.8 g/m^3) which are higher than the regional median (3.5 g/m^3) but equivalent to the value for all Lowland aquifers;
- A median pH of 6.1 which is lower than the regional value (6.5)
- A relatively high incidence of microbial contamination (approximately 26%), possibly reflecting the prevalence of poor wellhead protection in many bores and wells.

Overall, groundwater quality in the Knapdale groundwater zone is relatively variable, particularly in terms of observed major anion concentrations (chloride, sulphate and nitrate). **Figure 16** shows a plot of major ion chemistry from the three bores in the Knapdale groundwater zone analysed for major ion concentrations compared to median values for Lowland, Terrace and Riparian aquifers elsewhere in Southland (data from Hughes, 2010). The data show a relatively tight clustering of cation concentrations (lower left triangle) but show appreciable differences in anion concentrations in two of the three bores sampled in the Knapdale groundwater zone (F45/0171 and F45/0172).

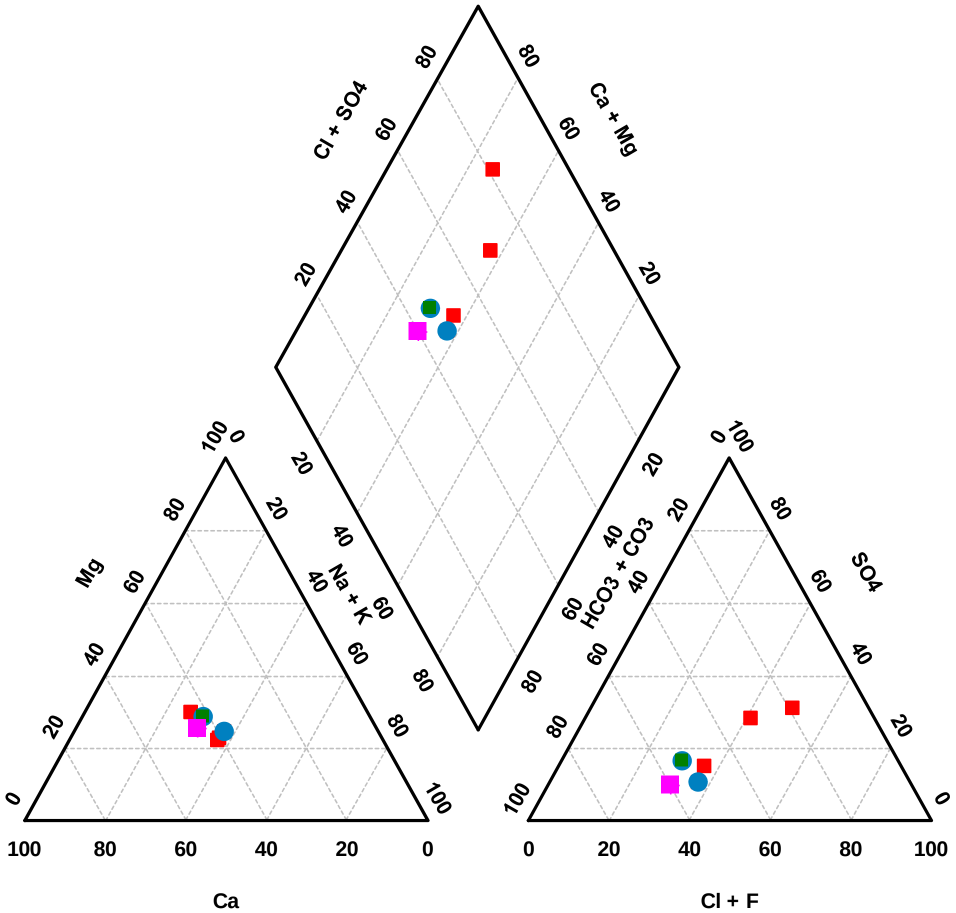

Figure 16. Piper plot of major ion concentrations for the Knapdale groundwater zone (red squares) compared to median values for Lowland (blue circle), Riparian (green circle), Terrace (pink square) aquifers in Southland (summary data from Hughes, 2010).

Figure 17 shows a plot of EC values recorded in the Knapdale groundwater zone (including results from bores/well with 3 or more samples). These data indicate EC values are lowest along the riparian margin of the Mataura River and increase toward the outer margin of the floodplain, particularly in the

Chatton area to the north of Otamita Road. This observation is consistent with an increased contribution from river recharge (having comparatively lower EC values than locally derived rainfall infiltration) along the riparian margin of the Mataura River.

