Groundwater Contamination Risk, Septic Tank Density and Distribution within Otago

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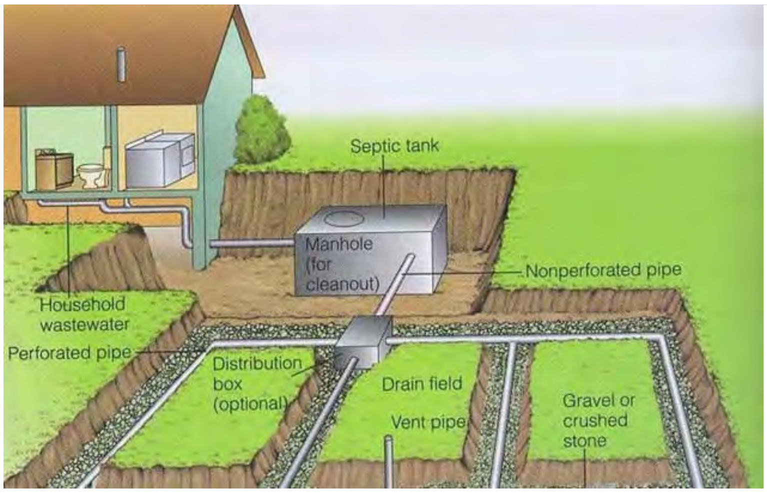

Otago Regional Council

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1. Executive Summary

This report examines some of the problems associated with septic tanks and their management under the current Regional Plan: Water for Otago (RPW) ‘permitted activity’ rules, and suggests some ways in which they might be managed in the future. Modelling of the number of septic tanks and the susceptibility of groundwater to septic tank leachate contamination was undertaken to facilitate ‘permitted activity’ management within the Otago Region.

A risk-based approach was developed, modelling the risk of groundwater contamination by leachates, combined with an attempt to model the density and distribution of septic tanks within the Otago region. This approach required the categorisation of both the septic tank densities and the groundwater contamination risk. The groundwater contamination risk was categorised as Negligible, Low, Medium, High, and Extreme. Based on the findings in ‘Description of the House Block Model within OVERSEER® Nutrient Budgets’ (Wheeler et al., 2010), septic tank densities were categorised according to nitrogen loading limits. These nitrogen loading limits were drawn from Water Plan Change 6A (PC 6A) and established using OVERSEER. It should be noted that the thresholds for nitrogen used in this plan are from the notified version of PC 6A rather than the operative version because those parts of this report were completed before the approval process was complete. Although PC 6A was originally intended to cover diffuse discharges from agricultural sources, Wheeler et al 2010 establishes that the cumulative effects of diffuse discharges from septic tanks in a rural-urban environment can be as damaging as discharges from agricultural activities. This comparison forms the basis of using PC 6A nitrogen thresholds to categorise septic tank densities.

The investigation detailed in this report finds that there may be up to 14,600 septic tanks in the Otago region with an estimated 2200 to 7300 of these in some stage of failure, and 2500 exceeding the threshold for their PC 6A nitrogen protection zone. This investigation also finds that approximately 70% of the aquifers within Otago may be at medium or high risk of contamination from surface sources,

It is proposed that those properties where nitrogen loading is expected to exceed 30 kgN/ha/annum and are in areas of high risk from groundwater contamination should be considered high priority. The risk-based and density-based models presented by this document were found to be the most effective means of prioritisation of septic tank controls.

It should be noted that while some focus has been applied to nitrogen loading in this report, it is not the sole intent of this report to regulate only nitrogen loading. The intent of this report is to explore options for regulating the groundwater contamination risk by regulating septic tank density to protect human health, alongside the chemical, and microbiological quality of groundwater.

2. Introduction

The Otago Regional Council (ORC) manages small-scale discharges from septic tanks and long drops using permitted activity rules 12.6.1.1 to 12.6.1.4 in the RPW. The permitted activity rules allow discharge of effluent, provided certain conditions are met. These conditions vary depending on whether the discharge predates or postdates 28 February 1998.

Historically, the approach used by the ORC to septic tank discharge permitted activity compliance has been a reactive one. This approach has been to investigate individual complaints, taking enforcement action only as necessary. A number of factors, such as the large number and distribution of septic tanks involved, have contributed to make this the only practicable approach, in spite of its shortcomings.

The septic tanks that are most likely to generate a complaint have one or more common features:

- They are in conspicuous locations,
- They discharge onto public land,
- They discharge onto a neighbouring property.

Management of the Permitted Activity rules in response to complaints can, however, only capture a small number of septic tank failures. This tends to be those septic tanks that fail in such a way as to affect public land, or pose an inconvenience to a neighbour. Septic tanks that fail ‘silently’ - for example, if the bottom of the tank is no longer intact, or any discharges are relatively contained - tend to pass un-noticed. These silent failures, however, breach the current permitted activity rules, and are likely to be occurring in significant numbers. As a result they pose a significant risk to the groundwater resources of Otago.

Another shortcoming of this approach is that finding evidence of any discharge or of any offense having occurred becomes a matter of luck and timing, reliant on the compliance officer being in the right place at the right time. This occurs because a septic tank only discharges when it has waste water flowing into it and so identifying the discharge may come down to being there when wastewater is entering the septic tank.

A recent study carried out by the Gold Coast City Council included an inspection of a set of septic tanks that met certain selection criteria. Of the septic tanks selected that were compliant with the outlet standards, one was found to be noncompliant upon inspection. Inspection revealed that the septic tank had almost no free space to provide retention time because the tank contained so much sludge and scum. Further investigation revealed that when the toilet was flushed the black-water was moving through the entire system as a slug in a matter of minutes, and what was being sampled was effectively residual grey-water from normal day to day activities. This suggests that, unless augmented with other techniques, outlet sampling may completely miss noncompliant septic tanks.

The same study found that 70% of the septic tanks were in need of immediate sludge removal. Within New Zealand inspections have revealed failure rates ranging from as low as

3% to as high as 77%, with the MFE stating in their 2008 National Environmental Standard (NES) discussion document that failure rates of on-site systems for different communities are estimated to range from 15 to 50 percent.

It can be inferred from the experiences of the Gold Coast City Council and some regional councils within New Zealand that the current complaints-based approach is missing a number of septic tanks having an actual effect on the environment.

3. Method

3.1. Nitrogen Loading

When determining the best approach to modelling nitrogen, it was found that Wheeler et al. (2010) had already used OVERSEER Nutrient Budgets to model nutrient loading from a generic farm house. Referring back to Wheeler et al. (2010) allowed us to establish a set of generic conditions for septic tank disposal that had already been modelled using OVERSEER.

The Voronoi[1] cells calculated in Section 3.2, of this report in combination with some of the assumptions made in 3.4, in concert with the information from Wheeler et al. (2010) were used to model nitrogen load from septic tanks. The assumptions made were:

An occupancy rate of 2.6 people per household. This number was derived from Statistics New Zealand, which state that the average occupancy of housing in New Zealand is 2.6 people[2].

Each house was occupied 365.25 days per year (365 days + leap years),

A starting point of 4.5 kg N /person/year,

A 30% reduction in N loading to account for loss processes to give a septic tank emission to ground water of 3.15 kg N/person/year.

This gives us an average N loading of 8.19 kg/household/year. It was then assumed that this quantity of nitrogen was being distributed evenly across the entire Voronoi cell associated with each septic tank, and a loading rate in kg/ha/annum was calculated and mapped.

3.2. Septic Tank Density Modelling

The initial obstacle faced by the ORC in approaching the problem of the whereabouts of septic tanks was a lack of information. The ORC holds no information about the location of those septic tanks relying on the permitted activity rules to operate. The Territorial Local Authorities (TLAs) within Otago were contacted but they did not have a comprehensive database of septic tank locations within their individual districts. After discussion of the problem of locating septic tanks with the ORC IT department, it was identified that the TLAs did possess a comprehensive database of which properties had wastewater reticulation. This database was then compared to the ORC's database of properties to identify which properties were not reticulated, on the assumption that those that were not were operating a septic tank under the permitted activity rules.

[1] A Voronoi cell represents the set of points closer to the centre of a particular cell than to the centre of any other cell. In the case of this report they represent the land uniquely available to each septic tank for disposal.

[2] Using Statistics New Zealand was considered, then disregarded, as they lack the spatial resolution required.

Starting with the list of properties in the ORC GIS property database:

- All properties that were known to be reticulated, lacked an address point, and had an area >6.7ha[3] were removed,
- Each property remaining on this list was represented as a point at the centre of that property and a 565m radius buffer with an area 1km^2 was applied to it,
- The centre points that lay within each buffer were counted, and the density value assigned to the centre point of that buffer,
- The buffers were combined into a single shape then divided up into a set of Voronoi cells.

This approach captures currently undeveloped sections that are intended to be developed in the future. A detailed analysis of the distribution of these properties is presented in section 4.2.

3.3. DRASTIC Groundwater Leachate Contamination Risk Modelling

Given the number of septic tanks identified by the method described in 3.2, the need to further prioritise areas for targeted monitoring or control was identified. Given the lack of available effects-based information at the time this project was undertaken, it was decided that septic tanks would need to be prioritised according to their risk of contamination of groundwater. Any prioritisation would need to take into account factors such as soil type, rainfall, and depth to groundwater. The DRASTIC model, developed by the United States Environmental Protection Agency (USEPA), was identified and ultimately used for this role.

DRASTIC modelling was carried out using the methods detailed in “DRASTIC: A Standardized System for Evaluating Ground Water Pollution Using Hydrogeologic Settings” (USEPA 1987). The modelling was carried out using the ORC’s GIS programme (MapInfo). Information for calculating the various scores was derived from Council groundwater reports published by the ORC.

The DRASTIC model takes into account the following variables:

- **D**epth to groundwater
- **R**echarge rate
- **A**quifer type
- **S**oil type
- **T**opography
- **I**mpact of the vadose zone media
- **C**onductivity of the aquifer

[3] This report was intending to look at areas of high density. 6.7 ha is the maximum average size of properties able to reach a density of 15 septic tanks/km^2

DRASTIC assigns each of the variables a weight and a rank. The rank of each of the seven variables is multiplied by its weight and the consequent scores are summed to generate a DRASTIC index. The DRASTIC index is sorted into the following ranges and then mapped:

Table 3.1 DRASTIC Index Categories

<80	**80-100**	**100-120**	**120-140**	**140-160**	**160-180**	**180-200**	**>200**

Higher DRASTIC indices indicate higher levels of risk of groundwater contamination by surface contaminants.

The DRASTIC modelling was carried out using the ORC's GIS tools by combining information from GrowOtago and various ORC reports. DRASTIC mapping has been completed for the majority of the named aquifers within Otago except for the Tokomairiro Aquifer which produced anomalous results.

3.4. Septic Tank Contamination Risk

Analysis of the density data suggested there were areas where the housing density was sufficiently high to indicate that disposal field effluent could become a significant contaminant. A method of quantifying this was sought. It was noted that in these areas discharge from septic tank irrigation fields would likely become a significant contributor to groundwater recharge. In these areas, when the Recharge component of the DRASTIC index was calculated based on rainfall, a contribution from septic tank discharges was calculated. The contribution was then added to the contribution from rainfall following the DRASTIC guidelines for contributions from irrigation. This total value was then reduced to account for surface evapotranspiration.

The septic tank component was calculated using the following assumptions:

- There is an average of 2.6 people occupying each property.
- Peak loading of 180 l per person of effluent through the septic tank per day. This number is derived from the AS/NZS 1547:2000 guidelines.
- The effluent generated on each property is distributed evenly across the entire area of the Voronoi cell associated with that property.
- The house is occupied 365.25 days of the year.

4. Results

4.1. Nitrogen Load Modelling of Septic Tank Discharges

The results of the nitrogen load modelling are presented numerically and graphically below and presented in terms of the nitrogen load limits from PC 6A.

Table 4.1 Septic Tanks by Nitrogen Loading

Nitrogen Load (kg/ha/yr)	< 10	10-20	20-30	>30
Number of properties	11044	783	499	2315
Average Nitrogen Loading (kg/ha/yr)	1.28	14.6	24.6	61.2

Table 4.1 displays the total number of properties and the averge loading of each nitrogen load category. Figure 4.1 shows the results graphically, illustrating the relative proportions of each nitrogen load category. In both cases, the results are framed in terms of the nitrogen loading requirements in PC 6A.

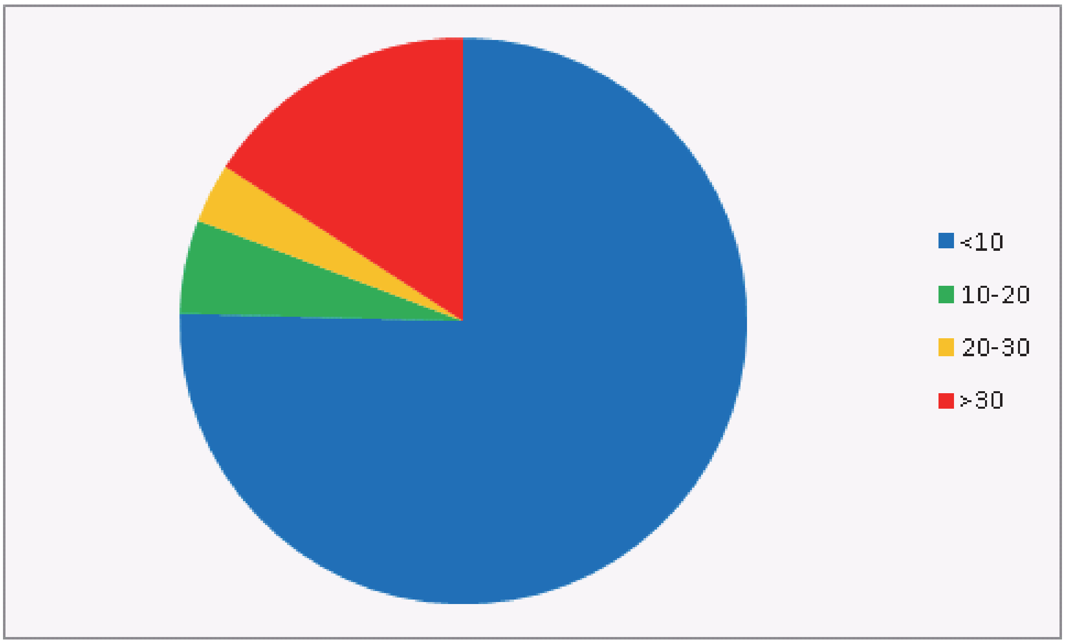

Figure 4.1 Proportion of properties in each PC6A nitrogen loading range

Using this method the following septic tank contamination hotspots were identified:

- Outram
- Clyde – Muttontown
- Allanton
- Glenorchy
- Kingston
- Otago Peninsula

The use of GIS software to perform these calculations allows us to summarise the nitrogen loading in the hotspots listed above and to make some inferences about the nitrogen load and septic tank densities in these area.

Table 4.2 Nitrogen Loading within Otago

	Total number of Septic Tanks	Nitrogen Loading				Number exceeding PC 6A Limits (kg/ha/yr)			
		Minimum	Average	Maximum	Total	<10	10-20	20-30	>30
Outram GPZ A	494	0.1	23	96	4000	282	20	17	175
Clyde GPZ A	139	0.23	14	92	1100	102	9	5	23
Clyde GPZ B	697	0.3	52	116	5700	0	134	22	541
Glenorchy	274	0.1	48	136	2200	40	22	29	183
Kingston Aquifer	270	0.23	59	186	2200	36	16	10	208
Otago Peninsula to Blueskin Bay	1905	0.09	20	180	15,600	1069	185	134	517

Other hotspots include, but are not limited to; Benhar, Pounawea, Waiera South, Waitahuna, Millers Flat, Tokoiti, Taieri Mouth, and Luggate.

4.2. Septic Tank Density and Distribution

When considering these data it should be remembered that the approach taken by this modelling may overestimate the number of septic tanks. Not all properties that have address points necessarily have dwellings on them. They include undeveloped sections and subdivisions, as well as communities like Hawksbury Village where there is some degree of reticulation that is not owned by the Territorial Authority. The information discussed in this section necessarily excludes Waitaki District because the data used to assemble the density model were unavailable in a useable format.

USEPA guidelines divide septic tank densities into three different categories according to the amount of risk posed:

- 'Low-density' is defined as less than 3.8 septic tanks per km^2
- 'Medium-density' is defined as between 3.8 and 15 septic tanks per km^2
- 'High-density' is defined as in excess of 15 septic tanks per km^2

Table 4.3 lists the number of septic tanks in each district within the Otago region. This is important because it illustrates that the territorial distribution of septic tanks is relatively even.

Table 4.3 Distribution of septic tanks within Otago by District

Otago Wide	Dunedin	Central Otago	Clutha	Queenstown - Lakes	Waitaki
14641	5685	3282	3147	2527	NA
99%	39%	22%	21%	17%	NA

Figure 4.2 shows the relative proportions of septic tanks distributed according to district within the Otago region.

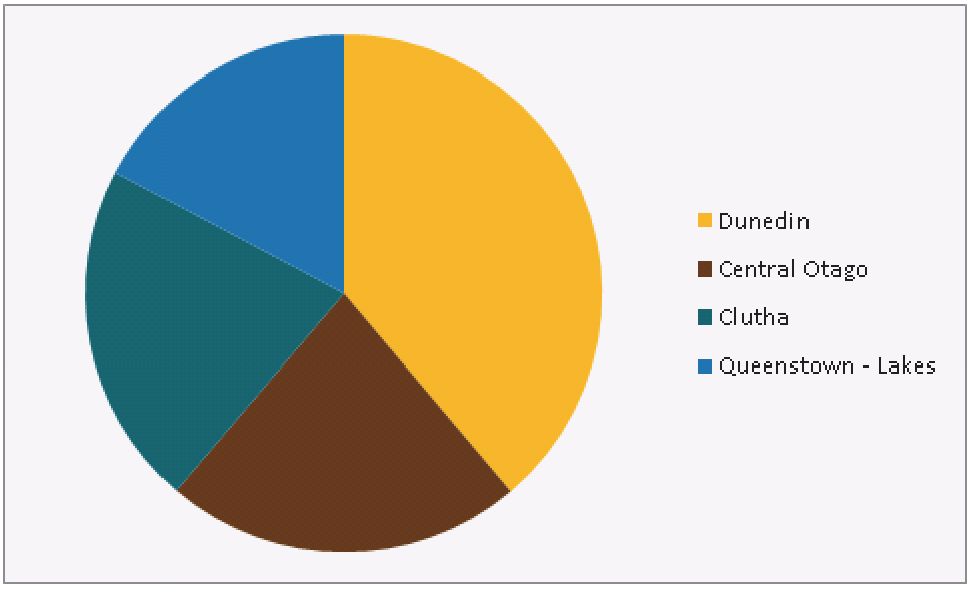

Figure 4.2 Distribution of septic tanks within Otago by district

Figure 4.3 illustrates the relative proportions of all Otago septic tanks within each of the USEPA density categories. The high density category has been further subdivided to illustrate the varying levels of high density found within Otago.

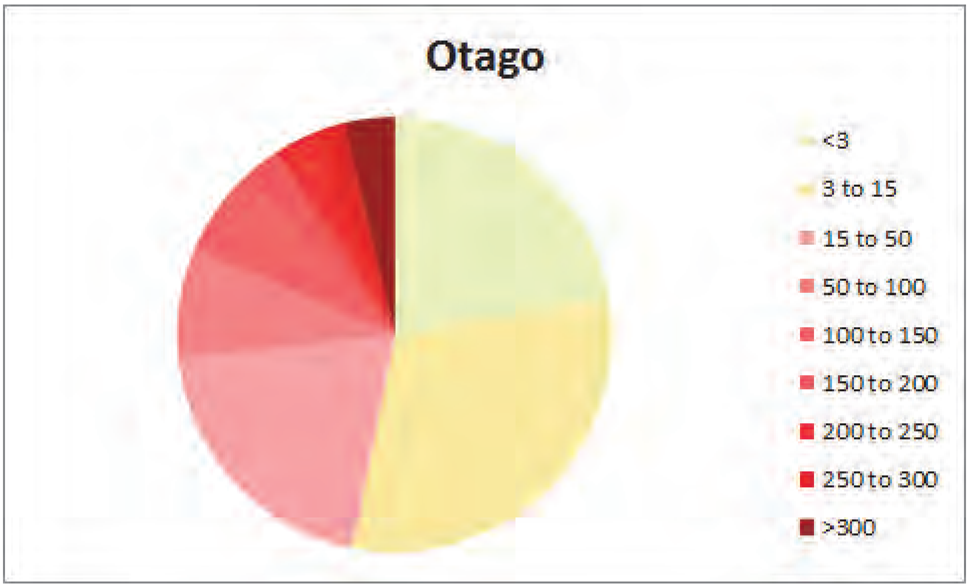

Figure 4.3 **Distribution of septic tanks within Otago by density (septic tanks/km^2)**

Any area where septic tank densities exceed 15 septic tanks/km^2 is considered by the USEPA to be at high risk of some degree of groundwater contamination by septic tank leachate.

Table 4.4 lists the number of septic tanks in each USEPA density category.

Table 4.4 **Distribution of septic tanks within Otago by density (per 1km^2)**

<3	3-15	15-50	50-100	100-150	150-200	200-250	250-300	>300	Total
3265	4519	2934	1199	938	441	445	354	546	14641
22%	31%	20%	8%	6%	3%	3%	2%	4%	99%

On a district-by-district basis, the following septic tank distribution was calculated (Table 4):

Table 4.5 **Distribution of septic tank densities within each district using reduced categories**

Density (/km^2)	Dunedin		Central Otago		Clutha		Queenstown-Lakes	
<3	644	11.33%	742	22.61%	1674	53.19%	205	8.11%
3 to 15	1816	31.94%	1112	33.88%	790	25.10%	801	31.70%
>15	3225	56.73%	1428	43.51%	683	21.70%	1521	60.19%
>100	1202	21.14%	713	21.72%	29	0.92%	780	30.87%
>200	269	4.73%	699	21.30%	0	0.00%	377	14.92%
>300	0	0.00%	546	16.64%	0	0.00%	0	0.00%

Figure 4.4 to Figure 4.7 illustrate the distribution of septic tanks within each district, and show the relative proportions of those septic tanks that fall into each density category.

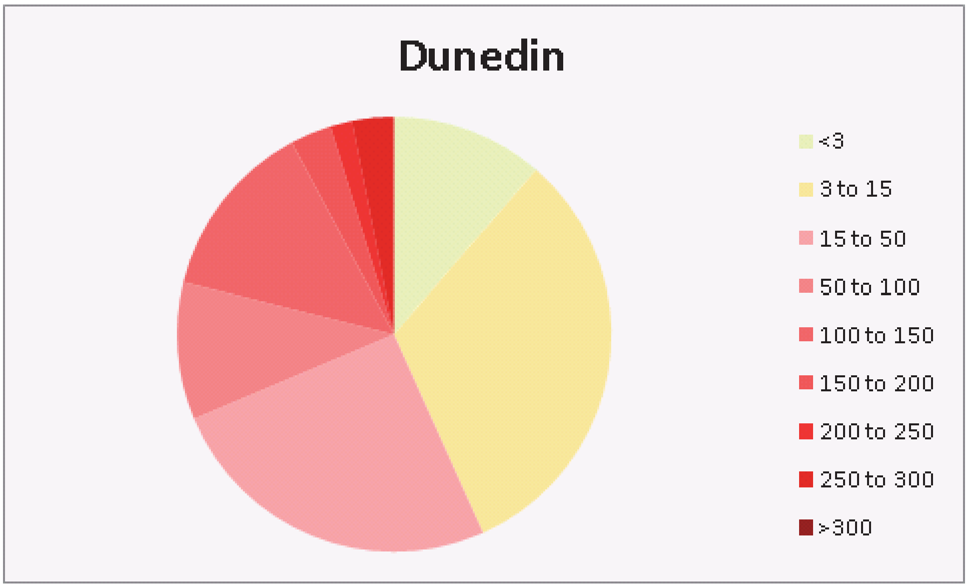

Figure 4.4 Distribution of septic tank densities within Dunedin (septic tanks/km^2)

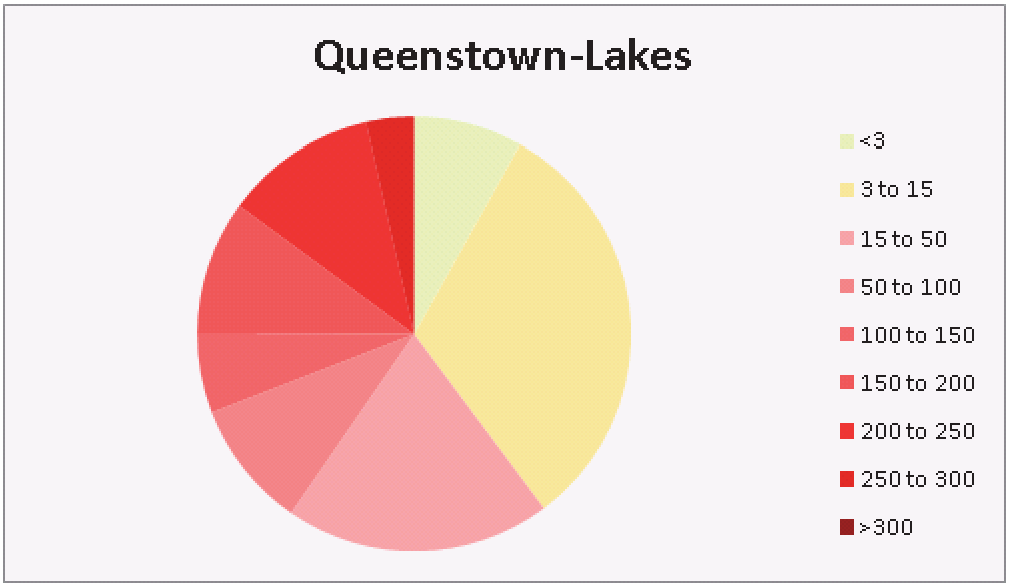

Figure 4.5 Distribution of septic tank densities within Queenstown-Lakes (septic tanks/km^2)

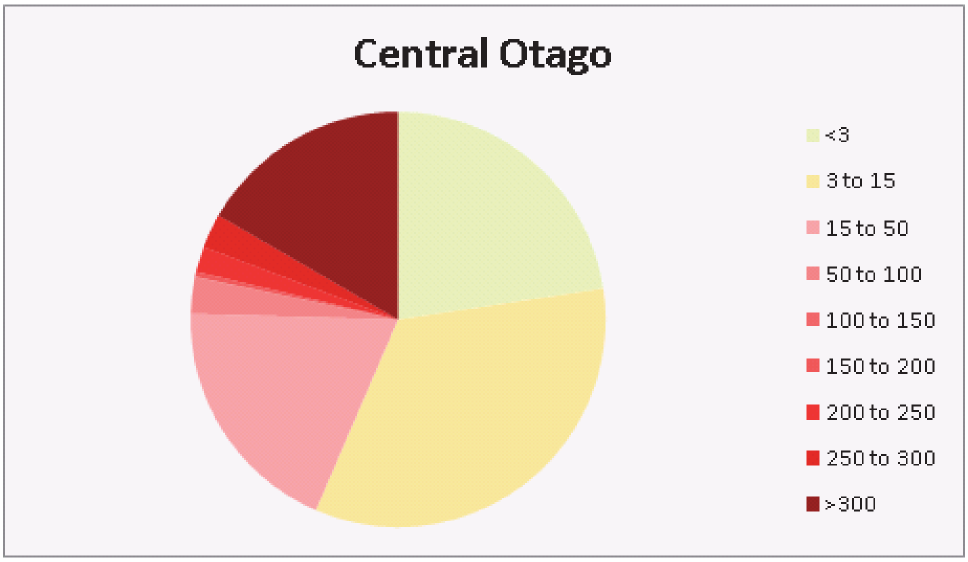

Figure 4.6 **Distribution of septic tank densities within Central Otago (septic tanks/km^2)**

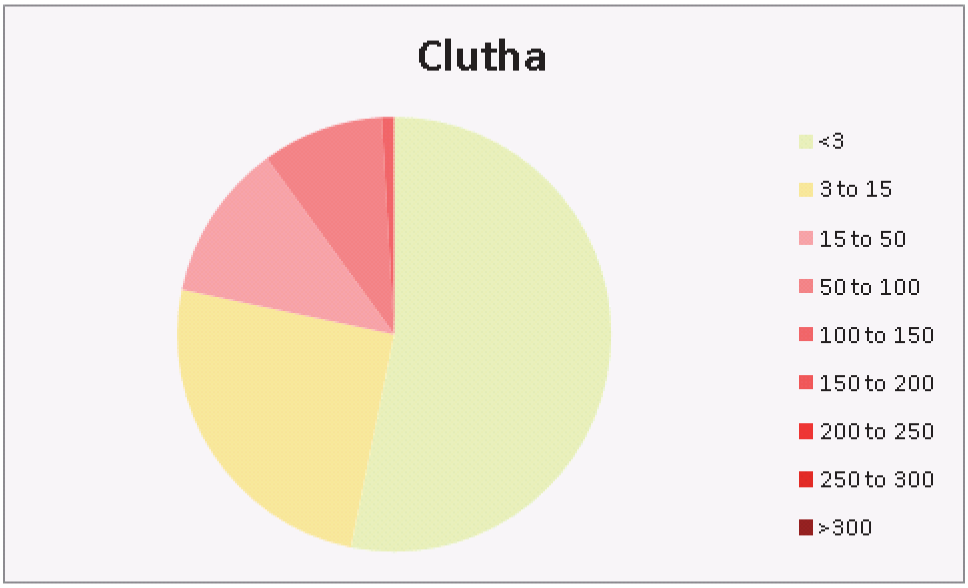

Figure 4.7 **Distribution of septic tank densities within Clutha (septic tanks/km^2)**

In terms of septic tank density, the Central Otago District is the stand-out with 16% of sites in areas with a density greater than 300 per km^2. This is a consequence of the densely populated, un-serviced township of Clyde. Almost a tenth of Otago's septic tanks and a third of Central Otago District's discharges are within the Alexandra Basin. This is similar to the situation on the Taieri Plans with the rural residential halo surrounding Mosgiel. Nearly 30% of septic tanks in Dunedin City, and one tenth of those in Otago, are on the Taieri Plans. However, none of these are in areas with septic tank densities >300 /km^2. The septic tank densities in these areas are consistently high, reflecting the prevailing rural residential halo surrounding major reticulated townships.

