BRIEFING

To:	**Gabriola Local Trust Committee**	**For the Meeting of:**	February 19, 2026
From:	**William Shulba, P.Geo** **Senior Freshwater Specialist**	**Date Prepared:**	February 12, 2026
SUBJECT:	Freshwater Footprint Gabriola Case Study Update		

PURPOSE

The purpose of this briefing is to present the consultant report of the Freshwater Footprint Gabriola Case Study. This report summarizes the project's background, analyzes the key outcomes including the Freshwater Hazard Map, and outlines the next steps for integrating this science into the ongoing Official Community Plan (OCP) review and upcoming community engagement.

BACKGROUND

The Freshwater Footprint Project represents the operational synthesis of the Islands Trust Freshwater Sustainability Strategy (FWSS). It functions as a "capstone" initiative, integrating years of foundational science into a unified decision-support tool for land-use planning.

The methodology builds upon a cascading scientific evidence chain established by FWSS programs and projects. The Aquifer Conceptualization project defined a hydrogeological framework or "container" of the Islands Trust Area, while the Groundwater Recharge Potential Mapping quantified the potential for precipitation entering those systems. These foundational layers were essential for establishing the inputs required for water balance modeling.

The Freshwater Footprint project refines the approach of the Southern Gulf Islands Groundwater Availability Assessments, engaging the formal external professional review of that earlier work and advances specific recommendations regarding water demand assumptions and uncertainty. This ensures that the Gabriola pilot benefits from the lessons learned in previous regional assessments, resulting in a more rigorous and defensible framework for defining carrying capacity. In addition, social science methods were engaged in the work that included survey analysis, public workshops, and interviews.

ANALYSIS

The primary deliverable of this project is a documented Freshwater Footprint methodology and its application to Gabriola Island. This project integrates water quantity (groundwater availability), water quality (chloride and TDS trends), and hazard indicators (seawater intrusion risk) into a holistic metric of freshwater sustainability. The defining output of this analysis is the Freshwater Footprint Hazard Map. The map identifies regions of freshwater hazard identifying areas with capacity for potential growth versus those facing cumulative resource limits. These outcomes provide the necessary evidence base for the current OCP and Land Use Bylaw (LUB) update. Planning staff will consider these hazard classifications when identifying criteria for evaluating changes to use and density. Hazard classifications will help validate proposed policy changes, ensuring that future development aligns with the physical limits of the island's aquifers.

IMPLEMENTATION AND NEXT STEPS

The professional report from GW Solutions is attached to this briefing providing opportunity for the Local Trust Committee and residents to review. A special meeting of the LTC will be held to discuss the project and to have a presentation from the consultant in March 2026. This session will allow the LTC and the community to learn more about the project and to ask questions regarding the methodology and results.

Planning staff will be bringing forward recommendations on how to explicitly embed the Freshwater Footprint Hazard mapping into the OCP policies and LUB regulations, potentially establishing new standards for development application review.

ATTACHMENT(S):

- Islands Trust Freshwater Footprint Methodology Gabriola Case Study Report
- Islands Trust Freshwater Footprint Methodology Gabriola Case Study Appendices

FOLLOW-UP:

Following the special meeting of the LTC in March, staff will return to the LTC with a staff report summarizing the meeting and identifying feedback from the engagement process.

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September 1, 2025
Project 24-16

Islands Trust Freshwater Footprint

Methodology Development and Gabriola Case Study

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Executive Summary

Maintenance and protection of freshwater supplies is essential for sustainable island communities. In this study, a freshwater footprint methodology was proposed that developed key indicators of groundwater quantity and quality to identify areas of freshwater stress unique to the island-setting of the Trust Area. The approach was then applied on Gabriola Island, east of Nanaimo, BC.

Globally, various approaches have been used to define sustainable limits for the use of water and other resources. In the simplest sense, sustainable groundwater management means:

- Water demand does not exceed supply
- Monitored water conditions (water level, flow, temperature, quality) remain dynamically stable
- Ecological needs, including groundwater baseflow to freshwater ecosystems, are considered
- Secure local water, food, and energy systems
- Preservation of resources for future generations, and
- Water governance models include First Nations leadership and perspectives, with municipal, regional and provincial government collaboration focussed on a long-term vision.

In practical terms, achieving these goals faces various challenges. Local planning and development are often undertaken without a sufficient understanding of water-related limits. In BC, implementation of the *Water Sustainability Act,* which came into force in 2016, has focused largely on water quantity, including licensing of non-domestic groundwater use. Water budget and water balance studies have been completed for various BC communities to quantify different components of the water cycle, including groundwater recharge and water use. However water of adequate quality for potable and other uses is equally important. Islands within the Trust Area are highly dependent on limited groundwater supplies that are vulnerable to hazards such as seawater intrusion. While overexploitation of groundwater sources may lead to drilling of deeper wells, that produce more mineralized groundwater from deeper fractures, which contains natural contaminants such as fluoride, manganese or arsenic. Decisions on land use including zoning and density can impact both water availability and quality, increasing stress on local water supplies.

To take a more holistic approach, the water footprint methodology included:

- Water balance component, which estimated groundwater use compared to recharge
- Water quality component that identified key water quality indicators (chloride and total dissolved solids), and

- Assessment of freshwater hazards including saltwater intrusion hazard, lot size and population density.

To apply the method, a comprehensive review of water quantity and quality information was summarized for Gabriola Island, including results for 540 groundwater samples. A conceptual and hydrostratigraphic model of the island was updated, and a water balance assessment was completed, including completing a detailed estimation of water demand based on land use and water sources on the island. The background concentrations and spatial distribution of water quality indices, including chloride and nitrate were evaluated in relation to contamination vulnerability and hazards. Chloride was confirmed as a useful indicator of seawater intrusion impact and mixing of fresh and brackish water in coastal areas. Total dissolved solids was considered a useful indicator of highly mineralized water, such as from deeper wells in coastal and inland areas.

The footprint hazard assessment identifies areas at risk from hazards such as sea water intrusion, housing density, water quality and water availability concerns by mapping the spatial extent of potential impacts. The results highlight zones with high, moderate, or low hazard levels. This information helps planners and developers pinpoint areas of concern where development may require mitigation measures. Conversely, it reveals safer zones with lower hazard footprints, presenting opportunities for future development with reduced risk. Using these results supports informed decision-making, prioritizes safety, and guides sustainable land use planning.

Recommendations for further work to evaluate the usefulness and applications of the footprint approach for land use planning were proposed. The project shows that even in relatively data-rich areas, gaps in knowledge need to be filled at the community level to assist with understanding and protection of precious water resources.

Acknowledgments: Funding for this project was provided by Islands Trust. We wish to thank the following people for their support and valued contributions to the project: William Shulba, Narissa Chadwick, Morgana van Niekerk and Chloe Straw, Islands Trust; Erica Forssman, Regional District of Nanaimo; Sarah Hardy and Neil Goeller, Ministry of Environment and Parks; Ally Badger, BC Conservation Foundation; Steven Earle, hydrogeologist; Alan Kohut, Hy-Geo Consulting; Jessica Doyle, Ministry of Water, Land and Resource Stewardship; Jill Lucko, Island Health;Mike Wei, Hydro-Geo Logic; Steve Usher, SLR Consulting; and Tom Gleeson, University of Victoria. Thanks also to the residents, staff and volunteers from Gabriola Island organizations that shared information and participated in the project workshops.

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1 BACKGROUND

The Islands Trust Area is a 5,200 km^2 region, encompassing 13 large islands and over 450 smaller islands in the Salish Sea between Vancouver Island and the British Columbia mainland (Islands Trust, 2025a). The Trust Area is found within the ancestral homelands and treaty territories of the Coast Salish peoples, including BOḰEĆEN, K'ómoks, Lək' ʷəŋən, Lyackson, MÁLEXEŁ, Qualicum, Quw'utsun Tribes, scəw̓aθən məsteyəxʷ, Scia'new, səli' lwətaʔɬ, SEMYOME, shíshálh, Sḵwx̱wú7mesh, Snaw-naw-as, Snuneymuxw, Spune'luxutth, SȾÁUTW̱, Stz'uminus, ɬaʔəmen, toq qaymɩxʷ, Ts'uubaa-asatx, Wei Wai Kum, We Wai Kai, W̱JOŁEŁP, W̱SIḴEM, Xeláltxw, Xwémalhkwu/ʔop qaymɩxʷ, and xʷməθkʷəy̓əm First Nations (Islands Trust, 2025b). The population of the Trust Area includes over 26,000 residents and increases significantly in the summer due to seasonal inhabitants and visitors (Islands Trust, 2025a). The Island Trust Area and Gabriola Island are shown in Figure 1.

GW Solutions was retained by the Islands Trust to develop a Freshwater Footprint methodology for the Islands Trust Area. The project was comprised of two main components:

- A *technical component* to develop a freshwater footprint methodology and to apply the methodology on Gabriola Island, and
- A *communications component* intended to engage, collect input and develop educational materials and tools that could facilitate collaborative water management within the subject area.

The results were intended to inform concurrent revisions of the Gabriola Island Official Community Plan and to be integrated within the Islands Trust Freshwater Sustainability Strategy (Econics and Compass Resource Management, 2021).

2 SCOPE

The project included the following scope:

- Review and summarize literature on freshwater footprint, water balance and water sustainability evaluation methods relevant to the study area;
- Develop a freshwater footprint methodology that includes quantity and quality related indicators of water availability and stress, climate change impacts and adaptation strategies, and community development scenarios;
- Collate, analyze and integrate existing water-related information to assess the freshwater footprint for a case study of Gabriola Island;

- Incorporate community input by conducting a residential water use survey and hosting a series of community workshops (on freshwater monitoring, and freshwater footprint method development);
- Assess the applicability of the freshwater footprint method to land use planning, water conservation and protection, and water authorization and allocation;
- Provide a GIS database of maps and spatial analysis layers.
- Compile a report, including diagrams, cross-sections and maps to summarize the results of the study and present the results to the local Islands Trust Council.

2.1 Report Organization

The report begins with outlining the general approach and methods used to develop the freshwater footprint methodology, provided in sections 3 to 5. Sections 6 to 7 provide the results of the freshwater footprint using Gabriola Island as a case study.

3 DEVELOPING A WATER FOOTPRINT METHODOLOGY – GENERAL APPROACH

3.1 Literature Review

A literature review was completed of methodologies and studies focused on the themes of water footprint, water sustainability and water security. Review and opinion papers on the *Water Sustainability Act,* water allocation, water planning, and governance in the BC context were also evaluated, to gather insights relevant to the current work and study area. The results of the literature and methods review are provided in section 4.

3.2 Regional and Local Studies

A comprehensive review of published hydrogeologic reports, studies, and assessments was completed for the study area, including Gabriola Island and other islands in the Trust Area. The methods and results of previous work were reviewed and used to identify trends and observations regarding the region's water sources, and island or site-specific water quantity and water quality concerns.

3.3 Gather Local Information and Input

The Trust Area has numerous residents, non-profit organizations and volunteer groups committed to environmental stewardship, action and education. This project sought ways to involve and gather input from local citizens, stewards and researchers, including through water survey, and community workshops.

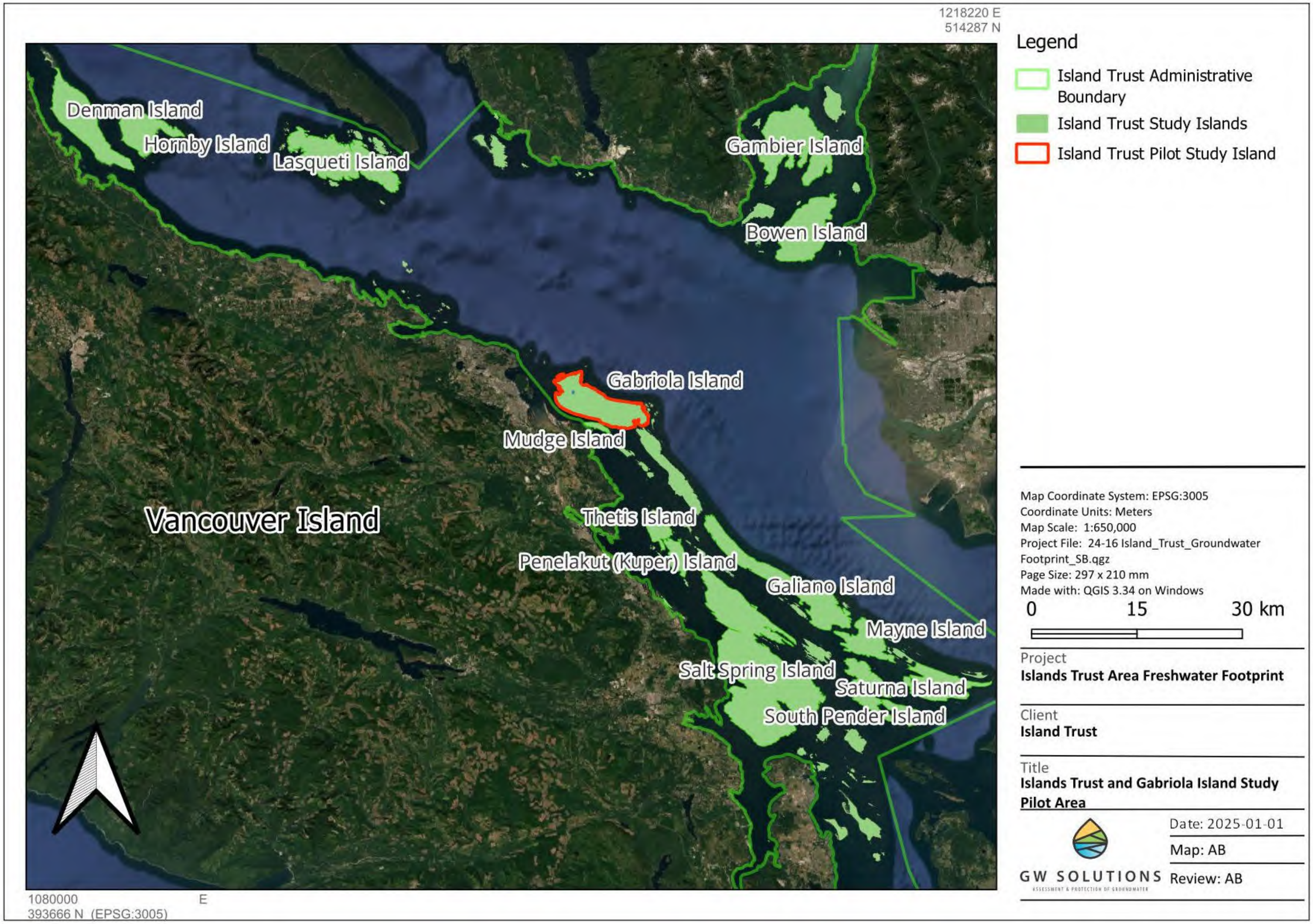


Figure 1: Islands Trust and Gabriola Island study area.

3.3.1 Water Use Survey

A residential water use survey was completed to gather information on water sources, conservation practices and water quantity and quality concerns experienced by island residents. The survey questions were developed based on similar surveys conducted in the Regional District of Nanaimo (RDN), Islands Trust, and in other communities, and modified based on feedback from RDN Drinking Water and Watershed Protection Program and Islands Trust staff. The survey was open for a period of two months from March 13, 2025 to May 18, 2025 and had 22 questions. The results of the survey are summarized in section 6.3, and included in Appendix D.

3.3.2 Workshop Series

Two workshops were held to share information about the project, local initiatives, and to gather input from local residents and groups. The workshops were advertised via the Islands Trust and project websites, via email to contacts, groups, and existing community email distribution lists, including Island Health's list of Gabriola Island water systems. The project process, outcomes and next steps will be presented to a special community meeting of the Gabriola Local Trust Committee in March 2026.

Monitoring Workshop: The first workshop in the series was held in May 2025 included presentations from staff in the Regional District of Nanaimo (RDN) Drinking Water and Watershed Protection Program, Ministry of Environment and Parks (ENV), BC Conservation Foundation (BCCF), Islands Trust and the GW Solutions project team. It provided examples of regional and provincial monitoring programs including the provincial observation well network, RDN volunteer observation well network and BCCF stream monitoring programs. The methods and benefits of monitoring and requirements of a successful monitoring program were discussed. The workshop was held online and a recording of the event was available for later viewing, garnering 78 views as of September 2025.

Developing a Freshwater Footprint Workshop: The second workshop was held in June 2025 and was available for in person and online participation. The workshop provided an overview of footprint concepts, presented preliminary analysis and datasets from the Gabriola Island study area. Participants shared local concerns and issues that could be considered when developing the project methodology. There were 30 in-person participants and 4 online participants.

3.3.3 Information Interviews

Informal telephone interviews were conducted with hydrogeologists and water scientists who have worked in the Trust Area and study island, to gather input on data sources, methods, and approaches to evaluate water security and sustainability.

3.3.4 Data Compilation

A comprehensive geospatial and monitoring data compilation was prepared and updated which included published map layers, and data from regional, provincial and federal data sources, in addition to analytical results from previous studies. Included datasets are summarized in Table 1.

Table 1: Data compilation categories, sources and application in the water footprint study.

Category	Data processing and application within the study
Surficial, Quaternary and bedrock geology	Detailed geological mapping of Gabriola Island and the Nanaimo Group Formations within the Georgia Basin was obtained from previous studies (Coutts, 2020; Cui et al., 2019; England, 1989). This provided information on bedrock units, geologic material types, formation process and origin (e.g. pre-glacial, glacial and post-glacial events, coastal processes such as the rise and fall sea level over geologic time) used to develop the 3D model. Terrain resource information mapping and soil mapping for the island was also reviewed to interpret surficial material types and thickness (Kenney et al., 1990a; Guthrie, 1993).
Groundwater Wells and Aquifers Database (GWELLS)	Data from GWELLS provided information on the locations and depths of wells, aquifer materials, depths of water bearing zones, groundwater levels, and estimated well yield) (Province of BC, 2025a). Lithological data were cleaned and standardized to develop a 3D Leapfrog model.
Mapped aquifers and lithological strata	Mapped aquifer boundaries and aquifer sub-regions (management areas) were compiled from provincial sources and previous studies (Province of BC, 2025a). Groundwater management area boundaries were defined from previous studies (GW Solutions Inc., 2021a; Hodge, 1978), considering watershed boundaries, flow systems and interpreted directions of groundwater flow and used as the base-scale for water balance calculations .
Groundwater monitoring data	Groundwater monitoring data were obtained from the Provincial Groundwater Monitoring Network (Ministry of Environment and Parks, 2025a, 2025b). Additional monitoring data were obtained for wells in the RDN Volunteer Observation Well Network (Regional District of Nanaimo, 2025a). The data were used to interpret seasonal, regional and long-term groundwater level trends in different areas of the island.
Aquifer vulnerability to sea water intrusion	Mapping of aquifer to vulnerability to sea water intrusion maps were obtained from previous studies (Klassen and Allen, 2016; Sivak and Wei, 2021). Methods and parameters used to assess sea water intrusion hazard and additional criteria were considered to refine the categorization of hazards within specific areas. The depth of to the interface between fresh and saline water was estimated using results of the 3D Leapfrog model and monitoring data sources.
Water licenses	The provincial Water Rights Database contained information on the locations and licensed volumes for surface water Points of Diversion (POD's), including licensed springs, and groundwater Points of Well Diversion (PWD's) (Water Management, 2025a, 2025b).
Digital Elevation Model	Topographic elevation of the landscape was based on a digital elevation model (DEM) layer (16 m x 16 m resolution) from Natural Resources Canada (2025) and high-resolution 1 m Light Detection and Range (LiDAR) survey from Islands Trust. The data were used to develop a three-dimensional conceptual model of the island, highlighting surface topography,

Category	Data processing and application within the study
	depressions, landforms and large scale physiographic and linear features that influence groundwater recharge and movement. Topographic elevation data were used to calculate slope (inclination of the ground) and aspect (direction of the slope) affecting precipitation infiltration and surface runoff, and to map groundwater flow direction, and the locations of recharge and discharge zones.
Water quality	Available data on groundwater and surface water quality was compiled from the Provincial Environmental Management System (EMS) database (Province of BC, 2025b). Data were also provided from the Regional District of Nanaimo, Drinking Water and Watershed Protection, Well Water Testing Rebate Program (Erica Forssman, personal communication, April 2025; Regional District of Nanaimo, 2025b), and previous studies (Earle and Krogh, 2006; Steve Earle, personal communication, June 2025). Additional data from sampling of water systems were digitized from files provided via a Freedom of Information Request submitted to Island Health (July 2025). The spatial locations of sample sites were validated, and the data were compiled into a comprehensive water quality database. Geospatial relationships between water quality, land use and hazards (e.g. saltwater intrusion vulnerability) were evaluated to assess regional trends and indicators of aquifers sustainability and impact.
Water systems and water demand	Parcels with non-domestic water use were determined from Island Health inventory of water systems and online inspection information that provided information on water sources and concerns (Island Health, 2025, 2020), GWELLS and the Water Rights database (Province of BC, 2025a; Water Management, 2025b) in addition to local directories and land use mapping (BC Assessment, 2025). Where possible, local water use data were obtained through personal communications with water system operators. Land use categories were used to infer water demand volumes based on published standards and guidelines (Miles, 2009; Ministry of Agriculture and Food, 2025; Ministry of Forests, Lands, Natural Resource Operations and Rural Development, 2012; Ministry of Health, Health Protection Branch, 2014; Statistics Canada, 2023a). Seasonal use and peaking factors were determined using long-term metered water system data from Regional District of Nanaimo and other island communities (Cowan, S., 2021; Regional District of Nanaimo (RDN), Water & Utility Services, 2025).
Cadastral mapping (lot boundaries) and land use	BC Assessment actual land use and zoning categorization was obtained from Islands Trust, and spatialized by linking to Parcel Map BC data (BC Data Catalogue, 2025). Actual land use and zoning were used to determine the locations and purpose of water use.
Land cover and vegetation cover	Vegetation and land cover play an important bearing on the amount of evapotranspiration and runoff and were used to estimate groundwater recharge potential. Land cover classification was obtained from Natural Resources Canada (Natural Resources Canada, 2022).
Historic climate data (long-term records and climate normals) and geospatial grid climate data (climate normals and future projections)	Statistical analysis of historic records on temperature and precipitation were completed based on compiled data from appropriately located climate monitoring stations (Environment and Climate Change Canada, 2024). The water balance model utilized gridded climate data (e.g. temperature and precipitation) and modelled future scenarios from the Pacific Climate Impacts Consortium (PCIC) (Pacific Climate Impacts Consortium, 2024).

Category	Data processing and application within the study
Existing hydrogeologic and environmental assessments	A detailed literature search was completed to gather and review information from numerous hydrogeologic, and environmental studies completed in the study area.
Field observations	A field visit was made to Gabriola Island in July 2025 to make observations with respect to land use and water sources on the island.

4 WHAT IS A FRESHWATER FOOTPRINT? DEFINING AND EVALUATING WATER SUSTAINABILITY FOR COASTAL BC ISLANDS

4.1 Freshwater footprint methodology: review of global and regional approaches

The concept of an ecological footprint was first used to estimate the resources such as land, water, or hydrocarbons, needed to sustain an individual or region living at a particular material standard (Rees, 1992). Ecological *carrying capacity* was defined as “the population of a species that can be supported indefinitely in a given habitat without permanently damaging the ecosystem upon which it depends. For human beings, carrying capacity was interpreted as the maximum rate of resource consumption and waste discharge that could be sustained indefinitely in a given region without progressively impairing the functional integrity and productivity of relevant ecosystems” (Rees, 1992). In contrast, the *ecological footprint* considered the land and resources needed to support a region’s population indefinitely at a given material standard.

Ecological footprint studies by William Rees, Mathis Wackermagel and others, often highlight the large quantities of water, land and carbon (greenhouse gas emissions) typically used by people in Western countries and the global inequity in resource distribution and intensity of use (Rees, 2014). The concepts of ecological footprint and carrying capacity are used to promote awareness of personal impacts and behavioral change among individuals. Current human behaviour, political and economic policy continue to favour an expansion model of growth and reliance on technological fixes to ecological problems such as climate change. In comparison, recognising and living within natural limits is identified as necessary to respond to ecological overshoot—the current over-consumption of Earth resources beyond its ecological capacity—involving changing individual lifestyles, changes in economic and governance systems, and emphasis on socio-economic equality between regions and nations.

The One Island, One Earth project completed on Galiano Island from 2020 to 2022 was an example of an island-scale assessment which considered the ecological footprint—human demand for natural resources—and ecological fingerprint—the values and attitudes that influence lifestyle choices and their related impact (Galiano Conservancy Association, 2022). The objective was to assess whether the population of Galiano Island was living sustainably within the resources of the island, and to identify resource limitations of small island communities, considering parameters such as food consumption, consumables and waste, and transportation. Water was not considered directly in the ecological footprint analysis; however the researchers referred to the results of existing water availability assessments (GW Solutions Inc, 2021), while highlighting the overall reliance on groundwater, mainly from privately operated wells, and need to further evaluate water availability, demand and associated ecological or hydrogeologic thresholds.