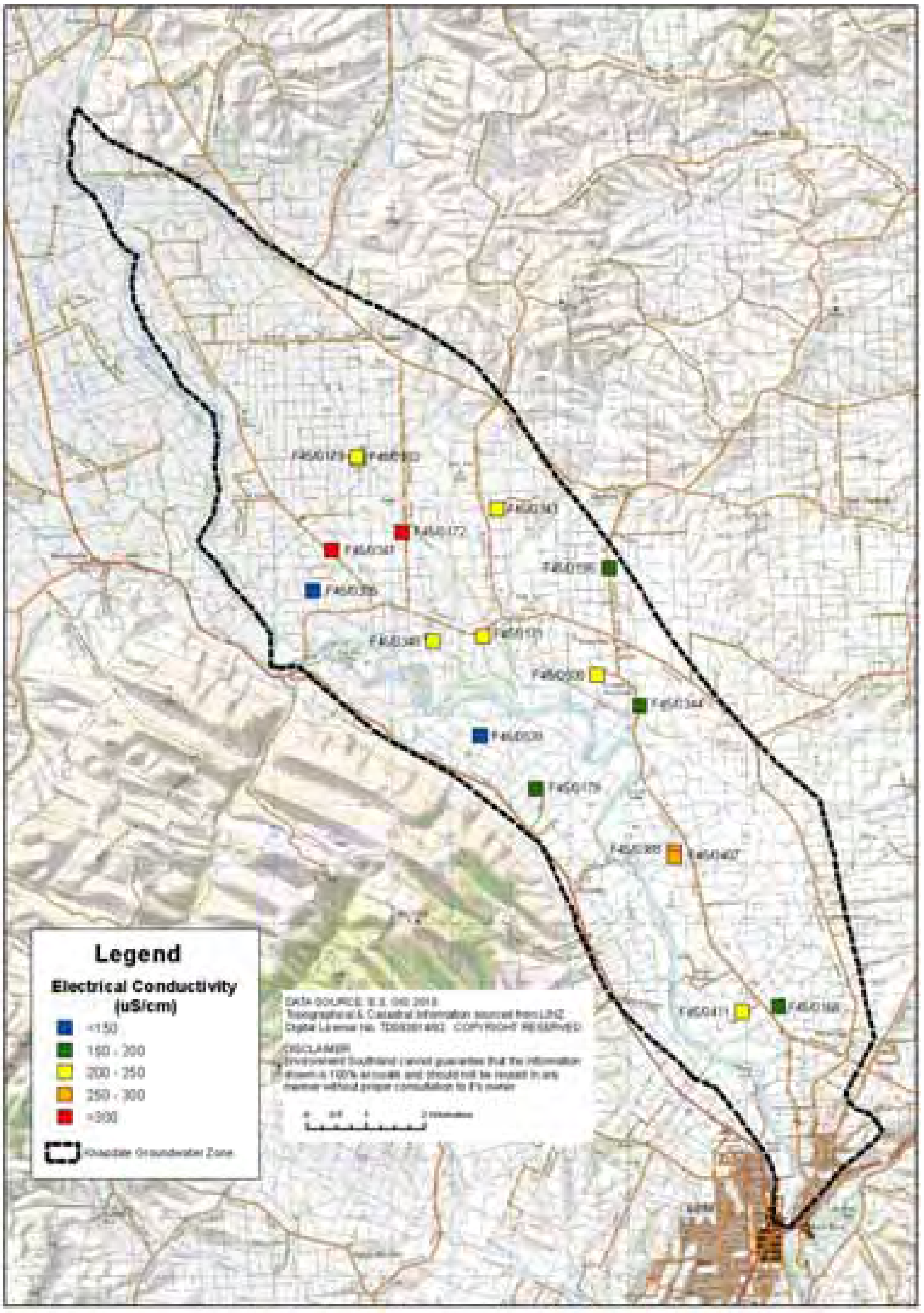

Figure 17. Spatial distribution of EC values in the Knapdale groundwater zone

Figure 18 shows a plot of nitrate-N concentrations in the Knapdale groundwater zone. These data show a similar distribution to EC values with concentrations generally less than 50 percent of MAV (i.e. <5.7 g/m^3) along the margins of the Mataura River increasing in excess of MAV in two bores in the Otama area (F45/0172 17.2 g/m^3 and F45/0343 11.9 g/m^3).

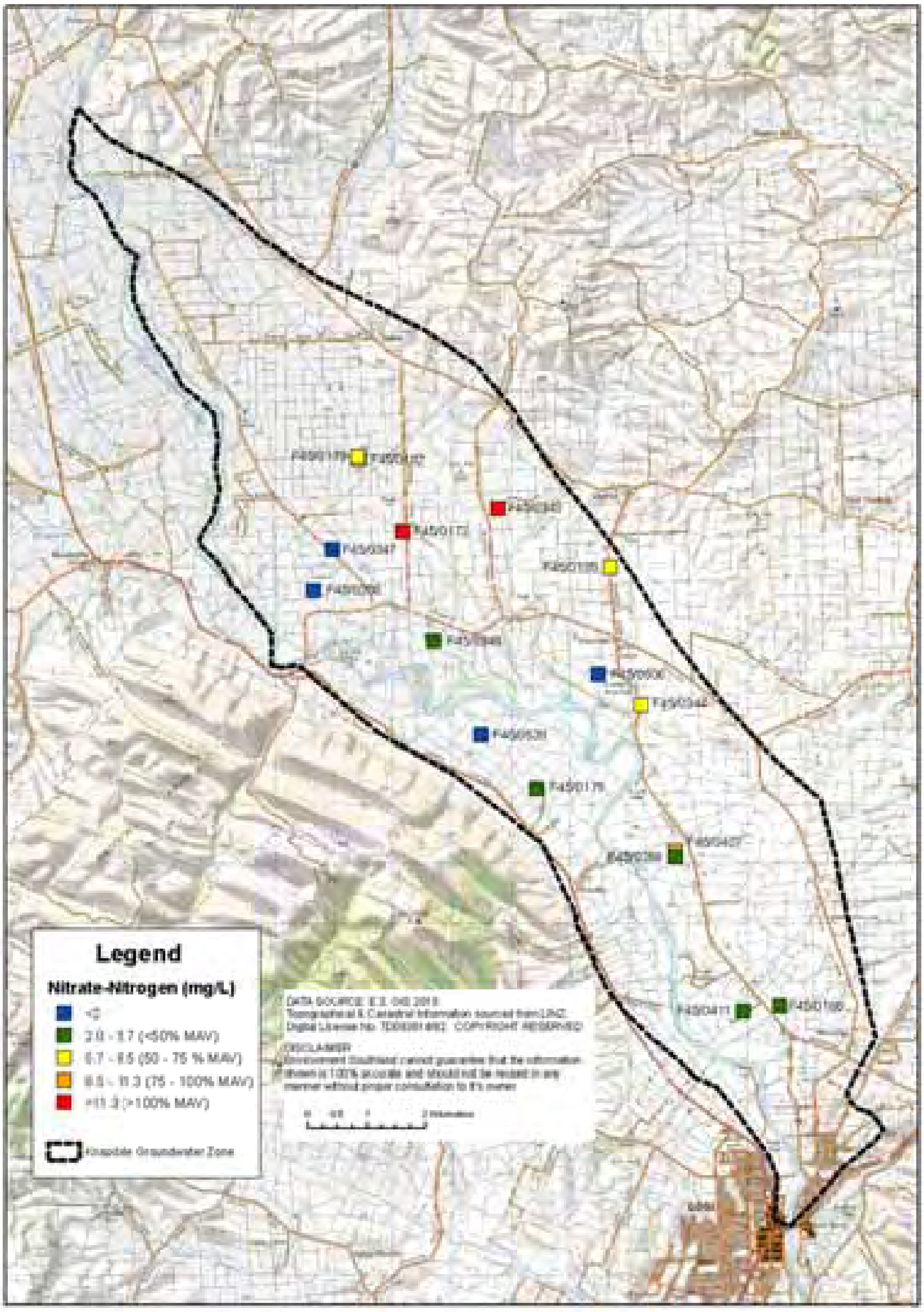

Figure 18. Spatial distribution of Nitrate-N concentrations in the Knapdale groundwater zone

Again, the spatial distribution of nitrate concentrations is interpreted to reflect greater groundwater/surface water interaction along the riparian margin of the Mataura River where aquifer permeability (and consequently groundwater throughflow rates) is highest. The elevated nitrate concentrations (>50% of MAV) occurring in areas removed from the Mataura River suggests the unconfined aquifer in the Knapdale groundwater zone is vulnerable to elevated nutrient concentrations associated with localised land use. This vulnerability potentially reflects a combination of:

- Oxidising conditions in the shallow unconfined aquifer;
- The predominance of soil moisture infiltration as the primary recharge source;
- The shallow water table and limited saturated aquifer thickness; and,
- The moderate to low permeability of the alluvial materials which limit groundwater throughflow rates (and associated 'dilution capacity')

In terms of temporal variation in groundwater quality, **Figure 19** shows a plot of major ion concentrations recorded in F45/0168 between 2000 and 2012. These data show considerable short-term (seasonal) variability in major anion concentrations (alkalinity, chloride and sulphate) while major cation concentrations (calcium, sodium and magnesium) are more stable. Over the period of record, statistically significant ($P>0.05$) increasing trends are observed in all major ion concentrations with the exception of nitrate which exhibits a decreasing trend[7].

