Auckland Council
Te Kaunihera o Tāmaki Makaurau

Summary of the GNS Science Report:

Groundwater and Surface Water Conceptual Flow from Environmental Tracer Signatures in the Pukekohe and Bombay Area [1]

May 2023

From: Auckland Plan, Strategy and Research Department

1. Introduction

High nitrate concentrations in groundwater from the Pukekohe/Bombay basalt aquifers and spring-fed streams have been recognised since the 1970s. Concentrations exceed the Maximum Acceptable Value (MAV) for drinking water and the National Policy Statement for Freshwater Management 2020 (NPS-FM) national bottom line (NBL) for nitrate toxicity in rivers.

The purpose of this study was to improve understanding of conceptual groundwater flow, its connection with surface water, nitrate pathways, the potential risk of nitrate contamination in deeper aquifers, future nitrate loads, and connections within the aquifer system. This will improve understanding of land use effects on water quality over time. It will also ensure any future nutrient management tools and regional plan provisions for the Pukekohe/Bombay area are evidence based.

Streams in the Franklin area (Hingaia, Ngakoroa, Oira Whangapouri, Whangamaire, Mauku and Waitangi) were studied. Flow gauging and surface water samples were collected down the length of each steam in February and April 2022 (low-flow conditions). Groundwater samples were collected in January and March 2021. Groundwater mean residence times (MRT) were established based on concentration of age tracers (radon, tritium). A range of water hydrochemistry variables, isotopes, and atmospheric gas concentrations were also analysed.

2. Hydrogeology

The hydrogeological units in the Pukekohe/Bombay area are summarised below.

Hydrogeological Unit	Description
Volcanics unconsolidated Pukekohe/Bombay basalt	• Fractured lava, scoria cones and tuff rings • Inter-finger with Pleistocene/Holocene age sediments
Holocene age sediments Pleistocene age sediment	• Sandy alluvial sediments • Comparatively low yield
Kaawa Formation	• Marine shell and sands
Waitematā Group	• Fractured, alternating sandstones/mudstones • Hydraulic properties and yields vary spatially
Greywacke	• Basement rock

[1] Morgenstern U, et al. 2023. (GNS Science report; 2022/63). https://www.knowledgeauckland.org.nz/media/2683/groundwater-surface-water-conceptual-flow-pukekohe-bombay-area-gns-sr2022-63-march-2023.pdf

The simplified geology of the area is shown in the GNS Science report, Figure 2.4.

