Sensitivity Of Domestic Food Supply To Loss In Vegetable Growing Production In Specified Vegetable Growing Areas

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Glossary/ Definitions

Māori Terms

Term	Meaning (within this document)
Kaitiakitanga	The act of guardianship, in particular with cultural oversight.
Mahinga kai	A food gathering place.
Maoritanga	Māori customs
Matauranga Māori	Traditional Māori knowledge.
Te Mana o te Wai	The mana or status of the water.
Te Mauri o te Wai	The inherent quality of the water.
Te Tiriti o Waitangi	The Treaty of Waitangi.

Science & Technical Terms

Term	Meaning
Clause 3.33	A provision in the NPS-FM 2020 that enables Councils to set specified Nitrogen-related attribute targets below National Bottom Lines if three conditions are met: a freshwater management unit or part of it are adversely affected by vegetable growing; the baseline state of one of the specified Nitrogen related attributes is below the National Bottom Line; achieving the National Bottom Line for the attribute would compromise domestic supply of fresh vegetables and New Zealander's food security. https://environment.govt.nz/assets/publications/National-Policy-Statement-for-Freshwater-Management-2020.pdf
Cyano-bacteria	microscopic organisms (sometimes called toxic algae) that play a very important role in many land and aquatic ecosystems. They can multiply and form blooms suspended in the water (known as planktonic), or dense mats attached to rocks on riverbeds (known as benthic). Some cyanobacteria can produce toxins that are harmful to animals and humans. https://www.lawa.org.nz/learn/factsheets/toxic-algae/
Dissolved Oxygen (DO)	The relative measure of the amount of oxygen (O2) dissolved in water. Excessive plant and algae growth and decay in response to increasing nutrients in waterways can significantly affect the amount of dissolved oxygen available leading to increased stress on aquatic life. https://niwa.co.nz/our-science/freshwater/tools/kaitiaki_tools/impacts/dissolved-oxygen
Forage	Crops grown for animal feed or grazing. https://www.mpi.govt.nz/agriculture/farm-management-the-environment-and-land-use/protecting-freshwater-health/intensive-winter-grazing/
Macro-invertebrates	Tiny animals that live on and under rocks, water plants, wood or debris. They have no backbones and can be seen without a magnifying glass or microscope. https://www.doc.govt.nz/nature/native-animals/invertebrates/freshwater/
N Leaching	The amount of Nitrogen which enters the surface and ground water system.
N Loss	The amount of Nitrogen that is not absorbed by the soil in the root zone area, and is therefore "lost" to the surrounding environment.
Periphyton	Periphyton is the mix of algae, fungi, and bacteria which grow on the beds of rivers, lakes and streams. While some algae are necessary for our ecosystems to flourish, too much can have the opposite effect. https://www.manawaturiver.co.nz/science/periphyton/
Phyto-plankton	Microscopic organisms that live in watery environments, both salty and fresh. Some Phytoplankton are bacteria, some are protists, and most are single-celled plants. https://earthobservatory.nasa.gov/features/Phytoplankton
Taxa	A unit used in the science of biological classification, or taxonomy. Taxa are arranged in a hierarchy from kingdom to subspecies, a given taxon ordinarily including several taxa of lower rank.

Acronyms and Abbreviations

Term	Meaning	Explanation
CASM	Contaminant Allocation and Simulation Model	Refers to a technical modelling tool used to model water quality in the Horowhenua region in a report by Landwaterpeople. https://landwaterpeople.co.nz/wp-content/uploads/2021/03/MW-Region-Catchment-Nitrogen-Models-ReportWeb.pdf
CCFFV	Codex Committee on Fresh Fruit and Vegetables	A committee within the FAO's Codex Alimentarius, with the purpose of o elaborating worldwide standards and codes of practice as may be appropriate for fresh fruits and vegetables; and to consult, as necessary, with other international organisations in the standards development process to avoid duplication. https://www.fao.org/fao-who-codexalimentarius/committees/committee/en/?committee=CCFFV
CVP	Commercial vegetable Production	Commercial Vegetable Production.
FAO	Food and Agriculture Organization	The Food and Agriculture Organization (FAO) is a specialized agency of the United Nations that leads international efforts to defeat hunger. Their goal is to achieve food security for all and make sure that people have regular access to enough high-quality food to lead active, healthy lives. https://www.fao.org/home/en
FWMT	Fresh Water Management Tool	Refers to a technical modelling report prepared for Auckland Council and Horticulture New Zealand. https://www.morphum.com/projects/fwmt
GAP	Good Agricultural Practice	Good Agricultural Practice is a set of principles, regulations, and technical recommendations applicable to production, processing and food transport, addressing human health care, environment protection and improvement of worker conditions and their families. https://www.fao.org/3/a1193e/a1193e00.pdf
GlobalG.A.P.	Global farm assurance program	GLOBALG.A.P. offers independent certification systems, translating consumer requirements into Good Agricultural Practice in a rapidly growing list of countries – currently more than 135. https://www.globalgap.org/uk_en/who-we-are/about-us/history/
Hort NZ	Horticulture New Zealand	Horticulture New Zealand is the umbrella industry association, representing fruit and vegetable growers on matters of common interest across all 20 product groups the organisation partners with. https://www.hortnz.co.nz/
ICMP	Integrated Catchment Management Plan	The ICMP relates to the Pukekohe SVGA and is a project due to conclude in July 2023. Ngāti Te Ata, Ngāti Tamaoho, Waikato-Tainui, the Ministry for the Environment and the Ministry of Primary Industries, have established an Iwi/Crown governance roopuu to lead this work - Te Tautara o Pukekohe (tToP). https://www.thesustainabilitysociety.org.nz/conference/2010/presentations/Young.pdf
IIS	Improved Irrigation Scheduling	The ability to control soil moisture using improved irrigation scheduling has positive environmental and economic outcomes. https://www.landcareresearch.co.nz/assets/Publications/Policy-Briefing-Guidance-Papers/Policy-Brief-26-Modelling-irrigation-management.pdf

Term	Meaning	Explanation
LUCAS	Land Use and Carbon Analysis System	The New Zealand Land Use and Carbon Analysis System (known as the LUCAS project) is a programme of work to measure and monitor the national level carbon stocks of New Zealand's forests and soils. https://www.interpine.nz/wp-content/uploads/2017/09/Landowner-Information-Handout-LUCAS-Post-89-Soils-Inventory-Jan-2014.pdf
MfE	Ministry for the Environment	The New Zealand Ministry for the Environment. https://environment.govt.nz/
MPI	Ministry for Primary Industries	The New Zealand Ministry for Primary Industries. https://www.mpi.govt.nz/
NPS-FM	National Policy Statement- Freshwater Management	The National Policy Statement for Freshwater Management 2020 (NPS-FM 2020) sets out the objectives and policies for freshwater management under the Resource Management Act 1991. https://environment.govt.nz/publications/national-policy-statement-for-freshwater-management-2020-amended-february-2023/
NZGAP	New Zealand Good Agricultural Practice	NZGAP certifies the safe and sustainable production of fruit and vegetables in New Zealand. https://www.nzgap.co.nz/NZGAP_Public/About/NZGAP_Public/About/About.aspx
RIMU		RIMU is the Auckland Council research and evaluation unit. https://www.knowledgeauckland.org.nz/about/
SVGA	Specified Vegetable Growing Area	Two specified vegetable growing areas are subject to specific direction under the NPS-FM 2020, one in Pukekohe and one in Horowhenua. https://www.environmentguide.org.nz/issues/freshwater/freshwater-management-framework/national-policy-statement-for-freshwater/
SVS	Sustainable Vegetable Systems	The Sustainable Vegetable Systems (SVS) project is a large, industry-led collaborative research project that aims to understand the nutrient flows in vegetable crop systems. https://www.plantandfood.com/en-nz/article/working-with-the-industry-on-sustainable-vegetable-systems-svs
TAS	Target Attribute State	A target attribute state is the state of the attribute that needs to be achieved in order to fulfil the associated objectives, outcomes, values and vision. https://environment.govt.nz/publications/guidance-on-the-national-objectives-framework-of-the-nps-fm/clause-3-11/
WHO	World Health Organisation	The United Nations agency that connects nations, partners and people to promote health, keep the world safe and serve the vulnerable – so everyone, everywhere can attain the highest level of health. https://www.who.int/

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Executive Summary

The National Policy Statement for Fresh Water Management 2020 (NPS-FM 2020) came into effect in September 2020. It is based on the concept of Te Mana o te Wai. Local authorities are expected to apply the NPS-FM 2020 by notifying freshwater plans that give effect to the NPS-FM 2020 by 31 December 2024.

Almost 3 years after the NPS-FM 2020 came into force, stakeholders are indicating concern, in one way or the other, that insufficient evidence exists to date, to provide for effective and efficient implementation of clause 3.33 of the NPS-FM 2020 around vegetable production in the Pukekohe and Horowhenua Specified Vegetable Growing Areas (SVGA).

The AgriChain Centre has been asked to test the assumption that "compliance with the National Bottom Line targets for relevant attribute states would pose a significant risk to domestic fresh vegetable supply", as the assumption had formed the basis for the inclusion of clause 3.33 in the NPS-FM 2020, otherwise known as "the exception".

Target Attribute States of Relevance to Project

Water Quality & Physical Habitat Attributes	Aquatic Life & Ecosystem Attributes	Human Health
• Total Nitrogen (Trophic State) • Ammonia (Toxicity) • Nitrate (Toxicity) • Dissolved Oxygen	• Phytoplankton • Periphyton • Macroinvertebrates	• Cyanobacteria

The outcome of this project is this report to MfE, advising on the likely sensitivity of domestic vegetable supply to changes in production arising from water quality improvements in the Horowhenua regions and Pukekohe SVGA.

MfE determined that this project involved specifically working with named designated project partners: the three local Councils responsible for the two SVGA regions, all iwi located in the SVGA, and a Māori Trust with a particular focus in water management.

The project also sought information from a variety of stakeholders within the fresh vegetable supply chain, to gain industry data and knowledge that would assist the project to develop its analysis.

The process of testing the assumption central to the project consisted of four components:

- Literature discovery on the subject matter, with a particular focus on the period since 2020, when the NPS-FM 2020 was published.
- Data discovery, ideally also from the post 2020 period, through connecting with various recently completed related projects, as well as data potentially available from within the commercial produce value chain.
- Answering 3 specific main questions and 7 supporting questions posed in MfE's RFP document.
- Modelling suitable datasets identified through the discovery project for verification purposes and as a contribution towards providing the answers needed to reach a conclusion about how to proceed with an effective and efficient approach to the challenges vegetable production in the SVGA represent.

Several of the Attributes requested to be modelled have been identified as lacking sufficient data across both SVGA for full modelling.

Where the streams in both SVGA do not meet the National Bottom Lines for Nitrogen and Ammonia, our modelling indicates that even removing 100% of all vegetable production would not be sufficient to meet the National Bottom Lines. For the remaining Attribute states, our modelling shows that they are either already meeting the National Bottom Lines, or where they are not, this failure to meet the National Bottom Lines cannot be appropriately explained by Nitrogen levels, and requires alternative solutions.

Modelling in the Horowhenua region has identified that the relevant TAS attributes which are not Nitrogen or ammonia (i.e., Periphyton, Phytoplankton, etc.) are indirectly linked to Nitrogen levels, and therefore are affected as Nitrogen levels change. As such, improvements in Nitrogen run-off are expected to have relative impacts on the other attributes, resulting in an indirect improvement in these attributes.

Nitrate levels in the Arawhata sub-catchment will not be able to meet NPS-FM 2020 bottom lines solely with a wetland, especially during high flow periods. This would also likely be the case for a wetland installed in the Pātiki Stream, if the Nitrogen reduction is at a similar level.

The water quality and ecological health of Lake Horowhenua and its inflow streams are compromised. Many of the NPS-FM 2020 freshwater attributes are not close to the NPS-FM 2020 bottom line requirements. Some attributes (particularly the biotic indices) are clearly impacted by variables outside the scope of this report (e.g., sediment). The reduction in Nitrogen required for the Inflow streams, and subsequently Lake Horowhenua, is beyond the scope of the best achievable reductions from proposed improved horticultural practice (GMP) and/or constructed wetlands being built to intercept Nitrogen & sediment in the Arawhata Stream.

With the modelled mitigation of 8.5% of all Pukekohe SVGA N Leaching, and 5.6% of all Horowhenua SVGA N Leaching being mitigatable by vegetable production practices following economically viable Good Management Practices (GMP), the reductions required in both SVGA to meet the National Bottom Lines for Nitrogen are 10-15 times greater than what is achievable from vegetable production mitigation alone.

Attempting reductions in N leaching, solely via removing all vegetable production within both SVGA, would not reduce the percentage of total N leaching beyond their percentage-based contributions (35% for Pukekohe, and 23% for Horowhenua) to total N leaching.

For the streams with Nitrogen levels lower than the worst cases in each SVGA, the data identified shows that their Nitrogen related National Bottom Lines are either already achieved without any changes being required, or are minimal changes that would not require changes in vegetable production.

Moving production out of the SVGA, whilst <u>theoretically</u> possible, has been identified as leading to <u>additional</u> economic and environmental challenges, beyond those already being experienced by the industry at present. These challenges, based on the evidence and literature available to the project team, are likely to result in reduced overall vegetable production within New Zealand, and higher overall Nitrogen leaching volumes across all New Zealand.

The conversion from field cropping to indoor production, where it is possible from a crop choice point of view, will nevertheless come with a high capital requirement. It is unlikely that any existing grower would be able to fund such a switch from operating revenue, or annual profits, regardless of whether they were wanting to switch their existing crop from field to undercover, or whether they wanted to move from growing outdoor crops to undercover crops.

There are natural transformations already occurring in the fresh produce production sector, and any thoughts related to alternative production methodologies and locations, or processes, would need to be very carefully introduced into the industry, with a high level of industry involvement, in order to avoid extreme fluctuations in certainty of supply.

Imports will not typically be cheaper or of equivalent price to domestic production, except in unusual circumstances. Instead, the higher pricing we can expect when importing vegetables renders the import solution unsuitable as an everyday activity. This is why imports are currently only used when New Zealand is unable to produce vegetables for seasonality reasons, or as a result of a natural disaster that impacted vegetable production.

The prevailing local Pukekohe and Horowhenua microclimates, the quality of the local soils, and the close access to transport networks that can both service their domestic market and provide access to ports for export shipments, are collectively responsible for these areas to be strategic contributors towards the domestic supply of fresh vegetables.

Good Management Practice alone will not be enough to reduce N leachate to National Bottom Line levels. However, strengthening Good Management Practice is an achievable good step into the right direction, as it has the potential to make a meaningful difference in the short to medium term, whilst long term sustainable solutions are also explored.

1 Background

In May 2020, a paper was jointly submitted to Cabinet by the Ministers for the Environment and for Agriculture.

The paper was entitled "Action for Healthy Waterways – Decisions on National Direction and Regulations for Freshwater Management".

Amongst the actions listed in the cabinet paper was "preserving domestic vegetable growing capacity". This section consisted of four paragraphs:

> *"Notwithstanding the importance of managing Nitrogen for ecosystem health, we recognise that food security and stability of supply for human health, depend on domestic production of adequate and affordable supplies of fresh vegetables. Although the total vegetable growing area is relatively small, the Pukekohe and Lake Horowhenua catchments are major supply areas for domestic fresh vegetable production (particularly of fresh leafy greens through winter) and have Nitrogen levels worse than the toxicity bottom lines.*
>
> *Following consultation, we consider that it will not be practicable to reduce Nitrogen to meet national bottom lines in the vegetable growing areas of those catchments for a range of attributes without significantly compromising vegetable production.*
>
> *We recommend allowing regional Councils to maintain freshwater at a level worse than the national bottom lines for Nitrogen in these catchments – to the extent that bottom lines would require Nitrogen reductions that compromise vegetable production. We recommend that officials spatially define in the new NPS-FM the areas to which this exception applies, and also direct regional Councils to improve water quality in these areas where practicable without compromising vegetable production.*
>
> *However, before making final decisions on this exception policy, further engagement with local iwi is needed to ensure that the policies are compliant with Treaty requirements and existing settlements. We propose to task officials to undertake this engagement, and we seek delegated authority to make final decisions on this policy concurrent with the drafting process."*

However, the paper does not mention, or define and discuss, volume related concepts like "maintaining current supply" or "allowing for expansion".

The National Policy Statement for Fresh Water Management 2020 (NPS-FM 2020) came into effect in September 2020.

The NPS-FM 2020 is a central government policy that gives local authorities direction on how freshwater should be managed in New Zealand. It is based on the concept of Te Mana o te Wai[1].

The policy sets out the regional authorities' functions and obligations with regards to developing, specifying, introducing, monitoring and enforcing regional rules and regulations connected to the state of freshwater in their respective jurisdictions. This includes the opportunity for differentiated decision making with regards to nutrient

[1] https://environment.govt.nz/publications/essential-freshwater-te-mana-o-te-wai-factsheet

pollution in the two designated Special Vegetable Growing Areas - Pukekohe and Horowhenua.

The NPS-FM 2020 includes a specific clause, clause 3.33 which:

- Requires Councils to have regard to the importance of the contribution of the SVGA to the domestic supply of fresh vegetables; and maintaining food security for New Zealanders.
- Enables Councils to set target attribute states below the National Bottom Line for the attribute on the condition that the target attribute state set is still an improvement) without compromising the domestic supply of fresh vegetables and maintaining food security for New Zealanders.

Local authorities are expected to apply NPS-FM 2020 by notifying freshwater plans that give effect to the NPS-FM 2020 by 31 December 2024.

Almost 3 years after the NPS-FM 2020 came into force, stakeholders are indicating concern, in one way or the other, that insufficient evidence exists to date, to provide for effective and efficient implementation of clause 3.33 of the NPS-FM 2020 around vegetable production in the SVGA.

The interactions between fertiliser application, vegetable production, nutrient leachate, and the health of the waterways is a matter of concern to all associated parties. This concern is not only a New Zealand one, but applicable in all global jurisdictions where vegetables are grown. This concern also extends, here and elsewhere, to other horticultural activities, i.e., fruit production and other primary industry activities such as grazing, forestry, viticulture, etc.

2 Introduction

The Ministry for the Environment (MfE) appointed The AgriChain Centre to manage a short-term project entitled,

> *"Sensitivity of domestic food supply to loss in vegetable growing production in Specified Vegetable Growing Areas".*

The outcome of this project is this report to MfE, advising on the likely sensitivity of domestic vegetable supply to changes in production arising from water quality improvements in the Horowhenua regions and Pukekohe SVGA, with the analysis performed both individually for each SVGA, and combined.

The purpose of this project is to continue to develop evidence for a project entitled,

> *"Enduring Solutions for improved water quality in Pukekohe and Horowhenua Specified Vegetable Growing Areas (SVGA)".*

The project Request for Proposal (RFP) discusses how the project is based on three factors related to the National Policy Statement on Fresh Water, released in 2020 (NPS-FM 2020), and the requirements within that Councils are legally obliged to meet:

- An assumption surrounding the impact of intensive vegetable production on water quality.
- An "exception" (this phrase contained within the project contract) clause within the NPS-FM 2020 for the Councils overseeing the two SVGA, allowing separate rules for managing water quality in the SVGA.
- Specific Target Attribute States (TAS) related to Nitrogen management to be investigated by this project, these being a subset of the full list of attributes contained in the NPS-FM 2020.

MfE expected that the impacts of requiring water quality improvements was not to be investigated on a per vegetable level, but to be investigated by "vegetable categories", these categories being the ones set out by the FAO in the 2016 report "Minimum Dietary Diversity for Women – A Guide to Measurement".

2.1 The Assumption

MfE has, to date, been working from this assumption, which is discussed and outlined in the RFP released by MfE:

> *"that compliance with the National Bottom Line targets for relevant attribute states would pose a significant risk to domestic fresh vegetable supply."*

The assumption was based on the information available to the Ministry during the development of the NPS-FM 2020, with this information including modelling reports developed by the Ministry for Primary Industries (MPI).

The AgriChain Centre has been asked to test this assumption, as the assumption had formed the basis for the inclusion of an exception option in the NPS-FM 2020.

2.2 The Exception

The exception is a general term for the provisions of clause 3.33 of NPS-FM 2020, as outlined in Section 1 – Background.

2.3 Target Attribute States (TAS)

The Target Attribute States required to be investigated by this project are as follows:

Target Attribute States of Relevance to Project

Water Quality & Physical Habitat Attributes	Aquatic Life & Ecosystem Attributes	Human Health
• Total Nitrogen (Trophic State) • Ammonia (Toxicity) • Nitrate (Toxicity) • Dissolved Oxygen	• Phytoplankton • Periphyton • Macroinvertebrates	• Cyanobacteria

Table 1: Target Attribute States of Relevance to Project

These TAS are those the exception applies to[2]. Note the attributes are not split into those applying to rivers and those applying to lakes.