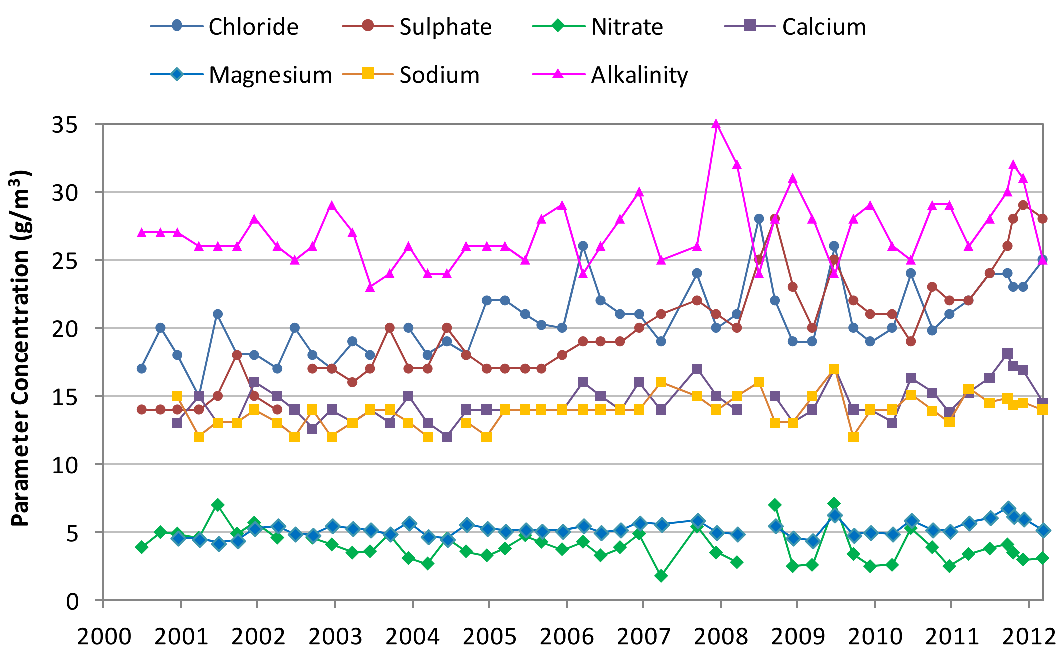

Figure 19. Temporal variation in groundwater quality recorded in F45/0168, 2000 to 2012

Figure 20 shows a plot of nitrate concentrations recorded in 10 bores located in the Knapdale groundwater zone between 2000 and 2012. The results indicate a wide variation in nitrate concentrations ranging from greater than MAV (11.3 g/m^3) in F45/0172 and F45/0343 to less than 2 g/m^3 in F45/0305. This variability again is interpreted to reflect the vulnerability of the unconfined aquifer to localised effects associated with land use, particularly in areas removed from the influence of groundwater/surface water interactions. Analysis of the sites shown indicates a statistically

[7] Trends calculated using the spreadsheet developed by Daughney (2005)

significant increasing trend in 3 bores (F45/0407, F45/0343 and F45/0195), a decreasing trend in F45/0168, with no trend in the remaining 6 bores.

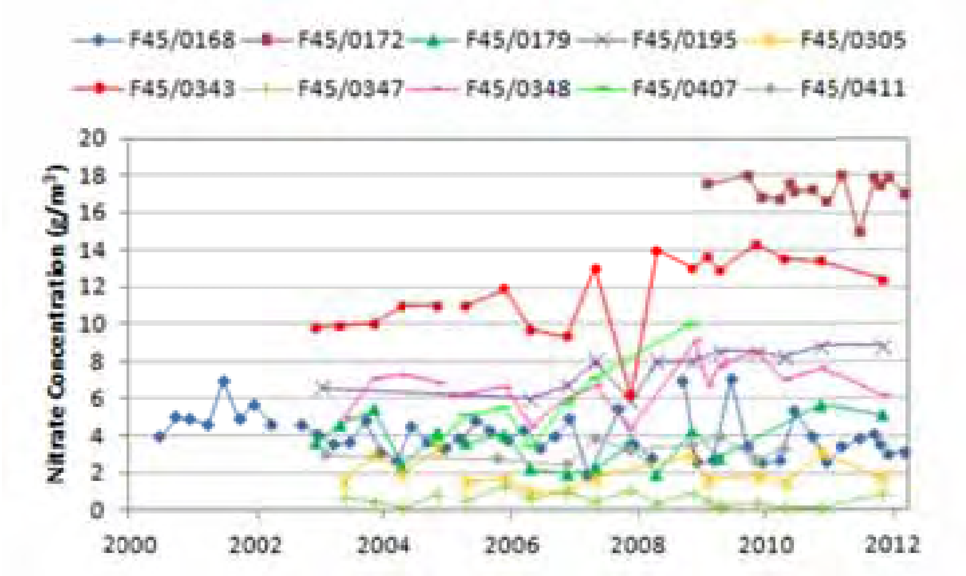

Figure 20. Temporal variation in nitrate concentrations recorded in the Knapdale groundwater zone

Overall, available groundwater quality data indicate groundwater quality in the Knapdale groundwater zone is vulnerable to contamination resulting from overlying land use. This vulnerability is elevated in areas away from the Mataura River where recharge is predominantly sourced from soil moisture infiltration, the water table is shallow and aquifer permeability is relatively low. This combination of factors increases the potential for accumulation of anthropogenic contaminants in the underlying aquifer. Conversely, higher permeability's and associated groundwater/surface water interaction along the margins of the Mataura River increase the rate of groundwater throughflow sufficient to dilute contaminant inputs to a greater extent. However, these factors also likely contribute to an increased contaminant loading in baseflow to the Mataura River.