Appendix C contains a series of maps showing the locations of clusters of septic tanks.

In Summary:

- Within Dunedin and Queenstown-Lakes, the majority of the septic tanks are in high-density areas.
- Within Central Otago the plurality[4] of septic tanks are in high-density areas. However, Central Otago shows the most even split among high, medium, and low densities.
- Within Clutha, the majority of septic tanks are in low-density areas, with the remainder split almost evenly between medium- and high-density areas.
- Dunedin, Central Otago, and Queenstown-Lakes all show greater than 20% of septic tanks in areas with densities greater than 100 /km^2, however, only Central Otago reaches densities greater than 300 /km^2.

4.3. DRASTIC Modelling of Otago Aquifers

In order to facilitate discussion of DRASTIC indices within the Otago region, the DRASTIC categories specified in Table 3.1 can be reduced to five. Those five index ranges have been represented by risk words. The comparison of the original groupings from Table 3.1 to the revised groupings is shown below.

Table 4.6 Original and Revised DRASTIC categories.

Category	Negligible	Low		Medium		High		Extreme
Index	<80	80-100	100-120	120-140	140-160	160-180	180-200	>200

It was found that when a contribution from septic tanks was included in the recharge score, in most cases the septic tank density made little difference to the risk of groundwater contamination. However, in a few cases it was noted that the contribution increased the DRASTIC index sufficiently to elevate the level of risk. Kingston and Clyde were two examples of the hydraulic loading from the discharge elevating the level of risk, albeit slightly.

DRASTIC modelling for Otago aquifers reveals the following when the results are tabulated in terms of land and are illustrated in Figure 4.8.

Table 4.7 Distribution of land area within Otago by DRASTIC category

Category	Negligible	Low		Medium		High		Extreme
Index	<80	80-100	100-120	120-140	140-160	160-180	180-200	>200
km^2	1	251	879	1291	1430	320	0	0

[4] A majority exists when a single group represents more than 50% of the population. A plurality exists where no single group achieves more than 50% representation, but still manages to achieve more representation than any other group.

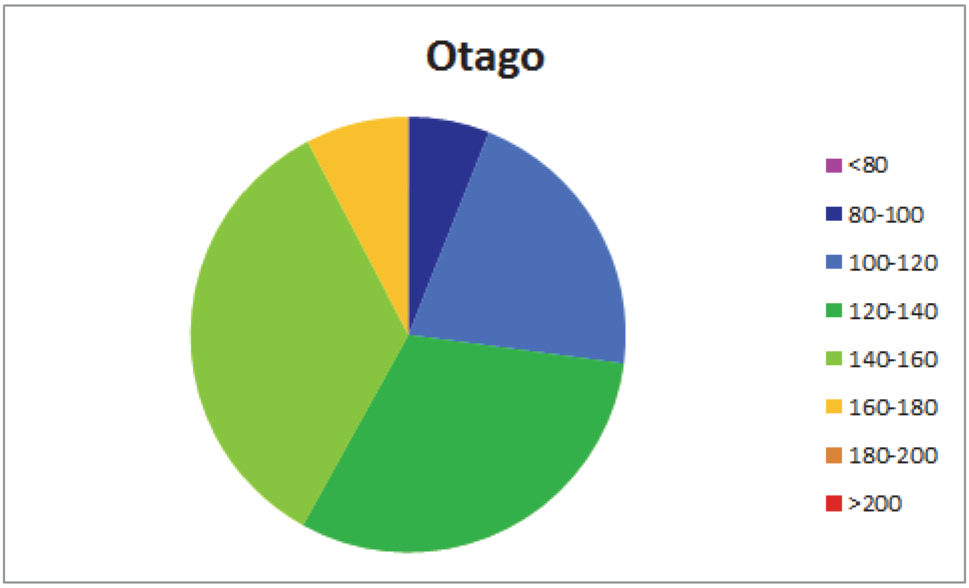

Figure 4.8 Distribution of land within Otago by DRASTIC category

The majority of Otago aquifers are at no more than medium risk of contamination, with only a small portion being at high risk.

The areas that are at a high risk of contamination are parts of the Lower Taieri aquifer; the Pomahaka aquifer; the Wakatipu basin; and those parts of the Wanaka-Cardrona aquifer and of the Hawea Flats aquifer where the groundwater is close to the surface.

Appendix D contains the results of the DRASTIC mapping, as applied to Otago aquifers.

In summary:

- Most aquifers within Otago are at no more than moderate risk of groundwater contamination.
- The factors governing the distribution of risk within each aquifer are unique.
- In Kingston topography governs risk.
- In Wanaka-Cardrona groundwater depth governs risk.
- In the Wakatipu Basin recharge rate governs risk.
- In the Pomahaka Basin soil type governs risk.
- On the Dunstan Flats there is no single factor; rather a combination of factors governs contamination risk.

5. Discussion

5.1. Why use Plan Change 6A Limits?

Effects-based approaches were initially considered, including approaches based on groundwater State of the Environment monitoring and District Health Board (DHB) reported diseases. These approaches were not pursued, however, because the information available was unable to distinguish between septic tank contamination and contamination from other sources. State of the Environment (SoE) monitoring was abandoned because SoE monitoring does not cover the analytes required to differentiate between septic tank leachate contamination and other sources. Using the DHB reported diseases information was abandoned because of the difficulties in collating the required information, and distinguishing between outbreaks caused by septic tanks versus those caused by contact with animals.

The risk of groundwater contamination by septic tanks is directly proportional to the density of the septic tanks. The higher the number of septic tanks in an area, the greater the volume of the discharge to the groundwater and the greater the risk of groundwater contamination. In order to control the risk of groundwater contamination the density of septic tanks must be controlled or the quality of the discharge improved. Three possible approaches were considered for controlling septic tank densities

The first approach that was considered was using the Environmental Science and Research Limited's (ESR) viral transport guidelines[5]. It was possible to map the $\log_{10}$ reduction actually achieved as a percentage of the $\log_{10}$ reduction required to ensure no groundwater contamination by viruses, based on the distance between any centre-point and its nearest neighbour. The results of doing so suggested that the ESR viral transport guidelines may be generally too protective within Otago aquifers. For example, according to these guidelines, the majority of the Lower Taieri Aquifer achieves a reduction of <70% of what is required.

In the second approach USEPA-based guidelines were examined and ultimately the maps contained within Appendix C are framed in terms of those guidelines. The guidance provided by USEPA in this matter is:

- <3.8 septic tanks/km^2 is low density
- 3.8-15 septic tanks/km^2 is medium density
- >15 septic tanks/km^2 is high density

According to these guidelines, anywhere that falls into the high density category is at risk of groundwater contamination. Applying these guidelines to the Otago region, as detailed in Table 2, would require some form of action to be taken on 6,857 septic tanks.

The third approach for categorising septic tank densities was based on a translation of the nitrogen loading limits from PC 6A into septic tank densities using the information provided in

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[5] Guidelines for separation distances based on virus transport between on-site wastewater systems and wells (ESR 2010).

Wheeler et al. (2010). The purpose here is to use nitrogen discharges as a tool to control septic tank densities and prioritise non-reticulated communities, thus controlling the risk of groundwater contamination by septic tanks.

While this reduces the maximum number to 4000 septic tanks requiring some form of action, it does so by trimming out septic tanks in smaller communities where septic tank densities are in the range 15-87 septic tanks/km^2. Taking this approach does not substantially change the hotspots identified for some form of targeted action. Using PC 6A to inform density categories has the added advantage of being able to introduce a unified management strategy for diffuse rural and rural-urban discharges.

5.2. Septic Tank Recharge Contribution

Although a contribution by septic tank discharge was included in the recharge calculations, it is not necessarily true that the presence of septic tanks will be sufficient to elevate the risk of groundwater contamination. The first step of the calculation for recharge score involves binning[6] the amount of annual recharge into one of five ranges:

- <51 mm
- 51 – 102 mm
- 102 – 178 mm
- 178 – 254 mm
- > 254 mm

Examination of the results of the mapping showed that if a septic tank is in an area that receives 50mm of rain per year, and the septic tank contributes an additional 5mm of recharge, that will be sufficient to elevate the risk rating. Alternatively, in the scenario where an area receives 100 mm of recharge due to rainfall, the contribution of 5mm of recharge from septic tanks is not going to be enough to raise the recharge score.

In addition to the binning of the recharge scores, the final DRASTIC ratings themselves are binned according to Table 3.1: DRASTIC Index Categories. Consider the above scenario in an area that has a DRASTIC index of 125. The additional 5 mm of recharge, while increasing the risk, is not sufficient to increase the risk category, and the area will not show up in the mapping. Alternatively, if the DRASTIC index is sitting at or above a value of 132, then the additional 5mm from the septic tank discharge will be sufficient to elevate the risk category and the area will show up in the mapping.

When considering these data, it is important to note that the approach taken will tend to over-estimate the contribution of septic tanks to aquifer recharge rates. This is because not all dwellings are necessarily occupied for the full year. Some dwellings, such as cribs or holiday homes might only be occupied for a few days each year. Additionally, in some areas the method used to determine septic tank density may overestimate the actual number of septic tanks in the ground because it also captures properties that have yet to be developed.

[6] Data binning, (or just “binning”) is the process of sorting a data-set into categories.

Areas where the septic tank density is sufficient to increase the risk of groundwater contamination based on the DRASTIC index alone, compared to the remainder of the aquifer, include Kingston, and Clyde.

5.3. Nitrogen Loading

The calculations outlined in Section 3.1: Nitrogen Loading allows us to model nitrogen loading using the density model as a proxy. Alternatively they allow us to express density constraints in terms of nitrogen-loading constraints and vice versa. Specifically, we can express the USEPA-density guidelines in terms of nitrogen load, and the PC 6A Nitrogen limits in terms of housing density.

These guidelines tell us that, unless an advanced wastewater treatment system is used:

- an individual property of 0.8 ha or less cannot comply with a threshold of 10 kg N/ha, neither can a cluster where the density exceeds 121 houses/km^2,
- an individual property of 0.4 ha or less cannot comply with a threshold of 20 kg N/ha, neither can a cluster where the density exceeds 243 houses/km^2,
- an individual property of 0.3 ha or less cannot comply with a threshold of 30 kg N/ha, neither can a cluster where the density exceeds 370 houses/km^2.

Table 4.2 illustrates one feature of considering septic tank density rather than Nitrogen loading. There are places within Otago where the method outlined in section 3.1 suggests that properties might exceed 30kg N/ha/yr, without exceeding a density of 370 houses/km^2.

5.4. DRASTIC Modelling

Several simplifying assumptions had to be made when calculating the DRASTIC index for aquifers in Otago:

Aquifer Composition

Excluding those aquifers based in bedrock, all aquifers were treated as gravel aquifers with a silt vadose zone. Those aquifers based in bedrock, or volcanic rock, were treated as silt on fractured crystalline rock, or silt on volcanic rock. All aquifers were treated as though they had average hydraulic conductivity for their type.

Depth to Water Table

Depth to groundwater was inferred using the ORC bores database in conjunction with the wells database. This was inferred by dividing each aquifer into a series of Voronoi cells centred on bores for which data was available. The depth to water in each well was taken as the depth to groundwater, and that value assigned to the cell. The drawback to this approach is that if a particular well is tapping a higher water source, e.g. a perched water table, or a shallow, local aquifer, it will overestimate the risk. This, however, is somewhat mitigated by the binning imposed by the DRASTIC model and the subsequent smoothing that doing so causes.

5.5. High Priority Areas

Overlaying DRASTIC data with the projected density was used to indicate potential hotspots where there is a risk of contamination of groundwater by disposal field leachate. In taking this approach, the number of DRASTIC categories and the number of septic tank densities were condensed, and then mapped on top of each other. DRASTIC categories were reduced to the risk categories used in Section 4.3. Septic tank densities were reduced based on nitrogen loading.

The nitrogen-loading rates, calculated as detailed in Section 3.1 were assigned to the Voronoi cells directly, as this gave the most reliable results. These results were mapped and used in the combined mapping presented in Appendix E, showing combined septic tank density and DRASTIC assessment.

The mapping in Appendix E uses a reduced number of housing density categories:

- < 15 septic tanks/km^2
- 15 – 121 septic tanks/km^2
- 121 – 243 septic tanks/km^2
- 243 – 370 septic tanks/km^2
- >370 septic tanks/km^2

Combined with reduced DRASTIC index ranges from Table 4.6:

- < 80
- 80 – 120
- 120 – 160
- 160 – 200
- >200

The combined mapping consists of the DRASTIC data overlain by the density data. The combination of these two datasets can then be used to prioritise locations for inspections according to risk.

A combined approach based on DRASTIC and septic tank densities is advantageous because any alternative approach is necessarily going to involve consideration of some or all of the same factors as the DRASTIC model and septic tank densities.

Although all septic tank densities in excess of 15 septic tanks /km^2 should be classed as high, for the purposes of discussion in this section septic tank densities have been categorised in the following manner:

Table 5.1 Septic Tank Density Risk Categories

Septic Tanks /km²	<15	15-121	121-243	243-370	>370
Category	Low	Moderately High	High	Very High	Extreme

The management strategies outlined previously suggest that the following locations should be prioritised for targeted permitted activity compliance monitoring.

Pomahaka Basin

The Pomahaka Basin is dominated by the high risk category, and appears to have a substantial proportion of properties in the low category. These properties are distributed fairly evenly throughout the basin, with a cluster of properties in the moderate category near Tapanui. The risk of groundwater contamination in the Pomahaka Basin is primarily dominated by the soil type, however, in some parts topography becomes more important.

The majority of the Pomahaka basin has septic tank densities of <3 /km^2 with some areas having densities in the 3-15 /km^2 range. Covering these areas of increased density is important because they lie in areas where DRASTIC modelling suggests a high risk of contamination.

Covering Tapanui, including Glenkenich, Pomahaka, and Crookston (including the intersection of Black Gully Road and Raes Junction Highway), would deal with the majority of properties in the low density range.

Wakatipu Basin

The Wakatipu Basin is fairly evenly split between the medium and high risk categories, with soil type generally dominating the variation. Most of the properties within the basin fall in areas of densities in the low range, with clusters in the moderately low range centred in the following areas:

- Spruce Grove/Mill Farm area
- vicinity of the intersection of Hunter Road and Mooney Road
- cluster of properties either side of Mountain View Road, extending to the intersection of Dalefield Road and Malaghans and between Mountain View Road and Littles Road
- triangle formed by Speargrass Flat Road, Lower Shotover Road and Domain Road
- vicinity of Arrow Junction

Covering those properties in the Mill Farm/Spruce Grove area is the minimum recommended in the Wakatipu Basin, as this area has a high risk of contamination of groundwater by septic tank leachate combined with a moderate septic tank density.

Kingston

Groundwater contamination risk in Kingston is generally dominated by topography. Some properties within Kingston are in areas of sufficiently high-density that the implied contribution to the recharge rates by the septic tanks elevates the risk of groundwater contamination from medium to high.

All septic tanks in Kingston should be included, as they are in the high or moderately high density categories.

Hawea Basin

The risk of groundwater contamination in the Hawea Basin falls largely into the medium category with a couple of areas of high risk. As with Wanaka–Cardrona, the degree of risk is dependent primarily upon the depth to groundwater. Within the Hawea Basin, any place where the groundwater is within 4.5m of the surface should be considered at high risk.

The notable exception to this is Windmill Corner, where, although it is not visible on the combined mapping, the DRASTIC mapping reveals the discharge from septic tanks may be sufficient to elevate the risk of contamination.

Most of the housing in the Hawea Basin area falls into the low category, suggesting low or no impact on the groundwater quality; however, there is a cluster of housing centred around Windmill Corner that falls into the Moderately High range, with a similar density found around Gladstone. These areas may be at elevated risk should further development occur. It should be noted that there is evidence indicating a nitrate plume in the groundwater in this area, but it is not conclusive as to whether this is related to the housing cluster or historic land use. The area, around Windmill Corner should be considered for targeted monitoring.

Lower Taieri

The Lower Taieri basin is of medium to high risk of groundwater contamination. Primarily the areas at high risk of contamination are those above the line connecting Berwick and Henley, and confined to the periphery of the basin, with the core of the basin being of medium risk.

Most of the basin falls into low category.

Outram lies in an area of medium risk of groundwater contamination, and has a core of septic tank density in the very high range surrounded by an area of high density and a relatively extended halo of moderately high densities.

Allanton lies in an area of medium risk of groundwater contamination, and has a core septic tank density in the high range. This is surrounded by an area in the moderately high range.

Outram and Allanton represent the two areas that pose the greatest risk of groundwater contamination in this basin, and would need to be given a high priority. Any action taken in and around Allanton should be weighed against the DCC's plans to reticulate wastewater in Allanton.

Other pockets of moderately high density housing include:

- Owhiro
- Momona
- From the intersection of Bush Road and Riccarton Road, along Riccarton Road through Wyllies crossing to Tirohanga Road and in the area bounded by Tirohanga Road, Mosgiel Road, School Road and Gordon Road
- Several pockets of moderately high density exist in the vicinity of the Taieri Aerodrome and around the outskirts of Mosgiel

Appendix E contains the results of the combined mapping of reduced septic tank categories and reduced DRASTIC risk index categories used to identify these areas.

5.6. Management Strategies

5.6.1. Time frame

Most guidelines suggest that septic tanks should be de-sludged on average every six to eight years. It would then seem to be a reasonable assumption that home owners will have to get their septic tanks de-sludged by 2020 regardless of any actions taken by the council. Should the council decide to go down the path of targeted inspections and/or monitoring, 2020 would seem to be a natural guideline.

5.6.2. Inspections

5.6.2.1. Introduction

This section examines the minimum requirements of a program of targeted inspections, should such a program be adopted. It is not however, the ultimate recommendation of this paper that such a program should be adopted.

5.6.2.2. Criteria

Septic tanks would need to be inspected when they are de-sludged to ensure that they meet certain minimum criteria. For example, each septic tank should have:

- four walls, a floor, and a roof – all of which are free of cracks or fractures
- an outlet filter
- a minimum operational volume of 2000 litres
- no flow from the discharge pipe back into the septic tank.
- a disposal field that distributes effluent evenly over or in an area of land

Meeting these criteria should be sufficient to ensure compliance with the existing permitted activity rule. Failure to meet these criteria could result in flooding around the septic tank or of the disposal field, producing discharge to a water body, drain, water race, the coastal marine area, or runoff to another person's property.

The presence of four walls, a roof and a floor will ensure effective isolation of the contents from groundwater resources. The absence of a floor or walls will allow direct discharge from the bottom of the septic tank to ground water. A missing cracked or ineffective wall or roof may permit the infiltration of groundwater into the septic tank, reducing its retention time. The presence of cracks in the walls and floors may additionally facilitate the exfiltration[7] of the contents of the septic tank. Outlet filters reduce the amount of sediment reaching the disposal field, thus reducing the likelihood of problems arising due to its blocking.

A disposal field provides for die-off of bacteria and viruses in the soil column, and some uptake of nutrients by plants and soil bacteria, and evapotranspiration of water before the effluent reaches groundwater.

Any targeted inspections that are to be carried out should examine the following as a minimum:

An inspection of gulley traps: Under ideal conditions, this should be sealed, and free of evidence of any overflows. Evidence of overflows indicates that the septic tank may be performing poorly, and may be in need of maintenance. If it is not sealed, then the possibility exists that stormwater may be entering it, which would result in an inadequate retention time. Evidence of discharge is most likely to be found at the lowest gulley trap, or the gulley trap closest to the septic tank.

An inspection of the septic tank: While an inspection of the septic tank itself, although ideal, is impractical at this stage, the ground in the vicinity of the vent pipe should be inspected. The ground should be free of evidence of discharges from the vent pipe. Likewise, the vent pipe should be free of odour, or if any odour is present, it should rate low on the FIDOL scale. Evidence of a discharge or a strong odour may be indicative of inadequate maintenance and possible groundwater contamination.

An inspection of the disposal field: An inspection of the disposal field should show the ground to be unsaturated, free of vehicle access, free of odour, and free of evidence of surface discharge. The presence of any of these could signal damage to the distribution piping or poor septic tank maintenance, which could be indicative of possible groundwater contamination.

Outlet sampling: Sampling the outlet should indicate the health and performance of the septic tank. Parameters to test for, at a minimum, should include ammoniacal nitrogen, nitrate/nitrite nitrogen, E. coli, BOD_5, and dissolved reactive phosphorus. This combination of parameters should provide a good cross-section of the performance of the septic tank. Although this approach may miss some failing tanks, it should be expected to capture the majority of them. Offensiveness

If a septic tank meets the minimum criteria, then it can be considered compliant with the existing permitted activity rules. Areas identified in Section 5.5 as high priority, using combined mapping, should be targeted for inspections.

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[7] Exfiltration is a gradual escape or a leak.

An example inspection sheet has been attached as Appendix F.

5.6.2.3. Why is regular desludging so important?

The basic operation of a septic tank relies on its ability to retain wastewater for a sufficient amount of time to enable solids, fats, and oils to settle. Other processes occur within a septic tank, allowing some degree of treatment. Nitrogen is released as ammonia gas, phosphorous is precipitated and settles with the sludge. Fine particles settle forming the sludge and reducing the five-day biological oxygen demand. This is further reduced by anaerobic processes that evolve methane. In a healthy septic tank a microbiological ecosystem is established that includes predatory flora, acting to reduce the bacterial loading of the wastewater.

A reproduction of the on-site portion of Table 10.2 from "Sustainable Wastewater Management: A handbook for smaller communities" by the Ministry for the Environment is provided to give an overview of the relative performance of septic tanks.

Table 10.2 Performance of different treatment technologies

	Raw domestic wastewater	**Septic tank**		**AWTS**[8]	**Sand filter**
BOD_5 (g/m^3)	**200-300**	**120-150**	**25-60%**	**3-9**	**5-15**
Suspended solids (g/m^3)	**260-400**	**40-120**	**54-90%**	**20-60**	**5-20**
Total nitrogen (g/m^3)	**30-80**	**40-60**	**0-50%**	**25-50**	
Total Kjeldahl Nitrogen (TKN) (g/m^3)	**30-80**	**40-60**	**0-50%**	**25-50**	**30-50**
Total phosphorus (g/m^3)	**10-20**	**10-15**	**0-50%**	**7-12**	**5-10**
Faecal coliform (cfu/100ml)	**10^6-10^8**	**10^3-10^5**		**10-10^3**	**10-10^3**

The hydraulic retention time (HRT) of a septic tank is governed by the equation $\text{HRT} = \frac{\text{Tank Volume}}{\text{Influent Flowrate}}$. The portion of the septic tank that is occupied by the layer of sludge and the layer of foam is unavailable for treatment, with the portion between them being free to provide treatment. Because some flow directly from the influent pipe to the effluent pipe (called short-circuiting) is inevitable, an average retention time is established within a septic tank. The average retention time is dependent upon a number of factors, including the septic tank's hydraulic retention time.

Anything that changes the free volume of a septic tank will change the average retention time of that tank. The normal operation of a septic tank causes the sludge to build up in the bottom portion, reducing the volume available for treatment. As the free volume of the septic tank decreases, the average retention time decreases and the quality of the effluent discharged to the disposal field degrades.

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[8] Advanced Wastewater Treatment System

The amount of sludge in a septic tank is important because a septic tank's ability to provide any treatment is dependent on how long the wastewater stays in the tank and, therefore, its volume. As was noted by the Gold Coast City Council, it is possible for sufficient sludge and scum to build up within the septic tank causing it to act as a straight pipe discharge of human effluent to groundwater. The direct discharge of human effluent from a septic tank to groundwater is a prohibited activity under the current RPW rules.

5.6.3. State of the Environment Monitoring

5.6.3.1. Introduction

The purpose of the current State of the Environment (SoE) monitoring network is not to identify specific problems but to give a baseline description of water quality in Otago various water bodies, including aquifers. SoE monitoring can potentially highlight areas where septic tank discharges are having actual detrimental effects. There are, however, several hurdles that would first need to be overcome for the full potential to occur. These hurdles will be discussed below.

5.6.3.2. Locations

Any attempt to monitor groundwater for septic tank contamination necessarily demands the use of bores. It is likely that this would require the construction of bores specifically for sampling as bores for drawing water are unlikely to be appropriately located. The density mapping provided within this report should help to determine whether or not existing bores are suitably located relative to the density distribution of septic tanks.