There is a limited availability of data on the <u>direct</u> link between vegetable production, for the Aquatic life & Ecosystem, Human Health, and Dissolved Oxygen attributes. However, evidence exists for the direct link between vegetable production and Nitrogen/Nitrate/Ammonia TAS, with further direct links between these three TAS and the other TAS in the exception. Therefore, this report focuses on the impact of vegetable production on the Nitrogen/Nitrate/Ammonia TAS, as improvements in these will result in improvements in the other TAS.

2.3.1 Macroinvertebrates

Macroinvertebrates are frequently used in water quality assessment programmes in New Zealand (Stark, 1985; Stark et al., 2001) and overseas (Allan, 1995; Friberg et al., 2011) Macroinvertebrate taxa show a range of responses to differences in water quality (Stark 1985). For example, Chironomidae and Gastropoda are generally considered to be pollution tolerant taxa while Plecoptera and Megaloptera are sensitive to pollution.

Their sedentary nature, high abundance, ease of sampling and identification and their longevity, long enough to record cumulative effects of stress and exposure over time, are good reasons for their use as bioindicators. Compared to spot chemical testing, macroinvertebrate indicators of water quality have the advantage of being able to integrate and monitor the effects of a wide variety of potential pollutants over an extended period of time (Rosenberg & Resh, 1993).

While pollutants may only exist in the environment for a short period of time, the impact on stream ecology may be more long term. The presence or absence of key macroinvertebrates may therefore be indicative of pollution, even if the responsible contaminant is no longer present or detectable in the environment. The macroinvertebrate community at a given site may be considered a result of the prevailing water quality at that site. Macroinvertebrates are a product of the food supply (Periphyton) and predators (fish) of a river ecosystem. As such, they may be the best representation of water quality in river systems.

Macroinvertebrates in New Zealand are assessed using a variety of indices. The MCI is the Community Index (MCI) (Stark & Maxted, 2007) is an index based on the presence of macroinvertebrate taxa which are assigned a score based on their tolerance to organic

[2] Refer to NPS-FM 2020 clause 3.33(3)(b) and Part B of Appendix 5.

pollution (1= highly tolerant, 10 = highly sensitive). MCI scores over 135 are considered clean water, an A in the NPS-FM 2020. Scores less than 90 are 'severely polluted'.

The QMCI is the Quantitative Macroinvertebrate Community Index (QMCI) and is similar to the MCI, but also takes into account the number of individuals of each species collected (Stark, 1993). The MCI uses the presence or absence of species, while QMCI uses densities and is not sensitive to finding taxa only represented by one or two animals. As some species may reach densities of tens of thousands per square metre of streambed, this may be important. A QMCI greater than 6.5 indicates clean water and an NPS-FM 2020 A band, while a QMCI of less than 4.5 indicates severe pollution.

The Average Score Per Metric (ASPM) was developed for New Zealand by (Collier, 2008) and combines normalised scores for MCI, %EPT (Ephemeroptera, Plecoptera and Trichoptera) abundance and EPT richness. Scores of greater than 0.6 indicate clean water and those below 0.3 polluted water.

2.3.2 Periphyton / Phytoplankton

Periphyton is the algae living on the surface of substrates in a river or stream. Phytoplankton is the algae that floats in the water column in large rivers and lakes. Periphyton often forms unsightly mats of filamentous 'slime'. Phytoplankton, similarly, makes the water green, smelly, and depending on the plankton species, toxic. Periphyton in rivers, and Phytoplankton in lakes indicate the state of nutrients in the surrounding water (Biggs, 2000; Abell, Özkundakci & Hamilton, 2010).

If Periphyton biomass becomes too high it can degrade the aesthetic, recreational and ecological health of a river system (Biggs 2000). Chlorophyll-a concentrations of Periphyton above 200 mg/m^2 is indicative of excessive growth beyond which degradation occurs. Phytoplankton chlorophyll-a concentrations above 12 mg/m^3 indicate eutrophication of the lake, low oxygen levels and degraded ecological health.

2.3.3 Nitrate/Ammonia/Nitrogen

Soluble inorganic Nitrogen is present in three forms (ammonia - NH4-N, nitrate - NO3-N and nitrite NO2-N). These are readily available for plant uptake, and can result in excessive levels of Periphyton or Phytoplankton. If nutrient levels increase, they can promote increases in algal biomass, that may quickly reproduce beyond the scope of resident algal grazing invertebrates to keep the biomass under control.

When this threshold is breached the algae continue to grow, making them unavailable for most grazing invertebrates, promoting a trophic cascade that rapidly reduces food sources for invertebrate and fish predators, which then either die or migrate out of the area. There is thus a change from mayfly, stonefly and caddisfly dominated communities to ones with worms, snails and midges. These do not support the same abundance, biomass or diversity of fish that the former communities do.

Respiration of this excessive algae at night reduces oxygen levels in the water, further exacerbating animal mortality, and eventually altering water chemistry. Periphyton can also build up to such a biomass that the lower layers start to rot. This can dramatically reduce the oxygen levels and change the pH of the water leading to significant adverse effects on many invertebrates and fish.

Ammonia and nitrate can also be toxic to aquatic life (macroinvertebrates and fish) at higher concentrations. In high concentrations, nitrate can interfere with macroinvertebrate and fish oxygen transport in the blood, and consequently, metabolic function (Hickey et al., 1999; Hickey & Martin, 2009). In humans, this effect is known as methemoglobinemia, or blue baby syndrome. Ammonia (NH3-N) toxicity occurs when accumulations inside the body interfere with metabolic processes and increase body pH (Hickey & Vickers, 1994). When exposed to high concentrations of ammonia, fish go into convulsions, followed by coma and death.

2.3.4 Cyanobacteria

In lakes and ponds, high levels of nutrients can result in blooms of a group of Phytoplankton called cyanobacteria, also called blue-green algae (Dodds & Whiles, 2010). Some cyanobacteria produce poisons called cyanotoxins. When people or animals are exposed to cyanotoxins, they can become sick or can die. Cyanobacteria are not always toxic at all times. Thus the NPS-FM 2020 gives two measures for cyanobacteria monitoring and assessment in lakes. The total biovolume of all cyanobacteria can be measured, or the biovolume equivalent of potentially toxic cyanobacteria can be measured. Only the former was assessed in this study.

2.4 Vegetable Categories

The vegetable categories set out in the FAO report were converted into a New Zealand specific list by Curran-Courane & Rush (2021)[3]. Table 2 shows their list, which is used as the basis for all vegetable category data included in this project:

Vegetable Categories

Vegetable Category	Vegetables in Category
Dark Green Leafy Vegetables	• Asian Greens • Silverbeet • Spinach
Legumes	• Beans • Peas
Other	• Asparagus • Beetroot • Broccoli • Cabbage • Cauliflower • Cucumbers • Eggplant • Garlic • Herbs • Kumara[4] • Lettuce • Melons • Mushrooms • Onions • Shallots • Sweetcorn • Tomato • Truffles
Vitamin-A	• Capsicum • Carrots • Pumpkin • Squash
White Roots & Tubers	• Potatoes

Table 2: Vegetable Categories

[3] Curran-Courane, F., and Rush, E (2021)."Feeding the New Zealand Family of Five Million, 5+ a Day of Vegetables?" *Earth 2021, 2(4), 797-808*

[4] Curran-Courane, and Rush determined that Kumara fell into the FAO 'Other' category on the basis that the FAO's 'White Roots & Tubers' category covers high carbohydrate products, including white-fleshed sweet potatoes. As New Zealand grown Kumara either have red, orange or yellow flesh, Kumara were assigned to the 'Other' category. There would have also been an argument to be made that Kumara should be included in the 'Vitamin A' category. As it stands, the project was directed to use the Curran-Courane and Rush (2021) list, so for the purposes of this project Kumara are classified as 'Other', despite the industry acknowledging that Kumara are indeed a tuber.

2.5 The Project Team

The Project team consisted of:

Project Team

Member	Role	Expertise
Dr Hans Maurer	Project Director	Strategic Commercial & Fresh Produce Chain Research
Jacob Lawes	Project Manager	Technical Research & Analysis
Dr Russell Death	Team Member	Freshwater Science
Dr Nick Roskruge	Team member	Soil Science & Iwi relationships
Anne-Marie Arts	Internal Peer Reviewer	Fresh Produce Food Safety/Food Security

Table 3: Project Team

2.6 Parties Involved

MfE determined that this project involved specifically working with named designated project partners: the three local Councils responsible for the two SVGA regions, all iwi located in the SVGA, and a Māori Trust with a particular focus in water management.

Project Partners

Councils	Iwi & other Māori Partners
Auckland Council	Ngāti Te Ata
	Ngāti Tamaoho
Waikato Regional Council	Ngāti Tipa
	Waikato-Tainui
Horizons Regional Council	Muaūpoko
	Ngāti Raukawa
	Lake Horowhenua Trust

Table 4: Project Partners

The project also sought information from a variety of stakeholders within the vegetable industry, in order to gain industry data and knowledge that would assist the project to develop its analysis.

The industry stakeholders we engaged with were:

Industry Stakeholders Consulted

Stakeholder	Sector Position
A. S. Wilcox	Potato and onion grower
Balle Brothers	Potato and onion grower
Countdown	Retailer
Foodstuffs North Island	Retailer
Horticultural Export Authority	Statutory Body
Horticulture New Zealand	National Industry Body
Kaipara Kumara	Packhouse & grower
Leaderbrand	Leafy greens & brassica grower and packer
MG Marketing	Vertically integrated wholesaler/grower/exporter
NZ Hothouse	Glasshouse tomato grower
Onions New Zealand	Product group, affiliated with Horticulture New Zealand
Plant & Food Research	Crown Research Institute
Primor Produce	Wholesaler
Pukekohe Vegetable Growers Association	Regional growers' association
Turners & Growers Fresh	Vertically integrated wholesaler/grower/exporter
United Fresh	The only pan-produce organisation in New Zealand covering the entire fresh produce supply chain
Vegetables New Zealand[5]	Product group, affiliated with Horticulture New Zealand.
Woodhaven Gardens	Leafy greens & brassica grower

Table 5: Industry Stakeholders Consulted

2.7 Other Projects Operating in Parallel

Throughout this project's active period, several other government funded projects investigating water quality improvements and vegetable production in the SVGA were also active.

Several Project Partners, as well as industry stakeholders, indicated to the project team their confusion on the separate projects being run, by the same Ministry/Ministries, with this confusion being attributed by the Project Partners and industry stakeholders to the similar frameworks, scopes, and objectives of these projects.

These Project Partners and industry stakeholders were often involved in multiple of these projects, yet they stated that they did not always clearly understand each project's scope, or the respective objectives, and would mix the details of each project up, including what information had been provided to each project, or what had been discussed with the respective project teams. Some referred to being of the opinion that they had already provided information to, for example, "the MfE water project", and so were confused as to why another "MfE water project" existed, and why it was requesting information that had already been provided to the other project(s).

[5] *Note: Vegetables New Zealand and Process Vegetables New Zealand are two separate Product Groups affiliated with Horticulture New Zealand. Vegetables New Zealand was consulted for this project.*

As such, these other projects operating in parallel are listed here for reference purposes:

Other Projects of Relevance

Project	Key Stakeholders	Purpose
Horticulture Typology Project for the Fresh Water Modelling Tool (FWMT)	• Auckland Council • Horticulture New Zealand • Pukekohe Vegetable Growers Association	Understanding baseline environmental and economic footprints for commercial vegetable production and kiwifruit permanent horticulture, as well as the opportunity, effect and cost of on-land interventions to mitigate contaminant losses.
Integrated Catchment Management Programme (ICMP)	• Ngāti Te Ata • Ngāti Tamaoho • Waikato-Tainui • Ministry for the Environment • Ministry of Primary Industries • Auckland Council • Waikato Regional Council • Horticulture New Zealand • Pukekohe Vegetable Growers Association	Enable faster water quality improvement and more sustainable use of highly productive soils.
Sustainable Vegetable Systems (SVS)	• Ministry for Primary Industries • Horticulture New Zealand • Plant & Food Research • Potatoes New Zealand • Vegetable Research & Innovation	Reducing the environmental impact of intensive growing of potatoes, onions, brassicas and leafy greens, by quantifying and modelling Nitrogen leaching, and engaging vegetable growers focused on improving crop modelling.

Table 6: Other Projects of Relevance

This project did not directly engage with the FWMT team, but talked to Auckland Council, Horticulture New Zealand, and the Pukekohe Vegetable Growers Association separately, with the FWMT project forming part of the conversations.

A similar approach was taken as far as the ICMP project was concerned.

MfE had facilitated an invitation for two project team members to attend an SVS hui at the end of May, which enabled the project team to directly engage with SVS team members to discuss their interim findings and workstreams.

3 Document Structure

Due to the complexity of the project, this report contains more sections than could typically be expected from a standard document of this nature. These various sections are therefore introduced here:

- Section 4 (Relevant Intricacies of the Vegetable Supply Chain) introduces and explains several concepts related to the process of moving vegetables from producers to consumers. The data collected by this project, and the potential impacts of any decision made on the basis of this project's findings, need to be understood within the context of these concepts, as these are baseline realities of how the fresh vegetable supply chain operates.
- Section 5 (Scope) consists of a comprehensive list of what matters are, and are not, in scope for this project. This scope was based around answering specific questions for MfE, and the project needs to be understood within this limited framework.
- Section 6 (Methodology) identifies the methodologies employed to test the assumptions listed and discussed in this report.
- Sections 7 (Data Stocktake & Gap Analysis), 8 (Stakeholder Positions & Perspectives), and 9 (Industry Data & Knowledge Contributions) report on the outcomes of having applied the methodologies introduced in Section 6, and our initial findings prior to beginning our modelling.
- Section 10 (Models) presents our modelling outcomes, based on the data provided, in order for us to be able to answer MfE's questions. This Section also contains relevant background information for the models shown, in order to assist the reader.
- Section 11 (MfE Project Questions) specifically lists and addresses the questions MfE has posed. This section aims to draw the various strands of information and data generated by the work The AgriChain Centre has undertaken into one cohesive message that can contribute towards finding enduring solutions for improved water quality in the SVGA.
- This message is then expressed in Section 12 (Conclusion).

4 Relevant Intricacies of the Vegetable Supply Chain

Within the context of delivering this piece of work, a number of process/supply chain steps relevant to the questions this project has been asked to address have arisen. There is a potential for misunderstanding to occur. These steps are therefore introduced here, and where possible defined, and then addressed in Section 9 (Discussion).

4.1 The Meaning of "Fresh" for this project

This report focuses on fresh vegetable production. The list of product categories examined on the basis of the FAO classification is shown in Table 2, page 17.

For the purpose of this project, we have been asked to interpret domestic fresh vegetable supply as 'a household's ability to access a wide range of nutritious vegetables at all times.'[6]

One of the reasonable questions that arise within the context of this project is:

> "What is the meaning of 'Fresh'?"

The Codex Committee on Fresh Fruit and Vegetables[7] (CCFFV) defines "fresh", from a global food standards perspective, as follows:

> *"Fresh: this word has different meanings depending how and where it is used in the standard. The most commons meanings are:*
>
> - *Recently harvested, not preserved by any means and in a state of vigour.*
> - *Not dull, stale, wilted or faded."*

Codex is jointly authorised by the Food and Agriculture Organisation (FAO) and the World Health Organisation (WHO), and is the recognised authority on fruit & vegetable health related standards.

We have therefore chosen to use the Codex definition of "Fresh" for this project.

4.2 Frozen, and Process Vegetables – What the Project is not examining

This category includes all vegetables specifically grown under contract to a processor, e.g. McCains or Watties, typically for the purpose of processing into frozen, canned or bottled vegetable products. Product examples are potatoes grown for French Fries production, or fresh peas that are snap frozen.

Vegetables grown for processing are typically specific varieties identified as being suitable for processing and many of those varieties are less suitable, or not suitable at all, for fresh market sale. Vegetables destined for processing are therefore grown as separate crops and in separate fields from those crops destined for the country's retail produce departments or greengrocers.

This degree of separation extends also to the supply arrangements between growers and processors. In the case of processed vegetables, supply negotiations typically involve a negotiated purchase price agreed upon at the time of planting. This approach differs to supply agreements being struck between retail buyers and fresh market growers, where

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[6] Staff. 2023. Sensitivity of domestic food supply to loss in vegetable growing production in Specified Vegetable Growing Areas. 1218-01-RFP. Ministry for the Environment.

[7] Codex Committee on Fresh Fruits and Vegetables (CCFFV). 2022. Definition of terms for application in the layout for codex standards for fresh fruits and vegetables. Accessed on 27 June 2023.

prices are typically reached on the basis of market conditions prevailing in any given week, or short-term periods longer than a week.

The rationale behind this approach is that processors require certainty of crop availability to justify the ongoing dedication of capital and operational funding required to run their processing plants. Process growers need a degree of certainty as well. Growers of process crops without a confirmed customer increase their business risk beyond what banks are typically prepared to fund.

Within the portfolio of twenty horticultural product groups affiliated with Horticulture New Zealand is Process Vegetables NZ, representing those growers who are classified as commercial process vegetable growers.

The bulk of the legume category, i.e., peas, is grown for processing, sold frozen into retail, and not managed by the fresh produce value chain beyond getting the unshelled peas to the processing factory. As such, while legumes can technically be purchased fresh by consumers, they are typically purchased in a frozen state. Production data available has identified minimal legume plantings in either of the SVGA. Given this data, and the project scope of examining only domestic consumption of <u>fresh</u> vegetables, there is no <u>fresh</u> legume food supply issue expected to occur if production is constrained in the SVGA.

4.3 Domestic versus Export Vegetable Production

Export vegetable production is out of scope for this project. The reality, however, is that vegetable crops produced for the "fresh market" are typically grown as a homogenous volume, with the decision of how much of the total crop harvested is committed to export being dependent upon yield, volumes, and market conditions in New Zealand & the importing countries. A relevant vegetable example in the Pukekohe SVGA is onions.

4.4 Crop Rotation

The term "crop rotation" refers to the practice of not repeatedly growing one crop in a particular field or paddock, but changing the crop grown in that particular location from one production cycle to the next, with the original crop being grown in a different location. This practice therefore requires several crops, and several growing locations.

The repeating pattern of the multiple crops grown at each location is known as a rotation. Connected to this practice is the practice of leaving parcels of land "fallow" (unplanted) for a period of time, to encourage natural regeneration.

Behind crop rotation sits a complex framework of interactive factors, that have to be in alignment, in order for effective vegetable production to occur. These factors are:

- The availability of sufficient owned land, or, access to sufficient lease land, or sufficient exchange land, within a production district, to allow for effective crop rotation to take place.
- The environmental and economic ability to grow multiple crops in a region, on the same land, at different times of the year, to enable rotation to take place.
- The logistical and market related ability to grow at least two different crops of similar acreage, to ensure crop rotation can occur, without major yield fluctuations.
- The presence of competing producers willing to cooperate in achieving rotational benefits across their respective multiple economic units.
- The skills and competencies amongst growers, to plan and manage complex crop rotation models, several growing cycles ahead.

4.5 Forage Vegetables

Forage vegetables are out of scope for this project. Forage vegetables are defined as vegetables grown as stock feed. Examples of forage vegetables are turnips, swedes and fodder beet, amongst others. Such crops are grown in both SVGA, are fertilised, and contribute to leachate, but are not destined for human consumption.

The obvious reason for why they are grown in both SVGA is that stock are also present in these areas, requiring supplementary feed to pasture. As fodder crops are not within our scope, we have not attempted to quantify the contribution they make to nutrient leachate in the SVGA. However, any possible future decision leading to a reduction of vegetable production in the SVGA areas would need to consider the role forage vegetable crops play as well.

4.6 Wholesalers, Retailers, and Data Anonymity

Any changes made on the growers' side of the farm gate will have consequences for those parts of the produce supply chain that operate on the post-harvest side of the farm gate. The role of wholesalers and retailers in managing any changes that are envisaged as part of NPS-FM 2020 is therefore critical.

Key wholesalers and retailers were therefore asked to contribute data to this project. Due to the time constraints of the project, the project applied the principle of sector sparsity, commonly known as the Pareto Principle or 80/20 rule. This data is introduced in Section 10 (Models).

This means that the number of wholesalers and retailers was limited but at least 80% of the market was covered through that approach. For that reason, we are unable to identify data by separate provider, as this would compromise their respective competitive positions. Instead data provided has been used for further analysis and trend determination across the sectors.

4.7 The Produce Imports Relationship with the Domestic Market

New Zealand imports a range of tropical fruits all year round, e.g. bananas and pineapple, as these cannot be commercially grown here. Also imported are table grapes from three different countries depending on the time of year, stone fruit on a counter seasonal basis to our local production, and crops such as winter vegetables (beans, courgettes, tomatoes) when market conditions provide a commercial window of opportunity. Whilst imported fruit generally arrives via shipping container or reefer vessel, imported vegetables are typically airfreighted to New Zealand. The principal reason for airfreighting vegetables is that the perishability of vegetables significantly exceeds that of fruit, particularly in the green leafy category.

The logistic requirements of importing limited volumes of selected crops, under counter seasonal conditions, by air, when such crops already represent a significant risk on the basis of perishability, are relatively complex.