3.6 Conceptual Hydrogeological Model

Figure 21 shows a schematic illustration of the conceptual hydrogeological model of the Knapdale groundwater zone. The figure shows a relatively thin unconfined aquifer hosted in Quaternary alluvium which overlies a thick sequence of Tertiary lignite measure sediments (predominantly low permeability mudstone and lignite). This aquifer system is recharged by local rainfall and infiltration of runoff from the higher alluvial terraces along the margins of the Mataura Valley. Groundwater flow occurs toward the Mataura River where baseflow discharge occurs both directly to the river as well as to numerous small streams, which drain the inner margin of the floodplain.

Interaction between groundwater and surface water occurs along the riparian margin of the Mataura River, particularly upstream of Otamita and in the Croydon area where aquifer transmissivity values are relatively high. Elsewhere, groundwater hydrographs are largely influenced by seasonal variations in rainfall recharge.

Groundwater quality in the Knapdale groundwater zone appears to be susceptible to the effects of localised land use due to a combination of factors including:

- The predominance of soil moisture infiltration as the primary recharge source;
- The shallow water table and limited saturated aquifer thickness; and,
- The moderate to low permeability of the alluvial materials which limit groundwater throughflow rates (and associated 'dilution capacity')

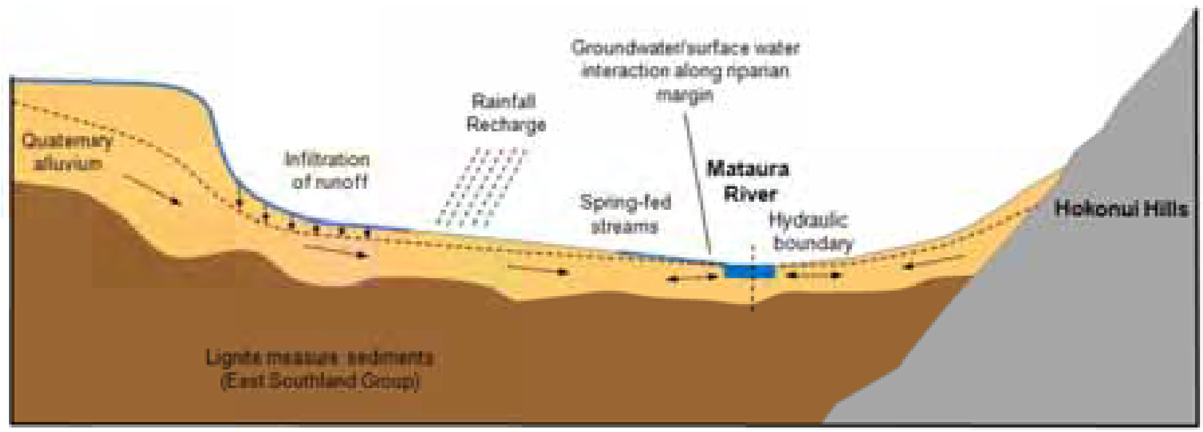

Figure 21. Schematic Cross section of the Knapdale groundwater zone

4. Groundwater Use and Development

At the current time a total of 136 bores and wells are recorded in the Knapdale groundwater zone on the Environment Southland Wells database. **Figure 22** shows a breakdown of this total by recorded primary usage category. Excluding monitoring and geological investigation (which include a number of deep geological investigation bores drilled during the LFTB investigations in the late 1970's) the most common uses are for domestic supply (18% of the recorded total), dairy supply (15%) and stock supply (10%).

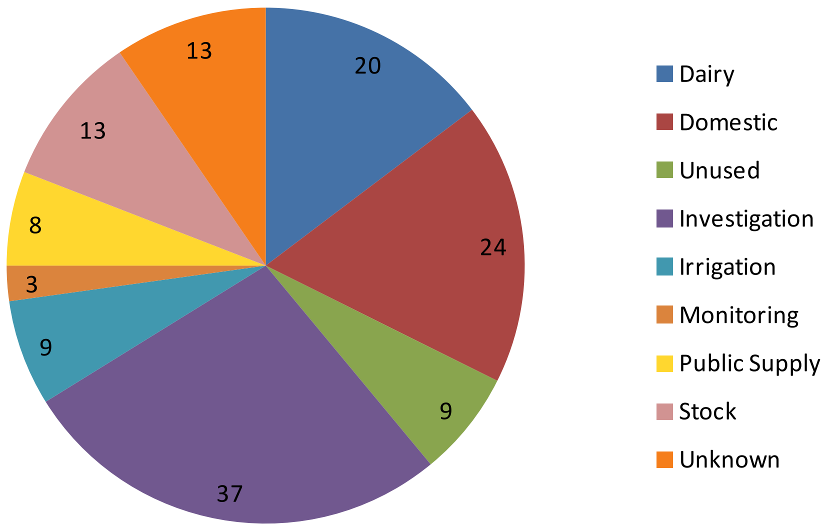

Figure 22. Recorded use for bores and wells in the Knapdale groundwater zone

Figure 23 shows the location of bores recorded in the Knapdale groundwater zone. The map shows dairy supply bores are mainly located in the Croydon area or on the Mataura River floodplain west of Wilson Road while domestic supply bores are more evenly distributed across the entire groundwater zone. The two primary municipal supply locations for the GDC are also shown by red squares located at:

- Jacobstown - comprising four (including two unused) shallow, large diameter wells located on the true right (south) bank of the Mataura River on the northern outskirts of Gore (approximately 300 metres from the Mataura River); and
- Coopers Wells - two shallow, large diameter wells located on the true left bank of the Mataura River approximately 2.4 kilometres north of Gore (800 metres from the river).

Irrigation bores are mainly located in the Croydon area, with the addition of two bores (associated with a single consent) located adjacent to Jaffray Road on the northern side of the river. A cluster of investigation bores is also shown in the area immediately north of Gore. These bores comprise combination of geological investigation bores drilled during LFTB investigations during the late 1970's and shallow investigation bores drilled by GDC in the vicinity of Coopers Wells.