Septic tank density, however, is only one consideration in regards to location. Aquifer structure must also be taken into account. Many of the aquifers within Otago exhibit anisotropic flow, meaning that they find it easier to flow in some directions than others. This flow can happen because of the shape of the individual rock clasts, for example schist-derived clasts tend to be strongly flattened in one direction. This flattened shape means the water has wide paths to follow between schist clasts in one direction, and narrow paths in the other. The combined result of the different path widths is to encourage horizontal flow and restrict vertical mixing. Another example of anisotropic flow occurs in alluvial ribbon aquifers where preferential flow paths can be created by old river beds, silt horizons, and gravel lenses.

The presence of anisotropic flow in Otago aquifers means that it is possible to put a bore in the right place according to density mapping and miss plumes of pollutants completely. The plumes can potentially be missed because either the flow is directed around, beneath, or in some cases, over the bore or its slots. Alternatively the plume might be missed because the bore happens to tap a lens of uncontaminated water that sits within, but is isolated from, the plume.

Once the area of interest has been defined, factors taken into account include not only the monitoring bore's location, but also its depth. These factors mean that trying to investigate septic tank contamination using SoE monitoring has a 'hit and miss' character.

5.6.3.3. Analytes

There are a number of components of wastewater discharges that are unique to human effluent. Testing for these components, however, is often costly as it requires a high degree of specialization, often associated with an increased cost. This is further complicated because many of the analytes unique to human wastewater are present in concentrations of the order of parts per billion at the point of discharge and are likely to be further diluted by the aquifer itself.

The analytes examined here are:

- Nitrates
- Sulfamethoxazole
- Carbamazepine
- Dehydronifedipine
- Caffeine
- Paraxanthine

5.6.3.4. Tracers indicative of septic contamination

Nitrates by themselves are not a reliable indicator of contamination of groundwater by human wastewater discharges. Studies done overseas, for example Persky (1986), have found strong correlations between septic tank densities and nitrate concentrations in groundwater. If septic tanks in a particular area are proving detrimental to groundwater values, then nitrate is likely to be present, but there are other sources of potential nitrate contamination, such as agricultural activities.

Sulfamethoxazole and carbamazepine were the only two analytes detectable in all seven septic treatment systems tested by Heufelder (2010). Most significantly, they represent some of the few analytes that were detected in the “Massachusetts Title 5” Septic System, which consisted of a single chamber septic tank discharging through a soil absorption system. The samples themselves were taken after the discharge had passed through an additional 1.5m (5 feet) of sand.

Sulfamethoxazole is an antibiotic and carbamazepine an anticonvulsant that is also used as a mood stabilizer. Although these were detected in the effluent from all systems tested, they are prescription drugs, meaning they will not be present in all systems. Although not ubiquitous, it is likely that in any given population, a group will be taking one or other of them.

Caffeine and its metabolite paraxanthine were detected in six of the seven systems tested. They have the advantage of being potentially more ubiquitous than prescription drugs, giving them an increased likelihood of being detected. They have the potential disadvantage, however, that they were not detected in the Massachusetts Title 5 system, which suggests they may not make it through the soil column to groundwater.

Dehydronifedipine is the major metabolite of nifedipine. Nifedipine is a prescription drug covered by Pharmac, and used for the management of angina and hypertension in certain groups of patients. Dehydronifedipine was found in five of the seven systems tested, including the Massachusetts Title 5. Being a prescription drug, however, it suffers from the same potential drawbacks as sulfamethoxazole and carbamazepine.

5.6.3.5. Monitoring

If an approach using SoE monitoring is to be adopted then the following approach seems to suggest itself.

Identify and prioritise areas for monitoring.

This step has largely been done in this report, using the approach of combining predicted septic tank densities with DRASTIC leachate contamination risk categories. This will identify those areas most at risk of septic tank contamination by identifying where areas of high risk and high density overlap. These areas are where cumulative septic tank operation is most likely to be having demonstrable detrimental effects on groundwater quality.

Identify suitable boreholes for monitoring

Not all boreholes in an aquifer are necessarily going to be suitably located for detecting whether or not septic tank operation is having a detrimental effect on groundwater quality. Modelling should be done to identify the likely location of any plume. Ideally at least two bores should be used, one within the plume and one up-gradient from the plume to provide a control. If suitable existing bores cannot be found, installing bores for monitoring groundwater quality may have to be considered.

Monitoring

Once suitable bores have been identified or created, it will then be necessary to establish a monitoring regime. The most cost-effective approach at this stage would appear to be monthly sampling and testing for the presence of nitrate/nitrite nitrogen. While nitrate/nitrite nitrogen is not unique to septic tank contamination, septic tank contamination is not likely to occur without its presence. If nitrate is detected above some threshold value, then that should act as a trigger to test for some or all of the analytes outlined in section 5.6.3.3 and to consider whether or not more frequent testing is required.

The threshold value should be decided on an aquifer-by-aquifer basis and should take into account the aquifer water chemistry. This can be done by considering the level of nitrogen found in the control bore and any relevant nearby bores.

5.6.4. Plan Change

The permitted activity rules, as they stand, mean that those septic tanks that are most likely to fail are ‘permitted’, and those that have been upgraded are more likely to be consented, either ‘restricted discretionary’ or ‘discretionary’ activity status.

A plan change addressing the septic tank permitted activity rule, utilising a nitrogen-loading approach, should be considered by the ORC. The framework for doing so is already laid out in PC 6A and simply requires the application of the nitrogen-loading limits in the context of septic tanks.

In line with this it might be useful to consider property size and density when considering permitted activity status.

Unless an advanced wastewater treatment system is used:

- A section with a size of 0.8 ha or less cannot comply with a limit of 10 kgN/ha, and neither can an area where the density exceeds 121 septic tanks/km^2
- A section with a size of 0.4 ha or less cannot comply with a limit of 20 kgN/ha, and neither can an area where the density exceeds 243 septic tanks/km^2
- A section with a size of 0.3 ha or less cannot comply with a limit of 30 kgN/ha, and neither can an area where the density exceeds 370 septic tanks/km^2.

The density mapping presented within this document, combined with the schedules laid out in PC 6A, could be used to inform groundwater zones within Otago with the aim of protecting groundwater quality from further damage or reducing existing damage. There should be a focus on single chamber septic tanks versus advanced wastewater treatment systems, which are capable of a generally better quality of effluent. There should also be some focus on servicing clusters of housing versus single dwellings, and whether it may simply be more appropriate to encourage TLA's to reticulate certain communities. Consideration should also be given to habitation patterns, for example, a community that has a significant seasonal component to its population is going to have different needs and different risks to one that does not.

Given the mobility of nitrates in the soil column and in groundwater, protecting against nitrates should provide adequate protection against viral loads. It should be noted that the ESR viral separation guidelines were examined for their applicability within Otago. They appeared, in places at least, to be over-protective.

6. Conclusions

The conclusions of this paper are that:

- There are an estimated 14,600 properties (38,000 people, approximately 20%) likely to be serviced by septic tanks in the Otago Region.
- A large number of septic tanks are in dense clusters with 2,700 properties (7,000 people, 3.5%) in areas where there are more than 100 septic tanks per km^2.
- The greatest number of septic tanks is in Dunedin district, while the highest concentration of septic tanks is in Central Otago District.
- The majority of aquifers within Otago are likely to be at moderate risk of contamination by septic tank leachate.
- Septic tanks that fail are likely to breach existing permitted activity rules; the problem lies in identifying failing septic tanks.
- The status quo management, an approach based on the receipt of complaints, can only be expected to capture a minority of failing septic tanks.
- Because of the potentially high number of septic tank failures expected within Otago, monitoring and enforcing the permitted activity rules may not be practical.
- Instigating a regime of permitted activity inspections that are informed by density criteria is likely to carry a workload comparable to dairy farm inspections.
- Instigating a plan change informed by the density modelling in this report, in conjunction with PC 6A, is likely to require some homeowners to upgrade or be reticulated.
- Although OVERSEER modelling suggests applying the same N-loading limits as PC 6A, some parts of Otago, notably in un-reticulated rural townships, would be unable to comply with these limits at this time.
- According to the nitrogen loading modelling 2500 properties may not be able to comply with the limits set in the nitrogen protection zones under PC 6A.

Appendix A – Glossary

Anisotropic: Exhibiting properties with different values when measured in different directions.

Bedrock: The solid unweathered rock that lies beneath the loose surface deposits of soil, sand, clay, etc.

Binning: Data binning, (or just "binning") is the process of sorting a data-set into categories. These categories can be described with a word or a range. An example of data binning is the grouping of heights into the categories of 'Tall', 'Average', and 'Short'. DRASTIC sorts most of its factors into categories based on range, and scores each range. For example, Recharge is sorted into the categories 0-2", 2-4", 4-7", 7-10", and >10".

Clast: A fragment of rock resulting from the breakdown of larger rocks.

Crystalline Rock: Rock made up of minerals in a clearly crystalline state for example, Igneous and metamorphic rock, as opposed to sedimentary rock.

FIDOL: A score-based method for determining the nuisance value of an odour. FIDOL is an acronym of Frequency, Intensity, Duration, Offensiveness, and Length of time, which describe the factors considered.

Hydraulic Conductivity: A measure of the aquifer's ability to transmit water when submitted to a hydraulic gradient.

Recharge Rate: The rate at which water is transmitted from the surface to the underlying aquifer. This is calculated by multiplying the amount of rainfall by a percentage factor that accounts for soil properties and climatic conditions.

Retention Time: The time during which raw sewage is retained in the septic tank, before being discharged to the disposal field as treated effluent. It is during this period of time that treatment of the household sewerage occurs.

Straight Pipe Discharge: a discharge of raw or partially settled sewage directly to a lake or stream, to a drainage system, or onto the ground.

Vadose Zone: The region of unsaturated soil or bedrock above the water table. That portion of the soil or bedrock where pores or fractures contain both air and water.

Voronoi Cell: The set of all points closer to the origin than to any other point. In this report, it represents the land closer to the centre of each property than to the centre of any other property. It could in this way be considered to represent the land area uniquely available to each property for the discharge of septic tank effluent.

Appendix B - References

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Appendix C – Septic Tank Density Mapping within Otago