Were one to consider expanding the range of fresh vegetables to be imported, as well as the time windows during which import would occur, several additional constraints would have to be considered. These include:

- Availability of vegetables available for export in other countries.
- The geopolitical risk of relying on another nation for part of our basic food needs.

- The degree of certainty that required by growers in the exporting countries, in order for them to commit to grow additional crops for the New Zealand market.
- The ability of airport facilities in the exporting countries, and New Zealand, to receive and manage large incoming quantities of fresh vegetables in a manner directly connected to the crops' perishability, i.e., fast.
- Sufficient numbers of wide-bodied aircraft, to maintain reliable supply chains.
- The impacts of phytosanitary treatments for pest & disease management at the border, and the quality & perishability impact this will have on imported produce.
- The impact of higher logistic cost components on the ultimate retail price, and the consumer reaction to significant price increases as a consequence.

Given the above realities, it needs to be acknowledged that attempting to move substantial volumes of fresh produce from domestic to offshore production will be complex, and constrained by factors outside New Zealand's ability to mitigate, either partially or fully. This is likely to result, at best, in fresh vegetable imports only being available at higher prices, lower volumes, and reduced/alternate seasonalities, compared to the pricing, volumes, and seasonality available with Zealand production.

Where the fresh produce value chain cannot mitigate these constraints to the satisfaction of consumers, substitutes will need to be found. For industry, this would involve imports of frozen vegetables, and for consumers, this could involve consumers rebalancing their purchases of vegetables, both within each category, and in total, as a response to the new market conditions.

The most likely outcome, therefore, if fresh vegetable marketable yields were to be reduced, is that New Zealand would replace production, and therefore consumption, of fresh vegetables with importation of frozen vegetables, due to the realities of the domestic and international supply chains discussed above.

Given increasing awareness of the impacts of greenhouse gas emissions to ship food internationally, as well as consumer perceptions about foodborne illness outbreaks related to imported produce, the potential exists that consumers could have concerns about the environmental impact, and health risks, related to an increase in imported vegetables (fresh or frozen) and may reduce their consumption of fresh produce, without substituting it for imported produce, resulting in an overall decrease in vegetable consumption.

New Zealand Food Safety released a report entitled "Microbiological risks associated with frozen raw produce used in uncooked food preparations" in July 2023. Whilst the major focus of this report relates to frozen berries, the global health-related incidents examined within the scope of the report include mixed vegetables, corn, tomatoes, onions, and beans from various countries.

An increase in the importation of frozen vegetables would be a highly likely consequence of any potential significant reduction of vegetable production in the SVGA or New Zealand as a whole. Whilst the New Zealand Food Safety report quite rightly focusses on frozen berries, due to the high number of incidents reported, consumers do not always operate on the basis of fact, with perceptions at times being more than capable of driving behaviours and opinions.

Therefore, consumer perception to the potential increases in imported frozen vegetable volumes, as a result of potential reduction of fresh vegetable domestic production, ought to be also considered in any future decision-making process.

5 Scope

The outcomes of this project will be of considerable interest to all the parties directly involved in this project, who will be directly impacted by the project's outcomes. This project's outcomes will also be of considerable relevance to New Zealand consumers, whose vegetable purchasing habits may be impacted by changes in fresh vegetable availability. Whilst scope needs to be well defined for any project, a clearly defined scope holds particular relevance for this project due to the potential implications of this evidence focused report.

5.1 In Project Scope

- Vegetable production in the SVGA destined for human consumption as fresh vegetables in the domestic market.
- Sourcing, analysing & modelling existing data from a variety of sources, and reporting on findings related to the role fresh vegetable production plays in waterway nutrient pollution in the SVGA.
- Domestic fresh vegetable supply: a household's ability to access a wide range of nutritious vegetables at all times (food supply), considering availability and affordability.
- Commenting on potential alternate production methodologies and/or alternate production regions.
- Discussing the findings.

5.2 Not in Project Scope

- Water quality related to catchments outside the SVGA.
- TAS attributes that are not the subject of the clause 3.33 exception, including sedimentation.
- Analysis of vegetable planting area & production related to non-human consumption (e.g., forage production for cattle feed).
- Fruits, grains, nuts, edible flowers, and other consumable plant products that are not vegetables.
- Economic and financial modelling outside the specified modelling required by the contract.
- Vegetable production in the SVGA destined for further processing into Fast Moving Consumer Goods (FMCG) products or similar (e.g., canned tomatoes, carrot juice, etc.).
- Vegetables that are sold frozen, even if not further processed (e.g., frozen beans/peas).
- Modelling & reporting on findings related to the role of other contributors to freshwater catchment pollution in the SVGA.
- Generating new data.
- Broader food security aspects not related to domestic fresh vegetable supply.
- Any modelling and reporting on economic considerations related to alternate production methodologies and/or production regions in specific detail.
- Modelling or reporting on broader economic considerations related to clause 3.33 of the NPS-FM 2020.

6 Methodology

The process of testing the assumption central to the project was prescribed by MfE and consisted of four separate yet connected components. These are:

- Literature discovery on the subject matter, with a particular focus on the period since 2020, when the NPS-FM 2020 was published.
- Data discovery, ideally also from the post 2020 period, through connecting with various recently completed related projects, as well as data potentially available from within the commercial produce value chain.
- Answering 3 specific main questions and 7 supporting questions posed in MfE's RFP document.
- Modelling suitable datasets identified through the discovery project for verification purposes and as a contribution towards providing the answers needed to reach a conclusion about how to proceed with an effective and efficient approach to the challenges vegetable production in the SVGA represent.

6.1 Project Constraints

The single largest constraint was time. The project time frame between commencement and delivery of the final report was 13 weeks. This proved particularly challenging in the following areas:

- The project team was unable to provide MfE's project partners, i.e. iwi and Councils, with sufficient notice to ensure a high attendance at the two face-to-face meetings MfE had specified in both SVGA areas. Attendance was therefore less than expected, which impacted on feedback received.
- A further contributing factor was that a number of representatives who could be reasonably expected to attend our meetings, and had every intention to do so, had conflicting appointments at other hui dealing with similar issues, including hui that had been called by MfE itself.
- In addition to the time-related constraints in terms of consulting with Tangata Whenua we need to add that the technical nature of this project and the lack of Māori producers specifically identified within each SVGA, meant that Māori were not consulted on the technical matters pertaining to this project. Māori are contributors to land use in the SVGAs but are not engaged in commercial horticulture in these regions. Iwi interests were presented at a soil and water quality level of the actual land use, so their interests and responsibilities as kaitiaki remain.
- Produce wholesalers and retailers had until this point not been part of any extensive discussion on the NPS-FM 2020 and its implications, nor had they been asked to contribute data for analysis. The process of 'onboarding' those supply chain participants therefore had to start from scratch. Whilst all parties talked to were, in principle, prepared to make data available, the practically of doing so not only took time but also exposed the data owners to learnings about the limitation of using their data for analysis other than the commercial purpose tailored to their specific business needs.

6.2 Assumptions

The project was tasked to test the central assumption that had led to the inclusion of clause 3.3. in the NPS-FM 2020[8]. The assumptions the project team then made at the outset of this project were:

- Data availability would be fragmented.
- Project timeframe would allow little room for delays.
- Some data provided might not be appropriate for use by the project.
- Some industry data would not be able to be provided, due to confidentiality and legal issues.
- Data sets may be of several differing periods, making comparisons difficult.
- Some data sets may have different methodologies, rendering data comparisons invalid.
- The timeframe for collecting data may mean that some sources are not identified or utilised in time.
- For legal considerations the data received from retailers and wholesalers would vary in its granularity.

[8] National Policy Statement for Freshwater Management (2020), Page 36.

7 Data Stocktake & Gap Analysis

Nitrate pollution of waterways through vegetable production is not a new topic and a selection of literature exists. Some literature is decades old, while some has been generated more recently. MfE contributed a number of documents directly. Others were sourced by The AgriChain Centre.

7.1 Literature Provided by MfE

At project commencement, MfE provided the project team with two documents related to previous MfE projects investigating the SVGA regions. These are:

- *Denne, T., and Curtis, A. (2022). Impacts of Water Quality Targets on Domestic Food Security: Indicators of Vulnerability. Report for the Ministry of the Environment*. This paper examined:
    - Links between the national bottom-lines for the TAS attributes.
    - Setting of targets below the national bottom-lines.
    - Domestic production of fresh vegetables & food security.
- *GHD (2022). Specified Vegetable Growing Areas Gap Analysis. Report for the Ministry of the Environment*. The purpose of this report is to:
    - Provide a stocktake of relevant evidence on the SVGA exceptions.
    - Present the findings on the relevance and comprehensiveness of evidence.
    - Identify evidence gaps and future work opportunities to focus on
    - Suggest how identified additional evidence could be obtained.

During the project activity, the Minister for the Environment released a letter to all Regional Councils requesting information on how the Councils planned to comply with the NPS-FM 2020 for both food security and water quality aspects. The Auckland Council version of this letter was provided to the project team.

7.2 Literature & Data Sourced by The AgriChain Centre

Outside of the literature provided by MfE, the project team also investigated a variety of sources from which relevant data could be obtained, including scientific research, reports held by Councils and/or iwi, and industry data & literature.

The data sources and literature were reviewed by the project team, and found to contain information or data that would be of use to this project. Not all of this data is quantitative, and several sources dealt primarily with qualitative data. The literature sources are presented in **Error! Reference source not found.**. Industry data sources are presented below.

Industry Data Sources

Data Source	Data Provided
Countdown New Zealand	Supply Chain volume and risk data
Foodstuffs North Island	Supply Chain volume and risk data
Horticultural Export Authority	Information on domestic & export production linkages in vegetable exports
Horticulture New Zealand	Grower and Grower Body perspectives & insights
Leaderbrand	Information on production costs within the Pukekohe SVGA
MG Marketing	Supply Chain volume and risk data
NZ Hothouse	Data on greenhouse & glasshouse construction costs
Onions New Zealand	Information on domestic and export linkages in onion production
Pukekohe Vegetable Growers Association	Information on Pukekohe SVGA grower actions and grower perspectives
Turners & Growers Fresh	Supply Chain volume and risk data
Woodhaven Gardens	Information on production costs within the Horowhenua SVGA

7.3 Gap Analysis

This Gap Analysis aimed to identify the extent to which we could determine what data was missing, what data sets were of limited use in the way they had been provided, the connection between the lack of data and industry dynamics, and what previous or parallel projects related to the topic had been able to achieve.

- Several documents with up-to-date data provided by the Councils involved in this project relate to active and ongoing projects running in parallel with this project (i.e., the SVS project, the ICMP project, the FWMT project). As such, this data could only be released to this project at specific times, once the other projects had authorised the release of their data. In one case, this meant that the data was not provided to the project until the last week of May.
- While horticulture and fresh produce industry stakeholders have been willing to share their data to the project, to enable some modelling of the likely economic impacts required by this project, their data systems typically do not hold data in the format required by this project. As such, the industry stakeholders providing the data have had to spend 1-2 weeks in some cases to analyse their data and create data in the format usable by this project.
- Even once the data from industry stakeholders had been prepared in a format that was usable by this project, some of that data then had to go through a release review process by the legal departments of some industry stakeholders. This is not a process that the project members, or the industry stakeholders, have been able to speed up or bypass. Some data was not provided to the project due to commercial sensitivities.

Due to the above-mentioned significant delays in receiving data, which were outside the project's control, the project was limited in what data it could receive from iwi, Councils, and industry.

As such, the discussion of the data gaps identified relates only to the gaps that existed at the time of writing this report, as several gaps may be answered by data that is made public following the release of this report, or following the completion of this project.

In some instances, we have been advised of potential availability of additional data, e.g., the SVS project and the ICMP project. We also believe it is a reasonable assumption that additional data sources will emerge as various sets of stakeholders continue to research current levels of leachate, when looking for solutions.

However, based on the data received, the project team is able to provide the following information:

- The fresh produce industry stakeholders who were willing to provide data to the project (from grower, wholesaler, and retailer perspectives), were unable to provide sufficiently accurate and detailed data to enable precise modelling of fresh produce price movement occurring if significant portions of the SVGA production were to be lost. This inability relates to the physical and commercial realities of the fresh produce industry, and regardless of the industry's willingness to provide data, this is not something that can be worked around. The modelling of the data that was provided therefore needed to be based on general "bands" of constrained production levels, and the associated bands of likely impact. The full discussion of this reality would require a significant report on its own, but in brief, some of the more significant factors which force this outcome include:

  - The manner in which the fresh produce supply chain manages logistics around New Zealand.
  - Time of year.
  - Import availability, and the impact this has on product availability at various price points.
  - Access to substitute crops.
  - Access to frozen alternatives.
  - Individual customer preferences.
  - Customer price point related purchasing decisions.
- The majority of the data provided on contamination in the SVGA, and identified from publicly available sources, relates to Nitrogen. Many of the other attributes that the project is investigating have very limited data available. The project team has found some data on the other attributes, but this data is at times generated outside the SVGA, or indeed outside New Zealand, and deals with linkages between the other attributes and Nitrogen entering waterways as a result of land use. This means that attributes other than Nitrogen are affected by vegetable production, because the Nitrogen entering the water alters the levels of the other attributes. The link between vegetable production and attributes other than Nitrogen is therefore an indirect link, which required consideration in our modelling.
- Models found in relevant literature were sometimes based on older third-party models/assumptions, which in turn were based on data sources which were themselves generalised assumptions – e.g., a modelling project prepared for Horticulture New Zealand in 2020, and presented to Horticulture New Zealand in 2021, was based on the 2016 LUCAS database for Pukekohe, and a "CASM Water Quality Model" for Horowhenua.

We have identified two caveats within this Data and Gap Analysis section, that were the cause of the main data gaps identified.

- "Recent" publications may involve data several years older than the year of document publication. Some literature examined was from 2020-2022, but referenced data collected and modelled at least as far back as 2014, meaning these findings and analytics may be on the basis of data a decade old[9].
- Where accurate data was provided by industry, this could only be used in a general manner by our project, as specific data sought by this project was either:
  - Data not held by industry.
  - Data held by industry, but not in a usable form within the project's timeframe, due to the further analysis and investigation required.
  - Industry data that could not be provided to the project team due to concerns by the legal departments of some industry stakeholders related to supplier & customer data privacy, or other legal reasons.
  - Data held by industry, but categorised and managed by each industry participant to meet their internal needs, such that when industry data involved product that may move between the industry stakeholders, some

[9] While data a decade old is likely to still be relevant, and able to be used for comparison purposes, the comment about the age of literature relates to MfE's verbally expressed desire for this project to utilise post 2020 data wherever available.

data related to duplicated product, and could not always be separated appropriately.

8 Stakeholder Positions & Perspectives

8.1 The Councils

The Horowhenua SVGA sits in its entirety within the jurisdiction of the Horizons Regional Council.

Responsibility for the Pukekohe SVGA is shared between Auckland Council and the Waikato Regional Council. The relevant boundary between the Councils starts at a geospatial point on the West Coast near Waiuku, skirts both Waiuku and Pukekohe townships to the South and incorporates the Waiuku and Tuakau vegetable growing areas before coming to an end near Pokeno[10].

Horizons Regional Council and Auckland Council were able to attend both stakeholder meetings. Waikato Regional Council was able to attend the second stakeholder meeting.

The known common position communicated to the project, by all local authorities involved, was that the provisions of clause 3.33 lacked sufficient clarity and evidence to allow the clause to be considered without exposing Councils to the risk of litigation.

8.2 Iwi

There are several iwi connected to the land contained in each SVGA. Ngāti Te Ata, Ngāti Tamaoho, Ngāti Tipa, and Waikato-Tainui are the iwi in the Pukekohe SVGA, and in the Horowhenua SVGA, Muaūpoko and Ngāti Raukawa. Other iwi exist in the wider Pukekohe and Horowhenua regions around each SVGA, but were not a part of this project.

Ngāti Tamaoho was able to attend both Pukekohe stakeholder meetings. A separate zoom meeting occurred with Ngāti Te Ata. Waikato-Tainui and Ngāti Raukawa were unable to meet with the project team.

Muaūpoko was able to attend the second Horowhenua stakeholder meeting. Although the Muaūpoko representative is a Trustee of the Lake Horowhenua Trust, neither the Trust nor Ngāti Raukawa were formally represented.

The common position of all iwi involved communicated by the iwi to the project team, was that insufficient consultation had taken place, prior to clause 3.33 being inserted into the NPS-FM 2020 document.

Based on the project team's discussion with iwi about clause 3.33, the project team is of the view that the provisions on how clause 3.33 can be implemented is not necessarily clear to all iwi. We are specifically talking to this clause only enabling Councils to have regard to specific matters when making decisions, or that decisions on whether and how the clause would be applied by the Councils would occur as a result of engagement with mana whenua and the wider community. A misunderstanding of this nature could potentially be affecting the position of iwi on this topic.

[10] The boundaries of the complete Pukekohe and Horowhenua SVGA are detailed in Part 1 of Appendix 5 of the NPS-FM 2020.

Pukekohe iwi are actively engaged in one of the parallel running projects, the ICMP project, working with local growers and other stakeholders on finding ways to achieve sustainable and commercially realistic solutions to reducing nutrient leaching into waterways in the catchment over time.

Iwi, in general, also informally communicated their frustration with the delays in their Waitangi Tribunal claims being addressed, and stated that in the absence of progress in that matter, their recourse in looking after their affairs were the provisions of Te Tiriti.

Whilst Waitangi Tribunal claims are most certainly not in scope of this project, we need to advise that the matter was raised, albeit informally, out of respect for the openness and realistic position taking by the iwi concerned.

8.3 Industry – Horticultural Bodies & Growers

Horticulture New Zealand and its grower members are engaged with the Councils involved, and in some cases with local iwi as well. Engagement ranges from making submissions to plan changes, participating in joint projects and, unfortunately, initiating legal action where they see no other options from their perspectives.

The position being taken by the growers and grower associations with whom we met, was, prior to commencement of this project, that they had already reduced their Nitrogen leaching as much as possible, without compromising their ability to produce vegetables, or run a viable business.

The concern expressed to the project was that growers in the SVGA would not be able to achieve any further significant reductions beyond those already achieved, without having to compromise on marketable yields, and economic viability.

If required to reduce Nitrogen leaching further, the growers were concerned about the expected consequence, this being a substantive loss of marketable yields, resulting in a loss of volume moving in the supply chain to the consumer.

8.4 Industry – Post-Harvest Industry Stakeholders

The wider produce supply chain, particularly produce wholesalers and retailers, had no position, prior to project commencement, as all discussions on the matter only involved on-farm industry representatives until the project commenced.

Both wholesalers and retailers then expressed a heightened degree of concern about the possibility of losing significant levels of production from both SVGA. This contributed to their willingness to assist with data to aid modelling, which is not a commonly taken approach by these organisations.

9 Industry Data & Knowledge Contributions

9.1 Growers

Growers contacted were typically very keen to be heard. We did not receive any documentary evidence from individual growers, but information was freely shared verbally. We were also able to access submissions made by growers to Horizons and Waikato Regional Councils during their Plan Change consultation processes.

Growers acknowledged the concerns and positions of iwi with regard to water quality, as well as the strategic need to improve the health of the water catchment. Growers also expressed the view that a balance will need to be achieved between those considerations with the need to provide the New Zealand consumer with a reliable source of a sufficient range of nutritious vegetables at affordable prices, as well as growers' own ability to earn a living, and operate profitably on their land.

Pukekohe SVGA growers are actively engaged in studies carried out in conjunction with iwi, Horticulture New Zealand, Auckland Council, MPI, MfE and others. These studies seek to understand the existing opportunities and constraints of attempting to further reduce waterway pollution by realistic amounts, while maintaining fresh vegetables' contribution to domestic food supply.

9.2 Produce Wholesalers

Produce wholesalers also shared their concerns freely. Unlike individual growers contacted, this element of the produce supply chain has a permanent overview of the national supply position of vegetables on almost a daily basis. Wholesalers are the primary source of produce for retailers not part of the Foodstuffs or Woolworths New Zealand groups. Foodstuffs, and Woolworths in particular, are increasingly relying on direct purchasing agreements with growers, whilst still utilising the wholesale system as and when appropriate from their respective perspectives.

Wholesalers operate trading floors to which produce destined for retailers and food service customers is consigned by growers. Wholesalers are increasingly trading produce directly from grower properties into retail destinations without the produce physically touching down on trading floors. In addition, the larger produce wholesalers are vertically integrated into vegetable production within several product categories, such as tomatoes, lettuce, broccoli, cauliflower, etc.

The two largest wholesalers provided data for the project's modelling requirements. Our requests were readily agreed upon, but the major limitation that emerged was that wholesalers' systems are not designed to easily answers questions not aimed directly at the primary objectives of their business. Nevertheless, data was very helpful in addressing the questions MfE had tasked us to find answers to.

We note that no Māori produce wholesale organisations were identified within the SVGA and any Māori organisation existing elsewhere was not asked to contribute towards the outcomes of this report.

