Waitaki Catchment Groundwater Information

Report prepared for
Ministry for the Environment

Report commissioned by the Ministry for the Environment

for consideration by the Waitaki Catchment Water Allocation Board.

Prepared by Sinclair Knight Merz
25 Teed Street
PO Box 9806
Newmarket, Auckland, New Zealand
Tel:+64 9 913 8900
Fax:+64 9 913 8901
Web: www.skmconsulting.com

Published in December 2004 by the
Ministry for the Environment
Manatū Mō Te Taiao
PO Box 10362, Wellington, New Zealand

ISBN: 0-478-18983-4
ME number: 569

This document is available on the Ministry for the Environment's website:
www.waitaki.mfe.govt.nz

COPYRIGHT: The concepts and information contained in this document are the property of Sinclair Knight Merz Limited. Use or copying of this document in whole or in part without the written permission of Sinclair Knight Merz constitutes an infringement of copyright.

Contents

List of figures

List of tables

List of plates

Document history and status

Revision	Date issued	Reviewed by	Approved by	Date approved	Revision type
Draft Rev A	5 Nov 2004	Jon Williamson			Internal QA
Draft Rev B	8 Nov 2004	Nigel Kay	Nigel Kay	9 Nov 2004	NZ Environmental Manager
Draft Rev C	9 Dec 2004	Jon Williamson	Jon Williamson	9 Dec 2004	QA/QC - Water Resource Team Leader
Final	15 Dec 2004	MfE type setter	Jon Williamson	15 Dec 2004	Type setting

Distribution of copies

Revision	Copy no	Quantity	Issued to
Draft Rev C	1	Email	Christina Robb (MfE)
Final	1-12	12	Christina Robb (MfE)
Final	13-15	3	SKM

Printed:	13 January 2005
Last saved:	9 December 04
File name:	I:\Aenv\Projects\AE02315\Reports\Waitaki Rpt_Draft C.doc
Author:	Tom Heller & Jon Williamson
Project manager:	Tom Heller
Name of organisation:	Ministry for the Environment
Name of project:	Waitaki Catchment Groundwater Information
Name of document:	Hydrogeological assessment of groundwater quantity in the Waitaki Catchment
Document version:	Final
Project number:	AE02315

Executive summary

Sinclair Knight Merz (SKM) was commissioned by the Ministry for the Environment in October 2004 to provide a preliminary hydrogeological assessment of groundwater quantity in the Waitaki River Catchment. The information obtained from this study, while preliminary in nature, will assist the Waitaki Catchment Water Allocation Board to understand groundwater resources and the groundwater interactions with surface water.

The specific objectives of the study were to provide assessments of:

- groundwater flow directions and quantity
- groundwater interaction with surface water bodies and its significance
- the level of confidence in the interpretations made

In general terms, the main considerations for groundwater in the Waitaki Catchment are:

- Groundwater flow generally occurs towards major surface water sinks (ie rivers, streams and lakes). However, some aquifer areas are recharged by stream flow where suitable hydraulic conditions permit (eg Irishman Creek and Tekapo River).
- There are larger groundwater storage areas located in the upper catchment (eg Tekapo and Twizel Basins), and also in the lower catchment (eg Glenavy and Lower Waitaki Plains).
- The impact on surface water from spring outflow depletions requires specific consideration when allocating groundwater in some basins that have existing surface water allocations (eg Omarama Basin, Hakataramea Valley, Maerewhenua Basin and Papakaio Formation).
- Currently, the Glenavy and Waitaki Plains areas receive a major component of recharge from the Waitaki River irrigation schemes.

Overall, a reasonable understanding of the aquifer flow regime has been established and should provide the Water Allocation Board with information appropriate for catchment-scale planning. However, it is important to note that the information contained in the report is not an appropriate basis for site-specific water allocation decisions.

1. Introduction

Sinclair Knight Merz (SKM) was commissioned by the Ministry for the Environment in October 2004 to provide a preliminary hydrogeological assessment of groundwater quantity in the Waitaki River Catchment. The demand for irrigation water, and particularly groundwater in areas underlain by high permeability gravel aquifers is increasing. In addition, the Waitaki Catchment faces unprecedented conflict over water allocation due to the various competing interests, such as hydroelectricity, irrigation schemes, farmers, and the interests of groups wishing to preserve the cultural and environmental values associated with water within the catchment.

The information obtained from this study, while preliminary in nature, will assist the Waitaki Catchment Water Allocation Board to understand groundwater resources and the interaction with surface waters.

The specific objectives of the study included:

- an assessment of groundwater flow directions and quantity
- reporting on groundwater interaction with surface water bodies and its significance
- providing the level of confidence in interpretations of groundwater flow directions and quantity.

The Waitaki Catchment

The Waitaki River Catchment comprises over 11,000 square kilometres extending from the Southern Alp headwaters to the South Island's East Coast north of Oamaru (Figure 1). The Waitaki River is the fourth largest river in New Zealand with a mean historical flow at the Waitaki Dam of $358m^3/s$ recorded between 1927–2000 (Opus, 2003). The four major tributary basins of the Waitaki Catchment are the Tekapo, Pukaki, Ohau and Ahuriri. The catchment includes the natural lakes of Tekapo, Pukaki and Ohau, and the artificial lakes of Benmore, Aviemore and Waitaki.

Groundwater information in the upper Waitaki Catchment is limited, whilst in the lower catchment, there has been extensive study of groundwater resources for regional councils and Project Aqua. Based on the existing knowledge of groundwater resources in the Waitaki Catchment, the current report focuses on groundwater zones, direction of groundwater flow and the relationship of groundwater to physical boundaries; for example, rivers, lakes, and topography.

- **Figure 1. Waitaki Catchment locality plan and aquifer boundaries**

  (see A3 attachment at rear)

2. Background information

Existing data on groundwater resources in the Waitaki River Catchment is available from the following sources:

- Environment Canterbury and Otago Regional Council 'Wells' databases
- Waitaki Catchment Commission, Environment Canterbury, Otago Regional Council-commissioned water resource reports
- records from drillers operating in the area (Washingtons Drilling & Exploration, Timaru, McMillan Water Wells/Drilling Ltd, Christchurch, McNeill Drilling, Alexandra)
- individual bore owner information, which also may have current groundwater (take) consents or consent applications
- Electricity Corporation of New Zealand (ECNZ) reports for drilling and groundwater investigations commissioned over a number of years as part of the pre-feasibility studies for the Upper Waitaki Hydroelectric Scheme
- Project Aqua Assessment of Environmental Effects (predominantly the URS groundwater bore data for the Lower Waitaki)
- anecdotal information from long-term Waitaki Catchment landowners.

2.1 Previous reports

There have been various studies and reports compiled for regional councils and for Project Aqua. The information contained in existing reports mainly relates to groundwater resources in the lower Waitaki Catchment downstream of Kurow. The existing groundwater information presented in this report is attributed to the following sources:

- Sinclair Knight Merz (2000), *Lower Waitaki Groundwater Investigation*
- Opus (2003), *Project Aqua Waitaki River Hydrology Study*
- URS (2003), *Project Aqua Water Balance*
- URS (2003), *Project Aqua Hydrogeological Assessment of Effects*
- Montgomery Watson Harza (2004), *Papakaio Aquifer Report: Outside of the Enfield Basin North Otago*
- Sinclair Knight Merz (2004), *Draft National Cost Benefit Analysis of Proposals to Take Water from the Waitaki River*.

SKM

2.1.1 Upper Waitaki groundwater

ECNZ commissioned the Ministry of Works and Development to perform a number of drilling and groundwater investigations over the years (1960s to 1970s) as part of the pre-feasibility studies for the Upper Waitaki Hydroelectric Scheme. However, overall information on groundwater in the upper Waitaki is limited and this signifies that there has been little groundwater development in the area to date.

Recent drilling for groundwater has been undertaken in the general vicinity of Twizel township for domestic and irrigation use in the shallow unconfined gravel aquifer adjacent to Lake Ruataniwha (Environment Canterbury, 2004).

In recent times, a number of bores have been drilled by individual stations prospecting for irrigation water supply. Results from those bores indicate that groundwater can be encountered at significant depth in basins in the upper Waitaki Catchment (greater than 80 metres).

The Waitaki Catchment Commission (1982) states that groundwater immediately downstream of the lakes in the Mackenzie Basin tend to lie at great depths. It is unclear whether this refers to groundwater levels pre- or post-canal development. The report indicates that groundwater within the river valleys may be perched above glacial silt layers deposited in the riverbed.

2.1.2 Lower Waitaki groundwater

Groundwater investigations within the lower Waitaki have been undertaken since the late 1970s associated with the hydroelectricity generation investigations for the Lower Waitaki Scheme. Since then a number of small investigations have been undertaken by the Waitaki Catchment Commission in 1986 and the Otago Regional Council in 1993–1994. In 1999, the Otago Regional Council commissioned a major investigation of the lower Waitaki alluvium on the south side of the river. The study comprised a comprehensive bore survey, nine months of groundwater quality and level monitoring, and an assessment of groundwater quantity and sustainability (SKM, 2000).

Environment Canterbury (2002) has undertaken an extensive (mainly water quality) investigation of the Glenavy (north bank) zone of the Lower Waitaki. Since this time, additional information has been compiled and a broader study encompassing Otago Regional Council and Environment Canterbury data, including further hydraulic analyses from test pumping and test pit data, has been completed as part of the Project Aqua Assessment of Environmental Effects (URS, 2003b). Bore surveys along the left and right banks of the Waitaki River from Kurow to Black Point were also completed as part of the study.

The Otago Regional Council commissioned Montgomery Watson Harza (MWH) to report on the groundwater resources of the Papakaio Formation in 2003. MWH (2004) discusses the occurrence and allocation of groundwater in the Maerewhenua Basin.

From the above reports the indications are that by far the highest yielding and important aquifers in the lower Waitaki are the Pleistocene and Post-Glacial gravel alluvium deposits, representing the upper and lower terraces of the lower Waitaki Valley, respectively (Glenavy and Waitaki areas – Figure 1). These aquifers are used for potable household domestic and stock drinking water, dairy shed washdown and irrigation. The biggest consumptive use of groundwater on an annual basis is related to dairying (excluding dairy farm irrigation); however while only a handful of bores use groundwater for irrigation, the maximum irrigation take during summer is nearly double that of non-irrigation use.

While most bores appear capable of yields between 2–5 l/s, groundwater is secondary to surface water sourced from the various irrigation schemes for irrigation and stock water (SKM, 2000).

Other sources of groundwater in the lower Waitaki include the cemented sedimentary and limestone aquifers associated with the Papakaio Formation (URS, 2003; MWH, 2004).

2.2 Bore and spring inventory

Bore information in the upper Waitaki Catchment has been gained from the existing Environment Canterbury Wells database and has also been compiled for the historic ECNZ investigations during the 1960s and 1970s, although to our knowledge, none of these wells is currently used for the monitoring of groundwater. The ECNZ bores generally consisted of a drilled and driven 50mm galvanised pipe (Plate 1 – Figure 1). The piezometers were normally left one metre above local ground surface, with a screw cap to enable access to probe groundwater level.

There are more than 300 bores utilised in the lower Waitaki catchment, mainly centred on the lower Waitaki alluvium areas. Appendix A contains a summary of the bores contained in the URS well inventory for Project Aqua investigations, which has been obtained predominantly from existing Environment Canterbury and Otago Regional Council Wells databases.

- **Plate 1. Typical ECNZ piezometer in the Twizel Basin**

2.3 This study

The information contained in the listings above have been utilised where applicable to derive groundwater maps and hydrogeological interpretation for the Waitaki River Catchment. In addition, a field exercise focusing mainly on the upper Waitaki Catchment was completed to gain piezometric information in areas where existing information was limited. The field data consisted of water table levels measured from various (historic) ECNZ boreholes, installed as part of the pre-feasibility studies for the Upper Waitaki Hydroelectric Scheme.

Field investigations also centred on the visual assessment of shallow water table, springs and smaller tributary river systems of the Waitaki Catchment.

3. Hydrogeological interpretation

3.1 Geological setting

A summary geology map for the Waitaki Catchment (Figure 2A and 2B) shows that the predominant geology of the aquifer basins in the catchment consists of Pleistocene and postglacial gravel deposits (Plate 2 – Figure 1) surrounded and underlain by Tertiary, Cretaceous and basement rocks.

There are, however, subtle differences in the composition of gravels and sediments within the Waitaki Catchment. Moraine areas located in the Tekapo and Twizel Basins contain poorly sorted sediments and glacial till. This implies that groundwater hydraulics will be low and bore yields in these areas is likely to be poor. There is also a difficulty in correlating piezometric surfaces within moraine areas compared to that of alluvial outwash areas, because of the alternating coarse and fine deposits, which can produce to localised perched water tables. The presence of moraine areas within basins also provides some topographical variation to that of the 'flatter' alluvial terraces. In the recent alluvial gravels of the lower Waitaki alluvium, bore yields are likely to be much greater given the higher range in permeability for these gravels

Major faulting occurs in the Waitaki Catchment and generally defines specific sub-catchments or basins. In the lower catchment, the Waitaki Fault delineates the sedimentary rocks to the south from the Lower Waitaki Alluvium. The Waitaki Fault tends to diminish near Black Point, where greywacke and schist basement outcrops. Occurrences of recent alluvium in the Lower Waitaki Catchment are variable from thin veneers surrounding local stream outwash areas to a deep alluvial trench (the Kurow Trench) associated with a small graben in vicinity of the Penticotico Stream area.

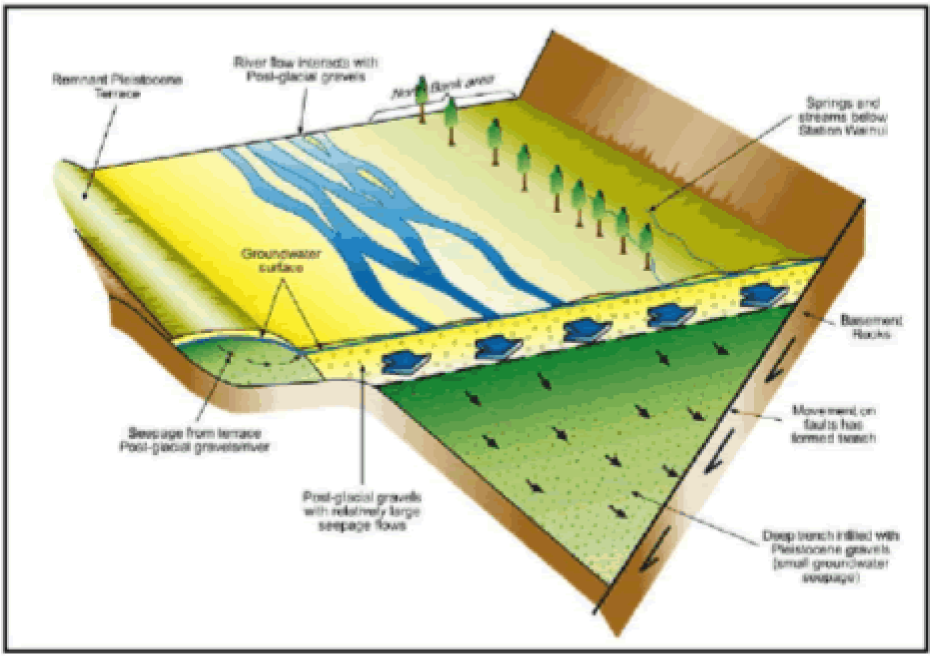
Waitaki Catchment geology delineates groundwater basins, which are mapped in Figure 1. However, exact delineations of some zones on the basis of geology alone is not possible, due to watershed or groundwater divides. The areas where there are 'soft' groundwater divides or uncertainty in geological extent within zones, have been shown using dashed lines for individual basins (Figure 1).

A schematic hydrogeological cross-section oriented south to north through the lower Waitaki and Glenavy basins is reproduced from the URS Project Aqua Report in Figure 3. Note that hydrogeological cross-sections could not confidently be provided for other areas of the Waitaki Catchment due to limited bore lithological and groundwater information.

- **Figure 2A & 2B. Summary geology map for the Waitaki Catchment**
  (see A3 attachment at rear).