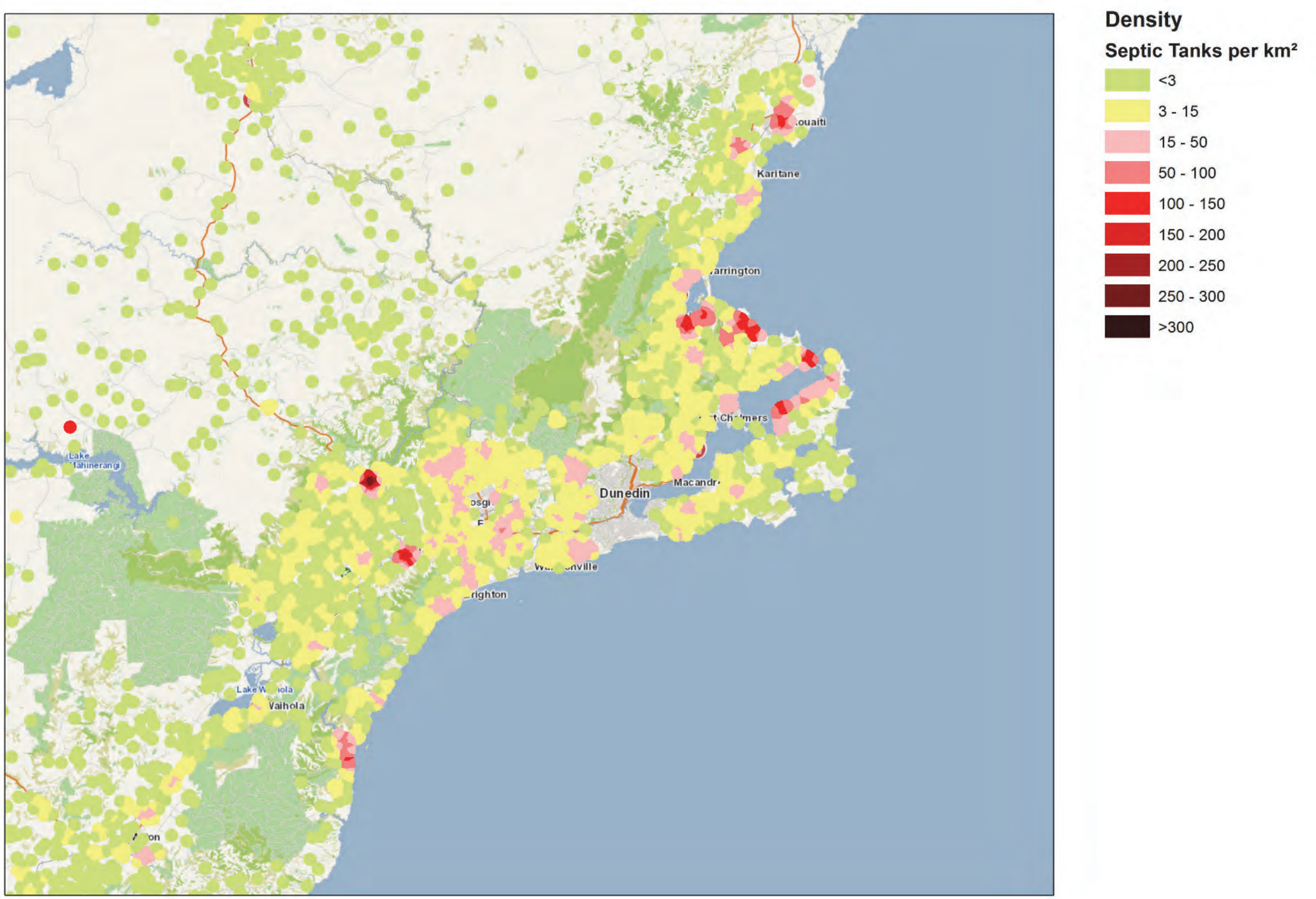

Figure C. 1 **Density Mapping Dunedin City and Surrounds**

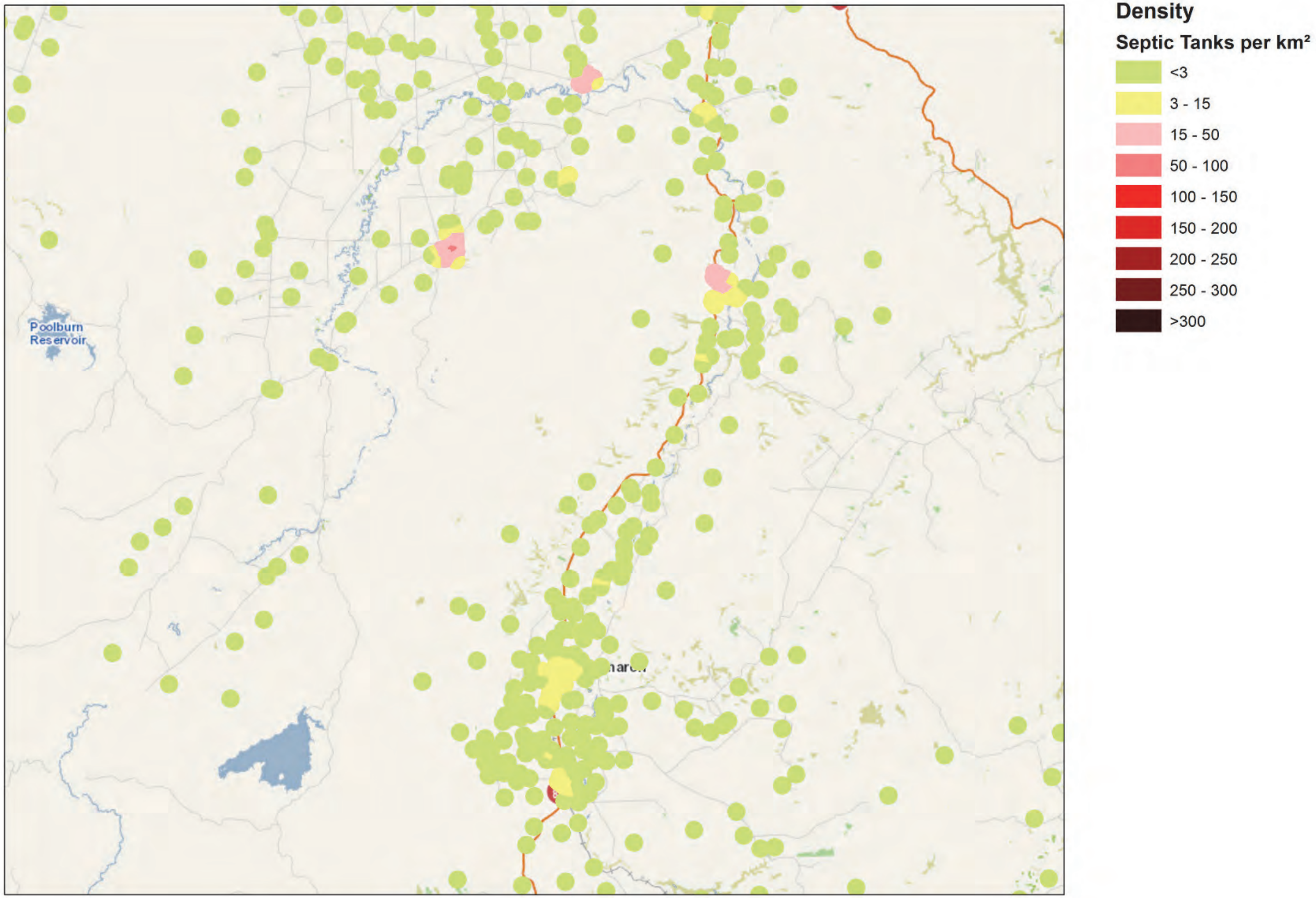

Figure C. 2 **Density Mapping Hyde - Middlemarch**

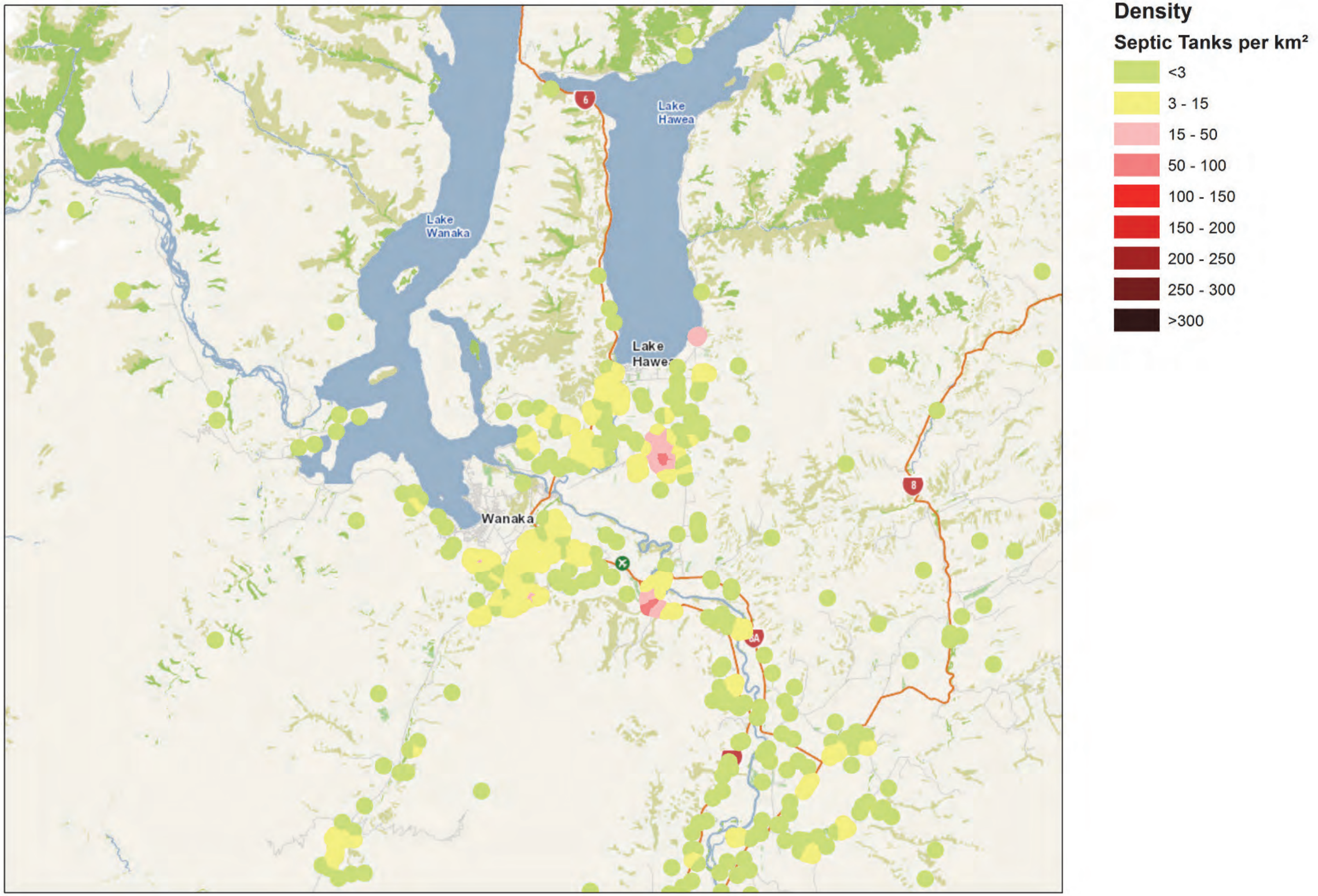

Figure C. 3 Density Mapping Hawea - Wanaka

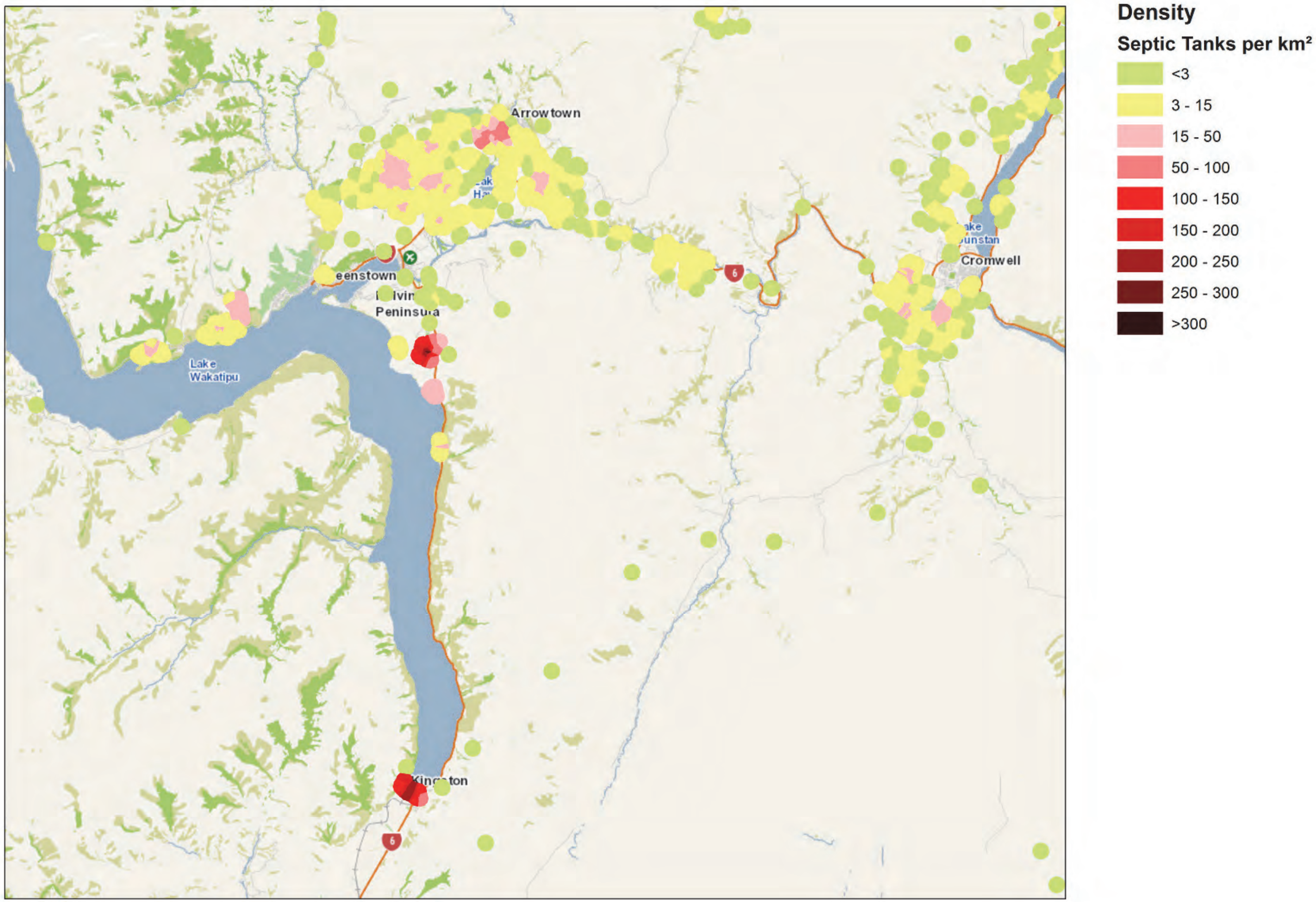

Figure C. 4 Density Mapping Kingston – Arrowtown - Cromwell

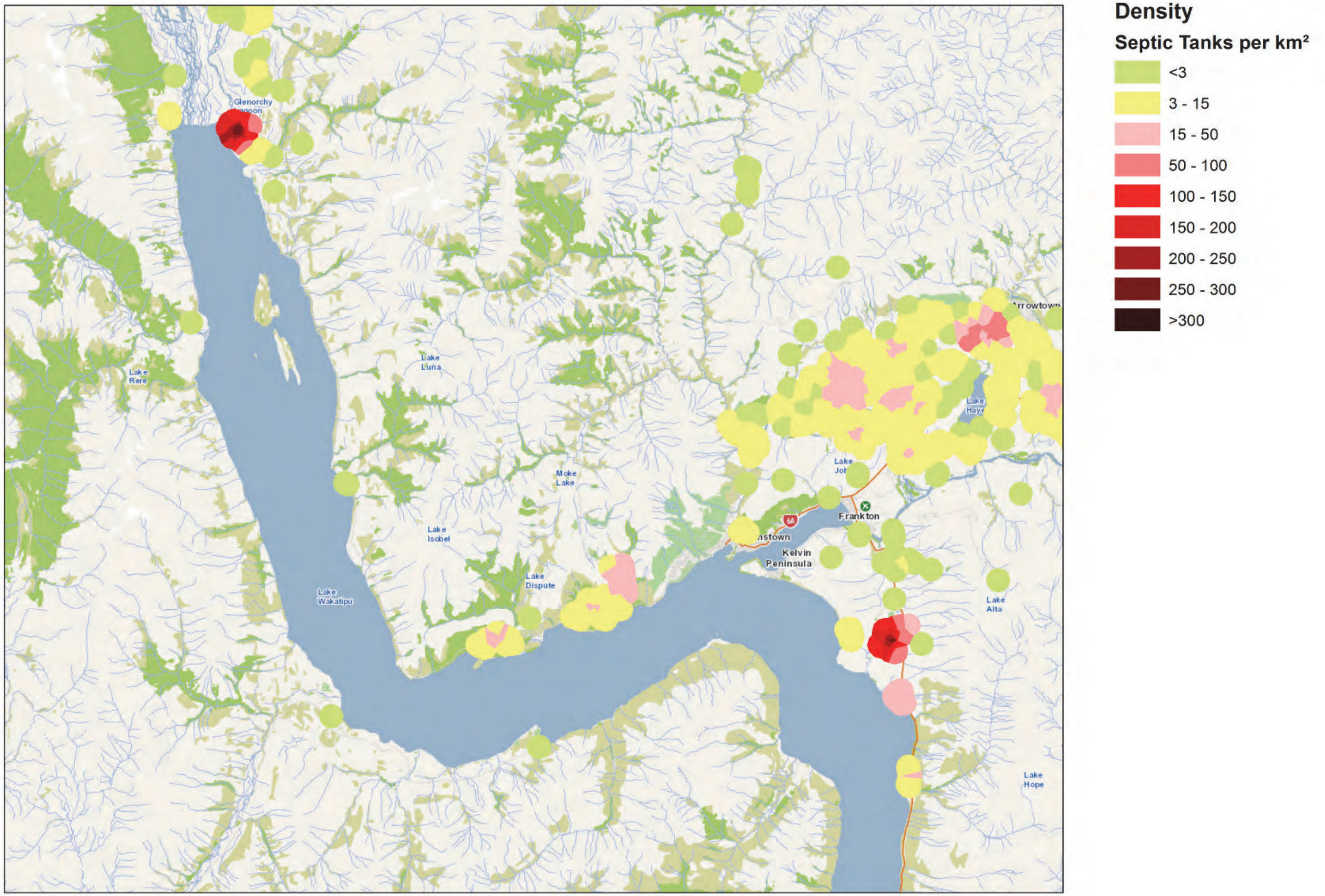

Figure C. 5 **Density Mapping Queenstown - Glenorchy**

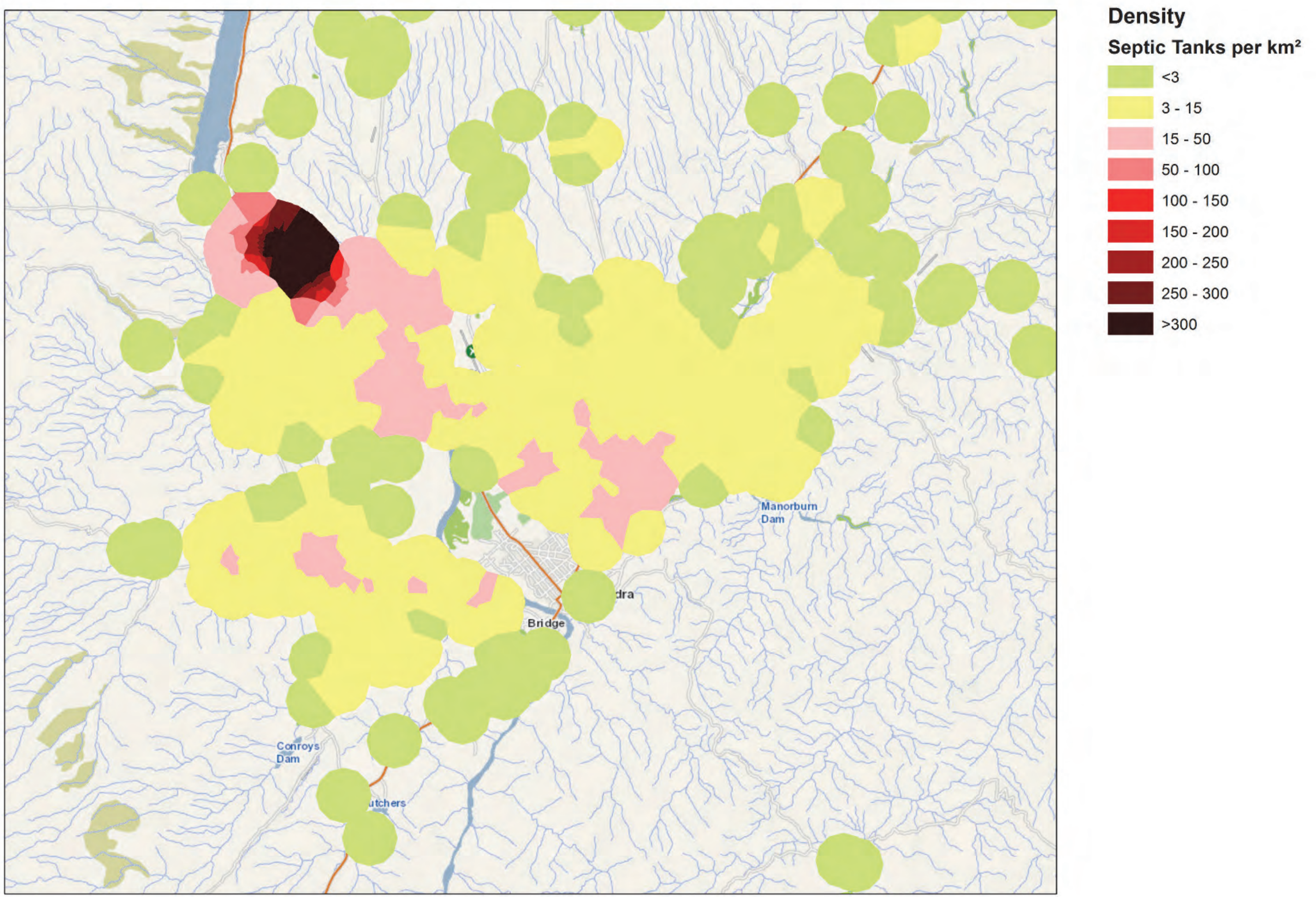

Figure C. 6 **Density Mapping Alexandra Basin**

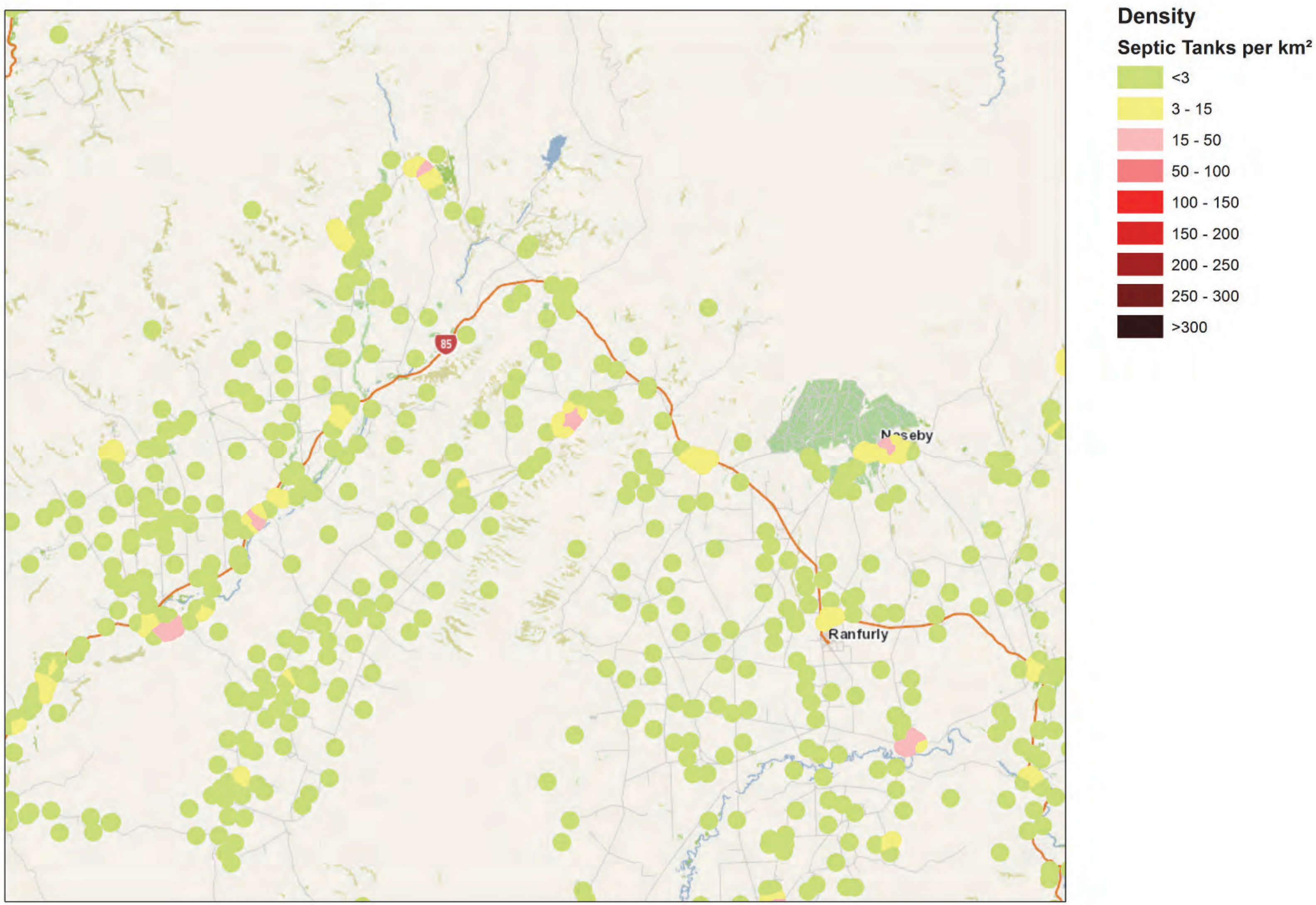

Figure C. 7 **Density Mapping Manuherikia Valley – Ida Valley – Maniototo**

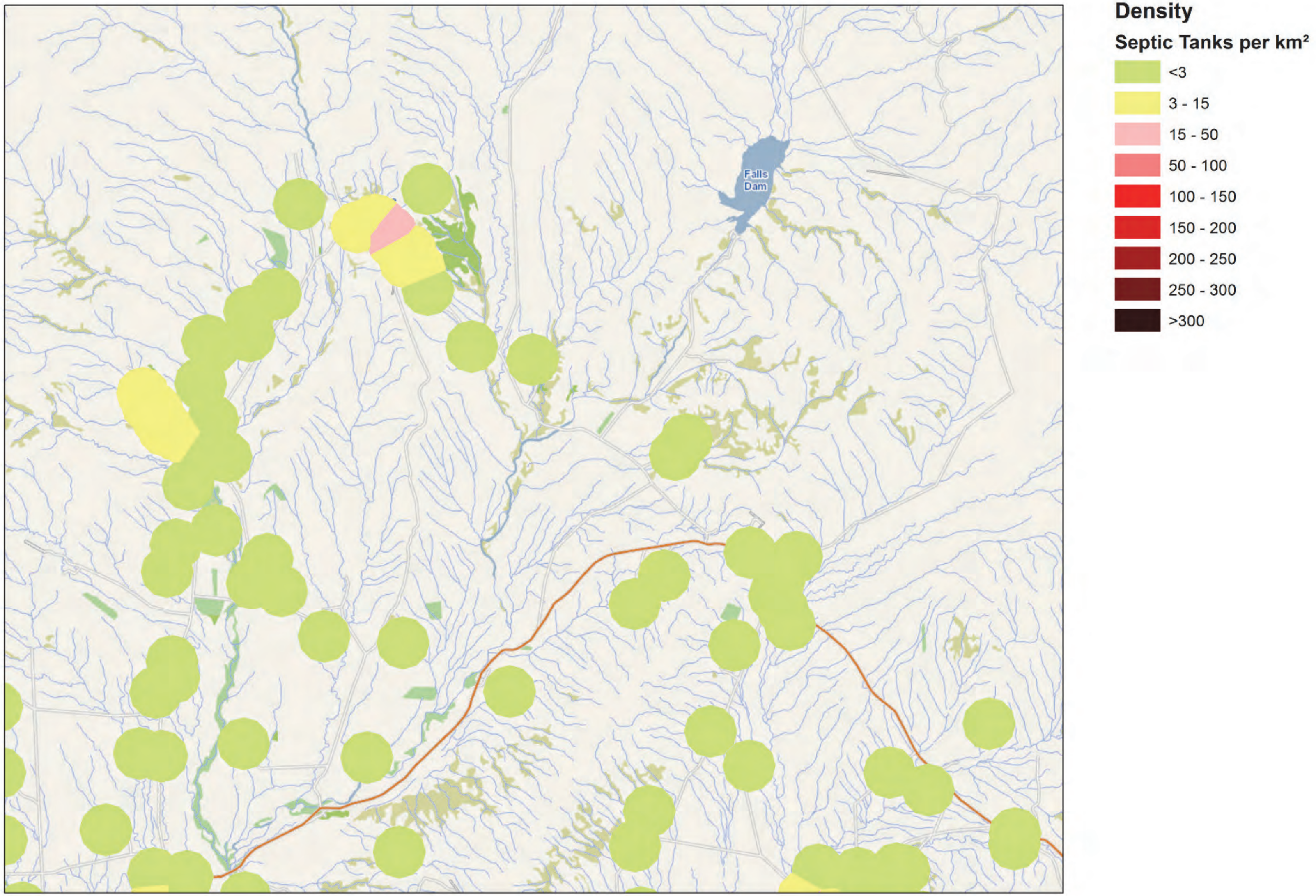

Figure C. 8 **Density Mapping St Bathans**

Figure C. 9 **Density Mapping Makarora**

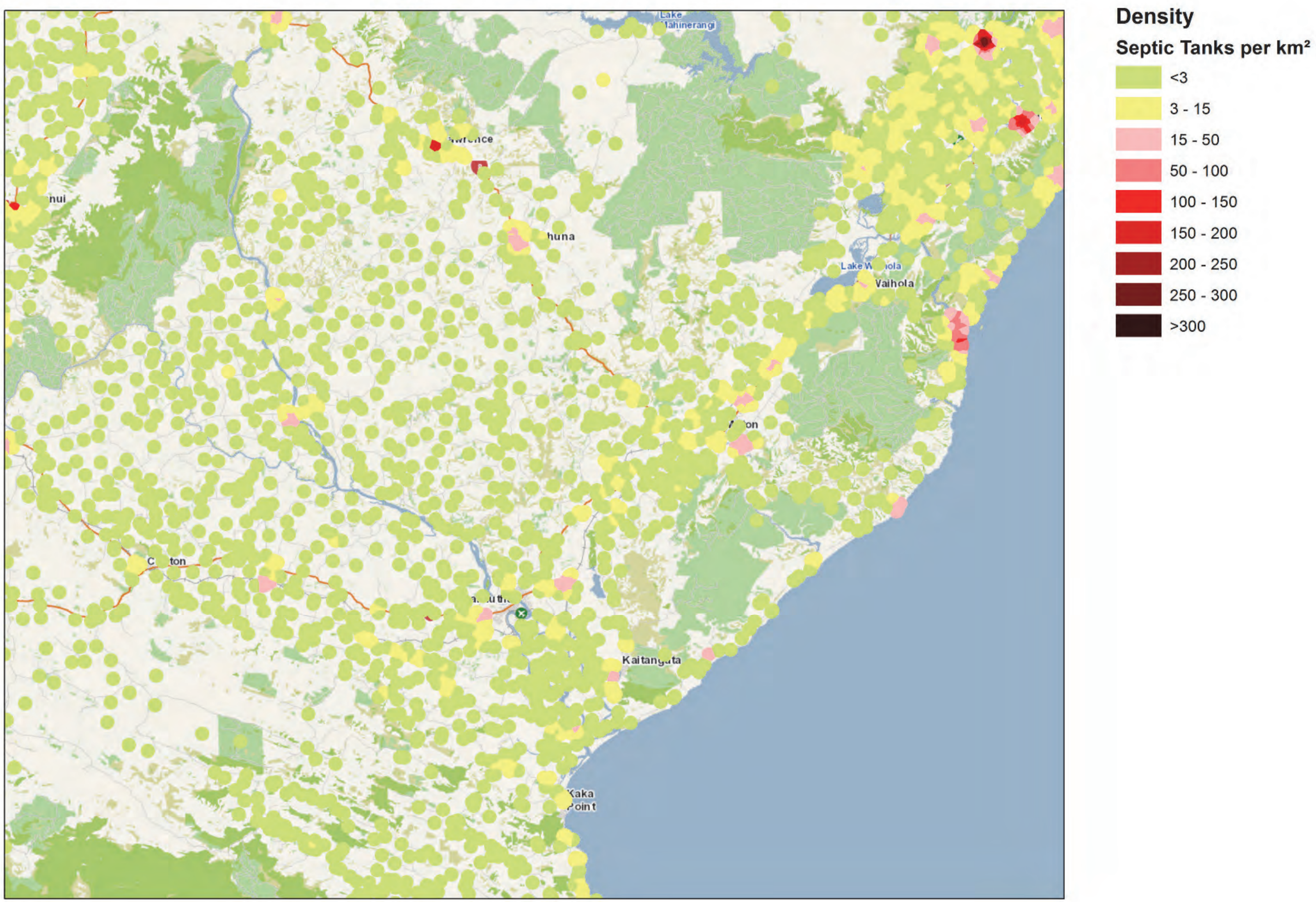

Figure C. 10 **Density Mapping Lawrence - Taieri Mouth - Kuriwao - Romahapa**

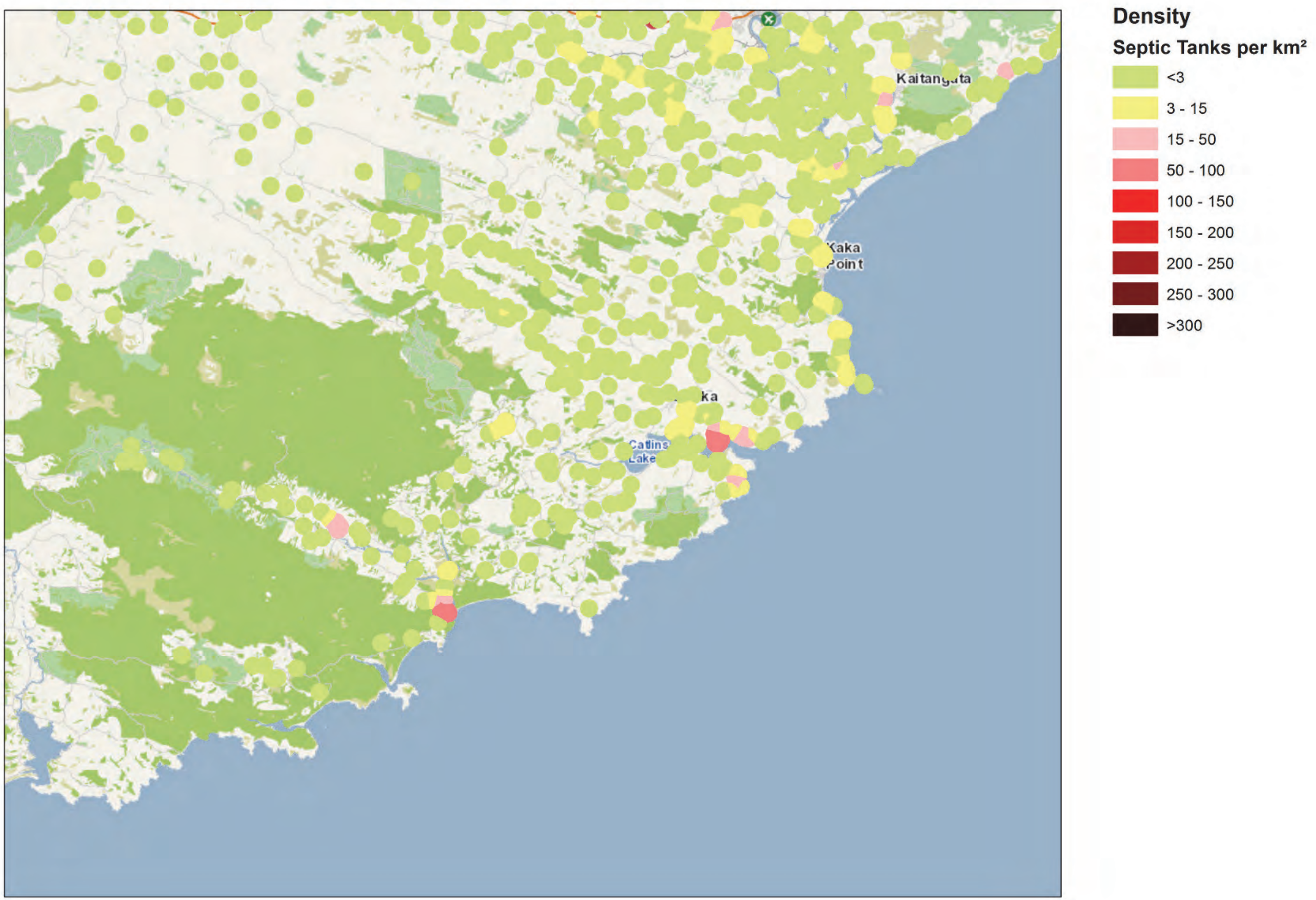

Figure C. 11 Density Mapping Caitlins

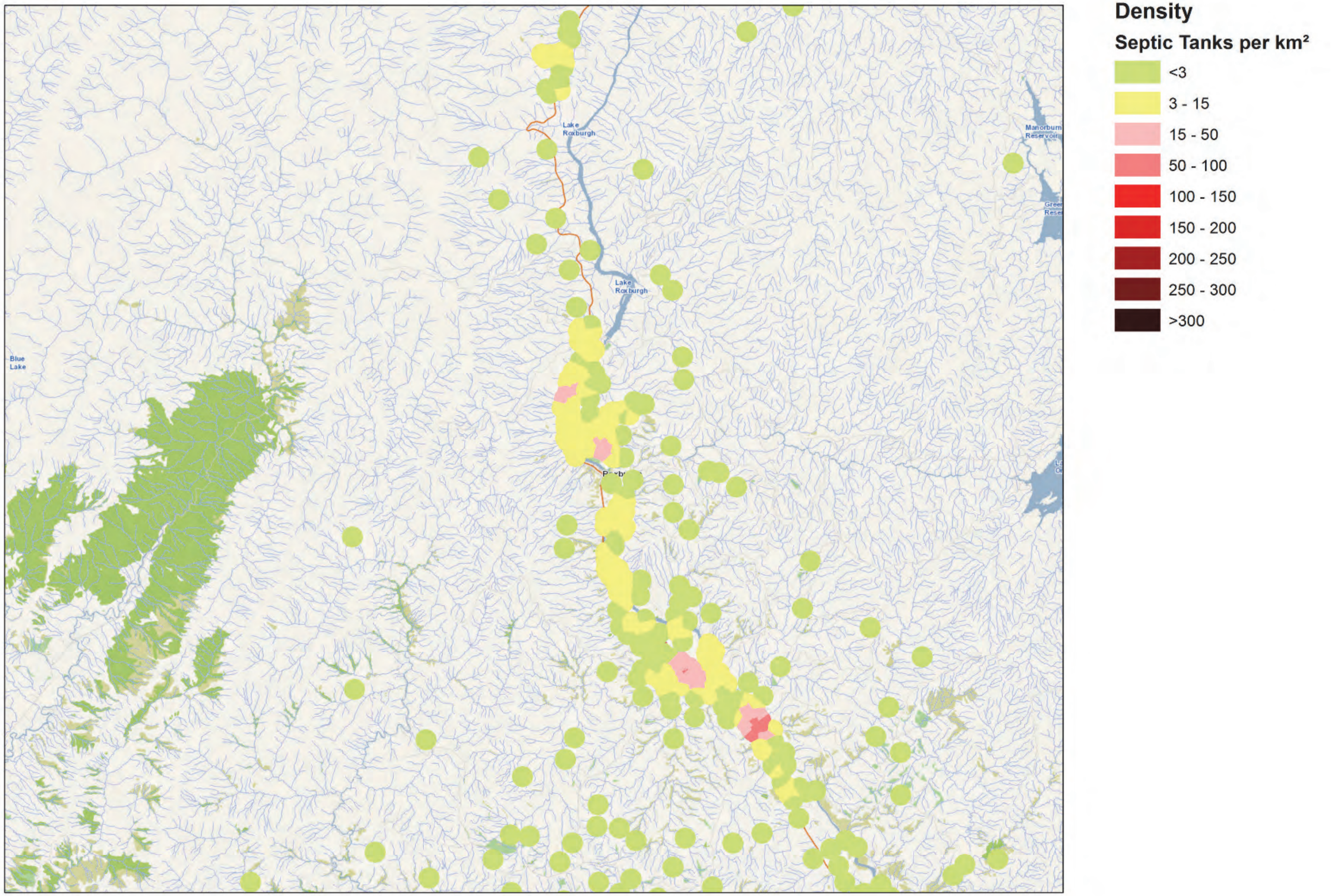

Figure C. 12 Density Mapping Roxburgh - Millers Flat

Otago Regional Council

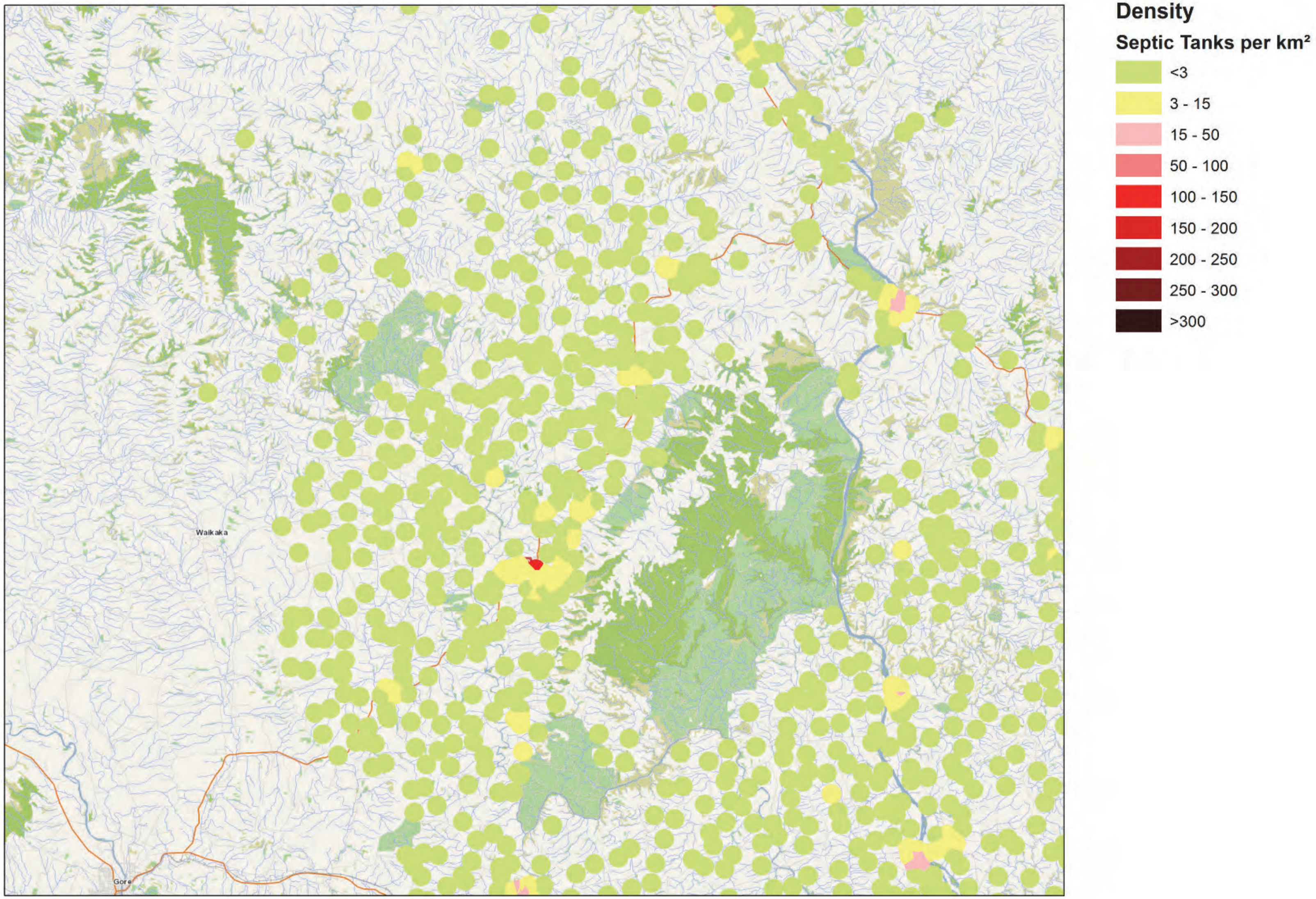

Figure C. 13 **Density Mapping Tapanui – Pomahaka**

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Appendix D – DRASTIC modelling within Otago