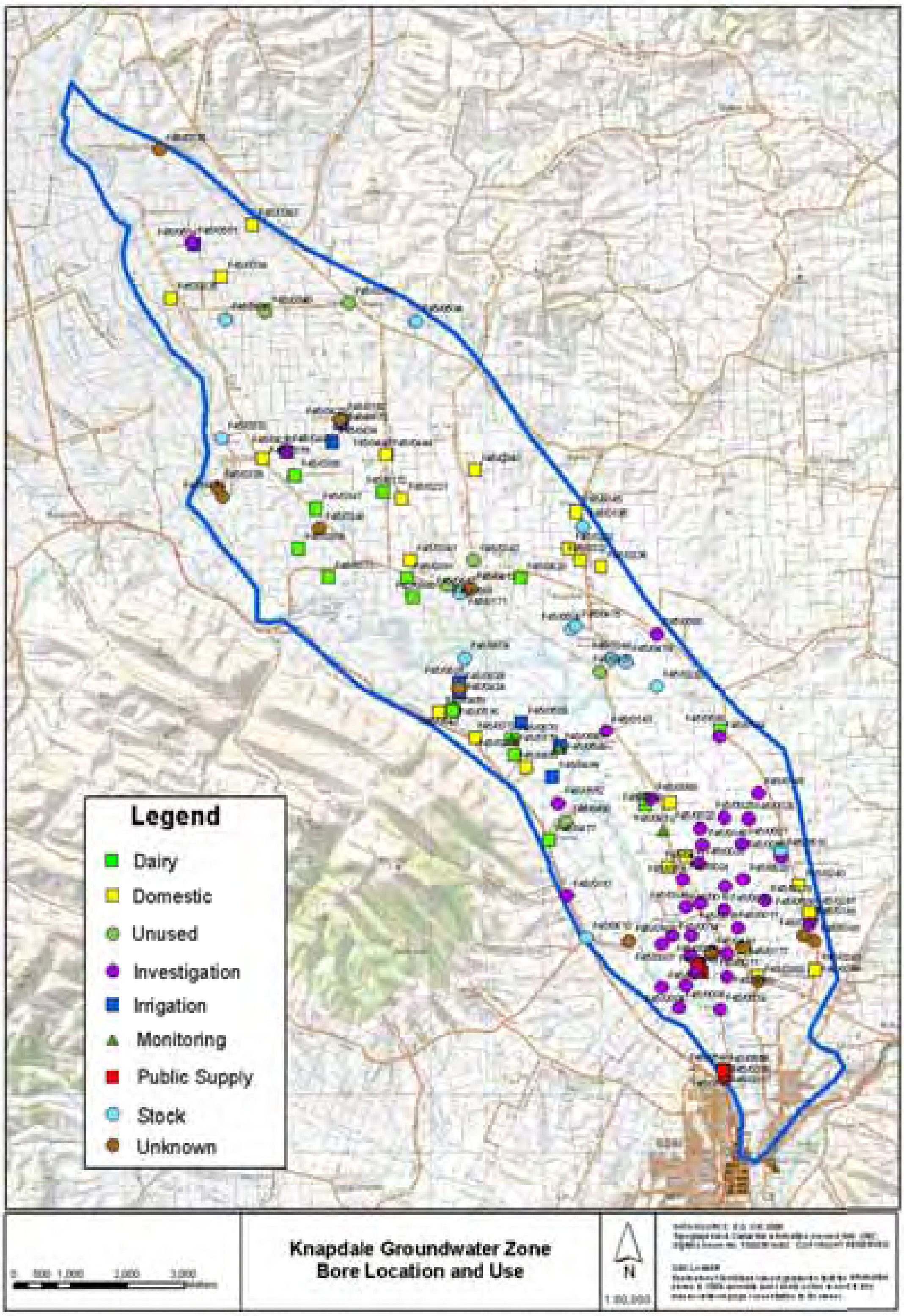

Figure 23. Bore locations in the Knapdale groundwater zone

4.1 Current Allocation

Table 5 provides a listing of current consented groundwater allocation in the Knapdale groundwater zone. The data includes 19 individual resource consents that have a combined maximum daily abstraction rate of 25,522 m^3/day and a cumulative seasonal allocation of 4,244,389 m^3. When potential effects on surface water are accounted for following the methodology specified in Policy 29 of the Regional Water Plan (RWP), the cumulative seasonal allocation reduces to 3,235,699 m^3/year.

Comparison of this total against the preliminary allocation for the Knapdale groundwater zone specified in Appendix H of the RWP indicates current allocation accounts for 15.6 percent of estimated land surface recharge. Under the Lowland aquifer classification assigned to the Knapdale groundwater zone under RWP Policy 30, this level of allocation means that further allocation from the Knapdale groundwater zone is classified as a non-complying activity under Rule 23.

As shown in **Figure 24**, in terms of maximum daily rate, irrigation is currently the largest water use in the Knapdale groundwater zone totalling 15,538 m^3/day (or 63 percent of total daily allocation). However, in terms of seasonal allocation, the ratio of irrigation to municipal supply is almost reversed with municipal water supply accounting for 2,336,000 m^3/year (or 55 percent of cumulative allocation). The differing contribution of different uses to daily and seasonal allocation reflects the seasonal nature of abstraction for irrigation compared to the more constant year-round municipal supply demand.

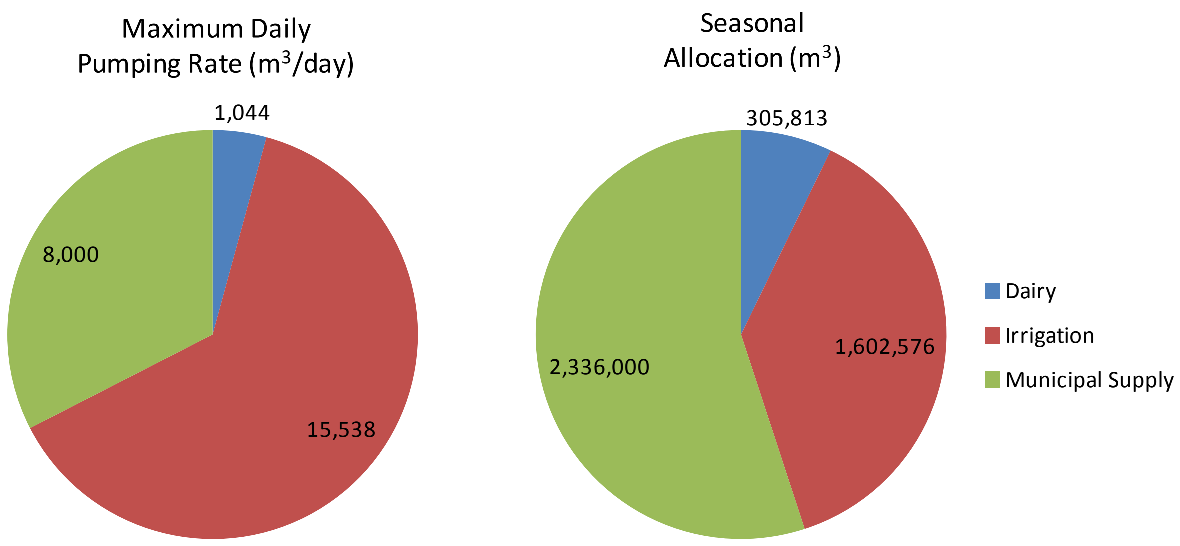

Figure 24. Contribution of varying water uses to total daily and seasonal allocation in the Knapdale groundwater zone

