AQUALINC

Water Management REPORT

# NEW ZEALAND GROUNDWATER ATLAS
## Groundwater Use and Drinking Water Supply Wells Serving More Than 100 People

**PREPARED FOR**
**The Ministry for the Environment (MfE)**

WL18027

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# EXECUTIVE SUMMARY


The purpose of this report is to present the approach and results of groundwater use in New Zealand for the Ministry of the Environment (MfE). This work was completed by Aqualinc Research Limited (Aqualinc) in consultation with GNS Science (GNS), and forms part of MfE's 'The New Zealand Groundwater Atlas' programme.

A key dataset forming the basis of the calculations is a GIS coverage of water use take consents. This work provides total groundwater use for different seasons and for different purposes comprising irrigation, municipal, industry, stock and permitted uses.

This report presents the results and describes the methodologies developed to estimate groundwater use for different purposes during the following time periods:

- Spring;
- Summer;
- Autumn;
- Winter;
- Annual total; and
- Peak use.

Seasonal irrigation groundwater use has been estimated based on irrigated area mapping that was developed previously by Aqualinc for MfE, groundwater consent data from MfE, and land use data. In addition, NIWA's Virtual Climate Network (VCN) and an estimate of potentially irrigable areas were used.

A range of assumptions have been applied, and are documented accordingly. This has led to the generation of national-scale raster data sets of estimated groundwater use (for different seasons) at the scale of NIWA's VCN grid (approximately 2,000-2,500 ha).

# 1 INTRODUCTION

MfE have requested the development of national-scale groundwater datasets of groundwater use estimates to inform future work streams related to the Environmental Reporting Act 2015 (Ministry for the Environment & Statistics New Zealand, 2016) and the National Policy Statement for Freshwater Management 2014 and 2017 (Ministry for the Environment, 2014; 2017), as well as to increase public awareness about groundwater. As part of the Groundwater Atlas programme, Aqualinc has prepared estimates of groundwater use in New Zealand for the following uses:

- Irrigation;
- Municipal;
- Industry;
- Stock; and
- Permitted.

This report presents the results and describes the methodologies and assumptions developed to estimate average groundwater use for the period 1973 to 2018 (44 irrigation seasons).

# 2 METHODOLOGY

A key dataset forming the basis of the groundwater use calculations is a GIS coverage of water use take consents. This was obtained from MfE's Data Service. Groundwater takes were extracted and grouped into the following dominant uses:

- Irrigation;
- Municipal;
- Industrial; and
- Stockwater

An allowance for permitted use (non-consented) was also provided. All surface water takes were excluded.

Groundwater irrigation use estimates were based on this consent information along with irrigated area mapping that was developed previously by Aqualinc for MfE (Dark *et al.*, 2017). In addition, the following datasets were also integrated into the calculations.

- Potentially irrigable areas;
- Land use; and
- NIWA's VCS coverage.

Different methodologies adopted to estimate seasonal groundwater use for different purposes are separately described below.

## 2.1 Irrigation Use

The groundwater consents database was intersected with the land use coverage and NIWA's VCS grid to assign a land use and VCS grid ID to each consent. The consents database did not include a field for actual irrigated area. Therefore, this was estimated by dividing the maximum groundwater take rate (in l/s) by 0.5 l/s/ha, which is a typical peak irrigation rate for most land uses within New Zealand. This resulted in a total irrigated area of approximately 805,000 ha, including irrigation from both surface water and groundwater sources. From Dark *et al.* (2017), the total irrigated area in New Zealand is estimated at approximately 794,000 ha, which is consistent with the estimate from the consents database. Of the 805,000 ha, approximately 437,000 ha is irrigated from surface water sources and 369,000 ha is irrigated from groundwater.

As part of the Groundwater Fluxes phase of the Groundwater Atlas project, Aqualinc's soil water balance model 'IrriCalc' was run for each of NIWA's VCS grid to calculate crop water use for four generic land cover types: pasture, arable crops, orchards and grapes. This was completed only for cells that contain 10% or more potentially irrigable area. The sum of groundwater consents that fall outside of these cells are relatively small.

The IrriCalc model uses the principles developed by the Food and Agriculture Organisation's method for daily soil moisture water balance modelling (Allen *et al.*, 1998). This modelling was completed from 1973-2018 (44 irrigation seasons) using climate data (rainfall and evapotranspiration) from NIWA's VCN grid. The model outputs include the minimum, maximum and average annual volumes, and average monthly volumes for a cell's combination of climate, soil and crop. Estimated irrigated areas and associated average monthly water use were used to report groundwater use for each VCS grid cell for each of the following categories:

- Spring;

- Summer;
- Autumn;
- Winter;
- Annual total; and
- Peak use.

## 2.2 Municipal Supply

Measured daily groundwater use for municipal supplies has been collated for Christchurch City, Motueka Plains and Waimea Plains. For each of these regions, the total municipal use was calculated for different components of time, as discussed above for irrigation use. The following assumptions have been applied:

1. Multipliers from the measured Christchurch City data were applied to groundwater takes for other larger cities, namely:
   - Auckland;
   - Waikato;
   - Bay of Plenty;
   - Gisborne;
   - Hawkes Bay;
   - Marlborough;
   - Canterbury;
   - Otago.
2. Averaged multipliers from Waimea and Motueka plains data were applied to groundwater takes for smaller towns, specifically:
   - Northland;
   - Taranaki;
   - Horizons Regional Council
   - Tasman;
   - Nelson;
   - West Coast; and
   - Southland.
3. Averaged multipliers from Christchurch City, Waimea and Motueka were applied to groundwater takes for Wellington, based on Wellington being larger than the above areas and smaller than the large cities.

This method was applied to groundwater takes noted for municipal supply. All municipal surface water takes have been excluded from the study.

### 2.2.1 Groundwater Supply Wells Serving More Than 100 people (by ESR)

Under a separate phase of the overall Groundwater Atlas project, the Institute of Environmental Science and Research (ESR) have generated a map of groundwater supply wells that serve more than 100 people. The methodology for this work, and the resulting map, is provided in Appendix B. This work was not used to generate estimates of groundwater use; rather, it has been included herein as it was sufficiently short not to warrant a stand-alone report. Any queries relating to this work should be directed to ESR.

## 2.3 Industrial Use

For the larger cities, measured groundwater data was available only for the combined use of both drinking and industrial in Christchurch City. For smaller cities measured groundwater industrial use was available for Motueka and Waimea. Those data were used to convert all consented takes into the above seasonal, annual and peak uses. The same assumptions as applied for municipal groundwater supply were adopted for industrial use.

## 2.4 Stockwater

Measured groundwater data for stock use was not available. Therefore, stockwater use (per hectare) has been estimated by applying the findings of Taylor (1996), assuming a peak summer use with reductions for other seasons. The following assumption have been applied:

1. An estimated use of groundwater for stockwater supply of 10% of the consented rate during summer.
2. For other seasons, stock groundwater use is less. 5% for winter and 7.5% for autumn and spring have been assumed.

## 2.5 Permitted Use

Permitted use is difficult to estimate as it is unmeasured. However, permitted annual use is expected to be relatively small compared to irrigation, municipal and industrial takes. Studies of permitted use estimates have been completed for Bay of Plenty, Waimea and Selwyn (Rutter, 2015; Weir & Thomas, 2018; Weir, 2018). For each of these areas, domestic groundwater use (in $m^3$/ha) were estimated from population statistics located outside of reticulated supply schemes. The annual pattern of use was estimated as a percentage of peak take for each month following a sinusoidal pattern derived from measured Christchurch City use, as shown in Figure 1.