9.3 Supermarket Retailers

Both Countdown and Foodstuffs North Island shared data related to their vegetable purchases from both SVGA. The commercial sensitivities related to the data are not inconsiderable, data received has therefore been anonymized. In addition, both retail organisations have expressed the view that consistently offering consumers a full range of domestically produced vegetables as is available now, without the ability or a reduced ability to draw from the SVGA, would be an unrealistic undertaking. In other words, range, availability and price structure of the fresh vegetable offer would change considerably, with frozen imports being the most likely alternative, should SVGA production be constrained to levels significantly lower than they currently are.

9.4 Other Organisations

Horticulture New Zealand (HortNZ) represents vegetable growers in matters of common interest with other products groups, such as environmental policy, law and regulations. The Hort NZ team is active in at least one of the parallel projects identified elsewhere in this document and has been happy to contribute to this project team's fact-finding undertakings.

The Horticultural Export Authority (HEA) is a statutory body whose services are used by some product groups for a structured approach to marketing export crops. Product groups, such as the Buttercup Squash Council, have to submit their marketing strategies to HEA. These marketing strategies confirm our assertion that export crops are not grown in isolation from domestic crops but that the decision of which part of a crop to export is reached typically after planting.

10 Models

Throughout this section, this report discusses N Loss and N Leaching, which are different concepts. N Loss is the amount of Nitrogen that is not absorbed by the soil in the rootzone, and is therefore "lost" to the surrounding environment. N leaching/leached/leachate is the amount of N which enters the surface and ground water systems in the SVGA. These numbers may not match, as a result of the surrounding environment containing more than just surface and ground water systems, but also:

- Other sections of land that may reabsorb lost N,
- N being decomposed or catalysed into other chemical products,
- and other factors that lead to "attenuation" (the ratio of N not absorbed against the amount that will actually enter the surface and ground water).

This attenuation ratio is dependent on environmental conditions, and is not necessarily equal between Horowhenua and Pukekohe.

The following data in this section, where generated by external parties, refers to general vegetable production, without mentioning whether all this production is directed into human food supply chains. The project team notes that vegetable forage is grown across New Zealand for animal consumption. While Statistics New Zealand maintains track of separate forage and human production data at a district level for some agricultural data sets, we cannot definitively confirm whether this has also occurred in the datasets that may have been used by other non-industry data sources that this project is using for modelling.

Data for each individual model is discussed where relevant. The data sources are listed in Section 7 (Data Stocktake & Gap Analysis).

Several of the Attributes requested to be modelled have been identified as lacking sufficient data across both SVGA for full modelling, or datasets were not comparable. As an example, a 2020 Auckland Council report[11] does not present data in a usable manner for Periphyton, noting further research is required to better understand Periphyton levels. Periphyton is therefore not able to be modelled accurately for Auckland using this data.

Additionally, the literature and data used by Dr Death for modelling in the Horowhenua region has identified that the relevant TAS attributes which are not Nitrogen or ammonia (i.e., Periphyton, Phytoplankton, etc.) are indirectly linked to Nitrogen levels, and therefore are affected as Nitrogen levels change. As such, improvements in Nitrogen run-off are expected to have relative impacts on the other attributes, resulting in an indirect improvement in these attributes.

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[11] Auckland Council, 2020. River water quality in Tāmaki Makaurau / Auckland 2020 annual reporting and National Policy Statement for Freshwater Management current state.

Section 10 begins with the modelling related to water conditions. It then shows the modelling related to industry risks and impacts as a result of changes in production needed to meet Nitrogen limits. The section concludes by combining the data generated by the first two sets of models into an analysis examining the modelled impacts of specific constraints on SVGA production.

10.1 Target Attribute States (TAS) Modelling

The Horowhenua SVGA modelling was completed by Dr Death.

10.1.1 Horowhenua Waterways

The TAS modelling for Horowhenua used LAWA (n.d.), Abell, Özkundakci & Hamilton (2010); Death *et al.* (2018), and Cox, Snelder & Kerr (2022). This modelling examined the links between Nitrogen and the Macroinvertebrate Community Index (MCI), Quantitative Macroinvertebrate Community Index (QMCI), and Average Score Per Metric (ASPM) levels for stream ecosystem health, and the required reduction in Nitrogen to reach the National Bottom Lines in the NPS-FM 2020.

For all Figures in this section, the green horizontal line distinguishes between the NPS-FM 2020 Attribute Bands A and B, the orange line beterrn B and C bands, and the red line between C and D bands (the red line being the National Bottom Line).

Some TAS will not meet the National Bottom Line if their measured levels are too high (e.g., Nitrogen), while others will not meet the National Bottom Lines if their levels are too low (e.g., Dissolved Oxygen). Table 8 shows which TAS need to increase or decrease in order to meet the relevant National Bottom Lines, if their values are not already meeting the National Bottom Line.

TAS Improvement Categorisation

TAS That Would Need To Increase To Meet National Bottom Lines	TAS That Would Need To Decrease To Meet National Bottom Lines
Dissolved Oxygen	Phytoplankton
MCI	Periphyton
QMCI	Total Nitrogen
ASPM	Ammonia
	Nitrate
	Cyanobacteria

Table 8: TAS Improvement Categorisation

Nitrate and Ammonia concentrations

Two monitored sites, the Arawhata Stream and Pātiki Stream, have nitrate levels above the NPS-FM 2020 bottom line of 2.4 mg/l (Figure 1). To meet the NPS-FM 2020 bottom lines for nitrate toxicity levels (below the orange line in Figure 1) concentrations would need to be reduced by 60 – 80%.

Horowhenua Waterways Nitrate Concentrations 2004-2021

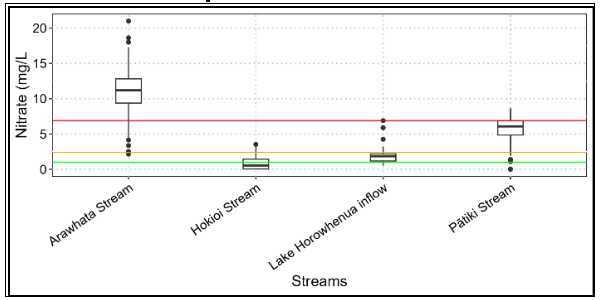

Figure 1: Horowhenua waterways Nitrate concentrations 2004-2021.

Horowhenua Waterways Ammonia Concentrations 2004-2021

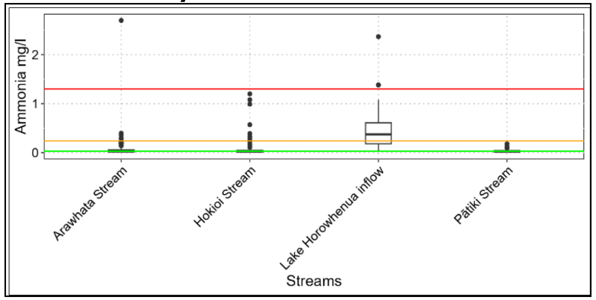

Figure 2: Horowhenua waterways Ammonia concentrations 2004-2021.

The median values at all but one inflow stream is below those of the NPS-FM 2020 bottom lines (Figure 2). The median ammonia concentration at the Lake Horowhenua inflow at Lindsay Road of 0.37 is above the 0.24 mg/l ammonia bottom line.

Nitrate and Ammonia Modelling

	Levels required to meet National Bottom Lines		Measured		Percent change required for nitrate/ ammonia to meet NPS-FM 2020 bottom line	
Regional Council Site	Nitrate (mg/l)	Ammonia (mg/l)	Nitrate (mg/l)	Ammonia (mg/l)	Nitrate (mg/l)	Ammonia (mg/l)
Arawhata Drain at Hokio Beach Road	<2.4	<0.24	11.20	0.030	-79%	Already compliant
Hokio at Lake Horowhenua	<2.4	<0.24	0.53	0.026	Already compliant	Already compliant
Lake Horowhenua Inflow at Lindsay Road	<2.4	<0.24	1.85	0.372	Already compliant	Already compliant
Pātiki Stream at Kawiu Road	<2.4	<0.24	6.08	0.030	-61%	Already compliant

Table 9: Nitrate and Ammonia Modelling

Arawhata Stream and Pātiki Stream Nitrate Reduction Modelling

Modelled Assumptions	Nitrate reduction against current levels	National Bottom Line met (>80% reduction)
Status quo	0%	No
Streams have 23% of N Loss related to vegetable production (Easton, 2021), and have 30% achievable reductions (MPI, 2020).	7%	No
Streams have 100% of N Loss related to vegetable production (Easton, 2021), and have 30% achievable reductions (MPI, 2020).	30%	No
Streams have 100% of N Loss related to vegetable production (Easton, 2021), and have 30% achievable reductions (MPI, 2020), and reduce vegetable production by 50%	65%	Potentially yes for Pātiki, no for Arawhata.
Streams have 100% of N Loss related to vegetable production (Easton, 2021), and have 30% achievable reductions (MPI, 2020), and reduce vegetable production by 70%	80%	Yes, for both streams

Table 10: Arawhata Stream and Pātiki Stream Nitrate Reduction Modelling

Using the modelling performed in Table 9 and Table 10, and Easton's (2021) finding that 23% of all Horowhenua SVGA N Loss was vegetable production related, the project team reached the following conclusions:

- Under any modelling assumption that has less than 80% of the Pātiki Stream Nitrate being related to vegetable production, or 60% in the Arawhata Stream, National Bottom Lines would not be achievable through a removal of 100% of vegetable production from these sub-catchments, as this would still have other sources of N Loss contributing nitrate to the water at levels above the National Bottom Line.
- Under an assumption that 100% of all N Loss in the Arawhata Stream and Pātiki Stream were vegetable production related, vegetable growers in these sub-catchments would need to reduce their N Loss by 80% to meet the National Bottom Line. The "Maximum Reductions" scenario modelled by MPI (2020) for the Horowhenua SVGA states that "a 30% reduction in Nitrogen loss per hectare was considered the upper limit that could be achieved with currently available technology and practices". Given MPI's findings, it would therefore be impossible to meet the National Bottom Line using achievable reductions in vegetable production N Loss.
- Assuming that the vegetable production is evenly distributed across the SVGA, contributing 23% of all nitrate in the Arawhata Stream and Pātiki Stream, the streams would not meet the National Bottom Line, even if 100% of vegetable production in these two sub-catchments was removed, as this 23% of total N Loss is below the 60-80% reductions required to meet the National Bottom Lines.
- Assuming that 100% of N Loss in the Arawhata Stream and Pātiki Stream is vegetable production related, and that vegetable production in these streams was able to achieve the full 30% reductions modelled by MPI (2020), the required reduction in vegetable production in these two sub-catchments to meet the National Bottom Lines would be 71%.

Given the modelling and the assumption-based conclusions, to meet the National Bottom Lines of an 80% reduction for both streams, with only reductions in vegetable production related N Loss, would require, <u>at a minimum</u>: for 100% of N Loss to be associated with vegetable production; for the vegetable production in these sub-catchments to be able to meet the <u>maximum achievable</u> reductions modelled by MPI (2020); and, a reduction in vegetable production of <u>70%</u> in these sub-catchments. Meeting the 60%+ reduction for Arawhata would require at least a 50% reduction in vegetable production under these constraints.

<u>Macroinvertebrate indices</u>

These assess the ecological health of a waterway via the sensitivity of the types of macroinvertebrates found in a stream. There are three indices in the NPS-FM 2020 that assess slightly different aspects of ecological health. The Lake Horowhenua Inflow is not measured in this data set. The results of the modelling are as follows: Macroinvertebrate Community Index (MCI) (Figure 3); Quantitative MCI (QMCI) (Figure 4); and Macroinvertebrate Average Score Per Metric (ASPM) (Figure 5).

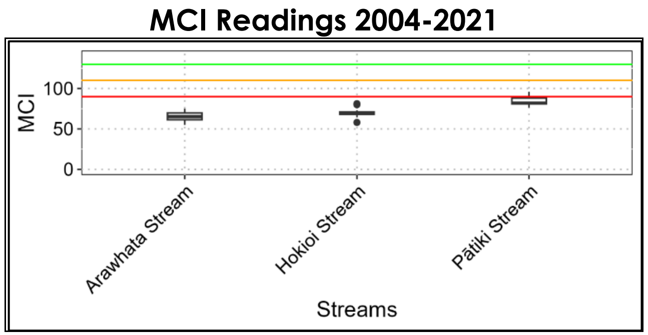

Figure 3: MCI readings 2004-2021.

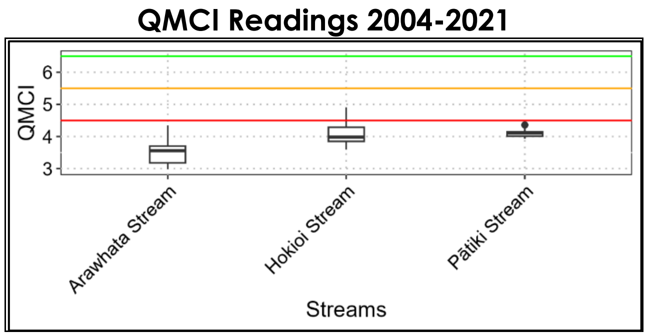

Figure 4: MCI readings 2004-2021.

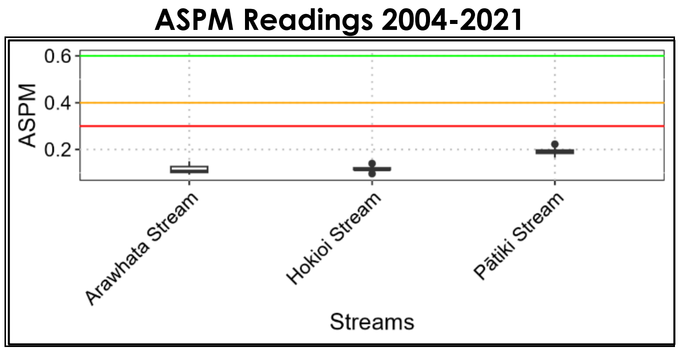

Figure 5 ASPM readings 2004-2021.

All three monitored inflow streams have biological indices well below the NPS-FM 2020 bottom line. Using the model from Death *et al.*, (2018) that links biological indices to nitrate concentration, it is possible to calculate what waterway nitrate level is required to achieve the NPS-FM 2020 bottom lines for MCI and QMCI. To attain an MCI of 90 and/or a QMCI of 4.5 would require nitrate concentrations of 0.97 and 0.73 mg/l for the MCI and QMCI, respectively. Table 11 shows the modelling of the Macroinvertebrate Indices changes with Nitrogen reduction.

This would require a reduction of nitrate in the Arawhata Stream of 90%, and for the Pātiki Stream a reduction of 60 – 80% (Table 11).

Horowhenua Waterways - MCI, QMCI, and ASPM modelling

	Levels required to meet National Bottom Lines				**Measured TAS Levels**				**Nitrate level required for MCI/QMCI to meet NPS-FM 2020 bottom line**		**Percentage change in Nitrate required for MCI/QMCI to meet NPS-FM 2020 bottom line**	
Regional Council Site	MCI	QMCI	ASPM	Nitrate (mg/l)	MCI	QMCI	ASPM	Nitrate (mg/l)	MCI	QMCI	MCI	QMCI
Arawhata Drain at Hokio Beach Road	>90	>4.5	>0.3	<2.4	64	3.5	0.11	11.20	0.97	0.73	-91%	-93%
Hokio at Lake Horowhenua	>90	>4.5	>0.3	<2.4	69	4.0	0.12	0.53	0.97	0.73	Already compliant	Already compliant
Pātiki Stream at Kawiu Road	>90	>4.5	>0.3	<2.4	81	4.1	0.19	6.08	0.97	0.73	-84%	-61%

Table 11: Horowhenua Waterways - MCI, QMCI, and ASPM modelling

Death's modelling has identified that for the MCI, QMCI, and ASPM National Bottom Lines to be met, with only a reduction in nitrate, a reduction of between 61% and 93% of <u>all</u> nitrate would be required across the modelled sub-catchments. Under any modelling that has less than those percentages of all nitrate in the sub-catchment contributed by vegetable production, National Bottom Lines would <u>not be able to be met</u> solely through vegetable production N Loss reductions.

Comparing the modelled reductions required here (Table 11) with the findings of MPI (2020) and Easton (2021), as well as the project team's modelling earlier in this section (Table 9 and Table 10) , a reduction of this scale, <u>solely through reducing vegetable production</u>, would only be feasible under the following assumptions:

- 100% of all N Loss in the modelled sub-catchments is vegetable related.
- All vegetable production in the sub-catchments achieves the maximum 30% N Loss reduction discussed in MPI (2020).

- Following the 30% reduction in N Loss via the mitigations discussed in MPI (2020), vegetable production in the sub-catchments are further reduced until the National Bottom Line is met. To meet the National Bottom Lines:
    - A reduction of 65% of N Loss requires 50% of all vegetable production within the sub-catchments to be removed.
    - For an 80% reduction in N Loss, a 70% reduction in vegetable production in the sub-catchment is required.
    - For an 95% reduction in N Loss, a 93% reduction in vegetable production is required.

Therefore, to meet the National Bottom Lines, by solely focusing on vegetable production, would require: the modelled sub-catchments to have all N Loss solely due to vegetable production; meet the maximum reduction levels proposed by MPI (2020); and, would still require up to 93% of all vegetable production in the sub-catchments to be removed, under the modelled scenarios.

Given reductions of vegetable production Nitrogen leaching of up to 30%, achievement of NPS-FM 2020 bottom lines via only reducing the vegetable related Nitrogen contributions does not currently seem feasible.

Reductions of Nitrogen in the Arawhata Stream of 80-90% at median or 40-50% at high flows (Minnis, Horizons Regional Council, pers. comm.) may be possible in the future with the construction of an artificial wetland planned for the Arawhata Stream. However, given the required nitrate reduction of 93% in this sub-catchment to meet the QMCI national Bottom Line, and this being above the 50% achievable at high flow periods, and potentially above the maximum achievable at median flow periods, nitrate levels in the Arawhata sub-catchment will not be able to meet NPS-FM 2020 bottom lines solely with a wetland, especially during high flow periods. This would also likely be the case for a wetland installed in the Pātiki Stream, if the Nitrogen reduction is at a similar level.

10.1.2 Lake Horowhenua

The relevant statistical characteristics of lake freshwater attributes from LAWA data collected by Horizons Regional Council is presented in Table 12. This data has then been further modelled by Dr Death to identify the required reduction in Nitrogen levels in order to reach the Phytoplankton and cyanobacteria National Bottom Lines.

Lake Horowhenua Attribute Modelling

Attribute	NPS-FM 2020 limits		Observed		N level to reach Phytoplankton limit	Percent reduction in N required to meet limits
	Annual median	Annual maximum	Annual median	Annual maximum		
Phytoplankton mg chl-a / m3	< 12	< 60	25	848	2652	+15% (to meet Phytoplankton limit)
Total Nitrogen Mg/m^3	800		2310			-65% (to meet Nitrogen limit)
	80th Percentile		80th Percentile			
Cyanobacteria mm^3/L	< 10		10.1		Already compliant	Already compliant

Table 12: Lake Horowhenua Nitrogen Linked Attribute Modelling

Dr Death's modelling identified that, using the calculations of Abell, Özkundakci & Hamilton (2010), total Nitrogen levels should be theoretically sufficient to reduce Phytoplankton to the NPS-FM 2020 limit. Given this, there are other primary factors affecting the growth of Phytoplankton that need to be mitigated, ahead of focusing on Nitrogen.

The water quality and ecological health of Lake Horowhenua and its inflow streams are compromised. Many of the NPS-FM 2020 freshwater attributes are not close to the NPS-FM 2020 bottom line requirements. Some attributes (particularly the biotic indices) are clearly impacted by variables outside the scope of this report (e.g., sediment). The reduction in Nitrogen required (60 – 80%) for the Inflow streams, and subsequently Lake Horowhenua, is beyond the scope of the best achievable reductions from proposed improved horticultural practice (GMP) and/or constructed wetlands being built to intercept Nitrogen & sediment in the Arawhata Stream.

10.1.3 Pukekohe catchment

The models related to Pukekohe were built based on the data we were able to find. We cannot tell whether additional data exists or not, only that we have not been able to find further data within the literature we have been able to examine in the time we had.

Data in this table was sourced from sample points within the SVGA recorded in the LAWA (n.d.) dataset.

Pukekohe LAWA Nitrate and Ammonia Levels Model

TAS monitored	Nitrate (Toxicity) mg/L				Ammonia (Toxicity) mg/L			
Levels required to meet National Bottom Lines	**Annual Median <2.4**	**Improvement required**	**Annual Maximum**	**Improvement required**	**Annual Median <0.24**	**Improvement required**	**Annual Maximum**	**Improvement required**
Ngakoroa Stream	3.0	-20%	No data found	No data found	0.0065	N/A	0.012	N/A
Wairoa Tributary	0.0062	N/A	No data found	No data found	0.0025	N/A	No data found	No data found
Waitangi Stream	1.79	N/A	No data found	No data found	0.0055	N/A	No data found	No data found
Whangamaire Stream	12.9	-82%	No data found	No data found	0.008	N/A	No data found	No data found
Whangapouri Stream	No data found	No data found	No data found	No data found	No data found	No data found	No data found	No data found
Awaroa River	No data found	No data found	No data found	No data found	0.0475	N/A	No data found	No data found
Whakapipi Stream	No data found	No data found	No data found	No data found	0.0125	N/A	No data found	No data found

Table 13: Pukekohe LAWA Nitrate and Ammonia Levels Model

The data available shows that none of the waterways in the Pukekohe catchment exceed the Ammonia National Bottom Line for annual median. The Ngakoroa stream and Whangamaire Stream exceed the annual median for nitrate (toxicity), requiring a 20% and 82% reduction respectively.

Pukekohe LAWA Oxygen and Macroinvertebrate Indices Model

TAS monitored	Dissolved Oxygen mg/L				Macroinvertebrate Community Index (MCI) score	Quantitative Macroinvertebrate Community Index (QMCI) score	Macroinvertebrate Average Score Per Metric (ASPM)
Levels required to meet National Bottom Lines	**Annual Median above 5.0**	**Improvement required**	**Annual Minimum: above 4.0**	**Improvement required**	**Score of 90 or more**	**Score of 4.5 or more**	**Score of 0.3 or more**
Ngakoroa Stream	9.26	N/A	6.8	N/A	73.1	1.7	0.178
Wairoa Tributary	10.41	N/A	8.64	N/A	129.4	6.16	0.600
Waitangi Stream	5.96	N/A	3.16	+26.5%	69.8	4.27	0.120
Whangamaire Stream	9.23	N/A	6.84	N/A	N/A	N/A	N/A
Whangapouri Stream	2.95	+69.5%	0.64	+525%	No Data	No Data	No Data
Awaroa River	No data found	No data found	No data found	No data found	No data found	No data found	No data found
Whakapipi Stream	No data found	No data found	No data found	No data found	No data found	No data found	No data found

Table 14: Pukekohe LAWA Oxygen and Macroinvertebrate Indices Model

Table 14 shows that for the majority of streams measured, no improvement in Dissolved Oxygen is needed to meet the National Bottom Line for minimum Dissolved Oxygen, with the exception of Waitangi and Whangapouri streams. The project was unable to find data on Whangapouri for Macroinvertebrate scores, but Whangamaire and Ngakoroa streams both fail to meet the National Bottom Line for all three measurements.

10.2 Commercial Vegetable Production Area Modelling

Commercial vegetable production area in both SVGA is modelled here, on the basis of the data generated by Easton (2021), with categories aligned between SVGA:

Pukekohe Production Area and Nitrogen Model

Land Use Type	Estimated Area (ha)	N Loss (kg/ha/yr)	N Loss across land type (kg)	% of total N Loss
Vegetable Production	*10,211*	*65*	*663,726*	*35%*
Orchards & Vineyards	829	11	9,117	<1%
Grazing Land	59,968	18	1,094,767	58%
Natural forest/water/grassland	13,217	4	52,867	3%
Other	543	4	2,172	<1%
Forestry	4,516	4	18,063	1%
Settlements, Roads, and Lifestyle Properties	5,242	9	48,077	3%
Total	94,526		1,888,790	

Table 15: Pukekohe Production Area and Nitrogen Model

Horowhenua Production Area and Nitrogen Model

Land Use Type	Estimated Area (ha)	N Loss (kg/ha/yr)	N Loss across land type (kg)	% of total N Loss
Vegetable Production	*504*	*66.5*	*33,541*	*23%*
Orchards & Vineyards	36	14	507	<1%
Grazing Land	4,315	23	98,644	68%
Natural forest/water/grassland	671	1	612	<1%
Other	119	2	239	<1%
Forestry	290	3	957	1%
Settlements, Roads, and Lifestyle Properties	1,026	10	10,260	7%
Total	6,963		144,759	

Table 16: Horowhenua Production Area and Nitrogen Model

This project has also referenced Easton's (2021) data[12] against the New Zealand Agricultural Statistics Census data from 2017, to compare against industry knowledge and experience. The Census data identified 10,030 ha of land allocated to vegetable production in the Auckland and Waikato regions, and 1,008 ha in the Horowhenua region. This aligns with wholesale and retail produce industry assessments that the majority of Auckland vegetable production is occurring in Pukekohe, and that the Horowhenua SVGA catchment is a significant part of the overall Horowhenua District production.

[12] This data, while in a 2021 report, was collated from datasets generated in 2016.

The recently released Agricultural Census 2022 (released May 22nd, 2023) data was then used to compare the likely proportional change in area under cultivation in the two SVGA, under a qualitative assumption that SVGA are somewhat likely to mirror the overall changes in the Districts containing them. The Statistics data identified that the Auckland and Waikato Districts experienced a loss of 16% of vegetable growing area between 2017 and 2022, while the Horowhenua District experienced a 30% production area growth.

While this District data is not directly related to production within the SVGA, if SVGA behave proportionally, it is likely the 2022 areas under cultivation would be 8,588 ha and 655 ha respectively, with the associated changes in vegetable production N Loss (assuming no change in N Loss per ha has occurred as a result of changed practices, different crops grown, soil condition, or other factors).

10.3 Production Impact - Cost Modelling

Our modelling for the volume of vegetables produced in the two SVGA is based on data provided by industry stakeholders to the project, with this data being anonymised and set into general bands where necessary, in order to protect commercial data, and to avoid legal issues related to privacy, anti-competitiveness, and other concerns. This data was, in several cases, already pre-analysed for the project by the data holder, and is therefore often not raw data.

Our modelling of this is therefore limited to the questions the industry was willing to provide data on, and where realistic assumptions and modelling could be developed. Where data was not provided, the project team lacked sufficient information to be able to generate useful or realistic assumptions.

Based on the data provided, the following modelling limitations need to be acknowledged:

- Data provided by the retailers and wholesalers was based on total volumes supplied by all tracked supply locations, based on their internal data tracking systems.
    - It was acknowledged that due to the manner of supply structure of at least one retailer, their system could only track the last known dispatch point, and therefore redirected product may not be acknowledged in the data. As such, the data provided is the volume of product which can be guaranteed to come from the SVGA. This means that vegetable production associated with "other" production areas may also include product redirected for supply chain reasons that originated in the SVGA. This volume cannot at this stage be quantified, and was therefore assumed as zero for modelling.
    - Data provided was based on retailers and wholesaler internal assessments of which of their suppliers are based in the Pukekohe or Horowhenua SVGA. Where a supplier is based in a SVGA, but may have crops growing just outside the SVGA, this would be considered part of the SVGA production volume by the retailers, as the grower has the majority of the fields for that growing location within the SVGA, and retailers do not operate to geospatial boundaries of this nature. The volume of product that this may affect was not quantifiable by this project.

- Data was modelled on 5/10/20% production loss bands. The data that the wholesale and retail industry was able to provide was limited in granularity, and these bands were assessed by the wholesalers & retailers as the most accurate that could be achieved for modelling risk and price impacts. This view was expressed, based on the commodity status of vegetables, seasonality, year to year environmental changes, and other factors related to the variabilities of production, which results in season-to-season volume and price variations. However, the wholesalers & retailers have assessed that these three points (5%, 10%, and 20%) were significant/critical points at which qualitative changes could be clearly observed, with regards to the pricing impacts. As such, modelling related to pricing uses these three points as the limit for each price band.
  - The risks and impacts modelled are based on the average pricing and supply across the year, at a whole-of-category level. At certain points of the year, seasonality issues may arise.
- Risk assumptions were not pricing-related for individual vegetables or vegetable categories, but represent the risk of physical supply disruptions, potential supply/demand misalignment at different supply chain points throughout the year, a need to modify logistics networks to reflect the new reality of production volumes/locations, and other physical impacts on the supply chain.
- Production losses of greater than 20% for each SVGA were not modelled. Conversations with wholesalers and retailers indicated that the impacts beyond this point would be so severe, and prone to significant long-lasting fluctuations, that accurate modelling would be impossible.
- Risk assumptions, and expected price impacts, do not include any other supply impacts affecting the supply chain at the same time (e.g., flooding or cyclones), but assume a supply chain with no other impacts from external sources. Additional constraints were noted by industry as being likely to be significantly worse within a constrained scenario, but modelling this was outside the scope of what could be achieved with the data made available.
- Legumes are not included in any useful data provided by the industry, due to the commercial realities involved. Legumes are primarily (>97%) supplied to consumers as frozen product, sold in retail store frozen food departments. These legumes are grown deliberately for processed use only, and are supplied directly to processors such as Watties or McCains, without ever entering the fresh produce supply chain. Once this product has reached retail, all relevant data is held by the grocery merchandise division, and is not available to the fresh produce division teams. This data could not therefore be provided to us within the tight timeframes required. In addition, the project required our focus to be on fresh produce. As a consequence of these two factors, Legumes were automatically assigned to the "no risk" category, as there is no intrinsic risk to fresh produce supply, regardless of the impact on frozen supply.

Based on this, our risk model for the impact upon the national supply chains, should production in the Pukekohe or Horowhenua SVGA be permanently constrained by up to 20% of production volume, is as follows:

Supply Chain Cost Impact Model (dependent on individual crop realities)

Production Volume Percent Constrained	Impact Band	Expected price impact (best case)	Expected price impact (worst case)
<5%	1	No change	10-20% price increases
5-10%	2	10-20% price increases	Price increases above, but not significantly beyond, 20%
10-20%	3	20% price increases	Significant price increases that are well beyond 20% or more
>20%	4	Significant price increases beyond 20%	Price increases in the region of 100% or more

Table 17: Supply Chain Cost Impact Model

Note: all price increases are modelled at the "first point of delivery" – this being either the wholesaler where a grower has sent his product for open market sale, or the retail distribution centre, due to the grower selling by supply agreement directly to the retailer.

Note: We were unable to model potential production losses for critical points above 20%, as supply chain participants were not able to provide us with the data necessary to develop additional production impact bands.

10.4 Supply Chain Risk modelling

In addition to the direct sets of supply data provided to the project for analysis, the industry stakeholders also indicated to the project team that they acknowledged the risks posed by potential loss of supply from the SVGA. These risk acknowledgements are based on institutional knowledge, generated by the businesses across decades of operation, and the vast range of internal data and learnings generated over this time period, but these have not been, as of yet, extensively quantified or documented.

Each industry stakeholder indicated they held their own "risk assumptions" for potential loss of supply from the two SVGA. These do not perfectly align, and are not entirely data based, but driven by senior industry members' perception of likely impacts expected to occur. This project is therefore modelling a combined, and generalised, industry risk profile per vegetable category as follows:

Factors included:

- The scope of data provided to us by the industry stakeholders, and the position articulated by industry, that below the point of production being constrained by 20% within the SVGA, most commercial impacts could be reasonably mitigated, to some extent. However, while technically achievable, such mitigation would involve several compromises, related to aspects such as pricing, supply volumes, seasonality, etc.
    - Beyond the 20% production constraint, permanent and irreversible commercial impacts were expected to occur, with the majority of impacts beyond what the industry could mitigate.

  - Industry could not provide us with any information on risks for modelling the impacts of 5% and 10% constraints, as the overall risk and impacts would change depending on what mitigations could be implemented, and how well consumers reacted to price changes.
  - Given the limited information and time available to the project, the project team had to assume that any changes below 20% could not be modelled, as this would involve extensive economic modelling to a depth not achievable by the project within the time constraints. This position was confirmed by industry data provided by industry.

  The project team therefore only modelled the single point at which industry indicated realistic modelling could occur: a 20% loss in supply from the SVGA.
- The basis of the modelled risk assumption is a <u>maximum</u> loss of <u>20%</u> of all production in each category from the SVGA, given <u>current</u> national production & demand levels, and how this would affect supply chains across the North Island (e.g., the "Vitamin A" risk profile is based on the impact of losing 20% of SVGA Vitamin A vegetable production, and how this would affect the entire North Island supply chain).
- The risk level model reflects the likelihood of the industry experiencing permanent and irreversible impacts to national supply chains, as a result of constrained SVGA production at the 20% level.
- The risk assumptions held by the industry stakeholders represents their perceived overall risk for their entire national supply chain, and the likelihood of significant disruptions, should an ongoing constraint result in permanent 20% reductions in the overall ability to supply vegetables from the SVGA.
- No other disruptions to supply, either within the SVGA or elsewhere, were modelled, as this was outside our project's scope.
- The modelled SVGA supply, if reduced by up to 20% for a category type, is not disrupted further through floods, earthquakes, volcanic eruptions, or other foreseen/unforeseen circumstances.
- The "Overall Risk" in Table 18 is considered to be the <u>highest</u> risk level experienced by any one participant with regards to that specific category of vegetables, as while an individual point in the supply chain may have a lower risk level, the high risks elsewhere in the supply chain may cause flow on effects to other industry stakeholders if impacts occur.

The data provided in this section assigns the risk level to the <u>national</u> supply chains, on the basis of the volume the SVGA contribute to the <u>North Island</u> fresh produce supply. This is due to several factors:

- the North Island and South Island fresh vegetable supply chains do not <u>typically</u> interact, due to the logistical costs and time required to ship product from the South Island to the North Island. This makes shipping vegetables which are grown in both islands uneconomical to ship between the islands.
  - Where vegetables may be economical to ship, long transport times, and the additional factor of potential for transport related damage, often results in shipped crop value loss, and increased wastage.

- Due to the economics of vegetable production and transport, barring significant regional or national scale events (e.g., flooding, cyclones), only certain crops, at economically viable times of the year, will be shipped (e.g., kumara, as commercial volumes cannot grow in the South Island and is therefore supplied all year round, compared to North island lettuce, which is predominantly shipped during winter months).

- The current North and South Island vegetable production and logistics networks have been optimised for the current demand levels, e.g., the South Island has the current hectares, staff, equipment, and storage capacity, to meet the current demands of the South Island population, for those crops that are able to be grown in the South Island.
    - Where the supply chain does cross between the islands, the overall capacity is limited by boat space. Therefore, unlike growing in a near-by region on the same island, and being able to change truck routes to manage the different transport requirements, deliveries between the North and South Island require space on maritime vessels that either cross the Cook Strait, or transit between the ports of this country. The overall capacity of both these transport methods is limited by boat space, which is not something the vegetable industry can control.
    - If using the vehicle ferry transport method between Picton and Wellington, the trip requires dedicating a truck and/or trailer unit to the full return journey. If this vehicle was delivering produce within an island, the vehicle may make 1-3 medium length trips per day. With a Cook Strait ferry trip being 4-4.5 hours each way, a truck or trailer used for this purpose may require 10-12 hours (including loading, travel, and unloading) between the two ferry trips, meaning that the truck driver and vehicle are not available for several collection/delivery trips, reducing the number of vehicles that can carry vegetables for the duration of the inter-island trip.
    - In addition, long-haul truck drivers are required to have stipulated rest periods, which adds further delays and costs.
- If shipping vegetables by coastal freighter, this requires altering the delivery schedules to meet shipping times, as well as meeting cargo port requirements around delivery schedules to enable the loading/unloading of cargo ships. If a cargo ship does not leave for some reason (e.g., mechanical issues), there is no alternate way to get the vegetables to the other island, and unavoidable delays will occur.
- Given the populational divide between the North and South Islands (3.9 million vs 1.2 million as of the 2022 census), shipping vegetables between the Islands will have differing impacts on the two optimised & interlinked supply networks.
    - any percentage-based production drop in the North Island, which is replaced with South Island grown vegetables, for a crop that is grown in similar per capita volumes in the South Island, will be equivalent to about a three times larger impact on the South Island. If, as an example, the North Island was to lose 10% of the total North Island production as a result of constrained production within the SVGA, this would be equivalent to around 30% of total production of the South Island.
    - Given this, any attempt to supplement a loss in supply in the North Island with production from the South Island requires a larger percentage of the overall South Island production.

As a result of these factors, and the data provided by industry, the project has identified that, should something constrain the industry production in the North Island to a significant extent, there exists the potential for South Island production to become economically viable to ship to the North Island. However, in such a situation, the industry expects price rises and stresses to be placed on both the North Island and the South Island supply chains, due to the necessary changes to manage any regulated production reductions.

Supply Chain Risk Model – Crop Categories Affected

Volume of North Island fresh produce supplied by SVGA	Risk level to National Supply Chains	Wholesaler A	Wholesaler B	Retailer A	Retailer B	Overall Risk to Entire Industry
75-100%	– Very High	– White Roots & Tubers – Dark Green leafy Vegetables	– Dark Green leafy Vegetables	– White Roots & Tubers – Dark Green leafy Vegetables	– White Roots & Tubers – Dark Green leafy Vegetables	– White Roots & Tubers – Dark Green leafy Vegetables
50-74%	– High	– Other Vegetables	– White roots-and-tubers – Other		– Other Vegetables	– Other Vegetables
25-49%	– Moderate	– Vitamin A Vegetables	– Vitamin-A Vegetables	– Other Vegetables	– Vitamin A Vegetables	– Vitamin A Vegetables
1-24%	– Low		– Legumes (see note)	– Vitamin A Vegetables		
0%	– No Risk (0%)	– Legumes (see note)		– Legumes (see note)	– Legumes (see note)	– Legumes (see note)

Table 18: Supply Chain Risk Model – Crop Categories Affected

Note: Around 97% of all legumes grown in New Zealand (Curran-Courane & Rush, 2021) are grown for sale as frozen vegetables. There are around 6,000ha of legumes grown annually across NZ for fresh and frozen consumption, with approximately 25ha of beans and peas grown in Auckland, Waikato, and Horowhenua (less than 0.5% of national production).

As this project is required by MfE's scope to examine only fresh vegetables (see scope section), and industry stakeholders indicated that any data they had would not be accurate enough to reliably model fresh legumes, this project has modelled fresh legumes as likely being at no risk of supply impacts. This is due to any restriction on 0.5% of all legume production having an overall miniscule impact on the national production volume. However, Wholesaler B has indicated that they have a degree of exposure to fresh legume wholesale, such that the risk for their business is higher than that which would be expected of the industry as a whole. Consequently, the risk for the legumes category for their supply chain is not 0%, although they expect a low actual impact.

Note: The risks and impacts modelled are based on the average pricing and supply across the year, at a whole-of-category level. We note that at certain points of the year, seasonality issues may arise.

For example, the production of carrots (a Vitamin A vegetable) is almost exclusively centred around Pukekohe in spring, as the rest of the country is, at that point, not able to produce a commercial crop. Thus, Pukekohe represents 25% of total carrot production in the country annually, albeit over a very limited time window, with the balance of the crop for the rest of the year being sourced from other locations, predominantly Ohakune for the North Island, and Invercargill for the South Island.

10.5 Mitigation Modelling

The following modelling is based on Easton (2021), supplemented with data from the MPI Whangamaire Report (2020) and Horowhenua Report (2020).

The viable relative reduction percentage used is from the "Horticulture Typology Modelling for the FWMT" Report (2023), which identified an economically viable percentage of N Loss which could be mitigated by Good Manufacturing Practices (GMP), this being 24% of all vegetable N Loss in their model. Reductions larger than this percentage using their modelling would result in vegetable production becoming non-viable.

SVGA Leaching Mitigation Model

	Pukekohe	Horowhenua
Vegetable Leaching (kg/yr)	**663,726 kg**	**33,541 kg**
Total Leaching (Kg/yr)	1,888,790 kg	144,759
Vegetable leaching of total (%)	**35%**	**23%**
Viable relative N reduction of total vegetable N Loss from economic GMP (%)	24% (of 35%)	24% (of 23%)
Remaining vegetable leaching (kg/yr)	504,431 kg	25,491 kg
Remaining horticultural leaching (kg/yr)	1,729,495 kg	136,709 kg
Remaining vegetable leaching % of total leaching	29.1%	18.7%
Overall N Loss reduction across entire SVGA	8.5%	5.6%

Table 19: SVGA Leaching Mitigation Model

Using our modelling of Whangamaire stream as the worst case for Pukekohe, and the Patiki and Arawhata streams in Horowhenua, both SVGA require an 80% reduction in Nitrate within these streams to meet the National Bottom Line. With the modelled mitigation of 8.5% of all Pukekohe SVGA N Leaching, and 5.6% of all Horowhenua SVGA N Leaching (as shown in Table 19) being mitigatable by vegetable production practices following economically viable Good Management Practices (GMP), the reductions required in both SVGA to meet the National Bottom Lines are 10-15 times greater than what is achievable from vegetable production mitigation, using the worst case of these streams. Even with an assumption of 100% of these streams' Nitrogen is related to vegetable production, the maximum of 24% reduction would still be less than the 80% total reductions required in both streams.

The cost mitigation modelling for Pukekohe presented here is the data contained in the "Horticulture Typology Modelling for the FWMT" Report (May 2023), which involved industry working with the Auckland Council to model a selected set of mitigations more accurately for various aspects of vegetable production, including Nitrogen loss. Their findings are modelled here.

Mitigation Cost Model (from Horticulture Typology Modelling for the FWMT Report)

Slope	Average annual summaries	Base	Improved irrigation scheduling (IIS)	IIS + Reduce N fertiliser on high N yield crops by 2%	IIS + Reduce N fertiliser on all crops by 5%	IIS + Reduce N fertiliser on all crops by 10%
Low slope land	Profit ($/ha/yr)	$3,740	$3,096 (-17%)	$392 (-90%)	-$1,615 (-143%)	-$5,361 (-243%)
High slope land	Profit ($/ha/yr)	$3,796	$3,153 (-17%)	$449 (-88%)	-$1,558 (-141%)	-$5,304 (-240%)
Independent	**N loss (kg N/ha/yr)**	**110**	**84 (-24%)**	**76 (-31%)**	**77 (-30%)**	**73 (-34%)**

Table 20: Mitigation Cost Model

The "Horticulture Typology Modelling for the FWMT" Report (May 2023) data modelling shows that, using their modelled mitigations on their selected sets of 5 different crop rotations, Improved Irrigation Scheduling could assist in a 24% average decrease in N Loss from commercial vegetable production in the Pukekohe area, but this results in a 17% reduction in profit/ha/yr. Please refer to the original FWMT report for their modelling assumptions and limitations, as the modelling, and its associated assumptions & limitations, cover more than 90 pages in the FMWT report, and are too extensive to summarise succinctly here.

That modelling also showed a reduction in N fertiliser by 2% on selected crops, combined with Improved Irrigation Scheduling, would increase the N Loss prevented percentage from 24% to 31%. However, their model also showed such a result would lead to a drop in profitability of 88-90% profit/ha/yr. Please refer to the original FWMT report for their modelling assumptions and limitations.

It was also noted by the Horticulture Typology project team that attempting a 2% N Fertiliser reduction would result in 3 of the 5 modelled rotations resulting in non-economic production, with costs higher than revenues, with the average return for all rotations becoming non-viable at 5% reductions in N fertiliser use on all crops.

11 MfE Project Questions

The answers to the questions here have, in the main, been answered at a national level, with the impacts considered on the basis of both SVGA combined. This is due to factors including:

- Limitations in the data provided preventing analysis as separate SVGA.
- Analysis of the industry data identifying that, due to the shape of the New Zealand produce industry, the two SVGA cannot be appropriately separated for individual analysis when it comes to certain information and modelling that was generated.
- Modelling indicating similar levels of nitrate reductions required in individual sub-catchments within each SVGA that fail the National Bottom Lines, and generally similar percentages of relative vegetable production contributions to the overall N Loss volumes.
- Data gaps relating to one SVGA or the other, resulting in the project team needing to assume for modelling purposes that the SVGA are identical.

Given this, while the project team has attempted to separate the SVGA where possible, having noted in our modelling, and in our answers, when we are discussing one SVGA in particular, where such separation was not possible, the SVGA were considered at a national level.

11.1 Question 1

How much domestic SVGA vegetable production loss will occur if we reduce relevant target attribute states to various (specified) levels, all other things being equal?

Given the several sets of models generated, as well as the data gathered by the project team from multiple sources, we can see that, with the exception of 1-2 streams between both SVGA, the waterways in the main already meet the National Bottom Lines for Nitrate and Ammonia. Where the streams do not meet the National Bottom Lines, these waterways are so far beyond the National Bottom Lines for Nitrogen and Ammonia that our modelling indicates that even removing 100% of all vegetable production would not be sufficient to meet the National Bottom Lines. For the remaining Attribute states, our modelling shows that they are either already meeting the National Bottom Lines, or where they are not, this failure to meet the National Bottom Lines cannot be appropriately explained by Nitrogen levels, and requires alternative solutions.

a) How much reduction in target attributes might be achieved through improvements in management practice?

The "Horticulture Typology Modelling for the FWMT" Report (2023), identified an economically viable percentage of vegetable related N Loss which could be mitigated by Good Manufacturing Practices (GMP). This was 24% of all vegetable N Loss, according to their modelled mitigations. Reductions larger than this percentage, using their modelling, would result in vegetable production becoming economically non-viable.

Other modelling of realistic vegetable growing related N leaching reductions possible expected reductions to be up to 30% (MPI, 2020, HortNZ attributed statement in GHD, 2022, et al) on the basis of all growers using GMP, without reducing production / yields / crop size, which further confirms the modelling performed by the Horticulture Typology modelling team.

Reductions at a rate higher than 30% of horticultural N leaching are therefore not realistic with current technology and economics, and will lead to loss of production / yields / crop size, if this is required.

Easton (2020) identified that horticulture contributes 35% of total Nitrogen (N) leaching in Pukekohe SVGA, and 23% in Horowhenua SVGA.

Given the findings of these reports, the realistic level of N Loss reduction from vegetable production would therefore be 24% of the vegetable-related N leaching contribution to the total N leaching, in both Pukekohe (35%), Horowhenua (23%). This results in 8.5% of total Pukekohe N leaching, and 5.6% of total Horowhenua N leaching being mitigated by changes in management practices. These are the maximum expected economically viable N leaching reductions achievable from reducing N leaching caused by vegetable production, without significantly impacting the economics of production.

Attempting further reductions in N leaching, via the sole method of fully removing all vegetable production within both SVGA, would not reduce the percentage of total N leaching beyond their percentage-based contributions (35% for Pukekohe, and 23% for Horowhenua) to total N leaching.

Based on our SVGA Leaching Mitigation Models (shown in Figure 1 to Figure 5, and Table 11 to Table 13), the N reductions required in both SVGA to meet the National Bottom Lines are still around 3.5 times greater than what is achievable from vegetable production mitigation, using an assumption of 100% of the stream Nitrogen being vegetable related.

It was not possible to quantify reduction opportunities for target attributes other than Nitrogen, through the project reports and literature analysed. There is, however, evidence that the target attributes other than Nitrogen are increasing and decreasing on the basis of the level of Nitrogen present in water catchments.

b) Could National Bottom Lines be achieved without loss of vegetable production (e.g. if target attribute discharges were reduced in all other land uses ahead of vegetable production)?

National Bottom Line Levels are currently 5.8 times the limit in at least one Pukekohe stream (MPI, 2020), and 4.4 times the limit in one Horowhenua stream (Jolly, 2023). On the basis of the data identified from previous reports, and our models, these two streams represent the worst-case scenarios for each SVGA, as other rivers and sampling points do not show Nitrogen or Ammonia levels close to those measured in these two streams.

Assuming vegetable production N leaching in these streams is equivalent to the average for the catchment and that a best-case scenario for the streams natural nitrate levels is 0 mg/l (no contributions from any non-human sources currently leaching Nitrogen, e.g., groundwater cycles), then reducing all other land use N leaching levels by 100% would result in these two streams having nitrate levels of 2.03 times the National Bottom Line for Pukekohe and 1.01 times the National Bottom Line for Horowhenua.

Therefore, with a theoretical best-case scenario, the National Bottom Line for N leaching would not be achievable in the Pukekohe stream via eliminating N leaching from all other land uses, and would potentially just fail to meet the National Bottom Line in the Horowhenua stream.

Eliminating N leaching from all other land uses by 100% is clearly not a realistic expectation. We therefore conclude that in the case of the Whangamaire and the Arawhata streams, on the basis of data available from MPI (2020) and Jolly (2023), reduction in N leachate will require a contribution from the vegetable production sector.

However, based on Death's modelling on Nitrate and Ammonia levels in the Horowhenua SVGA, two of the four modelled streams already meet the Nitrate National Bottom Line and three of the four streams modelled meet the Ammonia National Bottom Line, and do not need land use changes at present to maintain levels within the National Bottom Line.

Whilst our modelling shows that meeting the National Bottom Lines for Nitrate in the Arawhata stream would not be achievable, even with the 100% reduction of Nitrate leachate from other land users, the lower levels of Nitrate in the Pātiki stream suggest it could be theoretically possible to meet the National Bottom Line without impacting vegetable production.

For Lake Horowhenua, a 65% reduction in Nitrogen is required to meet the National Bottom Line. Given that vegetable production contributes 23% of the Horowhenua SVGA related N leachate, a best-case scenario of 100% reduction of N leaching related to other land uses (i.e., not vegetable production), and a natural lake N level of 0mg/l, would result in N levels reducing from 2.8 times the National Bottom Line to being 66% of the National Bottom Line.

For the other streams with Nitrogen levels lower than the worst cases in each SVGA, the data identified by the project shows that for these streams, their Nitrogen related National Bottom Lines are either already achieved without any changes being required, or are minimal changes that would not require changes in vegetable production (e.g., Ngakoroa stream requiring only a 20% reduction to meet the National Bottom Line).

11.2 Question 2

What is the impact on domestic food supply (volume and price by vegetable categories) from various (specified) reductions in SVGA vegetable production?

The information provided to the project team by industry was, as discussed in 10.4 (Supply Chain Risk modelling), only able to be modelled in certain bands, shown in Table 18. However, these bands were able to give a reasonable indication of the impact on domestic food supply at each category level, and where general production constraint levels would place each vegetable category into the price band impacts modelled in Table 17. Given the data available to the project team, and the risk assessment provided by the industry, the following general conclusions about food supply can be drawn:

- Legumes will have minimal to no price or volume changes if supply from the SVGA is constrained.
- Between 25-49% of all Vitamin A vegetables passing through certain supply chain points may be from the combined SVGA, posing a moderate risk to the supply chain if production is constrained. Production constraints of up to 10% of SVGA production would not be expected to result in more than 5% loss of supply in the North Island (i.e., the combined SVGA, which represent up to 50% of North Island supply, being constrained by 10%, would result in a 5% constraint to North Island supply), and falling into the price band 1 in Table 17.

- The Other Vegetables category may have up to 74% of supply, at certain supply chain points, coming from combined SVGA production. A 10% production constraint would therefore result in a price increase within price band 2 of Table 17.
- Both Dark Green Leafy Vegetables and White Roots & tubers may have between 75-100% of all supply at certain supply points coming from the SVGA. A 10% production constraint for the SVGA would result in a price increase within the price band 2 of Table 17, and into price band 3, if production is constrained further.

a) *what proportion of the fresh vegetables produced in the two SVGA is sold for domestic consumption vs export markets?*

Detailed verifiable data for SVGA domestic vs export production does not exist. Therefore, we cannot determine what proportion of the fresh vegetables produced in the two SVGA is sold for domestic consumption vs export markets.

However, some data is available for New Zealand as a whole. Horticulture New Zealand had commissioned KPMG in 2017 to analyse the domestic vs export production share for 10 key vegetables across New Zealand as a whole. Table 21 summarises the data from that report[13].

KPMG Domestic vs Export Share Analysis – All New Zealand

Vegetable	Domestic consumed or processed	Exported
Cabbage	97%	3%
Kumara	99%	1%
Tomatoes	96%	4%
Onions	10%	90%
Lettuce	99%	1%
Potatoes	94%	6%
Carrots	91%	9%
Broccoli & Cauliflower	99%	1%

Table 21: KPMG Domestic vs Export Share Analysis – All New Zealand

KPMG provided a regional split across the main growing regions for the 10 key vegetables identified, based on Statistics New Zealand data. At the time of this analysis being prepared in 2017, the SVGA concept had yet to be implemented. KPMG published the data shown in Table 22 on a by-region basis. We cannot retrospectively isolate any SVGA data from the regional data generated by KPMG.

[13] Proudfoot, I. 2017. KPMG. For Horticulture New Zealand. New Zealand domestic vegetable production: the growing story.

KPMG Regional Key Vegetable Production Share

Region	Product Share
Northland	– 97% of Kumara – 2% of Lettuce
Auckland	– 39% of Tomatoes – 33% of Cabbage – 32% of Lettuce – 25% of Broccoli & Cauliflower – 19% of Potatoes
Waikato	– 32% of Onions – 28% of Tomatoes – 19% of Potatoes
Poverty Bay	– 14% of Lettuce – 1% of Cabbage
Hawkes Bay	– 16% of Onions – 4% of Carrots & Parsnips – 3% of Carrots
Manawatu - Wanganui	– 22% of Broccoli & Cauliflower – 20% of Cabbage – 15% of Carrots & Parsnips
Wellington	– 1% of Broccoli & Cauliflower – 1% of Lettuce
Tasman	– 6% of Lettuce – 2% of Cauliflower & Broccoli – 1% of Onions
Canterbury	– 47% of Carrots & Parsnips – 46% of Potatoes – 16% of Lettuce
Otago	– 6% of Broccoli & Cauliflower – 6% of Cabbage – 2% of Lettuce
Southland	– 15% of Carrots – 2% of Potatoes

Table 22: KPMG Regional Key Vegetable Production Share

The SVGA are an integral part of the Auckland, Waikato, and Manawatu-Wanganui regional production share data sets in Table 21 and contribute to the domestic vs export data in Table 22.

b) *how much of the domestic SVGA vegetable production can only be grown in the SVGA (as opposed to other parts of NZ)?*

Many crops grown in the SVGAs are, at least in theory, able to be grown elsewhere, at least for part of the year.

In answering this question in more detail though, we need to start with the current realities of vegetable production, as the industry exists in its current form for a reason.

The publication 'Agriculture and Horticulture in New Zealand' (2021) is the most recent textbook published on the subject by Massey University. The publication contains a number of guiding principles that add context to the subject matter of this report. These include:

New Zealand relies on its soils for food production and economic wellbeing. For such a small country, New Zealand has a wide variety of soils, some of which pose a challenge to use and require careful management if they are to be farmed in a sustainable manner.

Knowledge of how soils form and their properties are of paramount importance for the development of good soil management practices[14].

In 2019, New Zealand households spent an estimated $890 million dollars on fresh and chilled vegetables and $390 million on processed vegetables. Land suitable for vegetable production is found throughout New Zealand. Many crops are grown based on their suitability to specific regions. However, the development of specialist growing systems means that some crops can be manipulated and grown almost anywhere, anytime. Producing vegetables successfully requires an understanding of a wide range of factors. Some are generic to any crop , while others are specific to a particular crop or region[15].

In 2018, Deloitte prepared a report for Horticulture New Zealand entitled, 'The Pukekohe hub'. The report attempted to quantify the economic relevance of Pukekohe to New Zealand's overall vegetable production capacity. Whilst the SVGA and the Pukekohe hub areas are not exact matches, the areas are similar enough for the Deloitte paper to be relevant to this report.

The Pukekohe hub is an area of 4,359 hectares of some of New Zealand's most fertile and productive soils. The hub's temperate, forgiving climate and proximity to essential transport routes makes it ideally located to supply year-round vegetables to our biggest – and fasted growing – region, Auckland.

Based on the Treasury's Living Standards Framework, the Pukekohe hub was estimated to make a current [2018] economic contribution of $261 million to Auckland's economy (0.3%) on the basis of representing 0.01% of the region's geographic area.

Pukekohe is generally frost-free which allows for year-round supply of leafy green vegetables to not only its primary market, Auckland, but on an out-of-season basis to other parts of the country[16].

No such independent document is available for the Horowhenua SVGA. However, Woodhaven Gardens Ltd, a large family-owned Fresh Cut Vegetable growing business based in the region, submitted a substantive evidence document in 2020 to Horizons Regional Council. Whilst the Woodhaven document was clearly written from the perspective of the company, it contains information that is also able to provide context for this report[17].

In general, Woodhaven's submission noted that:

- The Horowhenua region is relatively frost free and receives regular summer rain which reduces the need for irrigation.
- The ability to maintain crop rotation is a critical aspect of any vegetable growing operation, which is achievable in the Horowhenua SVGA.
- The Horowhenua region is estimated to supply up to 30% of New Zealand's leafy green vegetable demand.

Woodhaven further reported on the general range of their typical pre-tax margins in normal conditions, as well as the potential extremes that the margins may grow/shrink in unfavourable/very favourable market conditions (e.g., storm losses).

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[14] Palmer,A., Horne D. 2021. 'Soils'. In: Agriculture and Horticulture in New Zealand. Massey University.
[15] Roskruge, N. Stafford, K. 2021. 'Vegetable Production'. In: Agriculture and Horticulture in New Zealand. Massey University.
[16] Staff.2018. 'New Zealand's food story: The Pukekohe hub. Prepared for Horticulture New Zealand.
[17] Clarke, J. 2020. 'Woodhaven Gardens Ltd Horizons PC2 Evidence. Submitted to Horizons Regional Council.

The Woodhaven data range for their income and margins corresponds more or less with baseline modelling for crop rotations 1 and 2 in a recently published report related to the Pukekohe SVGA[18]. This indicates that the margins between Horowhenua and Pukekohe growers are likely similar for the same crops, and will experience the same production cost constraints.

The vegetables grown in both SVGA are grown there for several reasons, discussed throughout this report, which include:

- Local soils of the appropriate quality required by the vegetable crops.
- A prevailing local microclimate that supports the necessary plant growth for commercial production.
- Proximity to the country's growing urban regions, Auckland and Wellington, reducing logistical costs and maintaining access to infrastructure and resources necessary to run a vegetable growing business (i.e., trained staff, reliable power & water supplies, heavy equipment mechanics, etc.).
- Proximity to Auckland, Tauranga, and Wellington, and their markets, retail distribution centres, and ports, for efficient domestic and export supply chains.

Growing vegetables in these two regions works really well from a whole-of-New -Zealand perspective, in maximising the overall volume of fresh vegetables grown domestically, and ensuring consistent supply. However, the fresh produce supply chain, Government, Councils, and iwi all recognise the localised environmental impacts that are the reason for this report, as well as the reports that have come before, and those that will undoubtedly follow.

Multiple industry assessments, from all stages of the supply chain (from growers to retailers) were provided to the project, focusing both on the individual SVGA regions, as well as at a national scale. All assessments, at a strategic level, identified that substantial constraints would come into play if attempts were made to transfer significant vegetable production from both SVGAs to "elsewhere", as a result of different constraints for both production (e.g., temperature, soil, and rainfall levels reducing the achievable yields per ha), and for operating a business (e.g., lack of trained staff, a lack of packhouse and storage facilities, limited land available of the quality required to grow vegetables, etc.). Pukekohe and Horowhenua's unique soil structures & microclimates only in part exist elsewhere in New Zealand, and "elsewhere" would not be able to cope with acreage, infrastructure, and workforce size & availability required (interviews with multiple industry participants, May 2023).

Assuming all these challenges could eventually be overcome, this still leaves the central issue of this report: that the resultant nutrient leaching related to vegetable production would simply be transferred to "elsewhere". This leaves "elsewhere" also not being able to cope from an environmental perspective. Additionally, other Regional Councils are also required to reduce Nitrogen leaching activities under the NPS-FM 2020, and may not be able to accommodate the transfer of vegetable production without breaching their own National Bottom Lines.

If focusing solely on individual crops, which can be transferred without impacting crop rotation in either the SVGA, or in the new "elsewhere", then achieving selected transfer may be possible. However, transfer of a limited number of crops would not address the

[18] Staff.2023. Horticulture Typology Modelling for the FWMT. Prepared for Auckland Council and Horticulture New Zealand.

segment of the underlying water pollution issues related to vegetable production in SVGAs in its entirety.

Separately to this, the extreme weather events that we have been experiencing in the last 12 months have left their mark on the whole country, but also particularly on our horticultural production regions. Tairāwhiti, for example, also has excellent soils suitable for vegetable production. The region's largest green leafy vegetable producer has over the last 20 years professionalised their Gisborne farms into an operation of economic scale, before expanding their growing operations into Canterbury and the Pukekohe SVGA.

The key reasons cited were achieving climate change and natural disaster related risk reductions, associated with a remote location aiming to consistently service urban areas 6 hours' drive away, and also to improve the overall quality of their offer by placing growing operations in closer proximity to the markets they need to service. However, the producer still acknowledged constraints and compromises existed at each location.

As such, while domestic SVGA production could, in theory, be produced elsewhere in New Zealand, it is grown in the SVGA for compelling environmental and economic reasons. This has resulted in an optimised system of production, leading to commercial volumes of vegetables being viably produced in rotational cropping systems, designed to have reduced environmental impacts. The ability to effectively rotate crops amongst different land parcels on a seasonal or annual basis is critical to this endeavour. Easton (2021) identified different crop rotations result in different rates of N Loss. Any movement of crops, from within the SVGA to elsewhere, in order to reduce the impact of N Loss within the SVGA, would need to be carried out on the basis of enabling compatible crop rotations in both the SVGA and the potential future production area, in order to avoid adding to N Loss in the new region, or potentially increasing N Loss in the SVGA from the remaining crops.

The project team acknowledges that this position may seem to reflect a desire to maintain a status quo, or that the project team is pessimistic about the potential success of moving production.

However, given the industry production realities discussed here, as well as throughout this document, supported both by published literature, as well as by the commercial data provided from fresh vegetable supply chain participants, this position is based on evidence.

As such, moving production out of the SVGA, whilst <u>theoretically</u> possible, has been identified as leading to <u>additional</u> economic and environmental challenges, beyond those already being experienced by the industry at present. These challenges, based on the evidence and literature available to the project team, are likely to result in reduced overall vegetable production within New Zealand, and higher overall Nitrogen leaching volumes across all New Zealand.

c) *How would a loss in fresh vegetable production in the SVGA affect the price or accessibility of fresh vegetables locally, regionally or nationally? And how would this affect different socio-economic groups?*

There are several aspects to the price vs accessibility/consumption relationship. Various researchers have over the last 13 years presented the following conclusions from their work.