SKM

- **Figure 3. Schematic hydrogeological cross-section through the lower Waitaki alluvium (sourced from URS, 2003b)**



- **Plate 2. Pukaki Basin terrace adjacent to the Pukaki River**

3.2 Aquifer zones

Various groundwater basins with key surface water features have been identified in this report for the Waitaki River Catchment (Figure 1). The groundwater zones have been drawn on the basis of topographical and hydrological boundaries, geological control, and known and assumed groundwater flow direction in unconfined aquifers as discussed in Section 3.4. The 13 groundwater basins and their respective surface areas and surface water features are summarised in Table 1.

- **Table 1. Summary of groundwater basins**

Basin	Approx. Basin Area (km^2)	Surface Water Features
Tekapo Basin	644.7	Tekapo and Grays Rivers and tributaries, Mary Burn, Irishman Creek
Twizel Basin	685.1	Pukaki, Twizel, Tekapo and lower Ohau Rivers, and adjacent lakes Ohau, Ruataniwha and upper Benmore
Upper Omarama Basin	55.6	Hen Burn and Quail Burn Streams
Omarama Basin	196.2	Ahuriri River and Omarama Stream
Benmore Terrace	28.4	Otamatapaio River
Aviemore (Waitangi) and Waitaki flats	34.9	Waitangi Stream, Lakes Aviemore and Waitaki
Hakataramea Valley	336.1	Hakataramea River
Waitaki Valley (Kurow – Black Point) north bank	28.5	Penticotico Stream
Waitaki Valley (Kurow – Black Point) south bank	60.7	various streams including Otekaieke River
Maerewhenua Basin	22.5	Maerewhenua River
Papakaio Formation	111.3	Awamoko and Waiareka Streams
Lower Waitaki Plains – Waitaki (Otago)	179.6	Awamoko and Waikoura-Henderson Streams, Welcome Creek
Lower Waitaki Plains – Glenavy (Canterbury)	157	Waikahiki Stream

In the upper Waitaki Catchment, the Tekapo Basin is separated from the Twizel Basin on the basis of groundwater flow and relief features. However, the boundary of these zones is unclear in the upper Pukaki area and the extent of the Tekapo Basin in the upper Irishman Creek area is unknown, as little information is available on surface and groundwater hydrology in these locations (Section 4).

A groundwater divide separates the Twizel and Omarama basins in the vicinity of Clear Burn, between the Ahuriri River and Lake Ruataniwha. However, the exact position of the divide is not known in any detail, and is shown as a dashed line on Figure 1.

The upper Omarama Basin is separated from the Omarama Basin to represent the drainage features of the Quail Burn and Hen Burn streams. These two streams drain the basin through the 'Clay Cliffs' to the Ahuriri River. Groundwater divides exist to the north and south of the upper Omarama Basin, separating the Twizel and Omarama basins respectively.

The areas of the north and south bank of the Waitaki River below Kurow are also separated from the lower Waitaki Plain below Black Point. This has been delineated on the basis of piezometric contouring. It should be recognised that the boundaries may change over time, reflecting changes in state of the water table, irrigation season and Waitaki River flow.

Other areas such as the Benmore Terrace, Aviemore and Waitaki Flats have little or no information available on groundwater resources. The basins have been delineated (Figure 1) as groundwater yields may be available from these areas. The Maerewhenua Basin and Papakaio Formation are located to the south of the lower Waitaki Valley. These groundwater areas are separated by depth, with the Papakaio Formation underlying much of the Maerewhenua River alluvium.

3.3 Depth to groundwater

Figures 4A and 4B show the depth to groundwater in metres given the data available for groundwater basins in the upper and lower Waitaki Catchment respectively.

Depth to groundwater over the Waitaki Catchment and within specific groundwater basins is variable. For example, in the Twizel River area above SH8 the groundwater is very shallow with the groundwater table essentially close to or at ground level. However, further down the Twizel River at just above the Pukaki River confluence, the depth to groundwater in upper terrace areas is in excess of 30 metres.

Major areas of shallow groundwater in the catchment includes:

- upper Tekapo Basin (Plate 3 – Figure 1) and adjacent to the Grays River and Mary Burn
- upper Twizel Basin including the upper Wairepo Creek and adjacent to the upper Twizel River
- upper Omarama Basin surrounding the Hen Burn and Quail Burn Streams
- most locations in the Omarama Basin, particularly in the lower Ahuriri River area
- Waitaki Valley lower alluvial terrace and in the vicinity of the Otekaieke River, Maerewhenua River near Duntroon, and up-valley of the Penticotico Stream in the vicinity of Wainui Station
- lower Waitaki plains alluvial terrace areas from Black Point to SH1.

- **Figure 4A & 4B. Depth to groundwater in the upper and lower Waitaki Catchments** (see A3 attachments at rear).

SKM

- **Plate 3. Shallow groundwater in the upper Tekapo Basin**

Shallow groundwater is generally associated with wetlands and springs (as in the areas listed above). Major wetland areas and springs are shown on Figures 4A and 4B, and Figures 5A and 5B respectively with the most notable springs emerging in the lower Waitaki Valley on opposite sides of the Waitaki River near Duntroon. These are the Duntroon and Penticotico spring areas respectively (Plate 4 – Figure 1).

- **Plate 4. Duntroon and Penticotico springs**

Other significant springs in the lower Waitaki area includes Welcome Creek (Plate 5 – Figure 1). Welcome Creek is a major trout spawning stream in the lower Waitaki area, which derives flow (in the upper reaches) entirely from spring outflows from the lower Waitaki alluvium.

As previously mentioned, springs also emerge in the surrounding area of the upper Twizel River, adjacent to Twizel township (Plate 6 – Figure 1), and in the upper Ohau River terrace below SH8. It is probable that some leakage from Lake Ruataniwha is contributing to spring flows in that area.

- **Plate 5. Welcome Creek downstream of Ferry Road**

- **Plate 6. Small springs in the Twizel River area, excavated for land drainage**

3.4 Piezometric surfaces

Figures 5A and 5B show the piezometric surface geometry for aquifer basins in the upper and lower Waitaki Catchments respectively. The piezometric surface was constructed from depth to groundwater data and surveyed/reported and estimated ground reference elevations. The basis of information used for construction of piezometric surfaces is contained in Table 2.

- **Figure 5A and 5B. Piezometric surface in the upper and lower Waitaki Catchments** (see A3 attachments at rear).

SKM

■ **Table 2. Data used for piezometric map generation**

Groundwater Zones	Information Source
1. Tekapo Basin	Upper Waitaki (Environment Canterbury) & ECNZ piezometric data
2. Twizel Basin	Upper Waitaki (Environment Canterbury) piezometric data
3. Upper Omarama Basin	Upper Waitaki (Environment Canterbury) piezometric data
4. Omarama Basin	Upper Waitaki (Environment Canterbury) piezometric data
5. Benmore Terrace	No information
6. Aviemore (Waitangi) and Waitaki flats	No information
7. Hakataramea Valley	Upper Waitaki (Environment Canterbury) piezometric data
8. Waitaki Valley (Kurow – Black Point) north bank	URS piezometric surface map (Project Aqua)
9. Waitaki Valley (Kurow – Black Point) south bank	URS piezometric surface map (Project Aqua)
10. Maerewhenua Basin	MWH piezometric surface map (Otago Regional Council report)
11. Papakaio Formation	MWH piezometric surface Otago Regional Council report)
12. Lower Waitaki Plains – Waitaki (Otago)	URS piezometric surface map (Project Aqua)
13. Lower Waitaki Plains – Glenavy (Canterbury)	URS piezometric surface map (Project Aqua)

The piezometric surfaces in most basins tend to follow surface contours, and align to surface water features and no-flow boundaries (eg mountain ranges and groundwater divides). Groundwater levels in the Waitaki Catchment range from near sea level in the Lower Waitaki Plains to 680 metres above mean sea level (AMSL) for shallow groundwater in the Lake Tekapo area. The piezometric surface in many basins are relatively shallow and are close to or at surface water levels, suggesting a high degree of coupling. In addition, groundwater contours appear to run at an offset to major rivers in some locations, which suggests seepage to the aquifer from surface waters where favourable hydraulic gradients prevail (ie the water table is of sufficient depth beneath the river level).

Conditions where surface flow gains and losses occur in the Waitaki Catchment are discussed in Section 5 and are shown on Figures 6A and 6B. Generally, there is insufficient information to accurately determine the quantity of flow to/from surface waters in the catchment. However, by assessment of existing gauging information, stream occurrence and water table level data, some appreciation of the potential flow losses and gains can be made. Changes in the slope of the piezometric surface or groundwater gradient provide useful information regarding the hydraulic functioning of the aquifer flow regime, primarily with respect to aquifer permeabilities and recharge.

In the absence of significant recharge sources in addition to rainfall, steepening of the piezometric gradient generally indicates progressively lower aquifer permeabilities. This occurs to the north in the Tekapo Basin, to the west in the Twizel Basin, in the west of the Hakataramea Basin, and in the Papakaio Formation. With the exception of the Papakaio Basin, the reason for this is a combination of i) older more cemented glacial outwash deposits and ii) a higher proportion of clay colloids in the aquifer derived from colluvium washed off the surrounding hills.

Conversely, flattening of piezometric contours (wider spacing), generally indicates higher aquifer permeabilities. This occurs in the downgradient portions of most basins and particularly Tekapo Basin, Twizel Basin, Omarama Basin, and the north and south bank of the Waitaki Valley and within the Lower Waitaki alluvium. These areas are generally expected to have higher water yielding capability, although other variables such as aquifer thickness contribute to this, therefore there will be spatial heterogeneities or exceptions to this rule of thumb.

- **Figure 6A and 6B. Flow losses and gains from/to surface waters in the upper and lower Waitaki Catchments**

  (see A3 attachments at rear)

3.5 Base of aquifer, saturated thickness, and storage

For the upper Waitaki groundwater basins, only 13 bores across the entire region intersect underlying clay or hardrock base, making generation of a meaningful depth to base contour map impossible. It is also unclear whether water-bearing gravels exist beneath the clay horizons as reported in drillers logs. In this regard, Figure 7A shows all available bores with either depth to base (in red) or the maximum bore depth (in blue) where base of aquifer data was not available. In the absence of extensive data sets, this map at least allows formulation of a preliminary understanding.

For the lower Waitaki groundwater basins, the aquifer base elevation has been derived by URS as part of Project Aqua. This data is reproduced in Figure 7B. The Hakataramea Basin and Papakaio Formation are shown in a similar fashion to the upper Waitaki groundwater basins.

- **Figure 7A & 7B. Base of aquifer in the upper and lower Waitaki Catchment**

  (see A3 attachment at rear).

From Figure 7A, typical bore depths shown for the Tekapo Basin range from 2 metres along the Tekapo canal to 100 metres near Mary Range, with a basin wide average of approximately 28 metres. For the Twizel Basin, typical depths range from 2 metres near the centre of the basin along SH8 to 130 metres near Mary Range. There is only one bore located in the Upper Omarama Basin, of 30 metre-depth. Typical depths in the Omarama Basin range from 5 metres to 150 metres. There are no bores in the Benmore and Aviemore Basins.

From Figure 7B, there are three bores located within the Hakataramea Valley Basin ranging from 15 metres to 72 metres depth. Bore depths within the Waitaki Valley and plains range from 1 metre to 80 metres, with an average depth of 14 metres.

Saturated aquifer thickness has only been calculated for the Lower Waitaki aquifer basins from the interpolated depth to groundwater and depth to base of aquifer contours (Figure 8). This calculation is not meaningfully possible in the other groundwater basins due to the data deficiencies as discussed above. However, estimated average saturated thickness of the aquifers has been developed from the bore data available and hydrogeological intuition, as summarised in Table 3.

- **Figure 8. Saturated aquifer thickness in the lower Waitaki Catchment**
  (see A3 attachment at rear).

Table 3 also provides the estimated groundwater storage for each aquifer basin, calculated from the average saturated thickness, and estimated specific yield, which in this case has been assumed to equal porosity in basin areas. Aquifer specific yield (Sy) has been estimated from literature values. Sy for unconsolidated sandy silty gravels is normally in the range of 0.18–0.25 (Freeze & Cherry, 1979).

Large aquifer storage generally implies longer residence times for groundwater in the aquifer. Sizeable storage also implies increased time lags in terms of response in surface waters to groundwater abstraction, although actual effects are dependant on the location of bores and size of abstraction within the aquifer. The largest potential storage of groundwater within the Waitaki Catchment exists in the Tekapo and Twizel basins (Table 3).

- **Table 3. Groundwater storage for aquifer basins in the Waitaki Catchment**

Zone	Aquifer Surface Area (km^2)	Estimated Average Sy (-)	Estimated Average Saturated Thickness (m)	Total Storage (Mm^3)
Tekapo	644.7	0.2	20	2579
Twizel	685.1	0.2	20	2740
Upper Omarama	55.6	0.18	25	250
Omarama	196.2	0.2	6	235
Benmore Terrace	28.4	0.2	5	28.4
Aviemore & Waitaki flats	34.9	0.2	5	34.9
Hakataramea Valley	336.1	0.18	15	907
Waitaki Valley – north bank	28.5	0.2	20	114
Waitaki Valley – south bank	60.7	0.2	6	72.8
Maerewhenua	22.5	0.2	6	27
Papakaio Formation	111.3	0.07*	25*	195
Lower Waitaki	179.6	0.2	10	359
Glenavy	157	0.2	15	471

Note: The Papakaio formation varies from unconfined in the outcrop area to confined in the Maerewhenua basin. Average values for Sy and thickness have been taken from MWH (2004)

3.6 Aquifer hydraulic properties

Information on hydraulic properties is available from test pumping conducted on bores at the completion of drilling. However, there is a lack of bore test information in the upper Waitaki Catchment and in the Hakataramea Valley.

Hydraulic properties have been assessed in this study by:

- estimating transmissivity from specific capacity using a rearrangement of Jacob's equation (Driscoll, 1986)
- estimating transmissivity from drawdown information using unconfined Theis methodology (Freeze & Cherry, 1979)
- converting transmissivity to hydraulic conductivity (dividing by the saturated thickness of the aquifer)
- utilising hydraulic conductivity for aquifer basins previously reported on.

Figure 9A shows hydraulic conductivity values for bores in the upper Waitaki Catchment. Hydraulic conductivity in this region generally range from 0.1m/day to 100m/day, which is within the range of reported values for silty and clean sand and gravels (Freeze & Cherry, 1979).

SKM

Hydraulic conductivity in the lower Waitaki Catchment (Figure 9B) generally ranges from 43 to 86 m/day for the Pleistocene gravels and 604 to 1,730 m/day for the postglacial gravels (URS, 2003b). The range in values implies that there is a marked difference in the hydraulic capacity of the (recent) postglacial gravels to that of Pleistocene gravels, moraine and other sedimentary deposits located in the Waitaki Catchment. The hydraulic conductivity for the postglacial gravels can be regarded as high. The range of hydraulic conductivity for areas containing other than 'recent' gravels can be regarded as low to moderate; however the usefulness of these aquifers for groundwater exploitation is still possible on a site-by-site basis given the variation in hydraulic conductivity and saturated depth in the Waitaki Catchment.

- **Figure 9A and 9B. Hydraulic conductivity in the upper and lower Waitaki Catchment** (see A3 attachment at rear).

3.7 Preliminary water balance estimates

For the purpose of providing preliminary estimates of the aquifer water balances, we have assumed that groundwater outflows are equal to groundwater inflows or recharge.

Groundwater recharge is a complex issue for most unconfined aquifers as it is governed by a number of factors including rainfall characteristics (intensity, frequency and duration), soil moisture conditions, surface and sub-surface geology, meteorology, land surface gradients and various other factors. Collectively these factors govern the partitioning of the water balance into the various components, including surface evaporative losses (including interception), soil evaporative losses, surface runoff and groundwater recharge.

Groundwater recharge is complicated further when recharge within designated groundwater management zones is subject to water imports from outside the management zone (eg surrounding hardrock sub-catchment). This recharge component is often poorly quantified without stream loss gaugings or surface–groundwater interaction monitoring. Excess irrigation water, which occurs during the summer irrigation season, may also contribute a significant component to groundwater recharge on an annualised basis.

In the aquifer basins of the Waitaki Catchment, the most significant recharge components on a volumetric basis are likely to include:

- areal distributed rainfall infiltration
- stream leakage from major rivers and other smaller streams traversing the aquifer basins
- recharge derived from infiltration of border dyke, flood irrigation and spray irrigation waters.