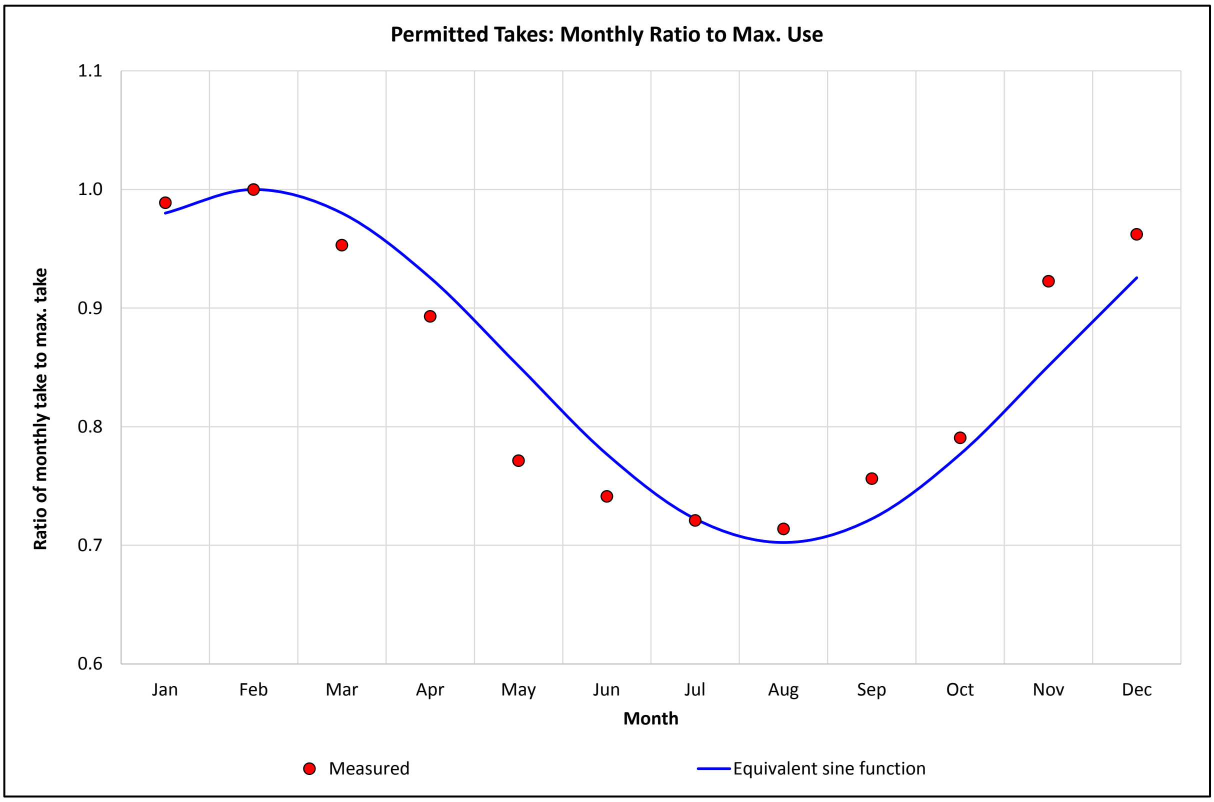


*Figure 1: Ratio of monthly take to maximum take (Weir & Thomas, 2018)*

Assuming this monthly distribution of use, seasonal, annual and peak uses were estimated.

The permitted groundwater use has only been estimated within the potentially irrigable areas, as it is assumed that domestic use outside of these areas is primarily sourced from surface water. The potentially irrigable area coverage was intersected with NIWA's VCS grid to estimate irrigable area (ha) inside each VCS grid cell. These areas were then multiplied by the seasonal and annual multipliers to estimate use volumes. The following assumptions were applied:

1. Data from Waimea was applied to smaller towns in the South Island.
2. Data from the Selwyn district was applied to rural South Island areas.
3. Average data from both Selwyn and Bay of Plenty were applied to the North Island.

## 2.6 Total Use

The combined groundwater use for all uses considered (irrigation, municipality, industrial, stockwater, permitted use) has been summed for each VCS grid cell for the annual, peak and season categories. This has then been translated into GIS raster files for visualisation and supply.

# 3 METHODOLOGIES THAT DID NOT WORK

Initially, an attempt was made to assign unique irrigated areas to each consent (both surface water and groundwater) from the irrigated area coverage (developed previously by Aqualinc for MfE; reported in Dark *et al.*, 2017). To achieve this, the irrigated area and consents coverages were intersected. However, over half of the consented takes were located well outside of an irrigated area polygon and could not be linked directly. As an alternative, the groundwater consents located outside an irrigated area polygon were then assigned to the nearest polygon, regardless of the distance between them. However, this resulted in many consents with distances many kilometres away from an irrigated area polygon, which would have introduced large uncertainty.

In an attempt to improve this, land parcel information was also introduced. Land ownership was grouped by owner, regardless of the property location, and then spatially joined to the consents coverage. This enabled a link between groundwater consent location and land owner where owners may have several properties serviced from a single consent. However, this resulted in little gain in accuracy, and was eventually abandoned.

# 4 RESULTS

Figure 2 shows average annual groundwater use (in million m³/year) for different regions over New Zealand. From this, the dominant groundwater use occurs in Canterbury. Compared to Canterbury, groundwater use in some other regions are almost negligible (e.g. Gisborne and Nelson).

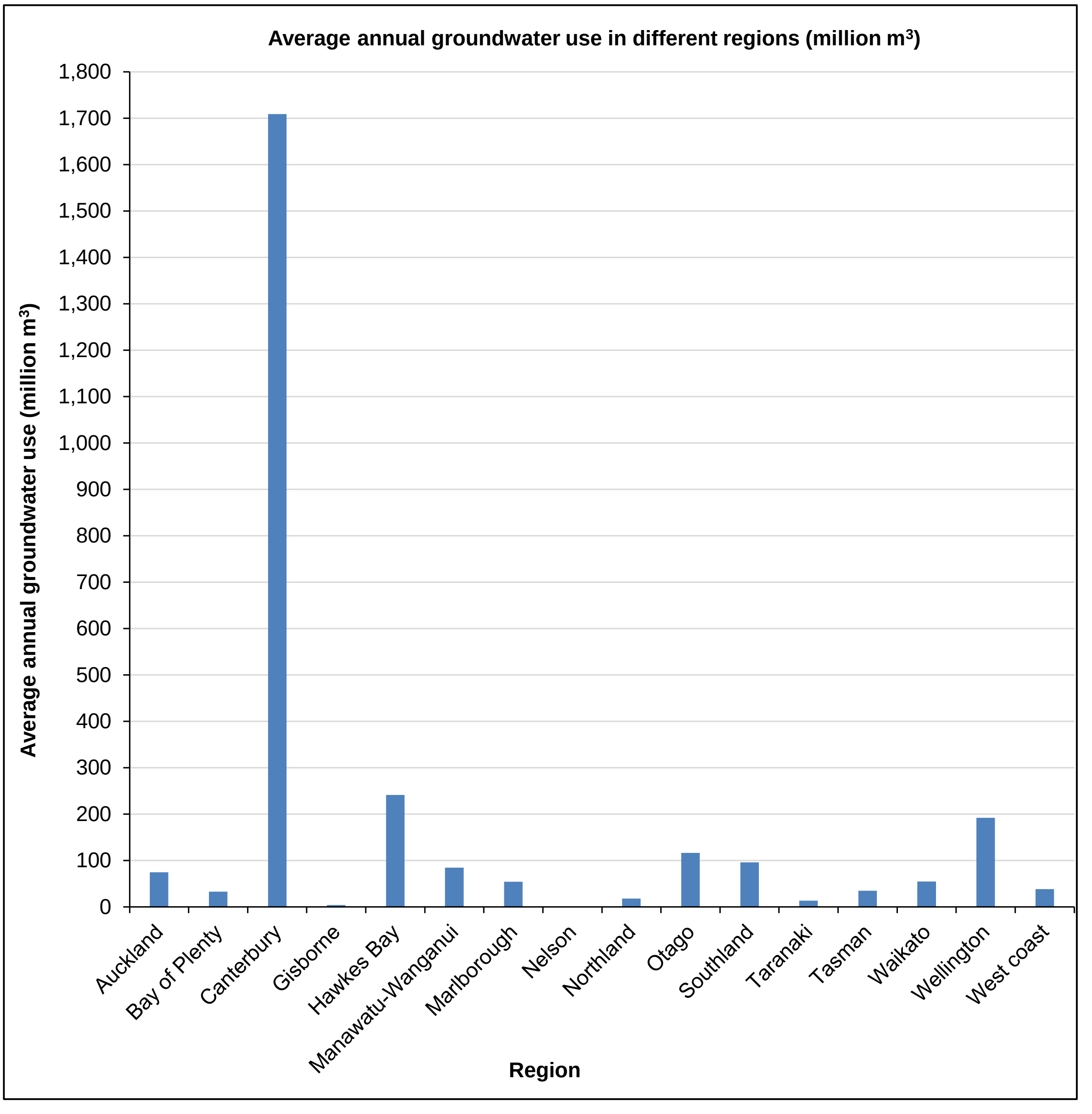


*Figure 2: Average annual groundwater use in different regions of New Zealand*

Figure 3 demonstrates the percentage share of national average annual groundwater use in different regions. Canterbury accounts for almost 62% of the total groundwater use, followed by Hawkes Bay with nearly 9%, then Wellington at 7%. The annual use for all other regions combined accounts for 22% of the national average groundwater use.