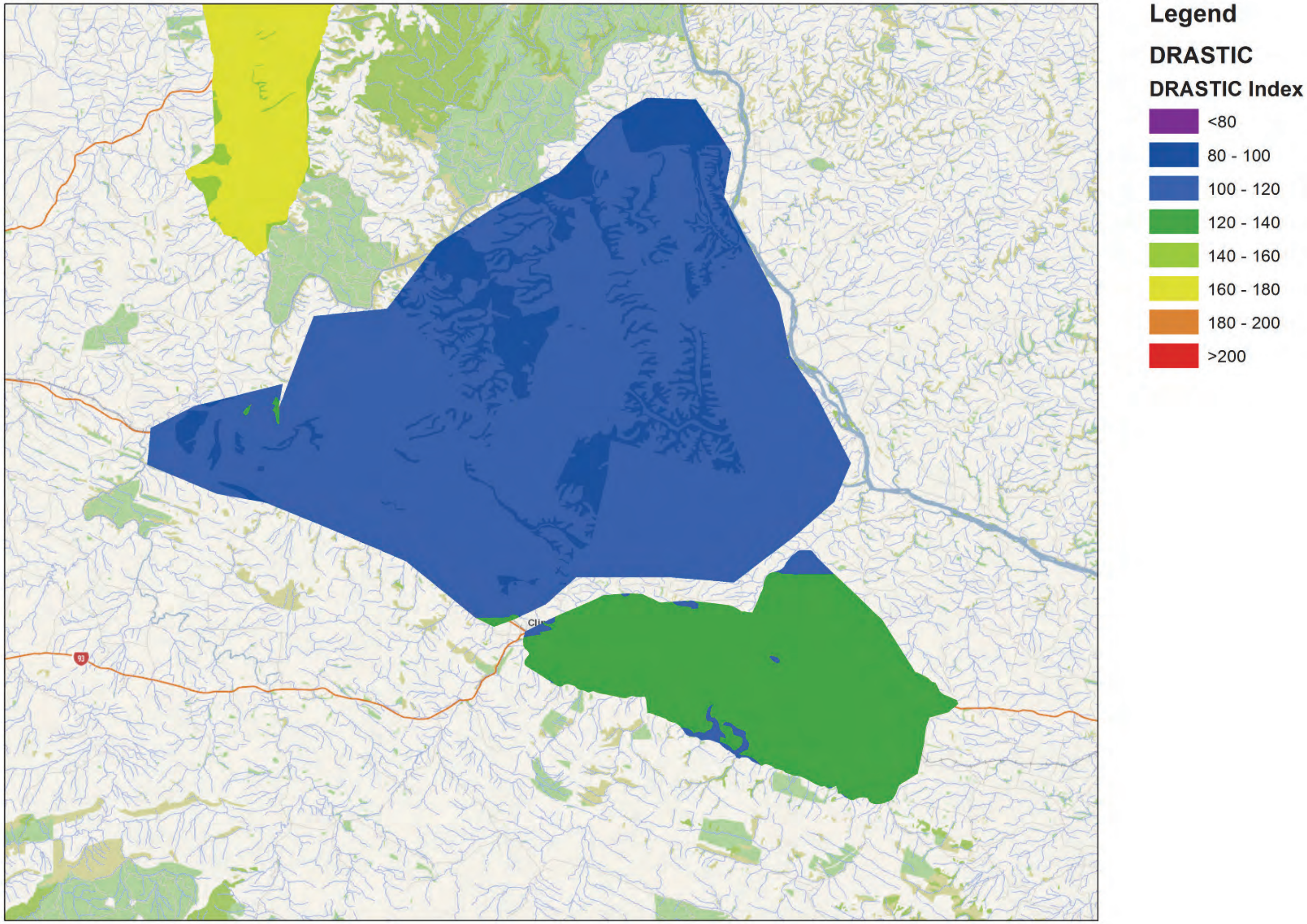

Figure D. 1 **DRASTIC Mapping Clydevale - Wairuna - Kuriwao**

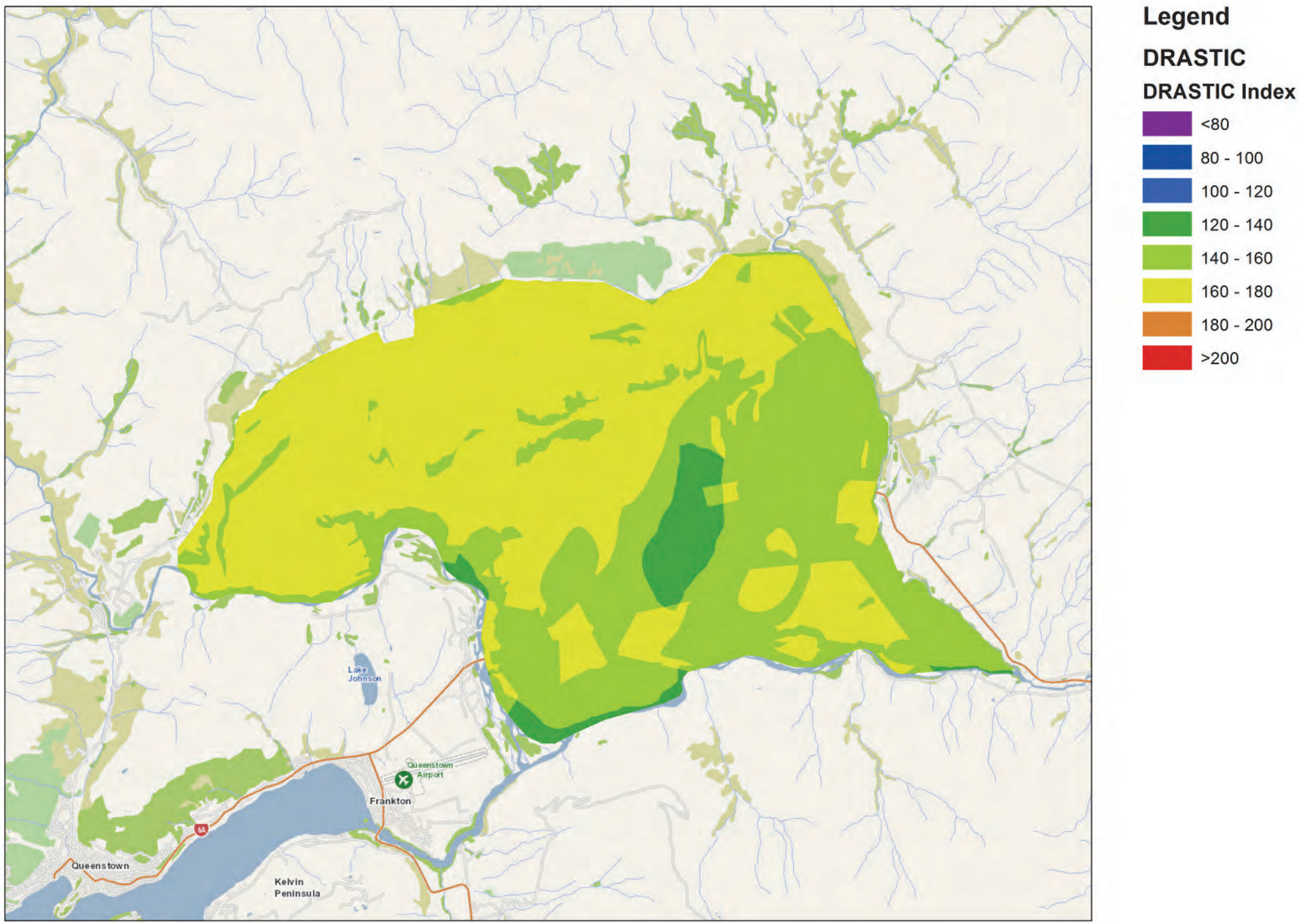

Figure D. 2 **DRASTIC Mapping Wakatipu Basin**

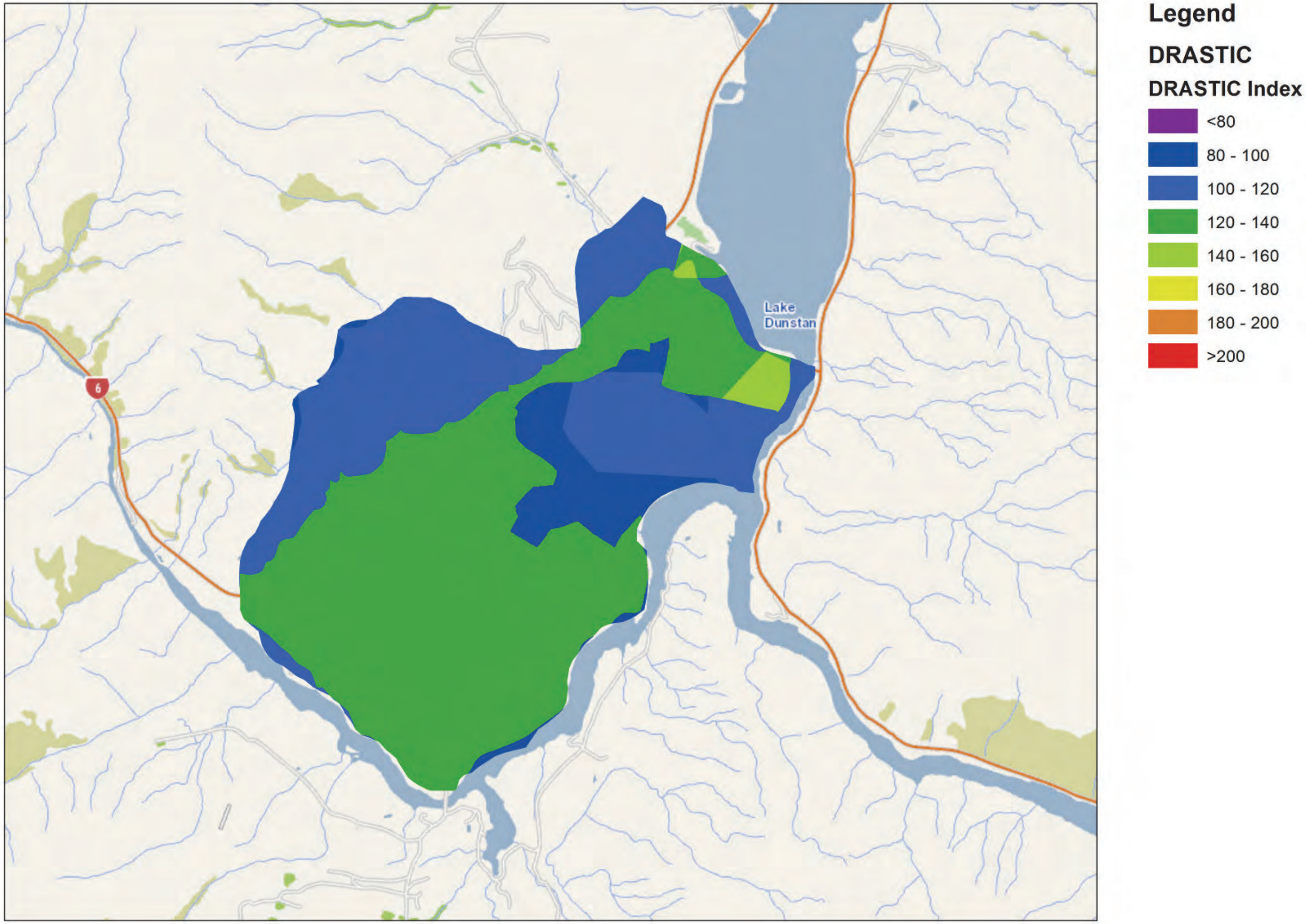

Figure D. 3 **DRASTIC Mapping Cromwell Terrace**

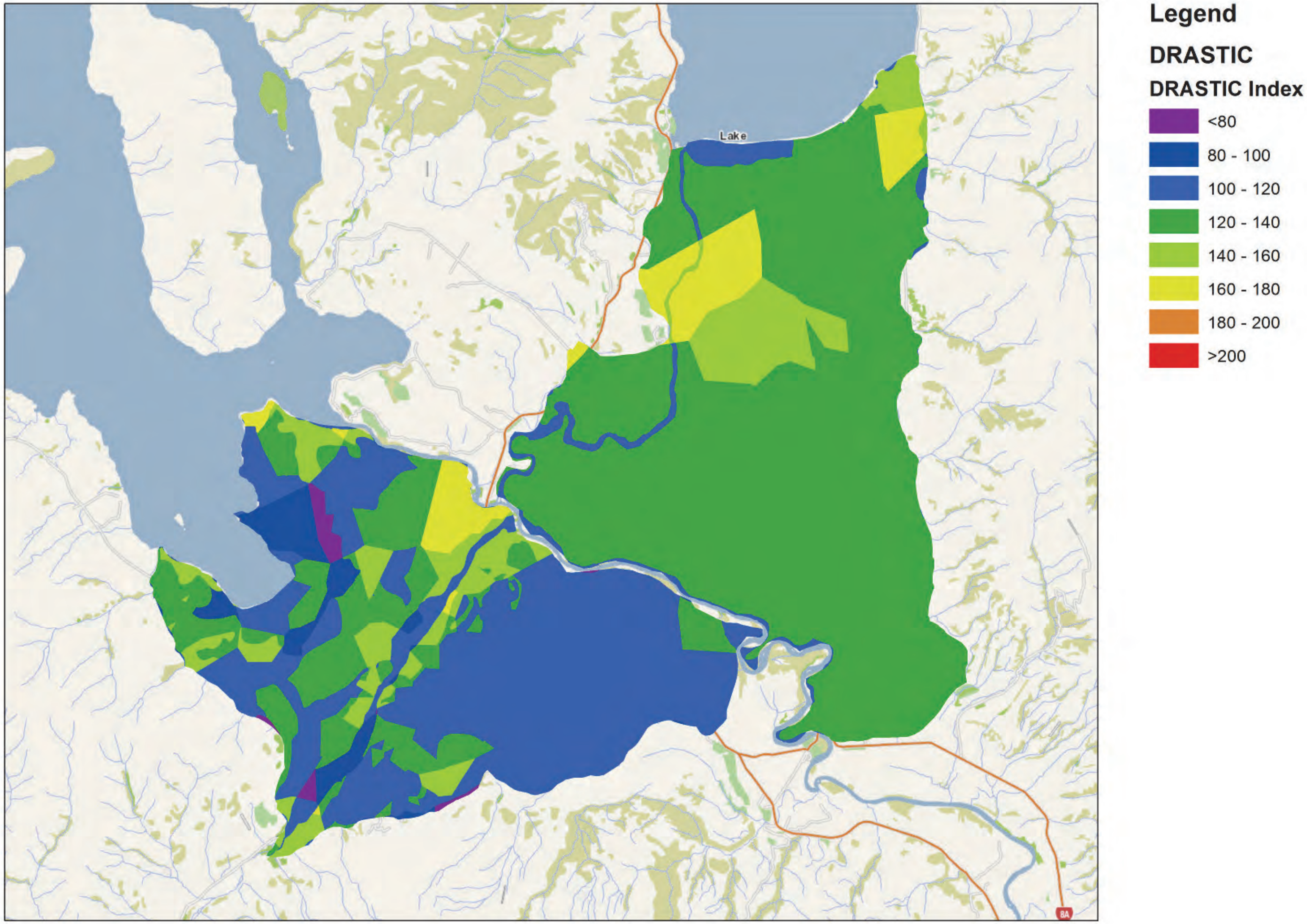

Figure D. 4 **DRASTIC Mapping Wanaka - Cardrona - Hawea**

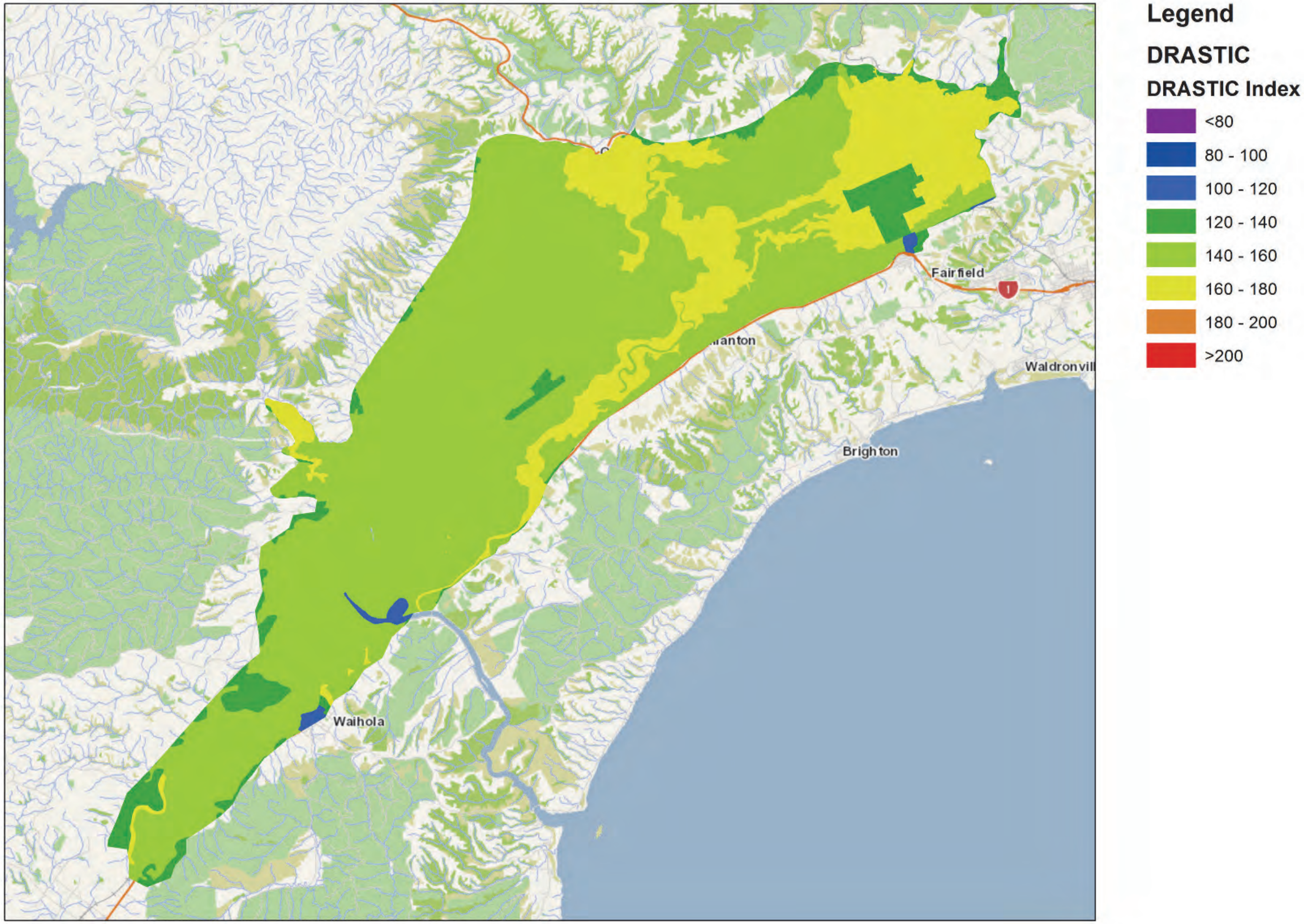

Figure D. 5 **DRASTIC Mapping Lower Taieri**

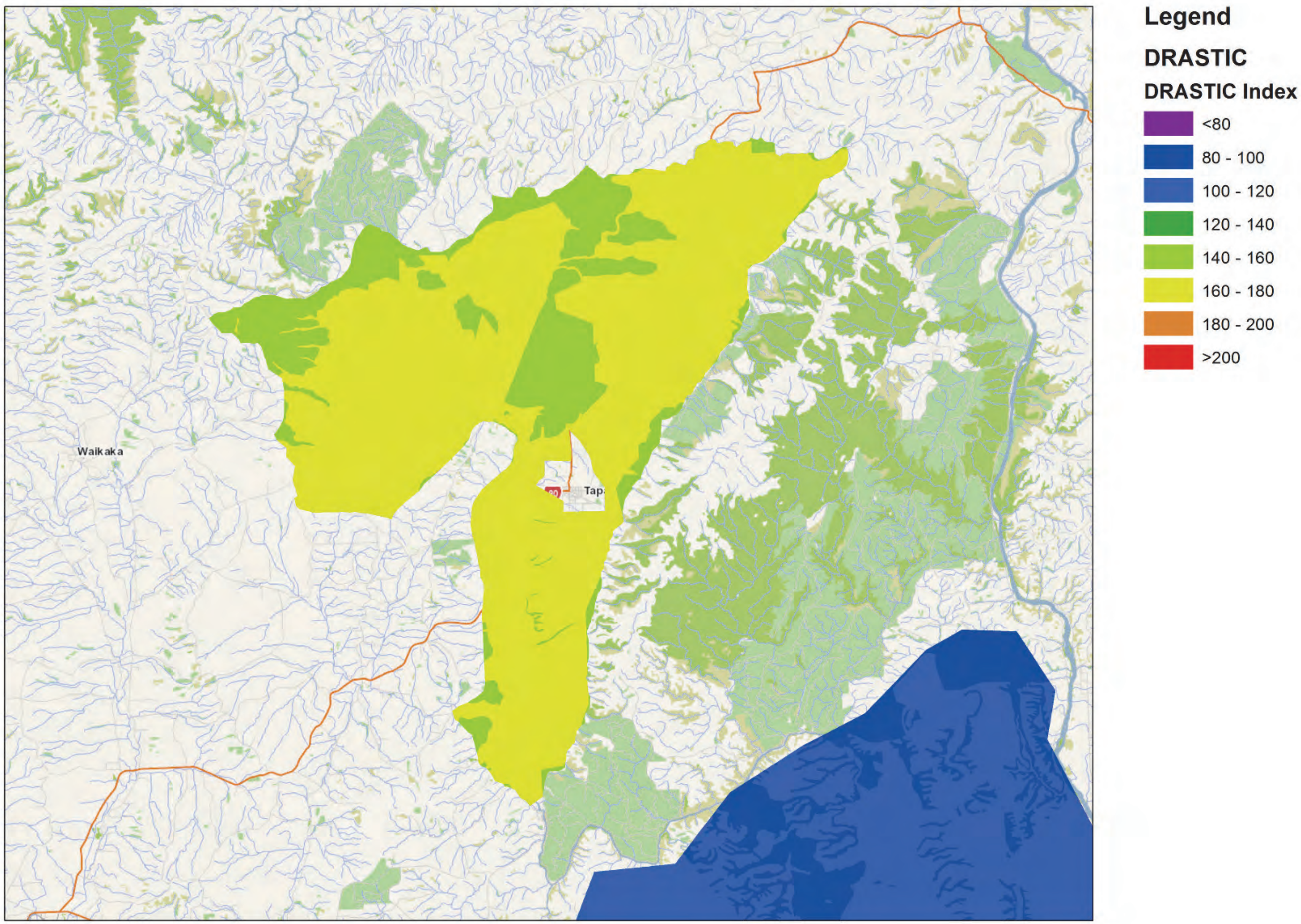

Figure D. 6 **DRASTIC Mapping Pomahaka**

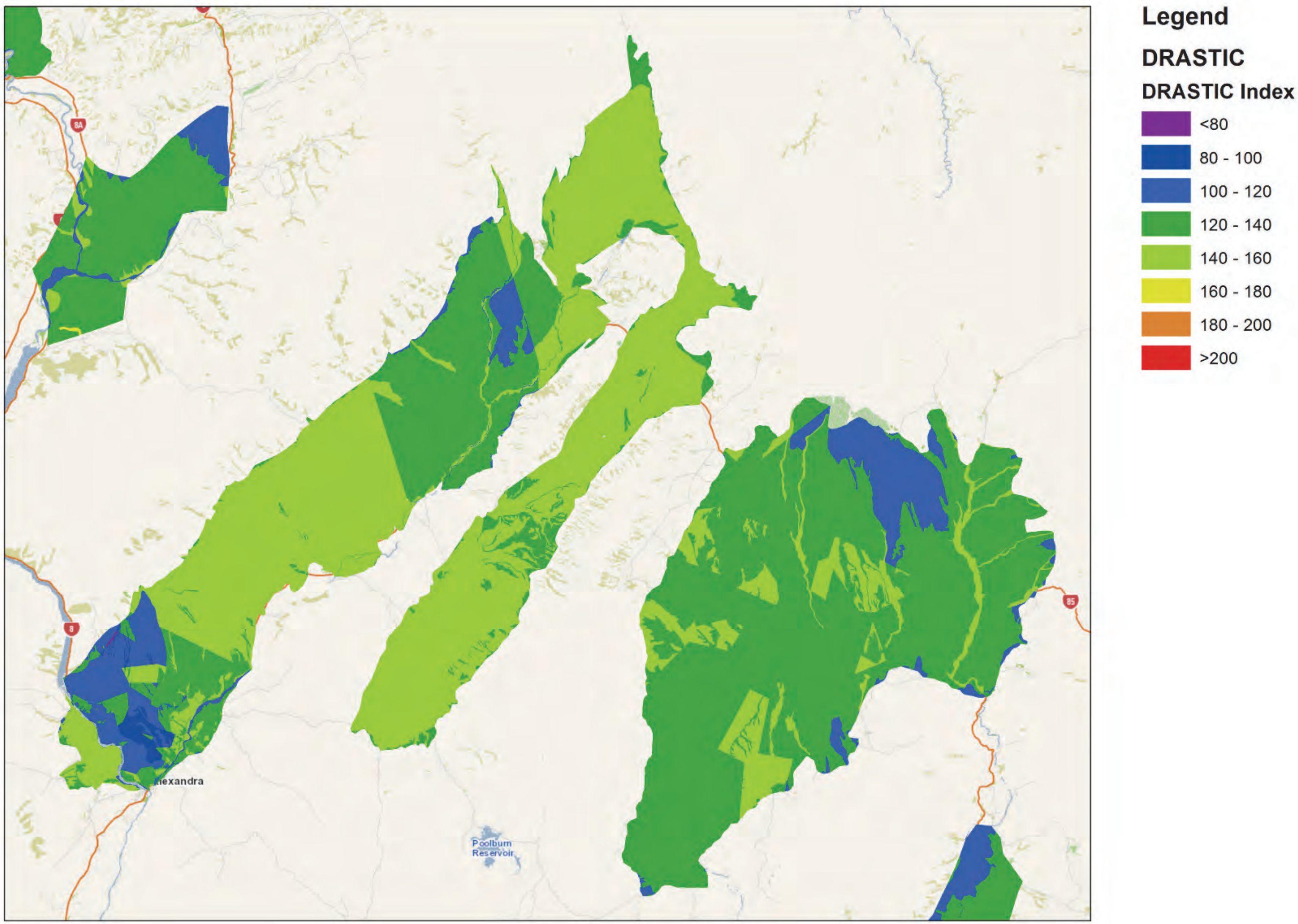

Figure D. 7 **DRASTIC Mapping Lindis - Bendigo - Maniototo - Ida Valley**

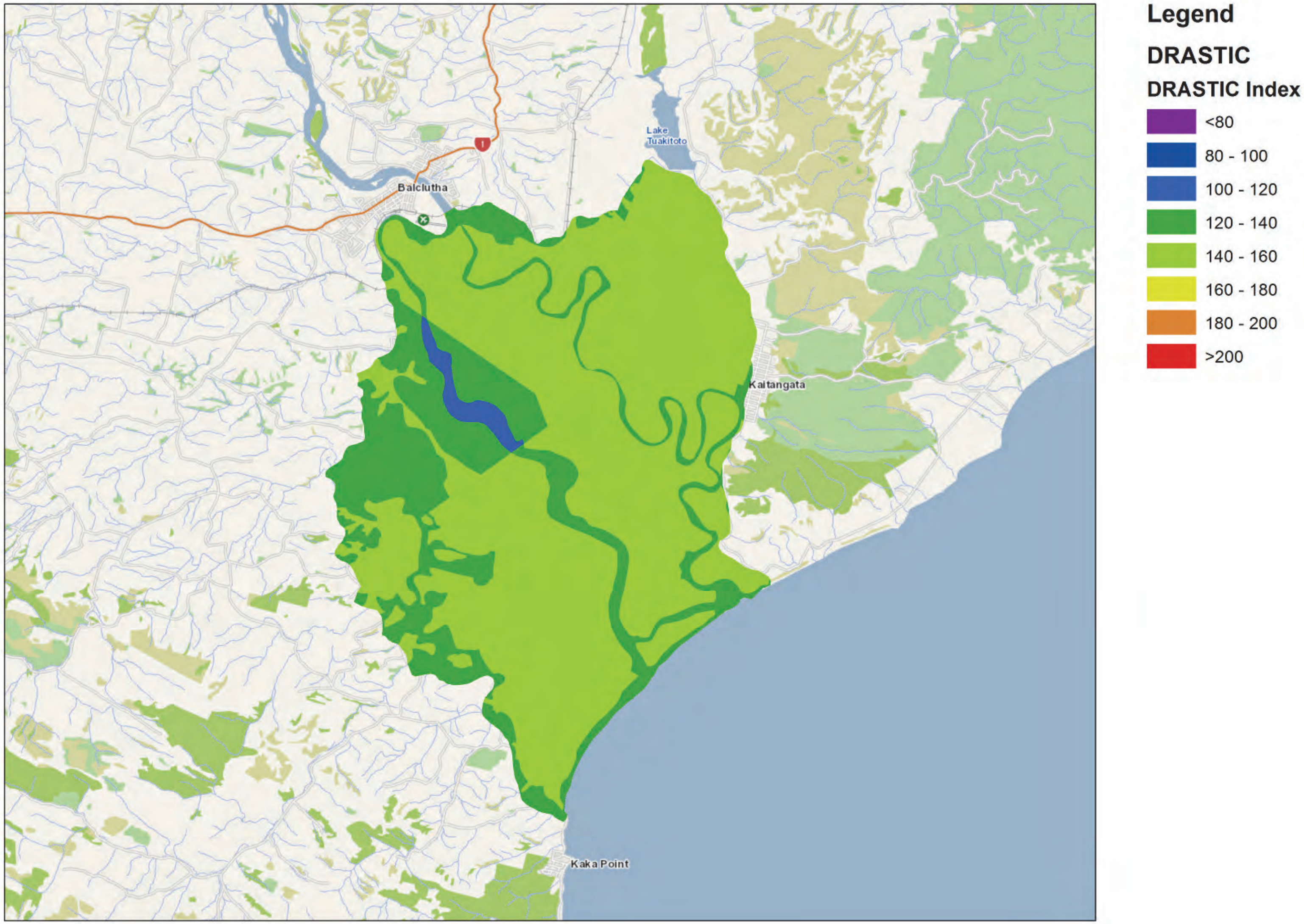

Figure D. 8 DRASTIC Mapping Inch Clutha

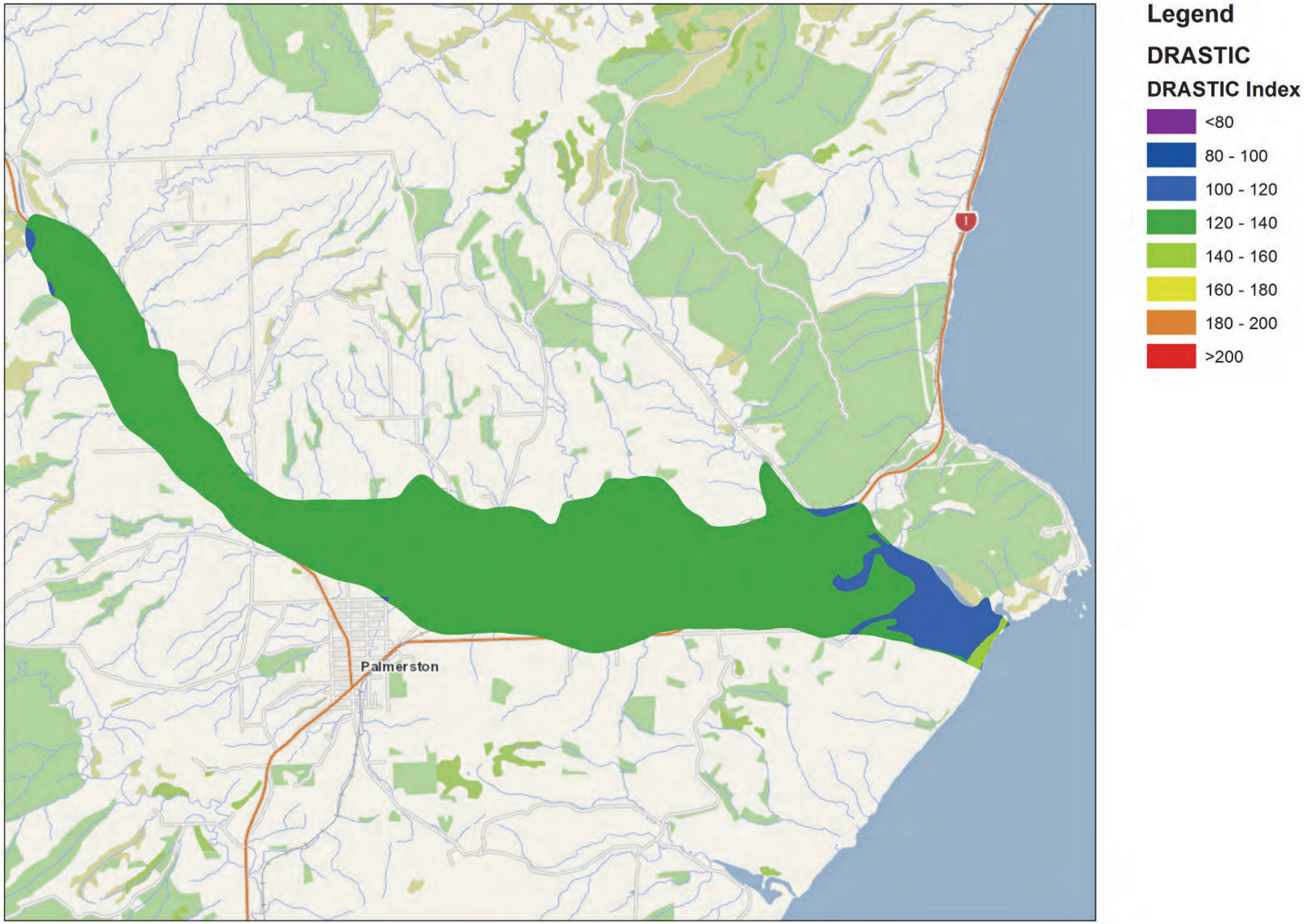

Figure D. 9 **DRASTIC Mapping Shag**

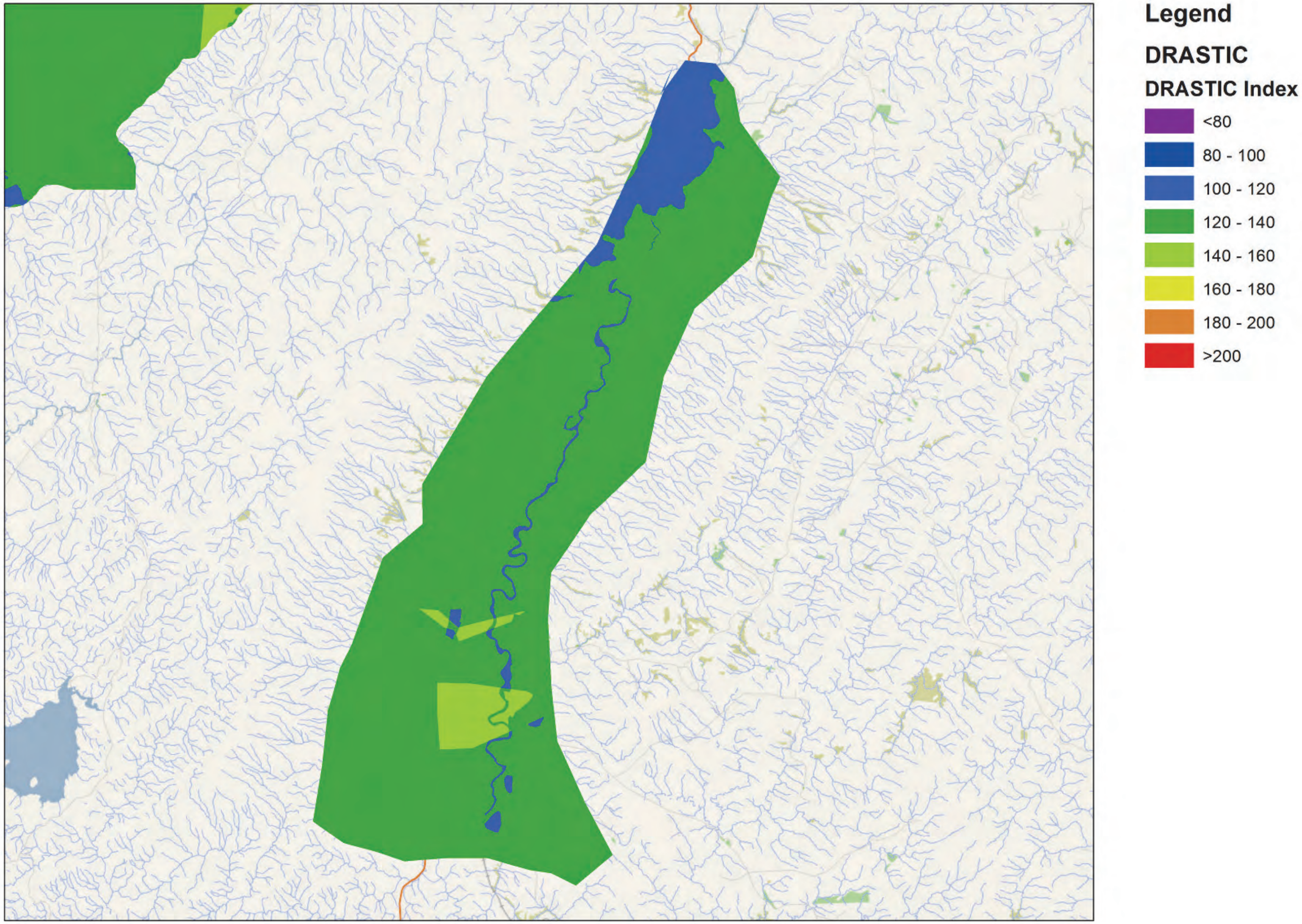

Figure D. 10 **DRASTIC Mapping Strath Taieri**

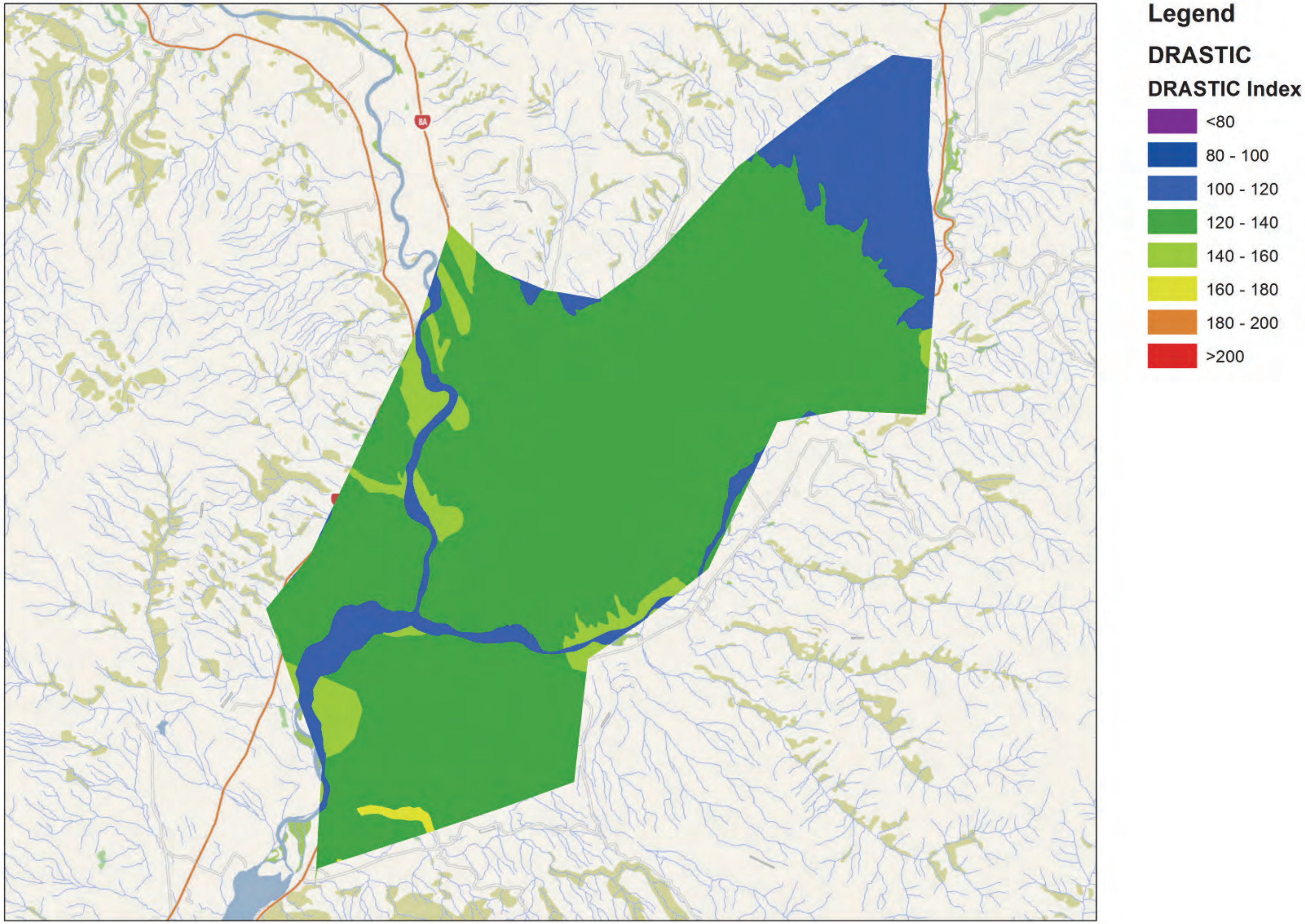

Figure D. 11 **DRASTIC Mapping Lindis - Bendigo**

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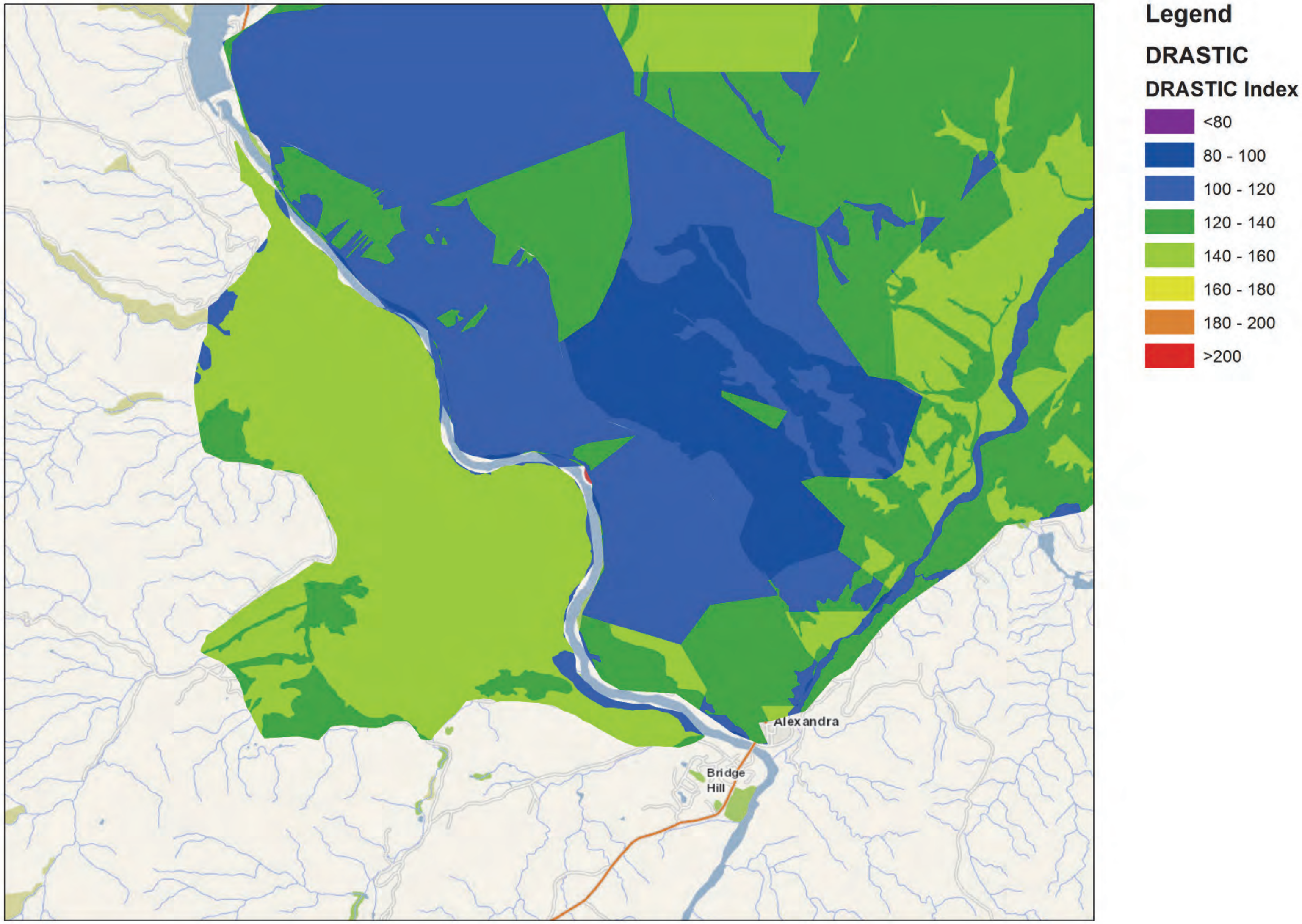