Building on the ecological footprint approach and focusing on the water component of goods, researchers in the Netherlands developed a water footprint method to estimate both direct water use by consumers or producers of different products, in addition to the indirect volume of water used to provide the product along its full supply chain (Hoekstra et al., 2011). In their approach, blue water referred to surface or groundwater resources consumed to produce and supply a product, green water referred to rainwater consumed, while grey water referred to the volume of freshwater required to assimilate pollution created by growing or manufacturing the product, considering natural background concentrations and water quality standards. By quantifying the water demand associated with the manufacture, consumption and trade of different products, policy and behavioural changes could be identified to improve water management and sustainability.

Many researchers have also sought ways to measure the sustainability of groundwater use from specific aquifer sources. Adapting methods applied by Gleeson and Wada (2013) to global-scale aquifer stress assessment, an aquifer carrying capacity and stress index was estimated for unconfined aquifers in BC using a groundwater footprint approach (Forstner et al., 2018). Recharge was estimated using multiple methods, including water balance modeling. Recognizing the connections between groundwater and surface water systems, the aquifer stress index incorporated an estimate of the groundwater contribution to environmental flows in hydraulically connected surface water environments. Aquifer stress was estimated as the ratio of groundwater use compared to water availability. The groundwater footprint was expressed as a unitless ratio of water use to availability (recharge minus environmental flow), per aquifer area. Approximately one in five mapped, unconfined aquifers in BC was considered to be stressed, providing a screening level estimate to prioritize additional monitoring and assessment (Forstner et al., 2018). One observation of the study methods and results is that potential bias in the stress assessment for fractured bedrock aquifers was introduced due to differences in aquifer mapping methods. Aquifers mapped with a large spatial area, defined by the geologic formation in which the aquifer occurs, had a smaller calculated footprint. However this approach did not reflect areas of greater groundwater use intensity and spatial variability in the distribution of constructed wells i.e., areas of very high well density and higher water stress could occur within a large mapped aquifer. Conversely, bedrock aquifers mapped based on area of development (where wells are drilled) were typically smaller and had a larger footprint and stress ratio. Their study also developed methods and highlighted the challenges of quantifying groundwater use with limited datasets (Forstner and Gleeson, 2019).

Dr. Diana Allen (Simon Fraser University), who, along with dozens of students and research partners has completed numerous studies in the Gulf Islands and British Columbia, has described the complexity of groundwater sustainability assessment in British Columbia and in groundwater dependent regions such as the Gulf Islands (*Climate change influence on groundwater in coastal BC, Dr. Diana Allen*, 2021). In general, recharge is difficult to quantify, spatially variable, and results in a wide range of results depending on the method used (Allen and Gleeson, 2023). Water balance methods which consider the ratio of water demand compared to recharge may not adequately quantify groundwater's necessary contributions to stream baseflow maintenance and thermal regulation (e.g., keeping water temperatures cooler in summer). Similarly, flux to the marine foreshore is important for ecological quality of coastal marine environments, maintenance of the freshwater lens under the island, sustaining the equilibrium between freshwater and saline water and preventing seawater intrusion (Allen and Suchy, 2001; Allen and Liteanu, 2006; Klassen and Allen, 2016). Moreover, despite decades of research in the Islands Trust Area, and positive community attitudes towards the critical value and importance of water, few examples exist of science-based indices of freshwater sustainability that have been successfully linked with significant changes in community behaviour, land use policies, or water allocation (Cohen, 2007).

> ***Groundwater sustainability defined:***
>
> *"maintaining dynamically stable groundwater levels, flows, and quality with equitable, effective, and long-term governance and management to sustain water, food, and energy security, environmental flows, and groundwater-dependent ecosystems, infrastructure, social well-being, and local economies for current and future generations"*
>
> *Gleeson, et al., 2018*

Since March 2016, diversion and use of groundwater for non-domestic purposes requires a license under the *Water Sustainability Act* (Province of BC, 2014). Considering the process of development and implementation of the new provincial water legislation, Curan et al., (2023) proposed additional changes to regulatory approaches that could be based on and responsive to the unique characteristics of groundwater, examples shown in Table 2. Some key recommendations include the need for adaptive management in response to monitoring observations and other indicators, recognition of indigenous rights and traditional knowledge, and development of regional approaches and priorities.

What does sustainability mean when it comes to use and management of water resources? Gleeson et al., (2018) propose the following definition: "maintaining dynamically stable groundwater levels, flows, and quality with equitable, effective, and long-term governance and management to sustain water, food, and energy security, environmental flows, and groundwater-dependent ecosystems, infrastructure, social well-being, and local economies for current and future generations." Consistent with this definition, the goal of a water footprint assessment is to develop appropriate indicators and measures that will help ensure the security (quantity and quality) of water sources for island communities into the future.

The concepts of footprint and environmental sustainability recognize several fundamental principles:

- Resources (water, land, consumables and pollution absorption capacity) are naturally limited, both within the larger Earth system, and within specific geographic or biophysical regions such as on an island;
- Need to maintain and conserve resources (for future population, future generations);
- Consideration of other than human needs (environmental flows, ecological needs);
- Precautionary principle;
- Area-based metrics and indicators;
- Appropriate temporal scale e.g., monthly timescale to consider seasonal conditions, and decadal or longer planning horizons;
- Appropriate spatial scale e.g., island, watershed or management area.

Table 2: Approach to regulation of groundwater that considers the hydrogeologic characteristics of groundwater. Adapted from (Curan et al., 2023).

Scientific characteristics of groundwater	Basics of the characteristic	Regulatory design implications	Example for study area
Processes	Hydraulic connectivity between groundwater and surface water	Treat groundwater and surface water as a single resource	Preserve streams and wetlands to provide storage for groundwater recharge Conduct local studies to identify groundwater dependent freshwater ecosystems (i.e., groundwater contributions to baseflow, thermal regulation)
Functions	Hydro-ecological, hydro-climatic, hydro-social, storage	Recognise inherent limits to groundwater use. Implement Integrated Water Resource Management to maintain groundwater fluctuations	Involve Indigenous rights & knowledge holders and community stakeholders in water management and land use decisions Aim to balance competing water demands (agriculture, industry, residents, environment)

Scientific characteristics of groundwater	Basics of the characteristic	Regulatory design implications	Example for study area
Qualities	Invisible, distributed, slow	Take a long-term approach to regulation, plans, and adaptive management	Sustainably fund, maintain and expand monitoring programs to evaluate long-term trends Consider cumulative and long-term effects of groundwater withdrawals on aquifer and ecosystem health (rather than one-off approvals)
Physical sustainability	Dynamically stable water levels and fluxes	Maintain dynamically stable water levels and flows	Develop sector-based water use and conservation approaches that can be modified based on monitoring, and changes in inter-annual and long-term conditions
Scale	Multiple spatial scales but predominantly regional scale. Multiple, long time scales	Regional scale regulation at multiple time scales. Governance at multiple spatial scales	Facilitate coordination and consistent policies across levels of government (e.g. for development approvals) Improve efficiencies and integration by investing in shared databases (water quality, water use) Develop region-specific drought indicators and thresholds to promote conservation during times of water shortage
Information and data	Challenging but possible to collect sufficient, representative information and data	Base regulation on sufficient, representative data. Apply precautionary principle.	Identify and implement strategies to fill gaps in monitoring and other data needed to make sound water related decisions
Physical state	A small but important number of highly stressed regions with widespread impacts	Create priorities based on stress levels and vulnerability	Develop policies and approaches based on unique regional characteristics and priorities in the Trust Area

4.2 Freshwater Characteristics and Vulnerabilities in Islands Trust Communities

Development of the freshwater footprint methodology considered parameters and indicators that respond to and reflect the unique vulnerabilities and features of this region.

Groundwater dependence: Islands in the Trust Area are primarily reliant on water supply from groundwater sources (Wei et al., 2014). Although some islands have lakes and streams utilized as source of potable water, including waterworks systems, notably Salt Spring Island with lakes such as St. Mary Lake, and Maxwell Lake, in most areas water is provided from wells, operated as individual or private water supplies or small water systems (Econics and Compass Resource Management, 2021). Freshwater sustainability strategies therefore must focus largely on groundwater sources and the processes influencing groundwater quality and quantity.

Groundwater resources within the Trust Area are influenced by aquifer characteristics and location within an island setting. Water availability is seasonally variable, and there is a contrast in the timing between periods of groundwater recharge and high groundwater levels in winter, compared to peak periods of water demand in summer, resulting in a seasonal water deficit during which water must be supplied from aquifer storage (GW Solutions Inc, 2021; Gorski and Sacre, 2019; Hy-Geo Consulting, 2015). Water quality can be impacted by natural contaminants, in addition to salinity from seawater intrusion in coastal areas, and pollution impacts from land use, such as discharges of sewage to septic ground disposal systems (Klassen and Allen, 2016; Denny et al., 2007, 2006).

Aquifer characteristics: Most aquifers in the Trust Area have limited water supplies due to their inherent properties. Table 3 describes the subtypes and classification properties of aquifers that have been mapped within the Islands Trust area (Ministry of Water, Land and Resource Stewardship, 2024). Only 17% of mapped aquifers are made up of unconsolidated (sand and gravel) materials, and there are typically small in size (e.g. 5 km^2 or less area).

Where overburden sediments are thin or unsaturated, groundwater is primarily supplied from wells constructed in fractured bedrock. Sedimentary bedrock aquifers made up of layered sandstone, shale, and or conglomerate rock in which groundwater is stored within and transmitted through fractures represent 64% of mapped aquifers on the islands. These aquifers generally have a low to moderate productivity and a limited storage capacity (Wei et al., 2014).

From a review of well data from Northern and Southern Gulf Islands, 40% of wells produce less than 8 L/min (2 USgpm), while the majority (80%) had yields less than 57 L/min (15 USgpm), based on pumping tests and air-lift test results reported by drillers following well construction (GW Solutions Inc., 2021a). Well productivity can also vary significantly from site to site, influenced by the presence of fault and fractures. Shale units typically have greater fracturing compared to more massive and less intensely fractured sandstone and conglomerate rocks as illustrated in Figure 2 (Denny et al., 2006). Similarly, the productivity of fractured crystalline bedrock aquifers on the islands is low to moderate, depending on the rock type, and geologic processes that have influenced fracture formation (Surrette et al., 2008).

Other observations relevant to the study area:

- Seasonal deficits: The water balance exhibits a seasonal water deficit. During the dry season little to no groundwater recharge occurs, therefore water use be supplied from water storage in regional aquifers or surface water sources.
- Fractured bedrock aquifers have limited storage capacity, i.e. in late winter they reach a recharge threshold after which no further water is stored.

- Fractured bedrock aquifers can be highly variable spatially. For example two wells located relatively close to one another can have different yield and water quality, depending on the number, depth and productivity of bedrock fractures intercepted by the well. Due to the low permeability of sedimentary bedrock fractures, pumping of individual wells is likely to influence a relatively small local area. Hence there is a need to assess and monitor conditions at an appropriate geographic scale, such as a groundwater region.

Table 3: Aquifer subtypes and characteristics in the Trust Area.

Aquifer Subtype	Subtype description	Number of mapped aquifers	Minimum area (km^2)	Average area (km^2)	Maximum area (km^2)	% mapped aquifers	Vulnerability	Productivity
3	Unconfined sand and gravel - alluvial or colluvial fan	1	-	-	1.0	2%	High	Moderate
4a	Unconfined sand and gravel - late glacial outwash	2	2.3	3.9	5.6	3%	Moderate	Low-Moderate
4b	Confined sand and gravel - glacial	7	0.1	1.3	4.0	11%	Low-Moderate	Low-Moderate
4c	Confined sand and gravel - glacio-marine	1	-	-	0.7	2%	Moderate	Low
5a	Fractured sedimentary rock	41	0.0	9.3	58.2	64%	Moderate-High	Mainly Low
6b	Fractured crystalline bedrock	12	2.8	14.5	51.4	19%	Low-Moderate-High	Mainly Low
Total		64	0.0	9.0	58.2	100%		

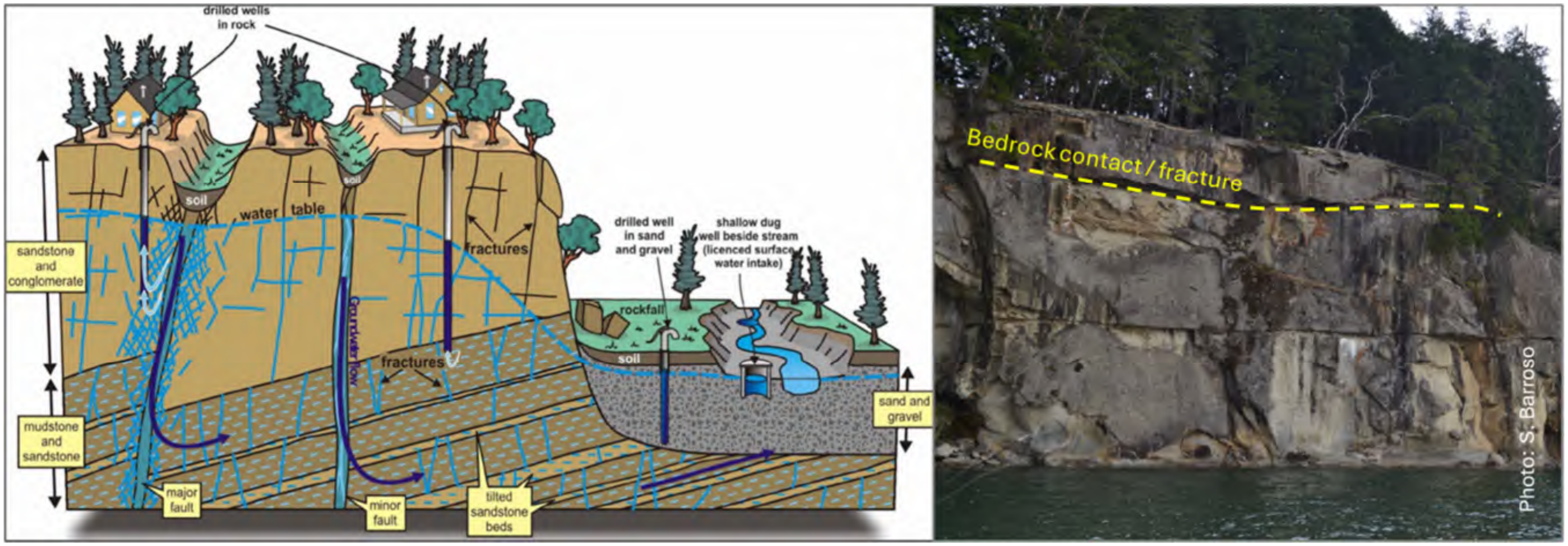


Figure 2: A) Gulf Islands fractured sedimentary bedrock aquifers conceptualization, reproduced from (Denny et al., 2006); B) Sandstone cliffs on south side of Gabriola Island showing layered deposits and horizontal fractures that can store and transmit water.

Island setting: All water that replenishes streams, lake and aquifers on the islands originates as precipitation over the island footprint. In coastal and island aquifers, fresh groundwater, which has a lower density than seawater, forms a freshwater lens that floats above the denser seawater around it (Bear et al., 1999). Beneath the Island, saline water circulates and extends inland from the coast forming a saline zone or wedge. Where the groundwater and ocean water come into contact is referred to as the freshwater-saltwater interface (Werner et al., 2013). A transition zone above this interface can contain a brackish mix of water from the two sources. The balance between freshwater and seawater is maintained by groundwater that is recharged in higher elevation areas and discharges in lower elevation areas along the coast. The depth of the saline interface and transition zone fluctuates seasonally, and can vary in response to tidal fluctuations and groundwater pumping (Klassen and Allen, 2016; US Geological Survey, 2000). A conceptual diagram of a coastal island setting is shown in Figure 3. Management of seawater intrusion hazards was considered one of the most important aspects to consider in the freshwater footprint methodology.

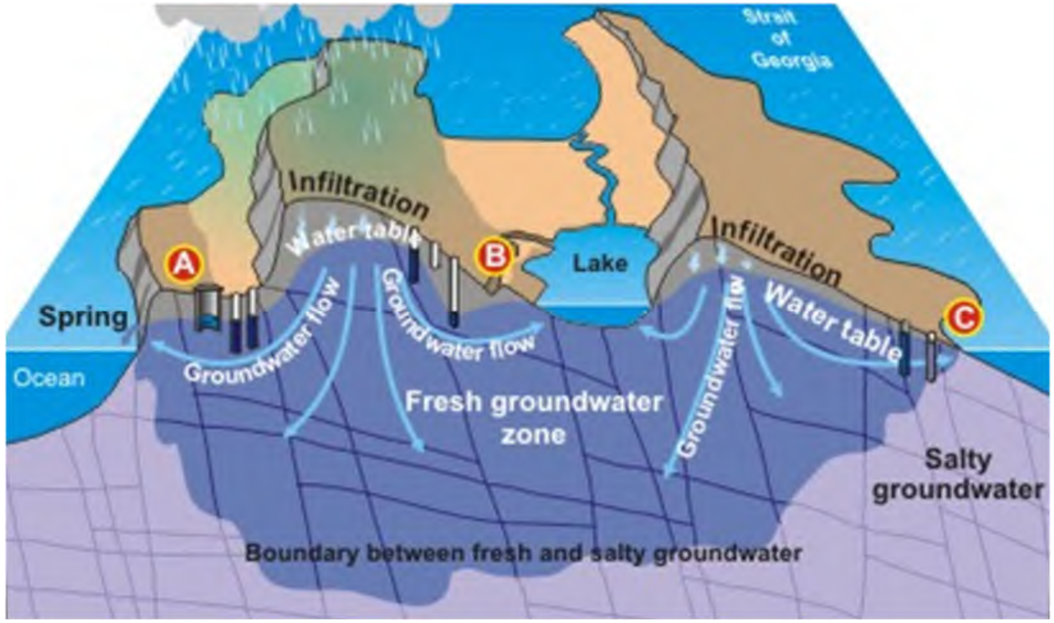


Figure 3: Coastal and island aquifer equilibrium between fresh and saline water, reproduced from (Turner et al., 2004).

Hydraulic connection between surface water and groundwater systems: As components of the water cycle, water flow and availability within surface water and groundwater sources are often closely linked (Winter et al., 1998). For example, even during long periods of low precipitation many streams in coastal BC maintain year-round flows which are sustained by groundwater discharge (Allen et al., 2010; Rathfelder, 2016). Streams, lakes and wetlands can also contribute to groundwater recharge via infiltration and losses to the subsurface (Woessner, 2025). The relationship between surface and groundwater sources is complex and can vary both spatially and seasonally.

Understanding and quantifying the mechanisms of interaction and hydraulic connection between surface sources such as lakes, rivers and wetlands, and groundwater aquifers is important to manage and protect water resources (Gleeson and Richter, 2018). In hydraulically connected systems, pumping of groundwater wells may influence conditions such as water level, flow, temperature, or water quality within nearby streams, lakes, rivers, creeks or wetlands (Barlow and Leake, 2012). The effects may be felt rapidly or may take from months to years to be observed. In the context of groundwater allocation and licensing the potential for depletion of surface water sources resulting from groundwater use must be considered (Wei et al., 2016). Understanding hydraulic connectivity between surface and groundwater is also important when considering ecosystem requirements, including water needed for maintenance of healthy aquatic habitats (Hatfield et al., 2004, 2003). The relative importance of measuring and quantifying hydraulic connection between surface and groundwater within a groundwater budget will vary by island and by watershed (Sivak et al., 2024). Inadequate surface water monitoring data can often limit the ability to quantify this connection. However as a baseline, characterizing the relationship and likelihood of hydraulic connectivity using key indicators and mapping methods was a necessary component of the freshwater footprint methodology.

Land Use: Land use within the Trust Area is mainly low density, rural residential, agricultural and forest land use, with small community centres with moderate density, or semi-urban and commercial development. As with water supply, sewage waste is generally disposed via ground disposal in septic systems. Sources of groundwater contamination originate from non-point sources, including sewage discharges and agricultural waste. The freshwater footprint considered lot size and density as indicators of potential contaminant sources that could impact long-term sustainability and quality of freshwater resources. Maintenance of natural hydraulic functions and drainage patterns in island watersheds and maximization of groundwater recharge capability are also linked to land use policies and practices.

Water Quality: Concerns related to water quality are known to occur on the islands, both due to the presence of natural contaminants such as arsenic, fluoride, iron and manganese, and as a result of contamination from land use impacts, for example introduction of nutrients such as nitrate. The concentration of elements such as chloride can increase from seawater intrusion in response to overuse of groundwater near the coast (Klassen et al., 2014). If shallow groundwater resources become depleted, wells may be drilled deeper, resulting in the pumping of older, mature groundwater with higher mineral content that is replenished more slowly (“groundwater mining”). Therefore water quality is an important indicator of sustainability to be considered within the freshwater footprint methodology.

Climate Change: Changes in regional climate within the Trust Area are likely to affect the water cycle, and influence water availability within streams and aquifers. For example, warmer wetter winters, higher summer temperatures and longer dry seasons will affect annual patterns of groundwater recharge, while increasing human water demand for household use and irrigation (Pinna Sustainability, 2020). Sea level rise, increasing storm intensity and coastal storm surges may increase shoreline erosion and influence groundwater quantity and quality in coastal areas (Klassen and Allen, 2016; Pinna Sustainability, 2020). The freshwater footprint considers current indicators of water stress that provide a baseline from which future conditions can be compared. It also identifies monitoring gaps, best practices and strategies for protection of water resources needed to adapt to a changing climate.

4.3 Freshwater Footprint Approach

Key components to consider within a Freshwater Footprint are outlined in Table 4. The methodology development described in the following sections has focused on freshwater quantity and quality criteria, and specifically groundwater related indicators. Criteria related to watershed health are included in related projects in the Trust Area, such as the mapping and protection of Coastal Douglas Fir ecosystems on Salt Spring Island (Transition Salt Spring, 2025a, 2025b) , and could be explored in future.

Table 4: Freshwater Footprint Components, Criteria and Indicators

Criteria	Objective	Indicator
Watershed Health	Natural watershed function is maintained (wetland ecology, maintenance of seasonal discharge and minimum instream flows for aquatic health, Environmental Flow Needs)	• Forest cover, species and age • % Impervious surfaces • Road network density • Drainage characteristics compared to undeveloped condition • Forest fire hazard assessment • Surface water flows and level (lakes, wetlands)
Freshwater Quantity	Sufficient water quantity for residential, agricultural, commercial, industrial needs (priority land uses)	• Demand < Availability (% with large safety factor to account for uncertainty) • Considers ecosystem needs and flux to coast • Appropriate for fractured bedrock aquifers • Stable aquifer (GWL) trends • Groundwater management area scale
Freshwater Quality	Water of adequate quality for residential, agricultural, commercial, industrial needs (priority land uses)	Indices or thresholds based on regional hazards: • Seawater intrusion indicators (e.g., chloride) • Contamination from land use, septic systems (nitrate, bacteria, viruses or emerging contaminants) • Water quality compared to background concentration • Long-term trends and changes over time • Comparison to guidelines and thresholds

5 FRESHWATER FOOTPRINT METHODS

5.1 Hydrostratigraphic Model

The foundation for many hydrogeologic studies is the compilation of maps and water-related datasets to development of a conceptual or hydrostratigraphic model. A conceptual model can be used to interpret and describe the key factors influencing groundwater availability, movement, groundwater quality, and potential interactions between aquifers, surface water bodies and coastal environments. A three-dimensional 3D stratigraphic model can be used to interpret the characteristics of subsurface layers and geologic features, to develop cross-sections and maps that illustrate water sources and hydrogeologic processes.

Previous work completed by GW Solutions in the Trust Area involved development of a 3D hydrostratigraphic models of each island environment using Leapfrog Geo software (Seequent, 2022). A 3D model was developed by GW Solutions for study islands in the Trust Area. Detailed methods and referenced data sources used to develop the models are outlined in the associated reports (GW Solutions Inc., 2021a, 2019). For the current project, the Gabriola Island model was updated and used develop additional interpretive maps and cross-sections, including interpolating the depth of the freshwater-saltwater interface beneath the island.

5.2 Gridded Water Balance Model

A gridded water balance model was developed to assess groundwater availability on Gabriola Island. The method involved estimating the different components of the water cycle to determine groundwater availability compared to water use. The gridded approach enables analysis of variable conditions over the island using a network of squares or pixels. The model inputs and outputs are calculated for each month and summarized annually. The methods are described in further detail in (GW Solutions Inc., 2021b).