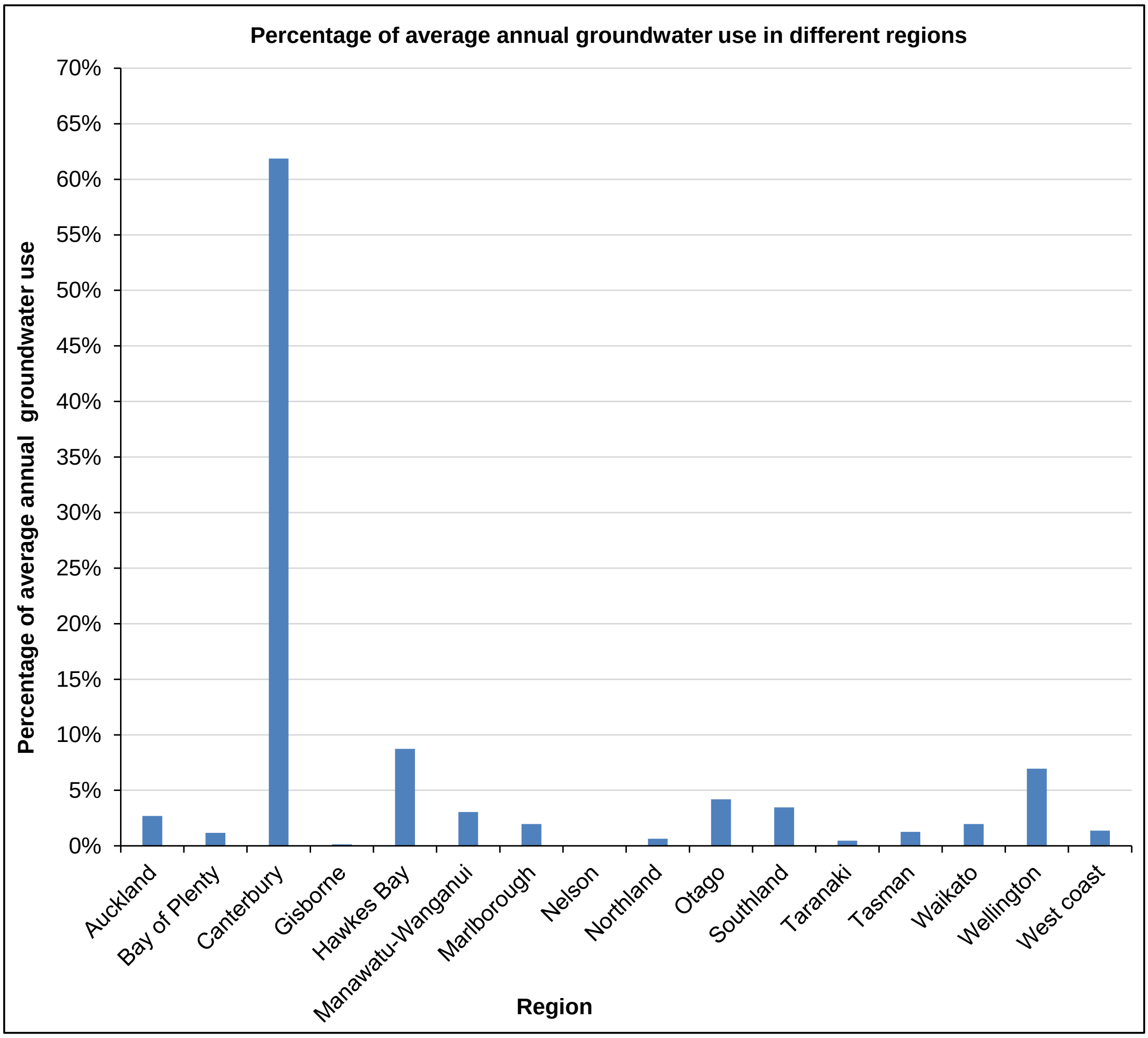


*Figure 3: Percentage of total average annual groundwater use in different regions*

Raster images of groundwater use are provided in Appendix A for all six categories: peak use, annual average, and spring, summer, autumn and winter averages). These GIS raster files are provided to MfE as an attachment to this report.

# 5 RECOMMENDATIONS

All information available to the project has been used to estimate seasonal groundwater use as best as possible for different purposes. However, due to limitations in the measured data, various assumptions have been applied. The influence of these assumptions can be substantially reduced by the use of additional measured data for all use types. It is therefore recommended that additional water use records be collated and used to refine these calculations. For example:

- Measure time-varying groundwater use separately for different sectors and regions throughout New Zealand;
- Measure and investigate the proportion of total consented stock water use in different seasons and regions; and
- Measure and investigate the permitted water use in different sectors, seasons and regions of New Zealand.

# 6 REFERENCES


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## Appendix A: Groundwater use for different categories