In addition to precipitation falling directly on to the aquifer itself, recharge may also be derived from runoff seepage and shallow sub-surface seepage from the upper terraces, hills and mountain ranges that surround the basins. The groundwater recharge component from these areas is unknown at present and additional work would help to confirm the significance, especially the larger catchments that drain into the Tekapo and Twizel basins, and the Hakataramea Valley. It is thought that this runoff seepage, while not necessarily significant in a temporal sense (ie it occurs infrequently), may on an annualised basis contribute significant volumes.

Consideration of recharge to aquifers in the Waitaki Catchment, for the purpose of this report (based on the information available at this time), is described in the following equation:

$$Rc = SL + RI + EII$$

Where *Rc* is recharge, *SL* is stream leakage, *RI* is rainfall infiltration, and *EII* is excess irrigation infiltration (all units in mm^3/annum).

Recharge estimates can also be obtained from assessments of groundwater throughflow assuming that aquifer outflows equal the combined inputs or recharge. This calculation is a useful cross check on other methods of estimating aquifer recharge in simple aquifer settings, but requires a reasonable understanding of average aquifer hydraulic conductivity, water table gradient, saturated thickness and the width of the aquifer normal to flow. In the Waitaki Catchment, however, the numerous locations where groundwater interacts with surface water makes basin endpoint calculation methods such as this less reliable and there is a lack of data in most cases to perform such calculations with any degree of reliability.

3.7.1 Areal rainfall recharge

Rainfall recharge to aquifer basins in the lower Waitaki Catchment has been reported as a net flux to groundwater of 54mm per year as an annual average (URS, 2003). This is the net soil moisture loss/drainage, assuming a soil moisture holding capacity of 90mm and annual rainfall and evapotranspiration totals of 548mm and 1,019mm respectively (URS, 2003). Reported net soil moisture losses in the elevated terraces surrounding the Maerewhenua Basin are in the order of 76mm (MWH, 2004).

The equivalent recharge components (based on an average annual rainfall of 680mm) for the Wanaka Basin is approximately 48 to 96 millimetres (Otago Regional Council, 2002). It follows that the upper limit for rainfall recharge on the aquifer surface in the upper Waitaki Catchment, based on an average annual rainfall variation of 400 to 500 millimetres, would be between 32 millimetres and 48 millimetres, allowing for minor runoff. This is similar to that reported for areas of central Otago, with similar rainfall patterns (Otago Regional Council, 1998). Based on the above figures, a conservative rainfall infiltration value of 40 millimetres or nine percent of average annual rainfall is assumed to represent rainfall recharge to the upper Waitaki Catchment area.

Estimation of the total volume of rainfall recharge requires consideration of the surface area of the aquifer basin. The total rainfall recharge for aquifer basins in the Waitaki Catchment is shown in Table 4.

- **Table 4. Estimated average annual rainfall-recharge volumes for aquifer basins in the Waitaki Catchment**

Zone	Area (km^2)	Infiltration rate (m/yr)	Recharge (Million m^3/yr)	Recharge (l/s)
Tekapo	644.7	0.040	25.8	817
Twizel	685.1	0.040	27.4	868
Upper Omarama	55.6	0.040	2.2	70
Omarama	196.2	0.040	7.8	247
Benmore Terrace	28.4	0.040	1.1	35
Aviemore & Waitaki flats	34.9	0.040	1.4	44
Hakataramea Valley	336.1	0.040	13.4	424
Waitaki Valley Plains – north	28.5	0.054	1.5	48
Waitaki Valley Plains – south	60.7	0.054	3.3	105
Maerewhenua	22.5	0.054	1.2	38
Papakaio	24*	0.076	1.8	57
Lower Waitaki	179.6	0.054	9.7	307
Glenavy	157	0.054	8.5	269

* **Note:** the Papakaio formation outcrop area for rainfall recharge has been taken from MWH (2004)

3.7.2 Stream leakage

Gauging records together with flow records, piezometric data and visual observations indicate that the many rivers and streams traversing aquifer basins in the Waitaki Catchment leak water to aquifers. Also, many streams or rivers gain flow from groundwater. In most cases in the upper Waitaki Catchment, streams lose water to groundwater in upper or mid reaches, only to regain flow in lower reaches. Section 5 provides further discussion on groundwater–surface water exchanges.

Environment Canterbury has performed many stream flow gaugings on various rivers and streams in the Waitaki Catchment over the years. However, only a small sub-set of the flow measurements provides a reasonable analysis of flow loss/gains in streams. Generally, flow gauging runs for the purpose of proportioning river gains and losses along the stream should occur concurrently at multiple sites on the same stream, and during low winter flows to avoid irrigation takes distorting the data. URS (2003) details water balances for surface stream input to groundwater in the lower Waitaki Valley, which has been used in the final water balance estimates in this report.

In 2003, Environment Canterbury performed concurrent flow gaugings in the Waitaki Catchment, of which a reasonable indication of flow losses or gains could be made. Figure 10 shows the flow regime for three streams in the upper Waitaki Catchment. Individual site data is contained in Table 5 while a full inventory of recent flow gauging data examined for flow loss/gain zones is contained in Appendix B. The site numbers in each case refer to down gradient gauging locations.

- **Figure 10. Flow measurements in Irishman Creek, Mary Burn and Omarama Stream during the period of 12–13 August 2003**

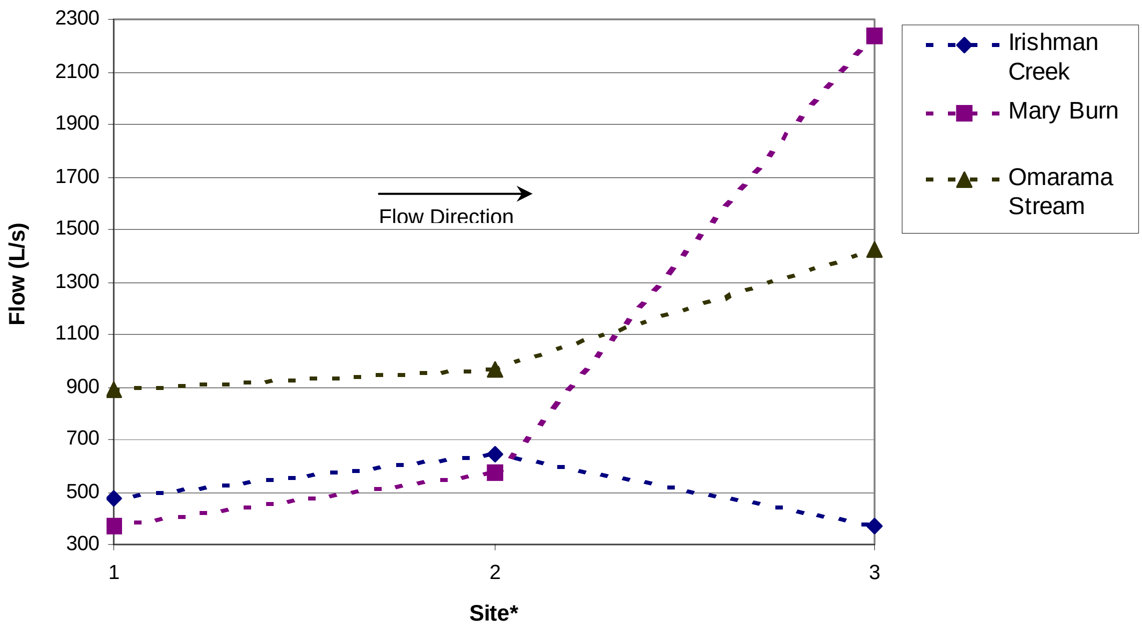


Table 5. Flow measurements in Irishman Creek, Mary Burn and Omarama Stream during the period of 12-13 August 2003

River	Site No	Site Name	Flow (l/s)
Irishman Creek	1	Braemar Road	477
Irishman Creek	2	Upstream SH8	643
Irishman Creek	3	Upstream Tekapo River Confluence	373
Mary Burn	1	Mt McDonald	371
Mary Burn	2	SH8 Bridge	576
Mary Burn	3	Upstream Tekapo River Confluence	2,236
Omarama Stream	1	Twin Peaks	889
Omarama Stream	2	Above Tara Hills	968
Omarama Stream	3	SH8 Bridge	1,422

From the data in Figure 10, a distinct contrast in the nature of downstream flow gain and loss within the Mary Burn and Irishman Creek is evident. Irishman Creek flows on to the upper Tekapo Basin, centrally located between the Mary Burn and the Tekapo River. Depth to groundwater is significant in this area and Irishman Creek flow is lost to the aquifer in the reach from SH8 to the Tekapo confluence. In contrast, the Mary Burn retains flow for most of the reach as it is located in a shallow water table area to the west of Irishman Creek. As the Mary Burn flows to the lower terraces of the Lower Tekapo Basin, it gains significant groundwater input due to the water table becoming progressively closer to the surface as the aquifer constricts into a bottleneck.

It is impractical to provide an exact measurement of aquifer recharge from streams and rivers in the Waitaki Catchment, given the scope of this study and the availability of data. However, the information obtained from flow gaugings, piezometric and depth to groundwater contours and visual observations allows aquifer basin functionality to be assessed, which is discussed in Section 5.

Available stream gauging data for assessment of flow losses and gains is limited to a small data set, bearing in mind that summer measurements are likely to be affected by abstractions. It is impractical at this time, and not within the scope of this project, to completely identify full flow regimes for surface waters in the Waitaki Catchment.

3.7.3 Excess irrigation infiltration

The agricultural profile throughout the Waitaki Catchment consists of mainly of dryland grazing enterprises in the upper Waitaki, with more intensive agriculture in the lower Waitaki valley and the Hakataramea Valley. For properties located in the upper Waitaki, a minor area (<2,000 ha) is irrigated to pasture and specialist crops (SKM, 2004).

In this regard it is difficult to assign excess irrigation infiltration values to aquifer basins in the upper Waitaki Catchment due to the lack of data for this and the low overall amount of irrigation practised in the area.

Where possible, irrigation infiltration volumes have been included in the overall water balance for each basin from published information. Published information on irrigation infiltration mainly relates to aquifer basins in the lower Waitaki Catchment (URS, 2003).

The irrigation infiltration rate specified in URS (2003) is based on the calculated average annual soil drainage rate under border dyke irrigation inclusive of rainfall infiltration. This is specified as 902 millmetres, which represents an average annual recharge rate per hectare of 0.00902 Mm^3. The source of the irrigation water for irrigation in the lower Waitaki is the Waitaki River (URS, 2003). Table 6 shows the estimated annual average irrigation infiltration to Lower Waitaki basins (where reported) in Mm^3/annum.

- **Table 6. Reported irrigation infiltration (URS, 2003)**

Aquifer basin	Reported irrigation infiltration* (Million m^3/annum)	Comment
Lower Waitaki – Otago	152	Excluding Rainfall Recharge
Lower Waitaki – Glenavy	133	Excluding Rainfall Recharge

*Reported irrigation infiltration consists of the total aquifer area (under irrigation) for both aquifer basins multiplied by (irrigation recharge rate – rainfall recharge rate) to separate each form of recharge

SKM

3.7.4 Summary: Water balance

Table 7 provides a summary of the preliminary aquifer water balances for groundwater basins in the Waitaki Catchment.

Table 7. Summary/reported groundwater balance for the Waitaki Catchment

Aquifer Basin	Recharge Sources	Estimated Volume (Mm^3/annum)	Discharge Sinks	Estimated Net Volume Gained (Mm^3/annum)	Estimated Net Volume Gained (l/s)
Tekapo	Rainfall Streams	25.8 N/A	Mary Burn, Grays and Tekapo Rivers	25.8	817
Twizel	Rainfall Streams	27.4 N/A	Tekapo River and Lake Benmore	27.4	868
Upper Omarama	Rainfall	2.2	Hen Burn Quail Burn	1.1 1.1	35 35
Omarama	Rainfall Streams	7.8 N/A	Omarama Stream, Ahuriri River and Lake Benmore	7.8	247
Benmore Terrace	Rainfall Streams	1.1 N/A	Lake Benmore	1.1	35
Aviemore and Waitaki flats	Rainfall Streams	1.4 N/A	Lakes Aviemore and Waitaki	1.4	44
Hakataramea Valley	Rainfall	13.4	Hakataramea River	13.4	424
Waitaki Valley – north	Rainfall Streams Waitaki River	1.5 1.9 93	Waitaki River (Inclusive of Peticotico Springs)	3.4	108
Waitaki Valley – south	Rainfall Streams	3.3 2.2	Waitaki River (Inclusive of Duntroon Springs)	5.5	174
Maerewhenua Basin	Rainfall	1.2	Maerewhenua River (Inclusive of losses to Papakaio Formation)	1.2	38
Papakaio Vormation	Rainfall Maerewhenua River Downward leakage	1.8 1.6 2.6	Waitaki River Awamoko Strm Waiareka Strm	3 1.5 1.5	96 48 48
Lower Waitaki	Rainfall Irrigation Streams	9.7 152 2.2	Waitaki River Pacific Ocean Welcome Creek	69 82 13	2,188 2,600 412
Glenavy	Rainfall Irrigation Streams	8.5 133 2.2	Waitaki River (Inclusive of Waikakihi Springs) Pacific Ocean	71.9 71.9	2,280 2,280

N/A – Insufficient data or reported values for estimate

Table 7 shows the recharge sources and discharge sinks listed where appropriate for each aquifer basin. Limited information is available for stream recharge and discharge in the upper Waitaki Catchment, thus Table 7 only lists direct rainfall recharge as groundwater contribution to surface waters in the Upper Waitaki. Also shown is the estimated ‘net volume gained’ at the discharge sinks, which is the cumulative sum of rainfall recharge contribution and other specific aquifer basin recharge.

In the lower Waitaki Catchment, estimates of stream flow leakage to groundwater have been made in URS (2003). Those estimates have been incorporated into Table 7 where appropriate. Also, MWH (2004) and Otago Regional Council (2004) specify individual recharge and discharge components for the Maerewhenua Basin area and SKM (2000) and URS (2003) provide information on source and sink flows for the lower Waitaki and Glenavy areas, respectively.

The lower Waitaki alluvium areas contrast to that of other basins, as irrigation recharge from the Waitaki River irrigation schemes dominate the water flux through the aquifers. Many smaller aquifer basins have limited local rainfall contribution and storage, which also rely on stream flow losses to sustain water table levels in the aquifers.

The value of 93 Mm^3 for the Waitaki River flux through the Waitaki Valley (north bank) is reported in URS (2003), as the potential throughflow for the Waitaki River in vicinity of the Kurow Trench area. However, as this water is re-worked from the Waitaki River, it does not represent any net gain of water.

Large potential rainfall recharge exists in the Tekapo and Twizel basins (Table 7). However, there may be limits on the availability of groundwater in those basins due to lower hydraulic conductivity and saturated depth of gravels. A large proportion of groundwater recharge in the Tekapo Basin may emerge in the Tekapo River, in the narrowing southern part of the basin at Grays Hills. It is unknown what proportion of Tekapo River flow then leaks to groundwater before entering Lake Benmore (as piezometric contours suggest river losses in that location).

4. Assumptions and limitations

The following is a list of assumptions and limitations that evolved during the development of this report on groundwater knowledge for the Waitaki Catchment. The limitations are mainly data specific; however interpretation or estimation of aquifer functionality based on limited information has been provided in this report.

- There is limited borehole information in the upper Waitaki Catchment including the Hakataramea Valley. Some areas, namely the Omarama and Twizel townships, have a reasonable number of bores drilled nearby. However, there are vast areas where no data for groundwater level, aquifer occurrence or aquifer hydraulic characteristics exists, such as the Tekapo and Twizel Basins. Thus, hydrogeological interpretation of the Tekapo and Twizel Basins is based on few widely distributed data points, including interpolation of surface water features and visual observations made during SKM's site visit.
- The upper extents of the Tekapo and Twizel aquifer basins are poorly controlled. The exact location of groundwater divides in those areas is unclear.
- Multiple layered aquifer horizons in the upper Waitaki Catchment are possible. However, there is insufficient data to assess the presence or extent of confined or semi-confined aquifers in groundwater basins.
- Virtually no data is available for Benmore Terrace, Aviemore and Waitaki terraces, and the Hakataramea Valley.
- Stream flow loses and gains for the majority of aquifer basins have not been specifically investigated. However, other environmental considerations such as depth to water table and piezometric contouring of groundwater, provides some information to determine the potential flow loss/gain areas of streams. Aquifers with reasonable reporting of stream flow loss/gains include the Maerewhenua and lower Waitaki basins.
- Aquifer hydraulic properties and saturated thicknesses is not well known in the upper Waitaki Catchment and the Hakataramea Valley. Hence, estimates of hydraulic conductivity, aquifer saturated thickness and specific yield, used to calculate total stored groundwater volumes in this report are considered broad estimates only.
- Rainfall recharge infiltration rates have not been investigated for the upper Waitaki Catchment. The infiltration rate estimate used in this report for the upper Waitaki Catchment reflects a typical Central Otago–Upper Clutha Valley situation, based on research done there. As such, the recharge estimate is a broad attempt to quantify the potential amount of rainfall recharge to the surface of each aquifer basin. Given the rainfall gradient in the upper Waitaki Catchment, rainfall infiltration may be highly variable.
- Recharge inputs to the aquifer basins from elevated catchments in the form of groundwater throughflow or surface runoff infiltration is not known. Further assessment of the significance

of these recharge contributions would help to refine the total rainfall recharge estimate. It is considered that by omitting this recharge component, the rainfall estimates provided for each basin are conservative.