The water balance model inputs are climate-related parameters including precipitation, temperature, solar radiation and soil available water capacity. The model estimates how much water is available for evapotranspiration, compared to the amount anticipated to be lost to the atmosphere and used by plants. If there is a deficit, less water is available than will be lost to evapotranspiration, and no water is available for runoff or groundwater recharge. If a water surplus is available, this can contribute to runoff or groundwater recharge. The potential for infiltration to occur that will contribute to groundwater recharge is then estimated spatially, based on geology, soil, topography and other factors. Actual groundwater recharge is estimated and compared to water demand, determined based on the aquifer conceptual model and land use at the land parcel scale.

A flow chart representing the parameter inputs and outputs for development of the water balance model is shown in Figure 4.

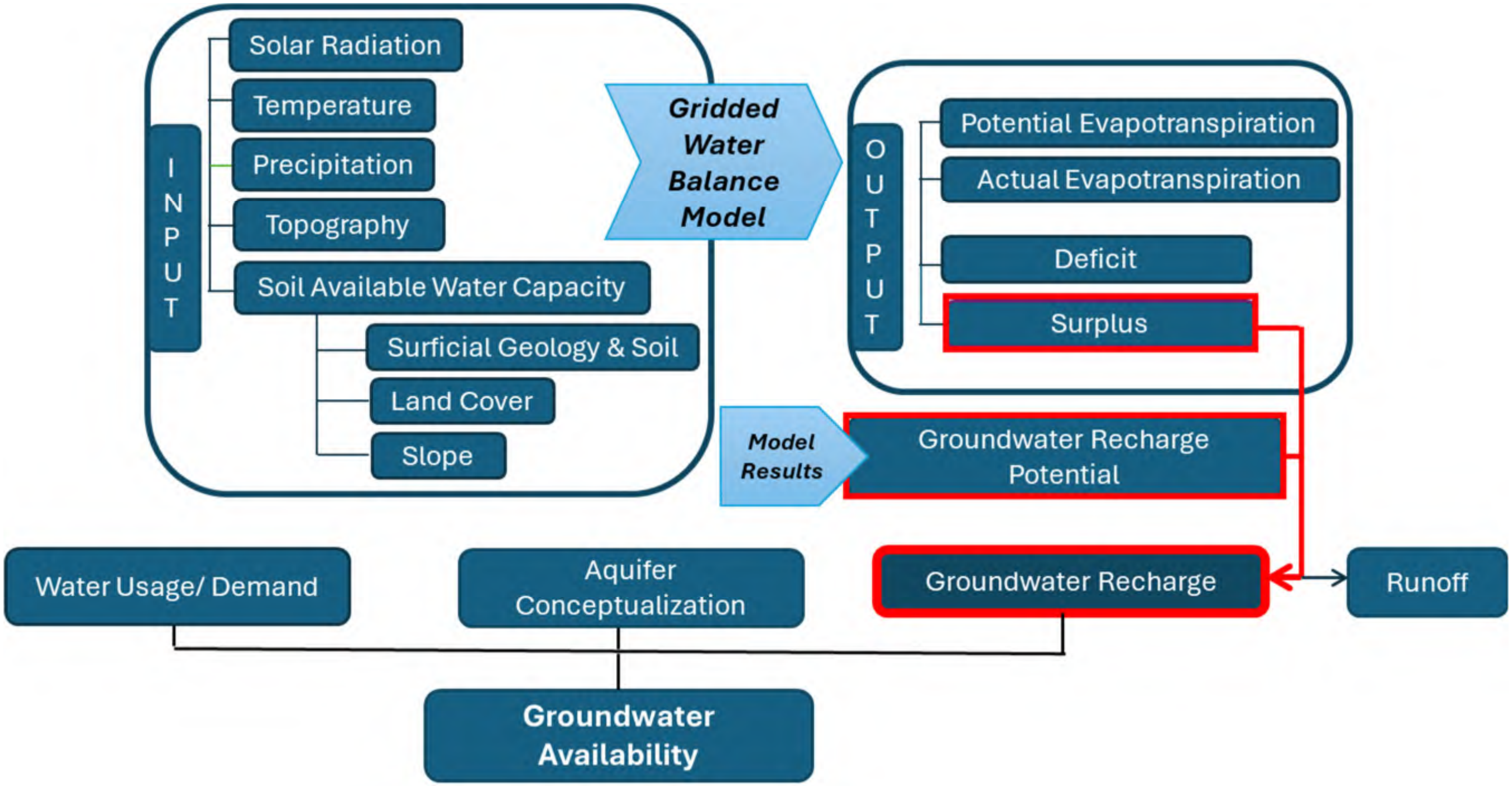


Figure 4: Groundwater availability input and output parameters.

5.2.1 Climate inputs, outputs and water surplus

To estimate the water balance, the study used GW Solutions R-code implemented from the ArcGIS-based model developed by James Dyer from the University of Ohio (Dyer, 2021, 2019). The model estimates monthly potential evapotranspiration, soil moisture storage, actual evapotranspiration, soil moisture deficit, and soil moisture surplus using a grid-based, Thornthwaite-Mather approach (Steenhuis and van der Molen, 1986). The main data inputs include elevation, determined from a digital elevation model (DEM), soil available water capacity (AWC), monthly temperature (average), precipitation, and solar radiation. The detailed methods and assumptions are further described in (GW Solutions Inc., 2021c).

Water balance model inputs include:

Digital elevation model (DEM), aspect and slope: Slope and aspect (slope direction) rasters (gridded data) were derived from the 1-m resolution digital elevation model (DEM) obtained from Islands Trust.

Soil Available Water Capacity (AWC): Digital soil map layers were obtained from the BC Soil Finder Tool ("BC Soils Information Finder Tool," 2025; Kenney et al., 1990b). Important soil characteristics considered in the model included soil composition (mineral or organic), soil layer thickness, texture, coarse fragment content, drainage, moisture holding capacity, as well as landform and parent material. In temperate forests, 95% of root biomass occurs within the top 1 m of soil (Jackson et al., 1996). Therefore, available water holding capacity at 0.90 m depth was used for the model input.

Geology (surficial geology, geomorphology): Surficial geologic mapping datasets were integrated into the model providing information on physiographic features, and the relative thickness, texture, and drainage characteristics of surface sediments (Dunn, 1980; Kenney et al., 1990b).

Solar Radiation: Solar radiation was estimated based on topography (DEM), the geographic location and the time of the year. Solar radiation values (kJ m^{-2} day^{-1}) were obtained from WorldClim (http://worldclim.org/version2) at a resolution of 30 seconds (~1 km). The data were converted to watt-hours per square meter (Wh/m^2) per month for input to the model.

Average temperature and total precipitation: Gridded monthly total precipitation and maximum and minimum temperatures for Gabriola Island were obtained from the Pacific Climate Impact Consortium (PCIC) (Pacific Climate Impacts Consortium, 2024). Two scenarios were utilized:

- Environmental conditions based on climate normal data from 1981-2010. The climate model parameters were compared to monitoring data from the study area (e.g. Nanaimo Municipal Yard, Environment Canada Station EC10253G0), the closest station with the most complete long-term dataset)(Environment and Climate Change Canada, 2025).
- Climate conditions modelled for 2025 (the current year) based on the Shared Socio-economic Pathway SSP 2.6 from PCIC.

The outputs of the model are:

Potential evapotranspiration (PE) is estimated using the Turc Method. PE is the potential evaporative water loss from vegetation if water is not a limiting factor. PE depends mainly on heat and solar radiation.

Actual evapotranspiration (AE) refers to water loss from vegetation given actual water availability from precipitation and soil moisture storage. If water is not a limiting factor, actual evapotranspiration is equal to potential evapotranspiration.

Deficit is the difference between potential and actual evapotranspiration and occurs when there is insufficient water available in the soil to meet evaporative demand.

Surplus is excess water that is not evaporated or transpired. It leaves a site through runoff or subsurface flow or a combination of both. There can be no surplus if soil storage is not at full capacity.

The above values are calculated for each month from January to December.

5.2.2 Groundwater Recharge Potential

To estimate water availability in the study area, the next step was to determine the groundwater recharge potential, which reflects the ability of water to infiltrate into the subsurface. Groundwater recharge is the process whereby water from precipitation moves into the subsurface to replenish aquifers (Healy, 2010).

Diffuse recharge refers to recharge over a broad geographic area, such as an aquifer footprint, and is the dominant recharge mechanism in areas where thicker layers of unconsolidated materials overlie bedrock, depending on factors such as the drainage capacity of the soil, land cover type, local topography or slope, and the depth to the water table.

In comparison, *focused recharge* refers to localized recharge facilitated by the presence of discrete physiographic features such as roadside swales and ditches, natural depressions, gulleys, gorges, bedrock faults, fractures and bedding planes. Focused recharge is the main mechanism for recharge in fractured bedrock aquifers, and in areas where the overburden is thin or bedrock is exposed. Large-scale linear features or lineaments, identified from air photos or satellite imagery, can indicate the potential location of geologic features such as fractures, faults and bedding planes, or contacts between different geologic units. Groundwater recharge and flow within the fractured bedrock system depends on the width, length, openness, storage capacity, inter-connectivity and transmissivity (hydraulic conductivity across an aquifer cross-section) of these bedrock fracture networks (Cook, 2003).

GW Solutions developed a GIS-based methodology to estimate the spatial variability of recharge potential based on different recharge mechanisms or pathways. The detailed methods and results for study islands in the Trust Area are further described in (GW Solutions Inc., 2021b). The method uses infiltration and groundwater recharge coefficients for each of the spatial, physical and temporal variables controlling recharge.

Groundwater recharge is dependent upon factors such as the amount and type of precipitation (snow/rain), the slope of the land surface (topography), the amount of water interception by plants (water retention or water used by plants), evaporation from the land surface and open water (lakes, rivers), and the permeability of the soil and subsurface geologic formations, including bedrock faults and fractures (observed on air photos and high-resolution digital elevation models as large scale linear features or lineaments). Each of these factors is assigned an appropriate weighting factor in the calculation of recharge potential. Weighting factors were determined based on previous studies and predominant factors influencing groundwater recharged observed across Vancouver Island and the Gulf Islands. Figure 5 is a flowchart for the integration of data inputs to estimate the groundwater recharge potential.

5.2.3 Groundwater Recharge Potential Parameters and Weighting Factors

Slope Coefficient: Topography greatly influences the potential for water infiltration to the subsurface. In groundwater recharge areas, low slopes promote infiltration whereas steep slopes promote runoff and decreased infiltration. Table 5 summarizes the slope infiltration factors. LiDAR at 1-m resolution as well as a 5-m Digital Elevation Model (DEM) were made available to GW Solutions through the Island Trust from the LiDAR project inventory for British Columbia. Slope was derived from the 5-m DEM processed from LiDAR.

Water Retention Potential (WRP) Coefficient: Vegetation and land cover data were combined into a Water Retention Potential coefficient.

Precipitation Interception: Potential Vegetation effects groundwater recharge through the interception of precipitation by foliage (i.e. evapotranspiration). Greater foliage interception leads to longer exposure to the atmosphere and increased evaporation. Data from a Vegetation Resource Inventory (VRI) available for the Islands Trust region was correlated with precipitation interception characteristics for different vegetation types, including canopy closure, forest cover type, herb storage capacity, and assigned with a relative weighting scheme dependant on their relative influence on precipitation interception. Table 6 summarizes the WRP coefficients based on the precipitation interception potential.

Land Cover/Land Surface: For non vegetated areas (exposed rock and developed areas), GW Solutions used NRCAN Land Cover polygons to derive land cover classes (Natural Resources Canada, 2022). Table 7 shows the coefficients based on the land use/cover for non vegetated areas.

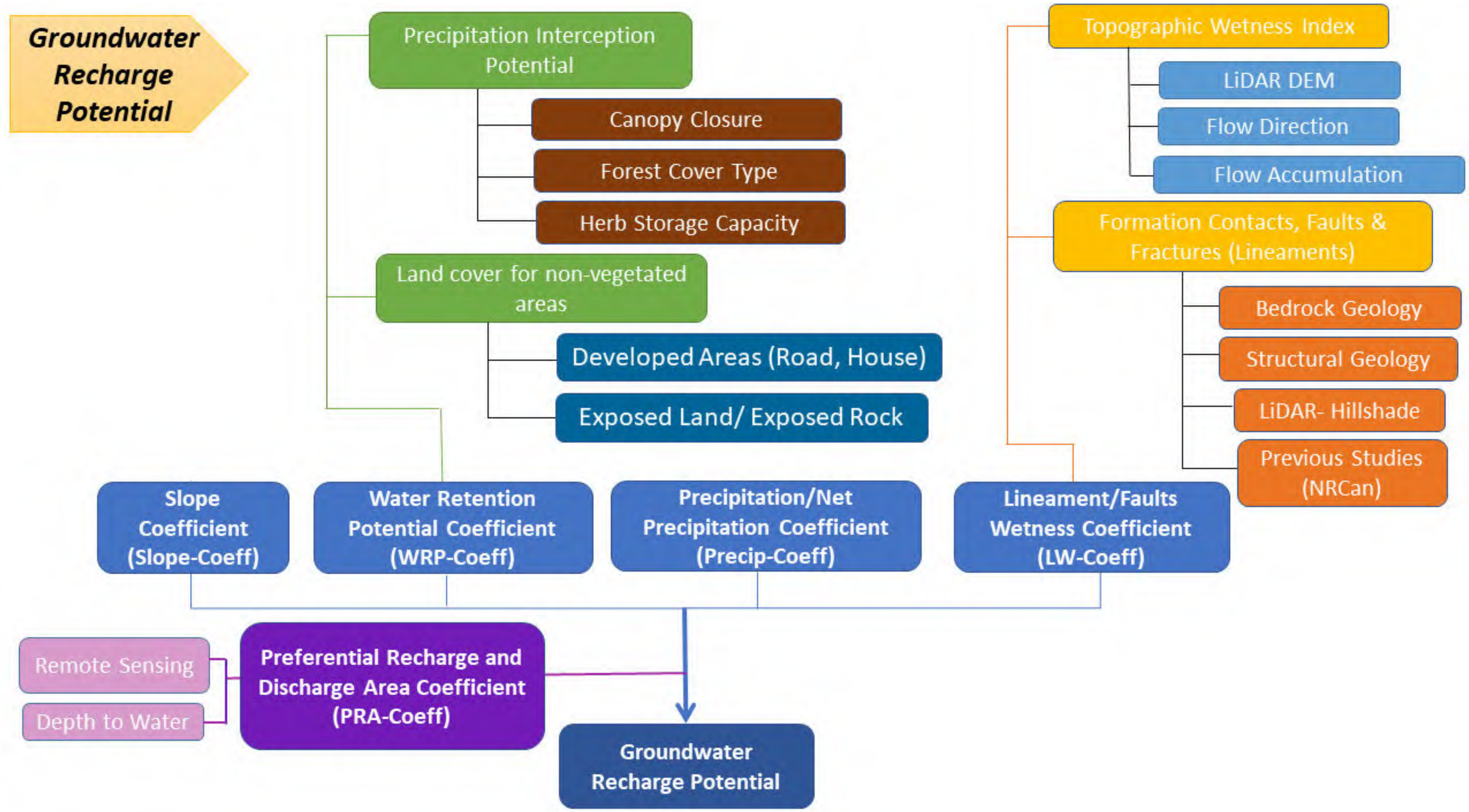


Figure 5: Flowchart illustrating the methodology used to estimate the groundwater recharge potential.

Precipitation Coefficient: Precipitation variability is the main driver in groundwater recharge. Gridded annual total precipitation data were obtained from the Pacific Climate Impact Consortium (PCIC) corresponding to climate normals for the 1981-2010 period. The precipitation coefficient categories for islands in the Trust Area are summarized in Table 8.

Bedrock Lineaments Coefficient: Mapped bedrock lineaments and Topographic Wetness Index (TWI) were combined to estimate discrete recharge potential for fractured bedrock aquifers. The Topographic Wetness Index (TWI) was calculated based on a gridded (raster) Digital Elevation Model (DEM). TWI is a function of the size and slope of the upstream contributing area associated with each grid cell. Large values of TWI are typically associated with lowlands having a larger contributing catchment area and indicate groundwater discharge areas where the water table intersects the land surface. At higher elevations in a watershed, high TWI values can indicate either a local water table that is perched above the primary aquifer, or it can indicate locations where surface water is directed into topographic depressions, contributing to focused recharge. The TWI was calculated using SAGA (System for Automated Geoscientific Analysis) tools and the 2 m resolution LiDAR DEM. Values with high TWI suggest a higher possibility for groundwater recharge along lineament features. The recharge potential values corresponding to the combined TWI and bedrock contacts/lineaments are listed in Table 9.

Preferential recharge/discharge areas (PRDA): Depth to Water and the Normalized Difference Vegetation Index (NDVI) and Normalized Difference Moisture Index (NDMI) methods were selected as inputs to estimate the spatial variability of recharge/discharge potential.

Depth to Water: Previous studies have illustrated how the depth of water table or the thickness of unsaturated zone has a significant role in controlling groundwater recharge of aquifers in the study area (Allen & Matsuo, 2002, SRK, 2013). For example, even when surficial conditions are suitable for groundwater infiltration, a shallow water table will limit the amount of water that can infiltrate into the subsurface. Average groundwater elevation surfaces were interpolated from groundwater levels reported in the GWELLS database, locations of known springs (where groundwater discharges at the ground surface) and other monitoring locations, such as the Provincial Groundwater Observation Well Network (PGOWN) (Ministry of Environment and Parks, 2025a; Province of BC, 2025a). Using Leapfrog a surface of groundwater elevation (groundwater elevation grid) was created and exported into QGIS as a raster file. The average depth to water in each raster pixel was calculated by subtracting the groundwater surface elevation from the land elevation (DEM) in QGIS. The preferential groundwater recharge or discharge area was classified according to the observed range in groundwater depths, which varied in each island setting. Example values for Gabriola Island are shown in Table 10. Refer also to (GW Solutions Inc., 2021b), Appendix 5.

Normalized Difference Vegetation Index (NDVI) and Normalized Difference Moisture Index (NDMI) methods use satellite multispectral image analysis to identify areas of potential groundwater discharge by using the relative colour and light signatures of different soil moisture and vegetation types (Doody et al., 2017). High perennial soil moisture can darken soils or encourage green vegetation to flourish in otherwise dry conditions (Barron et al., 2012). Such indications of landscape “wetness” and “greenness” detected using satellite imagery can indicate areas of probable groundwater discharge. The Normalized Difference Vegetation Index (NDVI) is used to highlight the presence of dense, green vegetation, or “greenness”, while the Normalized Difference Moisture Index (NDMI) is designed to highlight the level of moisture within vegetation or soil, defined as “wetness”. By comparing landscape “greenness” and “wetness” between wet and dry seasons, it is possible to observe which parts of the landscape preserve their wetness and greenness. Areas on the landscape that continue to be “green” and “wet” in the dry season indicate areas of groundwater discharge, inferred to be the primary source for continued moisture supply to the surface in the dry season (excluding irrigation). This methodology was adapted from (Barron et al., 2012) and applied to the study area initially reported in (2021b) (maps in Appendix 6).

5.2.4 Groundwater Recharge Potential Calculation

The recharge potential was determined using the following equation:

$$RP = R_{PRDA}\,[(R_{WRP}) + (R_{LW}) + (R_{Slope}) + (R_{Precipitation})]$$

where:

RP = Recharge potential (0-1)

R_{PRDA} = Preferential Recharge/Discharge Areas Factor (0.05-1)

R_{WRP} = Water Retention Potential Factor (0.1-0.3); Influence ranges up to 30%

R_{LW} = Bedrock Lineament Wetness Factor (0.1 – 0.25); Influence ranges up to 25%

R_{Slope} = Slope Factor (0.03-0.2); Influence ranges up to 20%

$R_{Precipitation}$ = Precipitation Factor (0.1-0.25); Influence ranges up to 25%

The final categories of Groundwater Recharge Potential are shown in Table 11. A recharge potential of 1 suggests high potential of recharge, such as where open fractures are found within areas with a high preferential recharge (PRDA). The lowest recharge potential values are in areas with paved surfaces.

Table 5: Slope infiltration coefficient and groundwater recharge potential based on the slope degrees.

Groundwater Recharge Potential	Slope degree	Infiltration coefficient
Lowest	> 24	0.03
Poor	12 - 24	0.06
Moderate	5.1 - 12	0.1
Good	2.7 – 5.1	0.15
Very good	0.3-2.7	0.18
High	< 0.3	0.2

Table 6: Recharge potential coefficients for Precipitation Interception Potential

Groundwater Recharge potential	Precipitation Interception Potential	Precipitation Interception Potential	Infiltration coefficient
Minimum	Very High	> 0.6	0.1
Low	High	0.5-0.6	0.2
Moderated	Moderate	0.4-0.5	0.25
good	Low	0.2-0.4	0.28
Very good	Very Low	0-0.2	0.3

Table 7: Recharge potential coefficients for non-vegetated areas.

Groundwater Recharge Potential	Land Use in None Vegetated Areas	Infiltration coefficient
Minimum	Developed area: pavement, building, road	0.1
good	Exposed bedrock and soil	0.28

Table 8: Recharge potential coefficients for precipitation.

Groundwater Recharge Potential	Precipitation range (mm)	Infiltration coefficient
Low	< 960	0.1
Poor	960 - 1010	0.15
Moderate	1010 - 1060	0.18
Good	1060- 1110	0.22
Very good	> 1110	0.25

Table 9: Bedrock Lineament Coefficient and groundwater recharge potential based on Topographic Wetness Index range.

Groundwater Recharge Potential	TWI Range	Bedrock Lineament Infiltration Coefficient
Low	< 3	0.1
Moderate	3 - 6	0.15
High	6 - 9	0.2
Very High	> 9	0.25

Table 10: Preferential GW Recharge/Discharge Areas Based on Depth to Water (Gabriola Island example).

Depth to Water (mbgs)	Preferential Groundwater Recharge/Discharge Area Category
< 4	Very high potential of groundwater discharge
4 - 15	High potential of groundwater discharge
15 - 30	Transitional zone – seasonally variable recharge or discharge zone
30 - 60	High potential of groundwater recharge
> 60	High potential of groundwater recharge

Table 11: Groundwater recharge potential coefficient based on the probability of groundwater discharge spatially.

Groundwater Recharge Potential	Probability of Groundwater Discharge Area	Groundwater Recharge coefficient
Minimum	Very High probability	0.05
Low	High probability	0.1
Moderate	Medium probability	0.3
Good	Low-Medium probability	0.7
Very good	Low probability	0.9
High	Very Low probability	1

5.2.5 Groundwater Recharge

Groundwater recharge was calculated from water surplus (water available after evaporative losses) and groundwater recharge potential across the study area, based on physiographic and geologic factors. Surface runoff is estimated as water surplus minus the groundwater recharge.

5.2.6 Water Demand

Development of the water balance model requires an estimation of water demand compared to water availability. Accurate estimation of water use is particularly challenging in rural areas where water is supplied from independent, typically un-metered, water sources such as domestic wells, and on islands with significant seasonal differences in population. Water demand for the study area was estimated based on land use, zoning and occupancy at the parcel level, combined with information on registered wells, surface and groundwater licenses, local directories, and personal information provided by well and property owners.

A flow chart showing the general approach for estimating water source and demand for each parcel is outlined in Figure 6. The assumptions, methods and resulting estimates of water use on the Island are discussed in the sections below, while the results are included in section 6. The method enabled assessment of water sources and usage per parcel, estimated using multiple datasets, to reduce potential errors associated with reliance on the GWELLS database which has known errors (i.e., mislocated, unused, or unregistered wells). The data sources and approaches used to estimate water demand are outlined below.

Population and Seasonal Occupancy: Census data were used to determine island population statistics including regional population, and average persons per household (Statistics Canada, 2023b). Additional referenced data sources were used to estimate the peak population in summer which increases due to tourism and seasonal residency.

Water Service Areas and Water Systems: Water systems were identified from data layers provided by Island Health (Island Health, 2020), published Drinking Water Reports and Summaries (Island Health, 2025b), island directories and local contacts. All of the inventoried water systems utilize a groundwater source, while two water systems use both a groundwater and surface water source (spring, and stream). Locations of non-domestic water use not associated with water systems were also inventoried e.g., nurseries, community gardens, and commercial operations that do not provide potable water directly to the public. The serviced population for water systems and facilities such as multi-unit housing facilities was determined from Island Health inspection reports and published information sources. Additional validation was provided from personal communications with Island Health staff.

