Applied Spatial Analysis and Policy (2024) 17:951–962
https://doi.org/10.1007/s12061-024-09571-0

# Examining the Structural Inequities in the Quality of Nationwide Drinking Water Data in Aotearoa New Zealand: A Geospatial Cross-Sectional Study

**M. Hobbs[1,2] · M. Puente-Sierra[1,2] · L. Marek[1,2] · J. M. Broadbent[3] · T. Chambers[4]**

Received: 12 September 2023 / Accepted: 9 February 2024 / Published online: 28 February 2024
© The Author(s) 2024

## Abstract

High-quality geospatial data are required to examine how the places in which we reside, work and play determine health outcomes; however, seldom is the quality of nationwide geospatial data reported. We examined the quality of geospatial data of public drinking water distribution zones (WDZ) across all territorial authorities in Aotearoa New Zealand to investigate structural inequities in data quality. In our national dataset of WDZ, we identified several differences in the quality of geospatial information that are associated with the population, area-level deprivation, ethnicity and most of all urban/rural classification. Our research highlights structural data inequity, which may undermine efforts to reduce health inequity.

**Keywords** GIS · Geospatial · Spatial · Data equity · Inequity · Environment · Water · Data

## Introduction

Globally, and in Aotearoa New Zealand (NZ), structural inequities and environmental injustice continue to undermine the health and wellbeing of underserved populations (Hobbs et al., 2019; Marmot, 2005, 2015). These persistent inequities have led to lower income and life expectancy, poorer education and health outcomes and

M. Hobbs and M. Puente-Sierra joint first authorship.

✉ M. Hobbs
matt.hobbs@canterbury.ac.nz

[1] Faculty of Health, Te Kaupeka Oranga, University of Canterbury, Te Whare Wānanga O Waitaha, Christchurch, Otautahi, New Zealand

[2] GeoHealth Laboratory, Te Taiwhenua O Te Hauora, University of Canterbury, Te Whare Wānanga O Waitaha, Christchurch, Otautahi, New Zealand

[3] Sir John Walsh Research Institute, Faculty of Dentistry, University of Otago, Dunedin, Otago, New Zealand

[4] Department of Public Health, University of Otago, Wellington, New Zealand

stigmatisation within health care among underserved populations (Hobbs et al., 2019). However, the continued attribution of inequity to downstream causes such as individual health behaviours, psychosocial resources or social status ignores significant upstream drivers such as economic, political and legal systems (Braveman, 2006; Minister of Health 2023).

One seldom-considered upstream driver of inequity is data inequity. Key tenets of data equity are that individuals, communities and policy-makers have access to meaningful and accurate data to enable informed decisions to reduce health risks (Mays et al., 2022). In the NZ context, data equity is central to the Government upholding its obligations under the Treaty of Waitangi, which guarantees Māori (NZ indigenous population) rights to health equity, among other rights. Data equity is also of vital importance to Māori to hold the Government to account and express tino rangatiratanga (self-determination) (Reid et al., 2017).

The reliable supply of safe drinking water is vital for the health of human populations as reflected in the United Nations Sustainable Development Goals (United Nations, 2022). Despite this, NZ has experienced major threats to its public drinking water. In 2016, a water-related campylobacteriosis outbreak made much of an entire town sick (~8,000 people), with 58 hospitalisations and four deaths (Wilson et al., 2021). Recent research has also raised concerns around the rising nitrate contamination of public drinking water (Richards et al., 2022), while other research has highlighted systematic flaws in delivery of community water fluoridation programmes (Chambers et al., 2022). Until compiled by the current authors, a nationally consistent geospatial database of water distribution zones (WDZ), the area supplied by a water supply, had not existed (Puente-Sierra et al., 2023).

There can be no health equity without data equity. High quality geospatial data underpin many analyses examining the impact of place on health, or in this context, the potential impact of water quality on human health (Desjardins et al., 2023; Hobbs & Atlas, 2019). Geospatial analyses enable the identification of health needs to inform system strengthening interventions and can help to identify localised gaps in service provision, masked by national or regional averages (Dotse-Gborgbortsi et al., 2018). Despite this, if the underlying data is not equitable in terms of access and quality then resources may be allocated inappropriately and those already suffering worse inequities may receive differential performance of services. This short communication examines potential inequities in the access to and quality of geospatial data for public drinking water supplies in NZ by sociodemographic characteristics.

## Methods

The study design is a cross-sectional audit of national geospatial data on WDZ in NZ. The audit involved grading our previously compiled geospatial data on WDZ on metrics relating to access and quality (Puente-Sierra et al., 2023). We assessed the potential data equity implications by relating our scorecard against the population numbers, proportion of residents by ethnicity and area-level deprivation and urban and rural classification of territorial authorities. Ethical approval was granted by

the University of Otago Human Ethics Committee (Health) (reference HD22/115) and Māori consultation was undertaken with the Ngāi Tahu Research Consultation Committee (reference 23679_20221114).

### Water Distribution Zones Dataset

The two key data sources used in this study were 1) a newly curated consistent nationwide dataset of water distribution zones (WDZ), which are linked to meshblocks across NZ (Puente-Sierra et al., 2023); and 2) the original source data provided for each area, which required adjustment prior to being incorporated into the validated dataset. The validated dataset is what marks our gold-standard comparison for the geospatial data in this study. In this study, the validated existing spatial information on WDZ from publicly-owned schemes varied in consistency due to, for instance, differences between the 67 territorial authorities responsible for the majority of drinking water provision in NZ (Puente-Sierra et al., 2023). The workflow of validating the data consisted of five steps which are outlined in more detail here (Puente-Sierra et al., 2023). However, we were able to use these two data sources to compare the validated and nationally consistent data to the original source data received from each area in the study.

### Study Design

Cross-sectional geospatial study.

### Data Access and Quality

To grade the data access and quality we developed a scorecard to individually grade each of the 67 territorial authorities as seen in Table 1. Data access was determined by whether the data was available online, and if so, whether it was view-only or downloadable. Data quality was determined against five criteria: 1) the format in which the spatial data was provided; 2) the completeness of WDZs against the drinking water register (Arowai, 2023); 3) the accuracy of the WDZ codes and names in the file's attribute tables relative to the drinking water register; 4) the severity of the adjustments to and of GIS files; and 5) the presence of mixed-use rural water supplies. Outlined in detail previously (Puente-Sierra et al., 2023), mixed-use water supplies involved substantial and unresolved uncertainty around the estimated resident population of people in that area who were on public or private water supply.

### Sociodemographic Factors

A range of sociodemographic data were obtained in order to examine differences in the quality of the geospatial data. The factors that were used in this study were: total population, ethnicity, area-level deprivation and urban/rural classification.

**Table 1** Data access and quality criteria and their definitions

| Score | 0 (Worst) | 1 | 2 | 3 (Best) |
|---|---|---|---|---|
| Data access | | | | |
| Online availability | No spatial data online | - | Online to visualise | Online to download |
| Data quality | | | | |
| Format supplied | No data provided | .jpeg,.pdf,.xlsx or .docx | GIS line (pipes) and/or multiple polygons (rateable properties) files | GIS polygon file (WDZ) |
| WDZ completeness | No data provided | More than 2 WDZ added/erased | 1 or 2 WDZ added/erased | All WDZ present |
| Accuracy of attribute table | Do not include WDZ codes nor names as per the drinking water register[16] | Only include WDZ names as per the drinking water register[16] | Includes WDZ codes but some were outdated and did not match those at the drinking water register[16] | All match WDZ codes and names as per the drinking water register[16] |
| GIS file adjustments | Created new or major adjustments (more than 35% of the source material surface) | Minor adjustments (less than 35% of the source material surface) | No adjustment required | - |
| Uncertainty on the estimates of people within WDZ | Presence of mixed-use water supplies | - | No presence of mixed-use water supplies | - |

First, total population was defined based on population data from the Usual Resident Population in the 2018 Census (Census place summaries, 2018). This was obtained for each of the 67 territorial authorities. Second, for ethnicity, Māori population data were obtained from the Usual Resident Population from the 2018 Census (Census place summaries, 2018) for each of the 67 territorial authorities in NZ, and the percentage of Māori among the total population was then calculated for each of these areas. Third, data on area-level deprivation were obtained for each meshblock from the 2018 New Zealand Deprivation Index (Atkinson et al., 2019). We calculated a population-weighted deprivation score for each territorial authority by multiplying the population in each deprivation decile by its corresponding decile value. Then we divided the sum of these multiplied deprivation values by the total population in that territorial authority. Fourth, urban/rural classification was based on the Statistics New Zealand Urban Rural classification (Statistics New Zealand, 2018) that differentiates areas that share common urban or rural characteristics: major urban areas, large urban areas, medium urban areas, small urban areas, rural settlements, rural others and inland waters. For the purposes of this study, the 4 first categories have been aggregated as "urban" and the last 3 as "rural". The urban/rural spatial data from 2018 was linked to the meshblock 2018 Usual Resident population and, by considering the percentage of addresses (LINZ. Address data., 2023) that each urban/rural area captured, a number of people living in each classification of urban/rural was estimated, and later processed by territorial authorities boundaries to get the total and relative numbers of people living in both urban and rural areas in each.

### Statistical Analyses

We examined the relationship between geospatial data quality score and our sociodemographic variables using Pearson's correlation coefficient in Microsoft Excel. We considered a correlation coefficient of less than 0.1 as a small or negligible effect, 0.3 as a moderate effect and 0.5 as a large effect. A p-value of 0.05 was used to determine statistical significance.

## Results

The individual scores for the 67 territorial authorities across NZ were created using the scorecard outlined in Table 1 (see online supplementary materials for scores for each territorial authority). As shown in Fig. 1, a final range of scores was from 2 (worst quality data) to 16 (best quality data) across territorial authorities. The histogram shows the frequency of each score with 8 and 12 being the most common scores, while 2, 14 and 16 only appear once.

Figures 2, 3, 4 and 5 present the association between geospatial data scores and territorial authority-level sociodemographic characteristics. The figures include a bubble for each territorial authority, with a size that varies according to the total

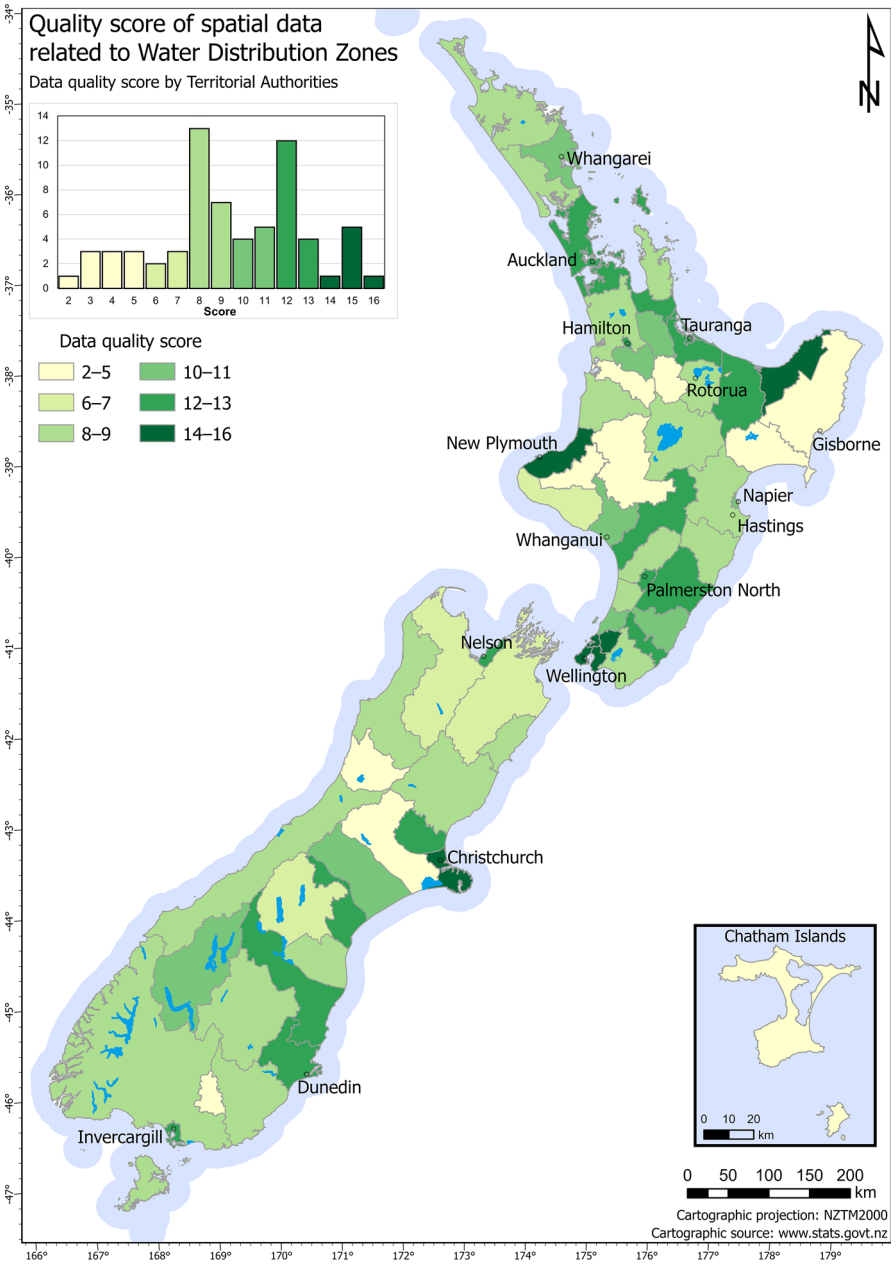



**Fig. 1** National map of data access and quality scores for spatial data related to drinking water distribution zones

population (except from Fig. 2 where population is the variable in the y-axis). Figures 2, 3, 4 and 5 also include a colour gradient that shows the proportion of the population that resides in a rural area (except from Fig. 3 where that is the variable

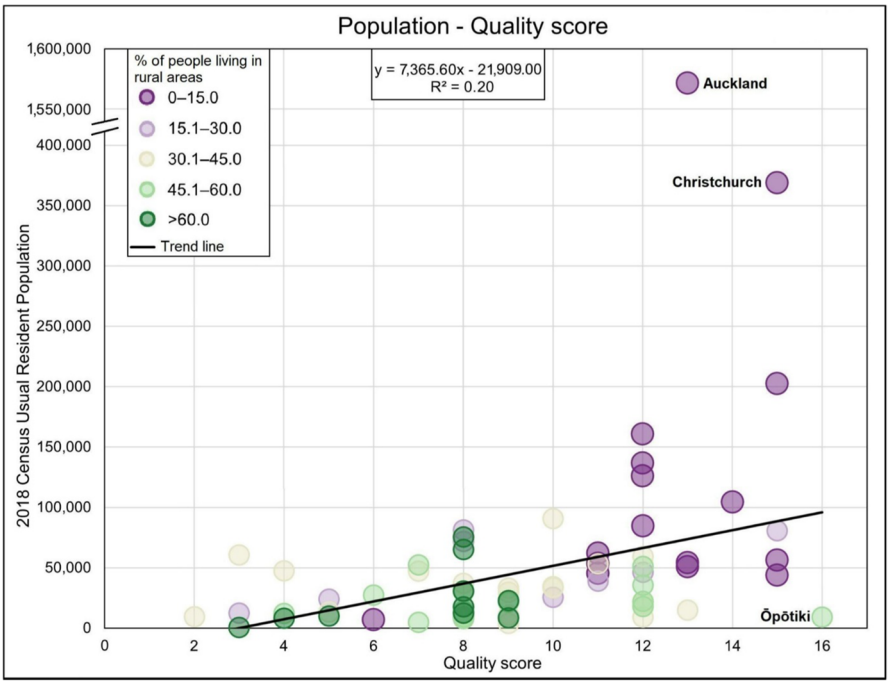



**Fig. 2** The 2018 Census Usual Resident Population by quality score (colour gradient of bubble indicates percentage of people living in rural areas)

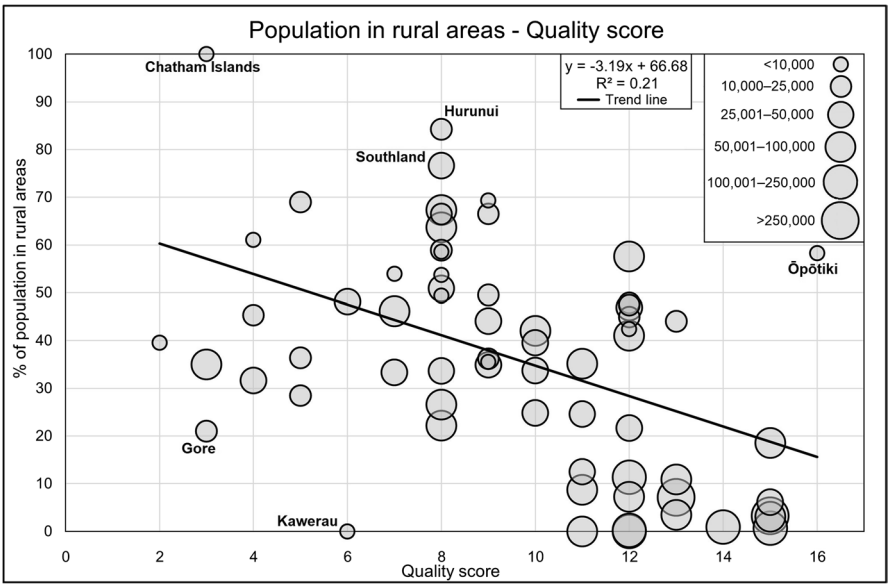



**Fig. 3** The percentage of people who reside in rural areas by geospatial data quality score (size of bubble indicates population size)

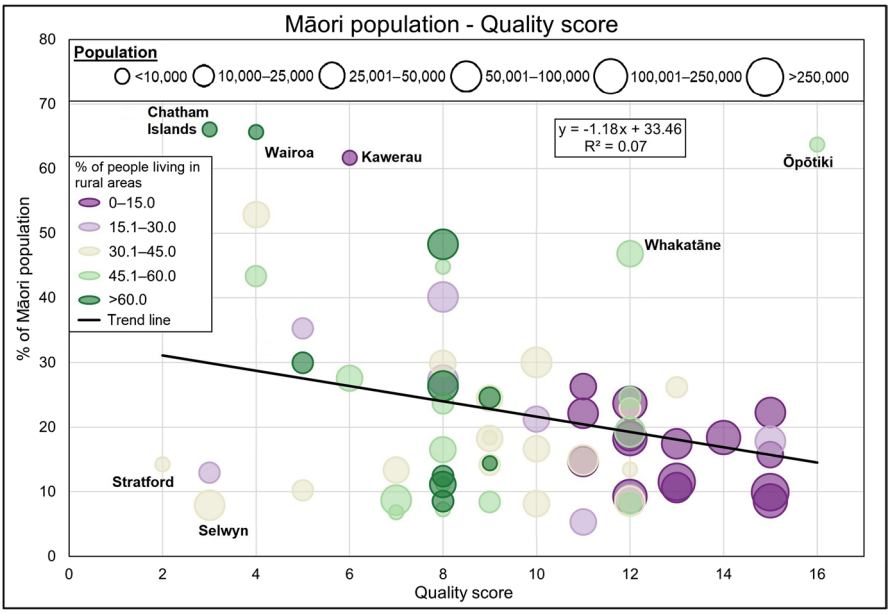



**Fig. 4** The percentage of the population who are Māori by geospatial data quality score (size of bubble indicates population size and colour gradient indicates percentage of people in rural areas)




**Fig. 5** The weighted average deprivation decile by geospatial data quality score (size of bubble indicates population size and colour gradient indicates percentage of people in rural areas)

in the y-axis). Finally, the figures include a trend line to represent the association between the quality score and factor of interest.

Figure 2 shows a positive correlation between geospatial data quality score and total population ($R^2 = 0.20$, p-value = 0.000). In Figs. 3, 4 and 5 there is a negative correlation between the geospatial data quality score and the percentage of population who live in rural areas ($R^2 = 0.21$, p-value = 0.000), percentage of Māori population ($R^2 = 0.07$, p-value = 0.031) and weighted average deprivation decile ($R^2 = 0.06$, p-value = 0.056). Interestingly, there are several outliers who are either outperforming or underperforming in terms of geospatial data quality relative to the expected scores by sociodemographic characteristics.

## Discussion

This study examined potential inequities in the access to and quality of geospatial data on public drinking water in NZ. Our findings showed that geospatial data were generally of poorer quality in smaller rural areas than in larger urban areas. To a lesser extent, there were also minor differences with lower data quality in areas of higher proportions of people living in deprivation and Māori than in areas of low deprivation and non-Māori.

Results in this study corroborate international evidence which has demonstrated inequities in geospatial data availability and quality (Dotse-Gborgbortsi et al., 2018; Lechner et al., 2014). For instance, recent evidence from the USA showed how the spatial and temporal resolution and uncertainty in data are not uniform with some places and populations having more precise data than others (Spielman et al., 2014). More specifically, the reliability of the American Community Survey data was strongly dependent upon the economic conditions of the tract measured; poor census tracts yielded lower quality estimates (Folch et al., 2016). For African American median household income, more than 75% of all census tracts in the USA failed to meet the NRC "reasonable" standard of precision (Spielman et al., 2014). Other research has shown variation in data quality across the urban rural classification with poorer quality data in suburbs versus urban cores[23]. Interestingly, this supports our recent evidence which demonstrated that the percentage of compliant observations for community water fluoridation in NZ was greater in larger than smaller supplies (Chambers et al., 2022). It is clear that differences in geospatial data quality may exist but seldom are they fully recognised in research, and it remains unclear how these data quality issues could impact analyses.

NZ recently issued its first-ever Rural Health Strategy, setting directives to improve the health of rural New Zealanders over the next decade (Minister of Health, 2023). Rural health is a priority, but our view of the rural health landscape is limited by a lack of available data and by poor quality data. This issue comes to the fore when investigating rural–urban disparities, especially since Māori are more likely to live rurally than other New Zealanders. The Rural Health Strategy gives oral health as an example of a priority health issue for rural New Zealand communities (along with mental health and mortality). Access to community water fluoridation (CWF) is much lower in rural areas, and work is underway to improve access

to CWF around NZ. Strategies such as CWF are less cost-effective and less feasible in smaller or rural communities (Moore et al., 2017), and quality data are needed in order to monitor whether implementation of CWF in larger population centres may exacerbate rural–urban disparities in access to CWF (and consequently differences in oral health). Improving rural health and rural health systems hinge on bolstering acquisition of quality data, and identifying prevention-focused strategies that are likely to be effective for rural people (Minister of Health, 2023).

A major contributor to the heterogeneity in spatial data for WDZ, and thus the observed inequities, is due to NZ's devolved system of Government and water regulation. The 67 territorial authorities (local Government) are responsible for the provision of drinking water to around 85% of the NZ population (n = ~4.2 million people) (Richards et al., 2022). This situation has resulted in some territorial authorities struggling to recruit the necessary specialist workforce (e.g. geospatial expertise) (Department of Internal Affairs, 2021). The Ministry of Health was responsible for the regulation of drinking water in New Zealand prior to the establishment of an independent water regulatory in 2022, however, neither entity has mandated to territorial authorities a standardised format for spatial data (Chambers et al. 2022). NZ is currently undertaking major reform of water services, which includes a proposal to move all the water assets owned by territorial authorities into ten separate entities with the intention of creating system efficiencies, reducing costs and fully utilising the limited specialist workforce available (New Zealand Parliament 2023). In conjunction with a central directive from the new water regulator, it is hoped the differential access to and quality of geospatial data for water assets may be reduced or eliminated through the reforms.