- Irrigation use and potential recharge from excess irrigation infiltration has not been quantified in this report for the upper Waitaki Catchment, as there does not appear to be any published data to make any reliable estimates. Due to the limited irrigation in the upper Waitaki Catchment, it is regarded as a minor recharge input to groundwater.
- Time dependent groundwater level data to assess the seasonal variability of groundwater and response to recharge events in the upper Waitaki Catchment does not exist. There is however data for the lower Waitaki Catchment (either manual or automated measurements).

5. Summary

This section provides a summary of the understanding developed of the aquifer functionality and surface water interaction for the various groundwater basins identified in the Waitaki Catchment.

5.1 Upper Waitaki

The upper Waitaki Catchment includes all groundwater basins above Kurow township. Aquifer basin functionality and surface water interaction for the upper Waitaki Catchment are discussed as follows.

Tekapo Basin

The Tekapo Basin aquifer extends from Grays Hills in the south to Lake Tekapo in the north. The aquifer is bounded by the Mary Range in the west and the Rollesby Ranges in the east.

Groundwater flow direction is from north to south toward the basin outlet at the Tekapo River at Grays Hills. The water table aquifer is of moderate permeability and saturated depth based on a small amount of data. Water table measurements at ECNZ piezometric sites in the north of the basin indicate that there is a degree of stratification of gravel layers in that area. Differences in water table measurements were observed at adjacent bores drilled to variable depths in that location. The connection between layers and their lateral extent is unknown.

The rainfall recharge component estimated for the aquifer is 25.8 Mm^3/annum (817 l/s), coupled with a large estimated groundwater storage in the aquifer of 2,579 Mm^3.

Stream flow leakage occurs in the basin from the Irishman Creek. However, limited flow measurements have been taken to fully understand stream/aquifer interaction. Piezometric contours and some gauging data show that the Mary Burn gains flow from groundwater in lower reaches. This is also true for the Grays and Tekapo Rivers. The water table is shallow in most reaches of the Mary Burn and the Greys River (Plate 7 – Figure 1).

SKM

- **Plate 7. Grays River, 7km upstream of Grays Hills**

A previously indicated, groundwater in the aquifer basin ultimately provides some baseflow for the Greys River, Mary Burn and Tekapo River. Given the potentially large storage capacity and local recharge component, it is likely that suitably located and appropriately screened bores may abstract limited amounts of groundwater without directly affecting surface waters on a seasonal basis. Shallow bores located in this basin are however likely to intercept aquifer recharge, representing a proportion of longterm baseflow for streams.

Twizel Basin

The Twizel Basin aquifer extends from Lake Benmore in the south to Lake Pukaki in the north. The aquifer is bounded by the Ohau and Ben Ohau Ranges in the west, Benmore Range in the south, and the Mary Range in the east. Groundwater in the basin flows from north to south toward Lake Benmore. However, in the western extent of the aquifer, groundwater flows in an easterly direction from wetland areas adjacent to Lake Ohau and the Upper Twizel River, toward Lake Ruataniwha and the Ohau River bed. The aquifer is of moderate permeability and saturated thickness, based mostly on drill data around the Twizel township area.

The rainfall recharge component estimated for the aquifer is 27.4 Mm^3/annum (868 l/s), and estimated groundwater storage in the aquifer is 2,740 Mm^3.

Piezometric contours and limited gauging data indicates that the upper Twizel River gains in flow from groundwater contribution, whilst it is expected that the Twizel River would lose water to the aquifer in lower reaches. Below SH8, it is likely that significant flow gains from groundwater may occur in the reaches of the lower Ohau and Twizel Rivers before entering Lake Benmore.

The Tekapo River, which enters the Twizel Basin south of the Grays Hills, may also lose water to the aquifer as it flows toward Lake Benmore. Piezometric contours suggest that significant losses may occur in reaches of the Tekapo River below Grays Hills (Plate 8 – Figure 1). However, no concurrent river flow gaugings have been carried out to confirm this hypothesis.

- **Plate 8. Tekapo River below Grays Hills**

The potentially large storage capacity and local recharge component for the aquifer (from rainfall and stream losses) indicates that suitably located deep bores may abstract limited amounts of groundwater without directly affecting surface waters on a seasonal basis. Bores located in the upper part of the Twizel Basin are however likely to intercept aquifer recharge and as such a proportion of long-term baseflow for streams in the area. Whilst bores located in the lower part of the basin may abstract quantities of groundwater without directly affecting surface water flows or long-term stream baseflows. This is most likely for bores located between the Tekapo River and Lake Benmore, as natural leakage to groundwater from surface waters in the area may be substantial. However, a long-term reduction in groundwater baseflow recharge to Lake Benmore may be measurable given the size of any abstraction, due to direct interception of river and rainfall based recharge to the aquifer, which ultimately discharges to Lake Benmore. Limited abstraction may not necessarily show any seasonal variation in measurable water table height and slope, and hence discharge to the lake. Although this remains unquantified at present.

Omarama (including upper Omarama) Basins

Rainfall recharge to the upper Omarama Basin provides baseflow to the Quail Burn and the Hen Burn streams, which ultimately flow to the Ahuriri River. There is limited information on groundwater in this basin, which is separated from the main Omarama Basin by the 'Clay Cliffs'. It is unlikely that large potential for groundwater exists in this basin, and abstraction of groundwater in the basin risks a reduction in baseflow to local streams.

The main Omarama Basin is within the Ahuriri River Catchment, which is bounded by the St Bathans Range to the south, and by a groundwater divide to the north, differentiating this basin from the Twizel Basin. The groundwater divide to the north is not very well known and the exact position may depend on seasonal variation in water table heights.

Groundwater flow in the Omarama Basin is mainly in an easterly direction, mostly toward and parallel with the Ahuriri River, ultimately draining to Lake Benmore. The storage in the aquifer is estimated at 235 Mm^3. However, the Ahuriri and Omarama Rivers bisect the Omarama Basin and it is likely that the groundwater is mostly shallow, in conjunction with the major surface streams. Abstraction from the basin would intercept a proportion of baseflow contribution to surface waters. However, adequately sited bores within the basin, having regard for the size of the abstraction, may not necessarily impact on surface waters on a seasonal basis. That is, the depressurisation cone of influence from groundwater abstractions may not come into contact with surface waters in any irrigation season. This may be due to the size of aquifer storage, bore location and rate of take, and mitigating seasonal recharge effects.

Benmore Terrace

No information exists for the groundwater resources of the Benmore Terrace. There is limited storage in the aquifer, and rainfall recharge is not large. However, some gauging information suggests that natural leakage from the Otamatapaio River would provide a groundwater resource there. The aquifer ultimately discharges to Lake Benmore.

Aviemore and Waitaki Flats

Again, no groundwater information is available to assess the groundwater potential in these areas. The aquifer(s) ultimately discharge to Lakes Aviemore and Waitaki.

5.2 Lower Waitaki

The lower Waitaki Catchment includes all groundwater basins below Kurow township, and including the Hakataramea Valley. Aquifer basin functionality and surface water impacts for the lower Waitaki Catchment are discussed as follows.

Hakataramea Valley

Limited groundwater information exists for the Hakataramea Valley. A few drill holes were put down in recent times as part of exploration for a deep groundwater irrigation source. The results of the drilling indicate that the aquifer is of limited saturated thickness and extent, being locally recharged by rainfall infiltration.

Piezometric contours indicate that the direction of groundwater flow in the basin is generally toward the Hakataramea River.

The overall storage within the basin is quite large (907 Mm^3). However, abstraction from the aquifer risks the interception of some baseflow to the Hakataramea River. Given the potential baseflow contribution from the aquifer to the river, groundwater abstraction from the basin may directly impact on river flows.

Lower Waitaki Valley – north bank

Piezometric contours indicate that the direction of groundwater flow is parallel to the Waitaki River. However, some aquifer recharge from foothills and streams traversing the area is expected to provide a hydraulic gradient toward the river.

Depth to the water table is small in the vicinity of the Wainui Station area, probably as result of the lower lying topography and the influence of the Waitaki River. Previous reporting (URS, 2003), suggested that some recycling of Waitaki River water through the Kurow Trench area was possible. The layout of the topography and the relationship of aquifer water levels to the Waitaki River tend to confirm this hypothesis. However, the Waitaki River throughflow may only occur on a seasonal basis, when groundwater recharge from other sources is low and Waitaki River flow is comparatively high.

Groundwater abstraction from the area is likely to induce throughflow from the Waitaki River. Also, abstraction of groundwater in the area is likely to have an impact on local spring flows to the Waitaki River.

Lower Waitaki Valley – south bank

The direction of groundwater flow in this area is generally toward the Waitaki River, with local rainfall and stream flow recharge providing an estimated 174 l/s input (average annual flow), to the river. Piezometric contours do suggest some recycling of Waitaki River water in the lower terrace areas; however this has not been quantified in any report.

Various streams flow on to the area (Kurow Creek, Oteike Stream, Otekaike and Maerewhenua Rivers), which in turn are expected to lose a proportion of (or all) flow to groundwater. The Duntroon Springs (adjacent to Duntroon township) are most likely to be sourced from the Maerewhenua River, and to a lesser degree, the Papakaio Formation, as some iron staining is evident from the spring waters. The springs then flow directly to the Waitaki River.

Maerewhenua Basin

The Maerewhenua Basin alluvial aquifer, which lies adjacent to the Maerewhenua River, generally has a thin saturated thickness, and water table levels are consistent with local river levels. Some local rainfall recharge provides a net gain to the Maerewhenua River, but it is only small at 38 l/s.

The storage volume in the aquifer coupled with proximity to the Maerewhenua River indicates that groundwater abstraction would have a direct impact on Maerewhenua River flows.

Natural flow losses occur in the Marerewhenua River in its mid reaches (Otago Regional Council, 2004). The flow losses are likely to sustain the Duntroon Springs located in the Waitaki Valley, and also recharge the Papakaio Formation (MWH, 2004), as discussed in the following section.

Papakaio Formation

The Papakaio Formation is a confined aquifer system extending in a spoon-shaped pattern over the Maerewhenua Basin (MWH, 2004). The aquifer receives outcrop rainfall recharge, Maerewhenua River leakage, and aerial distributed leakage from overlying water table aquifers. Outcrop rainfall recharge is defined as the amount of water percolation to the aquifer provided by rainfall to Papakaio Formation exposed at the surface in the Basin. Rainfall above and below Papakaio outcrop typically runs off to surface waterways, or is prevented from recharging the aquifer by overlying low permeability strata. The direction of groundwater flow is toward the northeast, to the Waitaki Valley, Awamoko Stream and Waiarekia Stream (part of the Kakanui River Catchment).

Abstraction of groundwater from this aquifer risks a reduction in baseflow contribution to the Awamoko and Waiareka Streams (Otago Regional Council, 2004). However, the contribution of groundwater to the Waitaki Valley, and the Awamoko and Waiareka Streams is of a diffuse nature, which is difficult to directly measure (Otago Regional Council, 2004).

SKM

Lower Waitaki – Otago

The Lower Waitaki alluvium has been studied in reasonable detail in the past. The basin extends from Black Point in the west, to the Pacific Ocean in the east. The northern and southern boundaries are the Waitaki River and the Tertiary sedimentary rocks of the Maerewhenua Hills respectively.

Groundwater flow in this aquifer is provided mainly by surface irrigation infiltration, including some rainfall recharge. The direction of groundwater flow is toward the Waitaki River and the Pacific Ocean. It is estimated that a 50/50 split of Lower Waitaki groundwater, discharges to the Waitaki River (including Welcome Creek), and to the Pacific Ocean.

The depth to groundwater in the Lower Waitaki is generally small (within 2 to 5 metres), and has a seasonal variation of up to 3.5 metres (SKM, 2000). The shallow water table in most areas reflects the seasonal influx of recharge from surface irrigation practices.

The major spring outflow (Welcome Creek) is sourced entirely from groundwater in the Waitaki Alluvium (Plate 9 – Figure 1), although it is unclear if there is Waitaki River water contributing in lower reaches.

- **Plate 9. Welcome Creek above Ferry Road Bridge**

The Awamoko, and Waikoura–Henderson Streams traverse the basin. However, they are generally dry as flow from these streams leaks to the aquifer within 100 to 300 metres of where they flow on to the plain.

Groundwater abstraction from the Lower Waitaki in the vicinity of Welcome Creek may impact on stream flow. However, given the large storage in the aquifer, the high artificial recharge and high throughflow flux on an annual basis (groundwater retention times in the aquifer are approximately only one to two years), abstraction of groundwater from the basin overall is likely to have limited impact on the Waitaki River.

Lower Waitaki – Glenavy (Canterbury)

The Glenavy groundwater basin extends from Black Point (across river) in the west, to the Pacific Ocean in the east. The southern boundary of the aquifer is the Waitaki River, and the northern boundary is a combination of Tertiary sedimentary rocks forming the catchment boundary of the Waihao River, and a local groundwater divide in the alluvium between Grays Corner and Morven, based on piezometric groundwater flow patterns.

The Glenavy basin is similar to that of the lower Waitaki (Otago) basin, in that a 50/50 split of groundwater contribution to the Waitaki River and to the Pacific Ocean based on piezometric contours is likely to occur.

The aquifer has a high recharge flux from the Morven-Glenavy Irrigation Scheme in the area, which also culminates in seasonally high water tables in a large part of the basin. The spring fed Waikakiki Stream receives recharge from the aquifer, which in turn flows to the Waitaki River immediately upstream of the SH1 bridge at Glenavy.

Groundwater abstraction from the basin, given aquifer storage and recharge components, is not likely to have significant impact on the Waitaki River. However, again the recharge flux is a large component of storage, as such the annual flushing of the groundwater system is very high.

6. Conclusions

This report contains a preliminary understanding of the functionality of groundwater systems within the Waitaki Catchment. Thirteen primary groundwater basins have been identified and the report collates available data for each of these. The report interpolates this data and presents information on groundwater elevation and flow direction, aquifer thickness, aquifer hydraulic characteristics and estimated aquifer storage volumes. In many instances the data were insufficient to form definitive conclusions and this has been clearly documented in the report and summarised in Section 4.

From the information available, conclusions have been drawn regarding groundwater and surface water interactions or water exchanges, and the significance of these in terms of the possible effects from abstraction on either water resource. These are presented in Section 5.

Overall, a reasonable understanding of the aquifer flow regime has been established and should provide the Water Allocation Board with information appropriate for catchment-scale planning. **However, the report is not an appropriate basis for site- specific resource-consent decisions.**

7. References

Brown, LJ, 2001. Regional groundwater summary – Canterbury. In MR Rosen & PA White (eds), *Groundwaters of New Zealand*.

Driscoll, FG, 1986. *Groundwater and Wells.* 2nd ed. Johnson Filtration Systems Inc: St.Paul, Minnesota.

Environment Canterbury, 2002. *Water Quality Investigations: South Canterbury Aquifers.*

Environment Canterbury, 2004. *Wells and Springs Database Information.*

Forsyth, PJ (compiler), 2001. *Geology of the Waitaki area*. IGNS 1:250,000 geological map 19. Lower Hutt, IGNS.

Freeze, RA, Cherry, JA, 1979. *Groundwater.* Prentice-Hall: Englewood Cliffs, New Jersey.

Meridian Energy, 2003a. *Project Aqua Assessment of the Effects on the Environment*. Meridian Energy Limited, May 2003.