Figure D. 12 **DRASTIC Mapping Alexandra Basin - Dunstan Flats**

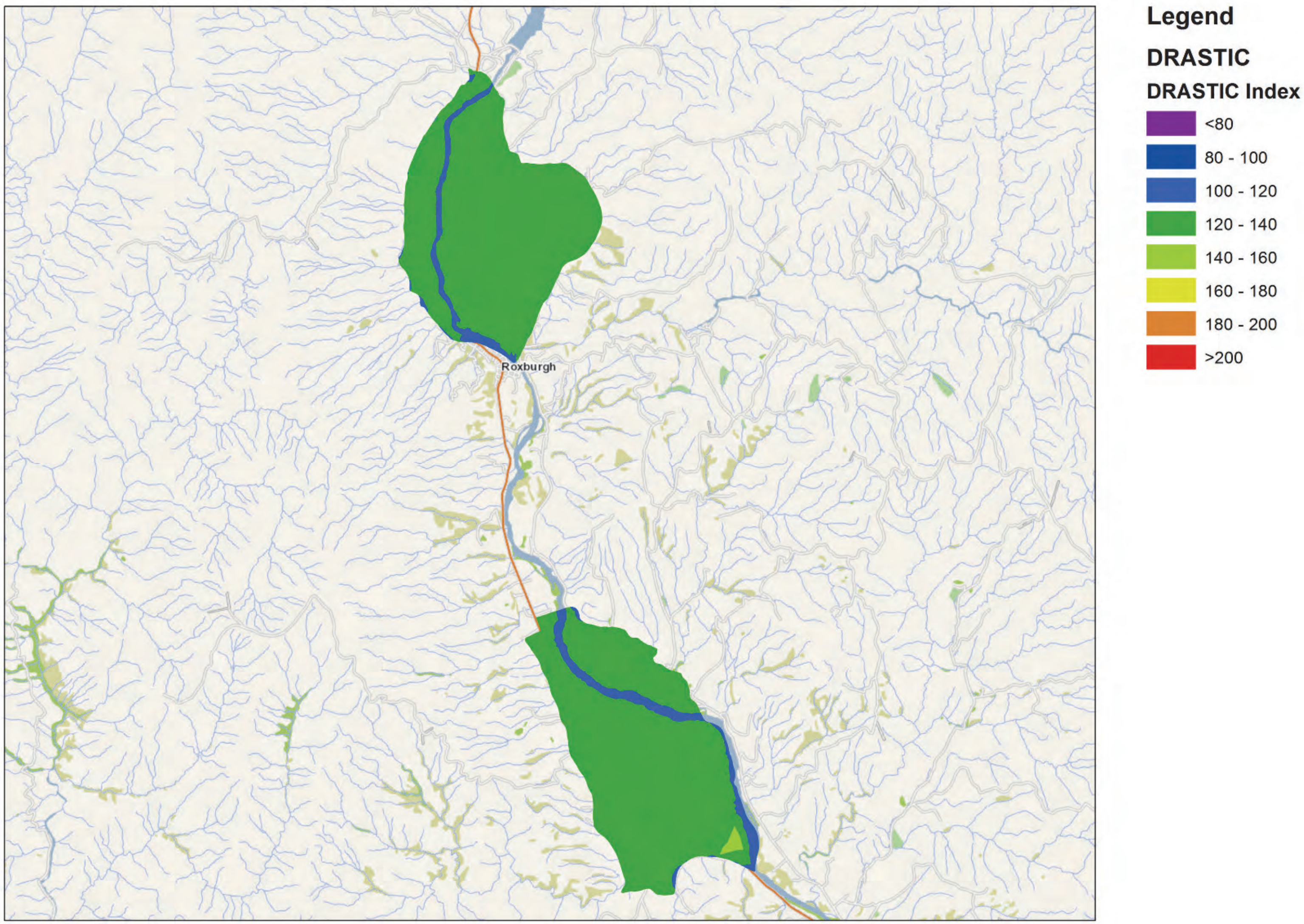

Figure D. 13 **DRASTIC Mapping Roxburgh - Ettrick**

Otago Regional Council

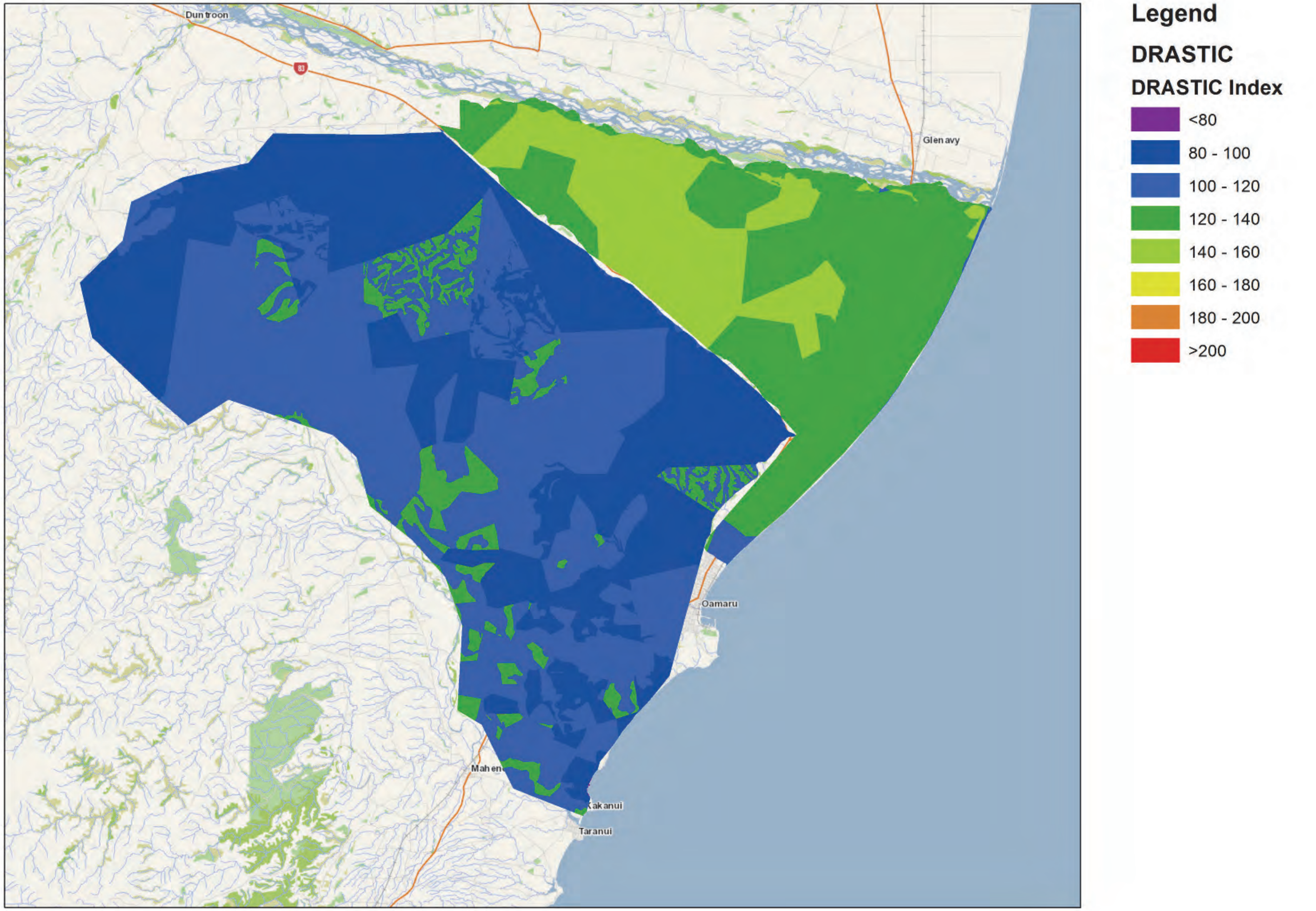

Figure D. 14 **DRASTIC Mapping Waiareka - Deborah - Lower Waitaki**

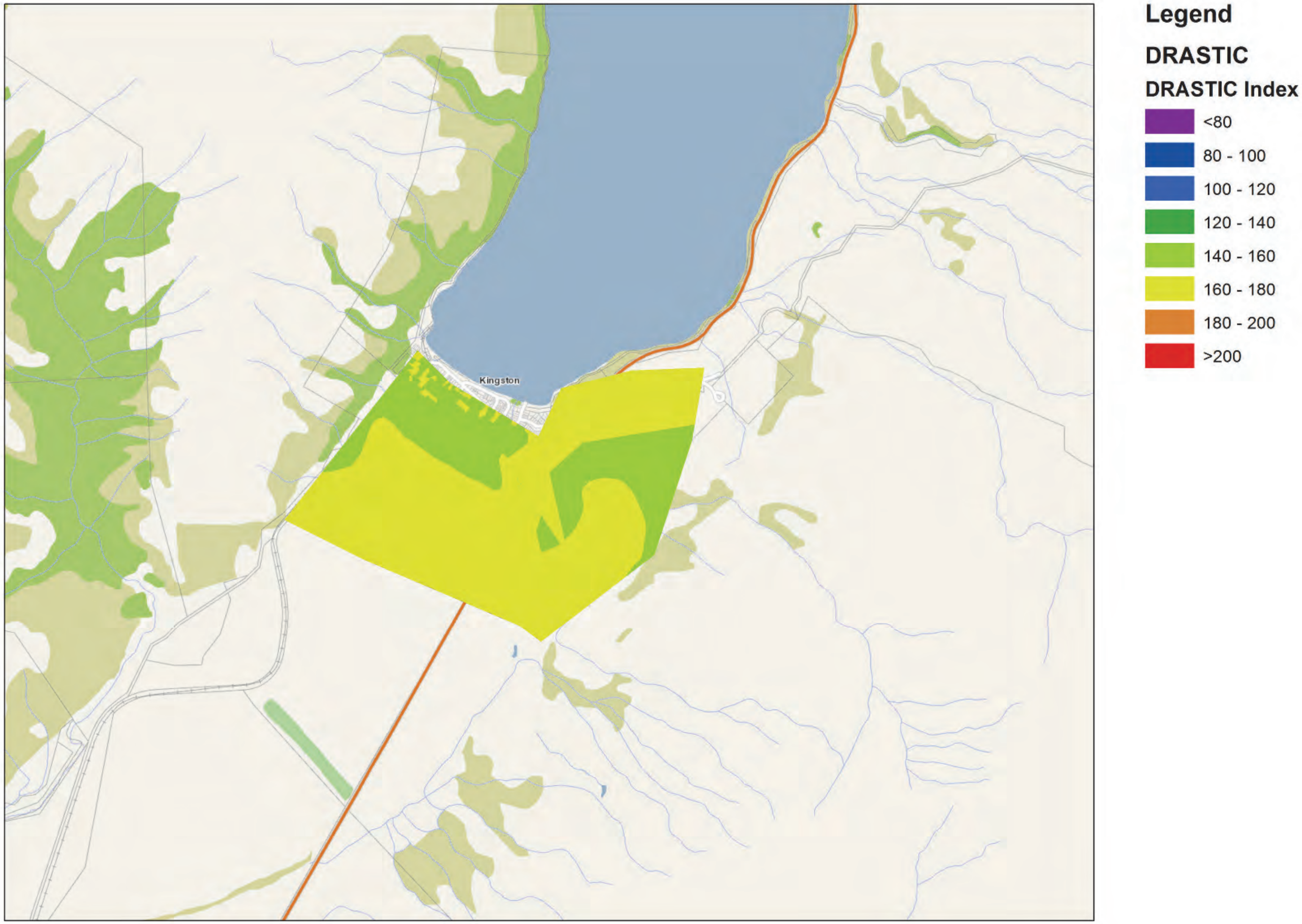

Figure D. 15 **DRASTIC Mapping Kingston**

Appendix E – Combined Septic Tank Density and DRASTIC Mapping within Otago.