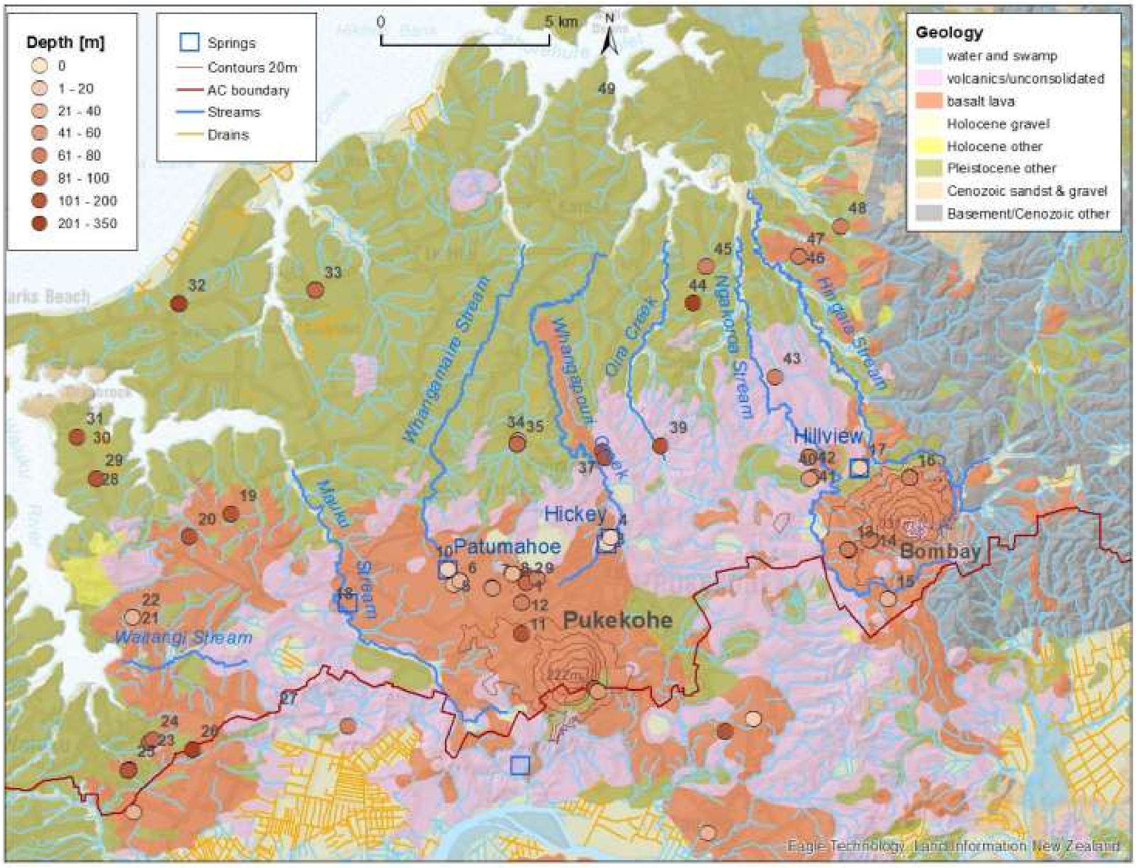

Figure 2.4 Simplified geology, well locations and annotated depth. Labels refer to number in Table 2.1. The springs are indicated by square box outlines.

Major streams draining the Pukekohe/Bombay basalts flow northward to the harbour. Springs at the perimeter of Pukekohe Plateau (Patumahoe and Hickey Springs) and Bombay cone (Hillview Spring), provide significant base-flow for some streams. Groundwater discharged via springs has high nitrate concentration. The upper Hingaia Stream catchment is partly greywacke rock.

3. Results

Water dating and age distribution

Most deep groundwater (Pleistocene, Kaawa, Waitematā and unconsolidated volcanics) is old (MRT >120 years) indicating limited recharge (infiltration of surface water into groundwater). Shallow basalt groundwater and springs are young (MRT <80 years) indicating active recharge. At Bombay, the youngest basalt groundwater and the springs are twice as old as that from the Pukekohe basalt. In the basalt to the west, near Waitangi Stream, groundwater is older than at Bombay. Deep Pukekohe basalt has significantly older groundwater.

Table 1: Groundwater mean residence time and springs mean transit times.

Aquifer	Youngest groundwater mean residence time (MRT) (years)	Springs mean transit times (MTT) (years)
Shallow Pukekohe basalt	16	18
Shallow Bombay basalt	30	36
West basalt (Waitangi Stream)	60-100	-
Deep Pukekohe basalt	Significantly older than shallow	-

Dating shows shallow basalt aquifers discharge via Hillview, Hickey and Patumahoe Springs to Hingaia Stream, Whangapouri Creek and Whangamaire Stream. The groundwater MRTs are consistent with their spring discharges and MTTs of the respective streams. The Ngakoroa Stream and Oira Creek mainly discharge water that does not match the nearby basalt. Ngakoroa Stream has younger water and Oira Creek has older water. They appear to drain small local groundwater systems. Mauku and Waitangi Streams discharge water with similar MTT to that from the Pukekohe basalts.

Hydrochemistry

Only shallow basalt groundwater is oxic, with dissolved oxygen (DO) typically >5 mg/L. Below the shallow basalts, in the Pleistocene deposits and deep volcanics the water is anoxic. Streams with major spring discharges (Hingaia Stream, Whangapouri Creek and Whangamaire Stream) from shallow basalts have high DO concentrations (c. 10.5 mg/L). Streams with lower DO (particularly Oira Creek and Waitangi Stream) indicate anoxic groundwater sources with denitrification potential and lower nitrate.