Meridian Energy, 2003b. *Draft Lower Waitaki River Management Strategy*. Appendix B to Project Aqua: Assessment of Effects on the Environment.

MWH, 2004. *Papakaio Aquifer Report: Outside of the Enfield Basin North Otago.* Report prepared for the Otago Regional Council.

Opus, 2003. *Project Aqua Hydrology Study* Appendix AG to Project Aqua: Assessment of Effects on the Environment. Report prepared for Meridian Energy Ltd April 2003.

Otago Regional Council, 1998. *Groundwater of the Alexandra Basin: Preliminary Survey.*

Otago Regional Council, 2002. *Wanaka Basin Groundwater Modelling Report.*

Otago Regional Council, 2004. *Allocation of Groundwater in the Maerewhenua Basin.* Draft Internal Council Report.

Sinclair Knight Merz, 2000. *Lower Waitaki Alluvium Groundwater Investigation Otago 1999/2000.* Report prepared for the Otago Regional Council. Project No 2103501.

Sinclair Knight Merz, 2004. *National Cost Benefit Analysis of proposals to Take Water from the Waitaki River.* Draft Report for Peer Review prepared for the Ministry of Economic Development and the Ministry for the Environment.

URS, 2003a. *Project Aqua: Water Balance. Appendix AE to Project Aqua: Assessment of Effects on the Environment*. Report prepared for Meridian Energy Ltd April 2003.

URS, 2003b *Hydrogeological Assessment of Effects. Final Report prepared for Meridian Energy Limited. Appendix AF to Project Aqua: Assessment of Effects on the Environment Rev 8A* Report prepared for Meridian Energy Ltd April 2003.

Waitaki Catchment Commission, 1982. *Waitaki Water and Soil Resource Management Plan.* Volume 2. 'Description of the Waitaki Catchment'. Prepared by Gabites Porter & Partners for the Waitaki Catchment Commission and Regional Water Board, Kurow.

SKM

Appendix A Bore details

- **Table A-1. Summary of bore details for the Waitaki Catchment**

ID	Type	Easting	Northing	Depth (m)	Diameter (mm)	Data source
H36/0001	Bore	2279150	5711710	27.0	175	Upper Waitaki
H36/0002	Bore	2276004	5715271			Upper Waitaki
H36/0003	Bore	2276004	5715272	12.0	50	Upper Waitaki
H36/0004	Bore	2276123	5714965	12.3	50	Upper Waitaki
H36/0005	Bore	2276127	5714971	10.5	50	Upper Waitaki
H36/0006	Bore	2276131	5714965	10.7	50	Upper Waitaki
H36/0007	Bore	2276392	5714900	9.0	50	Upper Waitaki
H36/0008	Bore	2276544	5714455	41.5	150	Upper Waitaki
H36/0012	Bore	2276300	5714360	72.0	150	Upper Waitaki
H36/0013	Bore	2276080	5715175	7.3	150	Upper Waitaki
H36/0014	Bore	2276080	5715190	1.7	150	Upper Waitaki
H36/0015	Bore	2276060	5715180	4.3	150	Upper Waitaki
H37/0001	Bore	2278317	5694784	21.0	150	Upper Waitaki
H37/0002	Bore	2278550	5696850	37.0	150	Upper Waitaki
H37/0003	Bore	2277000	5608000	40.0	200	Upper Waitaki
H38/0001	Bore	2281400	5664750	30.0	1000	Upper Waitaki
H38/0002	Bore	2281500	5664700	30.0	1000	Upper Waitaki
H38/0004	Bore	2275920	5659380	11.4	150	Upper Waitaki
H38/0005	Bore	2280930	5664830	20.5	50	Upper Waitaki
H38/0006	Bore	2281050	5664750	20.3	50	Upper Waitaki
H38/0007	Bore	2278325	5655738	19.7	50	Upper Waitaki
H38/0008	Bore	2278279	5655593	22.5	50	Upper Waitaki
H38/0009	Bore	2278095	5655453	20.0	150	Upper Waitaki
H38/0010	Bore	2277403	5655034	30.6	150	Upper Waitaki
H38/0011	Bore	2276385	5658317	50.0	250	Upper Waitaki
H38/0012	Bore	2277924	5659271	5.0	250	Upper Waitaki
H38/0013	Bore	2275169	5658386	21.0	115	Upper Waitaki
H38/0014	Bore	2276032	5657973	25.0	50	Upper Waitaki
H38/0015	Bore	2277125	5657945	21.0	115	Upper Waitaki
H38/0016	Bore	2276730	5656096	30.0	115	Upper Waitaki
H38/0017	Bore	2278029	5655439	25.0	50	Upper Waitaki
H38/0018	Bore	2278196	5658237	16.9	450	Upper Waitaki
H38/0019	Bore	2278041	5658352	12.2	450	Upper Waitaki
H38/0020	Bore	2277928	5658454	13.3	450	Upper Waitaki
H38/0021	Bore	2279518	5658092	12.2	150	Upper Waitaki
H38/0022	Bore	2279518	5658184	4.9	150	Upper Waitaki
H38/0023	Bore	2278007	5654634			Upper Waitaki
H38/0024	Bore	2278215	5654909			Upper Waitaki
H38/0025	Bore	2277547	5659071	4.0	150	Upper Waitaki
H38/0026	Bore	2279721	5657323	2.3	1500	Upper Waitaki
H38/0027	Bore	2277557	5658888	2.2	50	Upper Waitaki
H38/0028	Bore	2277103	5658995	4.0	100	Upper Waitaki
H38/0029	Bore	2277671	5659023			Upper Waitaki
H38/0030	Bore	2279498	5657256			Upper Waitaki
H38/0031	Bore	2279828	5656728	2.1	50	Upper Waitaki
H38/0032	Bore	2280392	5656101	2.9	50	Upper Waitaki
H38/0033	Bore	2280782	5655383	2.2	50	Upper Waitaki
H38/0034	Bore	2257210	5655810	24.1	125	Upper Waitaki

ID	Type	Easting	Northing	Depth (m)	Diameter (mm)	Data source
H38/0035	Bore	2285490	5651710	113.4	300	Upper Waitaki
H38/0036	Bore	2275220	5652580	8.0		Upper Waitaki
H38/0037	Bore	2257376	5655470	33.1	125	Upper Waitaki
H38/0038	Bore	2278930	5668600	36.2	125	Upper Waitaki
H38/0039	Bore	2276841	5655858	40.8	125	Upper Waitaki
H38/0040	Bore	2277310	5655460	30.0	125	Upper Waitaki
H38/0041	Bore	2276820	5656030	36.9	125	Upper Waitaki
H38/0042	Bore	2286920	5651840	120.0	300	Upper Waitaki
H38/0043	Bore	2287250	5651910	120.0	300	Upper Waitaki
H38/0044	Bore	2275560	5657750	65.8	300	Upper Waitaki
H38/0045	Bore	2275230	5656680	71.0	300	Upper Waitaki
H38/0046	Bore	2274930	5655470	50.0	300	Upper Waitaki
H38/0047	Bore	2276200	5656450	66.3	300	Upper Waitaki
H38/0048	Bore	2272520	5658720	51.0	150	Upper Waitaki
H38/0049	Bore	2270220	5657590	83.0	150	Upper Waitaki
H38/0050	Bore	2265890	5655510	41.0	150	Upper Waitaki
H38/0051	Bore	2276630	5655810	41.0	150	Upper Waitaki
H38/0052	Bore	2265450	5655170	53.0	150	Upper Waitaki
H38/0053	Bore	2265840	5655480	53.0	150	Upper Waitaki
H38/0054	Bore	2265840	5655480	60.0	150	Upper Waitaki
H38/0055	Bore	2265840	5655480	60.0	150	Upper Waitaki
H38/0056	Bore	2271550	5658790	95.0	150	Upper Waitaki
H38/0057	Bore	2272560	5657680	66.0	150	Upper Waitaki
H38/0058	Bore	2269150	5657290	90.0	150	Upper Waitaki
H38/0059	Bore	2268440	5656640	60.0	150	Upper Waitaki
H38/0060	Bore	2270742	5657234	83.0	150	Upper Waitaki
H38/0061	Bore	2277690	5658830	17.0	150	Upper Waitaki
H38/0062	Bore	2256890	5656130	20.0	150	Upper Waitaki
H38/0063	Bore	2278400	5668120	38.0	150	Upper Waitaki
H38/0064	Bore	2276990	5655150	39.0	150	Upper Waitaki
H38/0065	Bore	2276800	5655960	30.0	150	Upper Waitaki
H38/0066	Bore	2276580	5655730	50.0	150	Upper Waitaki
H38/0067	Bore	2256840	5655530	35.0	125	Upper Waitaki
H39/0001	Bore	2269100	5631100	10.4	150	Upper Waitaki
H39/0002	Bore	2269000	5631800	0.0	0	Upper Waitaki
H39/0003	Bore	2261350	5627450	35.0	0	Upper Waitaki
H39/0004	Bore	2268090	5630890	0.0	100	Upper Waitaki
H39/0005	Bore	2268110	5630880	5.1	250	Upper Waitaki
H39/0006	Bore	2268130	5630860	9.3	700	Upper Waitaki
H39/0007	Bore	2269400	5631200	10.5	250	Upper Waitaki
H39/0008	Bore	2270100	5632300	12.2	100	Upper Waitaki
H39/0009	Bore	2266600	5632100	12.2	100	Upper Waitaki
H39/0010	Bore	2271500	5632100	12.2	100	Upper Waitaki
H39/0011	Bore	2269400	5631700	3.8	1500	Upper Waitaki
H39/0012	Bore	2271800	5630800	6.4	0	Upper Waitaki
H39/0013	Bore	2266400	5629700	15.7	150	Upper Waitaki
H39/0014	Bore	2264600	5629800	13.4	150	Upper Waitaki
H39/0015	Bore	2285670	5647670	20.2	100	Upper Waitaki
H39/0016	Bore	2285880	5647410	20.2	100	Upper Waitaki
H39/0017	Bore	2268630	5631110	6.5	50	Upper Waitaki
H39/0018	Bore	2268620	5631110	6.0	50	Upper Waitaki
H39/0019	Bore	2268610	5631110	6.0	50	Upper Waitaki

ID	Type	Easting	Northing	Depth (m)	Diameter (mm)	Data source
H39/0020	Bore	2268630	5631110	6.0	50	Upper Waitaki
H39/0021	Bore	2268090	5630860	8.0	200	Upper Waitaki
H39/0022	Bore	2270080	5631030	15.0	150	Upper Waitaki
H39/0023	Bore	2268900	5631100	13.1	150	Upper Waitaki
H39/0024	Bore	2269270	5631400	18.6	150	Upper Waitaki
H39/0025	Bore	2269140	5631560	6.0	200	Upper Waitaki
H39/0026	Bore	2270520	5632430	1.5		Upper Waitaki
H39/0027	Bore	2270850	5632080	23.3	300	Upper Waitaki
H39/0028	Bore	2271190	5631240	18.2	150	Upper Waitaki
H39/0029	Bore	2271190	5631240	23.1	250	Upper Waitaki
H39/0030	Bore	2261060	5625330	6.0		Upper Waitaki
H39/0031	Bore	2262940	5633340	12.0	150	Upper Waitaki
H39/0032	Bore	2272880	5634360	10.0	500	Upper Waitaki
H39/0033	Bore	2272880	5634360	5.0	3000	Upper Waitaki
H39/0034	Bore	2272540	5633890	10.0	500	Upper Waitaki
H39/0035	Bore	2272540	5633890	5.0	3000	Upper Waitaki
H39/0036	Bore	2271200	5635400	10.0	500	Upper Waitaki
H39/0037	Bore	2271200	5635400	5.0	3000	Upper Waitaki
H39/0038	Bore	2272190	5636960	10.0	500	Upper Waitaki
H39/0039	Bore	2272190	5636960	5.0	3000	Upper Waitaki
H39/0040	Bore	2258980	5632280	30.0	200	Upper Waitaki
H39/0041	Bore	2269920	5632180	4.0	350	Upper Waitaki
H39/0042	Bore	2263670	5643930	100.0	300	Upper Waitaki
H39/0043	Bore	2263900	5643800	100.0	300	Upper Waitaki
H39/0044	Bore	2264280	5642720	100.0	300	Upper Waitaki
H39/0045	Bore	2257490	5626660	150.0	300	Upper Waitaki
H39/0046	Bore	2270300	5630960	23.0	150	Upper Waitaki
H39/0047	Bore	2271170	5631790	30.5	150	Upper Waitaki
H39/0048	Bore	2271830	5630950	12.0	150	Upper Waitaki
H39/0049	Bore	2270080	5631030	23.3	150	Upper Waitaki
H39/0050	Bore	2270170	5638180	5.0		Upper Waitaki
H39/0051	Bore	2271810	5630940			Upper Waitaki
H40/0001	Bore	2287500	5617400	6.1	187	Upper Waitaki
H40/0002	Bore	2287500	5617600	11.4	50	Upper Waitaki
H40/0003	Bore	2288400	5618500	6.7	150	Upper Waitaki
I37/0003	Bore	2299500	5689700	40.0	200	Upper Waitaki
I37/0006	Bore	2308030	5685910	25.1	120	Upper Waitaki
I37/0007	Bore	2307940	5685950	25.0	120	Upper Waitaki
I37/0008	Bore	2301450	5689820	6.0		Upper Waitaki
I37/0009	Bore	2301450	5689820	6.0	4000	Upper Waitaki
I37/0013	Bore	2272330	6478200	22.0	150	Upper Waitaki
I37/0014	Bore	2202100	5687000			Upper Waitaki
I37/0015	Bore	2202100	5687000	2.5	6	Upper Waitaki
I37/0017	Bore	2224830	5682060	10.0	500	Upper Waitaki
I37/0018	Bore	2224830	5682070	10.0	500	Upper Waitaki
I37/0019	Bore	2224790	5682520	10.0	500	Upper Waitaki
I37/0020	Bore	2224790	5682520	10.0	2000	Upper Waitaki
I37/0023	Bore	2301170	5682910	150.0	300	Upper Waitaki
I37/0024	Bore	2221090	5606110			Upper Waitaki
I38/0001	Bore	2221190	5677280	24.0	100	Upper Waitaki
I38/0002	Bore	2222000	5671300	40.0	200	Upper Waitaki
I38/0003	Bore	2306320	5657390	48.0	102	Upper Waitaki

ID	Type	Easting	Northing	Depth (m)	Diameter (mm)	Data source
I38/0004	Bore	2303110	5651520	60.0	150	Upper Waitaki
I38/0005	Bore	2290687	5657048	130.0	250	Upper Waitaki
I38/0006	Bore	2290287	5656579	130.0	250	Upper Waitaki
I38/0007	Bore	2290700	5656579	130.0	250	Upper Waitaki
I38/0008	Bore	2291155	5656593	130.0	250	Upper Waitaki
I38/0009	Bore	2290742	5656111	130.0	250	Upper Waitaki
I38/0010	Bore	2296380	5652680	7.0	500	Upper Waitaki
I38/0011	Bore	2296380	5652680	7.0	500	Upper Waitaki
I38/0012	Bore	2293745	5668545	105.5	300	Upper Waitaki
I38/0013	Bore	2295470	5662340	100.0	250	Upper Waitaki
I38/0014	Bore	2295470	5665150	100.0	250	Upper Waitaki
I38/0015	Bore	2294260	5666070	80.8	250	Upper Waitaki
I38/0016	Bore	2293640	5667610	100.0	250	Upper Waitaki
I38/0017	Bore	2215870	5659510	1.5	150	Upper Waitaki
I38/0018	Bore	2293400	5669500			Upper Waitaki
I39/0002	Bore	2326900	5629600	51.8	60	Upper Waitaki
I39/0003	Bore	2319820	5622320	72.0	250	Upper Waitaki
I39/0004	Bore	2291780	5647740	50.0	300	Upper Waitaki
I39/0005	Bore	2291240	5647180	50.0	300	Upper Waitaki
I39/0006	Bore	2293930	5638040	4.0		Upper Waitaki
I40/0003	Bore	2220770	5615690	3.0	1000	Upper Waitaki
I40/0019	Bore	2321650	5615670	15.2	900	Upper Waitaki
I40/0021	Bore	2217470	5618860	60.0	300	Upper Waitaki
I40/0098	Bore	2291120	5617200	6.0	100	Upper Waitaki
I40/0159	Bore	2221010	5615680	2.8	800	Upper Waitaki
I40/0160	Bore	2221010	5615680	2.8		Upper Waitaki
100	Bore	2273149	5656143	47.2		McKenzie
101	Bore	2274600	5661008	13.1		McKenzie
102	Bore	2274517	5661063	16.9		McKenzie
103	Bore	2274732	5660949	7.3		McKenzie
104	Bore	2282127	5664905	79.2		McKenzie
105	Bore	2281960	5664647	51.5		McKenzie
106	Bore	2281805	5664819	61.0		McKenzie
107	Bore	2274642	5661015	20.7		McKenzie
108	Bore	2274714	5661033	38.1		McKenzie
109	Bore	2281836	5664805	41.8		McKenzie
110	Bore	2281835	5664756	27.7		McKenzie
111	Bore	2281956	5664878	53.9		McKenzie
112	Bore	2279469	5657440	9.1		McKenzie
113	Bore	2279930	5656723	9.1		McKenzie
114	Bore	2280395	5656100	9.1		McKenzie
115	Bore	2280784	5655386	9.1		McKenzie
116	Bore	2279727	5657799	9.1		McKenzie
117	Bore	2279710	5658562	9.1		McKenzie
118	Bore	2279104	5658807	9.1		McKenzie
119	Bore	2277716	5658795	9.1		McKenzie
120	Bore	2278717	5658255	9.1		McKenzie
121	Bore	2279199	5657317	9.1		McKenzie
122	Bore	2273191	5658707	22.9		McKenzie
123	Bore	2273206	5656265			McKenzie
124	Bore	2272953	5660412	18.3		McKenzie
125	Bore	2265707	5653484			McKenzie