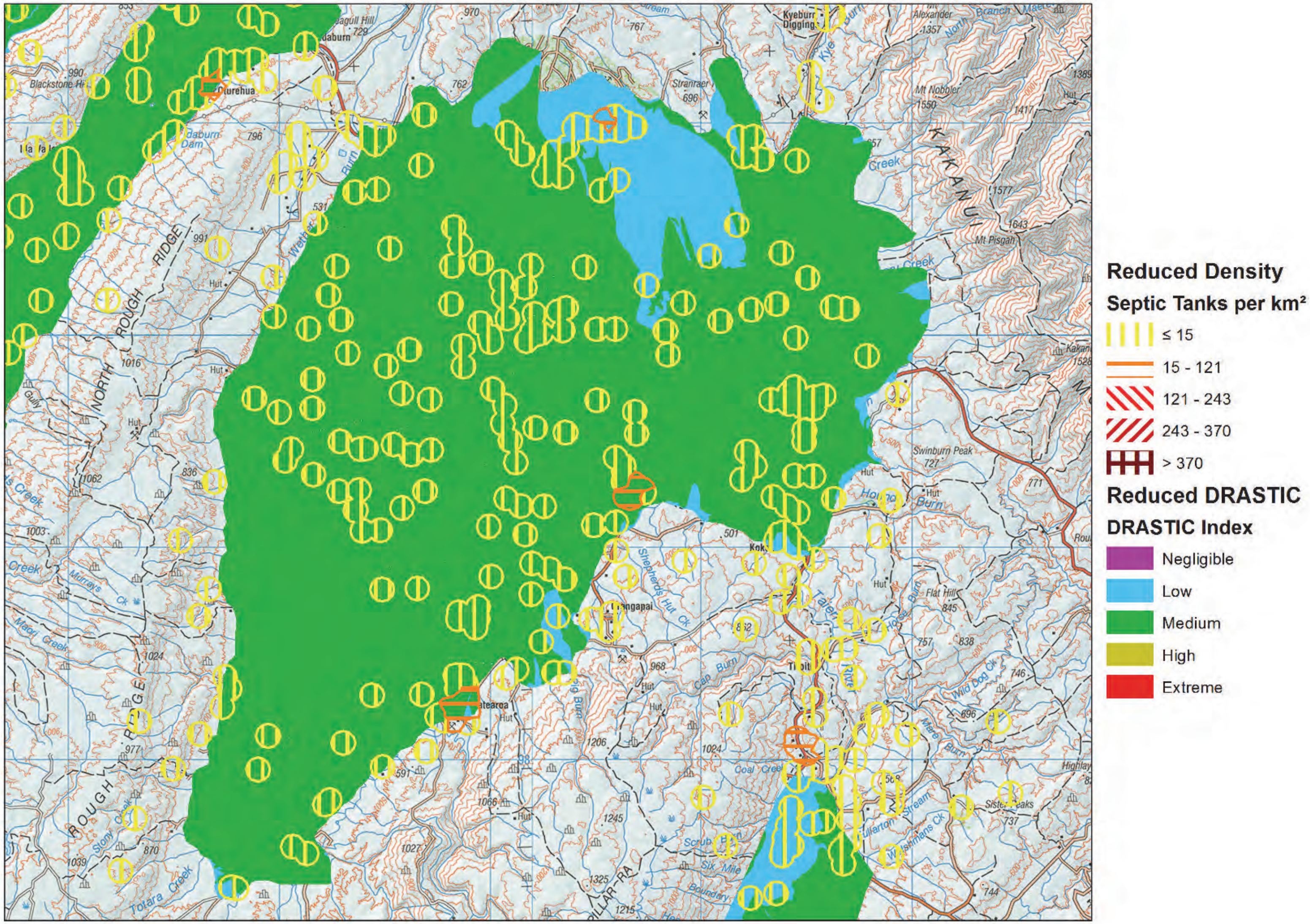

Figure E. 1 **Combined Mapping Maniototo**

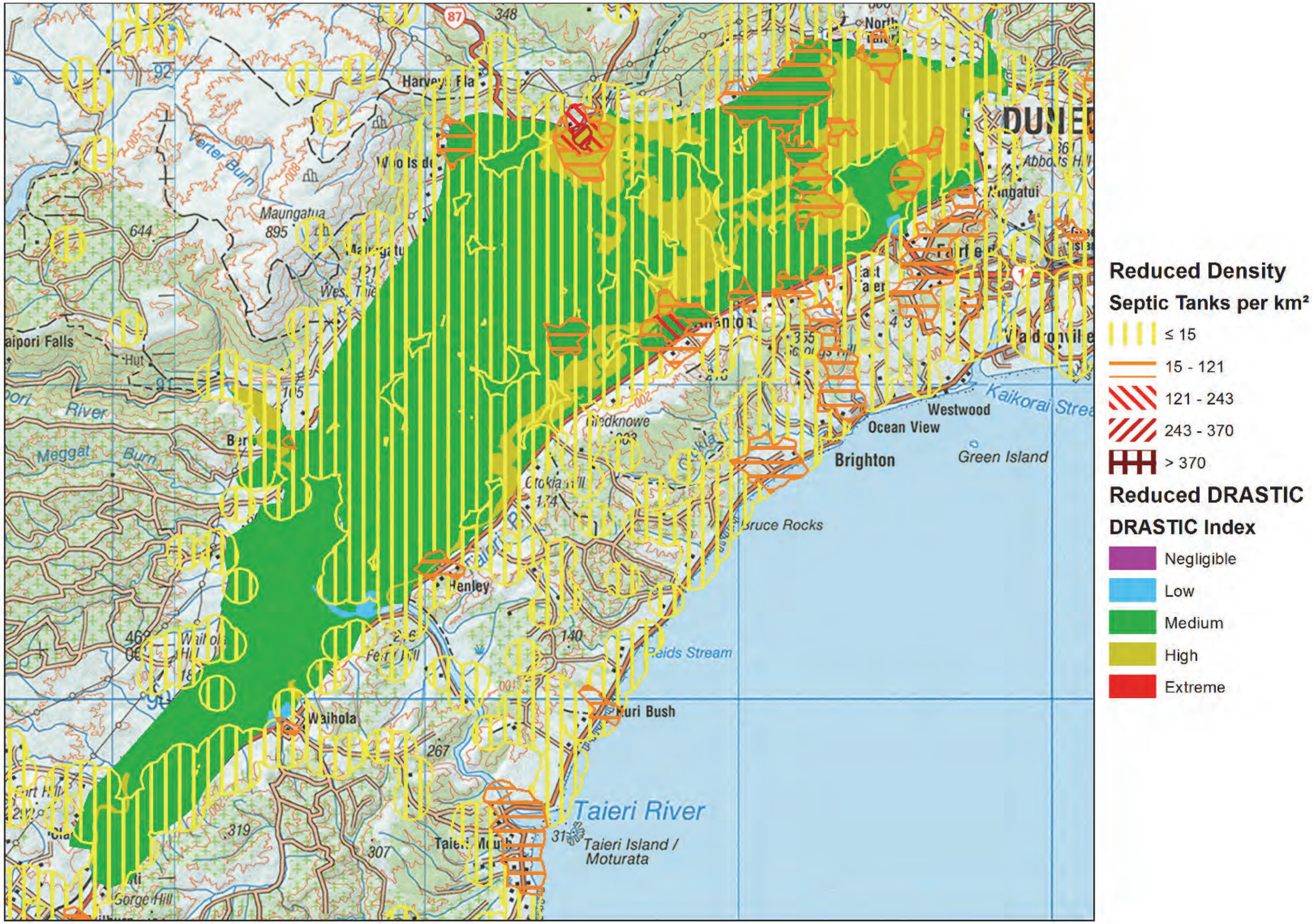

Figure E. 2 Combined Mapping Lower Taieri

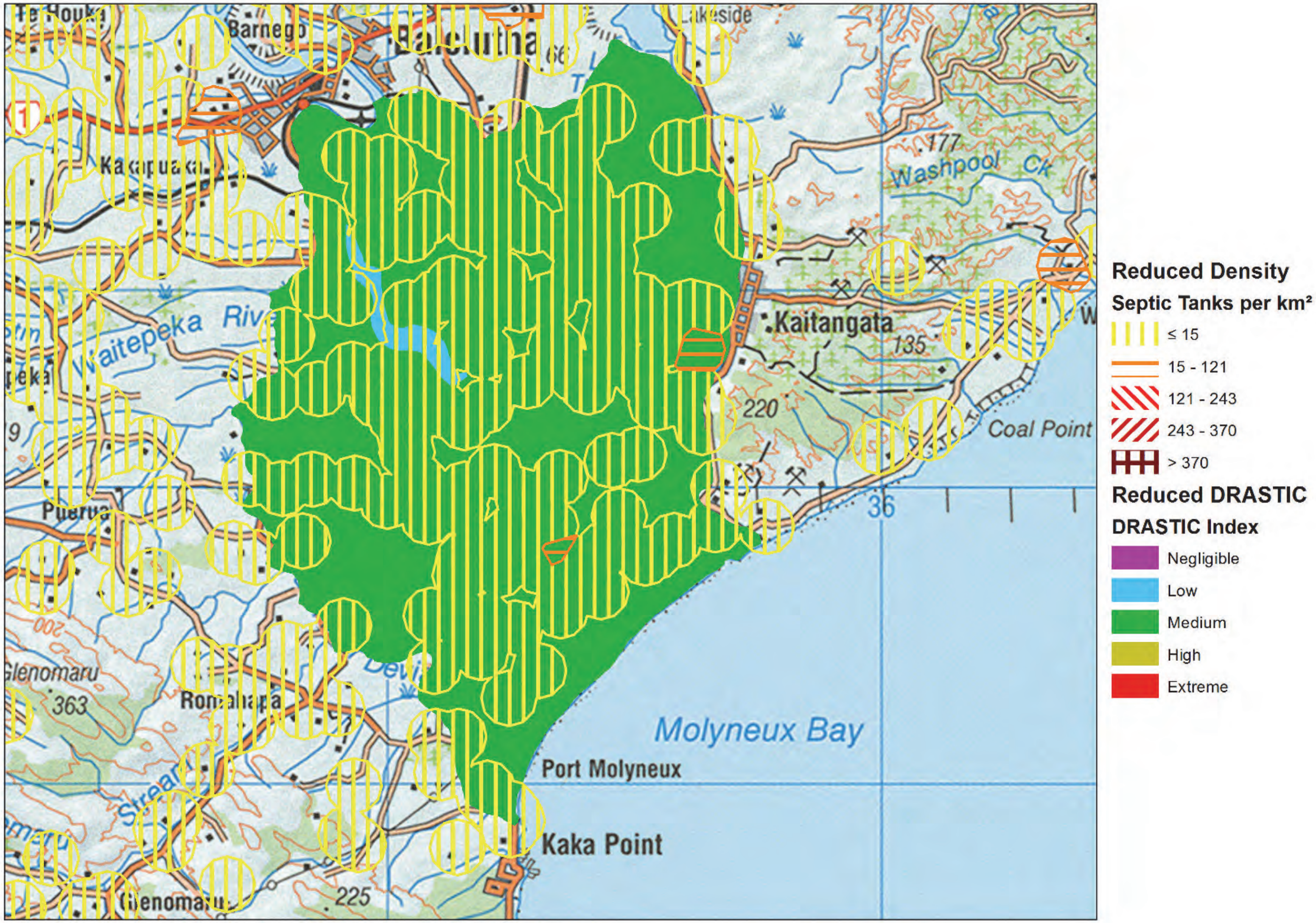

Figure E. 3 **Combined Mapping Inch Clutha**

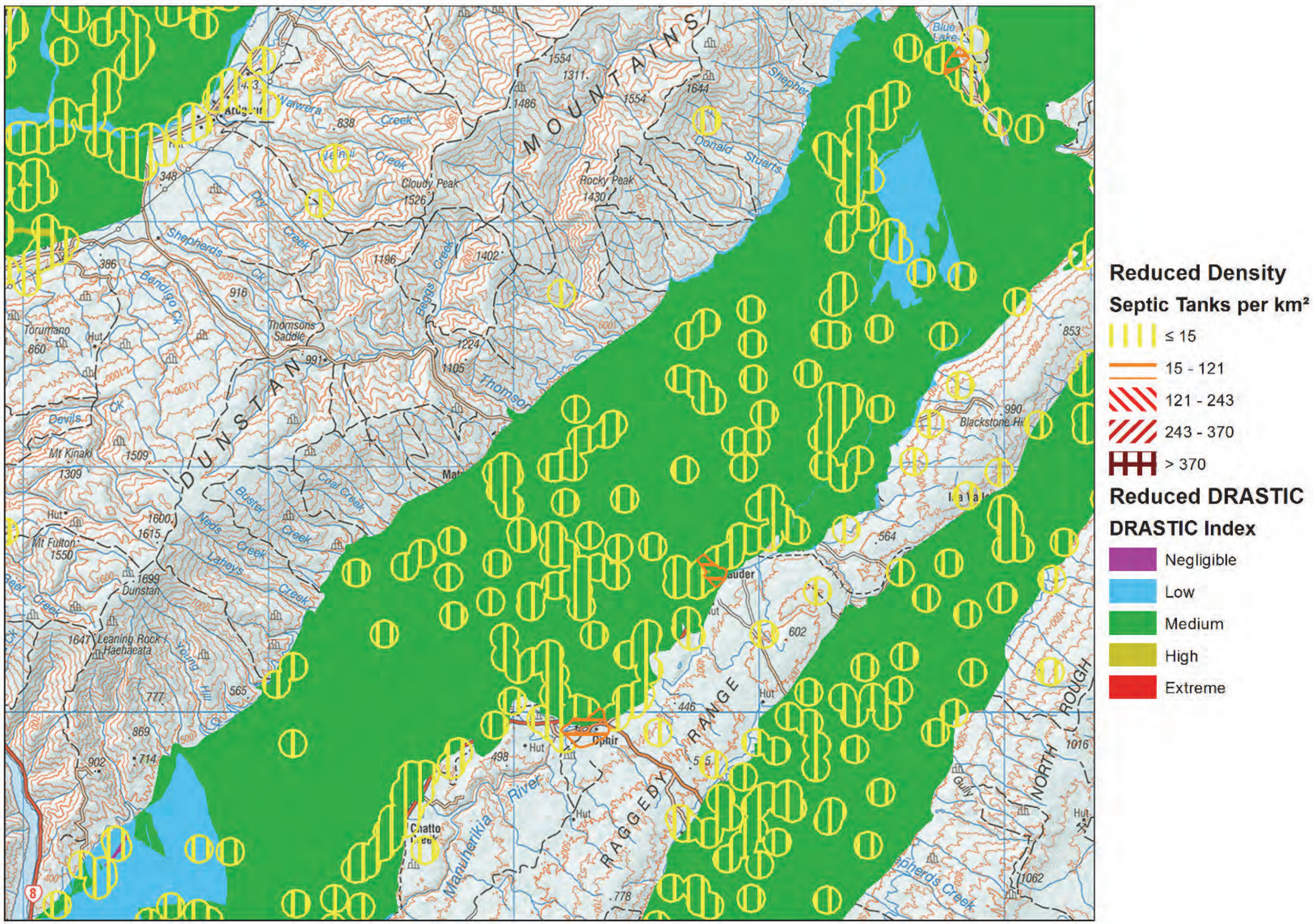

Figure E. 4 Combined Mapping Ida Valley

Otago Regional Council

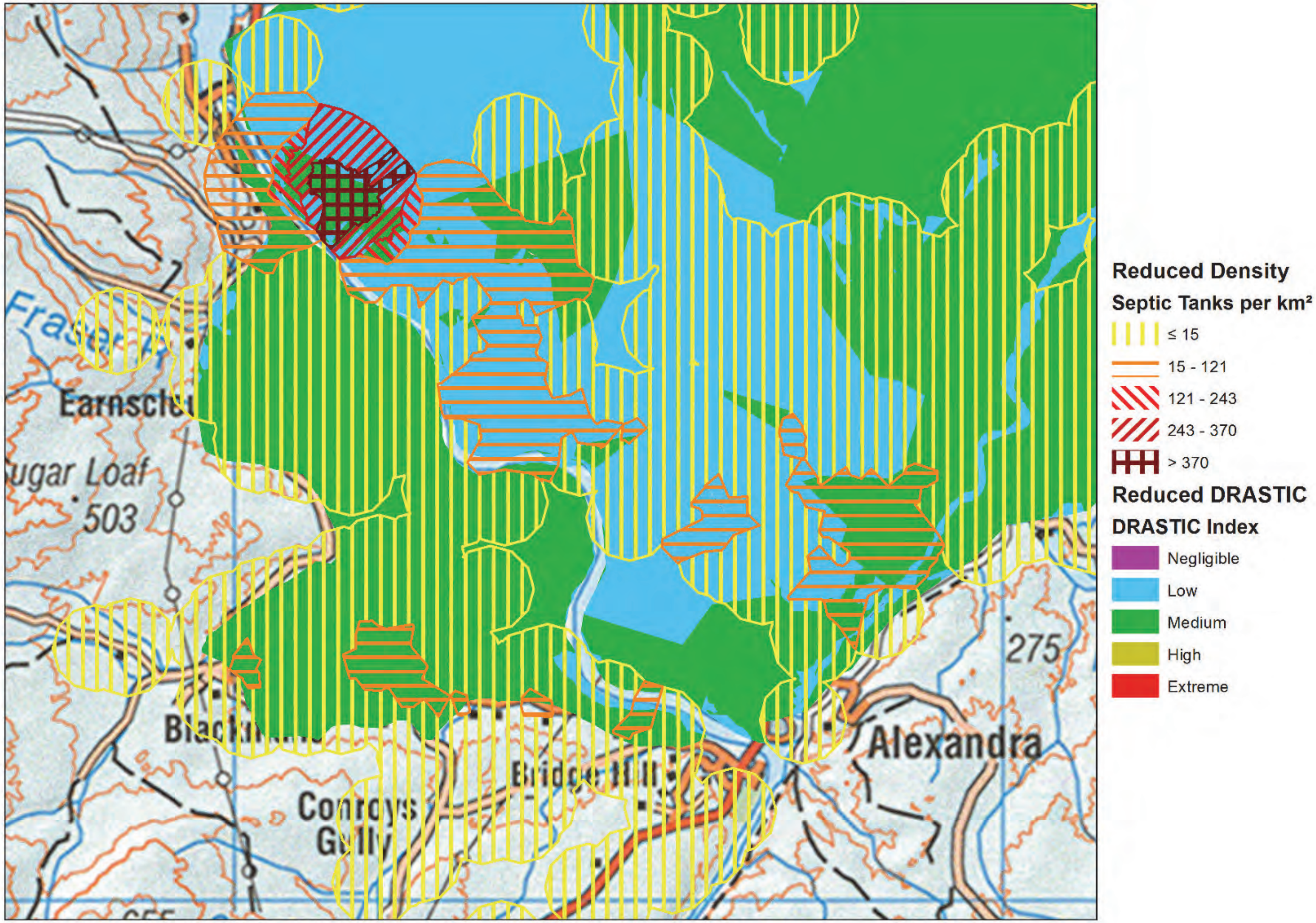

Figure E. 5 **Combined Mapping Dunstan Flats – Alexandra Basin**

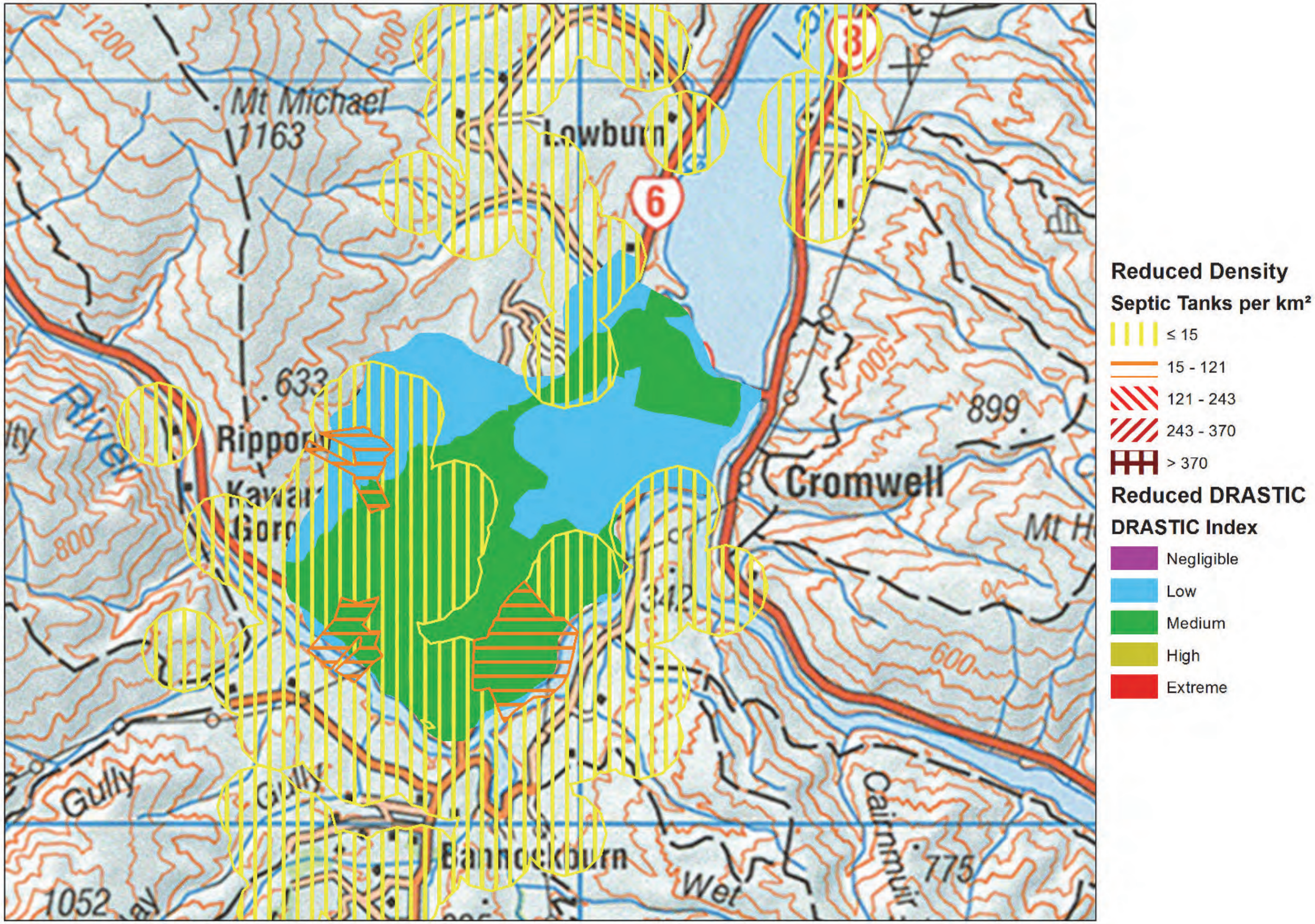

Figure E. 6 **Combined Mapping Cromwell Terrace**

Otago Regional Council

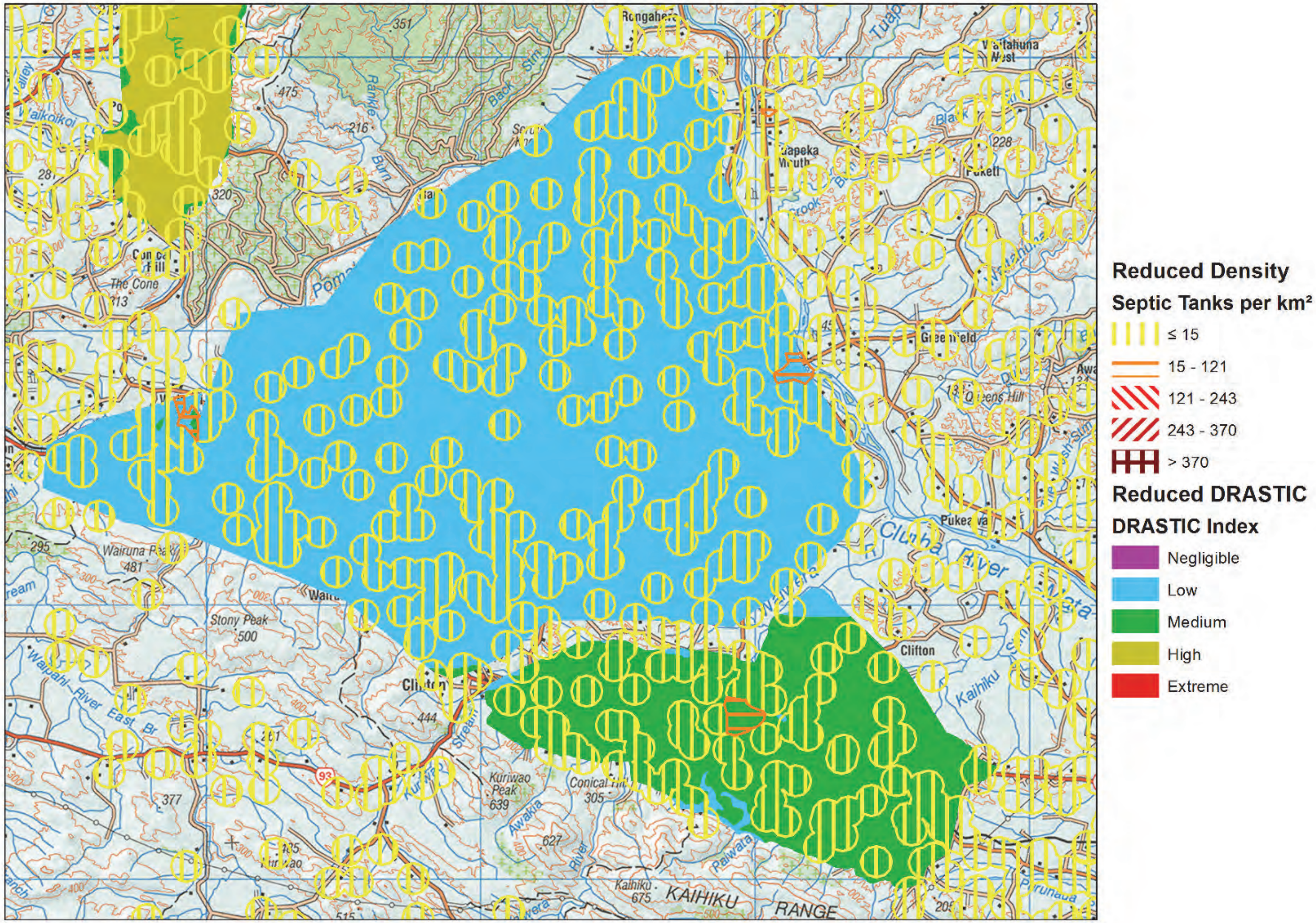

Figure E. 7 **Combined Mapping Clydevale - Wairuna - Kuriwao**

Otago Regional Council

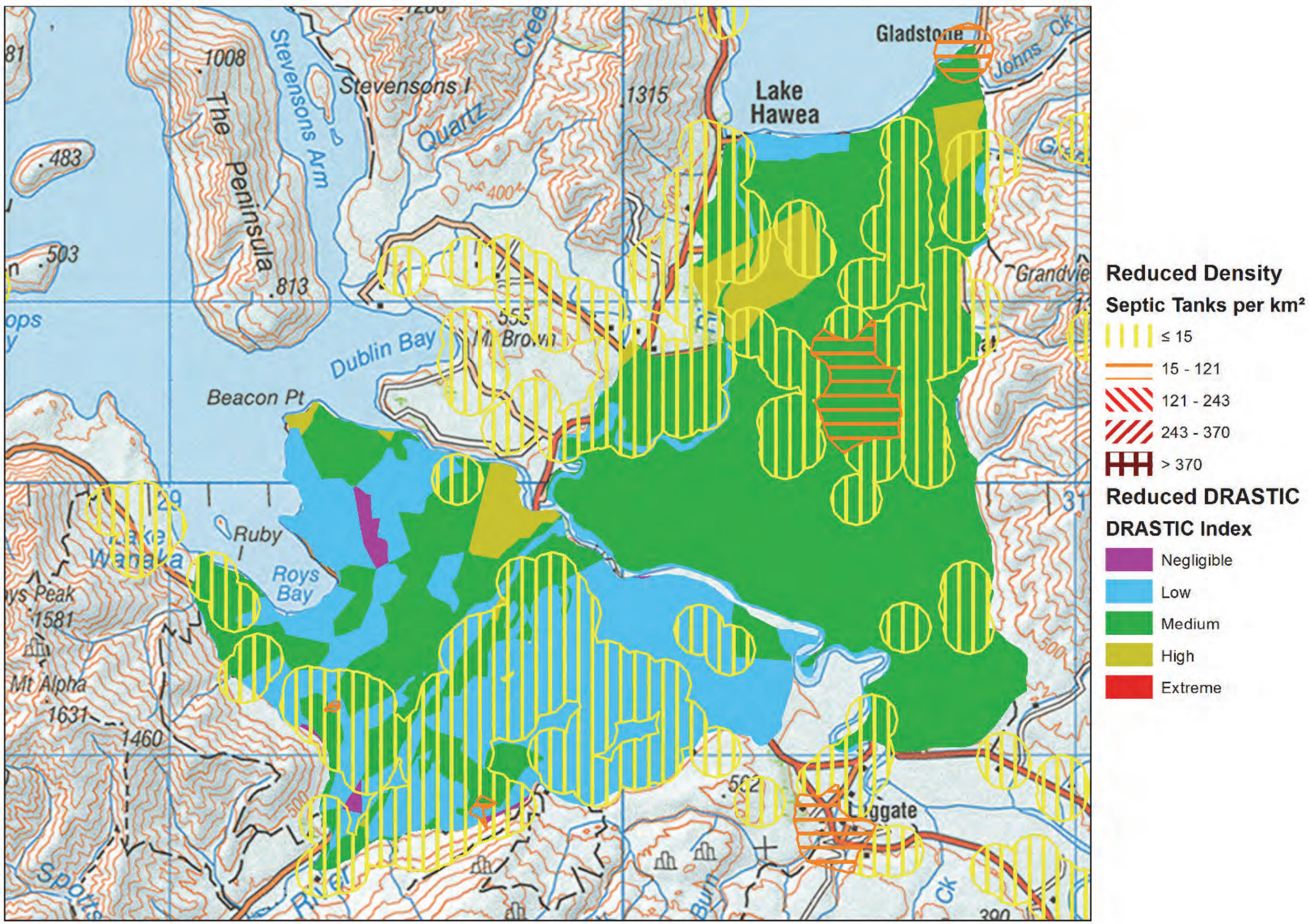

Figure E. 8 Combined Mapping Wanaka - Cardrona - Hawea

Otago Regional Council

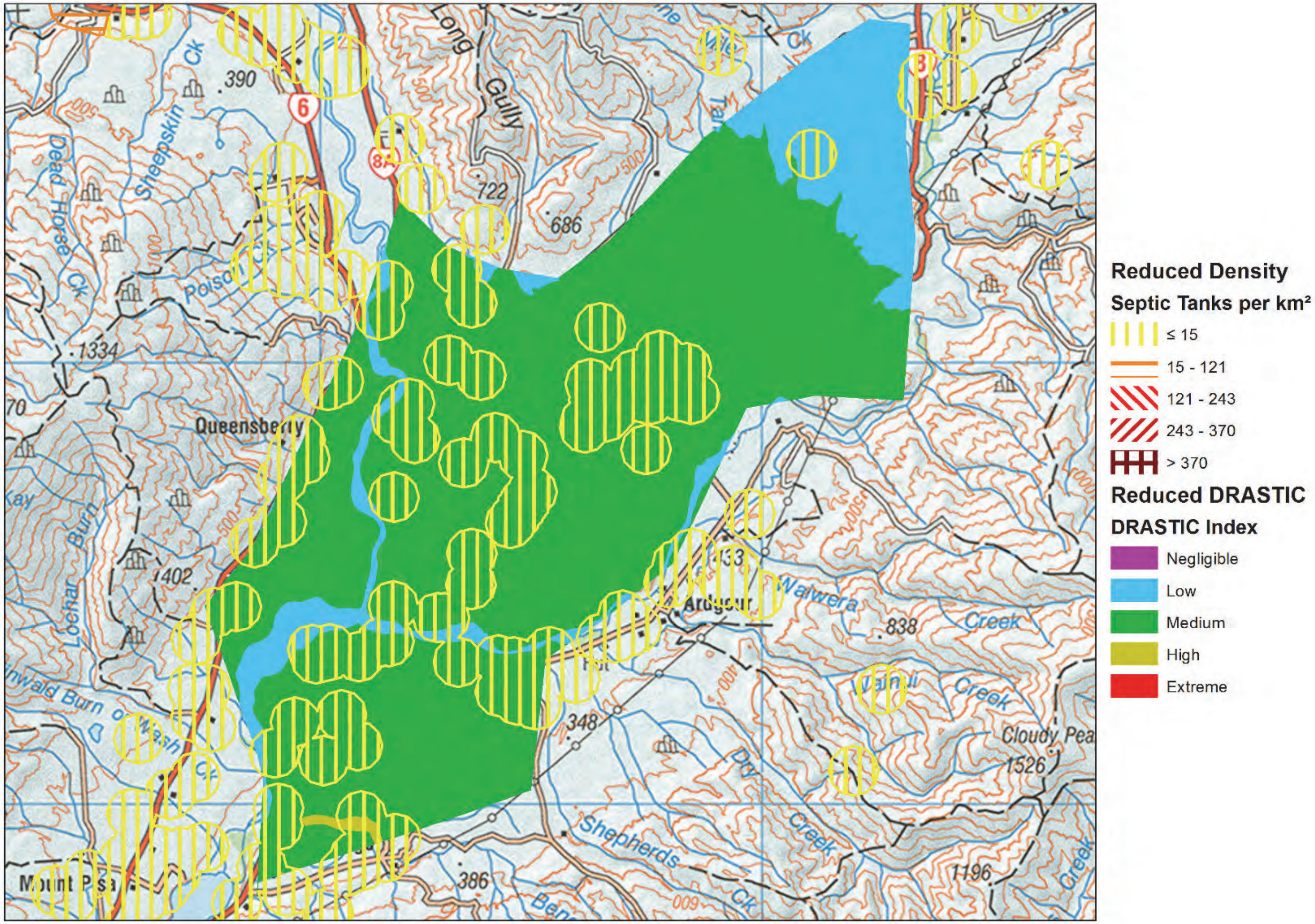

Figure E. 9 **Combined Mapping Bendigo - Tarras**

Otago Regional Council