The project was able to identify previous research in New Zealand[19], which found that vegetable consumption was strongly linked to pricing. Nationally, an average decrease in vegetable purchasing of approximately 0.9% was observed for every 1% price rise, across the entire population. This relationship between price rises and reduction in vegetable purchasing was also strongly linked to socio-economic status, with the lowest earning 20% of New Zealand families spending 1.1% less for each 1.0% price rise. By contrast, those in the highest socio-economic group studied (the richest 20%) had a significantly lower relationship between price and purchase volumes, with purchases declining by only 0.65% for each 1.0% price rise.

Looking at current vegetable pricing, and a family's ability to afford vegetables, research in 2009 found that for single-parent families, as well as for families with three or more children, the cost of basic foods such as fruit and vegetables for a healthy diet would take the majority of their food budgets[20].

This was reinforced by findings in 2018, with healthy diets being identified as more expensive than unhealthy diets[21], with those on minimum wage spending 31% of their disposable income on healthy diets, and 51% if on minimum wage & eligible for income support such as Family Tax credits. By contrast, for someone on a median income, the disposable income required for a healthy diet was 19%. Under these conditions, a family on minimum wage and requiring income support would be spending, as a fraction of their disposable income, three times what a family on the median income would be.

Given the granularity of the data provided by industry on the likely price impacts of a loss in SVGA vegetable production, we cannot accurately model significant amounts of information about the likely impacts of pricing impacts on consumers against expected price changes, with the exception of the critical points identified by industry. Using the best case scenario for a loss in production in the SVGA that is equivalent to 5-10% of national production of a vegetable category, and using the findings of the two papers above, we could theoretically expect a 20% price increase, resulting in up to 22% reduction in vegetable purchases by those in the lowest 20% of income, and for those on income support, having to spend significantly more of their disposable income on purchasing vegetables to meet dietary needs.

Moving beyond looking only at pricing impacts from reducing production in the SVGA, and examining general vegetable pricing over the last few years, Foodstuffs North Island published an on-line Fact Checker document in May 2022. In that document they published a consumer price index chart sourced from Statistics New Zealand, aimed at

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[19] Mhurchu, C., et al. (2013). Food Prices and Consumer Demand: Differences across Income Levels and Ethnic Groups

[20] Walton, M, Signal, L., and Thomson, G. (2009). Household Economic Resources as a Determinant of Childhood Nutrition: Policy Responses for New Zealand.

[21] Vandevijvere, S., Mackay, S., D'Souza, E., and Swinburn, B. (2018). How healthy are New Zealand food environments? A comprehensive assessment 2014-2017. The University of Auckland.

showing the behaviour of the Food Price Index (FPI) against the Consumer Price Index (CPI) over the period Jun 2017 to February 2022 on a monthly basis.

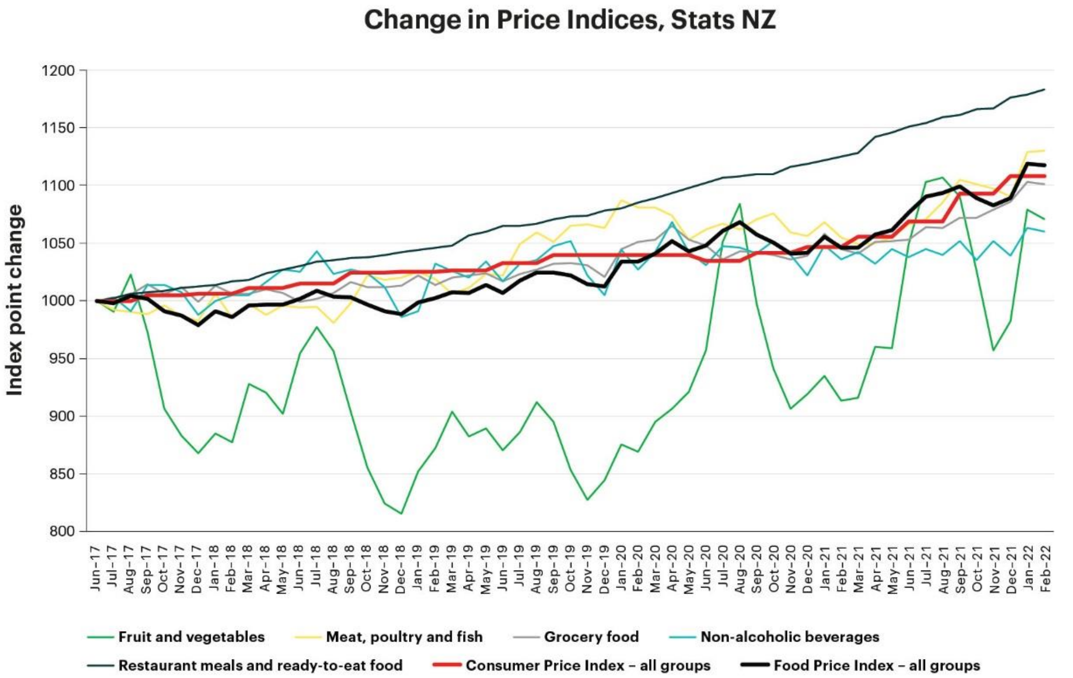

Figure 6: Change in Price Indices, Stats NZ

What is of interest to this project is that the various food categories measured, including fruit and vegetables, are shown separately, which offers an insight into the volatility of fresh produce retail pricing over an extended period of time when compared to meat, poultry and grocery foods.

If time had permitted the separation of vegetables measured to produce this index from the fruit included the 'fruit & vegetables' category, the volatility observed in the chart for the whole category would be expected to be further accentuated, as vegetable wholesale price volatility typically exceeds that of the fruit category.

The above demonstrated fresh produce volatility peaked beyond its usual fluctuations in June/July 2020, having risen in response to the March 2020 emergency measures taken in response to the Covid 19 pandemic, and the resultant 3 months of restrictions which impacted the entire vegetable supply chain from planting to retail. This suggests that a non-standard factor which impacts the vegetable industry, in a way that has not been experienced before, has the strong potential to significantly impact on price and therefore consumer acceptance and shopping habits.

Predicting the exact degree of such a reaction is next to impossible. Having experienced other supply shortages in the industry since the late 1980s, we would not be surprised if the fruit & vegetables part of the FPI would react in a similar manner as it did during the first Covid lockdown in 2020, and how it reacted in 2021, when the consequences of the labour shortages the industry experienced due to the Covid response resulted in loss of production and marketable yields, in the event of significant reduction in vegetables volumes being available from the SVGAs.

11.3 Question 3

What is currently realistic in terms of alternative production and supply?

Alternative production and supply breaks down into three sub categories. These being:

- The transfer of production from field grown to an indoors structure.
- The transfer of production out of the SVGA into other regions.
- The transfer of production to other countries with New Zealand increasing its reliance on fruit and vegetable imports (both fresh and frozen).

The transfer of production from field grown to an indoors structure

Indoor production offers controlled environment and efficiency options for crops suitable to be grown indoors but are not a 'wholesale' solution across the entire range of produce grown in the SVGA. Converting existing properties from outdoor to covered production is a major undertaking and, even for crops that are theoretically suitable to be grown indoors, such as lettuces, significant change will have to be navigated in terms of capital investment, competencies and skill sets, behavioural changes, and increased risk profiles.

Costs involved, and therefore the investment required, would accelerate further the already occurring rationalisation of vegetable producers. This is shown in the grower number figures included in the ICMP Stocktake Report, and further enhanced in 2022/2023 Horticulture New Zealand publications. The ICMP Stocktake Report visually suggests that the number of vegetable growers has declined from more than 3,000 growers in 2010, to less than 1,000 in 2020. Horticulture New Zealand has, until recently, consistently in its various outputs referred to 5,500 fruit & vegetable growers. Its recently published Annual Report 2022/2023 puts the combined fruit & vegetable grower number now at 4,200+.

The transfer of production out of the SVGA into other regions

The microclimates that form part of the SVGA success story in terms of their contribution to domestic food supply, are not in their entirety exchangeable with those in other regions. Challenges to market yield reductions through shifting production, resource availability, and increased production costs, will need to be factored in. In addition, the Crown is clearly expecting all Councils to ensure that TAS leachate into water catchment is achieving National Bottom Lines. Transferring vegetable production, which is known to be contributing to leachate, to other Regional Councils' regions, could potentially be blocked by these Regional Councils, as they are also having to meet their own NPS-FM 2020 obligations.

The transfer of production to other countries, with New Zealand increasing its reliance on vegetable imports

The high perishability of most vegetable crops rules out large-scale importation of fresh vegetables to replace domestic New Zealand production of fresh vegetables.

Regardless of country of origin, New Zealand has strict import health standards and legislation, such as the Biosecurity Act, aimed at managing the risk of plant diseases and plant and animal species, not native to New Zealand, entering the country.

The only option would then be replacing aspects of fresh vegetable production with importing greater volumes of frozen vegetables, from economies that are able to gear up to meet New Zealand requirements, in addition to those of their existing customers elsewhere, and their own domestic market. Overseas markets would have to be able to land the product cost-effectively in New Zealand, to ensure local consumers have continued access to realistically priced vegetables, even if they are now purchased frozen rather than fresh. This would also expose New Zealand to a greater geopolitical risk, related to consistent access to vegetable supply (both fresh and frozen).

What does appear to be occurring, is the planned exit from the Pukekohe SVGA, within a 10-year time frame, of the larger glasshouse operators for commercial reasons, which is not related to nutrient leachate, but related to access to cost-effective heating solutions, and the desire to reduce business risk.

a) *Is there insight or commentary on alternative production and supply options (e.g. hydroponics, untapped growing areas, greenhouses etc) including what categories of vegetables they are suitable for, their capital costs, operational costs and marginal production costs compared to outdoor traditional production methods?*

New Zealand Industry Information

New Zealand specific data for answering this question was essentially impossible to collect, as the industry stakeholders who provided information to this project could not give any information relating to these costs to the project, citing commercial sensitivity, supplier data confidentiality, and the fact that many costs would relate specifically only to individual locations, and could not be generalised (e.g., one location may be able to harvest water from bores, reducing their water cost significantly, whilst another site may be required by the Council to have connections into the main Council supply, and purchase at standard rates, while a third site may have negotiated a discount rate).

However, industry was able to provide information in the form of general assessments, regarding general expected pricing trends, and potential operational impacts.

The first assessment provided by industry, and reconfirmed by our own research, was that in general, the only vegetables that could be reliably grown in technology intensive growing systems (e.g., glasshouses, vertical farming, hydroponics, etc.), were those that took minimal space per plant to grow, had very short production cycles to allow multiple harvests per year, and were “premium priced” vegetables (i.e., a high value per kg).

This is because hydroponics, vertical farming, and other technology systems have an extremely high capital cost, and high operational costs, for each effective “hectare of growing space”, compared to field production. Because of this, each square metre of growing area in a technology intensive solution needs to produce high volumes of vegetables, often, and at high prices. Under this system, many crops cannot be economically produced in greenhouses/hydroponics/vertical farming/etc., and this is reflected in the economic realities of the current industry: greenhouses are almost exclusively used to grow tomatoes, capsicums, cucumbers, and some leafy greens, all of which meet the necessary criteria to be economically viable.

Greenhouses & Glasshouses

One industry stakeholder, while not able to share specific costings, was however able to share some generalised information on their potential costs for a glasshouse, as they have been investigating replacing one glasshouse that is reaching the end of its practical lifespan. This stakeholder had been investigating building a 10-hectare glasshouse, with an attached packhouse and storage area, to be able to effectively handle the production of the glasshouses.

When investigating installation costs, the stakeholder was given quotes by professional construction providers that were in the range of $7-8 million / ha for building an empty facility (one without any production or handling equipment installed), which would then be ready for the fit-out of the specific equipment required to grow their crops, and to operate the facility (e.g., the lights, heating system, computers & sensors, watering systems, raised plant beds, etc.). This is in contrast to the lower costs of field production, which were indicated as in the low to mid hundreds of thousands of dollars per hectare.

The conversion from field cropping to indoor glasshouse production, where it is possible from a crop choice point of view, will nevertheless come with a high capital requirement, as indicated by the above example given. It is unlikely that any existing grower would be able to fund such a switch from operating revenue, or annual profits, regardless of whether they were wanting to switch their existing crop from field to under glass, or whether they wanted to move from growing outdoor crops to glasshouse crops.

The only way existing growers are likely to afford such a change in circumstances, would be through third-party finance, and this amount is typically beyond their ability to borrow, unless they can convince lenders of the presence of stable income streams, with such lenders typically wanting to sight written supply agreements.

It is therefore far more likely that we are heading into a future where existing growers will exist the industry, and investors with access to the required capital and an appetite for investing in the value-add horticultural industry, will take their place. In part, such a transition is already underway. Whilst some growers in both SVGA have managed to achieve inter-generational success models (e.g., A. S. Wilcox, Balle Brothers, Woodhaven), other growers have not succeeded in convincing their offspring that their vegetable production business is a viable business.

If this, until now, naturally occurring transition, were to become part of government policy, then the pace of that change would substantially increase, with the result being semi-industrialisation and an impact on the social structure of the rural communities within not just the SVGA, but rural New Zealand as a whole.

Hydroponics

Industry stakeholders informed us that hydroponics was more restricted than typical greenhouses & glasshouses, due to the higher operational costs and inputs required. Hydroponics are suitable for a limited range of leafy greens (lettuce, microgreens, herbs, etc.) and some glasshouse tomato production, in certain circumstances, due to the financial requirements.

Vertical Farming

Vertical Farming is even more restricted again, compared to glasshouses & hydroponics, according to industry stakeholders. To date, the project knows of only two successful vertical farming ventures in New Zealand, 26 Seasons in Foxton, and Greengrower in Ruakura. The project team was not able to speak to either in the project timeframe, but notes that both businesses have only recently begun full scale production in the last 1-2 years, and that the effective long-term financials of these businesses cannot therefore be realistically identified.

Finally, industry also raised practical concerns about technology intensive growing. At least one industry stakeholder, who grows inside glasshouses, indicated that glasshouses require an effective form of heating, to maintain plant growth. Currently, many older glasshouses use gas-based systems, while others use geothermal. Solar, electrical, and heat-pump based heating systems were acknowledged as existing, but were also noted by site location and operational costs, to be a less desirable option given the price to performance efficiency of currently available technology.

Today, due to greenhouse gas emission concerns, Councils and government are regulating the use of gas, which means when glasshouses are replaced at the end of their life, many growers will not be able to continue using gas heating. This means that alternate heating systems need to be installed. This results in the most practical remaining option being geothermal heating. However, locations where geothermal heating is practical to install and operate at the necessary scale are limited, due to unavoidable geographic and geologic conditions, so this severely constrains where replacement glasshouses can be installed and operated.

The Financial Reality of Undercover Production

A business exists to make money. A business will not invest or change its operating model if it judges there is too high a degree of uncertainty about returns on any investment made. The fact that those New Zealand growers, whose crop is able to be grown undercover, continue to grow vegetable in the field, indicates that their considered assessment of the future business model they would have to operate in as under-cover producers, presents at least similar, if not more extensive, business risks, on increased investment, and uncertain returns per dollar invested.

What glasshouse production, hydroponics, and vertical farming all have in common, is that they revolve around indoor production models, aimed at optimising revenue per cubic metre, as the space above the ground can be used far more productively than is the case with outdoor production.

This, however, goes hand-in-hand with additional operating costs, such as heating, as optimised yields cannot be achieved by just putting crops under cover, and letting the sun do the rest. Given the amount of money invested, the return on investment expected from such costly operations, on an area basis, is also higher.

The willingness to invest in innovation often comes with unexpected additional costs. At the time of writing this document, the Court of Appeal has announced that the Tairawhiti District Council is perfectly within its right to add the value of Zespri Sungold Licenses, invested in by kiwifruit growers in the region, to the ratable property value, thus increasing property rates payable by kiwifruit growers substantially.

Whilst not directly related to vegetable production, this serves as an example to the fact that the production of vegetables, just like any other horticultural crop, is a business activity, that follows common business principles. A business exists in order to generate profit, and growers need to earn an income, as well as a return on investment, in order to be willing to reinvest in their business. If that level of profit is insufficient, reinvestment will not reoccur.

Increased operating profits as a result of having invested in under-cover production facilities, cannot be assumed automatically. That may be possible, if:

- A market for the under-cover crop truly exists.
- Supply and demand are balanced, to the point where, all things being equal, regular demand, and therefore supply, at higher prices is realistic.
- The barriers of entry to the market is such that any potential new entrant will make a considered entrance, rather than an impulsive entrance into a particular supply segment.
- Business is not constrained by influences that any investor cannot control, such as weather events and biosecurity incursions.

In reality, that is no different to the considerations for a field crop grower. The only thing that differs is the scale.

Profitable vegetable growers tend to be those with long-term buyer-seller relationships, with large customers, be they in the food service, or retail environment. The direct purchasing activities of retailers, and food service businesses, have contributed to the reality that larger growing entities are operating on a blend of commodity and product specific business models, whereas smaller growers without direct relationships are almost exclusively commodity based.

The consequence of this, is that there are natural transformations already occurring in the fresh produce production sector, and any thoughts related to alternative production methodologies and locations, or processes, would need to be very carefully introduced into the industry, with a high level of industry involvement, in order to avoid extreme fluctuations in certainty of supply.

b) To what extent could the loss be compensated by imports at various price points?

Given the wide variety of crops grown in New Zealand and globally, the various growing seasons in each country, and the sheer intricacies of the global fresh food markets, this question cannot be answered with specifics. However, general strategic information on market forces can be discussed, and the overall likely trends of import pricing identified.

In attempting to answer this question, the project team identified that attempting to replace SVGA production with imports from overseas, first requires an explanation of how the imports market for fresh vegetables works in New Zealand, as there are several barriers to importing vegetables that need to be considered.

The first critical aspect of importing are New Zealand's Import Health Standards[22]. These are documents issued under section 24A of the Biosecurity Act 1993, and without which product cannot be imported into New Zealand. For vegetables, these are not only crop

[22] https://www.mpi.govt.nz/legal/compliance-requirements/ihs-import-health-standards/

specific, but also often country specific, in order to best manage the risk of pests & diseases arriving from overseas. Any vegetable imports into New Zealand would either have to meet these Import Health Standards, or be imported as processed and frozen vegetables. These standards also include chemical residues, meaning that some countries that may use certain agri-chemicals on or around vegetables may not be able to export to New Zealand, regardless of the biosecurity situation.

The second aspect to be considered is location. New Zealand is geographically isolated from the majority of the world, with Australia as our only close neighbour. With no land borders, we cannot import food by road or rail, but instead must import by boat or plane.

If importing vegetables by boat, the travel time must be considered. Boat trips between New Zealand and Australia can be 3-5 days, as well as having 2-4 days at each end of the trip where loading and unloading occurs. If shipping vegetables by boat therefore, it is entirely possible that the time between a container of vegetables packed in Australia may not leave a New Zealand port and head for a distribution centre or retail store until more than a fortnight after it was initially delivered to an Australian port. This timeframe is extended even further if the vessel is travelling from another country that is further away. This has the consequent reduction in shelf life of the product, and means many highly perishable vegetables cannot be sea-freighted.

The other option, air-freight, has its own considerations. Air-freight, while fast, is extremely space limited on each plane, and has a significant cost. Heavy vegetables with low value per kg are therefore not viable products to deliver by air. In addition to this, airline freight capacity, post-COVID, has consistently had demand for space outstrip supply, often leading to delays in shipping, and the consequent loss of shelf life due to delays.

The third aspect to consider is actual availability of imports. If importing product, there must first be a country exporting. This means that if a vegetable is not grown overseas, at that month of the year, regardless of demand, there will be no supply. Given the majority of the global population, and their vegetable production, is in the Northern Hemisphere, any imports would typically have to occur around their production season.

Only once these points are realised, can pricing then be examined.

New Zealand is not a large country, and will never be able to realistically dictate import prices. Even with an estimated 5.2 million people (Statistics New Zealand, March 2023), our overall market leverage does not equate to other countries with tens to hundreds of millions of citizens, such as Australia, for example. We would therefore be a price taker, accepting whatever general price the market arrives at for vegetables (fresh or frozen).

This price taking position is extremely important, as global events such as the Ukraine conflict have caused significant upwards price pressure on many basic food categories, including vegetables. And, as climate change and the related environmental impacts continue to influence food production, while the growing world population looks for ever more supplies of food, this price pressure is not going to reduce in the next few years.

Given these international price pressures, plus the costs of international logistics and transportation, imports will not typically be cheaper or of equivalent price to domestic production, except in unusual circumstances. Instead, the higher pricing we can expect when importing vegetables renders the import solution unsuitable as an everyday activity. This is why imports are currently only used when New Zealand is unable to produce vegetables for seasonality reasons, or as a result of a natural disaster that impacted vegetable production. Significant domestic price increases in New Zealand could make imports price competitive with domestic production, or international price rises could make imports uneconomic to purchase, as consumers would not be willing to pay the increased prices over the typical domestic prices, even when domestic production is out of season.

The Local Production Replaced

The Pukekohe Hub report states that 10% of vegetables grown in the Pukekohe area are exported, 7% reaching domestic consumers via food service channels, and the balance being sold through all channels of the domestic fresh produce trade.[23]

The annual vegetable retail revenue generated by the Pukekohe hub was put at $327 million, which equates to 26% of New Zealand's value of total vegetable production, with that number reported by Fresh Facts 2017 as being $1.3 billion.[24]

The Horowhenua region is estimated to supply up to 30% of New Zealand's domestic green leafy and brassica vegetables supply (Woodhaven, 2020).

Given these figures, and the data available in Fresh Facts 2020[25], the calculated value of SVGA vegetable production for domestic consumption is at least $375 million at retail.

Using the New Zealand Statistics Infoshare Database, and looking at the total import value of all fresh vegetables (HS code 7), New Zealand's annual import of all fresh vegetables was valued at $140 million for the 2022 calendar year[26].

Comparing the assumed SVGA production against New Zealand's total imports of all vegetables, it can be seen that due to the size of SVGA production, and the limited scale of imports, any substitution of domestic production with imports would have a significant impact on the total value of imports. A replacement of 20% of SVGA production, for example, would require at least a 55-60% increase in imports, along with the required change to supply chains.

The Result

Given the above realities, it is unrealistic to expect imports to act as a substitute for constrained domestic production, with the exception of the limited niches discussed above. And, attempting to increase our reliance on imports opens New Zealand up to the increasing risks of the global market, which, as shown over the last several years, by pandemics, storms, and wars, is not a reliable or stable market from which consistent volumes and prices can be expected. Relying on imports should therefore be seen as a lesser, or even least desirable option, that would decrease food security in New Zealand, and risk inconsistent food supply at the prices consumers are willing to pay.

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[23] Deloitte. New Zealand's food story: The Pukekohe hub. Prepared for Horticulture New Zealand. p. 21. August 2018.
[24] Ibid. p.20.
[25] Fresh Facts 2020. https://www.freshfacts.co.nz/
[26] Stats New Zealand, n.d. Infoshare. https://infoshare.stats.govt.nz/ViewTable.aspx?pxID=3a89f9ea-35c3-4d46-a21d-420b17bac0ad

12 Conclusion

Reports and data examined by this project, and modelling carried out to meet MfE's project brief confirm that commercial vegetable production in the SVGA does significantly contribute to TAS leaching in the SVGA.

We also conclude, on the basis of the waterways we were able to model, that even in the event of discontinuing commercial vegetable production in the combined SVGA altogether, this is unlikely to bring water pollution levels caused by remaining polluters below the National Bottom Line for the worst affected streams.

The prevailing local Pukekohe and Horowhenua microclimates, the quality of the local soils, and the close access to transport networks that can both service their domestic market and provide access to ports for export shipments, are collectively responsible for these areas to be strategic contributors towards the domestic supply of fresh vegetables.

Transferring SVGA vegetable production to other regions is <u>theoretically</u> possible, but would likely result in significant challenges, ultimately resulting in worse environmental and economic outcomes, and reduced domestic supply of fresh vegetables.

New Zealand literature indicates a correlation between decreases in vegetable consumption and price rises. It also suggests that more disadvantaged parts of the population are likely to be more impacted by food price increases than the wealthiest consumer segment (Mhurchu 2010).

More recent research (Vandevijvere et al, 2020) suggests that healthy diets are unaffordable for low-income households. This finding is supported by retailers reporting increased frozen vegetable purchases when fresh produce prices increase in response to crop shortages related to the poor weather conditions in recent months.

Statistics New Zealand data has been analysed and published by Foodstuffs North Island, breaking down the performance of Food Price index categories against the Food Price Index as a whole. This has assisted in demonstrating the price volatility occurring in the fresh produce category, compared to other food price groups. Had vegetables been measured separately from fruit, the demonstrated volatility of vegetables would have exceeded that of the fruit category.

We anticipate that the fruit & vegetables component of the Food Price Index would show a measurable reaction to a changes to the SVGA vegetable supply position, if reduction in yield beyond the 5% level from the SVGA were expected. Reductions of less than 5% would not be accurately measurable, due to the volatility of the FPI related to the commodity nature of fresh produce within the New Zealand Fresh Produce Supply Chain, as discussed throughout this document.

Wholesalers and retailers contributing data to this project share very similar risk perceptions related to the importance of both SVGA to the domestic vegetable supply beyond their growing regions.

Glasshouse crops are likely to exit the Pukekohe SVGA over the next 10 years, due to a combination of diversification strategies being implemented, urban growth, and the opportunity to access geothermal energy, with gas no longer being an option for glasshouse producers.

A very substantive share of the crop grown in the Pukekohe area for domestic consumption, with the balance being exported. The exception are onions, where the ratios between domestic and export are reversed. No separate data to differentiate the Pukekohe area from the Pukekohe SVGA is available.

No independently prepared data was available to verify the Horowhenua SVGA domestic vs export share. The collective knowledge of wholesale and retail data contributors, however, suggests that the Horowhenua SVGA crop is also grown primarily for domestic consumption.

Growers, wholesalers, and retailers consulted during this project all shared the view that substantial supply constraints would emerge, if significant marketable yield reductions occurred in the SVGA, and the economic viability of some SVGA production would change. At the same time, crops produced in new locations, to compensate for production loss in the SVGA, could be impacted by a general shortage of labour, lack of trained staff, a lack of packhouse and storage facilities, limited land available of the quality required to grow vegetables, and other infrastructural & resource limitations.

Achieving a selected transfer of crops out of either of the SVGA may be possible, based on individual crop assessments, where it does not impact on crop rotations that minimise N leaching. Whilst such a move could contribute to a reduction in N leachate into local streams, it would not, on its own, address the underlying need for good management practices within the SVGA to be improved over time.

Good Management Practice alone will not be enough to reduce N leachate to National Bottom Line levels. However, strengthening Good Management Practice is an achievable good step into the right direction, as it has the potential to make a meaningful difference in the short to medium term, whilst long term sustainable solutions are also explored.

Appendix 1 - General Sentiments Expressed & Impressions Gathered

It became clear during our consultations with interested organisations and individuals that logic and rationale are not the only factors that shape views currently held. Emotion in a general sense, grievances and a lack of comprehension are also powerful factors that play a part in having reached the currently parties by the various parties.

Iwi consistently communicated the following concerns to us:

- the lack of consultation and the associated discourtesy of not consulting within the framework provided by Te Tiriti;
- the order of priority for food security concerns held by Māori is diametrically opposed to that by commercial vegetable growers. For tangata whenua water purity is not only the number one priority but is viewed as the underpinning assurance for sustainable food security.

In addition, Horowhenua and Pukekohe Iwi took different positions on finding a practical way forward.

The Horowhenua iwi focus, as stated to the project team, was on having Lake Horowhenua to be returned to its former clean state and available for the gathering of kai. This stated position considered a significant reduction, or complete removal, of all food production, including vegetables, as acceptable, if this was necessary to have Lake Horowhenua meet the water quality levels desired.

The Pukekohe iwi position communicated to the project team was that the iwi recognised the area's potential as a significant food bowl with the ability to provide employment for their people, and that given this, a significant reduction, or removal of food production, was not considered to be appropriate. Instead, the Pukekohe iwis' preferred position was for a stronger commitment and intensified actions by all relevant parties, to reduce nutrient leachate over time.

It was also pointed out to the project team that local iwi were frustrated that their Waitangi Tribunal claim has yet to be heard.

Vegetable growers acknowledge readily that fertiliser applications on land used for vegetables production, contribute to nutrient leachate but take the position that, at best, a degree of improvement is possible by way of a greater focus on *Good Management Practices* but any attempt to move beyond a certain point would result in significant numbers of growers having to give up commercial vegetable productions.

Growers across SVGA regions are exposed to weather events, labour shortages, a plethora of regulations, climate change related behavioural change expectations, demanding product specifications from their supply chain partners, as well as significant changes in consumer shopping behaviours.

Even the most structured and balanced thinkers amongst the growing communities are expressing a high degree of frustration with what they perceive to be a substantial lack of understanding by officialdom and the community at large about what it takes to produce marketable vegetable crops in the quantities and at the quality levels demanded by the consumer and needed to contribute towards a healthy diet for New Zealanders.

And given the available evidence of the benefits of increasing the plant-based portion of our food consumption, vegetable growers are concerned about their ability to increase production to meet the needs of a growing population, whilst potentially facing reduced marketable yields, as a result of additional future mitigations that could expected of them.

Councils are seeking clarity and guidance from the Crown as they perform the regulatory duties at regional level that are expected from them. The ability to place lower nutrient leachate expectations on vegetable growers, as long as progress in reducing TAS attributes is achieved, and food security considerations are not compromised, translates into conflicting objectives having to be managed and achieved in parallel.

Councils are required to have hard evidence that vegetable production in the SVGA is a significant contributor to the TAS attributes, in order to consider the use of the exception embedded in clause 3.33. Without such evidence, as well as a tighter definition of food security related to their decision-making envelope, Councils are reluctant to consider clause 33.3 out of concern about potential legal challenges from multiple directions.

Produce wholesalers with multiple branches across the country still play an important part in understanding seasonal and regional vegetable supply positions and ensure the produce grown reaches where it is in demand.

Supermarket retailers have in the last 20 years increasingly taken control over their discrete supply chains and are therefore contributing to a reduction in the number of vegetables that are grown speculatively. Whereas in the past individual crop acreages could fluctuate significantly between seasons, with oversupply of individual crops often being the norm rather than the exceptions, this trend has steadily reversed. Most vegetable crops are grown these days to meet an articulated demand position, often expressed directly by a retailer or by a wholesaler, acting on behalf of a retailer.

Growers, Produce Wholesalers and Supermarket Retailers are all alarmed by the possibility that fresh produce production in the SVGA could, in future, be restricted or become uneconomic altogether, due to requirements being placed upon vegetable producers, that could prove to be incompatible with the principles of operating viable horticultural production enterprises.

The authors of this report have therefore enjoyed unprecedented access to confidential commercial information supplied by wholesalers and retailers which enabled the development of the realistic models shown in Section 10 (Models).

Appendix 2 - Literature Sources

Year	Data Source	Data Focus	Data Function for this Project
1985	Stark J.D. A macroinvertebrate community index of water quality for stony streams., p. 52. Ministry of Works and Development, Wellington.	Document with relevant information and baseline knowledge for modelling	Reference information and modelling data
1993	Rosenberg D.M. & Resh V.H. Freshwater Biomonitoring and Benthic Macroinvertebrates. Chapman & Hall, New York.	Document with relevant information and baseline knowledge for modelling	Reference information and modelling data
1993	Stark J.D. Performance of the Macroinvertebrate Community Index: effects of sampling method, sample replication, water depth, current velocity, and substratum on index values. New Zealand Journal of Marine and Freshwater Research, 27, 463-478.	Document with relevant information and baseline knowledge for modelling	Reference information and modelling data
1994	Hickey C.W. & Vickers M.L. Toxicity of ammonia to nine native New Zealand freshwater invertebrate species. Archives of environmental contamination and toxicology, 26, 292-298.	Document with relevant information and baseline knowledge for modelling	Reference information and modelling data
1995	Allan J.D. Stream Ecology: Structure and Function of Running Waters, Chapman & Hall, London.	Document with relevant information and baseline knowledge for modelling	Background document
1999	Hickey C.W., Golding L.A., Martin M.L. & Croker G.F. Chronic Toxicity of Ammonia to New Zealand Freshwater Invertebrates: A Mesocosm Study. Archives of environmental contamination and toxicology, 37, 338-351.	Document with relevant information and baseline knowledge for modelling	Reference information and modelling data
2000	Biggs B.J.F. Eutrophication of streams and rivers: dissolved nutrient-chlorophyll relationships for benthic algae. Journal of the North American Benthological Society, 19, 17-31.	Prior modelling document used to inform our modelling	Data source for modelling
2001	Stark J.D., Boothroyd I.K.G., Harding J.S., Maxted J.R. & Scarsbrook M.R. Monitoring macroinvertebrates in wadeable streams. MfE.	Document with relevant information and baseline knowledge for modelling	Reference information and modelling data
2007	Stark J.D. & Maxted J.R. A user guide for the Macroinvertebrate Community Index., p. 58, Vol. 1166. Prepared for the Ministry for the Environment. Cawthron, Nelson.	Document with relevant information and baseline knowledge for modelling	Reference information and modelling data
2008	Collier K.J. Average score per metric: an alternative metric aggregation method for assessing wadeable stream health. New Zealand Journal of Marine & Freshwater Research, 42, 365-378.	Prior modelling framework document used to inform our modelling	Data source for modelling
2009	Hickey C.W. & Martin M.L. A review of nitrate toxicity to freshwater aquatic species. NIWA Report HAM2009-099, Hamilton.	Document with relevant information and baseline knowledge for modelling	Reference information and modelling data
2010	Maurer, H. The Value Braid. The ins and outs of the produce business. Prestoungrange University Press.	General data relating to commercial realities of the industry sentiment	Industry specific background
2010	Abell J., Özkundakci D. & Hamilton D. Nitrogen and Phosphorus Limitation of Phytoplankton Growth in New Zealand Lakes: Implications for Eutrophication Control. Ecosystems, 13, 966-977.	Prior modelling document used to inform our modelling	Data source for modelling
2010	Dodds W.K. & Whiles M.R. Freshwater ecology : concepts and environmental applications of limnology, Academic Press, Burlington, MA.	Document with relevant information and baseline knowledge for modelling	Reference information

Year	Data Source	Data Focus	Data Function for this Project
2011	Friberg N., et. al. Biomonitoring of Human Impacts in Freshwater Ecosystems: The Good, the Bad and the Ugly. In: Advances in Ecological Research, Vol 44. (Ed G. Woodward), pp. 1-68. Advances in Ecological Research. Elsevier Academic Press Inc, San Diego.	Document with relevant information and baseline knowledge for modelling	Reference information
2013	Mhurchu, C., et al. . Food Prices and Consumer Demand: Differences across Income Levels and Ethnic Groups	Consumer purchasing decisions related to price	Data Source for modelling
2014	Horticulture New Zealand. Code of Practice for Nutrient Management	Historic industry guidelines for nutrient management to reduce N Loss	Reference information
2014	The AgriBusiness Group. Nutrient Performance and Financial Analysis of Lower Waikato Horticulture Growers	Data related to N Loss modelling	Evidence of prior modelling
2017	Proudfoot, I. KPMG. For Horticulture New Zealand. New Zealand domestic vegetable production: the growing story.	Reference and Document with relevant information on the commercial vegetable industry	Reference information
2018	Death, R., G., Magierowski, R., Tonkin, J. D., & Canning, A. D. Clean But Not Green: A Weight-of-Evidence Approach for Setting Nutrient Criteria in New Zealand Rivers	Modelling data for water quality and Total Attribute States	Data Source for modelling
2018	Deloitte. New Zealand's food story: The Pukekohe hub	Details related to the commercial scope and reality of the Pukekohe region's horticultural scale	Data Source for modelling
2018	Vandevijvere, S., et. al. How healthy are New Zealand food environments? A comprehensive assessment 2014-2017.	Consumer purchasing decisions related to consumer income	Data Source for modelling
2018	Death R., Canning A., Magierowski R. & Tonkin J. Why aren't we managing water quality to protect ecological health? In: Farm environmental planning – science, policy and practice. (Eds L.D. Currie & C.L. Christensen). Fertilizer and Lime Research Centre, Massey University,.	Document with relevant information on water quality	Reference information
2018	Vandevijvere, S., Mackay, S., D'Souza, E., and Swinburn, B. How healthy are New Zealand food environments? A comprehensive assessment 2014-2017. The University of Auckland.	Document with relevant information on consumer spending on healthy foods	Data source for modelling
2019	Plant & Food New Zealand. Nutrient Management for Vegetable Crops in New Zealand	Industry guidelines for nutrient management to reduce N Loss	Reference information
2019	SVS project – Quarterly and Annual Reports	Relevant information related to Nitrogen mitigation	Reference information
2020	MPI. Modelling to reduce Nitrogen in Lake Horowhenua	Pukekohe catchment modelling data related to land use and N Loss levels by land use type	Data Source for modelling
2020	MPI. Modelling to reduce Nitrogen in Pukekohe (Whangamaire stream)	Pukekohe catchment modelling data related to land use and N Loss levels by land use type	Data Source for modelling
2020	New Zealand Government. National Policy Statement for Freshwater Management 2020	Reference for all statements related to the National Policy Statement	Reference information
2020	Snelder, T., Cox, T., Kerr, T., Fraser, C., Collins, S. Manawatū-Whanganui Region Catchment Nitrogen Models Supporting Regional Plan Change 2	Reference document for CASM modelling discussed in Easton, S. (2021). Memorandum: Land use and N load estimates - Pukekohe and Horowhenua.	Data Source for modelling
2020	Cabinet Economic Development Committee 2020. Action For Healthy Waterways. Decisions On National Direction And Regulations For Freshwater Management	Reference information related to the process that led to the creation of the NPS-FM 2020	Reference information

Year	Data Source	Data Focus	Data Function for this Project
2020	Woodhaven Gardens. Horizons Plan Change 2 evidence	Reference information related to Horowhenua vegetable production	Reference information
2020	Clarke, J. 'Woodhaven Gardens Ltd Horizons PC2 Evidence. Submitted to Horizons Regional Council.	Reference information on Horowhenua commercial vegetable production and economics	Reference information
2021	Easton, S. Memorandum: Land use and N load estimates - Pukekohe and Horowhenua	Pukekohe catchment modelling data related to land use and N Loss levels by land use type	Data source for modelling
2021	Groundwater Quality State and Trends in Tāmaki Makaurau / Auckland 2010-2019 State of the Environment Reporting. Revised October 2021	Focus is strongly on volcanic aquifers in the region and Nitrate, Ammonia and Zinc levels detected	Reference information
2021	River Water Quality State and Trends in Tāmaki Makaurau / Auckland 2010-2019. State of the Environment Reporting	Information on Auckland water, Matauranga Māori and enabling Māori functioning as Kaitiaki.	Data source for modelling
2021	Curran-Courane, F., and Rush, E. "Feeding the New Zealand Family of Five Million, 5+ a Day of Vegetables?" *Earth 2021, 2(4), 797-808*	Reference document for data collection on vegetable types	Reference information
2021	Roskruge, N. Stafford, K. 'Vegetable Production'. In: Agriculture and Horticulture in New Zealand. Massey University.	Reference information on vegetable production and nutrient management.	Reference information
2022	Auckland Council. Dissolved oxygen and ecosystem metabolism in Auckland rivers 2004-2022. State of the environment reporting.	Oxygen levels in Pukekohe catchment	Data Source for modelling
2022	Horizons Council. State and Trend of Water quality in the Lakes and Rivers of the Manawatū-Whanganui Region	Horowhenua water quality data	Data Source for modelling
2022	River Water Quality in Tāmaki Makaurau / Auckland 2020 Annual Reporting and National Policy Statement for Freshwater Management Current State Assessment	Makes reference to three of the four monitored streams in the Pukekohe SVGA being impacted by high Nitrate levels.	Data Source for modelling
2022	Cox T., Snelder T. & Kerr T. The Waiopehu FMU water quality model. LWP Client report 2022-05, Lyttelton, New Zealand.	Prior modelling document used to inform our modelling	Data source for modelling
2022	Codex Committee on Fresh Fruits and Vegetables (CCFFV). Definition of terms for application in the layout for codex standards for fresh fruits and vegetables.	Reference and Document with relevant information on international fresh vegetable standards	Reference information
2023	Ministry for the Environment. Our Freshwater 2023.	Water quality data	Data Source for modelling
2023	Pukekohe SVGA ICMP . Stocktake + Gap Analysis report.	Data related to land use and water quality	Information to support modelling
2023	WSP. Nutrient losses from Commercial Vegetables in Horowhenua	Pukekohe catchment modelling data related to land use, N Loss levels by land use type, and mitigation impacts	Information to support modelling
2023	LAWA (n.d). River Quality Sites. https://www.lawa.org.nz/explore-data/river-quality/	Attribute States for Modelling data	Data source for modelling
2023	LAWA (n.d). Lake Quality Sites. https://www.lawa.org.nz/explore-data/lakes/	Attribute States for Modelling data	Data source for modelling
2023	NZ Food Safety. Microbiological Risks Associated With Frozen Raw Produce Used In Uncooked Food Preparations. Prepared for Ministry for Primary Industries.	Reference information on food safety risks and incidents related to frozen fruits & vegetables	Reference information
2023	PerrinAg. Horticulture Typology Modelling for the FWMT. Prepared for Auckland Council and Horticulture New Zealand.	Data related to N Loss modelling and commercial impacts	Evidence of prior modelling