Groundwater DO decreases with time and old water becomes anoxic. Young groundwater ranges in nitrate concentration reflecting recent land use impacts. Old groundwater has low nitrate and high ammonia reflecting reducing conditions and bacteria-mediated processes.

Water-stable isotopes

Isotopic ratios[2] in water shows evaporation occurs in streams in the summer and is insignificant in groundwater. Matching surface and groundwater isotope compositions enables identification of connections between water bodies. Hingaia Stream, Whangapouri Creek and Whangamaire Stream have ratios matching the basalts, confirming connection. Ngakoroa Stream, Oira Creek and Mauku Stream ratios don't match the basalts, showing the water source is not the main basalts. There was no groundwater data for Waitangi Stream area to show the source.

Radon in groundwater and stream water

Radon gas is a radioactive decay product of uranium, common in rocks. Groundwater in contact with rock accumulates radon. Surface water concentrations are low due to limited rock contact and degassing to air. High radon concentration in streams indicates groundwater seepage. Low concentrations in groundwater indicates recent surface water recharge. Radon build up in groundwater takes approximately three weeks.

All groundwater samples were old enough to reach equilibrium with aquifer rocks. Major springs had high radon (around 30 mBq/L) as expected. Most basalt groundwater had lower than expected radon (around 10–15 mBq/L), which indicates reduced rock contact. Deep anoxic water with very low radon concentrations (<10 mBq/L), indicates absorption on organic matter. All streams have reaches with elevated radon indicating groundwater flow into streams. Whangapouri Creek showed elevated radon at all sites, especially Hickey Spring and at Paerata Falls.

[2] Deuterium (δ^2H), oxygen-18 ($\delta^{18}O$)

Nitrate distribution

The spatial distribution of nitrate is shown in the GNS Science report, Figure 5.33.