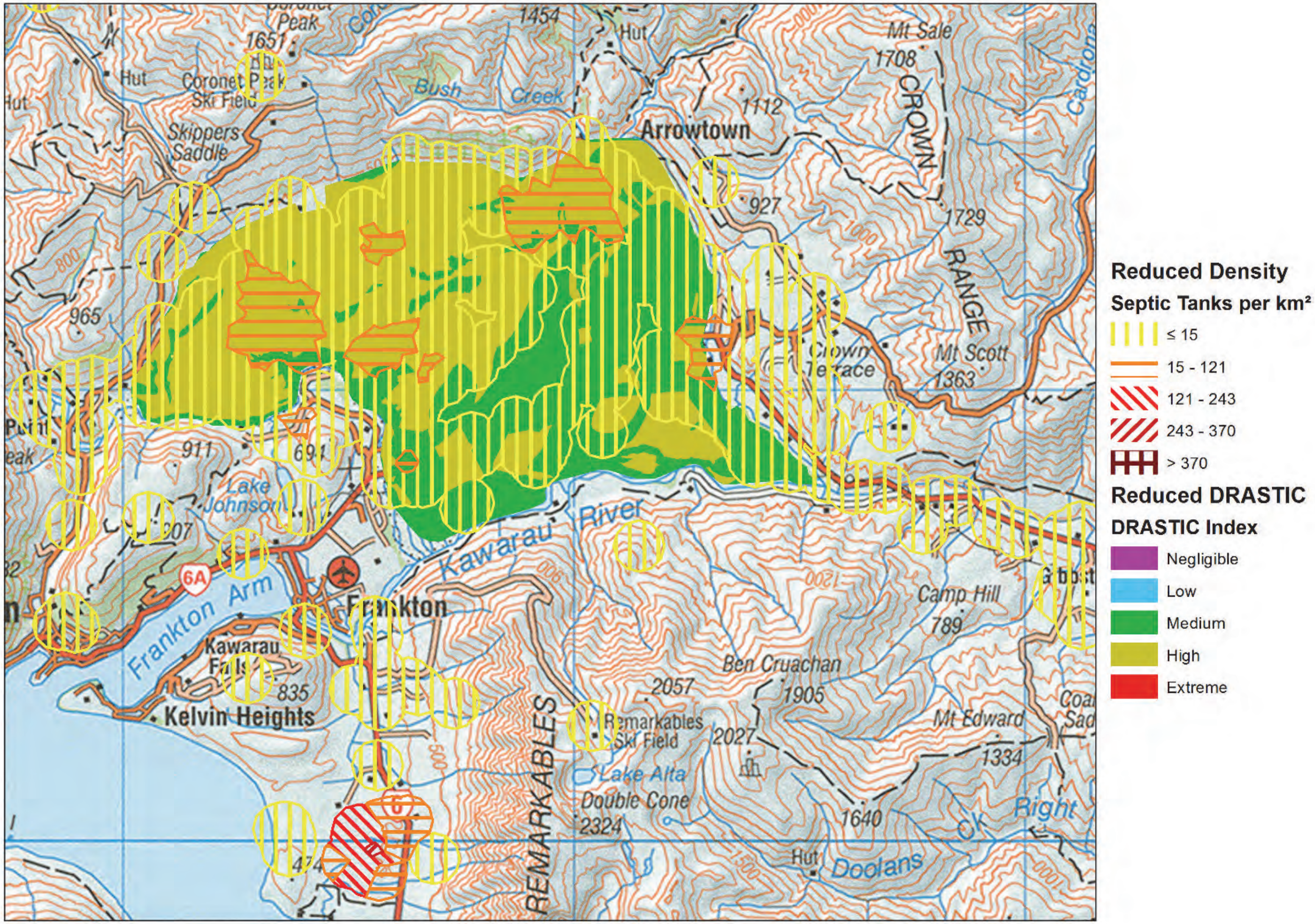

Figure E. 10 Combined Mapping Wakatipu Basin

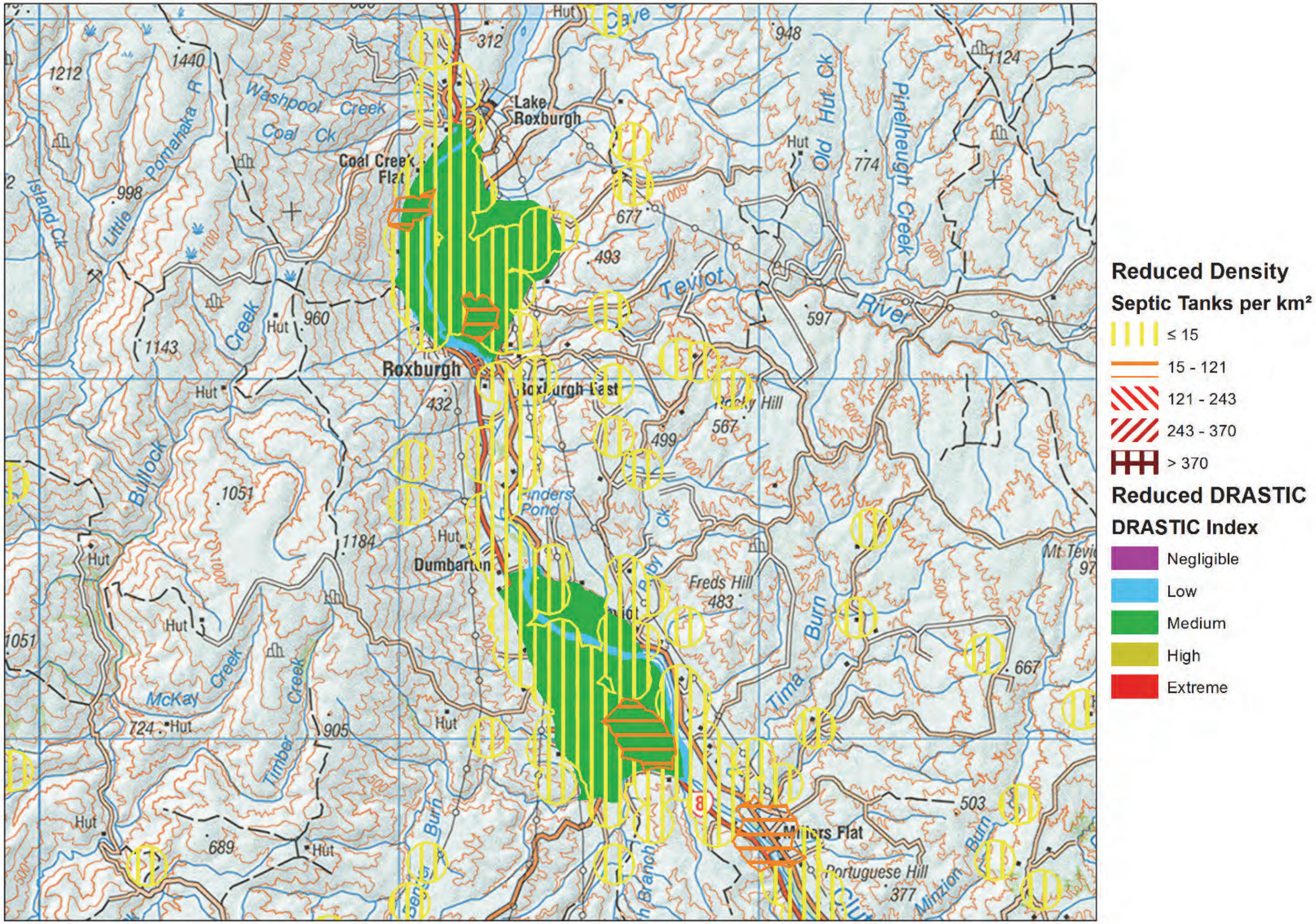

Figure E. 11 **Combined Mapping Roxburgh - Ettrick**

Otago Regional Council

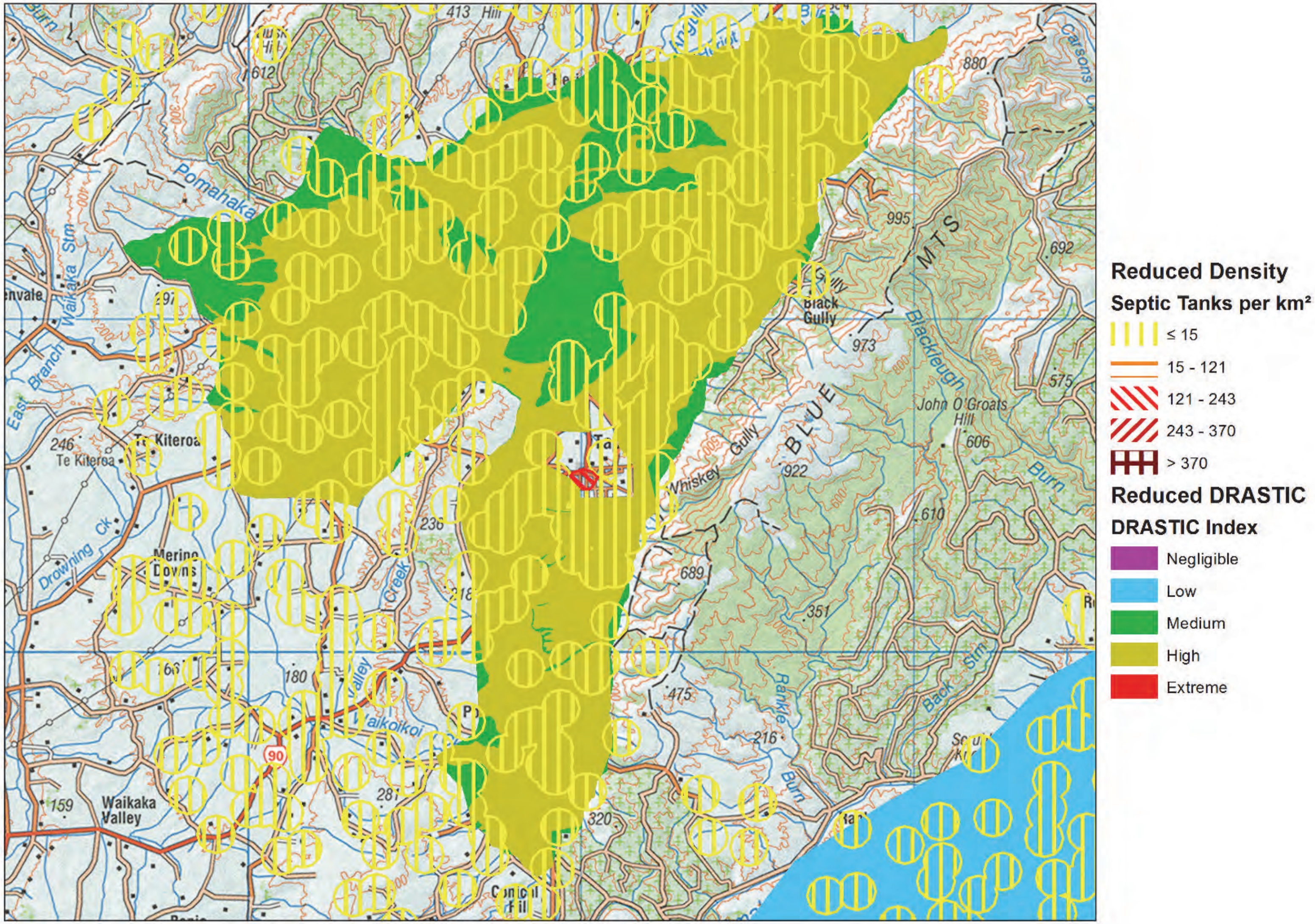

Figure E. 12 Combined Mapping Pomahaka

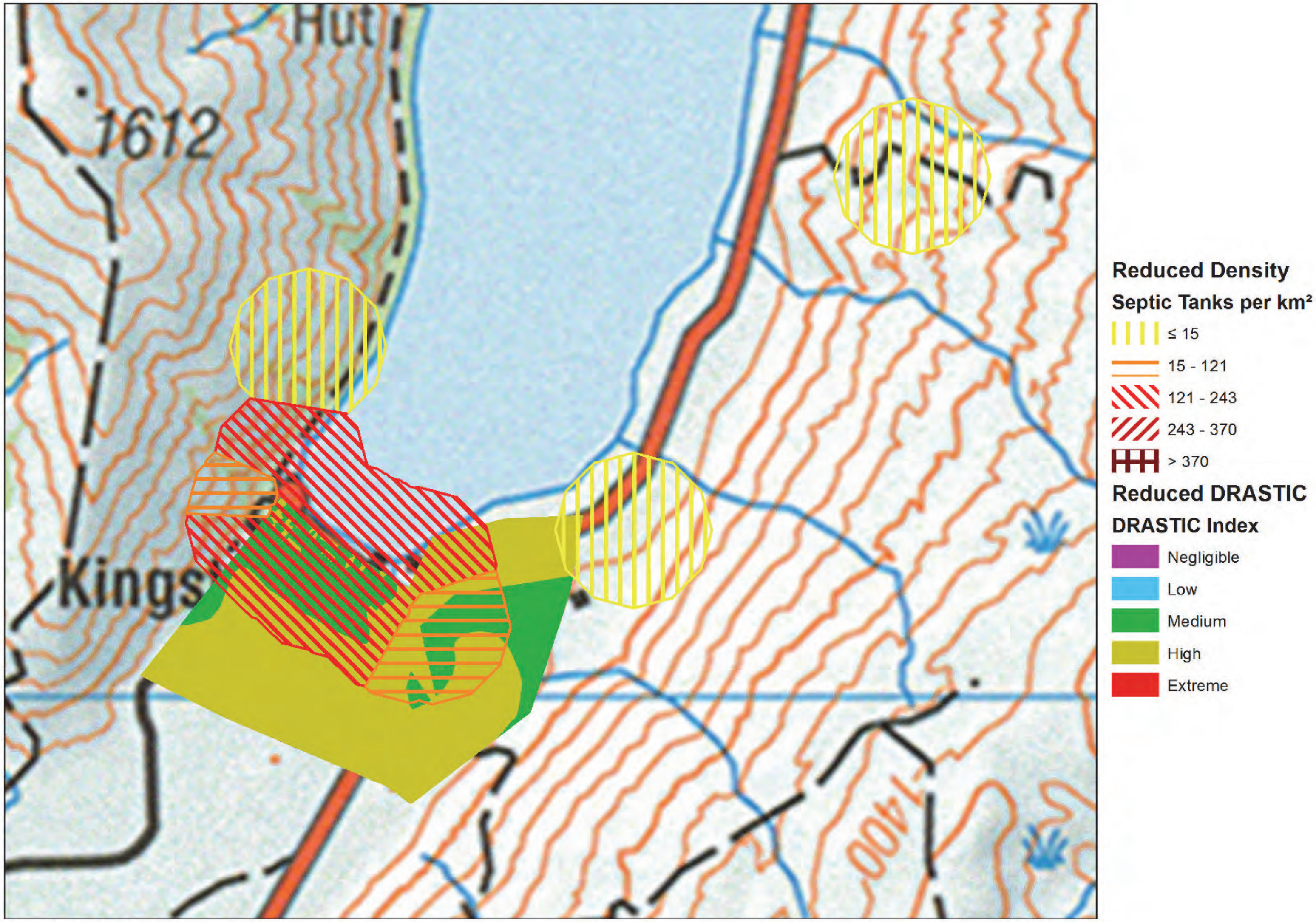

Figure E. 13 **Combined Mapping Kingston**

Appendix F – Sample Land Disposal Inspection Sheet

LAND DISPOSAL INSPECTION SHEET

Inspector:	**Date:**	**Consent:**
Last Audit Date:	**Compliance Certificate**	
Property Details		
Consent Holder:	**Land Owner:**	
Physical Location:	**Mailing address:**	
Town/District:	**Town/District:**	
Telephone:	**Mobile/e-mail:**	
Person spoken to (name and position):		
Map Ref:	**GPS:**	

Aerated:	
Tank odour:	
Field odour:	
Break out:	
Tank damage:	
Vehicle access:	
Clarity:	
Viscosity:	
Sludge discharge:	
Samples Taken:	
Management Plan:	
Estimated Discharge:	
Complaints received since last Audit:	

Other Comments: