Report to Environmental Performance Committee

Date:	22 July 2022
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Subject:	**Groundwater Nitrates – potential hotspots, legacies and lag (load to come)**
Section:	A (Committee has delegated authority to make decision)

Purpose

1. To provide an update to the committee on latest information summarising state and trends of groundwater nitrate levels, drivers of observed patterns and recent research into groundwater lags and 'load to come'.

Executive Summary

2. Groundwater quality in the Waikato region is highly variable, reflecting the diversity of regional geology, landscapes and land uses. The impacts of land-use activities are clearly evident and water quality guidelines are commonly exceeded.

3. Groundwater is extensively used in the Waikato region for purposes including drinking water supply, irrigation, stock water and industry. It also importantly sustains surface water flows and influences its quality. Land-use intensification impacts groundwater quality and its long-term sustainable management.

4. The monitoring of groundwater quality enables changes in state and trend to be identified. This is an important role of regional councils under the Resource Management Act (1991). Monitoring also enables us to assess the efficacy of management of this resource and provides information for future policy development. We have recently completed a comprehensive review of groundwater monitoring data, summarising the state of groundwater quality for the five years from 2016 to 2020 and investigating trends over an 18-year period from 2003 to 2020. Information is derived from data collected from a regional network of 110 state of environment (SOE) wells and a network of 80 'Community' or rural school water supply wells. The primary issue in respect to manageable groundwater quality is nitrate contamination.

5. Nitrate commonly exceeds the drinking water guideline, with medians being over the maximum acceptable value at 11% of the SOE monitoring network sites. The highest concentrations are associated with market gardening and dairy farming activities. These account for all exceedances with the exception of one point-source location related to effluent from a woolshed in the Lake Taupo catchment.

6. Areas with highest concentrations are the basalt aquifers of Pukekohe and Pukekawa and parts of the Hauraki Plains. These are also areas of the highest rates of increase. Areas of relatively low intensity land-use activity such as Coromandel have noticeably lower nitrate-N concentrations.

7. Data from the Community supply network indicates that nitrate-N trends at these wells are predominantly increasing.

8. Groundwater quality trends are mixed and the trends vary sub-regionally. Nitrate-N increases predominate in the northern basalt aquifers (~two thirds) along with many other major ions. This contrasts with a similar proportion of decreases (~69%) in nitrate-N and other major ions in the shallow monitoring wells of the Hamilton Basin. Other areas are more balanced although there are more increases (37%) than decreases (~22%) in nitrate-N concentration trends in the Hauraki area.

9. Recent research on Waikato aquifers indicates that deep groundwater might have a smaller influence on nitrogen loads to surface waters than previously thought. Near surface and shallow groundwater pathways are more dominant, suggesting that changes we make on the land now will be more quickly reflected in surface waters.

10. We are planning to review current networks to ensure regional representativeness and the networks remain relevant to monitoring objectives.

Staff Recommendation:

1. That the report Groundwater Nitrates – potential hotspots, legacies and lag (load to come) (Environmental Performance Committee 11 August 2022) be received.

Background

11. The water resources of the Waikato are of fundamental importance to the health and wellbeing of the wider environment as recognised in the concept of Te Mana o te Wai. Groundwater comprises the vast majority of freshwater in the region and notably sustains surface water flows. It is widely used for potable water supply, irrigation, industrial and many other purposes. There are considerable land-use pressures on the larger environment which can influence the quality of groundwater resources across the region. Information derived from monitoring the state and trends of groundwater quality assists resource management decision-making. It can also indicate the effectiveness of policy initiatives.

12. Nitrate-N concentrations, above low ambient levels, are of anthropogenic origin and therefore essentially differ from other inorganic contaminants that we monitor in that the levels are largely manageable. High concentrations of nitrate in drinking water can pose health issues. A health concern regarding nitrate is the formation of methaemoglobinaemia (blue-baby syndrome). Methaemoglobinaemia occurs when nitrate is reduced to nitrite in the stomach of infants, and nitrite is able to oxidise haemoglobin to methaemoglobin, which is then unable to transport oxygen around the body. This can cause cyanosis and asphyxia. For drinking water, the New Zealand Drinking Water Standards set a Maximum Acceptable Value (MAV) of 50 milligrams per litre (mg/l) for nitrate, which is equivalent to 11.3 mg/l nitrate-nitrogen.

13. Recent studies have also raised other health concerns related to lower concentrations of nitrate. For example, a recent Danish study identified a correlation with colorectal cancer risk and recommended an upper limit of 0.87 mg/l for nitrate-nitrogen (Schullehner et al. 2018). The Ministry of Health set up a task force to review the implications of new evidence for New Zealand and whether this would require a review of NZ's drinking water standard for nitrate. No change has been signalled at this stage.

14. Waikato Regional Council's groundwater quality monitoring programme derives information from two monitoring networks, with sampling wells widely distributed throughout the region (Fig. 1a). The principal state of environment (SOE) network comprises 110 wells, the majority of which are monitored annually (many since the mid-late 1990s). A second 'Community' network was established in 2000. This currently comprises a minimum of 80 rural schools which are monitored every two years.

15. The SOE network tends to over-represent vulnerable aquifers with relatively young groundwater in aerobic (oxygenated) condition, whereas the network has few sites in 'natural' state areas, or in older groundwaters. Monitoring network design is fundamentally important and a review of the groundwater SOE network is planned for 2022/23 to optimise the programme. An obvious focus for consideration is nitrate-N given the importance of this ubiquitous, manageable, contaminant both in respect to health and the environment.

Issue

16. There is growing interest and awareness of groundwater nitrate contamination from anthropogenic sources. It is important that Waikato Regional Council and the wider community have access to robust and timely information on groundwater quality patterns across the region, so that appropriate policy responses can be put in place.

State and trends of nitrates in Waikato groundwater

17. The regional SOE network distribution for nitrate-N state and trends is illustrated in Figure 1b. It is evident that the highest concentrations occur in the northern areas (Pukekohe, Pukekawa and Waiuku), the southern Hauraki Plains and Hamilton Basin. The concentrations in these relatively intensively used areas contrast with low nitrate-N concentrations in less developed Coromandel and Taupo sub-regions. It is noted that higher concentrations and all Maximum Acceptable Value exceedances are associated with dairy farming or market gardening areas (with one exception being a point-source from a woolshed in Taupo).

18. The equivalent map of nitrate-N state and trend from the Community network shows a more subdued concentration distribution. This in part reflects that groundwater exceeding the drinking water Maximum Acceptable Value is not used for potable school supply (although still may be used for other purposes). It nevertheless follows somewhat similar patterns with higher concentrations in the central region areas. This dataset includes wells from the west of the region, which all have low nitrate concentrations.

19. Whilst overall the trends from the SOE network are mixed (30.9% degrading and 30.9% improving), the Community network shows more degrading trends (22.5%) than improving (6.25%) (see Fig 1d).

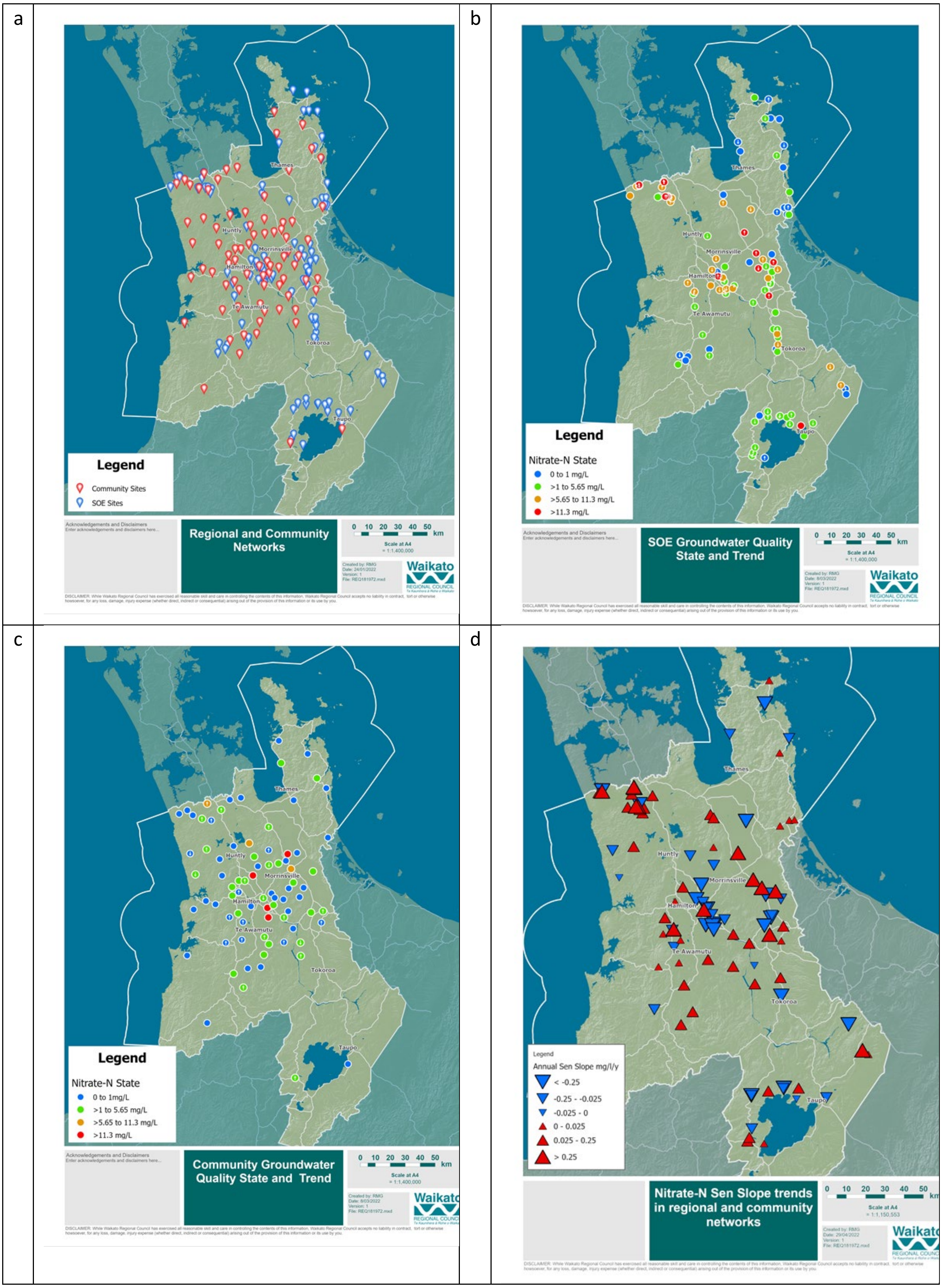


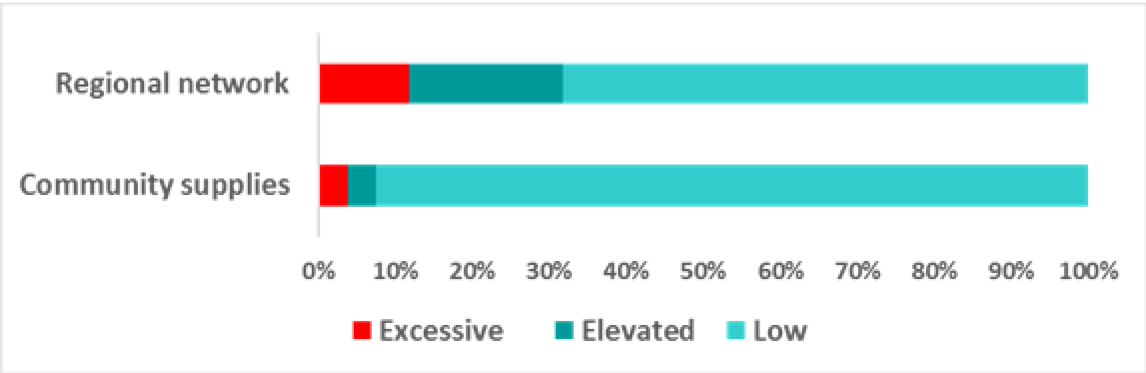
Figure 1. State and trends for Nitrate-N in Waikato groundwater. a) Network of SOE and community monitoring wells. a) State and trends for SOE wells. a) State and trend for Community wells. a) Magnitude of nitrate trends observed across SOE and Community wells.

Exceedances of drinking water guidelines

20. Groundwater in SOE wells commonly (22%) exceeded the nitrate-N Maximum Acceptable Value (MAV) at least once from 2016-2020. Median concentrations from the same five-year period also exceeded guidelines at 11% of SOE wells. Exceedances occurred at 5% of 'Community' (rural school) network wells. Apart from the exceedances reported above, nitrate-N in groundwater is also reported by WRC as one of a suite of environmental indicators on a biennial basis. The most recently reported (2020) nitrate indicator is presented below (Fig. 2) based on 110 Regional (SOE) wells and 80 Community (rural school) wells.

21. The indicator reports nearly 12% of the Regional (SOE) groundwater monitoring network wells exceeded the MAV for potable supply. A further 20% of wells had nitrate concentrations over half the MAV. The remaining two thirds (68.18%) have 'low' concentrations below half the MAV. Three quarters of these wells had concentrations greater than 0.87 mg/l (mentioned in the paper by Schullehner et al., 2018).

22. Exceedances of the nitrate MAV occurred at 3.75 % of the community supply wells. None of these wells are now used for potable supply but rather for other purposes. A similar percentage are described as elevated and a total of 92.5 % have concentrations below half MAV. About half (50.62%) of community supplies have nitrate concentrations over 0.87 mg/l.



Where: Excessive is > MAV 50 ppm (> 11.3 ppm NO_3-N)
Elevated is < MAV 50 ppm and > 25 ppm (<11.3 and > 5.65 ppm NO_3-N)
Low is < half MAV

Figure 2. Nitrate-N concentration indicator ([Nitrate in groundwater | Waikato Regional Council]*)*

Land use and nitrate patterns

23. The highest nitrate-N concentrations occur in the Northern areas, Hauraki and Hamilton Basin. These are the areas of traditionally most intensive agriculture and horticulture. There has also been conversion of non-dairy pastoral land to dairy. The number of dairy cows in the Waikato has increased by 43% in the period 1990 to 2019, going from 1.28 M to 1.82 M (Statistics NZ, 2021). The intensification of land-use is illustrated in Figure 3.

24. Such diffuse anthropogenic pressures as well as other point sources have consequences in groundwater quality contamination. Point sources include septic tanks, landfills, leaky underground storage tanks, industrial sites, sheep dips and woolsheds but are not addressed further here as they are not intentionally targeted by SOE monitoring. Although theoretically manageable, remediation of groundwater contamination is very difficult, and protection (or at least mitigation) is usually much more cost effective.

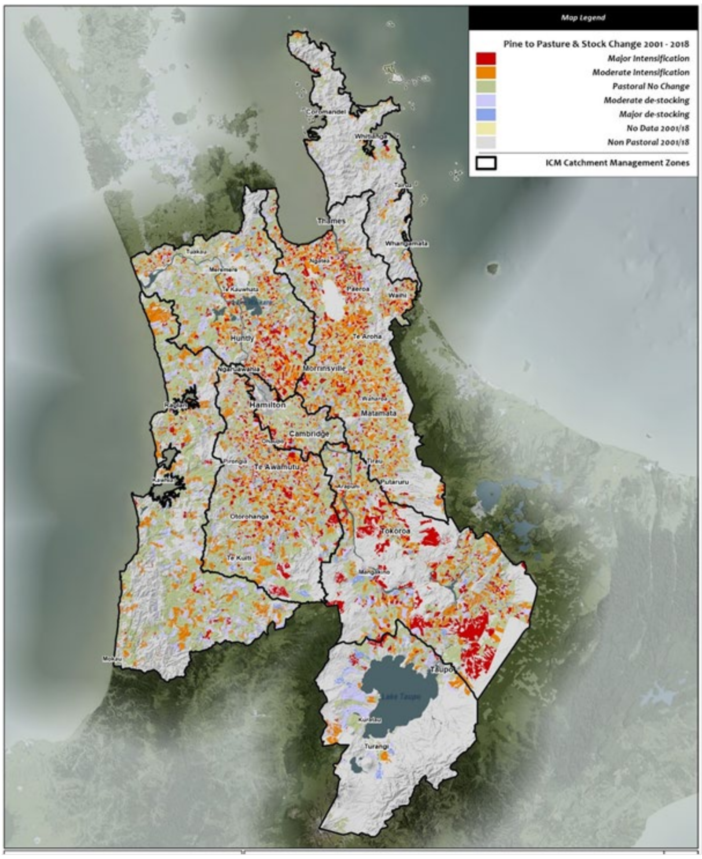


Figure 3. Map of pastoral land intensity change from 2001 to 2018 (Hill and Borman, 2022).

Nitrate Legacies and Lags

25. A nitrate 'lag' refers to the time required for water, or nutrients transported by it, to move from a source (e.g. urine patch) to a monitoring site. Depending on the pathway that water and dissolved nutrients take through the landscape, there can be a long or short lag. 'Legacy' nitrates reflect an accumulation of nitrates in the soil-groundwater system and is also often thought of as the 'load to come'.

26. Lags and legacies are important considerations for how we manage land and freshwater. For example, our policy response to nitrogen issues in Lake Taupo recognised a significant lag-time in older, deeper groundwaters and this meant we might expect to see continued increases in nitrate in lake Taupo for decades to come even with the policy interventions (Variation 5) and associated nitrate reductions.

27. Concerning the diffuse pollution of surface water bodies with agricultural nutrients, it is generally useful to consider three key questions:
    a. On which pathways does the nutrient reach the surface water body (stream, river)?
    b. How long does it take?
    c. What happens during transfer?

28. Nitrate transfers to surface waters can occur within days on near-surface pathways (surface runoff, interflow, artificial drainage) and within months to a few years on shallow groundwater pathways, with only the deep groundwater pathways having potential longer nitrate lags. The length of time it may take for a drop of rain to reach the stream varies significantly for different pathways. While rain may reach the stream within minutes to days on the near-surface pathways, it may take months to a few years via shallow groundwater, and years to decades on the deep groundwater (DGW) pathway. Accordingly, understanding the role of the deep groundwater pathway is the key requirement for understanding nitrate lag times.

29. Not all nitrogen lost from the soil zone will inevitably arrive at the stream. Attenuation processes occurring along the transfer pathways can result in a substantially lower delivered load. In the case of nitrate this is particularly due to denitrification occurring in reduced (= oxygen-depleted) parts of the subsurface environment.

30. Recent research by Lincoln Agritech and others in the Waikato has significantly improved our understanding of nitrate lags and legacies and the pathways that nitrate takes in different parts of the region. Scientists from Lincoln Agritech studied 29 catchments across the region, modelling the relative importance of near-surface (NS), shallow groundwater (SGW) and deep groundwater (DGW) pathways.

31. An important finding from the research is that there is always a mixture of water and nitrate sources, although some pathways do tend to dominate. This challenges the notion of a single 'dominant' pathway in each catchment.

32. As mentioned, the deep groundwater system is the only water reservoir with mean residence times exceeding a few years. The long hydrological lag times seem largely restricted to catchments with recharge areas in young volcanic geology in or adjacent to the Upper Waikato/Lake Taupo sub-region (Tahunaatara, Waiotapu, Pokaiwhenua, Otamakokore, Whareroa, Waihou). Deep groundwater contributions above 20% were only estimated for a small number of catchments outside of this area (Oparau, Waitetuna, Mangatutu, Puniu) and nowhere exceeded 30%.

33. Accordingly, only the Upper Waikato/Lake Taupo sub-region provides hydrological conditions that have the potential to result in substantial nitrate lag times.

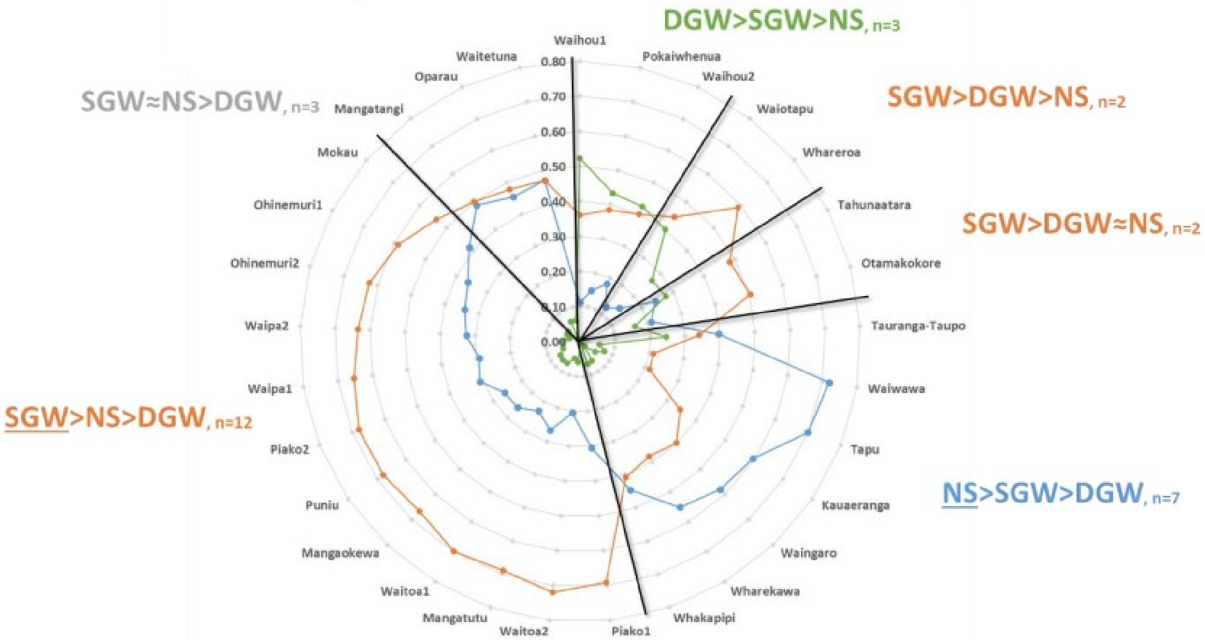


Figure 4: Modelled estimates of median total nitrogen load contributions by the near-surface (NS), shallow groundwater (SGW), and deep groundwater (DGW) pathways (2006-2020). Underlined pathways indicate that they were estimated to contribute >50% of the total nitrogen load. [Source: Dr Roland Stenger, Lincoln Agritech].

34. According to modelling results (Fig 4), deep groundwater is a less important contributor of the total nitrogen load than may have been previously thought.

35. For the 2006-2020 modelling period, deep groundwater was only estimated to make the greatest contribution to the delivered total nitrogen load in the Pokaiwhenua catchment (43%) and at both Waihou sites (52 and 42%, respectively). There are only five more catchments where the deep groundwater total nitrogen load contribution exceeded 10%, namely Waiotapu (40%), Tahunaatara (28%), Whareroa (27%), Tauranga-Taupo (25%), and Otamakokore (16%).

36. Shallow groundwater is estimated to convey the majority of the total nitrogen load in more than half of all catchments, while the near-surface pathway fulfils this role in six catchments, most of which are near-pristine Coromandel catchments with very low nitrogen loads.

37. The overall conclusion from this research is that groundwater lags are likely to be shorter than originally thought for much of the region, including the Taupo catchment. This has implications for assessing policy effectiveness, as the timeframes for changes in land management or land use are likely to be observed sooner than we might have expected. This also means that the 'load to come' is also less than we originally thought.

Conclusion

38. Waikato Regional Council has an extensive, long-term groundwater monitoring programme and this provides robust information on state and trends for important contaminants such as nitrates. Elevated nitrates and exceedances of drinking water guidelines occur in a number of areas throughout the region, most often associated with intensive agriculture and horticulture.

39. Monitoring network design is fundamentally important and a review of the groundwater SOE network is planned to optimise the programme. An obvious focus for consideration is nitrate-N given the importance of this ubiquitous, manageable, contaminant both in respect to health and the environment.

40. Waikato Regional Council and central government are continuing to invest in research to improve our understanding of nitrate contamination patterns.

References

Schullehner, J., Hansen, B., Thygesen, M., Pedersen, C.B. and Sigsgaard, T., 2018. Nitrate in drinking water and colorectal cancer risk: A nationwide population-based cohort study. *International journal of cancer*, *143*(1), pp.73-79.