Land Use: The primary sources of data included information on land use, and occupancy from BC Assessment Primary Actual Land Use categorization for the 2025 Assessment Roll Year (BC Assessment, 2025). Tabulated parcel data was obtained from Islands Trust, which provided the code and description of BC Assessment Actual Land Use, Islands Trust Land Use Designation and Land Use Bylaw applicability, for individual land parcels (cadastral lots). These data were spatialized and joined with Parcel Map BC lot mapping using the Parcel Identifier Number (BC Data Catalogue, 2025). Additional land use layers, including BC Parks, Ecological Reserves and Protected Areas, and Agricultural Land Reserve Parcels were obtained from the BC Data Catalogue (BC Data Catalogue, 2025). The land use categories were used to estimate water demand per developed lot for the designated land use. Vacant parcels have no associated water demand but could be developed in future.

Water Sources: The water sources for the land parcels were assigned into different categories based on review of active water licenses and water license applications, water license works, registered wells, and water system inspections reports (Island Health, 2025b; Province of BC, 2025a; Water Management, 2025b, 2025a). Parcel water sources were also validated by satellite imagery to identify property development status, information provided by local contacts and landowners via email, or field observations collected in June 2025.

Measured Water Use: Most water users do not monitor, record or report their water usage, although some water systems use water meters. Measured water use was reported by Island Health in some cases. Additional data were obtained through personal communications with operators. However in general it was a challenge to obtain metered data, and this is recognized as a data gap that could be addressed in future studies.

Estimated water use:

- **Residential (Acreage, Single Family and Multi-Family):** Monthly residential water use per parcel was estimated based on local information, and representative values from other communities. Long-term metered water use data were evaluated from representative groundwater sourced water systems in Regional District of Nanaimo and compared to national census values for BC. Residential peaking factors were developed based on monthly water use estimates. Multiple categories of parcel residential use were developed depending on parcel area and residential use category. R1 represents parcels less than 2 acres in area, R2 represents parcels equal to or greater than 2 acres. Higher water use (R2) was assigned to parcels of 2 acres or more; this is to account for larger potential irrigation area and outdoor water use for gardens, and likelihood of larger homes or multiple habitations to be constructed on larger parcels. Seasonal dwellings were assigned monthly seasonal peaking factors which accounted for reduced water use during the off-season (winter). Multi-family units or parcels (RU) were assigned water use according to the low water use residential category (R1) multiplied by the number of housing units e.g., duplex (2), or multi-unit strata lots. The category “Residential, outbuilding only” was also assumed to be occupied by a residence or building that utilized water (R1). Unless specified within the land use category (e.g. residential dwelling with suite), only one residence was assumed per parcel, although it is known that some parcels have multiple dwellings.

- **Agriculture and Mixed Use:** A desktop review of satellite imagery of representative agricultural parcels was completed estimate irrigation demand using the Agricultural Water Use Calculator (Ministry of Agriculture and Food, 2025). Based on the reviewed parcels, approximately 10% of each agricultural parcel was assumed to be irrigated. Example values of water use per month were used to develop irrigation volume per inferred crop type (e.g. vegetable and fruit vs forage) per parcel irrigated area, and to develop monthly peaking factors for the irrigation season, which were applied from May to September. All non-vacant mixed-use parcels in the agricultural category were also assigned a residential (R1) water demand to account for water use in onsite residences. Additional values for livestock parcels e.g., “Poultry” and “Beef” were based on parcel size and reference values (Miles, 2009; Ministry of Agriculture and Food, 2025).

- **Civic, Recreational and Commercial Use:** Water demand was based on the type of land use (actual use category, e.g. health clinic, school, church, firehall, store, hotel), information on specific sites obtained from internet sources (business websites, Island Health inspection reports) and communication with property owners (Island Health, 2025b). Daily water use per activity, facility size, or parcel area were determined using published empirical values including water loading estimates for sewerage systems (Miles, 2009; Ministry of Forests, Lands, Natural Resource Operations and Rural Development, 2012; Ministry of Health, Health Protection Branch, 2014; Statistics Canada, 2023a; United States Department of Agriculture Forest Service, 2007).

- **Industrial Use:** The Gulf Islands does not have significant proportion of industrial development and water use. Where this type of land use was indicated, site specific estimates of water use were developed for industrial land use categories.

- **Utilities:** Electrical facilities were assigned no water use. Groundwater use for ferry operations was reported by the operator, based on their groundwater license application volume.

- **Managed Forests, Parks and Protected areas:** No water demand was assigned to managed forest parcels, parks or protected areas, with the exception of the regional park campsite, for which water demand was estimated based on recreational water use estimates, campsite capacity and operational season (Regional District of Nanaimo, 2025c; United States Department of Agriculture Forest Service, 2007).

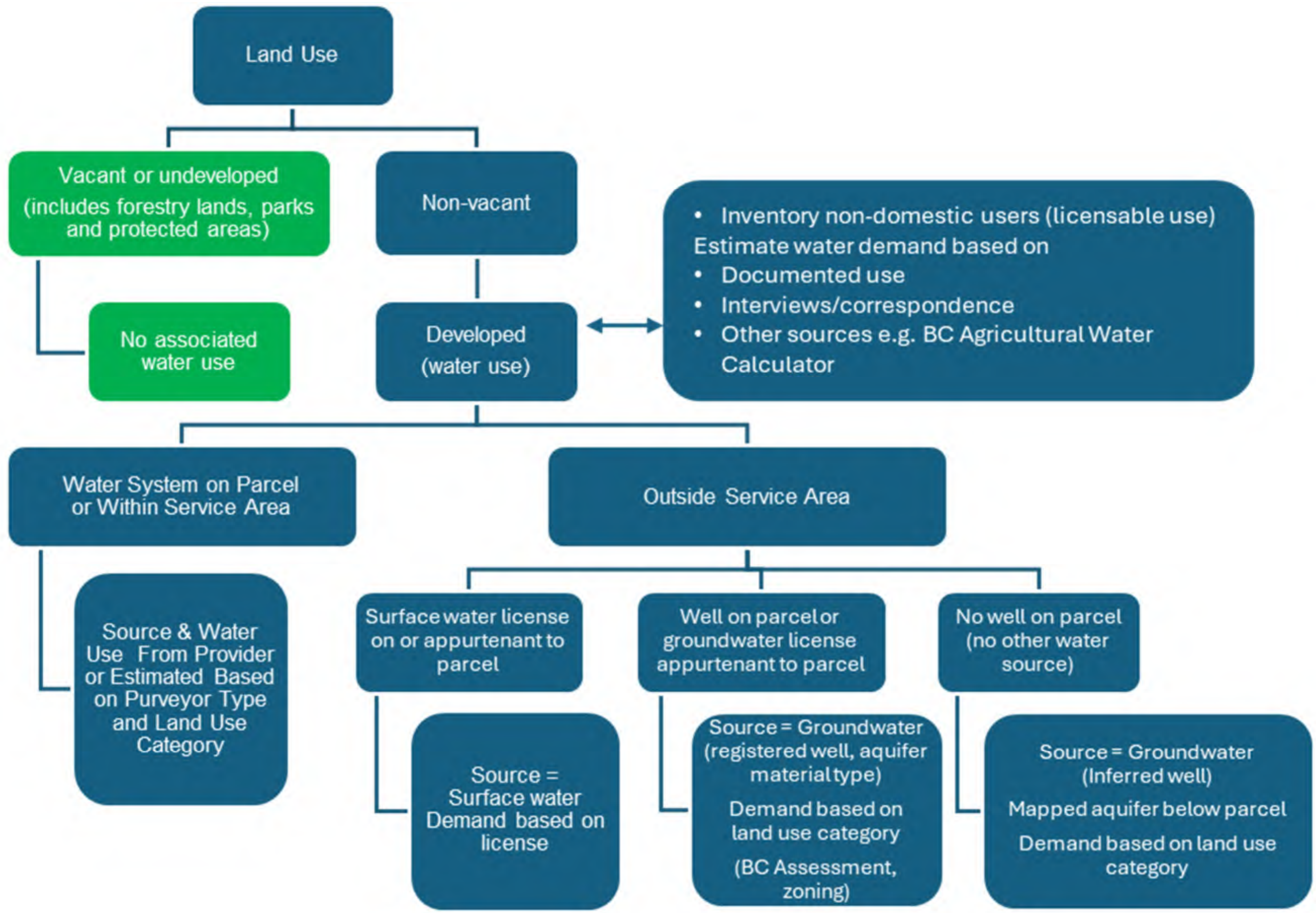


Figure 6: Determination of water source and demand for each parcel.

5.2.7 Groundwater Availability and Aquifer Stress

Groundwater availability was calculated by calculating the proportion of groundwater recharge utilized by groundwater demand. All calculations were determined on a monthly and annual time-step, for the island as a whole and for each groundwater management area. Aquifer stress was categorized according to the percentage of recharge utilized, according to criteria shown in Table 12. The criteria thresholds were determined based on literature examples (Alcamo et al., 1997; Sivak et al., 2024), and statistical examination of the findings. The results and further discussion of the approach are included in section **Error! Reference source not found.**.

Table 12: Aquifer Stress Index (Groundwater Use vs. Recharge).

Aquifer Stress Level	Ratio Groundwater Use/Recharge
Low	< 5 %
Moderate	5 – 10 %
High	10 – 20 %
Extreme	20-40 %
Very Extreme	> 40 %

5.3 Freshwater Hazard Assessment

5.3.1 Monitoring observations and trends

Seasonal and long-term trends in monitoring data provide an important indicator of water sustainability and impacts of climatic variation and water use. The RDN Drinking Water and Watershed Protection Program completes a semi-annual analysis of groundwater level trends monitoring locations across the region, focused on stations with 10 or more years of data (Regional District of Nanaimo, Drinking Water and Watershed Protection, 2024). Long-term trends are divided into categories listed in Table 13, depending on the direction (increasing or decreasing) and magnitude of change, consistent with provincial groundwater level trend assessment and reporting criteria (Environmental Reporting BC, 2024). The hydrographs of active monitoring stations in the study area were evaluated to assess long-term trends and indications of aquifer stress. The distribution of monitoring locations in comparison to areas of high water demand (well or population density) was also assessed, to identify data gaps and provide recommendations for expansion of local monitoring programs.

Table 13: Groundwater level trend categories.

Trend Category	Description
Increasing	Greater than 3 cm per year increase
Stable or non-significant	No trend, increasing or decreasing less than 3 cm per year
Moderate Decline	Decrease from 3 to 10 cm per year
Large Decline	Decrease of more than 10 cm per year
Insufficient Data	Not enough data to calculate trend (short length of record, or data loss)

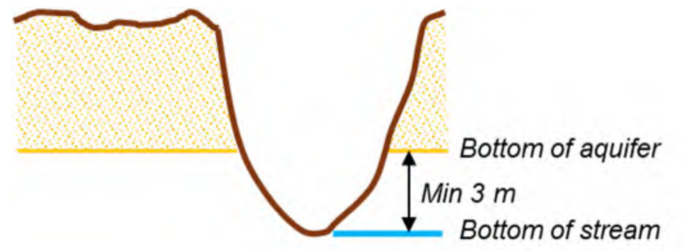
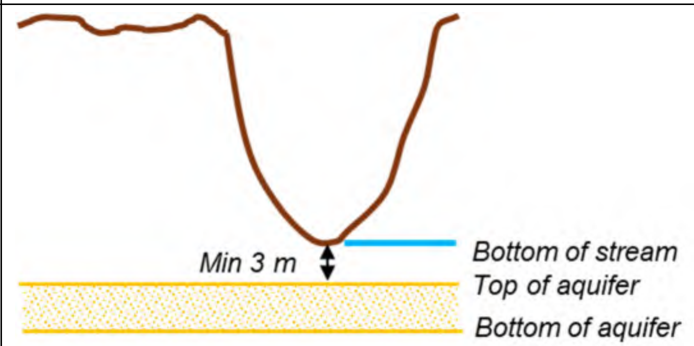
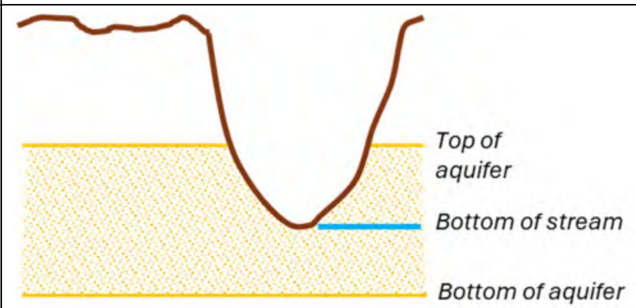
5.3.2 Hydraulic connectivity

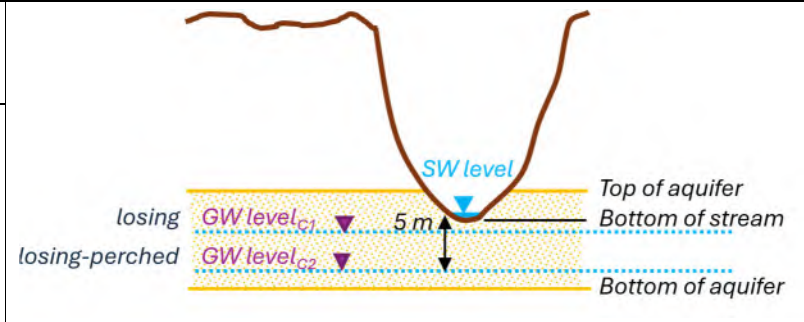
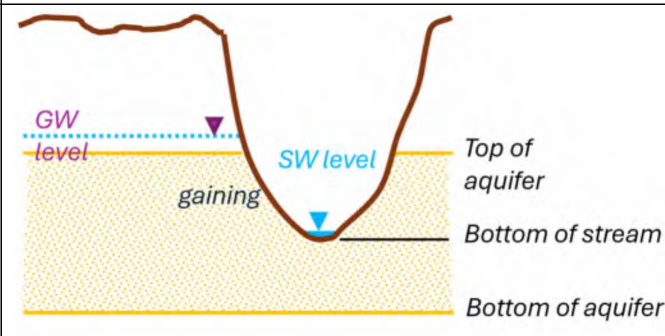
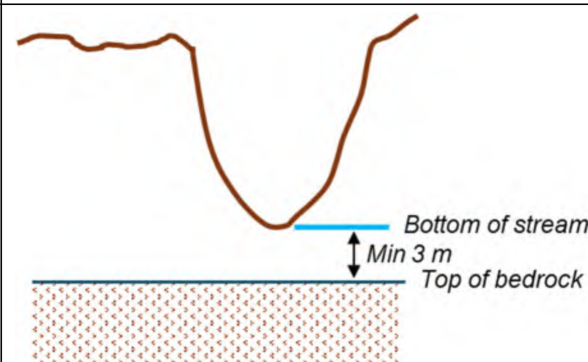
Hydraulic connectivity between surface water and groundwater is controlled by topography and factors influencing surface and groundwater gradients and flow direction, as well as the characteristics of geologic materials underlying and exposed along the stream bed (Barlow and Leake, 2012). The likelihood of hydraulic connectivity between surface and groundwater systems can vary depending on aquifer material, i.e., unconsolidated, sand and gravel, or fractured bedrock aquifers, location in the watershed, the relative depth or elevation of stream and groundwater table, and whether deposits of low permeability, confining materials overlay and aquifer and separate it from the overlying stream (Healy et al., 2007; Wei et al., 2016).

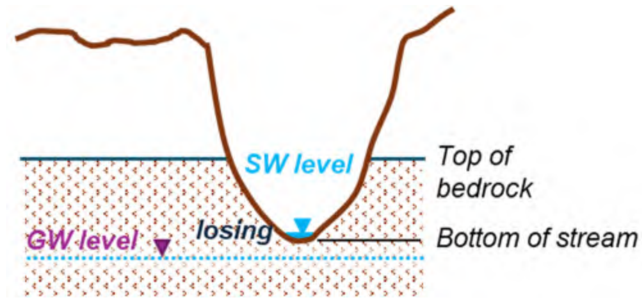
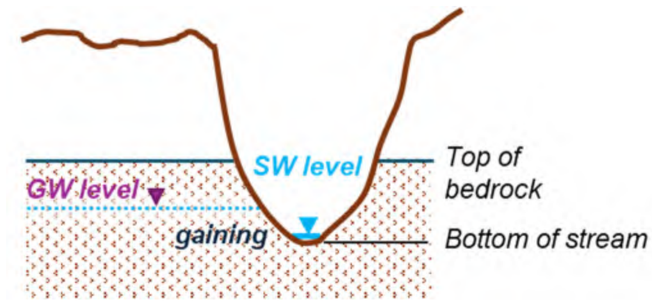
Where surface water and groundwater are connected, the direction of water movement can be from the aquifer towards the stream (the stream is gaining) or from the stream towards the aquifer (the stream is losing). Where a larger vertical separation exists between the elevation of water level in the stream and groundwater level in the underlying aquifer, the stream may be referred to as perched or disconnected; surface water from a perched stream my contribute to groundwater recharge indirectly through downward seepage. Within a single watershed, a stream may have different sections or reaches that exhibit perched, disconnected, losing or gaining conditions. Additionally, the flow direction and connectivity type can vary seasonally, or in response to groundwater pumping, rainfall or flood events and other influential factors.

Potential hydraulic connectivity was determined using a mapping methodology previously applied in watersheds on Vancouver Island (Sivak and Wei, 2019a, 2019b; Barroso et al., 2025). Using topography and elevation within a study area, the elevation of surface water streams is compared to elevation of the groundwater table, interpolated from groundwater level measurements and applied to a rasterized grid across an area of interest e.g. a watershed or island. The relationship between surface and groundwater systems is divided into categories based on the difference between elevations of the system, as summarized in Table 14. The methods applied on Gabriola are further described in GW Solutions (2021a). This type of preliminary analysis allows evaluation of areas of likely hydraulic connection, that could be evaluated further through field investigations and monitoring. If hydraulic connection is likely, it is also important to consider streamflow and potential impacts to surface water flows within the groundwater balance assessment.

Table 14: Likelihood of hydraulic connection assessment criteria.

Condition	Aquifer type	Criteria	Illustration
Not likely hydraulically connected	Unconsolidated	Elevation of the bottom of the aquifer is greater than 3 m above the stream elevation	
Not likely hydraulically connected	Unconsolidated	Elevation of the top of the aquifer is greater than 3 m below the stream elevation	
Likely hydraulically connected	Unconsolidated	Stream elevation (SW Level) is within 3 m of the top of the aquifer and	

Condition	Aquifer type	Criteria	Illustration
Hydraulically connected - stream is losing	Unconsolidated	Stream elevation is higher than groundwater elevation	
Hydraulically connected – stream is losing-perched	Unconsolidated	Stream elevation within 3 m of the top of the aquifer, but stream elevation is more than 5 m higher than groundwater level	
Hydraulically connected - stream is gaining	Unconsolidated	Stream elevation is lower than groundwater elevation	
Perched (disconnected)	Bedrock	Stream elevation is more than 3 m above elevation of the bedrock	
Likely hydraulically connected	Bedrock	Bedrock intersects the stream (< 3m difference in elevation) and	

Condition	Aquifer type	Criteria	Illustration
Hydraulically connected - stream is losing	Bedrock	Stream elevation is higher than groundwater elevation	
Hydraulically connected - stream is gaining	Bedrock	Stream elevation is less than groundwater elevation	

5.3.3 Seawater Intrusion Hazard

Seawater intrusion (SWI) refers to the change in groundwater quality that occurs from the mixing and movement of seawater into a freshwater aquifer. Seawater has roughly 35,000 mg/L total dissolved solids, including 19,000 mg/L chloride (US Geological Survey, 2000). Therefore, mixing in a very small quantity of seawater can significantly alter water quality in a freshwater aquifer. Mixing with 2% seawater can cause freshwater to taste noticeably salty (chloride 250 mg/L), while freshwater mixed with 4% seawater is unusable for many purposes (Klassen et al., 2014).

Sources of elevated chloride and total dissolved solids in groundwater can include:

- Minerals dissolving into groundwater in contact with rocks, including sedimentary rock formed in a marine setting. Older, deeper groundwater often has higher dissolved minerals as it has had a longer travel and residence time in the rock (Freeze and Cherry, 1979) ;
- Mixing of groundwater with sea water containing a higher chloride concentration (Klassen et al., 2014; US Geological Survey, 2000);

- Relict sea water trapped in deep pores or fractures during periods of higher sea level (Allen and Suchy, 2001). For example, in the Nanaimo Lowlands of eastern Vancouver Island, including the Gabriola Island region sea level was approximately 140m higher than present following the end of the last glacial period (Clague, 1981).
- Contaminants such as septic field discharge, effluent from wastewater treatment plants, agricultural runoff, wastewater from industries, and road salting (Health Canada, 1987).

Operating a well in a manner that causes the intrusion of saline water or sea water into an aquifer, causing significant adverse impact on the quality or existing use of groundwater from the aquifer is prohibited under the *Water Sustainability Act* (Section 58)(Province of BC, 2014). This statute may be interpreted to apply both to seawater that is actively drawn into an aquifer from marine sources (seawater intrusion), in addition to saline mature groundwater that may be intercepted and pumped from deeper wells (saltwater intrusion) collectively referred to as SWI.

Aquifer vulnerability to SWI depends on multiple factors including topography, climate and hydrologic conditions and human activities (Werner et al., 2013). Human activities that may increase the hazard of seawater intrusion include drilling of deeper wells into the freshwater-saline water transition zone and interface, drilling of wells in bedrock aquifers that intersect fractures containing saline water, and over-pumping of one or multiple wells in vulnerable areas. Aquifers or areas that have a greater risk of seawater intrusion include:

- Aquifers located in low-lying areas close to the coast, on narrow islands or peninsulas with a limited up-gradient recharge area.
- Aquifers with groundwater level close to sea level.
- Coastal areas with a high density of wells or high rates of groundwater pumping.
- Wells where the static or pumping water level is close to or below sea level.
- Coastal areas where wells are drilled deeper intersecting the freshwater saltwater interface or saline fractures, allowing circulation and movement of water between saline and freshwater zones.

Climate change is expected to exacerbate existing sea water intrusion risk for islands in coastal BC (Klassen and Allen, 2016). For example, some areas will be inundated by rising sea levels. While storm surges are likely to overtop and flood lower elevation coastal zones. Changes in precipitation, higher temperatures, higher rates of evapotranspiration, and reduced groundwater recharge may alter the groundwater flux to discharge areas along the coast, enabling sea water to encroach further inland. If water demand and pumping increase in vulnerable areas, this can add further aquifer stress, therefore management of water demand is critical to protect coastal aquifers (Ferguson and Gleeson, 2012). Figure 7 illustrates some seawater intrusion processes and hazards for coastal areas and islands.

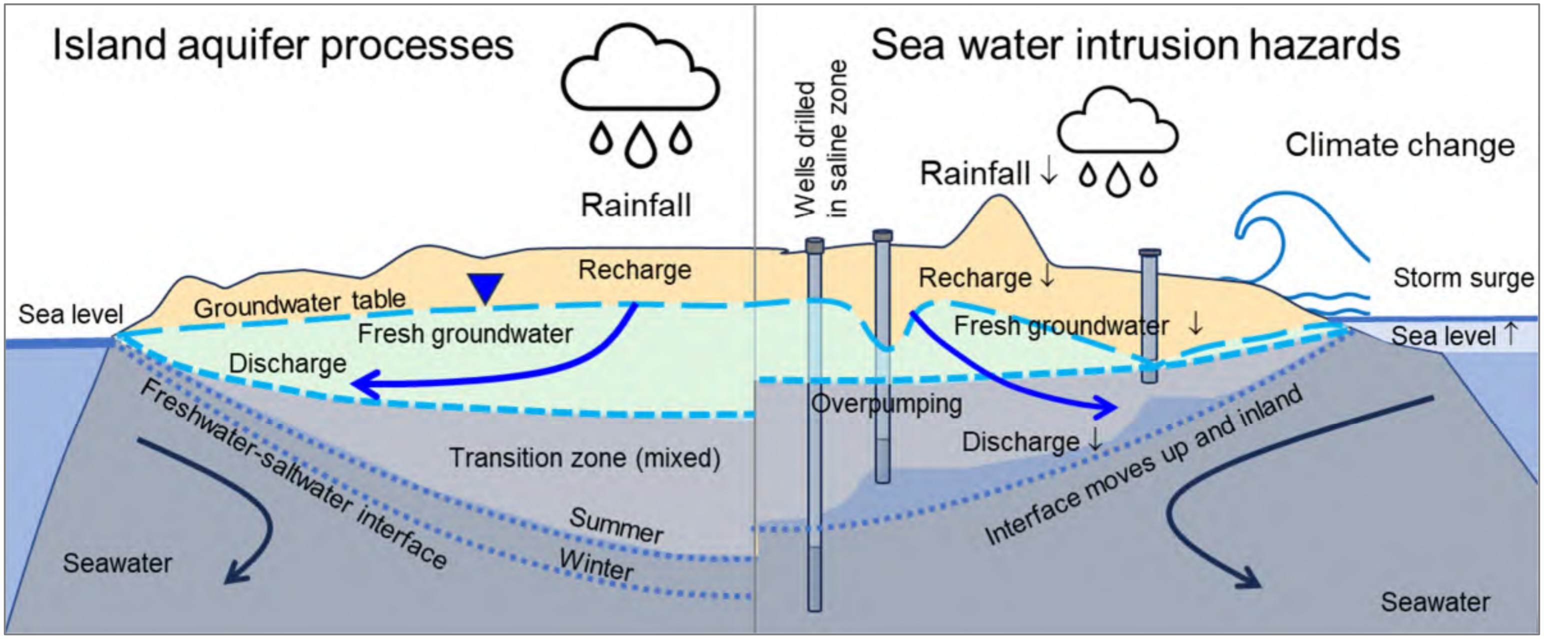


Figure 7: Seawater intrusion processes and hazards. After (Bear et al., 1999; Klassen and Allen, 2016; US Geological Survey, 2000).