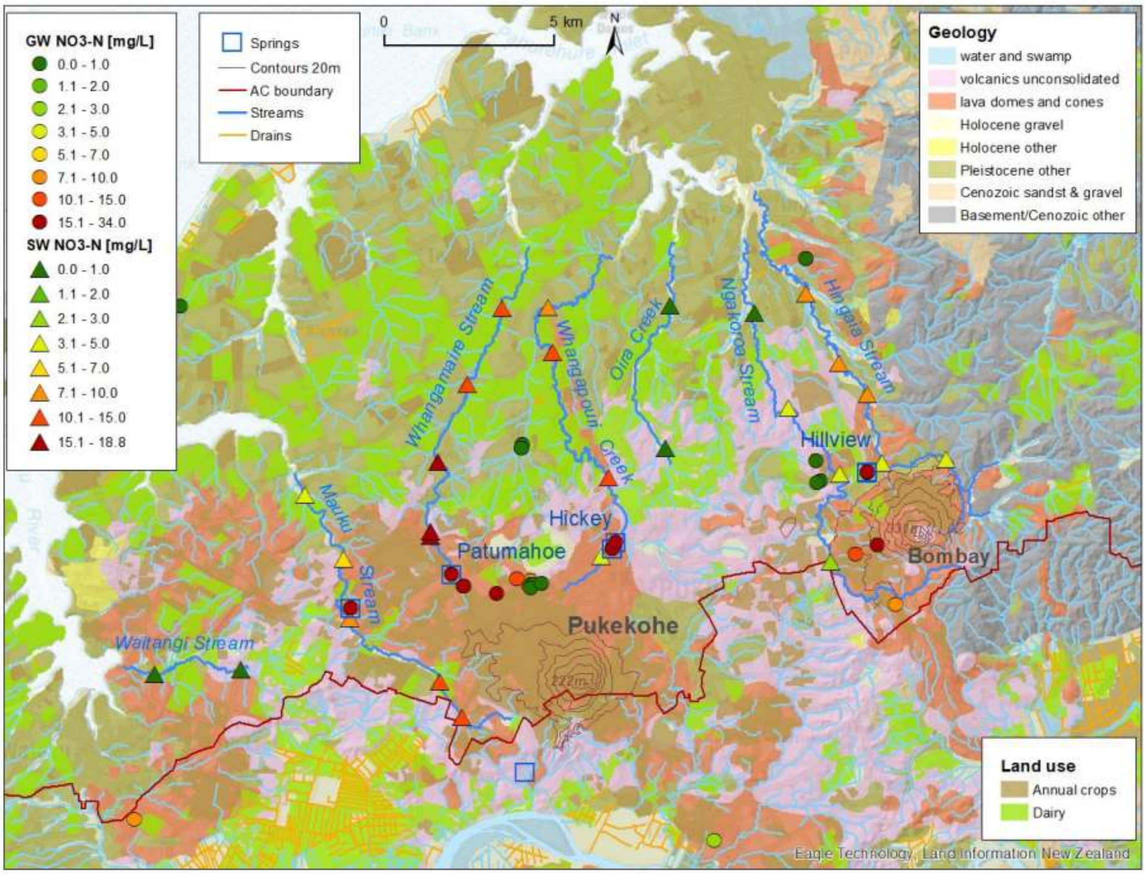

Figure 5.33 Spatial distribution of nitrate (NO_3-N) in groundwater (circles) and surface water (triangles), with consistent concentration scale for groundwater and surface water. Springs are denoted by blue square outlines. Also shown are the areas of land use that cause major nitrate leaching: crop production and dairy farming (MfE Data Service 2012).

Market gardening dominates the Pukekohe and Bombay basalts, which are subject to nitrate loss into groundwater. Major springs at the perimeter of Pukekohe Plateau and Bombay basalt cone discharge high nitrate groundwater. Matching nitrate concentrations, water ages and isotopes show the springs discharge from the basalts. High nitrates from the springs dominate nitrate concentrations in receiving streams.

Table 2: Summary of nitrate spatial distribution and concentration.

Stream/location	Nitrate spatial distribution	Concentration (mg/L)
Hingaia	• doubles at Hillview Spring • slightly reduces downstream with dilution	• above Hillview 4 mg/L • @ Hillview 9 mg/L
Whangapouri & Whangamaire	• similar to Hingaia, higher nitrates	• 10–19 mg/L
Ngakoroa	• elevated upstream • reduces downstream	• upstream 3–5 mg/L • downstream 0.7 mg/L
Mauku	• upstream little groundwater/high nitrate • reduces downstream with dilution of denitrified groundwater	• upstream 15 mg/L • downstream 4.5 mg/L
Waitangi	• old, low nitrate denitrified groundwater • higher nitrate from dairy in wet season	• @ base-flow <0.2 mg/L • @ wet season 3.5 mg/L
Oira	• similar to Waitangi, lower nitrates	• base-flow <0.02 mg/L
Pleistocene & deeper basalt	• anoxic, old, denitrified groundwater	

4. Conceptual understanding of groundwater flow

Base-flow drainage

During base-flow conditions, the area between the Pukekohe/Bombay basalts and the harbour is dominated by discharge from three large springs. There is little base-flow from Pleistocene deposits containing old water from the deeper system. Mauku Stream, Oira Creek and Ngakoroa Stream discharge localised groundwater mainly from the unconsolidated volcanics.

Recharge

Calculated recharge temperature for major springs is around mean air temperature, indicating recharge through the near surface unsaturated zone. Calculated recharge temperatures for basalts are significantly below the mean annual air temperature, indicating winter recharge. Lower radon concentrations in deep groundwater suggest fracture flow as a smaller ratio of water volume to rock contact area, results in less radon.

Deep basalt recharge rate of 280 mm/year was estimated from age (MRT)/well depth relationship and assumed permeability. Shallow recharge to spring is additional.

Nitrate lags and denitrification

High nitrate water from the basalts discharge to streams with a range of ages. The mean transit time is 18 years from the Pukekohe basalt and 36 years from the Bombay basalt. Therefore, significant lag times are expected in nitrate response to land-use/management changes. Modelled nitrate concentration at springs, assuming constant nitrate discharge from 1955, is shown in the GNS Science report, Figure 6.2.