The current study has a number of limitations. First, our approach assumes that the WDZ dataset we previously compiled is the gold standard (primarily based on pipe location). Thus, it is possible there could be other unobserved inequities or we may be overestimating the existing inequities if there are non-systematic errors in the piped reticulation data used to inform our validated dataset. A second limitation is that the scorecard developed for the current study is subjective and not easily generalisable. The scorecard was created specifically for the NZ context because the problems we encountered with the data were likely quite specific to our local context. In addition to this, it may be that some criteria in our scorecard may be viewed as more important than others; however, we treated each metric equally.

## Conclusion

Our national audit of spatial data for WDZs has highlighted differences in data access and quality. New data standards and regulations are needed to standardise the quality of geospatial data. While upcoming reforms may mitigate some of the observed inequities, the current study is a reminder of the importance of data equity. The results also suggest that other forms of data inequity may exist in fundamental public services in NZ, particularly those that are characterised by devolved governance and light touch central regulation. Finally, there can be no health equity without data equity.

**Supplementary Information** The online version contains supplementary material available at https://doi.org/10.1007/s12061-024-09571-0.

**Acknowledgements** We acknowledge the help of Professor Philip Schluter, Professor Murray Thomson, and Mr Sam Carrington in the conception of this study. We thank all the councils for the provision for the information on their WDZ and time provided for follow-up discussions. We thank ESR for the provision of the spatial WDZ dataset from 2010 and MoH for the WDZ dataset from 2021. We also thank Taumata Arowai for advice and data provision on details of the WDZ contained in their registry. We also thank June Atkinson for her support with the meshblock-level population estimates.

**Author Contributions** **MH**: Conceptualisation; Methodology; Software; Validation; Formal Analysis; Investigation; Resources; Data Curation; Writing – Original Draft; Writing – Review and Editing; Visualisation; Supervision; Project Administration; Funding Acquisition.

**MPS:** Conceptualisation; Methodology; Software; Validation; Formal Analysis; Investigation; Resources; Data Curation; Writing – Original Draft; Writing – Review and Editing; Visualisation.

**LM**: Conceptualisation; Methodology; Software; Validation; Formal Analysis; Investigation; Resources; Data Curation; Writing – Original Draft; Writing – Review and Editing; Visualisation.

**JB:** Conceptualisation; Writing – Review and Editing.

**TC:** Conceptualisation; Methodology; Investigation; Resources; Writing – Original Draft; Writing – Review and Editing; Supervision; Project Administration; Funding Acquisition.

**Funding** Open Access funding enabled and organized by CAUL and its Member Institutions. This work was supported by a 2023 Ministry of Health Oral Health Research Fund Project Grant and by a Health Research Council project grant (Ref ID: 22/059).

**Data Availability** Data are available in our data in brief article: https://www.sciencedirect.com/science/article/pii/S2352340923004687.

## Declarations

**Conflicts of Interest** None to declare.

**Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/.

## References

Arowai, T., (2023) Public Register of Drinking Water Supplies. https://hinekorako.taumataarowai.govt.nz/publicregister/supplies/ (accessed 24th August 2023).

Atkinson, J., Salmond, C., & Crampton, P. (2019). *NZDep2018 Index of Deprivation: Interim Research Report,* December 2019. Wellington, New Zealand.

Braveman, P. (2006). Health disparities and health equity: concepts and measurement. *Annual Review of Public Health, 27*, 167–194.

Chambers, T., Hales, S., Wilson, N., & Baker, M. (2022). Improvements to drinking water monitoring, reporting and record-keeping needed to protect health. *Policy Quart, 18*(2), 23.

Chambers, T., Hobbs, M., & Broadbent, J. M. (2022). An assessment of compliance with optimal fluoride levels for oral health benefit by New Zealand drinking water suppliers. *Journal of Public Health Dentistry, 83*, 217.