Table 5. Current allocation in the Knapdale groundwater zone

Consent No	Consent Holder	Well No	Use	Maximum Daily Rate (m^3/day))	Seasonal Allocation (m^3)	Groundwater Allocation (m^3/year)
Knapdale						
300791	Otama Flat Dairy Ltd	F45/0347 F45/0390	Dairy	60	17,520	17,520
201454	Willowmere Ltd	F45/0348 F45/0391	Dairy	100	29,200	29,200
201485	Otama Dairy Ltd	F45/0173	Dairy	98	29,616	29,616
202587	Otama Dairy Ltd	F45/0172	Dairy	20	5,840	5,840
202826	Sharp and Voice	F46/0411	Dairy	56	16,352	16,352
204062	Clachbreac	F45/0455	Dairy	84	24,528	24,528
204763	Gold Creek Dairy Ltd	F45/0443	Dairy	54	15,768	15,768
204911	PR & MD Swney	F45/0479	Dairy	42	12,264	12,264
205518	MJ & DM Millard	F45/0506 F45/0475	Dairy	96	28,032	28,032
205655	Closeburn Ltd	F45/0305	Dairy	110	32,120	32,120
300341	Whiterig Dairy Farm Ltd	F45/0559	Dairy	72	20,989	20,989
203151	Otama Dairy Ltd	F45/0426 F45/0422	Irrigation	6,050	589,681	474,394
204330	Gore District Council - Coopers Wells	F45/0394 F45/0463	Municipal	5,000	1,460,000	1,298,000
Sub-Total Knapdale				***11,842***	***2,281,910***	***2,004,623***
Croydon						
205088	River Downs Ltd	F45/0477	Dairy	132	38,544	38,544
301132	PA Steeghs	F45/0516 F45/0179	Dairy	120	35,040	35,040
206057	PA Steeghs	F45/0529	Irrigation	3,060	298,350	144,251
207215	CE & HR Webber	F45/0549	Irrigation	3,478	426,920	0
202868	PA Steeghs	F45/0424 F45/0458	Irrigation	2,950	287,625	137,241
99197	Gore District Council - Jacobstown	F45/0397 F45/0398	Municipal	3,000	876,000	876,000
Sub-Total Croydon				***12,740***	***1,962,479***	***1,231,076***
Total				**24,522**	**4,244,389**	**3,235,699**

Figure 25 shows a plot of cumulative allocation from the Knapdale groundwater zone over the period 2000 to 2012. The data show a gradual increase in allocation from around 2.3 million m^3/year in 2000 to 4.25 million m^3/year in 2011, driven largely by increases in allocation for irrigation and dairy supply since 2005.

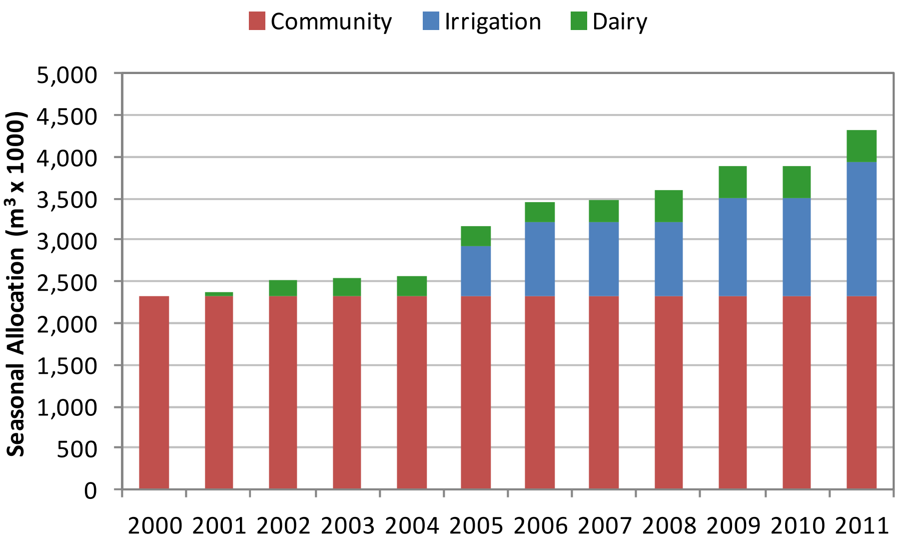

Figure 25. Cumulative allocation in the Knapdale groundwater zone, 2000 to 2012

4.2 Water Use

Table 6 provides a summary of water use compliance monitoring data held on the Environment Southland archive for groundwater takes in the Knapdale groundwater zone. This data is supplied as a condition of consent, however it is noted that compliance is not universal with a number of individual consents either not supplying data or providing data which suffers from a range of data quality issues.

The available water use data indicate cumulative abstraction for municipal supply (Consent No. 204330 and 99197) of up to approximately 1.5 million m^3/year between 2002/03 and 2008/09, two thirds of which is derived from the GDC Coopers Wells installation. This volume is approximately half of the total allocation for municipal supply from these consents. Seasonal municipal supply abstraction between 2002/03 and 2011/12 is shown graphically in **Figure 26** below.

Available data from irrigation consents is relatively sparse and it is difficult to draw any significant conclusions other than water use for Consent No. 202686 has ranged between 50 and 84 percent of seasonal allocation between 2007/08 and 2011/12 (equating to an application depth of between 169 and 284 mm over the nominal irrigated area).