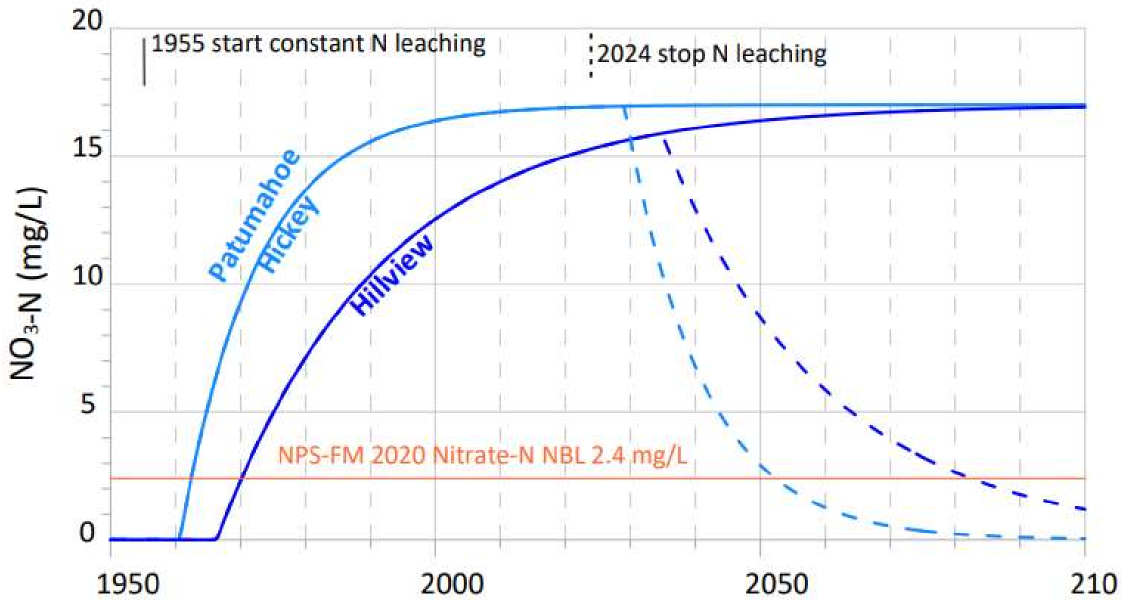

Figure 6.2 Response of nitrate concentrations for the main spring discharges from the Pukekohe and Bombay basalt lavas to the land-use scenario of start of constant nitrate loading at 1955 (full lines), followed by a theoretical discontinuation of nitrate loading in 2024 (dashed lines). Patumahoe and Hickey springs (MTT = 18 years) drain the Pukekohe basalt lava, and Hillview Spring (MTT = 36 years) drains the Bombay basalt lava.

Hillview Spring (Bombay) may have only currently reached 90% of its nitrate load. If nitrate loading stopped in 2024, improvement to below NBL (national bottom line) would only be seen by 2050 for Pukekohe and by 2080 for Bombay. Times to reach NBL are likely to be longer, as nitrate loads probably increased recently. Response will be faster in non-basalt areas where nitrate is flushed seasonally. Pleistocene deposits, Kaawa Formation and Waitematā Group water is old, anoxic and is low in nitrate.

Conceptual groundwater flow from tracer signatures

Conceptual groundwater flow is shown in the GNS Science report, Figure 6.3.