Department of Internal Affairs. (2021). *Strategic regulatory impact analysis*. Wellington, Department of Internal Affairs.
Desjardins, M. R., Murray, E. T., Baranyi, G., Hobbs, M., & Curtis, S. (2023). Improving longitudinal research in geospatial health: an agenda. *Health & Place, 80*, 102994.
Dotse-Gborgbortsi, W., Wardrop, N., Adewole, A., Thomas, M. L. H., & Wright, J. (2018). A cross-sectional ecological analysis of international and sub-national health inequalities in commercial geospatial resource availability. *International Journal of Health Geographics, 17*(1), 14.
Folch, D. C., Arribas-Bel, D., Koschinsky, J., & Spielman, S. E. (2016). Spatial variation in the quality of american community survey estimates. *Demography, 53*(5), 1535–1554.
Hobbs, M., & Atlas, J. (2019). Environmental influences on behaviour and health: a call for creativity and radical shifts in thinking within contemporary research. *New Zealand Medical Journal, 132*(1505), 97–99.
Hobbs, M., Ahuriri-Driscoll, A., Marek, L., Campbell, M., Tomintz, M., & Kingham, S. (2019). Reducing health inequity for Māori people in New Zealand. *Lancet, 394*(10209), 1613–1614.
Lechner, A. M., Raymond, C. M., Adams, V. M., et al. (2014). Characterizing spatial uncertainty when integrating social data in conservation planning. *Conservation Biology, 28*(6), 1497–1511.
LINZ. Address data. 2023. https://data.linz.govt.nz/data/ (accessed 24th August 2023).
Marmot, M. (2005). Social determinants of health inequalities. *The Lancet, 365*(9464), 1099–1104.
Marmot, M. (2015). The health gap: the challenge of an unequal world. *The Lancet, 386*(10011), 2442–2444.
Mays, V. M., Cochran, S. D., Salemi, J. L., & Pathak, E. B. (2022). The accumulation of disadvantage: black children, adolescents, and COVID-19 data inequity. *American Journal of Public Health, 112*(10), 1407–1411.
Minister of Health. (2023). *Rural health strategy*. Wellington: Ministry of Health.
Ministry of Health and University of Otago. Decades of disparity III: ethnic and socioeconomic inequalities in mortality, New Zealand 1981–1999. Wellington: Ministry of Health.
Moore, D., Poynton, M., Broadbent, J. M., & Thomson, W. M. (2017). The costs and benefits of water fluoridation in NZ. *BMC Oral Health, 17*(1), 134.
New Zealand Parliament. (2023). Water Services Entities Amendment Bill — First Reading. (accessed 24th August 2023).
Puente-Sierra, M., Chambers, T., Marek, L., Broadbent, J. M., O'Brien, B., & Hobbs, M. (2023). The development and validation of a nationwide dataset of water distribution zones in Aotearoa New Zealand: A cross-sectional geospatial study. *Data in Brief, 49*, 109349.
Reid, P., Paine, S. J., Curtis, E., et al. (2017). Achieving health equity in Aotearoa: Strengthening responsiveness to Māori in health research. *New Zealand Medical Journal, 130*(1465), 96–103.
Richards, J., Chambers, T., Hales, S., et al. (2022). Nitrate contamination in drinking water and colorectal cancer: exposure assessment and estimated health burden in New Zealand. *Environmental Research, 204*, 112322.
Spielman, S. E., Folch, D., & Nagle, N. (2014). Patterns and causes of uncertainty in the American community survey. *Applied Geography, 46*, 147–157.
Statistics New Zealand. (2018). Census place summaries. 2020. https://www.stats.govt.nz/tools/2018-census-place-summaries/ (accessed 10th January 2021).
Statistics New Zealand. (2019). *Statistical standard for geographic areas 2018: new standard released*. http://archive.stats.govt.nz/methods/classifications-and-standards/current-classifications-and-standards-review/review-geographic.aspx. Accessed 16 Apr 2020.
United Nations. (2022) Sustainable Development Goals. https://sdgs.un.org/goals. Accessed 12 Aug 2023.
Wilson, B., Jones, N., Wood, T., Jagroop-Dearing, A., Kubovy, J., & Baker, M. G. (2021). Clinical outcomes of campylobacteriosis: a case series analysis of hospitalisations associated with the Havelock north campylobacter outbreak. *New Zealand Medical Journal, 134*(1547), 71–84.

**Publisher's Note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.