Table 6. Recorded water use in the Knapdale groundwater zone, 2002/03 to 2011/12

	203151	202868	207215	204330	99197
Use	Irrigation	Irrigation	Irrigation	Municipal	Municipal
Seasonal Allocation (m^3)	589,681	287,625	426,920	1,825,000	1,095,000
2002/03				515,060 (28.2)	389,363 (35.6)
2003/04				602,276 (33.0)	435,994 (39.8)
2004/05				816,114 (44.7)	407,970 (37.3)
2005/06	252,850 (42.9)			1,099,950 (60.3)	365,040 (33.3)
2006/07				856,372 (46.9)	355,148 (32.4)
2007/08	145,889 (24.7)	241,397 (83.9)		1,026,981 (56.3)	438,986 (40.1)
2008/09	65,570 (11.1)	143,626 (49.9)		984,216 (53.9)	342,475 (31.3)
2009/10		147,183 (51.2)		986,462 (54.1)	
2010/11		184,808 (64.3)		868,304 (47.6)	
2011/12		170,652 (59.3)	71,857 (16.8)	832,806 (45.6)	

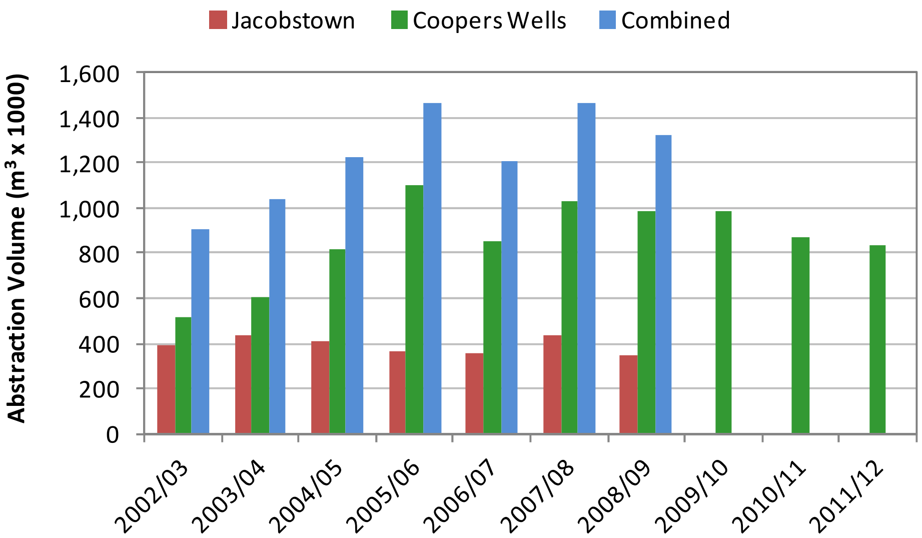

Figure 26. Cumulative municipal supply abstraction from the Knapdale groundwater zone, 2002/03 to 2011/12

5. Summary and Recommendations

5.1 Current monitoring and management

The Knapdale groundwater zone is extensively utilised for municipal, irrigation, dairy and domestic water supply. As described in **Section 4**, current allocation from the Knapdale groundwater zone totals approximately 3.25 million m^3/year (once stream depletion effects are taken into account following RWP Policy 29). This allocation equates to approximately 15.6 percent of the estimated mean annual land surface recharge outlined in Appendix H of the RWP. Given its classification as a Lowland aquifer system, this level of allocation means further allocation from the Knapdale groundwater zone will be classified as a non-complying activity under RWP Rule 23. This activity status means that any future applications to take water will be subject to a relatively rigorous assessment to ensure ongoing sustainability of the resource (following criteria outlined in RWP Appendix A and sufficient to satisfy RMA Section 104D[8]).

Actual groundwater use in the Knapdale groundwater zone is difficult to determine due to the limited amount of water use compliance monitoring data available. Based on available data, it would appear likely that actual groundwater use is less than 50 percent of the allocated volume (on an annual basis). It is noted that future efforts to increase the supply of water use compliance information would greatly assist accurate determination of actual groundwater use.

Current water level monitoring in the Knapdale groundwater zone comprises three, monthly manual groundwater level monitoring sites and one automatic groundwater level recorder installation. Data for this monitoring is useful to characterise temporal response in aquifer storage, particularly in terms of the contribution of rainfall and river recharge. Data from the monitoring network does not indicate any long-term variations in aquifer storage, other than those occurring in response to natural climate variability.

Two bores in the Knapdale groundwater zone are included in the Environment Southland baseline groundwater quality monitoring network. Data recorded at F45/0168 since 2000 indicate a statistically significant increasing trend for a number of major ions (with the exception of nitrate which exhibits a declining trend). The remaining site (F454/0172), although having a much shorter monitoring record, exhibits nitrate concentrations significantly above the NZDWS MAV. Combined with results of dairy discharge compliance monitoring the available groundwater quality data indicate the Knapdale groundwater zone is vulnerable to localised contamination associated with land use activities, particularly in areas removed from the zone of groundwater/surface water interaction along the riparian margin of the Mataura River.

Other than rules relating to specific discharges (e.g. dairy effluent and septic tanks) there are no specific rules applying the Knapdale groundwater zone related to management of groundwater quality.

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[8] RMA S104D establishes that consent for a non-complying activity can only be granted if the consent authority is satisfied that either:

a. The adverse effects on the environment will be minor; or
b. The application is for an activity which is consistent with objectives and policies of the relevant plan.

5.2 Recommendations for future management

Rule 23 of the Regional Water Plan establishes the groundwater management zones defined under Policy 30 as the basic unit for management of groundwater allocation in the Southland Region. These zones delineate individual groundwater flow systems based on a range of criteria including geology, geomorphology, hydraulic characteristics and observed spatial and temporal variations in groundwater levels and groundwater quality. Although the groundwater zone boundaries generally correspond with physical or hydraulic boundaries, it is important to note they do not necessarily reflect no-flow boundaries. As a result, the groundwater zones as currently mapped may be hydraulically connected to adjacent zones and/or comprise more than one discrete water-bearing unit.

As described in **Section 2.1**, the Knapdale groundwater zone is currently defined as the area encompassing the floodplain of the Mataura River and associated alluvial terraces on the northern (true left) bank of the Mataura River between Knapdale and East Gore and on the southern (true right) bank between Otamita and Jacobstown.

The Mataura River bisects the centre of the Knapdale groundwater zone before exiting the mid-Mataura basin at Gore. Available information indicates the river interacts with the surrounding unconfined aquifer gaining or losing flow across alternate reaches depending on the relative hydraulic gradient between the river and surrounding aquifer. The hydraulic connection with the surrounding unconfined aquifer along the alignment of the Mataura River forms a hydraulic boundary which effectively divides the Knapdale groundwater zone (as currently delineated) into two separate groundwater flow systems. These aquifer systems essentially respond independently to variations in the local aquifer water balance, linked only by their common connection to the Mataura River. It is therefore recommended that future management of groundwater allocation in the Knapdale groundwater zone be undertaken in terms of two separate groundwater management zones; a 'Croydon' zone covering the area on the true right (south) bank of the Mataura River and a modified Knapdale zone covering the balance of the current area. The spatial extent of the proposed management zones is shown in **Figure 27** below.