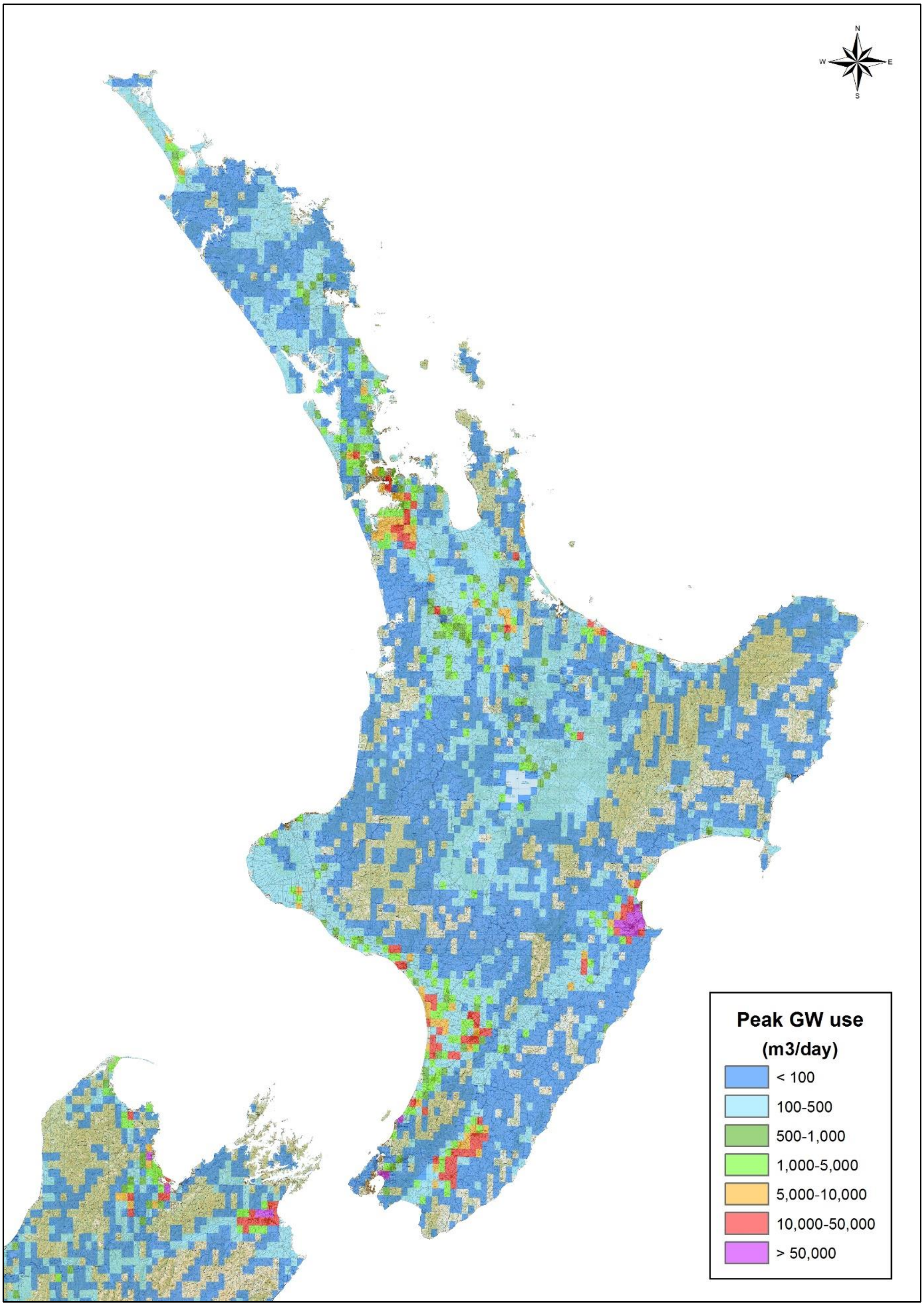


*Figure 4: Peak groundwater use in the North Island*

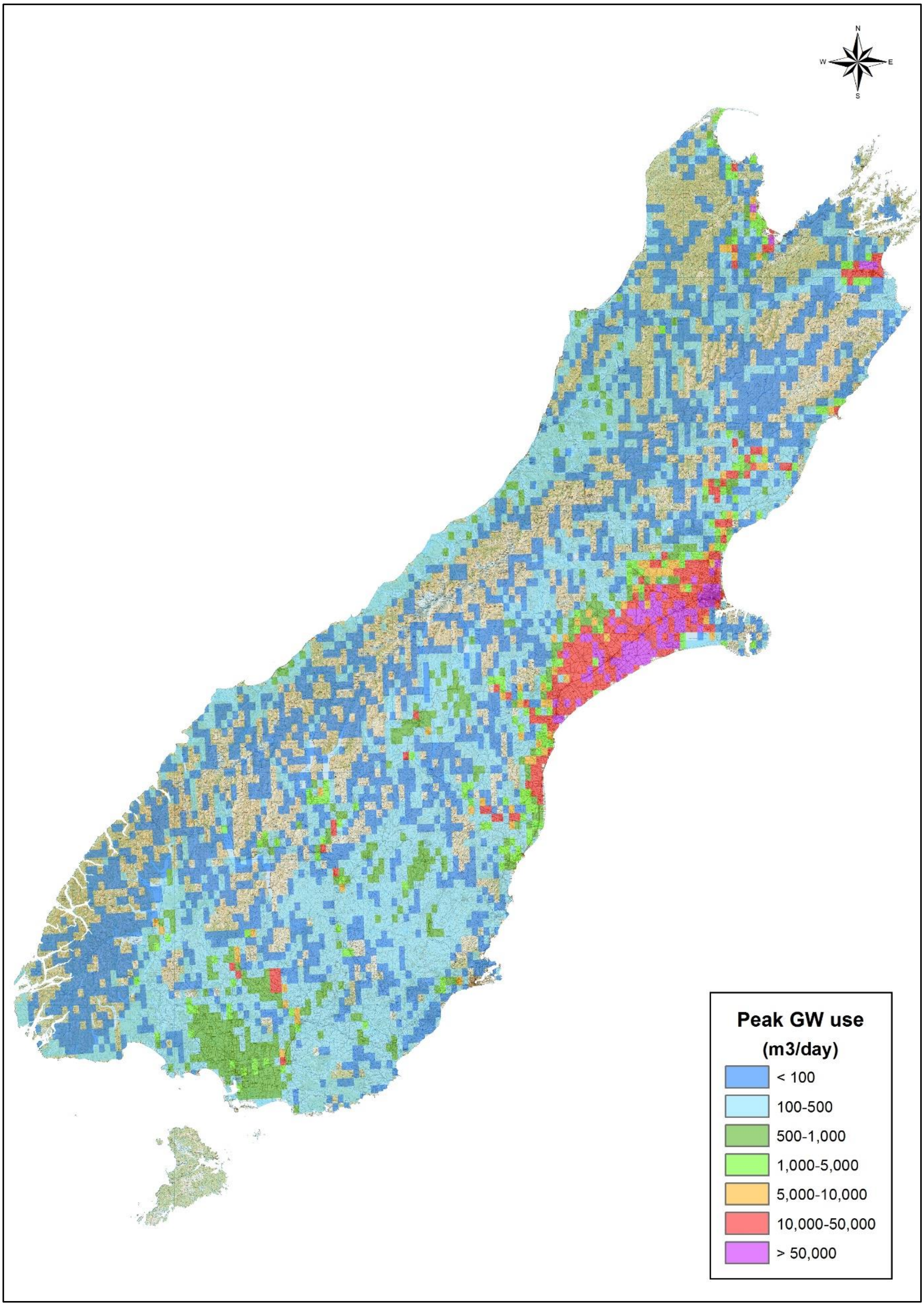


*Figure 5: Peak groundwater use in the South Island*

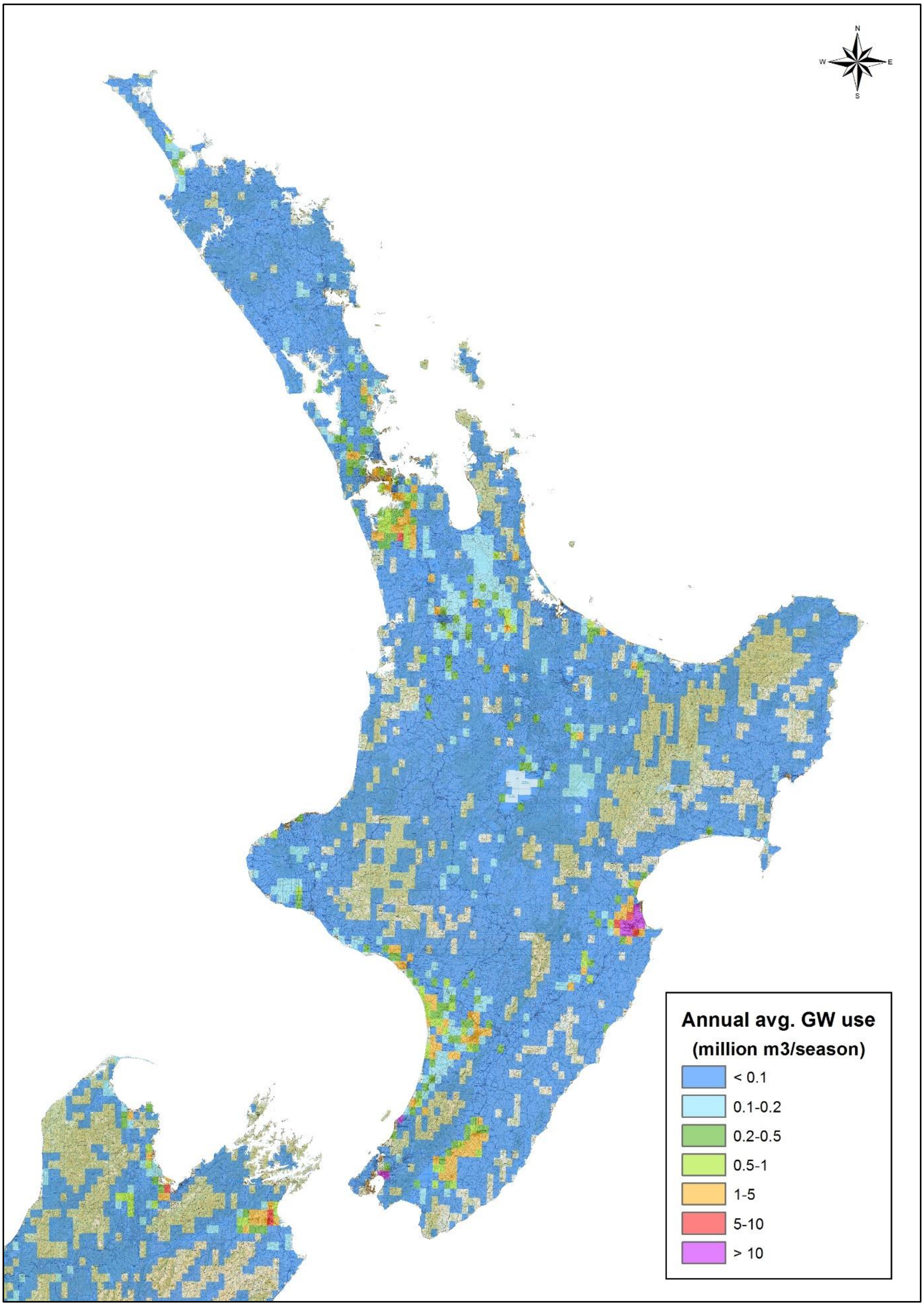


*Figure 6: Annual average groundwater use in the North Island*

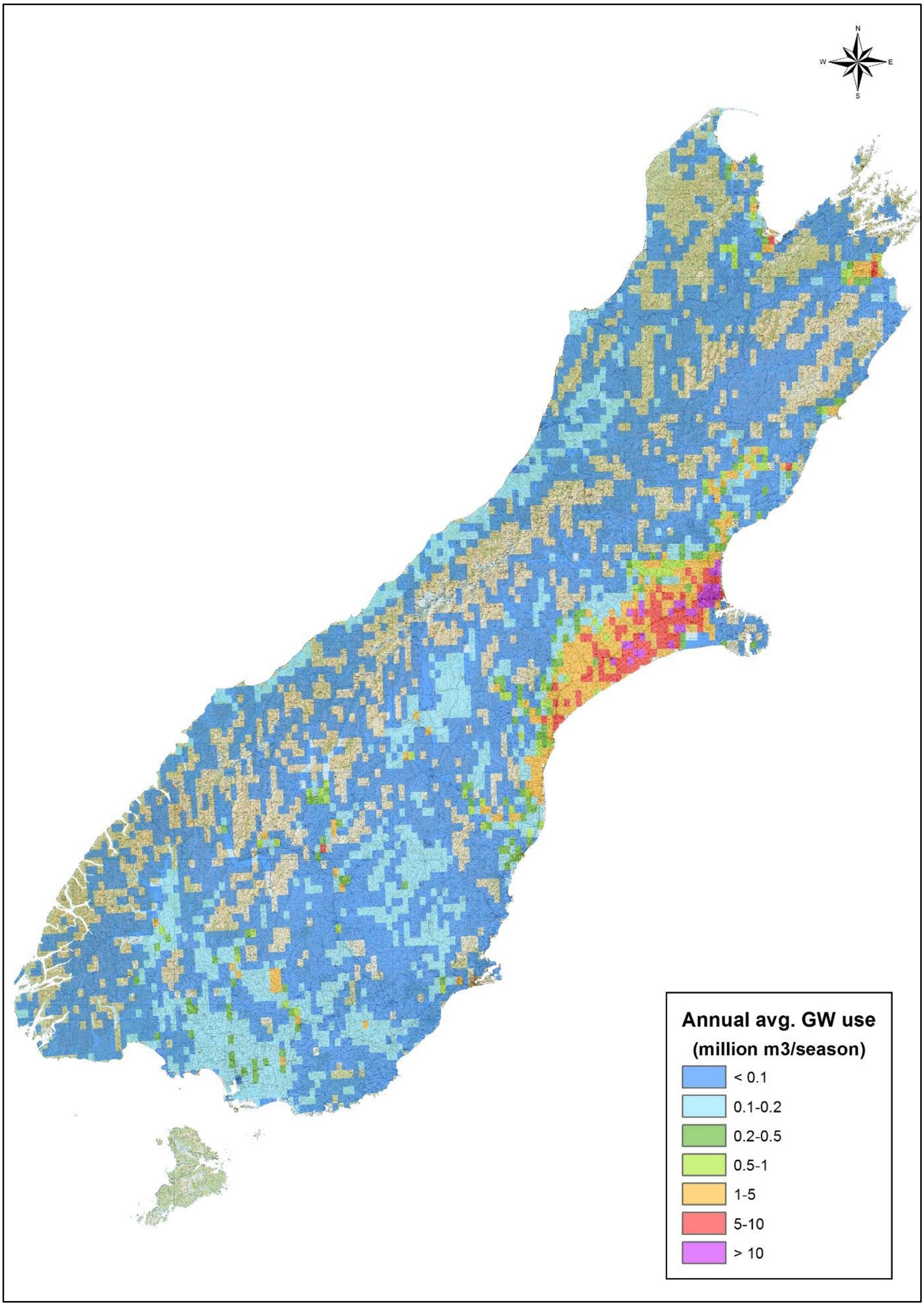


*Figure 7: Annual average groundwater use in the South Island*

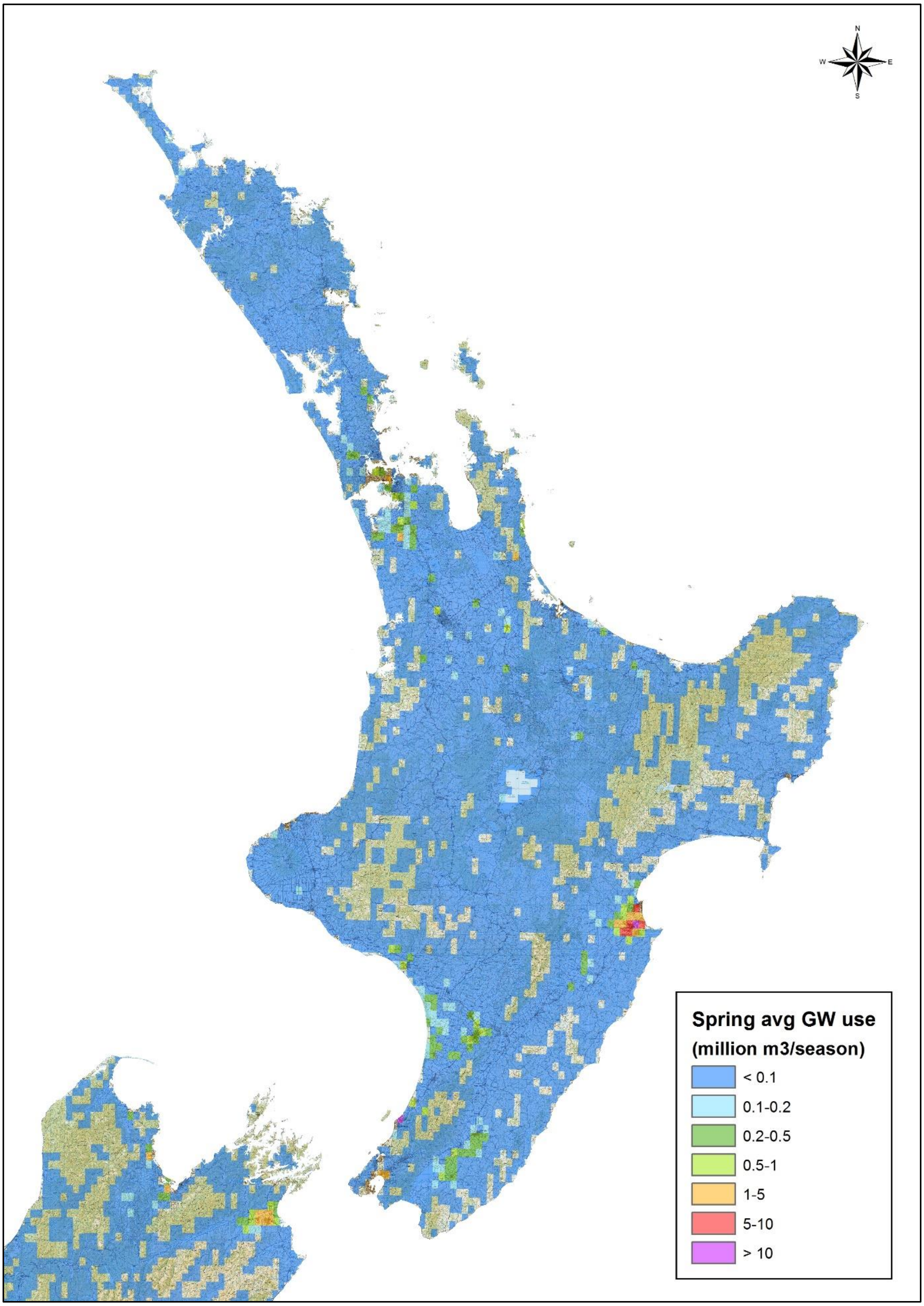


*Figure 8: Spring average groundwater use in the North Island*

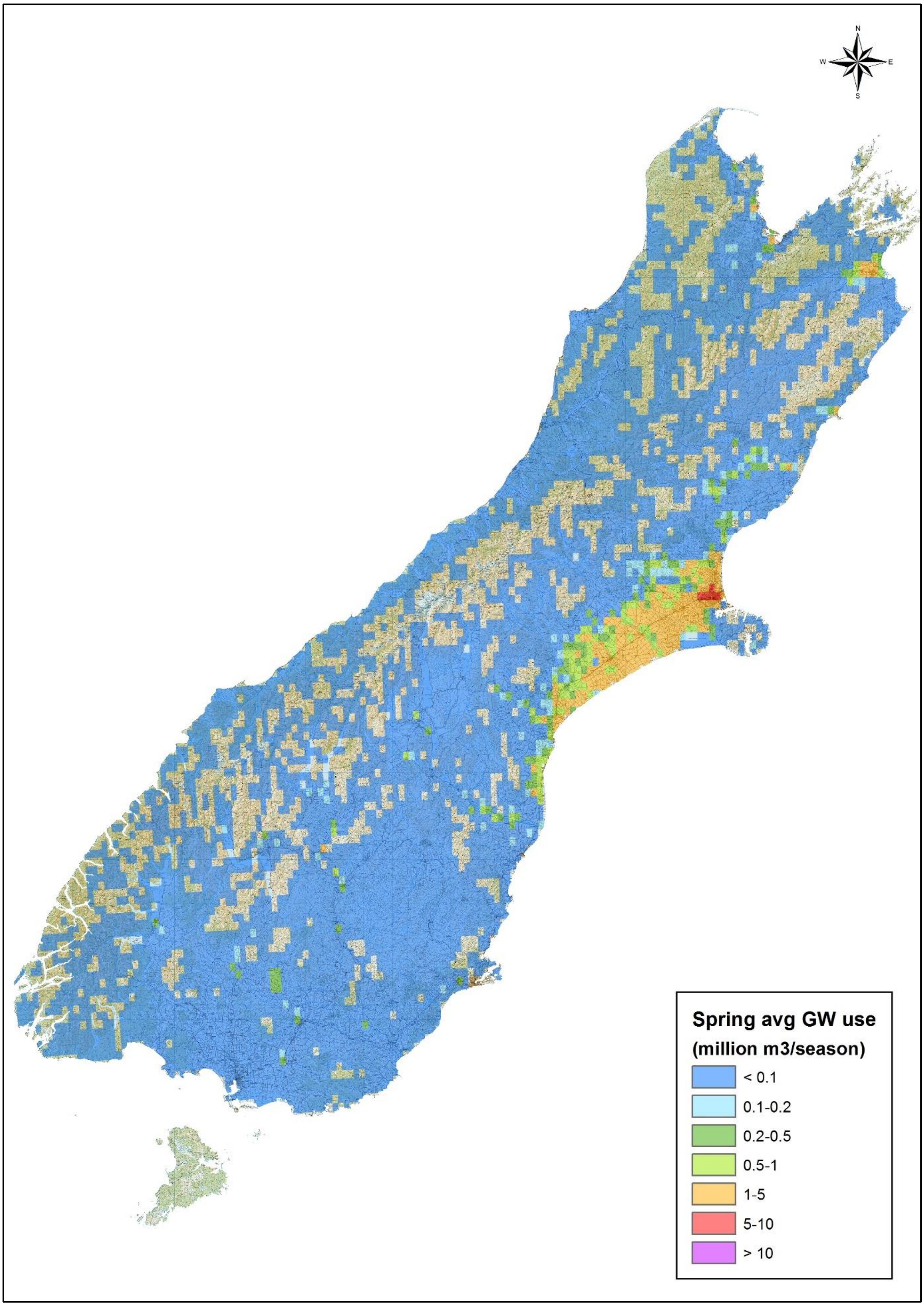


*Figure 9: Spring average groundwater use in the South Island*

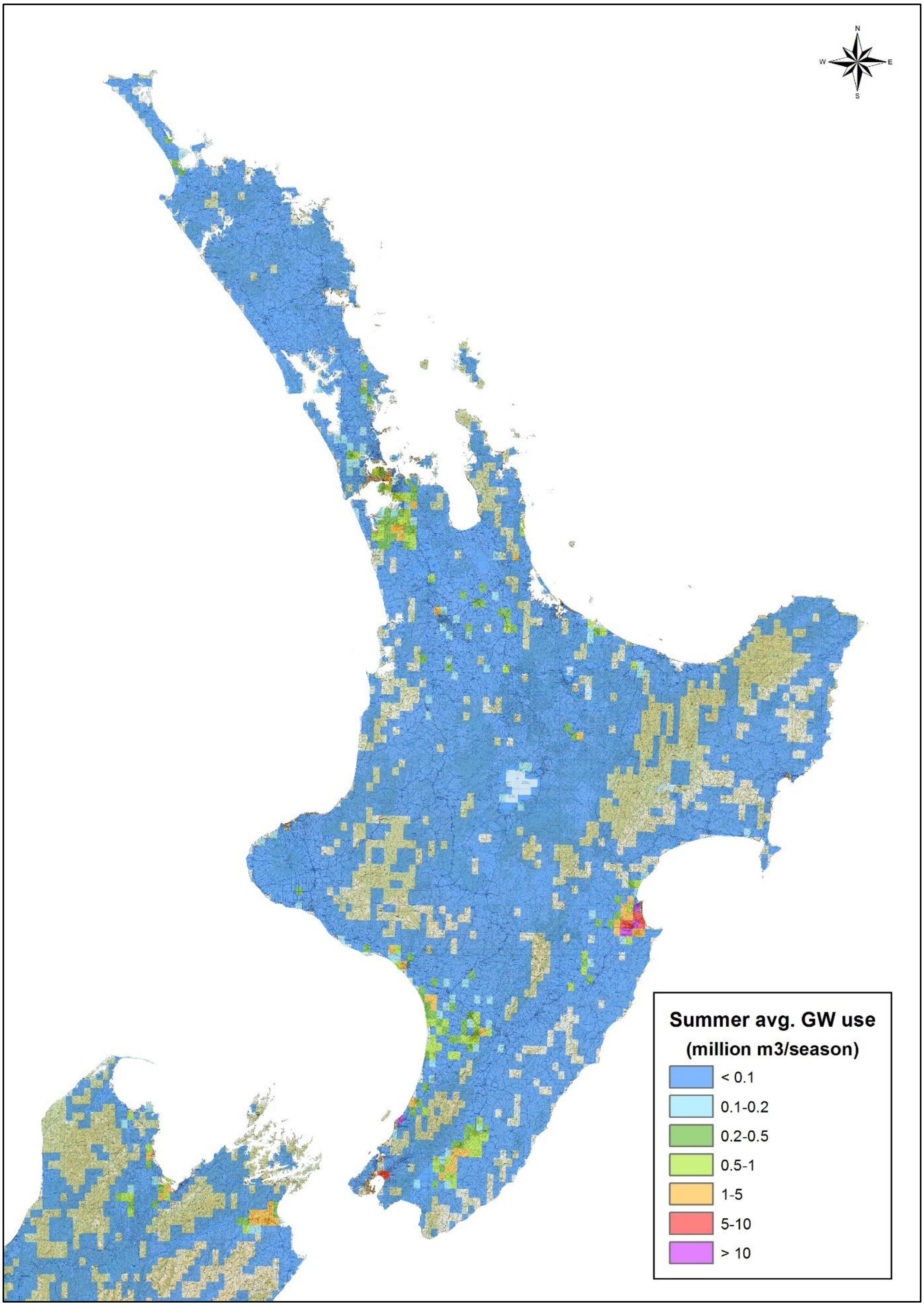


*Figure 10: Summer average groundwater use in the North Island*

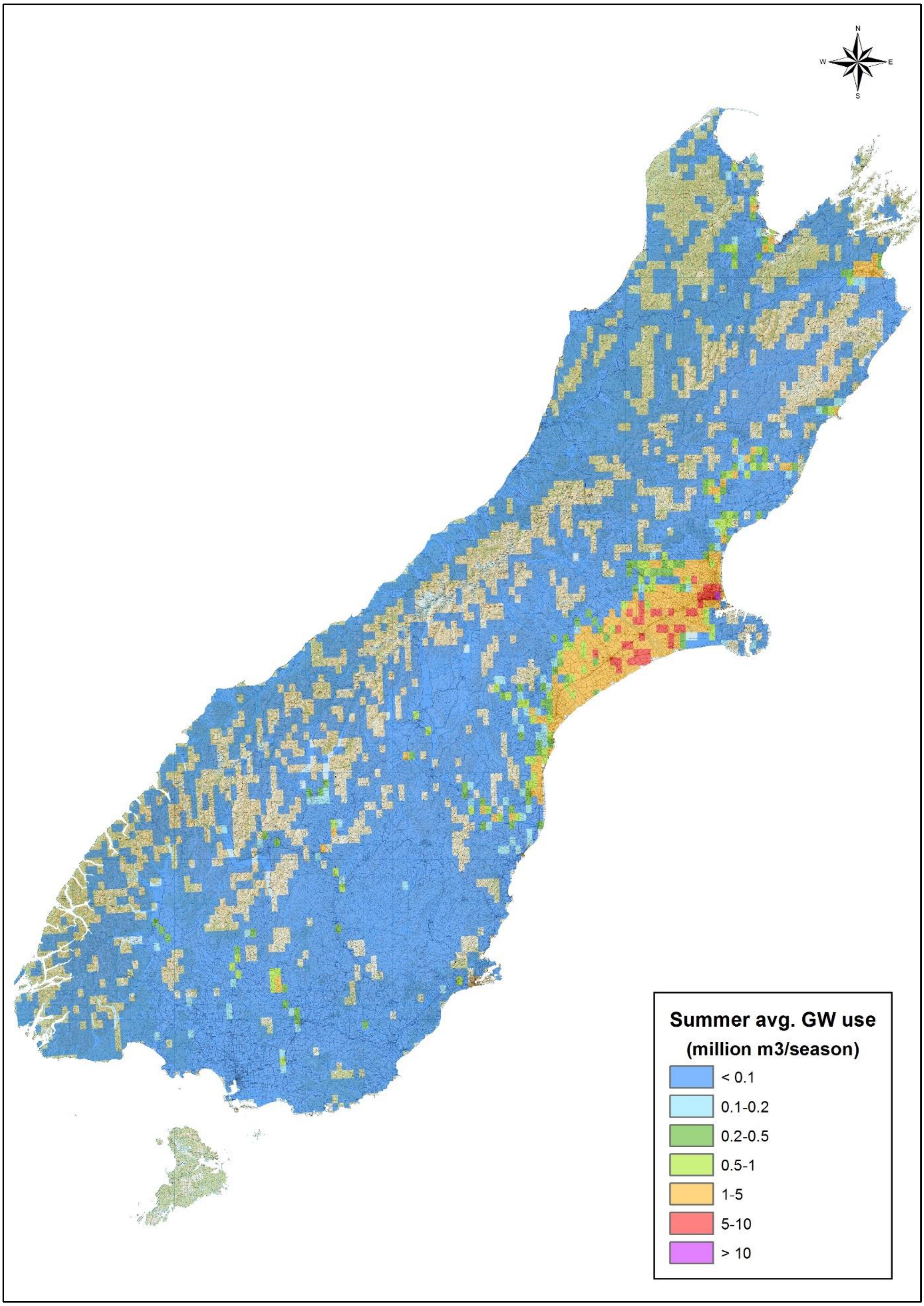


*Figure 11: Summer average groundwater use in the South Island*

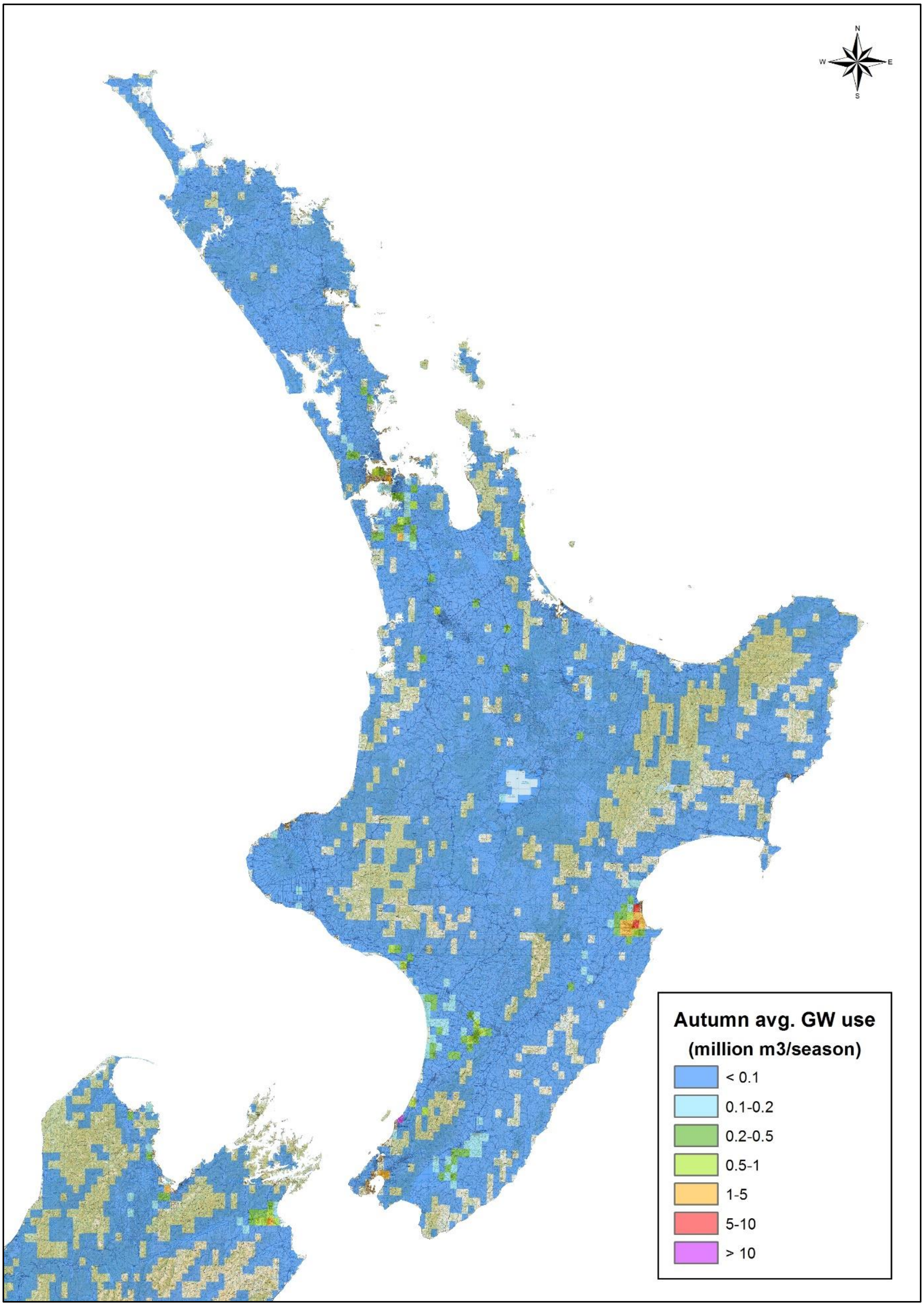


*Figure 12: Autumn average groundwater use in the North Island*

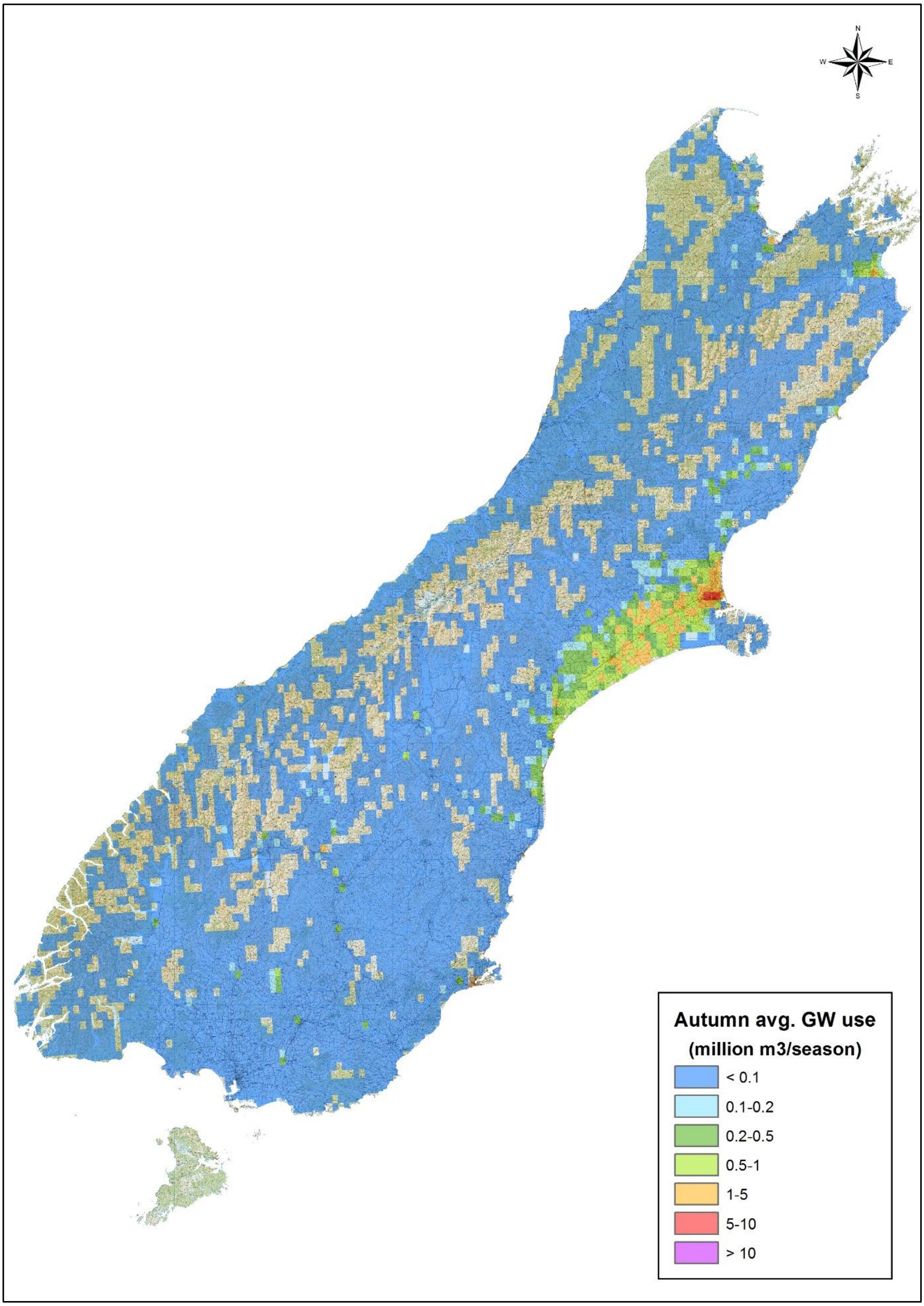


*Figure 13: Autumn average groundwater use in the South Island*

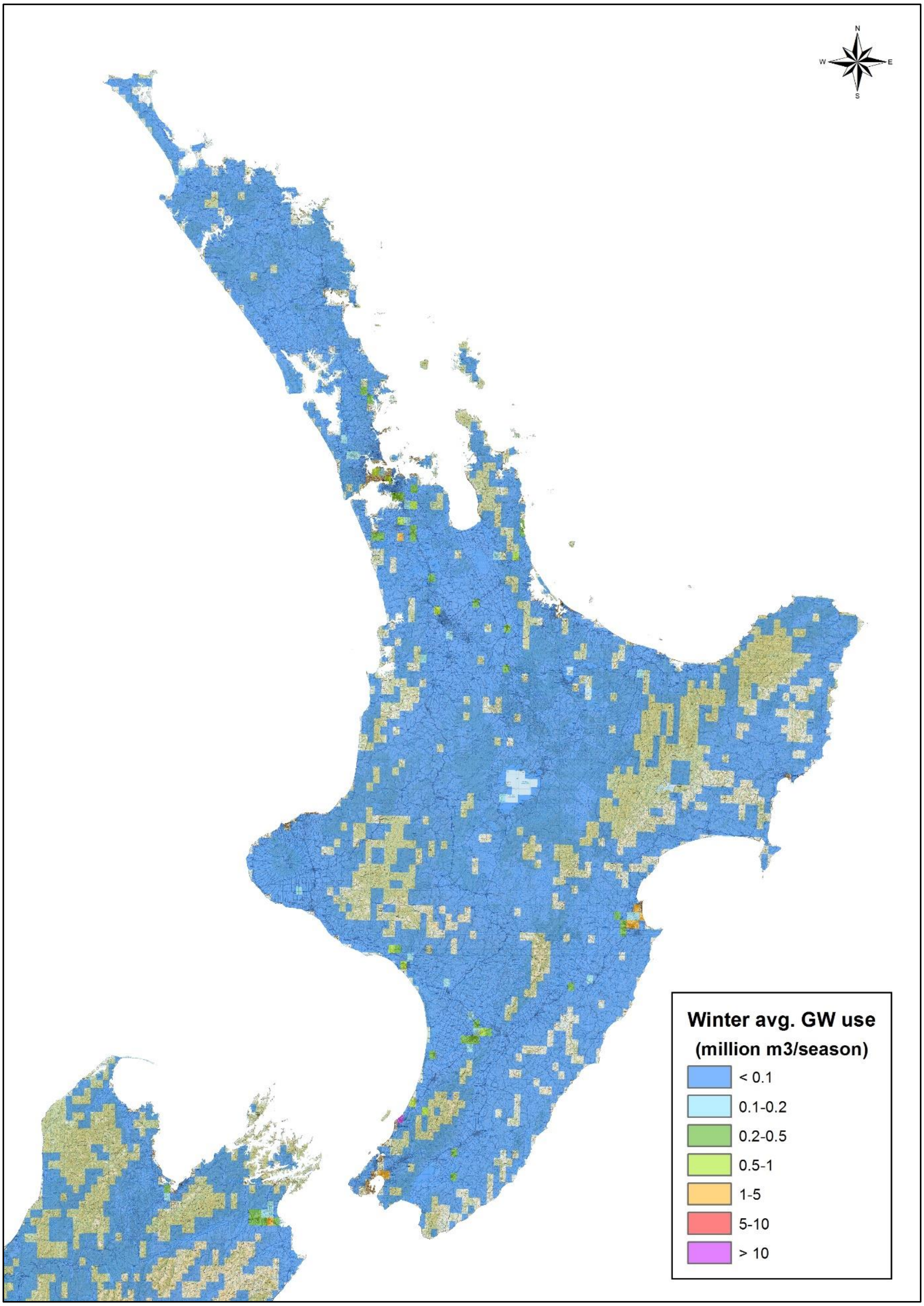


*Figure 14: Winter average groundwater use in North Island*

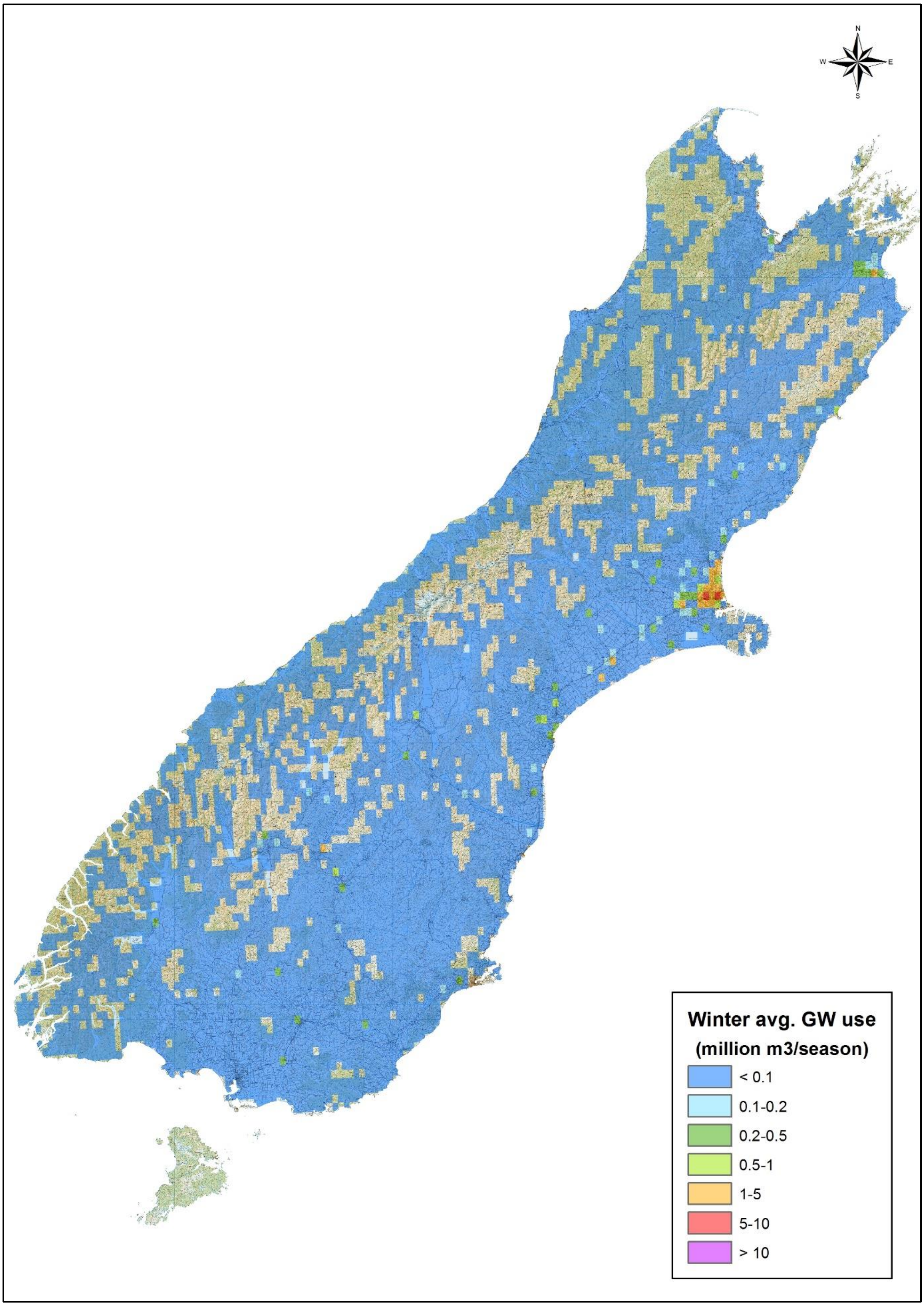


*Figure 15: Winter average groundwater use in the South Island*

# Appendix B: Drinking water supplies (prepared by ESR)

# 1. Preparation of National map of drinking water supply wells

Murray Close, Barry Mattingley and Laura Banasiak
