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Kate Scott
Manuherikia Catchment Water Strategy Group
PO Box PO Box 122
Alexandra 9340

MCWSG FEASIBILITY STUDY - GROUNDWATER AND DRINKING WATER SUPPLY REVIEWS

Dear Kate

The Manuherikia Catchment Water Strategy Group (MCWSG) is currently undertaking a feasibility level study of the Manuherikia River Catchment to provide water storage and distribution for irrigation. In October 2013, a group led by Golder Associates (NZ) Limited (Golder) was commissioned to undertake the following four components of the feasibility study:

1) Geotechnical and engineering.
2) Environmental investigations.
3) Land tenure, water allocation, planning and resource management act (RMA) issues.
4) Economic and commercial investigations, scheme ownership and management models.

The feasibility study is focused on the following five irrigation development options:

Option 1: Raising Falls Dam by 6 m

Option 2: Raise Falls Dam by 27 m

Option 3: Raise Falls Dam by an intermediate increase of around 15 m

Option 4: Develop efficient water distribution systems in the Manuherikia Valley

Option 5: Construct of the Mt Ida Dam and associated irrigation scheme

Groundwater is an important physical resource within the Manuherikia River Catchment. Springs and groundwater bores / wells supply much of the areas drinking water and groundwater discharges provide base flow in the area's watercourses. Irrigation directly effects groundwater recharge and land use intensification associated with irrigation can influence groundwater quality. The five irrigation development options have the potential to effect groundwater quantity and quality. Drinking water supplies bear some relation to the Manuherikia River Catchment's groundwater resource as bores, galleries and springs are the primary source for raw water feeding these supplies. The sources and raw water infrastructure works are also potentially affected by the five irrigation development options, in terms of downstream effects and changes in irrigation practice that are consequential to the developments. Within the feasibility study, it is necessary to investigate groundwater as a potential water resource and to assess the consequences for groundwater and drinking water of the proposed irrigation developments.

Scope & Method

As part of the feasibility study, Golder has reviewed the groundwater environment and its current utilisation. The consequences for drinking water supplies and groundwater (quantity and quality) generally of proposed irrigation developments have also been assessed. This letter[1] documents Golder's review and key findings. It is envisaged that the key findings in this letter will be incorporated into the feasibility reports. The commissioned groundwater and drinking water supply review by Golder is an analysis of existing information relating to the Manuherikia River Catchment, and more widely where relevant and appropriate. As part of the drinking water review a meeting was held with Russell Bond of Central Otago District Council (CODC) on 27 January 2014, to discuss the CODC's public water supply activities.

Sources of Information

The territorial local authorities, CODC and Otago Regional Council (ORC), were the primary sources of raw data and other information on the region's groundwater and drinking water supplies. Additional information was obtained from the published geological surveys of the catchment and the Ministry of Health in terms of water supply records. A list of references used in preparing this letter is provided in Attachment B..

Key Findings

Groundwater

Hydrogeological Setting

Groundwater resources are an important complimentary water resource in many parts of Otago. The Manuherikia River Catchment has a range of groundwater environments, from the Dunstan Flats comprising Clutha outwash gravel aquifers with yields providing for higher capacity irrigation, to thin silty gravel alluvium of much of the middle and upper Manuherikia Valley that have little yield beyond household supply. In most instances, groundwater provides a minor ancillary resource compared to the extensive water race distribution networks which deliver surface water to large areas of the Manuherikia River Catchment.

The Manuherikia River Catchment sits astride a tectonic environment that could be termed, 'basin and range', comprising a series of northwest-trending sedimentary basins intervening between block-mountains such as the Dunstan, Rough Ridge and Raggedy ranges McSaveney & Stirling (1992). The block-mountains are faulted folds in the earth's crust and a result of the prevailing tectonic plate collision at the Alpine Fault to the west (Markley & Norris, 1999). The sedimentary basins have been in-filled with terrestrial sediments of three distinct geological eras, lake and river sediments of the Miocene Manuherikia Group; river sediments of the Pliocene Maniototo Conglomerate; and Quaternary / Pleistocene age fan, outwash and alluvial deposits. The basement schist and greywacke rock underlays the entire catchment, including forming the base to Tertiary sediments, and exposed by erosion on the ranges.

Groundwater saturates all of these geological materials below a water table that reflects the balance of the climate and position of connected surface water courses. Most of the potentially available groundwater within the catchment is contained within Quaternary / Pleistocene gravel deposits. The sedimentary texture and silt / clay composition of these gravels are the principal factors in determining how much groundwater can be taken by bores or wells from these deposits (groundwater yield). Distinct contrasts in the groundwater yield and gravel aquifer composition have been detected within documented bore / drilling logs from the catchment. In this context, mapped stratigraphy of glacial outwash and alluvium is useful for classifying the catchment's aquifers.

Two recent ORC groundwater resource investigations of parts of the Manuherikia River Catchment provided insights into the availability of groundwater particular to the regions studied (Alexandra basin and Ida Valley) and to the wider catchment. ORC also holds 355 well records for wells, bores and galleries in the catchment, although the database is acknowledged to be incomplete and includes exploration, decommissioned and dis-used bore holes. The ORC database also includes depth, bore yield and geological data, which are used as context in parts of this letter.

[1] This letter is provided subject to the Report Limitations in Attachment A.

ORC groundwater investigations and monitoring have been undertaken in the 'Alexandra basin' aquifers (comprising the Earnscleugh, Dunstan, Manuherikia Claybound and Manuherikia Alluvium) from 1997 and were summarised in 2012 as part of a groundwater allocation report (ORC 2012a). In general, the younger glacial outwash terrace gravels (correlated with the Hawea, Albert Town, Luggate and Lindis glacial advances) have higher permeability and porosity for groundwater, and display higher groundwater through-flow rates and bore yield. Generally also, the older outwash terraces and fans (correlated with the Lowburn glacial advance, Q10 terraces and oxygen isotope stage 12 – 26 Waikerikeri fan deposits) have distinctly lower permeability that manifests in low to marginal bore yields. The Manuherikia Alluvial Aquifer (MAA) mapped by ORC (2012a) from the end of the Ophir Gorge to Clutha confluence is primarily Manuherikia River alluvium deposited since the last (Hawea) glacial advance. All such main stem alluvial aquifers on the flood plain in the Manuherikia River Catchment are typically in close hydraulic communication with the adjoining river. Figure 1 below shows the location of wells and bores within the Manuherikia Catchment for which ORC's have records. The relevant sections of the Otago Water Plan (ORC 2004) require that groundwater in hydraulic communication with a perennial river is managed in conjunction with the river flow restrictions and surface water allocation regime.

Groundwater investigation of the Ida Valley found a paucity of river-deposited outwash and only very thin Quaternary alluvium overlying pervasive, thick Tertiary sediments beneath the valley floor (ORC 2012b). Significantly, analysis of the associated drilling investigations found moderate size irrigation supplies potentially available from stratified, re-worked schist sands of early Quaternary age. As detailed further below, these deposits have low capacity irrigation potential in the tens of litres per second range. Tertiary sediments of Manuherikia Group (Manuherikia and Bannockburn formations) fill the remainder of the 200 – 300 m deep sedimentary basin that runs the length of the Ida Valley, and have not been found to be a useful groundwater prospect. The Manuherikia Valley upstream of the Ophir Gorge has not been investigated to any great extent, but is considered to follow a similar hydrogeological pattern to that of the Ida Valley. The likelihood of stratified, re-worked schist sands and gravels of early Quaternary age being found in the Manuherikia Valley was discussed in the ORC (2012b) report and an area was defined centred on Matakanui in the Thompsons Creek catchment as a potential higher bore yield zone.

An analysis of drilling and water bore records collated by ORC from the wells database, indicates that the Ida Valley and Manuherikia Valley upstream of Ophir Gorge have low groundwater potential compared to the valley floor areas of the rest of the Upper Clutha Catchment. This area is considered markedly water-short, being semi-arid and having less access to the water resources of large rivers or lakes, and commercial drilling exploration has failed to locate high yielding wells since high penetration drilling rigs became available in the 1950s. It is reasonable in those circumstances, to infer that there are few areas of high groundwater yield within either the Ida Valley or the Manuherikia Valley upstream of Ophir Gorge. Nonetheless, there are isolated areas of high groundwater yield have been encountered in the Manuherikia River flood plain and the middle reaches of Thompsons Creek.

Aquifer Parameters

There have been very few aquifer tests or pumping tests to determine aquifer parameters in the Manuherikia River Catchment (Figure 2). Aquifer testing associated with vineyard development on the Manuherikia Claybound Aquifer (MCA) (bores G42/0626 and G42/0613) found values of hydraulic conductivity of approximately 1 m/d from silty gravel of the Waikerikeri fan alluvium. Pumping tests on a test bore (G41/0396) on the Larkhall Dairy Farm, Omakau found a hydraulic conductivity of approximately 2,500 m/d from coarse sandy gravels within the Manuherikia River flood plain. Testing of the stratified, re-worked schist sands of early Quaternary age of the Ida Valley in four test bores drilled in 2011 (ORC, 2012b) indicated a range in hydraulic conductivity between 3 m/d and 38 m/d.

Groundwater Recharge

Groundwater recharge has been the subject of study in the Alexandra basin, including the parts of the MCA and MAA that lie within the Manuherikia River Catchment (ORC 2012a). The Profile Readily Available Water (PRAW) soil physical property across the MCA and MAA ranges from 21 mm to 90 mm. The PRAW parameter is the chief determinant in the calculation of aggregate annual recharge rate through the soils overlying the MCA and MAA. Figure 3 shows the Alexandra basin aquifers used in the ORC (2012a) analysis of groundwater recharge.

The Rushton et al. (2006) equation was used alongside a 25 year climate data-set to model daily and annual groundwater recharge rates through ten soil zones over the MCA and seven zones over the MAA. ORC (2012a) showed that under natural rates of recharge with rainfall only feeding soil-moisture that mean rates of recharge would range between 5 mm per annum (mm/a) for the MCA soil dominated by high retention, slow draining soil types and 50 mm/a for the MAA reflects the low retention properties of the alluvial soils covering the Manuherikia alluvium. In addition, the ORC model approach included irrigation of the current extent of irrigated soils at rates considered 'efficient' using the Aqualinc pasture irrigation tables (Aqualinc 2006) rather than existing irrigation practices. The MCA and MAA are served by the Manuherikia Irrigation Society and the Galloway Irrigation Society, respectively. The existing irrigated extent was modelled to be irrigated at rates between 780 mm/a and 885 mm/a depending on the soil field capacity. The resulting aquifer specific recharge modelling results are provided in Table 1.

Table 1: Summary of groundwater recharge model results (ORC, 2012a).

	Non-irrigated (natural) recharge	**Irrigated recharge**	**Total aquifer area**	**Percentage of aquifer irrigated**	**Combined aquifer recharge**
	(mm/a)	(mm/a)	(ha)	(%)	(mm/a)
MCA	5	486	6,872	4%	22.8
MAA	50	238	937	54%	150.9

Table 1 reveals that even efficient irrigation (780 to 885 mm/a applied) has the effect of increasing the groundwater recharge rate over that of natural recharge. If the irrigation applied in the recharge model was to be increased to rates closer to current practice between 900 mm/a to 1200 mm/a, recharge would be increased by almost the difference between the two irrigation rates (i.e., if irrigation was raised from 780 mm/a to 1,200 mm/a, the increase in recharge would be approximately 380 mm/a). Indeed, the ORC (2012a) report found that the aquifers' water balances were dominated by additional recharge related to the respective irrigation schemes through the infiltration of race water, soil drainage and intentional by-washes of surplus irrigation to the ground.

The implication is that upon modernisation of the current irrigation scheme from water races and surface irrigation to distribution pipes and spray irrigation, the aquifer water balances would be substantially diminished. The water balances of the MCA, Dunstan Aquifer and MAA make it clear that any significant decreases to the losses of irrigation water would have the knock-on effect of reducing the recharge of the underlying aquifer. The second implication of the ORC recharge modelling is that even efficient irrigation increases the flux of soil water descending to the water table bearing dissolved nutrients such as nitrate nitrogen.

Golder understands (pers comm. Russell Bond of CODC) that a number of shallow bores in the Muttontown area rely on recharge from neighbouring irrigation and when irrigation is curtained water levels drop with the result that a number of bores have gone dry.

As part of the current Manuherikia Catchment feasibility study AgResearch are undertaking Overseer modelling of the farms of the Manuherikia River Catchment. Current Overseer modelling is focused on five case study farms spread representatively throughout the catchment. Once complete the results from the case study farms will be used to scale up to assess the entire Manuherikia River Catchment. Overseer is a farm based biophysical model of nutrient flows through agricultural systems. Overseer is particularly strong in quantifying soil surpluses draining through to the water table, including the nutrients lost to the farm in the form of nitrate nitrogen. It also quantifies the amount of water draining through the soils to join groundwater. Thus, the Overseer simulation of Manuherikia River Catchment nitrogen loadings and drainage rates will provide tonnages, concentrations and drainage volumes for parts or all of the catchment under modelled current and future land use/water resource options. These parameters will go some way to answering questions around the possible reduction in groundwater recharge under more efficient irrigation or the concentration of soil leachate with respect to nitrate nitrogen under various farm nutrient or irrigation practices.

Groundwater Quality

The quality of groundwater within the Manuherikia River catchment reflects the high quality of most surface water and the relatively low intensity of land use within the catchment. Table 2 summarises recent State of the Environment (SOE) groundwater monitoring conducted in the lower Manuherikia River Catchment by ORC. Total dissolved solids (TDS) concentration in two bores in the MCA averages 90 g/m^3, while TDS averages significantly higher for the two bores in the MAA at 240 g/m^3. Groundwater nutrient concentration is also low by the standards of developed pasture lands in New Zealand with the highest nitrate nitrogen concentration found at 4.2 g/m^3, while the monitored aquifers average 2.7 and 1.1 gN/m^3 for the MCA and MAA, respectively. There is a marked difference in the median dissolved reactive phosphorus (DRP) concentration between the MAA (0.04 gP/m^3) and the MCA (0.01 gP/m^3), possibly due to the low anion storage capacity (ASC) of the alluvial soils on the Manuherikia flood plain compared the older soil of the Waikerikeri fans.

Counts of bacterial content were found in both aquifers, although the maximum concentration was 4 E. coli or faecal coliform counts per 100 mL. This is consistent with the unconfined nature of both aquifers and the possibility of the semi-continuous entry of bacteria that is eventually immobilised by filtration, mortality or other removal processes. The difference in sulphate, potassium and chloride concentrations between MCA and MAA is suggestive that agricultural soil additives of gypsum and potassium chloride to the more intensively farmed MAA soils on the Manuherikia flood plain results in the residual ions becoming more enriched.

Table 2: Summary of groundwater quality from ORC SOE monitoring (31/3/2011 – 17/12/12).

		Manuherikia alluvial aquifer (MAA)				**Manuherikia claybound aquifer (MCA)**			
Analyte	**Unit**	**Mean**	**Median**	**Max**	**Min**	**Mean**	**Median**	**Max**	**Min**
Ammonia-N	g/m^3-N	0.0105	0.01	0.017	0.01	0.01	0.01	0.01	0.01
DRP	g/m^3-P	0.042	0.045	0.060	0.021	0.012	0.009	0.044	0.004
E. Coli MPN	cfu/100mL	1.1	1	4	1	1.0	1	2	1
Faecal coliforms-	cfu/100mL	1.3	1	4	1	1.1	1	2	1
Dissolved oxygen	g/m^3	8.5	8.5	9	8	5.7	5.7	8.5	1.2
Sulphate	g/m^3	25.5	25.5	35	15.4	6.5	6.6	7.7	5.8
Magnesium	g/m^3	13.99	13.7	20	8.49	3.59	3.57	4.6	2.7
Potassium	g/m^3	4.37	4.37	6	3.2	1.57	1.56	2.1	1.11
Sodium	g/m^3	26.22	26.7	34	18.9	7.51	7.58	9.6	5.6
Boron	g/m^3	0.032	0.032	0.041	0.024	0.016	0.014	0.03	0.01
Conductivity	mS/cm	28.6	37.1	47.7	_	10.92	14.4	17.3	0.11
pH		6.9	6.85	7.7	6.7	6.8	6.7	7.8	6.3
Hardness	g/m^3	128.6	125.2	172	84	54.5	55.2	70	38
Free carbon dioxide	g/m^3	32.3	33.5	46	5.6	23.0	25.8	45	2.2
Nitrate-N	g/m^3-N	2.72	2.75	4.2	1.58	1.17	1.16	2.2	0.62
Alkalinity	g/m^3	142.6	150.5	198	87	66.0	67.7	89	43

		Manuherikia alluvial aquifer (MAA)				Manuherikia claybound aquifer (MCA)			
Analyte	**Unit**	**Mean**	**Median**	**Max**	**Min**	**Mean**	**Median**	**Max**	**Min**
Chloride	g/m^3	21.58	21.35	31	11.9	3.41	3.39	4.4	2.2
Arsenic	g/m^3	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Iron	g/m^3	0.0168	0.02	0.02	0.005	0.0181	0.02	0.023	0.008
Manganese	g/m^3	0.0010	0.0005	0.005	0.0005	0.0010	0.0005	0.005	0.0005
Calcium	g/m^3	28.53	28	36	19.7	16.01	16.17	20	11.5
Alkalinity	g/m^3	122.18	125.5	163	87	56.87	56.5	73	42

Note: Min = minimum, Max = maximum, Ammonia-N = ammoniacal nitrogen, DRP = dissolved reactive phosphorus, MPN = Most Probable Number, cfu = colony forming units, nitrate-N = nitrate nitrogen, all ion and metal / metalloid concentrations are dissolved phase rather than total, hardness is total hardness, alkalinity is total alkalinity.

A single set of groundwater quality samples were taken from the four Moa Creek test bores from the stratified, re-worked schist sands of early Quaternary age (ORC 2012b) in 2001. These results are reproduced in Table 3. Despite originating from semi-confined sand aquifers, the sample results reflect relatively recent soil drainage under agricultural soils. Nitrate nitrogen is elevated in all samples, and the phosphorus is elevated in three of the bores, pointing to agricultural soil drainages. The relatively enriched nature of most ions in the Neville Lane test bore, plus the low DRP points to the groundwater being relatively stagnant compared to the others

Table 3: Moa Creek, Ida Valley snap-shot groundwater quality results (2011).

Analyte	Units	Moa Creek Bore	*"Idavale"* Bore	Neville Lane Bore	Meade Road Bore
Electrical conductivity	mS/cm	26	20	24	39
Calcium	g/m^3	23	18.3	34.4	44.1
Sodium	g/m^3	22.2	19	26.8	31.3
Potassium	g/m^3	3.1	1.1	1.5	0.9
Magnesium	g/m^3	10.9	9	15.6	15.9
Chloride	g/m^3	20.6	15	52.4	36.3
Sulfate	g/m^3	7.1	13.6	19.6	23
Nitrate-N	g/m^3-N	1.5	1.9	4.5	2.3
Ammonia	g/m^3-N	<0.01	<0.01	0.02	<0.01
DRP	g/m^3-P	0.017	0.052	<0.005	0.041
Arsenic	g/m^3	<0.001	0.001	<0.001	<0.001
Iron	g/m^3	0.02	0.02	1.31	<0.01
Manganese	g/m^3	0.0041	0.0016	0.405	<0.0005
Alkalinity	g/m^3	121	86	92	164

Note: Ammonia = ammoniacal nitrogen, DRP = dissolved reactive phosphorus, Nitrate-N = nitrate nitrogen, all ion and metal / metalloid concentrations are dissolved phase rather than total, alkalinity is total alkalinity.

Schist and Greywacke Rock Groundwater

All information on the Manuherikia River Catchment thus far, has concerned groundwater within porous deposits such as sands and gravels. A modest groundwater resource can also be found within the basement rock. The Manuherikia River catchment traverses a transition from relatively low metamorphic grade rock called greywacke to higher grade metamorphism that produced the textural grade III schist found in the lower and western catchment (Mortimer 1993). Throughout this continuum, the basement greywacke or schist contains groundwater within foliation partings, joints and fractures within the rockmass.

ORC (2012b) made a study of this groundwater resource in the Ida Valley. It was noted that peak transmissivities within drill holes ranged from 0.7 m^2/d to 1 m^2/d, which is theoretically capable of supplying domestic and modest stock water requirements from wells drilled in schist rock. The groundwater study concluded that well yields from fractured rock within the Ida Valley were unlikely to satisfy irrigation requirements for water. Nonetheless, fractured rock groundwater systems provide important base flow to creeks and streams in the ranges at the catchment's margins. Most high ground in the Manuherikia River Catchment is made up of schist or greywacke. The ability of these rock units to soak up and hold precipitation through a system of fractures is reflected in the delayed yield the rock groundwater system contributes to streams and wetlands (also known as base flow). Without this tendency, the catchment's surface water would decline to negligible flows between rainfalls or snow melt.

Groundwater Use

A review of ORC's resource consent information (Golder 2014) indicated that there are 43 current resource consents to take groundwater from within the Manuherikia River Catchment (including the Waikerikeri Creek Catchment takes in the Dunstan Flats Aquifer). The consents are predominantly clustered around Alexandra and particularly in the MCA, MAA and Dunstan Flats Aquifer. Of the 43 resource consents, information on the maximum rate of take is available for 21 resource consents. Together, these 21 resource consents authorise a maximum abstraction of 663.5 L/s, although 600 L/s of this is associated with the flood protection scheme around Alexandra and is not considered a consumptive use. Furthermore, the total does not include CODC's 400 L/s groundwater take for the Alexandra public water supply scheme. The maximum rate of take associated with the remaining 22 resource consents are currently being investigated, however, the Alexandra basin aquifers were quantified as part of the ORC (2012a) groundwater allocation study and ORC has provided a list of groundwater takes in the catchment above Ophir Gorge.

Groundwater in Otago is generally allocated in units of millions of cubic metres per annum (Mm^3/a). ORC (2012a) provided the following list of groundwater takes and allocation dating from 2011, which is reproduced with an ORC update[2] for the Manuherikia River Catchment upstream of Ophir Gorge in Table 4.

Table 4: List of consented groundwater takes in the Manuherikia River Catchment.

	No. of consented takes	**Consented allocation**[¥]
Units:	#	(Mm^3/a)
Dunstan aquifer (in Waikerikeri Creek catchment)	34	1.450
Manuherikia claybound aquifer	11	0.611
Manuherikia alluvium aquifer	4	0.014
Manuherikia catchment upstream of Ophir Gorge	1	0*
Catchments total – (Manuherikia & Waikerikeri)	**50**	**2,075**

Note: * The sole currently consented groundwater take in the upper catchment is for a mining-related 'take and discharge' activity for pit dewatering with nil net consumption, therefore no allocation of groundwater is assigned to it. [¥] All aquifers' consented allocation totals lie below the groundwater allocation limit operative for each respective aquifer, meaning they are not fully allocated (ORC 2012a).

[2] Emailed spreadsheet from Rebecca Morris, ORC Resource Scientist - Groundwater, 17/03/2014

An examination of the uses specified for the above groundwater take consents indicated that groundwater occupied an often specialised role in the catchments' water resource spectrum. Water taken from bores and wells under consent frequently provided water for drip, spray (typically pod) irrigation and communal water supply. Few, if any, uses of groundwater in the catchment could be considered bulk irrigation supply of the type that race irrigation schemes currently provide within the catchment. When placed alongside the estimated 260 Mm^3/a that is taken for irrigation within the catchment[3], the groundwater allocation of only 2 Mm^3/a is indicative of the relatively low importance of sub-surface water resources to the quantity of water used within the Manuherikia River Catchment.

Potential for Managed Aquifer Recharge

Managed Aquifer Recharge (MAR) is a system of artificially enhancing the rate and volume of recharge accruing to an aquifer, often combined with an aquifer extraction scheme. The implementation of MAR may include the following recharge enhancement approaches:

- Diversion of surface water into infiltration basins where recharge occurs at elevated rates.
- Diversion of water into water courses with a high bed conductance under conditions where elevated rates of stream bed recharge occur.
- Spreading of water onto land in a manner where the natural recharge rate(s) are exceeded.

The last approach is the unintended consequence of contour and border dyke irrigation or water race losses, as outlined above in Groundwater Recharge. There is a concern that with modernisation of the Manuherikia irrigation networks that higher efficiency methods of irrigation would predominate with the consequence of reduced net recharge rates for groundwater. Despite the relative lower importance of groundwater as a water resource in the Manuherikia River Catchment, sub-surface flows are still very important in sustaining base-flow for streams, wetlands and rivers.

The availability of groundwater is adversely affected by the following inherent factors in the Manuherikia River Catchment:

- Low hydraulic conductivity / transmissivity of the aquifer leading to low bore yield.
- Rudimentary levels of drilling and well construction technology leading to lower bore yields than would otherwise be possible with measures such as sand-pack well development (ORC 2012b).
- In unconfined aquifers, thin thickness of saturated gravel or sand between the water table and aquifer base.
- Fluctuation of the water table causing variance in the saturated thickness and therefore transmissivity, affecting bore yield when the water table drops.
- The absence of year-round groundwater recharge or aquifer storage leading to the water table fluctuation set out in the point above.

Little can be done to improve an aquifer's hydraulic conductivity. However, enhancing the recharge of the aquifer would ordinarily maintain the transmissivity and aquifer storage, with the benefit of allowing higher bore yield. Accordingly, the main opportunity for enhancing the groundwater resource in a part of the Manuherikia River Catchment is by locating a zone with adequate aquifer hydraulic conductivity and high bore yield as inherent features. Undertaking MAR on such a zone would have the positive effect of increasing the perennial groundwater resource and minimising the potential for groundwater extraction to lead to generalised groundwater level decline. An examination of the information available for the Manuherikia River Catchment highlighted the Thompsons Creek and associated deposits where the creek exits Thompsons Gorge at Matakanui. This part of the Thompsons Creek catchment was also the subject of alluvial gold exploration, from which the review gained most its sub-surface information. Figure 4 shows the location of the potential MAR zone.

[3] Estimated for the Campground hydrological site using naturalised and actual summer river flow, *pers. comm.* Lu Xiaofeng, 17 January 2014. Median naturalised 2009-10 summer flow was estimated at 7.85 m^3/s. Median measured 2009-10 summer flow rate was recorded as 1.21 m^3/s. The 6.64 m^3/s difference is inferred to be net abstraction, overwhelmingly for irrigation storage and run-of-river abstraction for use in pasture irrigation. This difference by subtraction of the naturalised from the recorded flow is equivalent to 257 Mm^3/a.

Gold exploration near Matakanui included several dozen exploration drill holes between the end of the gorge and Glassford Road (Jacobs et al. 1995, Becker 2004). The profiling of the drilling results allowed the delineation of an alluvial fan and a set of paleo-channels comprising sandy, cobbly gravel beneath the Thompsons Creek flood plain. The paleo-channels extend to depths ranging between 20 m and 25 m, which are remarkably deep for an area of average Quaternary alluvium depth being 6 m (Becker 2004). The water table lies approximately 5 m below the ground surface suggesting the ability of Thompsons Creek to lose water into the aquifer by infiltration.

Observations of Thompsons Creek losses to the underlying aquifer were made during ORC field work on 11 – 12 January 2011 (pers comm. Matthew Hickey, ORC Science Manager, 3 April 2014). A water intake straddles Thompsons Creek in Thompsons Gorge in the hill country to the west of Drybread. The race has spillway and by-wash discharges from which the flow into the downstream creek was gauged at 236 L/s. On 11 January 2011 and during dry weather, the flow of creek water was observed to diminish downstream, especially over the deepened zone of alluvium outlined in the paragraph above. The creek was observed to diminish by 120 L/s at the Glassford Road crossing. Downstream of Glassford Road to Mawhinney Road the creek exhibited further losses to the aquifer, but the pattern was complicated by further irrigation intakes, a water race siphon and by-washes.

The interpretation of these observations is that Thompsons Creek loses all or a portion of its flow to the alluvium as it crosses into the deepened, higher transmissivity alluvial materials. The elevated hydraulic conductivity of the creek bed and the deeper water table provide the conditions for the loss of creek flow and recharge of the aquifer. The flow of groundwater is laterally constrained by the past deposits of Thompsons Creek (the aforementioned paleo-channels) so the creek receives water back from the aquifer downstream once the water table begins to intersect the base of the creek. This downstream seepage zone is probably the result of thinning of the aquifer downstream of Glassford Road and down-cutting of the creek to the alluvium. Such infiltration - seepage couplets are found in a number of Clutha catchment tributaries where the river concerned crosses from the basement rock to a porous alluvial or outwash terrace, e.g., Cardrona, Lindis or Fraser rivers.

Such settings are also potentially workable as MAR reservoirs. The pumping of groundwater from the aquifer and flows in the creek could be manipulated to optimise the storage of water for release when required. In addition, the better water quality and microbiological security of an aquifer can be utilised to provide water more suitable for drinking water than surface water. For example, were CODC to establish intake bores in the Thompsons Creek alluvium, but found water table fluctuations impaired the quantity that could be obtained, MAR could alleviate that vulnerability. Through strategic releases of irrigation race water to offset low creek flow from the natural headwaters, the alluvial aquifer might be managed to maintain a more consistent water table height for optimal bore field operation.

Drinking Water

Current Community Water Supplies

The 2011 Ministry of Health (MoH) register of community water supplies (MoH 2011) lists 13 registered community water supplies (Table 5 and Figure 5) in the Manuherikia River Catchment. The largest of these serves Alexandra and environs with treated, piped water from six shallow gallery bores installed adjacent to the Clutha River near the Manuherikia River confluence. Omakau and Ophir are served for water supply by a gallery on the banks of the Manuherikia River. Apart from these two township water supplies operated by CODC, the remaining smaller water supplies are operated by private water supply companies, school boards of trustees, commercial owners, and informal community groupings. MoH (2014) refers to such supplies as ‘self-supplied’ and in the Manuherikia catchment they are expected to serve a population of approximately 440 individuals.

The raw water sources within the catchment are diverse, ranging from the shallow (13 m) deep gallery[4] bores at Alexandra to small springs in farmland. In some cases, the ‘bore’ referred to as the source of raw water is instead a collection chamber tapping spring flow. As far as could be ascertained, none of the

[4] ‘Gallery’ is often used to refer to a chamber, well or bore that is within or alongside the bed of a river, lake or stream. The water level of the gallery and water body are tied, except when the gallery is pumped. Under pumping the gallery has the effect of drawing some of its water from the water body, and certainly intercepting groundwater that would otherwise form part of the surface water’s flow.

groundwater sources could be defined as 'secure groundwater' in terms of the drinking water standard (MoH 2008a). For the two water supplies reviewed in the most recent annual review of water quality (MoH 2014), the Alexandra and Omakau supplies achieved bacterial and chemical minimum compliance, but not protozoan. Omakau – Ophir water supply has not yet started the required Public Health Risk Assessment Plan (MoH 2014). The rest of the community water supplies are ungraded.

Table 5: List of registered community water supplies in the Manuherikia River Catchment.

Code	Community	Population	Source	Grading
ALE001	Alexandra	5,000	Bores 1 - 6 (Clutha River)	Ee
ALE002	Alexandra, Long Gully*	172	Long Gully Spring	Uu
BEC002	Becks Hotel	2	Creek at Becks Hotel	Uu
CHA002	Chatto Creek Tavern	25	Chatto Creek Tavern Bore	Uu
LAU002	Lauder Tavern	25	Lauder Tavern Bore	Uu
LAU001	Lauder, NIWA	30	Manuherikia River Gallery	Uu
OMA018	Omakau, Tiger Hill[¥]	50	Tiger Hill Bore	Uu
OMA005	Omakau/Ophir	400	Manuherikia River gallery	Uu
OTU009	Oturehua	35	Oturehua Bore	Uu
OTU002	Oturehua Tavern	25	Oturehua Tavern Bore	Uu
POO002	Poolburn Hotel	25	Poolburn Hotel Bore	Uu
POO001	Poolburn School	40	Poolburn School Bore	Uu
VUL001	Vulcan Hotel, St Bathans	10	Vulcan Hotel Water Race	Uu
	Total	5,839		

Note: Information from the Register of Community Water Supplies in New Zealand (MoH 2011) * Operated by the Long Gully Rural Water Scheme Inc. [¥] Operated by the Tiger Hill Water Supply Company Ltd. Grading Ee = a grading of "Unacceptable level of risk". Grading Uu indicates "Ungraded".

Alexandra

The Alexandra area is currently served by a pressurised piped community water supply scheme which draws water from six shallow gallery bores installed adjacent to the Clutha River approximately 1,750 m upstream from the main road bridge. The bores draw a mixture of groundwater and river water filtered through a layer of riverbed gravels. The current system services a resident population of approximately 5,000 people, which increases to more than 8,500 during peak holiday periods. Annual average water consumption is approximately 2 Mm^3 (CODC 2014), largely derived from the Clutha River / Mata Au. Alexandra residents have expressed concerns regarding the aesthetic qualities (particularly hardness) of the water in that it is not always pleasant to drink and has effects on physical assets around the home. The hardness levels in the Alexandra public water supply typically range between 120 and 160 g/m^3 (CODC 2014). To address these concerns the CODC have investigated various options for upgrading or replacing the current water supply system. The investigations to date have concluded that there are only two realistic options for public water supply for Alexandra namely:

1) A supply based on Clutha River water in the vicinity of the existing Alexandra water infrastructure, or

2) A lake or groundwater source in the vicinity of the current Clyde supply bore on the shores of Lake Dunstan.

CODC are currently consulting with Alexandra water consumers and the wider community regarding the issues and options for the Alexandra public water supply. As neither the current Alexandra public water supply system nor the development options will affect the water resources of the Manuherikia River Catchment, Alexandra's public water supply will not be discussed further in the MCWSG feasibility assessment.

Omakau and Ophir

The communities of Omakau and Ophir are currently served by a low pressure piped community water supply scheme, which draws water from an infiltration gallery under the river bed of the Manuherikia River. An average flow rate of approximately 11-15 L/s is understood to be taken (MWH 2012) or 130,000 cubic metres per annum (m^3/a) and is used to service a resident population of approximately 400 people (CODC 2014). The water is treated via sand filtration, chlorination and pH correction before being pumped to tanks which provide gravity reticulation to connected properties (CODC 2014). In conjunction with the water system, the CODC operate a reticulated wastewater system for the Omakau - Ophir area which treats wastewater via oxidation ponds.

CODC have investigated various options of upgrading the water supply scheme and have drilled approximately a dozen bores in the Omakau - Ophir area, most of which have provided insufficient yields to be considered viable for public water supply sources. In January 2012, a 150 mm diameter exploration bore was drilled on the road verge of Mawhinney Road approximately 7 km north of Omakau Township. The bore is located approximately 50 m east of the Thompsons Creek Bridge and was drilled to a depth of 12.0 m. The bore was pumped at 9.4 L/s for two hours for a drawdown of 0.94 m (MWH 2012). The yield of the bore is considered promising for potentially supplying the Omakau - Ophir area. Water levels in the bore have been measured on an approximately weekly basis since January 2012 (Figure 6). The data indicate that water levels fluctuate by approximately 0.8 m with water levels influenced by both rainfall and summer irrigation. Flow fluctuations in Thompsons Creek may also exert an influence on observed water level fluctuations.

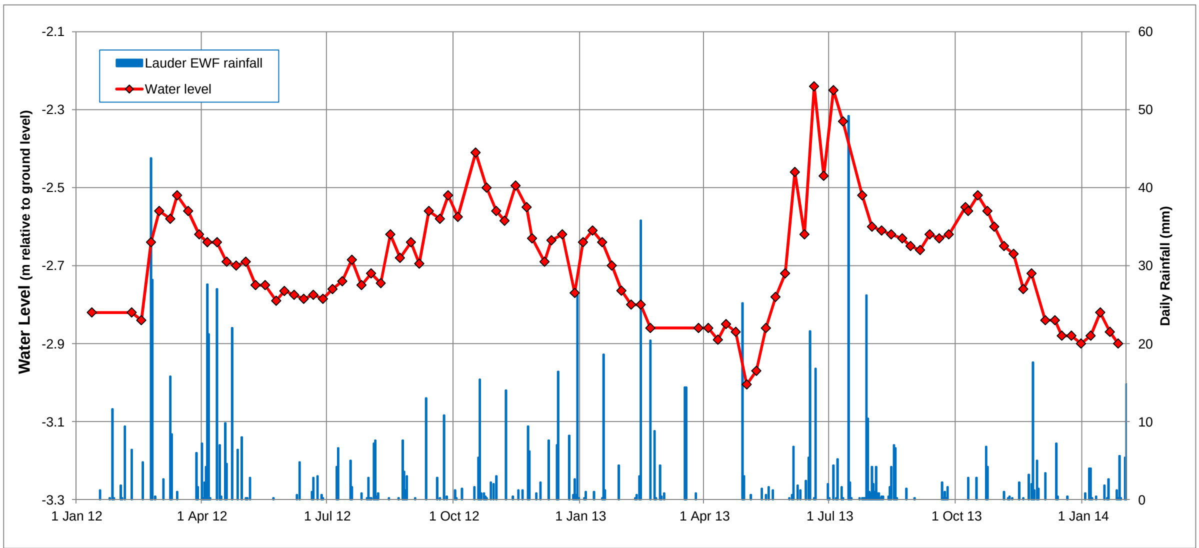

Figure 6: Water levels in Mawhinney Road bore and local rainfall January 2012-January 2014.

The results from testing a water sample taken from the bore in January 2012 (Table 6) indicate that the bore water is relatively soft and has low nitrogen concentrations, but it is corrosive and shows signs of faecal contamination.

Table 6: Mawhinney Road, Omakau groundwater quality results January 2012.

Analyte	Units	Mcwhinney Road 11 January 2012
Total coliform	Colony forming units per 100 mL	54
Faecal coliform	Colony forming units per 100 mL	4
Entercocci	Colony forming units per 100 mL	4
pH		6.35
pH after aeration		7.91
Turbidity	NTU	5.95
Total hardness	g/m^3 as $CaCO_3$	41
Calcium hardness	g/m^3 as $CaCO_3$	30
Magnesium hardness	g/m^3 as $CaCO_3$	11
Iron	g/m^3	0.06
Nitrate nitrogen	gN/m^3	0.82
Ammoniacal nitrogen	gN/m^3	0.02
Chloride	g/m^3	3
Manganese	g/m^3	0.01

The bore is located near one of the case study farms selected for the feasibility study. During the feasibility study, the nitrogen leaching potential of the land surrounding the bore will be assessed using Overseer both for the current land use and potential future land uses under various irrigation development scenarios. The Overseer assessment will assist in identifying the consequences for nitrogen concentrations of the proposed irrigation developments.

Individual Domestic Water Supplies

Only 9 % of the New Zealand population receive water from individual, unregistered water supplies (Ministry of Health 2008b). However, a significantly greater proportion of the population is likely to be supplied in this way for the rural parts of the Manuherikia River Catchment. Bores and wells are among the most common sources of drinking water supply outside of community water supply areas. While individual household water supplies are not generally recorded within agency registers, ORC maintains a register of wells, bores and galleries. There are 201 well records specified for primarily domestic use within the Manuherikia River Catchment, this represents 84 % of all operational water bores / wells recorded within the catchment. As the Manuherikia River Catchment upstream of Ophir Gorge has not been the subject of an ORC groundwater investigation recording existing bore, well and spring locations, the well records held by ORC is likely to under-represent the total number of groundwater extraction systems. Each bore or well would typically supply a single rural household outside of townships and settlements.

Additional individual domestic water supplies would be drawn from roof catchment water stored in tanks and from water races. While irrigation companies remind their customers, and householders through which water races pass, not to use race water for drinking water supply, the practice persists. The main reason for irrigation companies preferring that no drinking water is obtained from their supplies is to avoid entanglement in the drinking water standards (MoH 2008a) and the drinking water supply water quality management guidelines (MoH 2013a). The 2007 amendment to the Health Act may clarify the situation by providing a new definition of Rural Agricultural Drinking Water Supply, which would allow for irrigation water suppliers to allow water to be taken from an irrigation system and used as drinking water provided the water is treated in-house before consumption (MoH 2013b).

CODC has indicated a clear preference for any application for new dwelling building consent outside of a public or communal water supply area to establish an individual supply from groundwater ("bore, spring or well")[5]. Within the building consent process CODC building inspectors require evidence of source protection,

[5] http://www.codc.govt.nz/services/planning/water-supply-for-dwellings/Pages/default.aspx

chemical analysis and treatment system design. Information supplied by CODC building inspectors to potential applicants in the above circumstance indicates that alternative surface water sources (e.g., water races or ponds) will only be approved if the groundwater option can be shown to be unavailable, plus satisfactory access, water treatment and storage of the alternative source water is demonstrated.

Water Quality Requirements for Individual Water Supplies

Individual water supplies have a drinking water and domestic water supply role, so the most appropriate water quality and microbiological security standard is the drinking water standards of New Zealand (MoH 2008a). CODC building inspectors require analyses of the individual water supply's raw, and treated water (if applicable). However, this scrutiny at the time of applying for a new dwelling building consent is one-off and there is no normal requirement for regular monitoring. In addition, individual water supplies need not demonstrate compliance with protozoa criteria, often the most difficult part of the standards for small water supplies to comply with. Accordingly, individual water supplies are not regularly monitored and would not have systematic barriers against the protozoan contamination that surface water is prone to, hence the preference by CODC building inspectors for source water drawn from groundwater.

The principal contaminant of shallow, oxygenated groundwater in rural parts of New Zealand is nitrate nitrogen. The nitrate concentration in such settings fluctuates and may slowly rise in response to increases in the intensity of up-gradient land use. One-off sampling and analysis to check for drinking water contaminants exceeding the drinking water standard would not ensure that the nitrate concentration exceeds the maximum acceptable value (MAV) later in the life of the water supply. Nitrate is also not readily removed by conventional water treatment. This is a justification for the regional authority managing land use to hold the groundwater nitrate nitrogen loading on overlying land to values consistent with maintaining aquifers below the MAV [e.g., ORC Plan Change 6A (Rural Water Quality) that becomes effective on 1 May 2014].

Consented takes for Drinking Water Supplies

The drinking water source takes are generally authorised by surface water take consent. Examples would be the CODC consent to take 400 L/s of water from the six gallery bores adjacent to the Clutha River / Mata Au, and the gallery in the bed of the Manuherikia River at Omakau (ORC consent number 99169). Four small water schemes drawing on groundwater of the MCA, namely McArthur Ridge, Springvale Water Supply, Bruce's Hill Water Scheme and Bain Family Trust, hold consents for their consumption of water under ORC consent numbers 2004.888, 2006.195, 2006.268 and 2006.535, respectively.

In recognition of the essential nature of drinking water for a human population, the Otago Regional Plan: Water ("Water Plan": ORC, 2004) the taking of water for public water supply is a *controlled* activity rather than a *restricted discretionary* or *discretionary* activity for the purpose of administering the water take consent application. Rule 12.1.3 of the Water Plan specifies that in the case of such a controlled activity, consent is required but always granted. Policy 6.4.8 of the Water Plan exempts specified public and community water supplies from the requirement to cease taking during low flows below the river's minimum flow. Schedule 1B of the Water Plan identifies the Manuherikia River Catchment water supplies of Omakau – Ophir (Table 5 code OMA005 and ORC consent number 99169) and St Bathans (VUL001 and 2003.917) as specified water supplies.

Permitted use takes for Drinking Water Supplies

Rules 12.1.2.1 and 12.2.2.1 of the Water Plan authorise the taking and use of surface water and groundwater within the Manuherikia River Catchment for domestic needs or the needs of animals for drinking water as a permitted activity providing:

- The take volume is less than 25,000 litres per day; and
- For surface water takes the rate of take is not greater than 0.5 litres per second, and
- The taking or use does not have an adverse effect on the environment.

There are expected to be a considerable number of properties within the Manuherikia River Catchment which operate under the permitted activity rules, primarily for the purpose of providing domestic and stock water needs.

Summary

The Manuherikia River Catchment has a modest groundwater resource when compared with the rest of the Clutha / Mata Au catchment. Small, scattered and geographically restricted pockets of high yield aquifers may be found, particularly in association with the Manuherikia River flood plain. The groundwater resources generally have good water quality, but show clear indications of being exposed to the residues characteristic of grazing agriculture (i.e., nitrate, phosphorus, potassium and chloride). Outside of the outwash and alluvial materials that form a thin veneer over the valley floors, the Tertiary sediments are not prospective for groundwater, although re-working of the top of the Tertiary and schist has lain down lenses of sand that contain useful but modest yields of groundwater. At the base of all of the geological materials discussed, the basement rock holds minor reserves of groundwater within the rocks' fracture network.

The groundwater resources of the Manuherikia River Catchment are not a large contributor to overall water use in the catchment. However, in certain locations (Dunstan Flats, Lower Manuherikia River alluvial gravels and potentially the Thompsons Creek area and parts of Ida Valley) they will provide a potential water source for small-scale irrigation. Throughout the catchment groundwater is a significant source of drinking water and stockwater.

The groundwater review is prepared in the knowledge that subsequent Overseer modelling of the farms of the Manuherikia River catchment is to be undertaken by AgResearch. The Overseer simulation of Manuherikia River catchment nitrogen loadings and drainage rates will provide tonnages, concentrations and drainage volumes for parts or all of the catchment under modelled current and future land use/water resource options. These parameters will go some way to answering questions around the possible reduction in groundwater recharge under more efficient irrigation or the concentration of soil leachate with respect to nitrate nitrogen under various farm nutrient or irrigation practices.

Drinking water supplies in the Manuherikia River Catchment have been shaped by the pattern of population and land settlement. Public water supplies under council management are restricted to the two main concentrations of population at Alexandra and Omakau – Ophir. Both the Alexandra and Omakau – Ophir water supply sources have significant issues with their water quality and compliance with the MoH drinking water standards. In both instances, replacement water source infrastructure is under investigation by CODC. Private water supplies are found in a dozen, or so, settlements throughout the catchment. Individual household domestic water supplies are also known to be obtained from wells, bores, springs (i.e., groundwater), roof catchments and water races according to the household's water resources and means. Little is known about these individual drinking water supplies and they generally only come to CODC scrutiny when a new dwelling is being consented.

Closing Remarks

We trust this letter summarises the current groundwater resources and drinking water supplies relevant to the Manuherikia Catchment water strategy. Once this letter is finalised its contents will form part of the feasibility report covering groundwater and drinking water. If you wish to discuss the above please contact Ian lloyd (illoyd@golder.co.nz or telephone 03 377 5696).

Yours sincerely

GOLDER ASSOCIATES (NZ) LIMITED

Jens Rekker
Senior Hydrogeologist

Ian Lloyd
Senior Water Resources Engineer

JR/IL/dmj

Attachments: Attachment A: Report Limitations
Attachment B: References
Attachment C: Figures 1 to 5

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Attachment B: References

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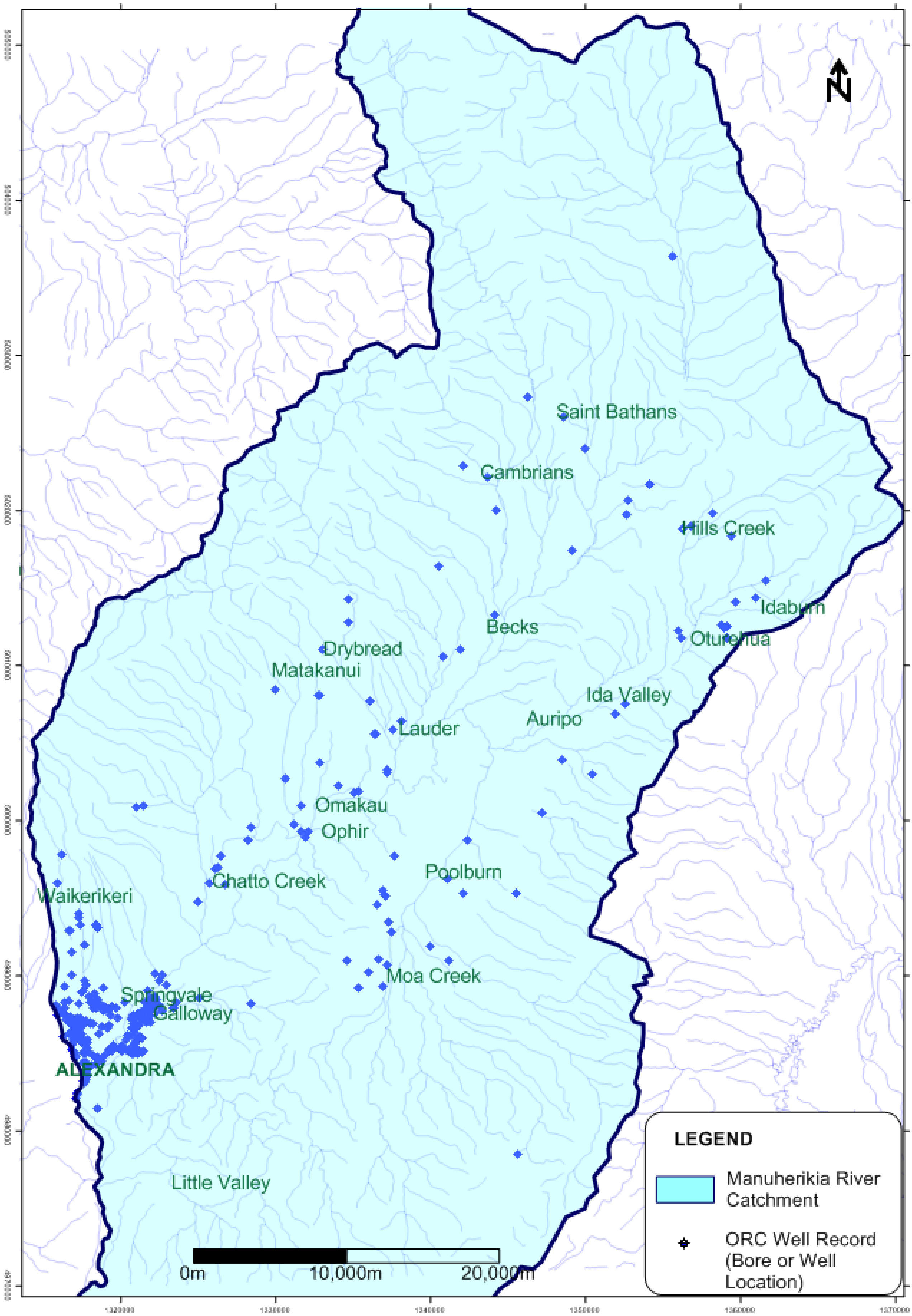
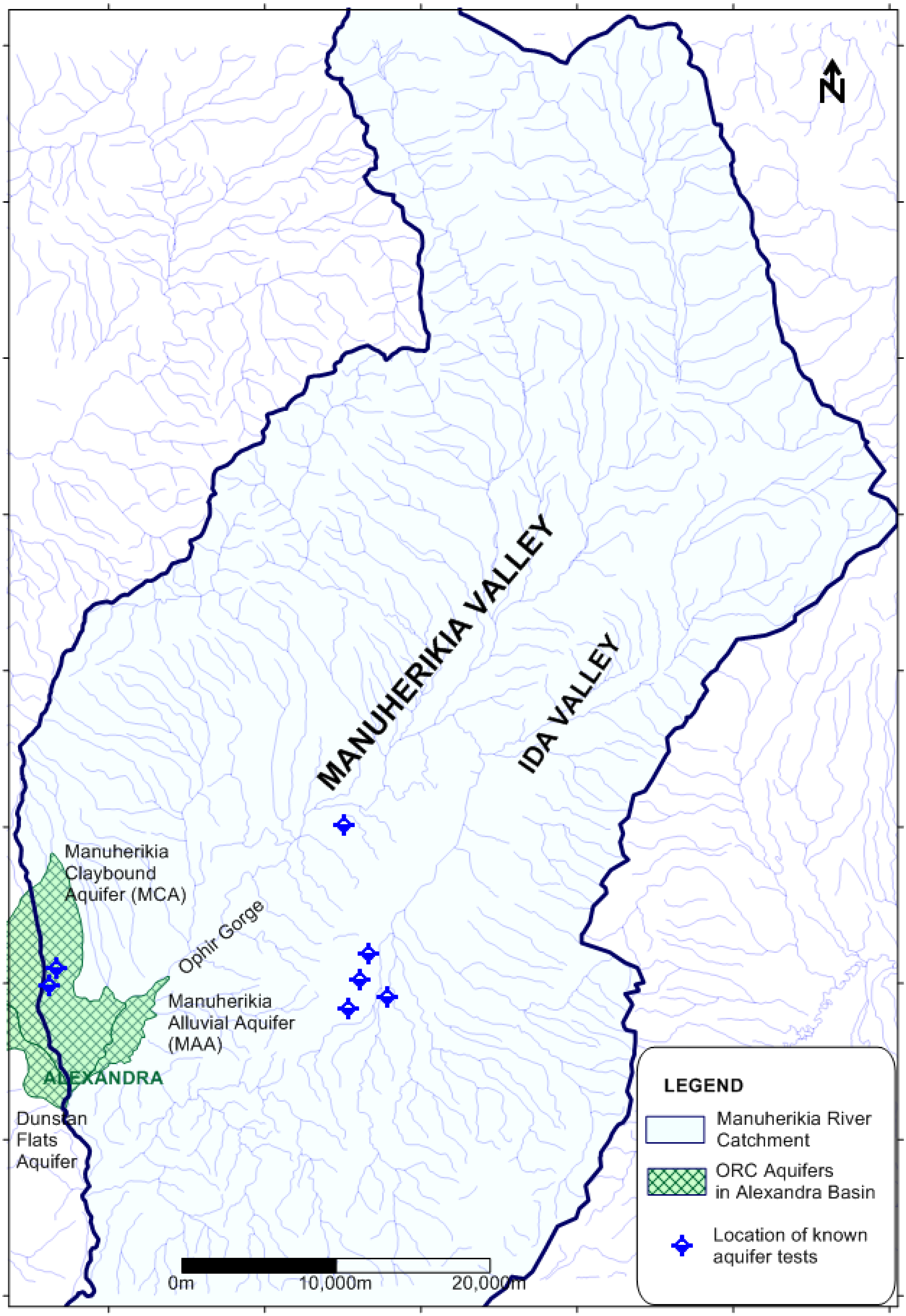
Attachment C: Figures 1 to 5



CLIENT Manuherikia Catchment Water Strategy Group	PROJECT MCWSG FEASIBILITY STUDY Groundwater Review

CONSULTANT			TITLE
Golder Associates	YYYY-MM-DD	2014-03-25	**MANUHERIKIA RIVER CATCHMENT LOCATION OF ORC WELL RECORDS**
	PREPARED	JHR	
	DESIGN	JHR	
	REVIEW		
	APPROVED		

PROJECT No.	PHASE	Rev.	####
1378110-270	2008	01	01



CLIENT
Manuherikia Catchment
Water Strategy Group

PROJECT
MCWSG FEASIBILITY STUDY
Groundwater Review

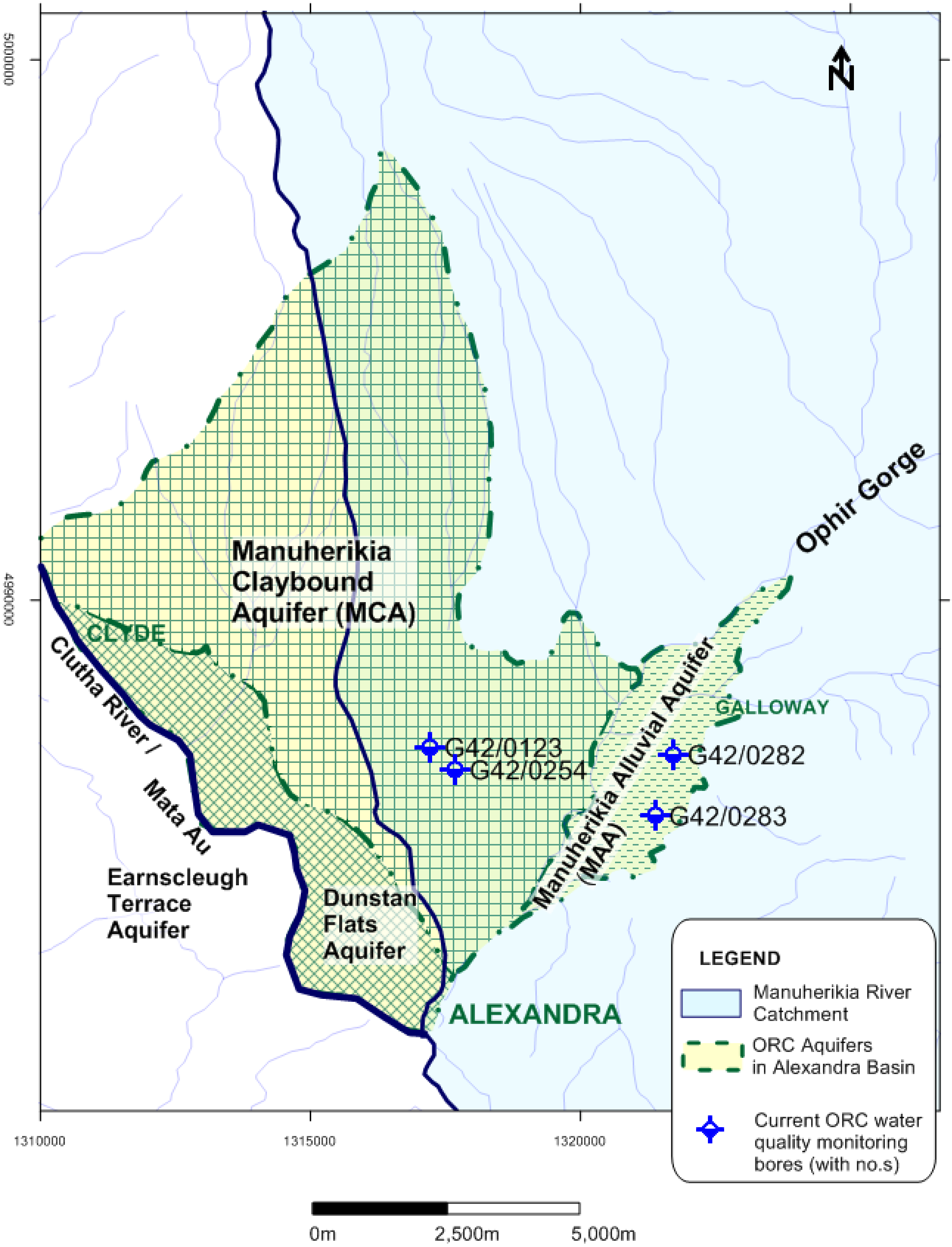
CONSULTANT

Golder Associates

YYYY-MM-DD	2014-03-25
PREPARED	JHR
DESIGN	JHR
REVIEW	
APPROVED	

TITLE
MANUHERIKIA RIVER CATCHMENT
LOCATION OF ORC AQUIFERS AND
KNOWN AQUIFER TESTS

PROJECT No.	PHASE	Rev.	FIGURE
1378110-270	2008	01	02



CLIENT	PROJECT
Manuherikia Catchment Water Strategy Group	MCWSG FEASIBILITY STUDY Groundwater Review

CONSULTANT			TITLE
Golder Associates	YYYY-MM-DD	2014-03-25	**ALEXANDRA BASIN AQUIFERS AND STATE OF ENVIRONMENT MONITORING BORES.**
	PREPARED	JHR	
	DESIGN	JHR	
	REVIEW		
	APPROVED		

PROJECT No.	PHASE	Rev.	FIGURE
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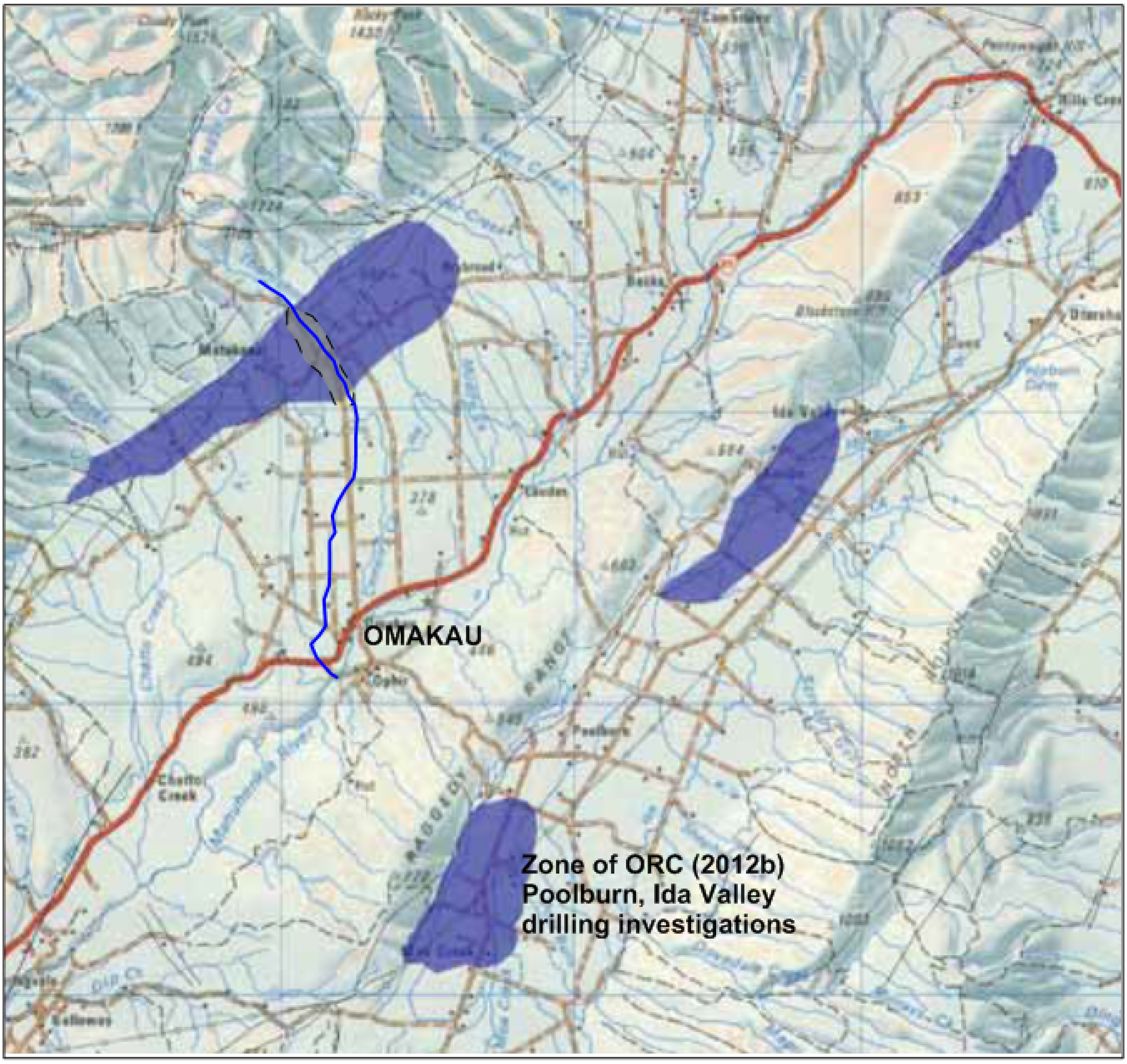


Source of image: ORC (2012b)

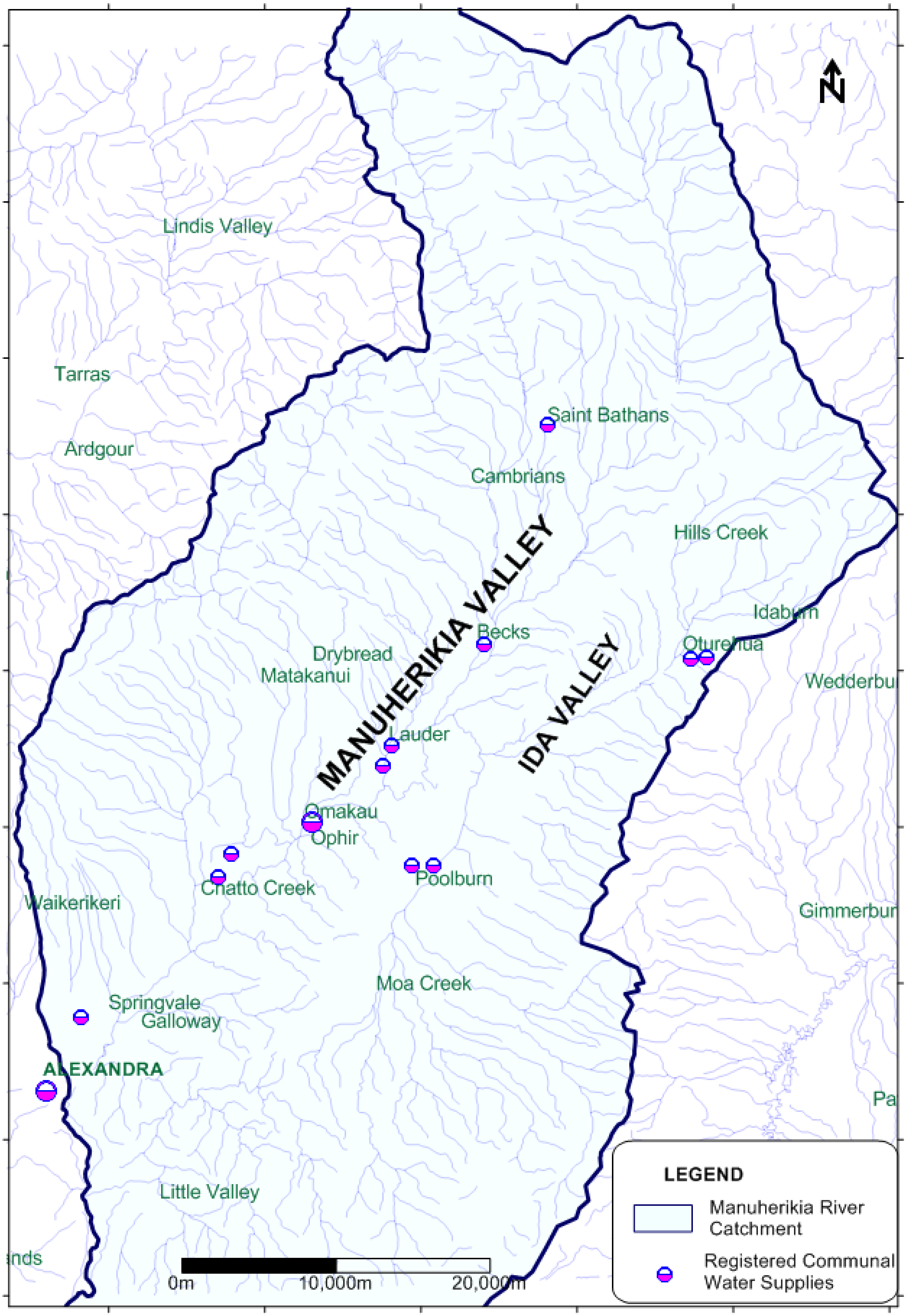
LEGEND

- Inferred Areas of Re-Worked Early Quaternary Sands
- Thompsons Creek
- Potential MAR zone

0m 5,000m 10,000m

CLIENT Manuherikia Catchment Water Strategy Group	PROJECT MCWSG FEASIBILITY STUDY Groundwater Review

CONSULTANT Golder Associates	YYYY-MM-DD	2014-03-25	TITLE **INFERRED LOCATION OF RE-WORKED QUATERNARY SAND AQUIFERS & POTENTIAL THOMPSON CREEK MANAGED AQUIFER RECHARGE ZONE**
	PREPARED	JHR	
	DESIGN	JHR	
	REVIEW		PROJECT No. 1378110-270 · PHASE 2008 · Rev. 01 · #### 04
	APPROVED		



CLIENT
Manuherikia Catchment
Water Strategy Group

PROJECT
MCWSG FEASIBILITY STUDY
Groundwater Review

CONSULTANT

Golder Associates

YYYY-MM-DD	2014-03-25
PREPARED	JHR
DESIGN	JHR
REVIEW	
APPROVED	

TITLE
MANUHERIKIA RIVER CATCHMENT
LOCATION OF REGISTERED
COMMUNAL WATER SUPPLIES

PROJECT No.	PHASE	Rev.	FIGURE
1378110-270	2009	01	05