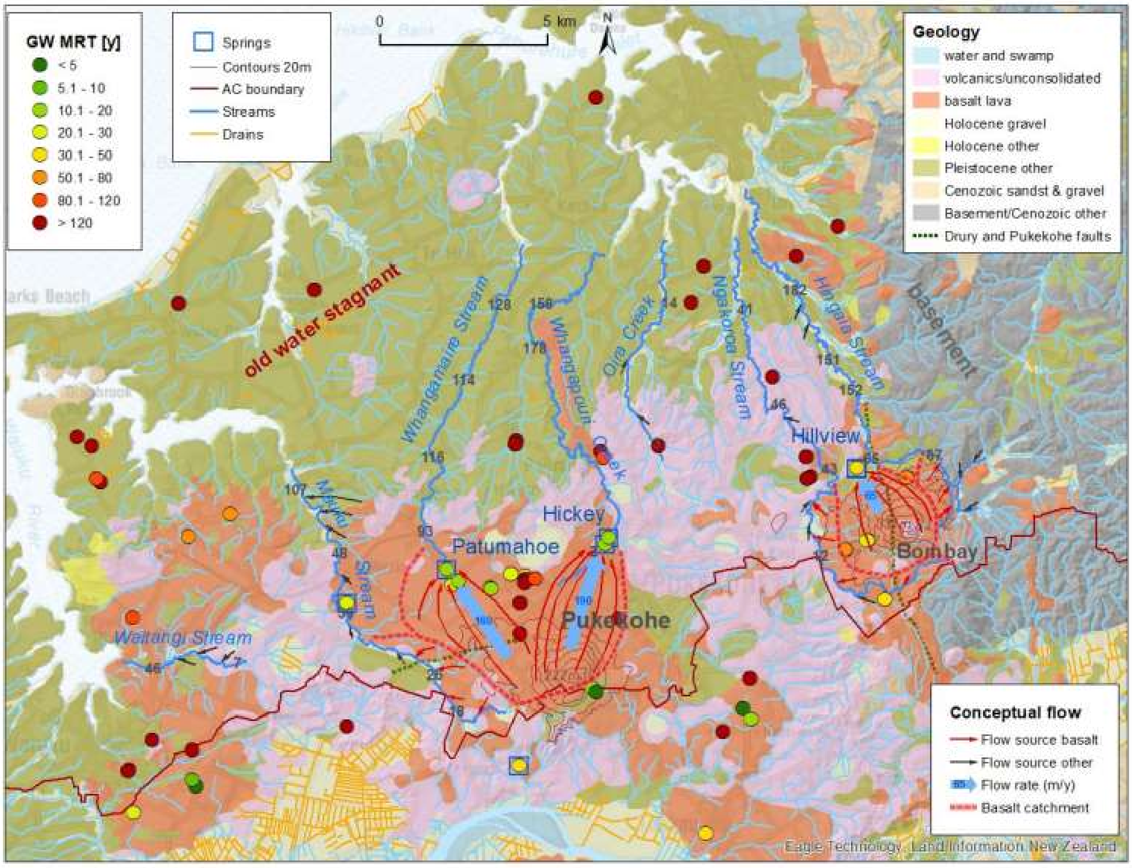

Figure 6.3 Groundwater dynamics and conceptual flow in the Pukekohe–Bombay area inferred from groundwater ages (MRT, circles) in conjunction with stable isotope and nitrate data (not shown). Deeper groundwater recharge and flow in areas outside of basalt lavas is negligible, with the water being stagnant. Major water drainage through large groundwater systems occurs only through the basalt lavas (red arrows), with flow rates indicated by blue arrows (blue numbers indicate flow rates in m/y, length of arrow proportional to flow rate). Dashed red lines indicate approximate catchment boundaries. Black arrows indicate baseflow water contribution to streams from sources other than basalt lavas. Numbers superimposed on streams are measured baseflow rates in L/s.

Pukekohe/Bombay basalt are drained via three main springs (Patumahoe, Hickey and Hillview). The upper Hingaia drains low nitrate greywacke catchments and high nitrate basalt. The upper Ngakoroa drains high nitrate basalt, with no significant flow downstream from Pleistocene deposits. Whangamaire Stream and Whangapouri Creek drain basalt, with no significant flow downstream from Pleistocene deposits. Mauku Stream drains the Pukekohe basalt, with increased flow and reduced nitrate downstream. Oira Creek discharges a small flow of locally derived, low nitrate water. Waitangi discharges locally derived, low nitrate water. The north-western Pukekohe basalt discharges anoxic, low nitrate water due to attenuation.

5. Summary

This study provides a comprehensive understanding of groundwater flow, nitrate pathways, and aquifer connections. This knowledge is essential for effective nutrient management and regional plan provisions. The study highlights the role of different geological units, land use, and hydro-chemical processes on the age, flow-paths and quality of groundwater in the wider Franklin area.

Find out more: phone 09 301 0101, email
rimu@aucklandcouncil.govt.nz or visit
aucklandcouncil.govt.nz and knowledgeauckland.org.nz

Auckland Council
Te Kaunihera o Tāmaki Makaurau