Institute of Environmental Science and Research (ESR)

## 1.1. Background

As part of a project that GNS Science is undertaking for the Ministry for the Environment (MfE) to produce a 'New Zealand Groundwater Atlas', ESR was asked to provide a national map of drinking water supply wells serving > 100 people, including a shapefile, metadata and associated datasets. These data were extracted from the Water Supply Information databases that ESR currently maintains for the Ministry of Health.

## 1.2. Extraction of data from databases

There are currently two databases relevant to the drinking water supply wells: Water Information New Zealand (WINZ) and DrinkingWater Online (DWO). WINZ was the national dataset of drinking water supplies from its origins in 1998 through to 1 July 2017. It is now archived data. DWO replaced WINZ on 1 July 2017. All Networked supplies serving 25 people or more were migrated but Self Supplies and Specified Self-Supplies were not migrated. Therefore, for this project, networked supplies were extracted from DWO, using current data at 29 August 2018, while Self and Specified Self supplies were extracted from the archived (2017) WINZ data. The two lists were collated in an Excel Spreadsheet together with additional notes describing the data. One comment of relevance is that a source may represent multiple individual bores in some cases.

The lists of wells from each database were combined, input into GIS and a map (Figure 16) and a shapefile produced. This GIS shapefile and an excel spreadsheet are provided as an attachment to this report.

We are aware that in some situations the locations of some wells in the WINZ or DWO may not be the same as the location given for a well in the LAWA database. In these situations, the location given in the LAWA database should be used as the more reliable location for the well.


*Figure 16: National map of drinking water supply wells serving > 100 people (prepared by ESR)*