Current allocation from these zones equates to 12,740 m^3/day and 1,231,076 m^3/year in the Croydon zone and 11,842 m^3/day and 2,004,623 m^3/year in the amended Knapdale zone. For the respective groundwater zone areas this allocation equates to 11.6 percent of land surface recharge in the Knapdale groundwater zone and 34.8 percent of land surface recharge in the Croydon zone[9]. The comparatively high level of allocation for the proposed Croydon zone reflects the presence of four relatively large takes (1 municipal supply and 3 irrigation) in this comparatively small area[10].

Given the geometry of the proposed Croydon groundwater zone and the observed hydraulic connection with the Mataura River it is suggested this groundwater zone would be best classified as a Riparian aquifer system.

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[9] These percentages would increase slightly if the average rainfall recharge figure outlined in Section 3.3 were used to calculate land surface recharge

[10] Although it is noted that this level of allocation would reduce significantly under Policy 29 if the current low degree of hydraulic connection assigned to the GDC Jacobstown supply were to change

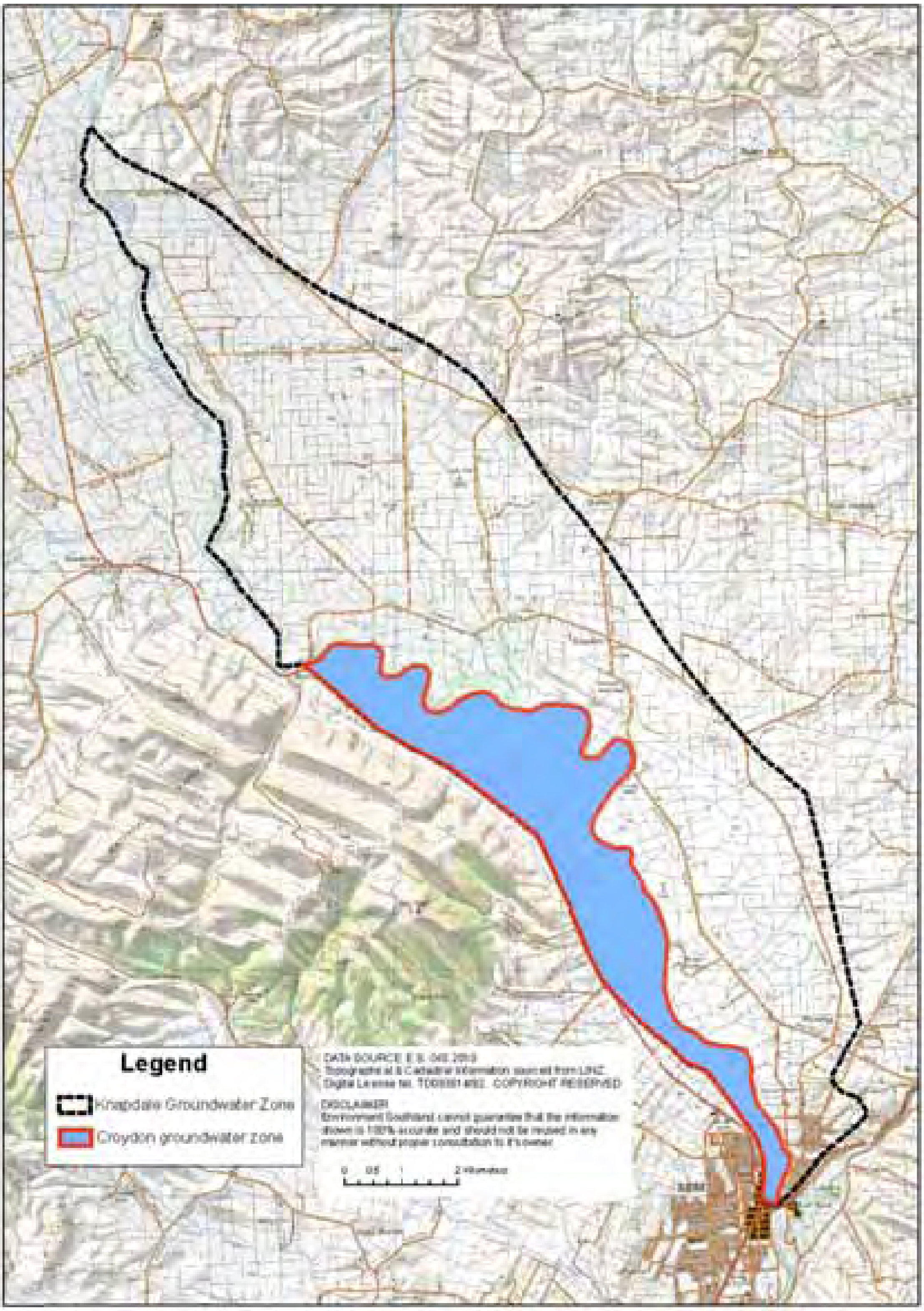

Figure 27. Suggested amendment to existing groundwater zone boundaries in the Knapdale groundwater zone

In terms of groundwater quality, available data suggest the unconfined groundwater resource in the Knapdale groundwater zone is vulnerable to localised effects associated with land use. This vulnerability is interpreted to reflect a combination of factors such as the limited saturated thickness, moderate to low aquifer transmissivity and the relative contribution of land surface recharge, particularly in areas away from the Mataura River. While further investigation would be required to reliably establish linkages between land use and associated effects on groundwater quality, it is suggested that the elevated risk indicated by available groundwater quality data should be taken into consideration when determining future compliance monitoring requirements.

5.3 Recommendations for future monitoring

At the current time all groundwater level and quality monitoring in the Knapdale groundwater zone occurs in the area north of the Mataura River. Given the comparatively high level of allocation in the proposed Croydon groundwater zone it is recommended the current groundwater level monitoring network is extended to include sites in this area. Ideally, an automatic groundwater level recorder would yield useful information to characterise temporal variations in groundwater storage in response to rainfall, river flow and abstraction and enable a direct comparison to data recorded at F45/0569 on the north side of the river. Alternatively, if it is not possible to automate a groundwater level monitoring site in the Croydon area, it is suggested at least two monthly manual dipping sites be added to the network in this area.

In terms of groundwater quality, available data suggest a wide variation in groundwater quality (particularly in terms of nutrient concentrations) in the Knapdale groundwater zone. In order to better characterise spatial variability, it is recommended Environment Southland consider undertaking a one-off groundwater quality investigation in the Knapdale groundwater zone. Data from such a survey would be useful to improve understanding of the existing groundwater quality state[11] and ensure SOE monitoring provides a 'representative' indication of overall groundwater quality (particularly in terms of F45/0172). It is further recommended a baseline groundwater quality site is added in the proposed Croydon groundwater zone.

[11] Including potential relationships with land use and other factors influencing groundwater quality risk

6. References

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