ID	Type	Easting	Northing	Depth (m)	Diameter (mm)	Data source
126	Bore	2270772	5656698			McKenzie
127	Bore	2281888	5664684	29.3		McKenzie
128	Bore	2268453	5656895	12.2		McKenzie
129	Bore	2276679	5662795	10.1		McKenzie
130	Bore	2278593	5663322	9.1		McKenzie
131	Bore	2274554	5661454	9.8		McKenzie
132	Bore	2273072	5659497	27.1		McKenzie
133	Bore	2279815	5663435	8.5		McKenzie
134	Bore	2278758	5657364	12.2		McKenzie
135	Bore	2281032	5664826			McKenzie
136	Bore	2277560	5653745			McKenzie
137	Bore	2282245	5664679	33.2		McKenzie
138	Bore	2282425	5664507	17.7		McKenzie
139	Bore	2281976	5664595	44.3		McKenzie
140	Bore	2282055	5664439	57.9		McKenzie
141	Bore	2281923	5665045	33.1		McKenzie
142	Bore	2282007	5664814	71.6		McKenzie
143	Bore	2281892	5665302	44.0		McKenzie
144	Bore	2281941	5665191	47.5		McKenzie
145	Bore	2281782	5664699	89.4		McKenzie
146	Bore	2278224	5658166	9.1		McKenzie
147	Bore	2278201	5658247	15.2		McKenzie
148	Bore	2278196	5658214	16.5		McKenzie
149	Bore	2278166	5658216	18.9		McKenzie
150	Bore	2278169	5658245	15.2		McKenzie
151	Bore	2278191	5658237	27.0		McKenzie
152	Bore	2278188	5658228	20.4		McKenzie
153	Bore	2278182	5658229	21.3		McKenzie
154	Bore	2278181	5658236	23.2		McKenzie
155	Bore	2278790	5654977	30.5		McKenzie
156	Bore	2274116	5660084	15.2		McKenzie
157	Bore	2280837	5664243	53.0		McKenzie
158	Bore	2283024	5662154	4.6		McKenzie
159	Bore	2283099	5662294	4.3		McKenzie
160	Bore	2283194	5662376	4.6		McKenzie
161	Bore	2283083	5662594	5.4		McKenzie
162	Bore	2291049	5678930	16.2		McKenzie
163	Bore	2291721	5678801	9.1		McKenzie
164	Bore	2287972	5680557	27.4		McKenzie
165	Bore	2287058	5672312	31.7		McKenzie
166	Bore	2286850	5672007	17.4		McKenzie
167	Bore	2287112	5672252	11.3		McKenzie
168	Bore	2293767	5677241	26.8		McKenzie
169	Bore	2292684	5677849	18.3		McKenzie
170	Bore	2292863	5677840	30.6		McKenzie
171	Bore	2286310	5672269	5.6		McKenzie
172	Bore	2286358	5672259	6.5		McKenzie
173	Bore	2286458	5672237	7.8		McKenzie
174	Bore	2287585	5680190	7.6		McKenzie
175	Bore	2287588	5680294	3.4		McKenzie
176	Bore	2287438	5680313	3.4		McKenzie
177	Bore	2287106	5680056	3.4		McKenzie

ID	Type	Easting	Northing	Depth (m)	Diameter (mm)	Data source
178	Bore	2287551	5680272	5.2		McKenzie
179	Bore	2305027	5682089	21.3		McKenzie
180	Bore	2299102	5679886	15.2		McKenzie
181	Bore	2296264	5678354	10.7		McKenzie
182	Bore	2294381	5677187	24.4		McKenzie
183	Bore	2290848	5673414	24.4		McKenzie
184	Bore	2290475	5671311	15.2		McKenzie
185	Bore	2289894	5671336	15.2		McKenzie
186	Bore	2306804	5668580	27.1		McKenzie
187	Bore	2305733	5668865			McKenzie
188	Bore	2304567	5668889			McKenzie
189	Bore	2307795	5680348	33.5		McKenzie
190	Bore	2307108	5680892	33.5		McKenzie
190A	Bore	2307108	5680892	33.5		McKenzie
191	Bore	2306192	5681598	33.5		McKenzie
191A	Bore	2306192	5681598	33.5		McKenzie
192	Bore	2302283	5669127			McKenzie
193	Bore	2297732	5678353	9.1		McKenzie
194	Bore	2297286	5678094	9.1		McKenzie
195	Bore	2287420	5680355	68.0		McKenzie
196	Bore	2287181	5680237	34.7		McKenzie
197	Bore	2287226	5680067	32.9		McKenzie
198	Bore	2286995	5680430	25.0		McKenzie
199	Bore	2287650	5680268	61.0		McKenzie
200	Bore	2287553	5680620	51.8		McKenzie
201	Bore	2287356	5680551	70.1		McKenzie
202	Bore	2287520	5680242	99.4		McKenzie
203	Bore	2287156	5680464	51.8		McKenzie
204	Bore	2287360	5680152	83.5		McKenzie
205	Bore	2287696	5679727	26.5		McKenzie
206	Bore	2287857	5679823	61.0		McKenzie
207	Bore	2287680	5680043	13.1		McKenzie
208	Bore	2287027	5679971	42.7		McKenzie
209	Bore	2287056	5672189	45.7		McKenzie
210	Bore	2286464	5682743	38.4		McKenzie
211	Bore	2286399	5682691	13.1		McKenzie
212	Bore	2286854	5672161	45.7		McKenzie
213	Bore	2286417	5682670	46.9		McKenzie
214	Bore	2287130	5672355	53.0		McKenzie
215	Bore	2287033	5672524	45.7		McKenzie
216	Bore	2286762	5672416	33.5		McKenzie
217	Bore	2286990	5671086	23.8		McKenzie
218	Bore	2295014	5677454	12.2		McKenzie
219	Bore	2294908	5677422	14.0		McKenzie
220	Bore	2294946	5677528	13.1		McKenzie
221	Bore	2294911	5677700	12.2		McKenzie
222	Bore	2286887	5672417	39.0		McKenzie
223	Bore	2297787	5678600	14.3		McKenzie
224	Bore	2286958	5672393	82.9		McKenzie
225	Bore	2286910	5672332	38.4		McKenzie
226	Bore	2287004	5672450	38.4		McKenzie
227	Bore	2292671	5677867	70.7		McKenzie

ID	Type	Easting	Northing	Depth (m)	Diameter (mm)	Data source
228	Bore	2292882	5677846	11.0		McKenzie
229	Bore	2286899	5672376	21.3		McKenzie
230	Bore	2286921	5672358	17.1		McKenzie
231	Bore	2303174	5679188	3.0		McKenzie
232	Bore	2304244	5681313	3.0		McKenzie
233	Bore	2303612	5679019	3.0		McKenzie
234	Bore	2303323	5679095	3.0		McKenzie
235	Bore	2301231	5678333	2.1		McKenzie
236	Bore	2300951	5678148	2.1		McKenzie
237	Bore	2299474	5679513	2.4		McKenzie
238	Bore	2298522	5679689	3.4		McKenzie
250	Bore	2274093	5660255	18.3		McKenzie
251	Bore	2274644	5661738	43.3		McKenzie
252	Bore	2276004	5662291	12.4		McKenzie
253	Bore	2274484	5661588	18.9		McKenzie
254	Bore	2281883	5664901	40.2		McKenzie
255	Bore	2281991	5664766	48.1		McKenzie
256	Bore	2281829	5664968	8.1		McKenzie
257	Bore	2291841	5665199	12.5		McKenzie
258	Bore	2273645	5654289	17.0		McKenzie
259	Bore	2273264	5653432	14.3		McKenzie
260	Bore	2279623	5651593	8.6		McKenzie
261	Bore	2282399	5649217	18.0		McKenzie
262	Bore	2282800	5649006	21.0		McKenzie
263	Bore	2282714	5649281	12.5		McKenzie
264	Bore	2278861	5652559	5.8		McKenzie
265	Bore	2279616	5652481	30.0		McKenzie
266	Bore	2274485	5661736	14.9		McKenzie
267	Bore	2274679	5661040	8.7		McKenzie
268	Bore	2285274	5647947	50.0		McKenzie
269	Bore	2265525	5654909	55.0		McKenzie
270	Bore	2279711	5659604	11.5		McKenzie
271	Bore	2281960	5652242	6.9		McKenzie
272	Bore	2276131	5662236	3.0		McKenzie
273	Bore	2276507	5662464	2.8		McKenzie
274	Bore	2277519	5662725	4.6		McKenzie
275	Bore	2278301	5662506	2.1		McKenzie
276	Bore	2278769	5662465	2.0		McKenzie
277	Bore	2279046	5662695	3.6		McKenzie
278	Bore	2273566	5658589	3.9		McKenzie
I40/0003	Bore	2328302	5590073			MWH
I40/0009C	Bore	2327057	5591526			MWH
I40/0059C	Bore	2326414	5592844			MWH
I40/0096C	Bore	2323534	5593335			MWH
I40/0101C	Bore	2327275	5590163			MWH
I40/0001C	Bore	2323882	5588349			MWH
I41/0002	Bore	2327887	5582243			MWH
I41/0008	Bore	2326621	5588506			MWH
I41/001C	Bore	2328560	5588093			MWH
I41/0016	Bore	2326377	5585678			MWH
I41/0001	Bore	2329137	5582357			MWH
J41/0085C	Bore	2331767	5589461			MWH

ID	Type	Easting	Northing	Depth (m)	Diameter (mm)	Data source
Meikle	Bore	2320877	5585440			MWH
UNK1	Bore	2323213	5582431			MWH
UNK2	Bore	2324515	5583323			MWH
UNK3	Bore	2328685	5590828			MWH
I41/0039	Bore	2323624	5583008			MWH
I41/0042	Bore	2326332	5582018			MWH
J41/0489	Bore	2332899	5584683			MWH
I41/0023	Bore	2329506	5586698			MWH
30112a	Well	2317893	5599977	6.3	1500	URS
10083a	Well	2354336	5584316	11.5	152	URS
1789a	Well	2329779	5591133	5.8	152	URS
1949a	Well	2339502	5587093		25	URS
2447a	Well	2316580	5596675	7.2	100	URS
59a	Well	2315147	5597106	7.8	100	URS
2453a	Well	2315974	5597175	7.4	100	URS
1856b	Well	2332618	5589970	6.0	152	URS
69b	Well	2323540	5593335	4.3	1750	URS
2438a	Well	2316930	5595504		75	URS
2224a	Well	2312727	5599418	5.1	900	URS
2225a	Well	2312899	5599459	6.2	152	URS
10084a	Well	2355333	5584097	11.0	152	URS
101a	Well	2348885	5585762	3.3	750	URS
1953a	Well	2339399.237	5588367.654	3.0		URS
2232a	Well	2313581	5600009	3.9	250	URS
10084b	Well	2355553	5583314	8.0	152	URS
2433a	Well	2316105	5596154		152	URS
2219a	Well	2312530	5598833	7.4	600	URS
10088b	Well	2356444	5583861		500	URS
2228a	Well	2312888	5599359	5.7	650	URS
J41/0409	Well	2340700	5586100	7.0	600	URS
99a	Well	2346239	5584459		50	URS
867a	Well	2325942	5592532	4.2	600	URS
69a	Well	2325724	5591175	3.7	1000	URS
4159a	Well	2350837	5582656		152	URS
40004a	Well	2310598	5603631		100	URS
24a	Well	2310166	5603961	8.2	152	URS
244a	Well	2349354	5582485	18.1	200	URS
2449a	Well	2316790	5596965	1.5	300	URS
2361a	Well	2310273	5604451	4.7	750	URS
2346a	Well	2310150	5603873	8.2	50	URS
2314a	Well	2310078	5603933	9.4	120	URS
2298a	Well	2311056	5601890	23.5	152	URS
2284a	Well	2311154	5602925	20.8	152	URS
2281a	Well	2310936	5602956	23.8	152	URS
2276a	Well	2310236	5603142	25.5	152	URS
2270a	Well	2310811	5602390	24.1	200	URS
1987a	Well	2346430	5584671	6.1	100	URS
1982b	Well	2346039	5584531	5.3	500	URS
1982a	Well	2346771	5582554	7.7	75	URS
1980a	Well	2344507	5585318	14.9	152	URS
1975a	Well	2344303	5585069		100	URS
1933a	Well	2342712	5584956	8.2	1000	URS

ID	Type	Easting	Northing	Depth (m)	Diameter (mm)	Data source
1923a	Well	2341300	5584800	18.0		URS
1782a	Well	2328678	5591416		open pit	URS
1768a	Well	2327805	5591750		200	URS
1595b	Well	2347628	5582956	8.0	100	URS
1595a	Well	2347581	5583115	12.0	200	URS
1590b	Well	2347328	5582723	6.1	750	URS
1590a	Well	2346886	5583636	4.7	500	URS
1586a	Well	2346771	5582584	9.0	1000	URS
10233a	Well	2353093	5581557	7.5	1000	URS
10228b	Well	2349998	5579590	15.4	150	URS
10228a	Well	2350219	5580218	10.1	700	URS
10227a	Well	2353345	5579769		182	URS
10226a	Well	2353970	5579529	10.7	500	URS
10225a	Well	2352800	5578220	8.6	750	URS
10224a	Well	2353403	5574836	20.1	100	URS
10219a	Well	2354130	5576888	12.0	1000	URS
10172a	Well	2356572	5576097	9.9	152	URS
10171a	Well	2357133	5576520		152	URS
10168a	Well	2358374	5575884	18.9	400	URS
10166a	Well	2358936	5577182	24.1	152	URS
10165a	Well	2357930	5580095			URS
10150a	Well	2360518	5578347	17.0	150	URS
10146a	Well	2360629	5579731		152	URS
10145b	Well	2360186	5579267		152	URS
10145a	Well	2359846	5579481	16.7	100	URS
10140a	Well	2358020	5577743		120	URS
10137a	Well	2356062	5576583	23.4	152	URS
10133a	Well	2352544	5577623		152	URS
10125b	Well	2355197	5577602	7.9	152	URS
10125a	Well	2355197	5577602	2.7	1500	URS
10121a	Well	2356110	5578025	9.1		URS
10118a	Well	2356739	5577455	19.7	600	URS
10116b	Well	2357502	5579272		50	URS
10116a	Well	2357735	5579984	17.0	152	URS
10113a	Well	2356462	5579576	18.0	200	URS
10112a	Well	2355817	5579139	7.1	100	URS
10111b	Well	2354629	5579390		152	URS
10111a	Well	2354333	5578372	16.0	500	URS
10109b	Well	2356830	5581149	13.7	152	URS
10109a	Well	2356826	5581149	24.6	152	URS
10107a	Well	2362533	5583165	5.8	152	URS
10106a	Well	2362425	5582982	2.1	75	URS
10104b	Well	2362300	5583101	7.3	900	URS
10104a	Well	2362363	5582702	4.6	152	URS
10102a	Well	2361209	5582757	4.8	100	URS
10101a	Well	2361165	5583475		20	URS
10100b	Well	2360928	5583259		30	URS
10100a	Well	2360834	5583312	4.3	240	URS
10099a	Well	2361058	5581168	23.3	180	URS
10097a	Well	2359235	5582280	9.8	500	URS
10096a	Well	2358869	5582102	12.8	152	URS
10095a	Well	2357943	5580893	11.2	180	URS

ID	Type	Easting	Northing	Depth (m)	Diameter (mm)	Data source
10094c	Well	2358233	5582436	17.0	152	URS
10085a	Well	2355515	5582421	16.2	180	URS
10080a	Well	2354247	5583667	10.9	130	URS
10079a	Well	2353928	5583725	5.8	152	URS
10078a	Well	2354200	5582753			URS
10077a	Well	2353322	5582360		152	URS
10076a	Well	2354435	5581534	9.7		URS
10075a	Well	2349396	5580552		500	URS
10073a	Well	2349482	5581120	9.6	200	URS
10072a	Well	2349759	5583480	13.0	152	URS
10068c	Well	2351385	5580853	11.5	800	URS
10068b	Well	2350471	5580676	5.8	900	URS
10068a	Well	2350884	5581885		180	URS
10065a	Well	2351021	5578490		152	URS
10064b	Well	2347150	5582530	12.5	152	URS
10064a	Well	2348480	5581631		900	URS
10063a	Well	2348158	5582188	10.0		URS
10052a	Well	2311322	5605956		200	URS
10051a	Well	2311443	5605668	2.5		URS
10050c	Well	2311432	5605531	4.2	800	URS
10050b	Well	2311445	5605562	2.5	1500	URS
10050a	Well	2311496	5605597	2.3	1500	URS
10013a	Well	2346867	5580980	10.2	150	URS
10012a	Well	2347349	5582055	11.8	200	URS
10011a	Well	2346280	5582536	6.9	900	URS
10008a	Well	2345740	5581775	6.0	900	URS
40025	Well	2310300	5606300	4.0	150	URS
1989a	Well	2345578	5585702	6.3	150	URS
10231a	Well	2359588	5583713	3.8	1500	URS
10218a	Well	2359780	5583948	4.3	100	URS
10217b	Well	2359778	5583874	7.6	125	URS
10217a	Well	2359777	5583873	3.7	300	URS
10215a	Well	2359695	5583759	3.6	75	URS
10214a	Well	2359704	5583711		50	URS
10213a	Well	2359684	5583683		50	URS
10212a	Well	2359665	5583665	4.4	50	URS
10210a	Well	2359600	5583956	8.5	900	URS
10209a	Well	2359687	5583970	6.1	25	URS
10208a	Well	2359748	5584052	5.7	700	URS
10207a	Well	2359797	5583983	4.5	100	URS
10205a	Well	2359721	5583896	6.2	100	URS
10204b	Well	2359592	5583600	2.3	500	URS
10204a	Well	2359698	5583888	5.2	100	URS
10203a	Well	2359714	5583866		60	URS
10202a	Well	2359751	5583871	2.9	100	URS
10201a	Well	2359718	5583793	5.2	50	URS
10200a	Well	2359671	5583824	4.1	50	URS
10199a	Well	2359669	5583799	4.9	75	URS
10198a	Well	2359606	5583805	3.7	50	URS
10197a	Well	2359648	5583780	3.8	100	URS
10196a	Well	2359584	5583779		100	URS
10195a	Well	2359634	5583731	3.1	100	URS

ID	Type	Easting	Northing	Depth (m)	Diameter (mm)	Data source
10194a	Well	2359601	5583712	5.2	125	URS
10192a	Well	2359545	5583659	4.0		URS
10191a	Well	2359945	5583451	3.2	100	URS
10190a	Well	2359854	5583504	4.3	75	URS
10189a	Well	2359911	5583774	2.9	75	URS
10187a	Well	2359795	5583603	3.9	75	URS
10185b	Well	2359456	5583460	2.4	160	URS
10185a	Well	2359557	5583448	4.0	30	URS
10124a	Well	2359707	5583737		50	URS
10092b	Well	2359382	5583915	5.2	75	URS
10092a	Well	2359382	5583915	3.9	300	URS
10094b	Well	2359164	5582753	4.7	1000	URS
10094a	Well	2359163	5582755	2.8	200	URS
20320a	Well	2340373	5591322	8.3	900	URS
20318a	Well	2341457	5590959	9.0	100	URS
20317a	Well	2341560	5590935		500	URS
20316c	Well	2342369	5591763	8.2	120	URS
20316b	Well	2341949	5591193	8.7	900	URS
20316a	Well	2342250	5591841	80.0	152	URS
20313c	Well	2341769	5590641	8.6		URS
20313a	Well	2342776	5590376	52.0	152	URS
20312a	Well	2349863	5588758	8.8	1000	URS
20311a	Well	2351463	5588622	12.3	152	URS
20309b	Well	2353450	5588440	1.5		URS
20309a	Well	2353602	5588391	22.7	500	URS
20306a	Well	2355277	5587982		1500	URS
20305a	Well	2356773	5587709	11.8	200	URS
20302c	Well	2343299	5590600	19.2	152	URS
20302b	Well	2355543	5587592			URS
20302a	Well	2354161	5587296		152	URS
20301a	Well	2355993	5586920	7.1	152	URS
20303a	Well	2357828	5586560	8.8	152	URS
10091a	Well	2359105	5584086	3.2	900	URS
10091b	Well	2359073	5584065	5.7	200	URS
10071b	Well	2350880	5584218		250	URS
10081a	Well	2354332	5584323	5.9	800	URS
30111a	Well	2315907	5601099	4.3	130	URS
30012a	Well	2315587	5601146	3.3	100	URS
30011a	Well	2322107	5597180	2.6	1500	URS
30006c	Well	2324880	5595520	3.4	75	URS
30006b	Well	2325124	5595632	3.9	200	URS
30006a	Well	2324241	5595734	2.7	100	URS
30006d	Well	2323964	5595889	4.1	75	URS
20313b	Well	2342711	5590267	3.4	152	URS
30011d	Well	2321348	5597522	5.8	152	URS
30011c	Well	2321028	5598099	4.7	152	URS
30011b	Well	2322103	5596817	5.3	100	URS
20327d	Well	2323891	5595950	11.2	110	URS
20327c	Well	2323630	5596343	5.4	100	URS
20327a	Well	2323322	5596926	6.7	1000	URS
92a	Well	2340237	5586779	17.0	152	URS
10088a	Well	2356242	5582914		152	URS

ID	Type	Easting	Northing	Depth (m)	Diameter (mm)	Data source
20326a	Well	2323983	5596226			URS
20322a	Well	2339774	5590384		152	URS
1997a	Well	2346510	5585284	11.0	75	URS
10087a	Well	2357891	5584254	4.6	75	URS
1997b	Well	2346511	5585412	2.2	800	URS
10186a	Well	2359581	5583510	2.6	40	URS
2011a	Well	2343782	5586837	6.4	152	URS
2010a	Well	2343962	5586883	5.0	100	URS
10089a	Well	2357565	5583840	2.8	1000x300	URS
10070a	Well	2349906	5584491	13.0	250	URS
868a	Well	2325253	5593246	3.0	1000	URS
2474a	Well	2315946	5597782	3.0	100	URS
2291a	Well	2312564	5601097	16.5		URS
96a	Well	2346803	5586265	5.6	100	URS
4196a	Well	2330802	5591023	4.1	75	URS
4148a	Well	2348658	5584968	6.7	120	URS
2227b	Well	2311938	5600483	15.3	152	URS
1954a	Well	2339503	5587665		50	URS
2229a	Well	2314203	5599692	1.3	750	URS
63a	Well	2317364	5595755	12.1	100	URS
2436a	Well	2316800	5595785	10.4	100	URS
1856a	Well	2332837	5589993	4.9	152	URS
2227a	Well	2312932	5600317	15.1	200	URS
2005a	Well	2349380	5585377	9.2	150	URS
2437a	Well	2316964	5595601	11.9	100	URS
2428a	Well	2317096	5595482	16.2	100	URS
2427a	Well	2316981	5595314	11.1	75	URS
618a	Well	2313418	5600182	4.8	750	URS
10082b	Well	2353911	5584355		152	URS
10082a	Well	2353852	5584458		152	URS
20327b	Well	2323429	5596639		152	URS
1859a	Well	2333576	5589718	4.0	1500	URS
10071a	Well	2350369	5584985	9.7	1000	URS
2454a	Well	2317344	5595014			URS
2458a	Well	2317637	5595263	9.1	75	URS
1779a	Well	2331762	5589462	10.4	152	URS
1738a	Well	2335990	5588765			URS
1734a	Well	2335200	5588500	8.0	1000	URS
1734b	Well	2335200	5588500			URS
2300a	Spring	2312528	5601919			URS
2291b	Spring	2312606	5601739			URS
1788a	Spring	2328841	5591496			URS
1966b	Spring	2342352	5588247			URS
2002a	Spring	2348387	5585974			URS
40007a	Spring	2310673	5604101			URS
101b	Spring	2348747	5585607			URS
855a	Spring	2321803	5593932			URS
1966a	Spring	2342711	5584955			URS
2216a	Spring	2312991	5597869			URS
2219b	Spring	2312765	5598225			URS
849a	Spring	2325670	5591245			URS
1764a	Spring	2326460	5591615			URS

ID	Type	Easting	Northing	Depth (m)	Diameter (mm)	Data source
51a	Spring	2313603	5600217			URS
812a	Spring	2319280	5595494			URS
812b	Spring	2319280	5595494			URS
2469a	Spring	2319490	5595255			URS
3a	Spring	2328100	5594675			URS
2a	Spring	2332090	5592815			URS
2b	Spring	2333430	5592485			URS
2445a	Spring	2315470	5596145			URS
C1-B001	Geotech	2310905	5603705	14.0		URS
C1-B002(S)	Geotech	2310945	5603362	20.1		URS
C1-B003(S)	Geotech	2310936	5603221	20.1		URS
C1-B004	Geotech	2311275	5603073	24.9		URS
C1-B005	Geotech	2311674	5602780	19.4		URS
C1-B006	Geotech	2311894	5602516	17.5		URS
C1-B007(S)	Geotech	2311931	5602121	12.2		URS
C1-B008(S)	Geotech	2311989	5602049	20.0		URS
C1-B009	Geotech	2311803	5601768	20.5		URS
C1-B014	Geotech	2312750	5598620	16.0		URS
C1-B015	Geotech	2313305	5598313	16.0		URS
C1-B016	Geotech	2313914	5597976	20.8		URS
C1-B017(S)	Geotech	2314132	5597978	26.3		URS
C1-B018(S)	Geotech	2314337	5597909	26.4		URS
C1-B019	Geotech	2314465	5597897	20.5		URS
C1-B020	Geotech	2315340	5597702	40.1		URS
C1-B021	Geotech	2310778	5604277	10.3		URS
C1-B022	Geotech	2310408	5604604	9.9		URS
C1-B023	Geotech	2312482	5598844	20.5		URS
C1-B024	Geotech	2312390	5598715	20.3		URS
C2-B001(S)	Geotech	2315602	5597703	40.2		URS
C2-B002(S)	Geotech	2315532	5597786	40.1		URS
C2-B005	Geotech	2316173	5597320	30.4		URS
C2-B006	Geotech	2316291	5597179	14.3		URS
C2-B007	Geotech	2316459	5596995	20.0		URS
C2-B008	Geotech	2316691	5596752	12.0		URS
C2-B009	Geotech	2316963	5596460	19.9		URS
C2-B010	Geotech	2317322	5596148	16.4		URS
C2-B011	Geotech	2317598	5595832	22.3		URS
C2-B012(S)	Geotech	2317909	5595549	39.9		URS
C2-B013(S)	Geotech	2318068	5595344	24.2		URS
C2-B014	Geotech	2318216	5595335	20.8		URS
C2-B015	Geotech	2318794	5595360	14.5		URS
C2-B016	Geotech	2319589	5595405	14.8		URS
C2-B017	Geotech	2320276	5595092	5.1		URS
C2-B019	Geotech	2315851	5597398	30.0		URS
C2-B020	Geotech	2315675	5597608	60.1		URS
C3-B001	Geotech	2321702	5594487	40.1		URS
C3-B003	Geotech	2322151	5594142	31.2		URS
C3-B004	Geotech	2322342	5594088	20.3		URS
C3-B005	Geotech	2322653	5593921	23.2		URS
C3-B006	Geotech	2322990	5593798	23.1		URS
C3-B007	Geotech	2323236	5593679	1.9		URS
C3-B008	Geotech	2323523	5593591	20.6		URS

ID	Type	Easting	Northing	Depth (m)	Diameter (mm)	Data source
C3-B009	Geotech	2323920	5593749	18.8		URS
C3-B010	Geotech	2324253	5593792	20.4		URS
C3-B011	Geotech	2324585	5593743	20.2		URS
C3-B012	Geotech	2324796	5593638	20.4		URS
C3-B016	Geotech	2325917	5593100	15.6		URS
C3-B017	Geotech	2326629	5592717	15.7		URS
C3-B018	Geotech	2327256	5592612	15.8		URS
C3-B019	Geotech	2327388	5592411	15.7		URS
C3-B020(S)	Geotech	2327943	5592207	18.2		URS
C3-B021(S)	Geotech	2328103	5592225	19.6		URS
C3-B023	Geotech	2329828	5591495	15.5		URS
C3-B024	Geotech	2330552	5591400	40.2		URS
C3-B100	Geotech	2323017	5594168	5.6		URS
C4-B001	Geotech	2330877	5591188	39.4		URS
C4-B003	Geotech	2331559	5590936	30.9		URS
C4-B004	Geotech	2331801	5590942	30.8		URS
C4-B005	Geotech	2332086	5590720	25.2		URS
C4-B006	Geotech	2332209	5590838	25.6		URS
C4-B007	Geotech	2332593	5590556	25.4		URS
C4-B008	Geotech	2332970	5590472	25.1		URS
C4-B009	Geotech	2333334	5590241	25.6		URS
C4-B010	Geotech	2333733	5590303	19.9		URS
C4-B011	Geotech	2333745	5590041	20.2		URS
C4-B012	Geotech	2333904	5590216	20.5		URS
C4-B013	Geotech	2334045	5590463	14.8		URS
C5-B001	Geotech	2333916	5590129	20.2		URS
C5-B002	Geotech	2334203	5589680	18.7		URS
C5-B003	Geotech	2334551	5589503	20.2		URS
C5-B004	Geotech	2334927	5589373	15.5		URS
C5-B005	Geotech	2335253	5589191	15.7		URS
C5-B006	Geotech	2335715	5589158	10.0		URS
C5-B007	Geotech	2336108	5588929	9.9		URS
C5-B008	Geotech	2336871	5588662	16.8		URS
C5-B009	Geotech	2337620	5588113	7.9		URS
C5-B010	Geotech	2338366	5587562			URS
C5-B011(S)	Geotech	2338947	5587199	14.8		URS
C5-B012(S)	Geotech	2338893	5587111	14.5		URS
C5-B013(S)	Geotech	2339511	5586897	15.0		URS
C5-B015	Geotech	2340030	5586443	15.0		URS
C6-B003	Geotech	2340953	5586272	30.1		URS
C6-B004	Geotech	2341204	5586278	20.5		URS
C6-B005	Geotech	2341490	5586195	26.3		URS
C6-B006	Geotech	2341882	5585867	26.1		URS
C6-B007	Geotech	2342224	5585689	26.2		URS
C6-B008	Geotech	2342519	5585564	24.4		URS
C6-B009	Geotech	2342921	5585374	25.1		URS
C6-B011(S)	Geotech	2343365	5585098	22.4		URS
C6-B012	Geotech	2343693	5584987	20.8		URS
C6-B013	Geotech	2344056	5584813	20.4		URS
C6-B014	Geotech	2344454	5584665	20.4		URS
C6-B015	Geotech	2344967	5584411	14.2		URS
C6-B016	Geotech	2345496	5584278	16.0		URS

ID	Type	Easting	Northing	Depth (m)	Diameter (mm)	Data source
C6-B017	Geotech	2345914	5584255	14.5		URS
C6-B018(S)	Geotech	2346321	5584321	15.3		URS
C6-B019(S)	Geotech	2346321	5584227	15.0		URS
C6-B020	Geotech	2347253	5584285	8.8		URS
C6-B021	Geotech	2347969	5584332	9.8		URS
C6-B022(S)	Geotech	2348697	5584493	14.6		URS
C6-B023(S)	Geotech	2348697	5584334	14.4		URS
C7-B004(S)	Geotech	2350353	5584562	25.1		URS
C7-B005	Geotech	2350624	5584549	23.8		URS
C7-B007(S)	Geotech	2351239	5584505	20.0		URS
C7-B008	Geotech	2351677	5584413	15.1		URS
C7-B010(S)	Geotech	2351931	5584117	30.5		URS
C7-B016	Geotech	2353791	5583323	8.5		URS
C7-B017	Geotech	2353965	5583326	14.3		URS
C7-B018	Geotech	2353965	5583226	14.4		URS
C7-B019	Geotech	2354348	5583253	14.2		URS
C7-B020	Geotech	2354911	5583091	14.1		URS
C7-B022	Geotech	2356482	5582649	14.9		URS
C7-B024	Geotech	2355939	5582898	49.1		URS
C8-B001	Geotech	2356569	5582967	27.5		URS
C8-B002	Geotech	2356731	5583156	24.2		URS
C8-B003	Geotech	2356833	5583224	25.5		URS
C8-B004	Geotech	2356973	5583519	18.1		URS
C8-B005	Geotech	2357168	5583881	25.3		URS
C8-B006	Geotech	2357339	5584081	20.1		URS
C8-B007	Geotech	2357231	5584130	19.7		URS
C8-B008	Geotech	2357445	5584308	19.9		URS
C8-B009	Geotech	2357693	5584510	14.4		URS
C8-B010	Geotech	2357949	5584666	14.5		URS
C8-B011	Geotech	2358189	5584807	14.4		URS
C8-B012	Geotech	2358128	5584883	14.2		URS
I-B001	Geotech	2310176	5605353	14.5		URS
I-B002	Geotech	2310076	5605270	14.5		URS
I-B003	Geotech	2310320	5604993	13.5		URS
I-B004	Geotech	2310266	5604917	14.4		URS
I-B007	Geotech	2310213	5605145	9.8		URS
I-B008	Geotech	2310026	5604928	9.9		URS
I-B009	Geotech	2309845	5605387	10.1		URS
I-B010	Geotech	2309721	5605497	14.6		URS
I-B011	Geotech	2309868	5605610	20.0		URS
I-B012	Geotech	2309682	5605455	14.9		URS
I-B013	Geotech	2309991	5605682	14.3		URS
I-B014	Geotech	2310066	5605744	14.4		URS
I-B015	Geotech	2310249	5605894	14.5		URS
PS1-B201	Geotech	2315433	5597727	39.8		URS
PS1-B203	Geotech	2315507	5597695	40.0		URS
PS1-B203B	Geotech	2315552	5597745	50.3		URS
PS1-B203C	Geotech	2315478	5597767	40.1		URS
PS2-B201	Geotech	2321601	5594538	37.3		URS
PS2-B202	Geotech	2321484	5594574	39.5		URS
PS2-B203	Geotech	2321619	5594452	40.1		URS
PS2-B204	Geotech	2321378	5594686	39.8		URS

ID	Type	Easting	Northing	Depth (m)	Diameter (mm)	Data source
PS2-B205	Geotech	2321329	5594721	40.7		URS
PS2-B206	Geotech	2321307	5594622	45.1		URS
PS3-B201	Geotech	2330702	5591347	39.9		URS
PS3-B202	Geotech	2330745	5591288	39.6		URS
PS3-B203	Geotech	2330621	5591269	59.3		URS
PS4-B201	Geotech	2340114	5586476	40.1		URS
PS4-B202	Geotech	2340188	5586537	39.9		URS
PS4-B203	Geotech	2340187	5586433	41.7		URS
PS6-B201	Geotech	2356433	5582799	50.5		URS
PS6-B202	Geotech	2356471	5582890	50.3		URS
PS6-B203	Geotech	2356546	5582853	50.5		URS
LF-B001	Geotech	2310016	5605465			URS
LF-B004	Geotech	2309959	5605524	2.5		URS
LF-B005	Geotech	2310048	5605534			URS
LF-B006	Geotech	2310032	5605701			URS
NB01	NBPiezo	2314147	5602716	2.5		URS
NB02	NBPiezo	2314194	5602641	1.7		URS
NB03	NBPiezo	2314259	5602600	1.9		URS
NB04	NBPiezo	2314416	5602164	1.7		URS
NB06	NBPiezo	2314598	5601744	1.5		URS
NB07	NBPiezo	2314698	5601602	1.7		URS
NB09	NBPiezo	2315145	5601165	1.9		URS
NB10	NBPiezo	2315441	5600573	2.7		URS
NB24a	NBPiezo	2319312	5599048	2.9		URS
NB27	NBPiezo	2319915	5598605	2.0		URS
NB30	NBPiezo	2320794	5598705	1.8		URS
NB31	NBPiezo	2320920	5598654	1.6		URS
NB37	NBPiezo	2320573	5597797	1.9		URS
NB38	NBPiezo	2320540	5597742	1.6		URS
NB39	NBPiezo	2321874	5597473	1.5		URS
NB42	NBPiezo	2320302	5597364	1.6		URS
NB43	NBPiezo	2321798	5598306	1.7		URS
NB44	NBPiezo	2321201	5598261	1.7		URS
NB46	NBPiezo	2321099	5598144	1.9		URS
NB47	NBPiezo	2321603	5598026	1.3		URS
NB48	NBPiezo	2322417	5598046	1.6		URS
NB49	NBPiezo	2321485	5596827	1.8		URS
NB53	NBPiezo	2322317	5597802	1.2		URS
NB61	NBPiezo	2322029	5596732	2.0		URS
NB63	NBPiezo	2321802	5596408	2.1		URS
NB65	NBPiezo	2322291	5596624	1.9		URS
NB73	NBPiezo	2323234	5596180	2.0		URS
NB75	NBPiezo	2323749	5595781	2.2		URS
NB80	NBPiezo	2324330	5595419	2.2		URS
NB81	NBPiezo	2324627	5595833	2.3		URS
NB82	NBPiezo	2325022	5595396	1.7		URS
NB83	NBPiezo	2325027	5595149	1.5		URS
NB86	NBPiezo	2325143	5595533	2.4		URS
NB87	NBPiezo	2325530	5595514	1.7		URS
NB92	NBPiezo	2329765	5593025	1.9		URS
NB93	NBPiezo	2329789	5593142	1.4		URS
NB96	NBPiezo	2332801	5592193	1.2		URS

ID	Type	Easting	Northing	Depth (m)	Diameter (mm)	Data source
NB97	NBPiezo	2313328	5603365	1.8		URS
NB98	NBPiezo	2313214	5603234	1.5		URS
NB201	NBPiezo	2312500	5604178	2.1		URS
NB202	NBPiezo	2311476	5605039	2.3		URS
NB13	NBTestpit	2316810	5600295			URS
NB15	NBTestpit	2316960	5600690			URS
NB18	NBTestpit	2317834	5600086			URS
NB19	NBTestpit	2317907	5600426			URS
NB21	NBTestpit	2318410	5599584			URS
NB22	NBTestpit	2318532	5600183			URS
NB69	NBTestpit	2323174	5596431			URS
NB72	NBTestpit	2323938	5596584			URS
NB76	NBTestpit	2324465	5596725			URS
NB77	NBTestpit	2324316	5596185			URS
NB78	NBTestpit	2324625	5596384			URS
NB84	NBTestpit	2325800	5595687			URS
NB89	NBTestpit	2326166	5595184			URS
NB90	NBTestpit	2326827	5594885			URS
NB91	NBTestpit	2328023	5594027			URS
NB94	NBTestpit	2331624	5592720			URS
NB95	NBTestpit	2332854	5592465			URS
NB05	NBTestpit	2314435	5602108			URS
NB08	NBTestpit	2315187	5601249			URS
NB100	NBTestpit	2312453	5604132			URS
NB103	NBTestpit	2311533	5605129			URS
NB11	NBTestpit	2315781	5600593			URS
NB24b	NBTestpit	2319154	5598784			URS
NB25	NBTestpit	2319007	5598512			URS
NB28	NBTestpit	2319827	5598393			URS
NB33	NBTestpit	2321332	5598482			URS
NB45	NBTestpit	2321140	5598183			URS
NB50	NBTestpit	2322249	5597416			URS
NB60	NBTestpit	2321365	5596697			URS
NB62	NBTestpit	2321742	5596516			URS
NB64	NBTestpit	2322291	5596670			URS
NB74	NBTestpit	2323675	5595888			URS
NB79	NBTestpit	2324184	5595707			URS
WS01	Monitor Wells	2362129	5582428			URS
WS02	Monitor Wells	2362880	5582080	13.5		URS
WS03	Monitor Wells	2363123	5582701	18.3		URS
WS04	Monitor Wells	2363127	5583011			URS
WS05	Monitor Wells	2362032	5582942			URS
WS06	Monitor Wells	2361856	5583640	10.5		URS
WS07	Monitor Wells	2360784	5583156	4.8		URS
WS08	Monitor Wells	2360767	5583478	4.9		URS
WS09	Monitor Wells	2359865	5582885	7.1		URS
WS10	Monitor Wells	2359164	5583232	5.1		URS
WS11	Monitor Wells	2358760	5582915	5.3		URS
502	URS 2000	2314485	5599893			URS
503	URS 2000	2314429	5599853			URS
504	URS 2000	2314370	5599798			URS
1004	URS 2000	2349814	5587772			URS

ID	Type	Easting	Northing	Depth (m)	Diameter (mm)	Data source
1005	URS 2000	2349771	5587653			URS
1006	URS 2000	2349737	5587595			URS
3012	URS 2000	2319855	5597841			URS
3011	URS 2000	2320384	5598390			URS
3013	URS 2000	2319748	5597761			URS
3014	URS 2000	2319688	5597718			URS
9003	URS 2000	2321016	5598084			URS
9011	URS 2000	2326241	5595395			URS
9012	URS 2000	2327870	5594065			URS
9013	URS 2000	2330509	5592973			URS
3023	URS 2000	2324858	5596114			URS
1024	URS 2000	2333465	5591966			URS
1012	URS 2000	2354049	5585496			URS
3002	URS 2000	2322629	5594792			URS
3003	URS 2000	2322611	5594750			URS
3004	URS 2000	2322534	5594620			URS
8003	URS 2000	2335363	5589528			URS
8005	URS 2000	2335513	5590105			URS
8010	URS 2000	2343950	5587637			URS
8011	URS 2000	2343989	5587732			URS
8012	URS 2000	2344008	5587775			URS
8015	URS 2000	2354050	5585677			URS
8016	URS 2000	2327032	5593071			URS
8017	URS 2000	2327075	5592993			URS
8018	URS 2000	2327088	5592851			URS
8025	URS 2000	2326866	5592435			URS
8029	URS 2000	2354037	5585238			URS
1014	URS 2000	2346223	5586748			URS
1016	URS 2000	2346221	5586849			URS
1018	URS 2000	2346235	5586909			URS
3015	URS 2000	2319637	5597670			URS
3017	URS 2000	2323828	5595341			URS
3018	URS 2000	2323755	5595304			URS
3020	URS 2000	2323910	5595452			URS
3021	URS 2000	2324881	5595529			URS
4017	URS 2000	2310182	5604686			URS
4018	URS 2000	2310066	5605636			URS
4019	URS 2000	2310322	5605356			URS
8004	URS 2000	2335393	5589607			URS
9008	URS 2000	2322754	5597823			URS
9009	URS 2000	2322365	5597326			URS
9010	URS 2000	2325582	5595726			URS
C1-1175	T&T	2316045	5596190			URS
C2-0020	T&T	2316378	5596038			URS
C2-0040	T&T	2316613	5596081			URS
C2-0060	T&T	2316755	5596261			URS
C2-0085	T&T	2317048	5596246			URS
C2-0110	T&T	2317257	5596207			URS
C2-0130	T&T	2317321	5596011			URS
C3-0980	T&T	2330334	5590472			URS
C3-1010	T&T	2330495	5590411			URS
C4-0010	T&T	2330956	5590227			URS

ID	Type	Easting	Northing	Depth (m)	Diameter (mm)	Data source
C4-0030	T&T	2331268	5590154			URS
C4-0050	T&T	2331333	5590051			URS
C6-0920	T&T	2348784	5584359			URS
C6-0935	T&T	2348957	5584277			URS
C6-0940	T&T	2349050	5584437			URS
C6-0960	T&T	2349197	5584358			URS
C6-0985	T&T	2349525	5584279			URS
C7-0005?	T&T	2349785	5584495			URS
C7-0030?	T&T	2350002	5584605			URS
C7-0055?	T&T	2350271	5584546			URS
C7-0700	T&T	2356285	5582699			URS
C80001	T&T	2356767	5583065			URS
C80040	T&T	2356810	5583346			URS
C80065	T&T	2357027	5583518			URS
C80085	T&T	2357064	5583757			URS
C80120	T&T	2357261	5583961			URS
C8-0140	T&T	2357301	5584204			URS
C8-0175	T&T	2357530	5584491			URS

Appendix B Flow gauging data

▪ Table A-2. Summary of recent flow loss gauging information for the Waitaki Catchment

Date of gauging (yymmdd)	Irishman Creek at Braemar Road	Irishman Creek at Windy Ridge	Irishman Creek above Tekapo Confl.	Mary Burn at Mt. McDonald	Mary Burn at Mary Hill	Mary Burn at SH8 Bridge	Mary Burn above Tekapo Confl.	Omarama Stream above Tara Hills	Omarama Stream at Twin Peaks	Omarama at SHB (Wardells)	Otamatapaio River at footbridge	Otamatapaio River above Otamatapai Stn.	Otamatapaio River above SH bridge	Twizel at DS Gladstone Conf	Twizel River at Lake Poaka
28/05/2003				359				521							
29/05/2003				349		483		484	442						
24/06/2003				561		674		792	652						
24/07/2003	738	1046	485	484	550?	638	2666	1060			489	463	128		1210
25/07/2003				435				965	945	1647					
12/08/2003	477	643	373	371	450?	576	2236	979			325	363	0	1771	663
13/08/2003				377				968	889	1422					
25/08/2003				361				855							
18/09/2003				1137		1466		917							
30/09/2003				1404				1956	1901						
2/10/2003				1251		1351		2180	2231						
30/10/2003				574		355		1866	1510						
20/11/2003				445				1087	875						
21/11/2003				435		193		1144							
27/11/2003	627	885	469	416		226	2078	1059						3781	3686
28/11/2003				500				1087	899	2307	856	954	450		
11/12/2003	459	663	373	380	489	244	2038	790			573	491	0	4934	3252
12/12/2003				348				771	620	2074					
13/01/2004				301		217		424							
14/01/2004				298				443	376						
27/01/2004				359				1036							
1/02/2004				306				3282							
2/02/2004				305				3662							

Date of gauging (yymmdd)	Irishman Creek at Braemar Road	Irishman Creek at Windy Ridge	Irishman Creek above Tekapo Confl.	Mary Burn at Mt. McDonald	Mary Burn at Mary Hill	Mary Burn at SH8 Bridge	Mary Burn above Tekapo Confl.	Omarama Stream above Tara Hills	Omarama Stream at Twin Peaks	Omarama at SHB (Wardells)	Otamatapaio River at footbridge	Otamatapaio River above Otamatapai Stn.	Otamatapaio River above SH bridge	Twizel at DS Gladstone Conf	Twizel River at Lake Poaka
2/02/2004								3519							
3/02/2004				297				3405							
12/02/2004	401	543	386	273	323	184	1174	1300			1047	1002	805	3365	2799
13/02/2004				274				1263	991	2099					
18/03/2004		766		291		380	1745	2164			1061	1086	1119		2989
19/03/2004				267				1944							
25/03/2004				258				1707							
30/03/2004	335	521	575	281	382	417	2004	1406		2571	621	538	218	4038	2515
31/03/2004				261				1324							
14/04/2004	317	418	391	262	356	365	1767	1039			518	462	99	2154	1180
15/04/2004				250				1229							
23/04/2004		369	371	256		342	1590	1139						1945	713
30/04/2004				244				1028							
27/05/2004		1089	403	299				1688		2254					2083