The concentration of chloride, electrical conductivity and total dissolved solids (TDS) in a water sample can be used identify groundwater that is affected by SWI (Klassen et al., 2014). Groundwater from islands in BC's south coast is generally fresh. In the southern Gulf Islands, from a dataset of more than 900 groundwater samples, over 90% had a chloride (Cl) concentration below 150 mg/L, electrical conductivity (EC) below 1000 µS/cm and TDS below 700 mg/L (Klassen et al., 2014). These values have been recommended as SWI operational thresholds. If the concentration of chloride, TDS and EC go above the operational thresholds the reasons for the exceedance should be assessed and well operation, pump depth/pumping rate or other factors may need to be modified to prevent adverse impacts to water supplies from the subject well, the aquifer and other groundwater users. In a San Juan Islands study, wells with chloride concentration over 100 mg/L were considered impacted by SWI (US Geological Survey, 2000). Water quality guidelines and recommended operational thresholds are shown in Table 15.

SWI can cause permanent or long-term impacts on aquifers and drinking water supplies, with adverse impacts on well operation and water use. For example, groundwater that is high in chloride and TDS is corrosive, potentially leading to deterioration and need to replace water fixtures or well components more frequently. Drinking water with elevated chloride and sodium should be avoided for people with health conditions such as hypertension (Health Canada, 1992, 1987). While chlorine disinfection of water mixed with a marine or mixed source containing elevated bromide can lead to formation of disinfection byproducts that are harmful to drink (Health Canada, 2006a).

Protection of existing freshwater supplies and prevention of seawater intrusion impacts is a fundamental objective and measure of freshwater sustainability within the Trust Area islands. While sometimes proposed as a water supply option in areas of limited freshwater availability, desalination of seawater or brackish groundwater is not an optimal solution for drinking water and household use. The treatment technology is costly, utilizes a significant amount of energy and the process creates a concentrated saline brine that can cause environmental harm if not disposed of safely (Orfi et al., 2025). In areas with limited groundwater and surface water supplies, rainwater collection and storage is likely to be a more affordable and sustainable option compared to using desalination.

The concentration chloride, total dissolve solids and electrical conductivity of the water can be used to indicate water that is being impacted by SWI (Table 15). A lower operational threshold below federal and provincial drinking water quality guidelines is proposed as a precautionary limit to indicate where impacts may be occurring that should be further investigated to determine the potential cause. Best management practices to prevent and reduce SWI are included in Appendix A.

Aquifer vulnerability to seawater intrusion due to natural characteristics, coastal hazards and the impacts of groundwater pumping has been mapped for the Southern Gulf Islands (Klassen and Allen, 2016). A later project expanded the seawater intrusion hazard mapping to the entire coastal BC (Sivak and Wei, 2021). In these studies, the total hazard is significantly impacted by the location and theoretical pumping rate of wells; this can result in an inland location receiving a higher hazard rating than a more coastal one (i.e. the maps show heterogeneity or spatial inconsistency relative to distance from the coast). For the coastal BC mapping, because very high-risk areas (e.g., Fraser Delta) were considered, the weighting of parameters may also result in an underestimated risk in other areas such as the Gulf Islands.

To assess SWI hazard for the current project, various measures were utilised. The depth to the seawater interface was mapped and compared to compiled water quality and monitoring data specific to the study island. The hazard of seawater intrusion was categorized according to the thickness of the freshwater lens and criteria outlined in Table 16. Hazard maps were prepared indicating the relative risk level in coastal areas. The resulting maps highlight areas in which seawater intrusion is likely to be a greater concern and therefore where precautions in terms of well drilling and operation can be applied. The hazard mapping also highlights areas that may be vulnerable to adverse impacts related to increased water demand, which can influence regional growth policies.

Table 15: Guidelines and operational thresholds for salinity indicators Total Dissolved Solids (TDS), Electrical Conductivity (EC) and chloride.

	TDS mg/L	EC µS/cm	Chloride mg/L	Notes
Guideline for Drinking Water Quality (Health Canada)	500	ng	250	Aesthetic objective. Concentration of chloride and Total Dissolved Solids (TDS) which causes a noticeable salty taste to the water. Drinking water with elevated chloride and sodium can be harmful to vulnerable persons with health conditions such as hypertension. Water with chloride and TDS above these values can also cause corrosion and scaling in pipes, water heaters and household appliances.
Ambient Water Quality Guideline for Irrigation (BC)	ng	ng	100	BC guideline based on potential impacts to more sensitive plant species. Some plant species may be adapted to irrigation with water with higher concentrations of chloride. Irrigating with water containing higher concentrations of dissolved minerals or ions (e.g. sodium, chloride, boron and nitrate) can reduce soil fertility and affect plant health.
Operational Threshold to Prevent Saltwater Intrusion	700	1000	150	Threshold indicates concentration significantly above the concentration in fresh groundwater sampled in coastal BC (concentration higher than 90th percentile of over 900 samples from aquifers the Vancouver Island and Gulf Islands Region). Because the thresholds are lower than the drinking water guideline, they are precautionary, indicating that well operation (or other factors) may be leading to deterioration of water quality in a well or aquifer.

TDS=Total Dissolved Solids EC=Electrical Conductivity or Specific Electrical Conductivity (adjusted to standard temperature) measured in field or lab ng=No guideline.
References: (Health Canada, 2024a; Klassen et al., 2014; Province of BC, 2024).

Table 16: Seawater intrusion hazard criteria.

Hazard Rating	Category	Depth to groundwater interface (meters below sea level)
1	Low	< 40 m
2	Moderate	40 - 160 m
3	High	> 160 m

5.3.3.1 *Depth of transition zone and saline interface*

Within an island aquifer setting, the relative depth of the interface between fresh and saline water is proportional to the groundwater level above sea level (Bear et al., 1999). The equilibrium between freshwater and saltwater can vary spatially, and seasonally in response to fluctuations in groundwater recharge, discharge, tidal fluctuations, and groundwater pumping. The depth of the saltwater-freshwater interface is an important indicator of freshwater availability and vulnerability of coastal aquifers to seawater intrusion.

The thickness of the freshwater lens, and depth of the transition zone between fresh and saline water below the study island, was estimated using a solution that considers the interaction of two fluids with different density (Verruijt, 1980). A network of sampling points (75 m spacing) was created in the 3D model. The thickness (d_i) of each lithological layer at the sample point on the grid was calculated. The hydraulic conductivity was then estimated for each geologic layer, based on the values from literature and historic reports for the study area (Allen et al., 2002; Burgess and Allen, 2016; Livingston, 1970; SRK Consulting Inc., 2013; Wei et al., 2009) . The equivalent hydraulic conductivity (K) was calculated at each point according to the equation:

$$K = \frac{\sum k_i \times d_i}{\sum d_i}$$

Where k_i is the hydraulic conductivity, and d_i is the thickness or depth of each geologic layer (i). A grid was developed for the Island interpolating the K values from the sample points to represent horizontal hydraulic conductivity for each grid cell. Similar grid layers were developed for groundwater elevation (H_f) and distance from the coastline (x).
Groundwater flow in each layer (q) and the elevation of the sea water interface (H_s) were calculated using the raster calculator tool in QGIS, using the formulas from Verruijt (1980):

$$q = \frac{{H_f}^2 K(1+\beta)}{2\beta x}$$

$$H_s = -\sqrt{\frac{q^2}{\beta^2 K^2} \times \frac{1-\beta}{1+\beta} + \frac{2qx\beta K}{\beta K(1+\beta)}}$$

The density of freshwater was determined from the water quality data summary in the AqQA program (RockWare). The density of sea water in the Georgia Strait, obtained from Ocean Networks Canada (Ocean Networks Canada, 2024). The density ratio, β is approximately 0.02, calculated based on the density difference between fresh (ρ_f) and saline water (ρ_s):

$$\beta = \frac{\rho_s - \rho_f}{\rho_f} \approx 0.02$$

To calibrate the model, the generated grid layer for the elevation of the saline-fresh water interface was compared water quality data (electrical conductivity), and groundwater level monitoring stations on the study island. QGIS was then used to interpolated contours of the saline interface depth from the raster layer. The depth is reported in meters above sea level, with a negative value indicating it is below sea level. The depth of the interface will move in response to tidal fluctuations, seasonal variations in groundwater recharge, discharge, and mixing within the transition zone containing a mixture freshwater and seawater above the saline interface (Bear et al., 1999). The model results are sensitive to minor changes in groundwater level, and subject to greater uncertainty in areas with minimal data.

5.3.4 Water quality indicators of SWI

All available water quality data were summarized, and current water quality was assessed in comparison to drinking water quality guidelines. Background concentrations, regional trends and relationships between SWI water quality indicators chloride and TDS were examined in comparison to factors such as well depth, and distance from the coast. A background concentration is defined as the concentration of a substance naturally present in an environment that has had minimal alteration from human activities. If a substance is above the background concentration this can provide information on processes or contamination sources that are influencing changes in the environment (Panno et al., 2006).

Background concentrations of chloride and TDS were calculated and used to determine the characteristics of average groundwater, or groundwater potentially impacted by land use, SWI or other factors. Although closely related, the concentrations of chloride and TDS were observed to relate to different processes and activities potentially affecting groundwater salinity, therefore it was considered useful to consider each as separate indicators. Based on this assessment, a relative hazard rating associated with different chloride and TDS concentrations was determined, shown in Table 17 and Table 18 below, and used within the final freshwater footprint calculation. More information on the approach to background data analysis and rationale for the hazard rating is included in section 6.5.6.

5.3.5 Population, Land Use, and Contamination Source Indicators

Population and land use density can impact both water quantity and water quality. From a quantity perspective, areas of higher lot density support a larger population, which increases water demand per area. Higher populations and smaller lot sizes can also influence water quality. In rural and mixed semi-rural areas such as the Gulf Islands, most properties treat and dispose liquid waste using onsite septic systems. The discharge of septic effluent to ground can result in an increase in the concentration of substances such as nitrate in the groundwater. Sewage waste can also contain pharmaceuticals, household chemicals and pathogens such as bacteria and viruses that can enter the groundwater system through recharge, however testing for viruses or household contaminants is rarely done.

To provide an indicator of potential impacts nitrate concentrations in groundwater samples were evaluated for spatial and temporal patterns and trends, and the background concentration was calculated. Land use density (size of lots, and number of adjacent lots within a distance of 150 m) were used as a proxy for potential non-point source pollution impacts. The lot size criteria and hazard rating are shown in Table 19 and the population density criteria and hazard rating are shown in Table 20.

Table 17: Chloride concentration criteria

Hazard Rating	Concentration	Hazard Category
1	<30 mg/L	Freshwater potable (low background)
2	30-75 mg/L	Freshwater potable (average)
3	75-150 mg/L	Freshwater (above average)
4	150-250 mg/L	Saltwater intrusion impacted
5	>250 mg/L	Not potable

Table 18: Total Dissolved Solids (TDS) concentration criteria

Hazard Rating	Concentration	Hazard Category
1	<200 mg/L	Freshwater potable (low background)
2	200-300 mg/L	Freshwater potable (average)
3	300-400 mg/L	Freshwater (above average)
4	400-500 mg/L	Higher salinity (impacted or mixed source)
5	>500 mg/L	Not potable

Table 19: Lot size criteria.

Hazard Rating	Lot area (acres)	Hazard Category
1	> 2 acres	Low
2	2-1 acres	Moderate
3	1-0.5 acres	High
4	0.5-0.25 acres	Very High
5	<0.25 acres	Extreme

Table 20: Population density criteria.

Hazard Rating	Population per km^2	Hazard Category
1	< 10 people	Very low
2	10-50 people	Low
3	50-100 people	Moderate
4	100-400 people	High
5	>400 people	Very high

5.4 Freshwater Footprint Calculation

The Freshwater Footprint assessment combined the results of the water quantity, water quality, and hazard criteria shown in Figure 8 into a relative measure of total hazard. While most of the included criteria had a 1 to 5 rating, SWI hazard criteria (depth to saline interface) had only a three point rating (1 to 3) therefore an additional weighting factor (x3) was applied within the final footprint calculation so it would have a consistent scale when combine with the other factors. The freshwater footprint hazard was calculated spatially across the island to highlight areas that are unimpacted (very low to low footprint) or are impacted to an increasing degree by the assessed hazards (moderate to very high freshwater footprint). The results for the Gabriola Island case study, further interpretation and implications of the footprint calculation in terms of land use and development policy are discussed further in section 6.6.

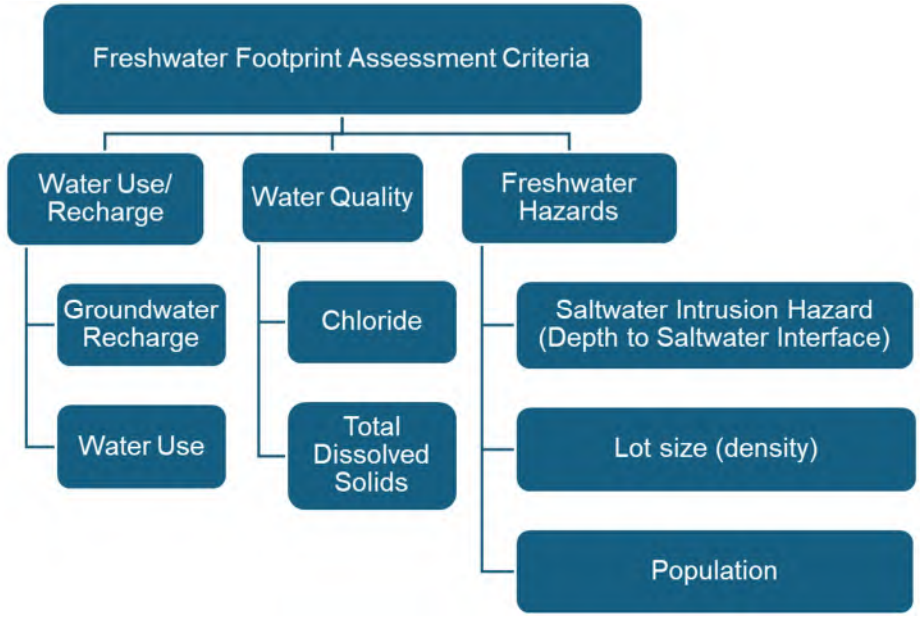


Figure 8: Freshwater Footprint assessment criteria.

Table 21: Assessment matrix for freshwater footprint calculation

A		B		C	
Use/recharge +3* SWI Hazard		Land + Population + Chloride + TDS		Freshwater Footprint Sum A+B	
Hazard Level	Value	Hazard Level	Value	Final Value	Description
1	<5	1	<6	2	Very Low
2	5-8	2	6-10	3	Low
3	8-11	3	10-15	4	Moderate
4	>11	4	>15	4-6	High
				>6	Very High

6 GABRIOLA FRESHWATER FOOTPRINT CASE STUDY

6.1 Hydrogeology of Gabriola Island

There are two provincial mapped aquifers on the island (listed in Table 22), both composed of fractured bedrock sedimentary bedrock of the Nanaimo Group, mainly sandstone, with smaller amounts of shale and conglomerate. Aquifer 706 (AQ706) is 5.9 km^2 in area and mapped in the northwest end of the island from Descanso Bay to Lock Bay (Province of BC, 2004a). Central and southeastern Gabriola Island is mapped as Aquifer 709 (AQ709), with an area of 46.8 km^2 (Province of BC, 2004b). The aquifer boundaries and division between AQ706 and AQ709 were based on geology, topography, and the presence of a major fault/fracture system that divides the northern section from the remainder of the island.

Groundwater moves from high to low elevation, and from the centre of the island toward the coast, as show in Figure 9. Hodge (1978) further divided Gabriola Island into eleven groundwater regions (Figure 10), defined based on watershed divides and surface drainage systems, which were further refined in (GW Solutions Inc., 2021a). The groundwater characteristics and conditions within each water region are expected to be interrelated, therefore in the current study, the water balance, water quality and other assessment criteria were determined for the island and compared primarily by water region rather than by aquifer. An example hydrogeologic cross-section across northeast Gabriola Island illustrating the sedimentary bedrock layers, well locations and groundwater level is shown in Figure 11. Additional cross-sections are included in Appendix D.

Table 22: Gabriola Island mapped aquifers (Province of BC, 2025a).

Aquifer Number	Year Mapped	Location	Material	Sub-type	Area (km^2)	Vulnerability	Productivity	Demand
706	2004	Gabriola; Northern area	Bedrock	5a - Fractured sedimentary rock	5.9	High	Low	High
709	2004	Gabriola; excluding northern portion	Bedrock	5a - Fractured sedimentary rock	46.8	High	Low	Moderate

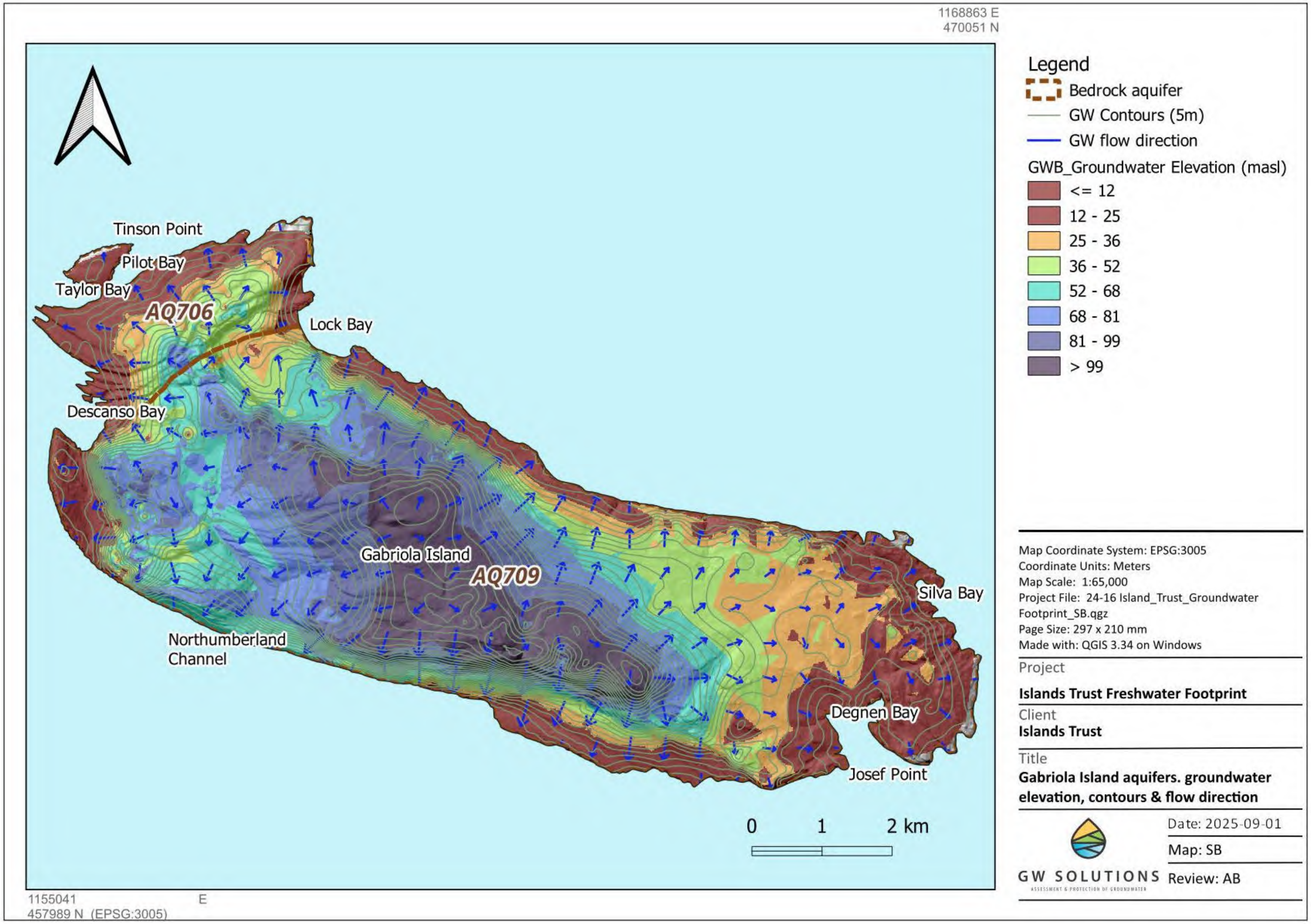


Figure 9: Gabriola Island mapped aquifers, groundwater elevation and direction of groundwater flow.

Figure 10: Gabriola Island groundwater regions.

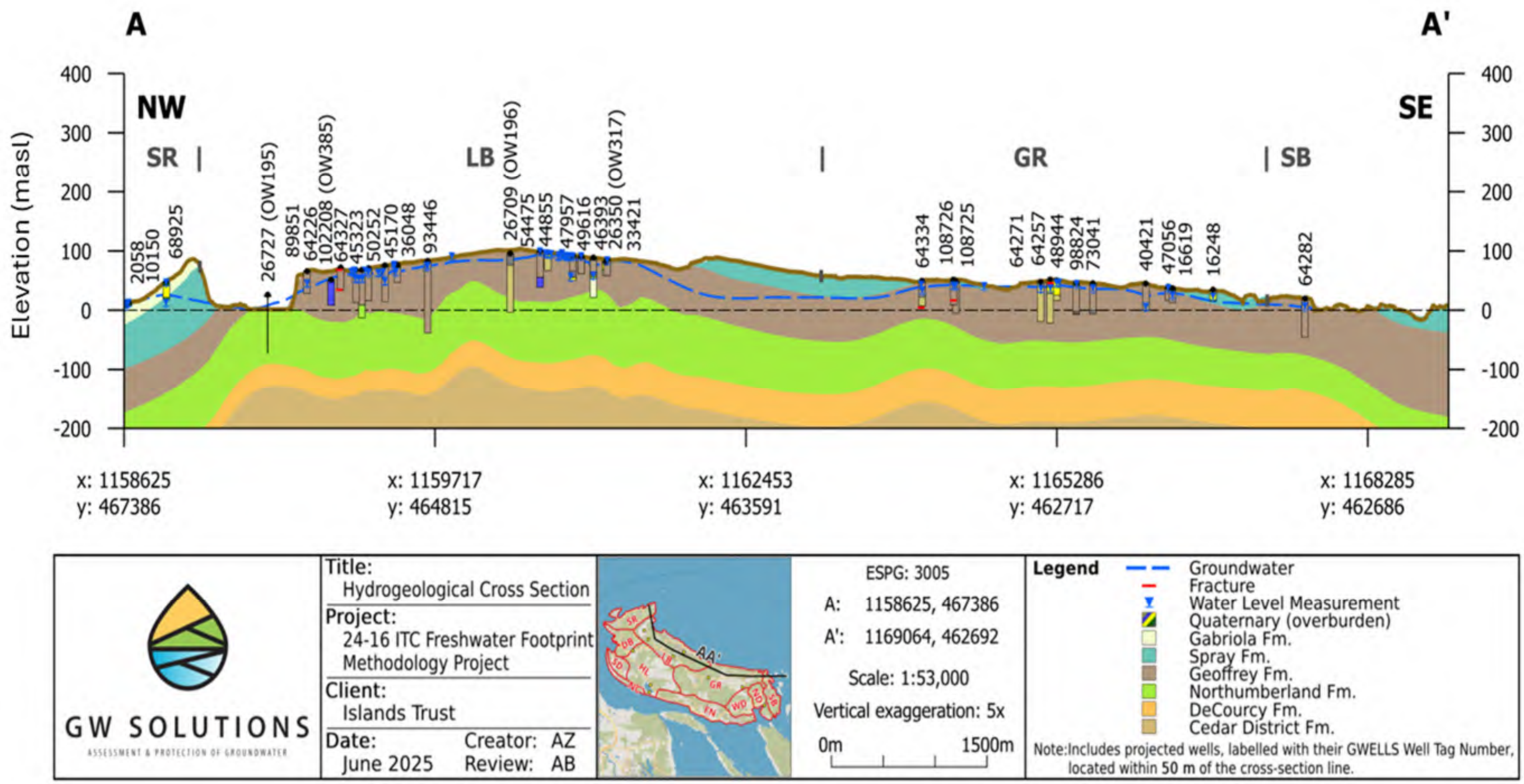


Figure 11: Hydrogeologic cross-section A-A' across north-central Gabriola Island.

6.2 Previous Studies

Gabriola Island has been a subject of numerous hydrogeologic studies, including island-wide and site-specific assessments. The earliest well inventory and aquifer characterization reports showed that well yields were generally low while local water supplies were limited due to the low permeability and storage within bedrock fractures. Sea water intrusion was identified in wells with high chloride concentrations (e.g. up to 2,000 mg/L chloride) in the low lying coastal areas with restricted groundwater recharge, and areas of high well density including in the Taylor Bay, Lock Bay, Degnan Bay and Siva Bay areas (Hodge, 1978).

Studies of water availability included the RDN Phase 1 water budget (SRK Consulting Inc., 2013), which estimated annual and monthly water demand compared to recharge as a percent of precipitation, using the water level fluctuation method (Healy, 2010). Burgess and Allen (2016) developed a numerical model, using MIKE SHE software, to estimate aquifer recharge as approximately 20% of precipitation; groundwater recharge or seepage (discharge) was mapped, highlighting seasonal and spatial differences across the island, and predicting groundwater conditions under future climate scenarios, however variations in vegetation, soil cover and geology were not considered.

GW Solutions (2021; 2021a, 2021b) developed methods to characterize and quantify groundwater conditions in the Islands Trust Area using a gridded water balance approach, that considered detailed climate, geologic and physiographic parameters. The methods and results, including further refinements in this study are described in this report.

6.3 Local water concerns and perceptions

An online survey of Gabriola residents on water-related issues was conducted from March 13, 2025 to May 18, 2025. A total of 66 responses were received, mainly from residential property owners, who answered 22 questions related to water sources used, and observations related to water quality and water quantity on their properties. The survey highlights are provided in Figure 12, Table 23 and Table 24 and the complete results are included in Appendix E.

Community participants in the Gabriola Freshwater Footprint workshop (May 29, 2025) showed an awareness of concerns with water quantity and quality on the island. Water-related concerns were reported including areas with low or reduced well yields, or deep wells. Questions were raised regarding the effect of forest loss on the hydrologic cycle, and the potential impact of impervious surfaces both groundwater quality and quantity. Water quality issues discussed included seawater intrusion, natural minerals such as fluoride, and contaminants from septic systems (e.g., nitrates, pharmaceuticals or pathogens). Identified data gaps included the value and need for local monitoring networks (weather, groundwater and surface water monitoring). The discussion also touched on options such as support for water testing and treatment, controls on development parcel size and density, and strategies to increase storage of surface water and rainfall.

Table 23: Gabriola Island water survey responses (2025).

- A total of 66 responses were received. Survey respondents were mainly Gabriola Island landowners (95%). A smaller number identified as renters (3%), indigenous persons with a relationship to the island (1.5%), farmers (1.5%), or visitors.
- Most are full-time residents (on the island for 6 months or more per year)(89%).
- All water management areas of the island were represented, except for West Degnan Bay. The highest number of responses were received from the Sands and Lock Bay Regions (20% in each area).
- The number of residents residing on each property ranged from 1 to 20, an overall average of 2.7 persons per household.
- Most surveyed use water from a drilled well (73%, 47 respondents). People also report using rainwater catchment (59%, 38 respondents). Smaller numbers report using a shared water source (3%), local water service (1.6%), or surface water source such as a stream (1.6%).
- The purpose of water use is mainly household use (drinking water, non-potable use and garden irrigation)(>90%). Approximately 5% (3 respondents) report using water for livestock or agricultural irrigation. This suggests that the survey did not reach many of the agricultural users on the island, whom could be approached separately for input in future. Similarly, commercial water users were not represented.
- Most properties have water storage including in above or below ground cisterns (total 93%, 59 out of 63 responses), or rain barrels (16%). Reported storage volumes ranged from 1,200 up to 30,000 gallons.
- Bulk water is used by nearly a third, 26% (16) respondents, occasionally, seasonally, or during dry years, but only 1.6% reported using bulk water as their primary water source, and 67% (41 respondents) never use bulk water.
- A variety of water conservation strategies are being used including low water use appliances and fixtures, reducing frequency or duration of showers, laundry and dishwashing, and methods to limit outdoor use (e.g. watering timers, garden mulching, water re-use).
- Most people surveyed report that they have an active well on their property (78%, or 50 respondents).
- Of active well owners, 60% (31 respondents) report that the well produces enough for their needs, while 25% (13) indicate limited well water supply in summer, or limited supplies all year (6%, 3 respondents). Approximately 4% of those surveyed indicate that they sometimes run out of water, while 6% run out of water every year. Several people indicated that they change sources seasonally, e.g., rely more on storage in summer.
- For people whose well water supply is limited occasionally or every year, the most common periods of water shortage are in July (7.5%), August (20%) and September (15%).
- A total of 46% (23 responses) of well owners indicate that the quality of water from their well is fresh and meets drinking water quality guidelines. Others report that the water has a high mineral content (26%), seasonal changes in water quality, sulfur odor, salty taste or parameters exceeding drinking water quality guidelines including manganese.
- Only 12% (6) respondents indicate that they have never tested the quality of water from their well, while most (48%, 24 respondents) test their water quality every 3 to 5 years, or at another frequency (e.g., once to twice per year, or less often). The most frequent water quality parameters tested were bacteria (76%), and geochemical parameters (63%).
- Nearly 18% report lack of information as the reason for completing laboratory tests, while 29% indicate that cost is a barrier.
- In terms of water treatment, 16% report using no form of water treatment. A total of 66% report using ultraviolet disinfection, compared to 8% that chlorinate their water. A total of 50% of respondents use a filtration method installed in the pump house, 2% use a water softener, while others report using point of use treatment methods such as carbon filters (18%) or reverse osmosis (14%).
- Most indicate that wastewater from their property is treated using a septic tank and disposal system with a basic level of treatment (73%), compared to roughly 24% who report using a septic system with an enhanced level of treatment (i.e. , secondary or tertiary treatment). Composting toilets, or shared septic systems were reported more rarely. Septic maintenance performed includes an annual inspection (42%), and pumping of solids from the septic tank every 3-5 years (675 of respondents). 11% indicate that they have never maintained their wastewater treatment system.
- Issues related to rainwater harvesting, water conservation and climate change and aquifer vulnerability were considered most important. While comments were submitted on the themes of rainwater collection, groundwater availability, development density and population growth, contamination and bulk water hauling.

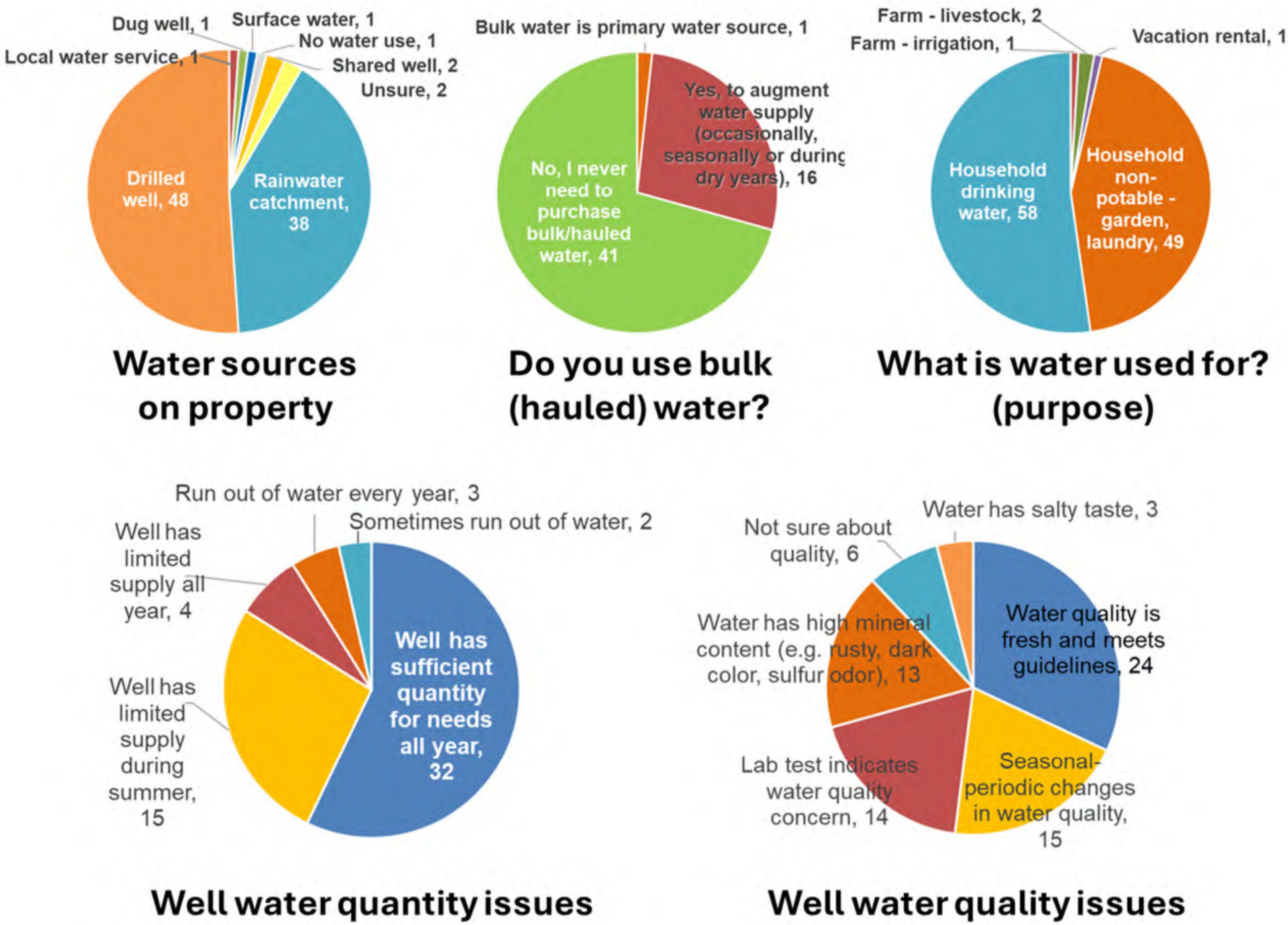


Figure 12: Gabriola 2025 water survey results (answers to key questions and number of responses).

Table 24: Gabriola survey water topic level of importance.

Water topic level of importance	Very important	Important	Weighted average importance
Rainwater harvesting	53%	36%	4.29
Water conservation, recycling& reuse	45%	41%	4.24
Rural rebates, financial supports forwell owners	25%	31%	4.24
Aquifer vulnerability& groundwater contamination	51%	34%	4.23
Climate change impacts on water resources	55%	24%	4.22
Household well / water system construction & maintenance	41%	38%	4.17
Local food security & agriculture	52%	34%	4.14
Wastewater treatment systemconstruction & maintenance	39%	40%	4.14
Water balance and aquifer carrying capacity	46%	30%	4.02
Groundwater connection with streams or coastal ecosystems	42%	32%	4.02
Freshwater monitoring	36%	38%	4.00
Water use for production of food& consumer goods	34%	32%	3.84
Seawater intrusion	25%	36%	3.47

6.4 Gridded Water Balance Model

6.4.1 Climate

Gabriola Island does not currently have an active Environment Canada monitoring station; the closest active station is on Entrance Island approximately 800 m northwest of the island. Based on published climate normal data, the average daily temperature on Gabriola is 9.6 °C. Average annual precipitation is 957.2 mm per year. Most (96%) precipitation falls as rainfall during the wet season (October to April), while the dry season lasts from May to September, with minimal precipitation particularly in July and August annually (Environment and Natural Resources Canada, 2025). The water balance assessment utilized gridded climate normal data for the historic (1980-2010) and projected current (2025) period, obtained from the Pacific Climate Impacts Consortium (Pacific Climate Impacts Consortium, 2024).

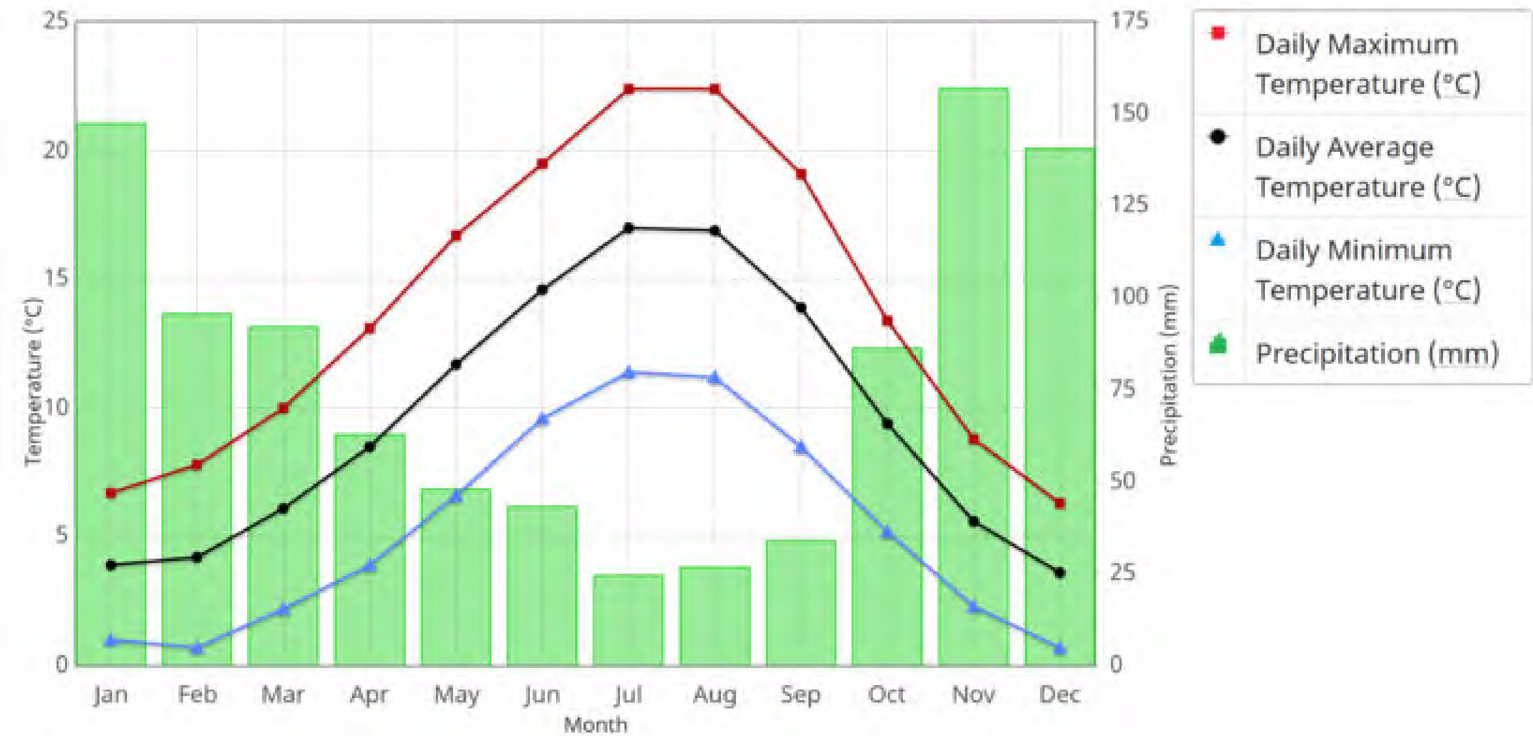


Figure 13: Climate Normals (1981-2010) for Gabriola Island, Environment Canada Station EC1023042 (Environment and Natural Resources Canada, 2025).

6.4.2 Water Use

An important aspect of understanding the freshwater footprint of Gabriola Island was estimating in the volume of water use. Metered water use data were not available. Water use estimates were based on compiled well and water license information, but importantly primarily relied on land use categorization and analysis.

6.4.2.1 *Population*

Based on the most recent national census in 2021, Gabriola Island has a population of 4500 people. The average household size is 1.9 people per dwelling, and 78% of the 3062 surveyed private dwellings are occupied by full time residents (Statistics Canada, 2023b). This occupancy pattern is different than some other islands in the Trust Area that have a greater proportion of seasonal or part-time residents. However the population of Gabriola does increase in summer due to visitors, seasonal workers and tourists.

6.4.2.2 *Water sources*

Water on Gabriola Island is obtained from a range of different sources, shown in Figure 14 and described below.

Groundwater: The primary source of water for most areas of Gabriola Island is groundwater wells. The GWELLS database contains records of 2,762 registered wells on the island, most of which are constructed in sedimentary bedrock (sandstone and shale) (Province of BC, 2025a). For an island of 57.6 km^2, this represents a well density of 48 wells per km^2, which is considered a high level of groundwater development (Berardinucci and Ronneseth, 2002). Prior to 2016, submission of well records to the database by drillers was voluntary. Although GWELLS has known inaccuracies in well location co-ordinates, missing and duplicate records, it remains a critical data source to understand groundwater use patterns on the island. Figure 15 shows the number of registered wells by year of construction. The GWELLS database uses a date of 1950 to indicate wells for which the date of construction is not known, therefore the plot shows a large number of wells (105) for this year. The period of greatest groundwater development on the island was from the 1970's to the 1990's, with much fewer well records being submitted in recent years. Figure 16 shows boxplots of well depth (in feet) by decade of construction. Both the median and maximum range of well depths has increased over time. Most wells on the island are 107 m (350 ft) deep or less but wells greater than 200 m (650 ft) have been reported. Most groundwater is not currently licensed on the island, and there are 4 active groundwater licenses in the Water Rights database, one for AQ706 and three for AQ709. From the 2025 water use survey, 47 (73%) of respondents, mainly residential users, indicated that they use a groundwater source.

Surface water: Surface water from streams, creeks, and springs is considered a minor source of water on Gabriola Island. Information on surface water use was mainly obtained from the Water Rights Database ((Water Management, 2025b, 2025a). A total of 40 active water license points of diversion are mapped on the island, 37 (93%) for surface water sources, including 14 springs (50% of named license sources). Non-consumptive use for land improvement, power generation and storage (power, non-power) account for 97% of annual licensed water use by volume. Seasonal availability of water from surface sources is likely to decrease with climate change as the dry season becomes longer, increasing reliance on groundwater sources. There is no monitoring either of quantities of surface water withdrawal to validate licensed volumes, nor of streamflow or spring discharge. Previous studies observed that streams, creeks and springs generally provided a small proportion of water used the island. The RDN Phase 1 Water Budget (SRK Consulting Inc., 2013) did not account for surface water use for the island water balance. While GW Solutions (2021) estimated that approximately 20% of annual water use on the island could be from surface water sources (based on license data). However, because licensed use is not metered or reported it is believed that the quantities of surface water use may be significantly overestimated; for example a typical domestic surface water license is allotted 2.27 m^3/day year-round, which is likely much higher than actual use, particularly during the winter. The current study found that nearly all (98%) of non-domestic water users including permitted water systems utilize a groundwater source. If a surface water license was identified on or appurtenant to (licensed to be used on) a parcel, it was noted as a water source, but in many cases concurrent groundwater use was also indicated on the parcel. The spatial locations of licensed springs were noted as potential indicators of groundwater discharge areas. However detailed quantification of surface water volumes was not included within the current water balance calculation. Future work could be undertaken to review and quantify surface water demand.

Rainwater collection and bulk water hauling (cisterns): Capture of rainwater from rooftops and storage in water cisterns and tanks is an important water source either to augment or replace water from other sources. Rainwater collection is known to be used in many areas of the island, such as where an onsite well produces water of inadequate quantity, or poor quality, or where drilling of a well has not been possible e.g. smaller waterfront properties along Berry Point Road. Many residential properties also use rainwater for irrigation or backup supply. The 2025 water survey found that most properties use some method for water storage including above or below ground cisterns (total 93%, 59 out of 63 responses), or rain barrels (16%), with water storage volumes ranging from 5.5 to 136 m^3 (1,200 to 30,000 imperial gallons).

Provision of water from on-island and off-island water haulers is an important water source either seasonally, where rainwater collection or well sources are not viable, or year-round for properties with no other water source. From the 2025 water survey, only 1 respondent (2%) indicated bulk water was their main water source, but an additional 16 respondents (26%) indicated that they use bulk water periodically, seasonally, during times of water shortage or high water use (e.g. “after having many visitors”). At least two permitted non-domestic water systems on Gabriola Island use bulk water hauling as their primary source, including one park and one commercial operation. Bulk water is also purchased for infrequent large volume needs such as hot tub or pool refilling.

Information on groundwater use for bulk water delivery was shared by the local water hauler, Summer Rain Water Delivery, which reports a regular clientele of approximately 40 properties, plus numerous additional sites that receive periodic deliveries. The volume of water delivered by Summer Rain in 2023 and 2024 are shown in Figure 17. From this, roughly 10,000 to 11,000 m^3 of water were delivered in 2023 and 2024 on Gabriola by this supplier, with up to a third of the volume coming from off-island sources, mainly in the months of July and August to lessen demand on his well supplies (Dan Foley, personal communication, July 2025).The annual bulk delivery volume averages to approximately 700 litres/day per customer, within the range estimated for a typical residence. GW Solutions also conducted phone interviews with off-island water haulers, but these companies were not able to provide information on volumes or areas of delivery.

A proportion of hauled water from local (island-based) suppliers, and most water from off-island providers is obtained from City of Nanaimo filling stations. Data were provided from the City of Nanaimo for water purchased by Summer Rain Water Delivery and Island Water Haulers, which deliver water to Gabriola Island and other Vancouver Island communities (Mike

Squire, personal communication, January 2026). Off-island water purchased from Nanaimo city by Summer Rain from 2020 to 2025 are shown in Figure 18. This shows that annual hauling from off-island sources for this provider was the highest in 2021, up to 5,000 m^3 (up to 1 million gallons), likely due to increased residency during this time following the Covid-19 pandemic. However, on average Summer Rain bring from 1,000 to 3,000 m^3 of Nanaimo water per year to the island. For comparison to other haulers, the months and volume of water purchased by Island Water Haulers and Summer Rain Water Delivery from City of Nanaimo in 2020-2025 are summarized in

Table 25. The volumes purchased by Island Water Hauling, with year-round service, and delivery to a much larger geographic area, are significantly more than the volumes reported for Summer Rain.

Based on the current billing method for bulk water from City of Nanaimo, it is not possible to identify where water is being delivered, which could help to indicate trends or areas of water shortage. Simple ways to measure and track patterns of bulk water use could be developed in future and would be useful to identify locations and periods of water shortage indicative of water stress on Gabriola Island, and in other communities.

For this study, rainwater collection and bulk water were not accounted for separately in the water balance. Some areas where wells were unlikely to be drilled or in use, based on local information sources, were noted when assigning a water source to different parcels e.g., selected waterfront lots on the northeast island. However, this preliminary analysis shows that while bulk water use represents a small proportion of the overall water balance (less than 2%), water hauling is an essential service for properties that do not have another viable water source, and for well owners who experience seasonal declines in groundwater quality and quantity.

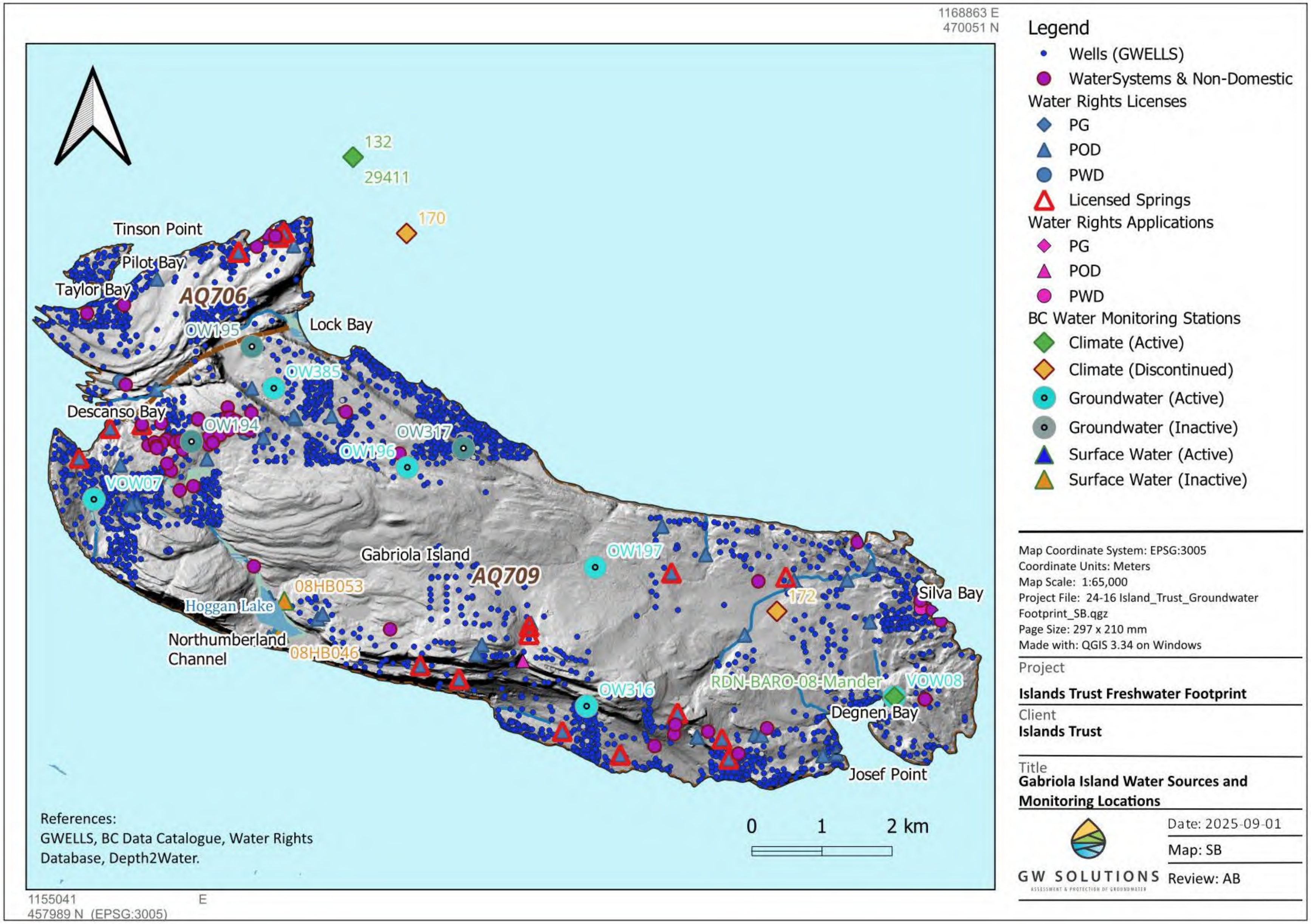


Figure 14: Gabriola Island water sources and monitoring locations.

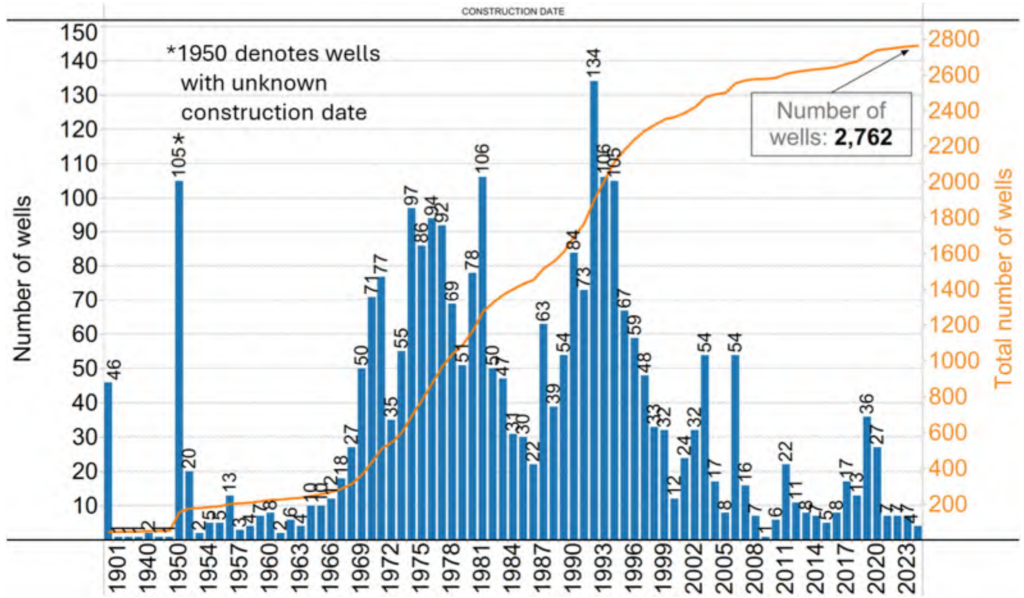


Figure 15: Gabriola Island wells registered in the GWELLS database, by year of construction.

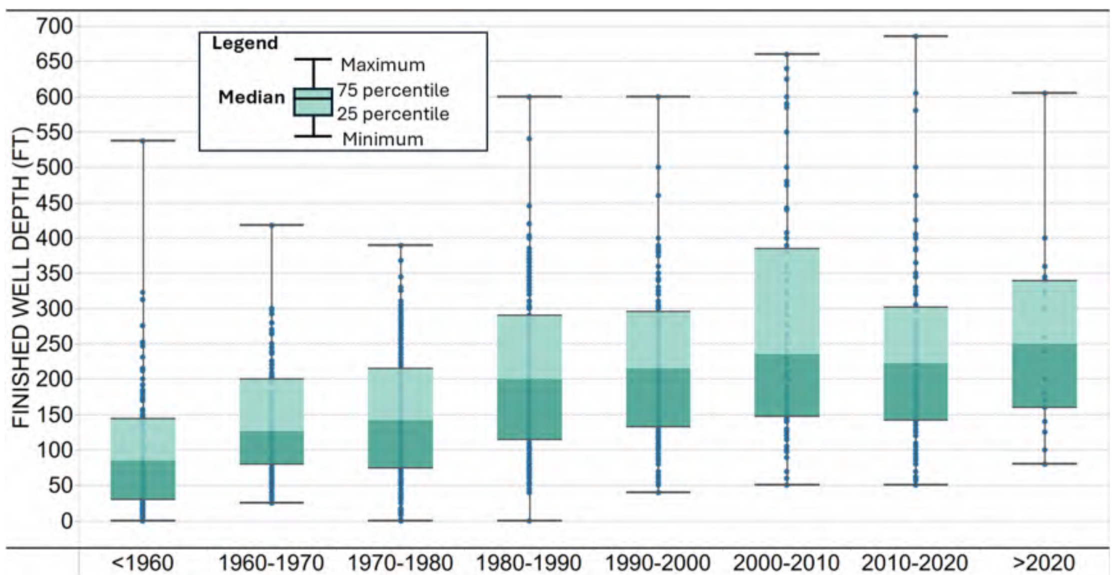


Figure 16: Boxplots of well construction depth (ft) of Gabriola Island wells by decade.

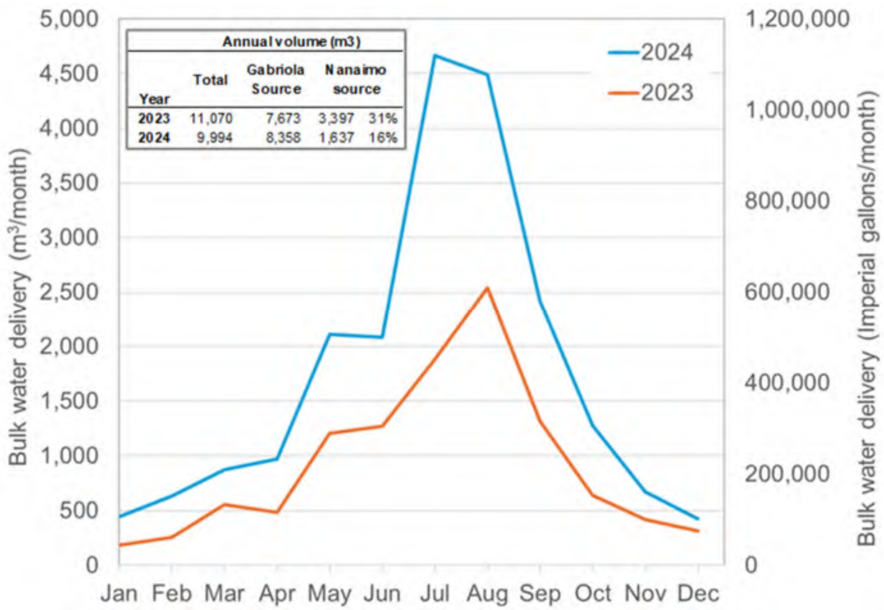


Figure 17: Summer Rain bulk water delivery volumes on Gabriola Island, 2023-2024.

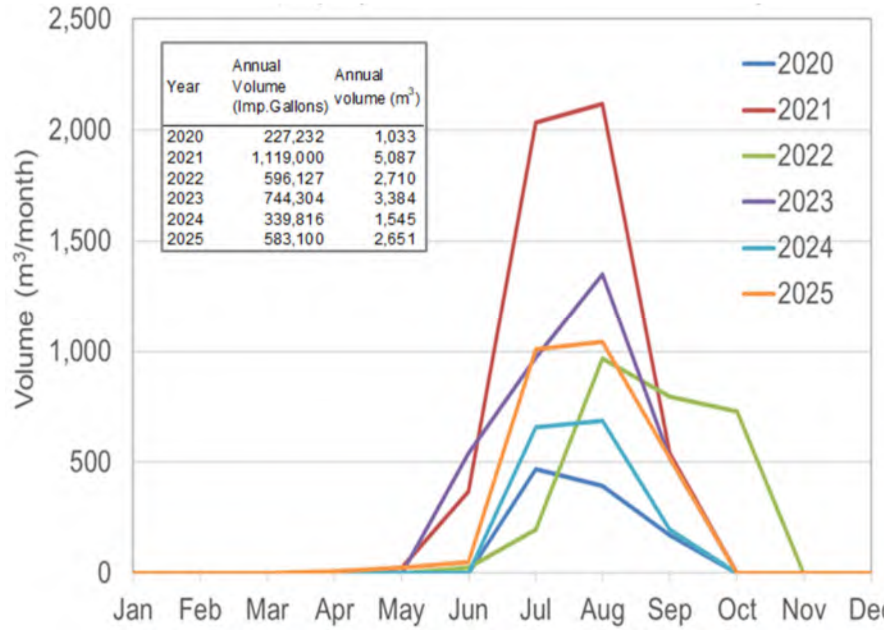


Figure 18: Bulk water hauled per month from City of Nanaimo water supply.

Table 25: Bulk water purchased from City of Nanaimo by Summer Rain and Island Water Hauling 2020-2025.

	Total	2020	2021	2022	2023	2024	2025	Note
Summer Rain Water Delivery (m^3)	16,409	1,033	5,087	2,710	3,384	1,545	2,651	
Summer Rain Hauling Months		Jul-Sep	May-Sep	Jun-Oct	Jun-Sep	Jun-Sep	May-Sep	(1)
Island Water Hauling (m^3)	119,115	2	14,997	19,005	43,175	18,062	23,875	
Island Water Hauling Months		Jan-Dec	Jan-Dec	Jan-Dec	Jan-Dec	Jan-Dec	Jan-Dec	(2,3)

Reference: Mike Squire, City of Nanaimo, personal communication January 6, 2026. Notes: (1) Summer Rain delivers mainly to Gabriola Island. (2) Island Water Hauling delivers to Gabriola Island and other Vancouver Island Communities. (3) 2025 Data included to December 18, 2025.

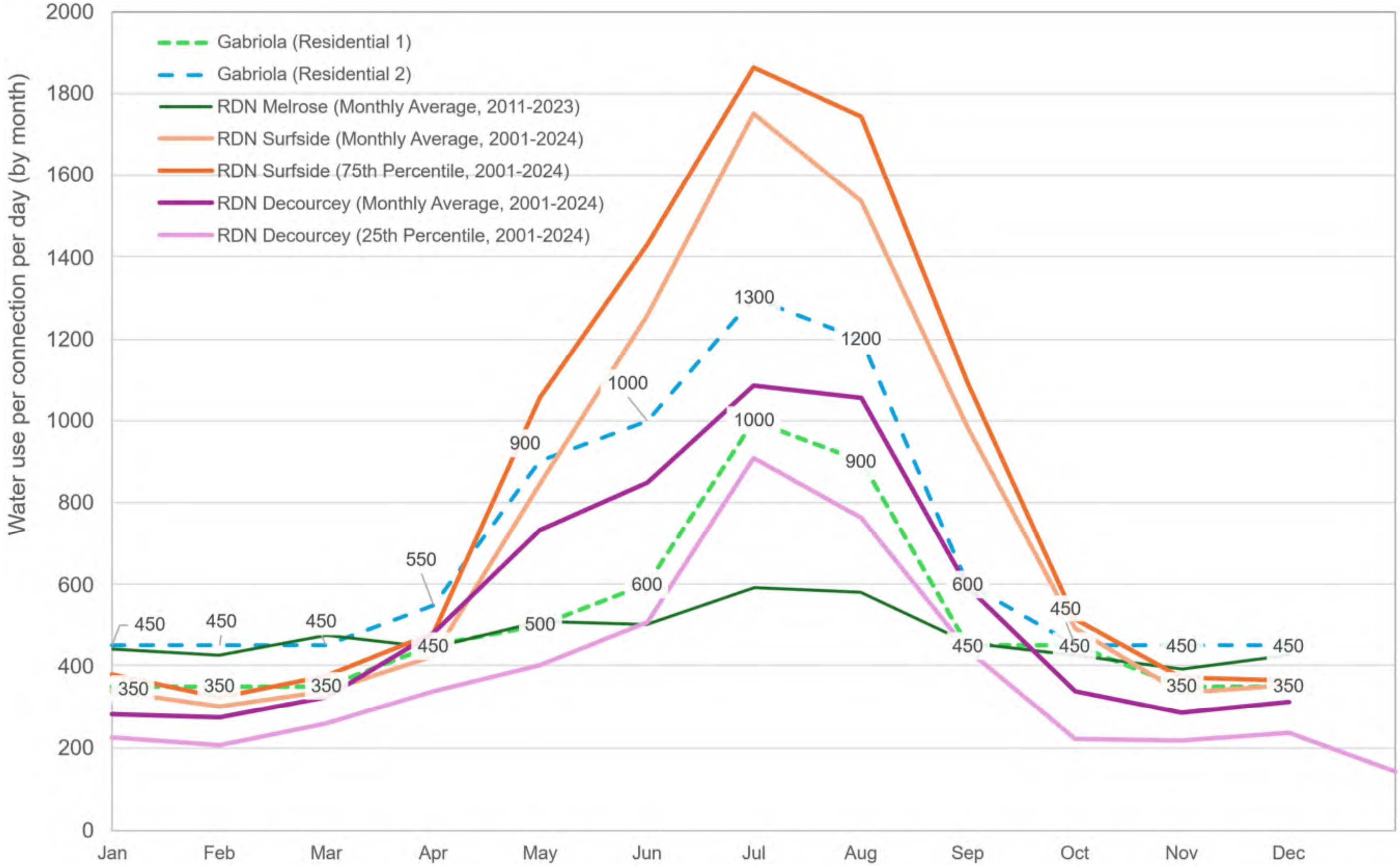


Figure 19: Gabriola Island estimated daily residential water use for R1 (small) and R2 (large) parcels compared to long-term metered data from comparable Regional District of Nanaimo water systems.

6.4.2.3 *Annual and monthly water demand*

Water demand was summarized per lot, based on land use type, occupancy and the inventory of non-domestic water uses, including water systems. The following observations were made:

- A total of 58 water systems were identified on the island, ranging from water purveyors supplying multi-unit housing developments and stratas, commercial facilities and farms. (The full list of non-domestic groundwater users is included in Appendix A).
- The highest water demand is in summer months (July-August) and the largest water use by volume is for residential demand.
- The highest water use region is Lock Bay on the northeast side of the island, followed by the Sands Region on the northwest island, and False Narrows Region on the south island.
- The greatest water use for agriculture is in Central Gabriola and North Degnan Bay.
- Not surprisingly, the greatest water use by aquifer is for mapped aquifer AQ709 which encompasses the majority of the island.

Table 26: Gabriola Island annual water use by purpose and region.

Region	Use Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total Use (m3)	Total Use Region (m³)	Total Use Gabriola (m³)
Central Gabriola Region	Residential use	2,865	2,588	2,865	3,168	4,093	4,753	8,185	7,367	3,565	3,274	2,772	2,865	**48,360**	**81,858**	**742,824**
	Agricultural use	91	82	91	117	3,104	7,203	9,841	8,053	3,579	195	88	91	**32535**		
	Industrial-Commercial use	15	14	15	89	115	133	229	206	100	17	15	15	**963**		
Descanso Bay Region	Residential use	2,141	1,934	2,141	2,368	3,058	3,552	6,117	5,505	2,664	2,447	2,072	2,141	**36,140**	**46,617**	
	Agricultural use	30	27	30	34	53	74	118	103	50	34	29	30	**612**		
	Industrial-Commercial use	574	518	574	641	844	980	1,688	1,520	735	662	555	574	**9865**		
False Narrows Region	Residential use	4,946	4,468	4,946	5,471	7,066	8,206	14,132	12,719	6,154	5,653	4,787	4,946	**83,494**	**97,568**	

Region	Use Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total Use (m3)	Total Use Region (m^3)	Total Use Gabriola (m^3)
	Agricultural use	61	55	61	73	1,069	2,427	3,335	2,736	1,219	99	59	61	**11255**		
	Industrial-Commercial use	67	61	67	74	343	398	685	617	298	77	65	67	**2819**		
Hoggan Lake Region	Residential use	3,254	2,939	3,254	3,599	4,649	5,398	9,297	8,367	4,049	3,719	3,149	3,254	**54,928**		
	Agricultural use	62	56	62	73	885	1,994	2,739	2,249	1,008	94	60	62	**9344**	**71,452**	
	Industrial-Commercial use	473	427	473	445	624	725	1,094	984	544	460	458	473	**7180**		
Lock Bay Region	Residential use	7,823	7,066	7,823	8,652	11,175	12,978	22,351	20,116	9,733	8,940	7,570	7,823	**132,050**		
	Agricultural use	58	52	58	65	332	687	968	803	362	72	56	58	**3571**	**138,057**	
	Industrial-Commercial use	38	34	38	42	317	368	634	571	276	43	37	38	**2436**		
North Degnan Bay Region	Residential use	1,361	1,229	1,361	1,505	1,944	2,258	3,888	3,499	1,693	1,555	1,317	1,361	**22,971**		
	Agricultural use	15	14	15	30	2,309	5,438	7,418	6,062	2,675	90	15	15	**24096**	**47,578**	
	Industrial-Commercial use	30	27	30	34	43	50	87	78	38	35	29	30	**511**		
Northumberland Channel Region	Residential use	1,223	1,104	1,223	1,352	1,747	2,028	3,493	3,144	1,521	1,397	1,183	1,223	**20,638**		
	Agricultural use	0	0	0	3	577	1,366	1,861	1,520	670	18	0	0	**6015**	**26,765**	
	Industrial-Commercial use	0	0	0	0	16	19	33	30	14	0	0	0	**112**		
Sands Region	Residential use	6,157	5,561	6,157	6,809	8,795	10,214	17,591	15,832	7,661	7,036	5,958	6,157	**103,928**	**116,312**	
	Agricultural use	15	14	15	18	243	549	754	619	277	24	15	15	**2558**		

Region	Use Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total Use (m3)	Total Use Region (m³)	Total Use Gabriola (m³)
	Industrial-Commercial use	117	106	117	202	868	1,404	3,101	2,791	756	134	113	117	**9826**		
Silva Bay Region	Residential use	1,279	1,155	1,279	1,415	1,827	2,122	3,655	3,289	1,592	1,462	1,238	1,279	**21,592**	**24,971**	
	Industrial-Commercial use	48	43	48	269	413	480	826	743	360	55	46	48	**3379**		
South Descanso Bay Region	Residential use	4,072	3,678	4,072	4,504	5,817	6,755	11,634	10,471	5,067	4,654	3,941	4,072	**68,737**	**69,860**	
	Industrial-Commercial use	0	0	0	0	164	191	329	296	143	0	0	0	**1123**		
West Degnan Bay Region	Residential use	643	580	643	711	918	1,066	1,836	1,652	799	734	622	643	**10847**	**21,492**	
	Agricultural use	57	52	57	68	1,011	2,298	3,155	2,588	1,154	93	55	57	**10645**		
West Degnan Bay Region	Industrial-Commercial use	17	16	17	19	25	29	50	45	22	20	17	17	**294**	**294**	

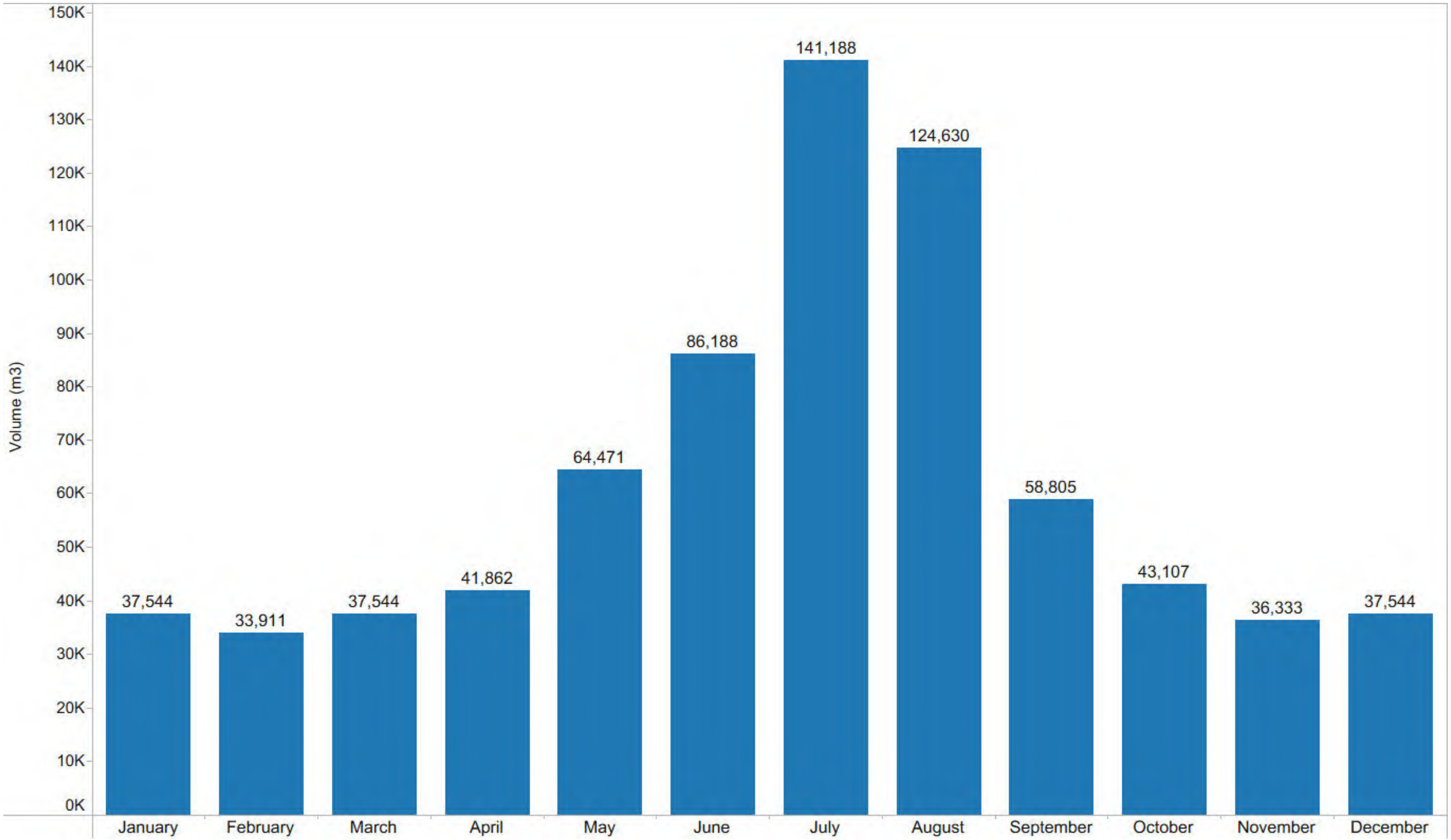


Figure 20: Gabriola Island monthly water use.

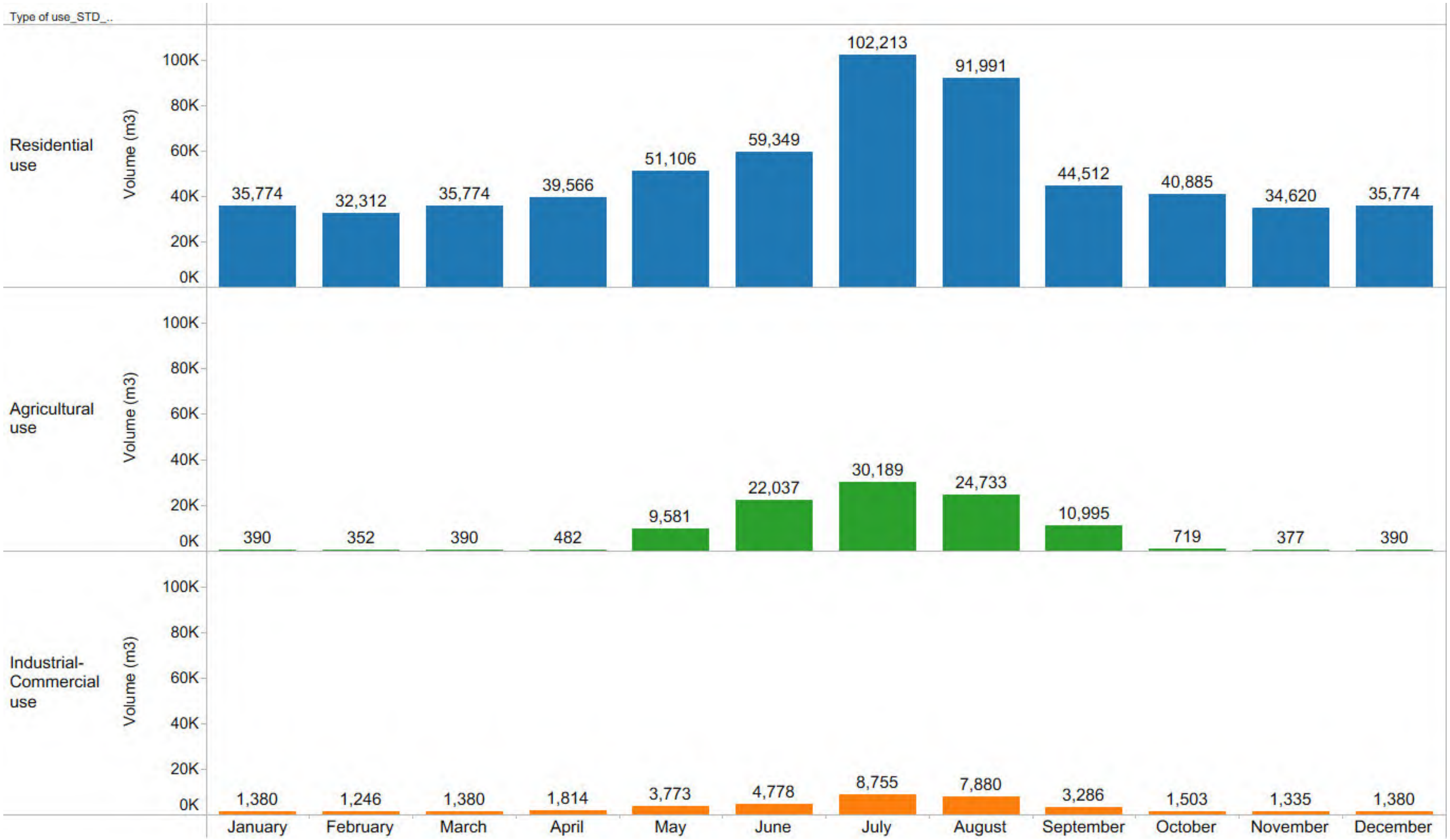


Figure 21: Gabriola Island monthly water by purpose.

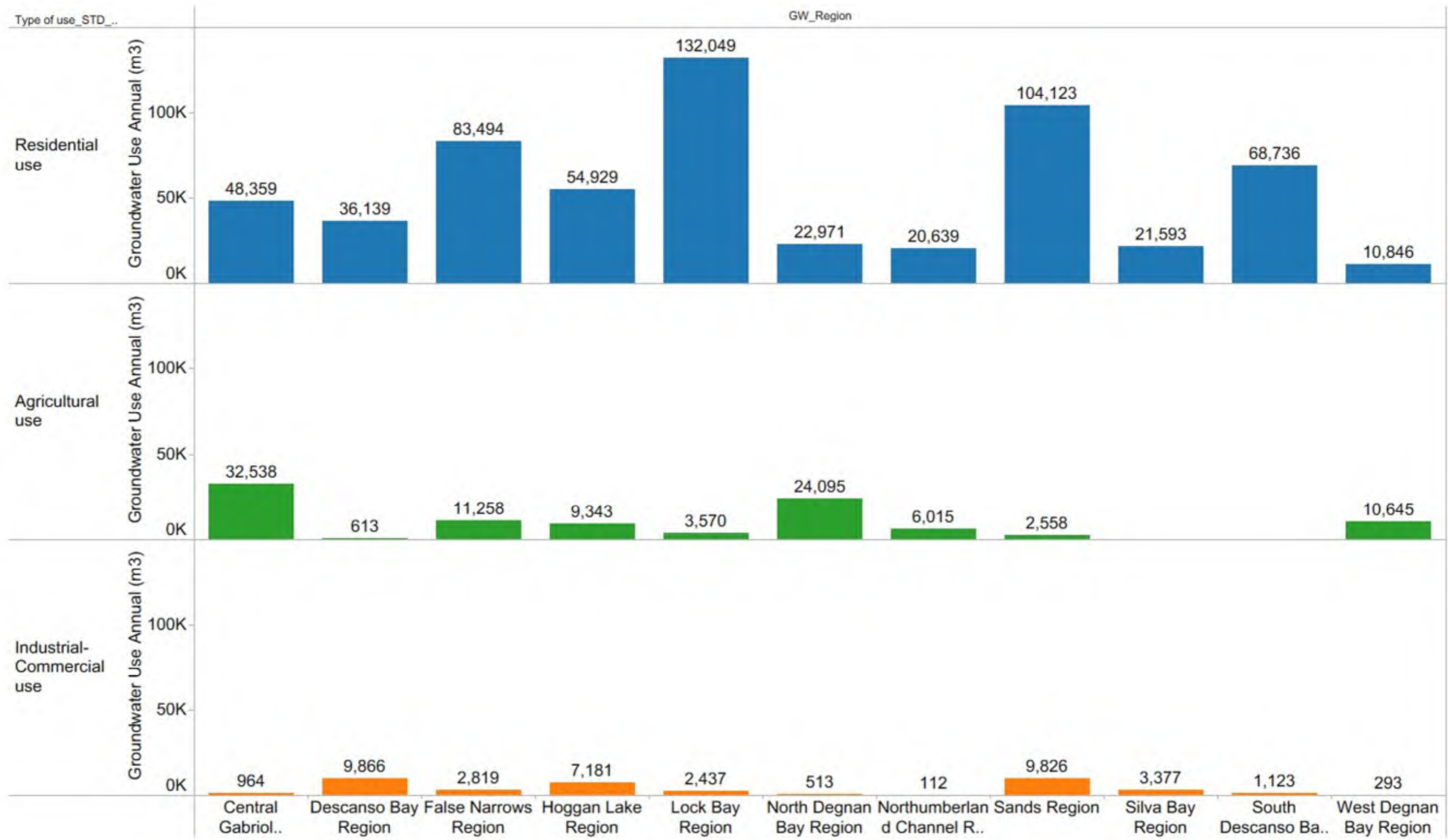


Figure 22: Gabriola Island annual water by purpose per region.

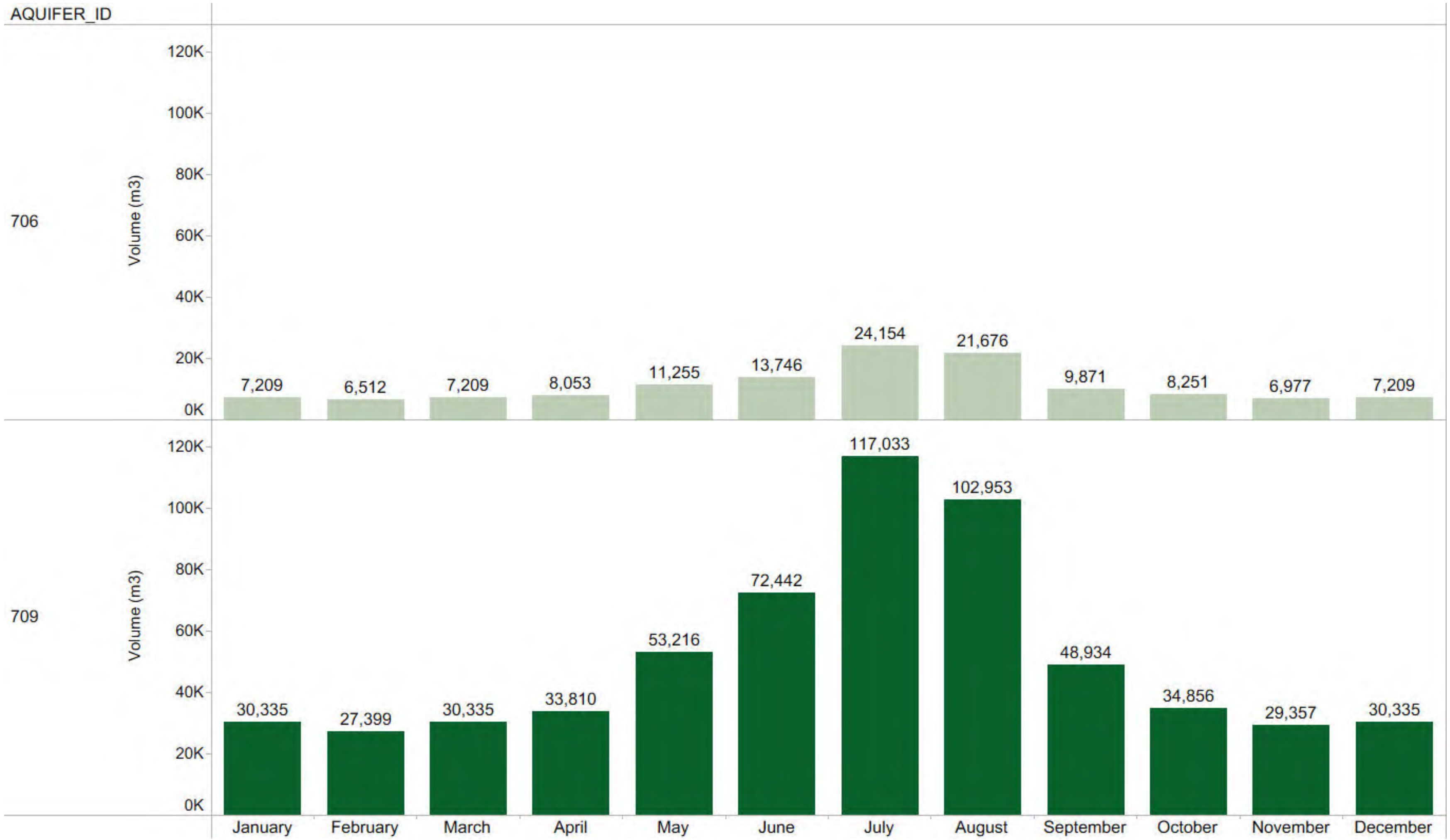


Figure 23: Gabriola Island monthly water per aquifer, for AQ709 central to south Gabriola Island and AQ706 (Northwest Gabriola).

6.4.3 Groundwater recharge potential

Within the water cycle, a proportion of precipitation received at the ground surface will infiltrate into the ground creating groundwater recharge. Groundwater recharge typically occurs in upland areas where the unsaturated zone is thicker and the depth to the groundwater table is deeper, allowing water to percolate underground and replenish the aquifer. In contrast, groundwater discharge areas are typically located in topographic lows such as along streams, valleys and shorelines, providing seasonal or year-round baseflow to streams, wetlands and springs (Fetter, 2018).

Groundwater recharge potential (GRP) represents the relative ability for precipitation to infiltrate into the subsurface and contribute to groundwater recharge. GPR was calculated for a 10 x 10 m raster grid across Gabriola Island. Maps of representative input criteria used to calculate the groundwater recharge potential (GRP) are shown in Figure 24, including groundwater discharge probability based on Normalized Difference Vegetation Index (NDVI) and Normalized Difference Moisture Index (NDMI), slope co-efficient, lineament topographic wetness coefficient and water retention potential coefficient.

The depth of the groundwater table or the thickness of the unsaturated zone has a significant role in controlling groundwater recharge rate across Gabriola Island. Despite surficial materials and/or exposed fractured bedrock that are suitable for groundwater infiltration, a shallow water table limits the amount of water that can infiltrate into the ground. For instance, if the groundwater level is close to or above the ground surface, it indicates a groundwater discharge zone, within which groundwater recharge will be limited. The opposite condition is observed when the groundwater level is below ground and allows mostly groundwater recharge to occur. A map of potential groundwater recharge/discharge based on depth of the groundwater table is shown in Figure 25.

The final groundwater recharge potential (GRP) map is shown in Figure 26. The GRP is a unitless, ranging from 0 representing preferential groundwater discharge zones such as in lowland areas, stream valleys and close to the coast, to 1, representing areas where groundwater recharge is greatest, such as in in the centre of the island and in upland areas.

6.4.4 Precipitation, evapotranspiration, surplus and recharge

The water balance considered precipitation inputs, water losses to evapotranspiration, and surplus available to contribute to groundwater recharge.

Precipitation: Precipitation across the island varies from 21 mm up to 165 mm per month. The wettest months are November to January, and the driest months are July and August. The precipitation is considered spatially consistent the island ,with slightly higher values toward the northwest. Monthly data for the island footprint are shown in Figure 27.

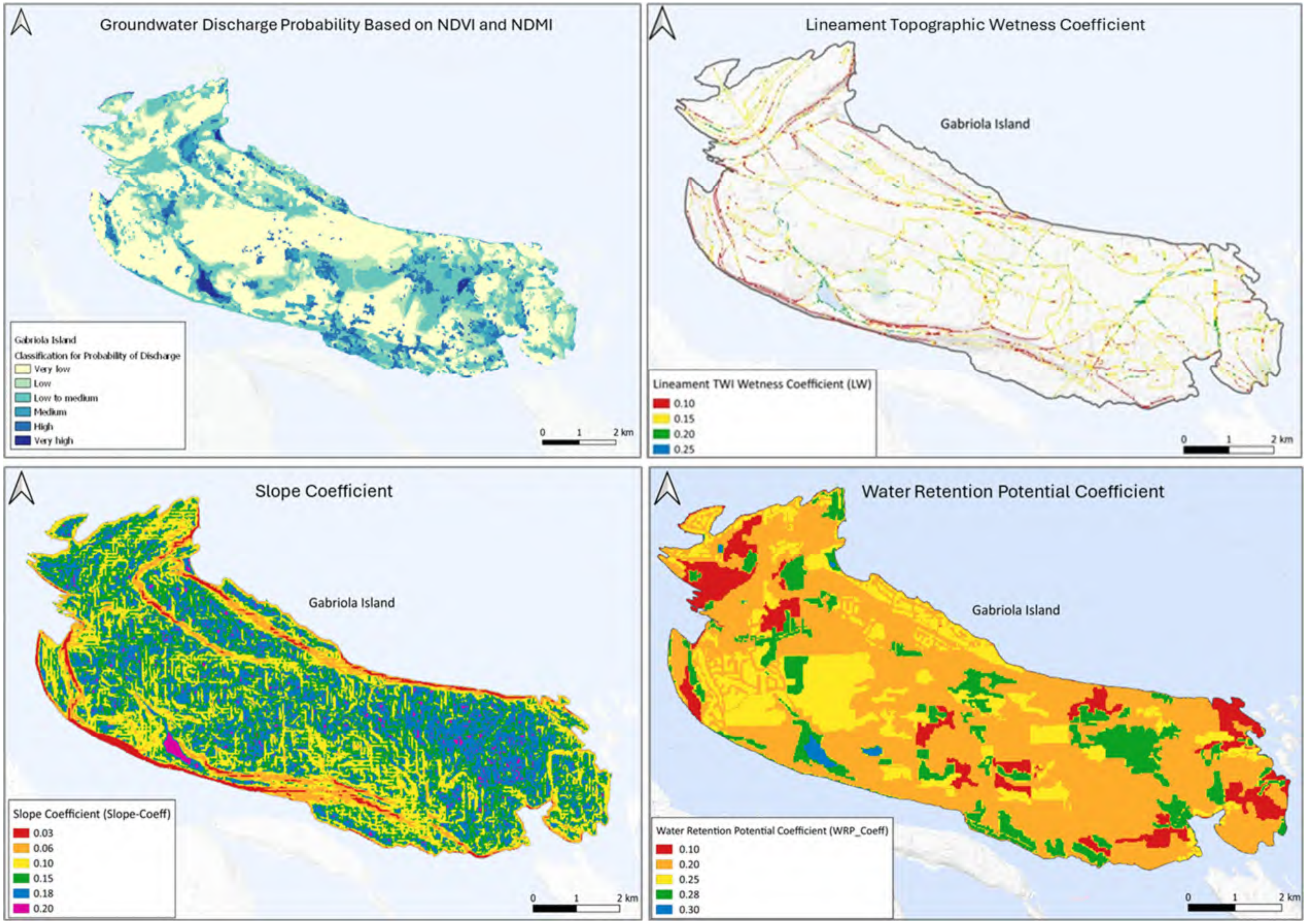


Figure 24: Input Components Used to Estimate Groundwater Recharge Potential: groundwater discharge probability based on Normalized Difference Vegetation Index (NDVI) and Normalized Difference Moisture Index (NDMI), Lineament Topographic Wetness co-efficient, slope co-efficient, and water retention potential coefficient.

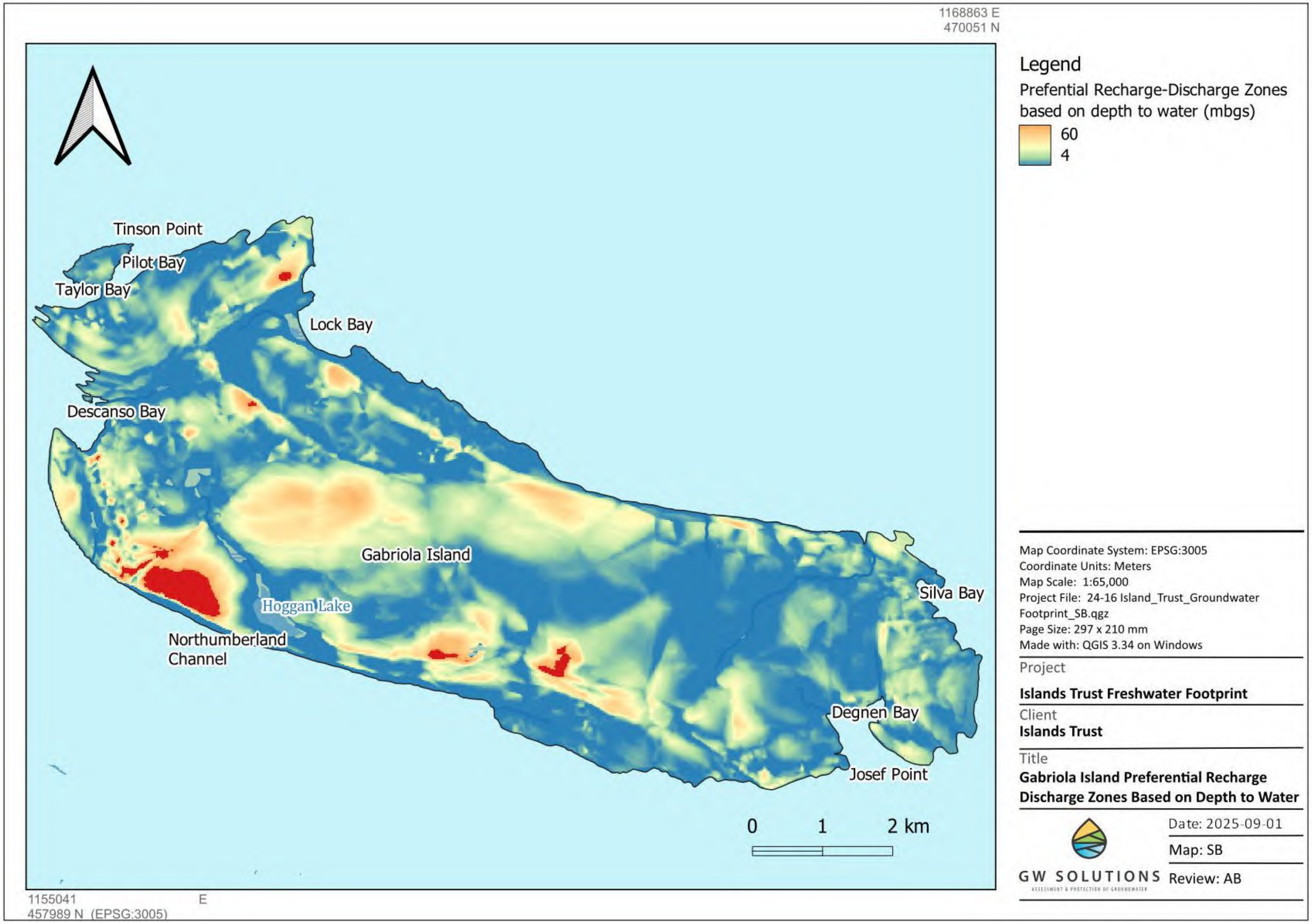


Figure 25: Gabriola Preferential Groundwater Recharge and Discharge Areas Based on Depth to Water.

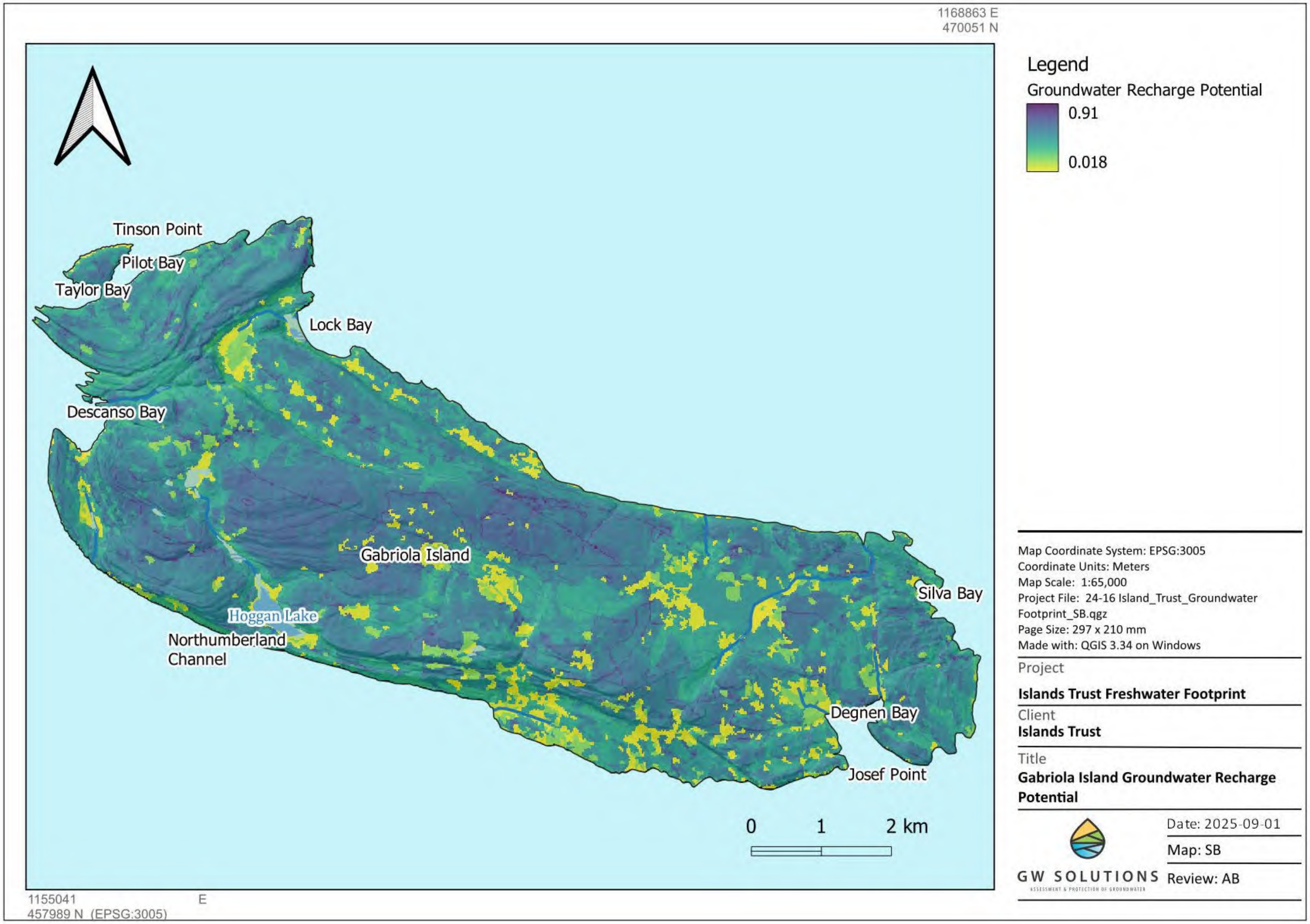


Figure 26: Gabriola Island Groundwater Recharge Potential (GRP). GRP is high in recharge areas and low in discharge areas.

Evapotranspiration: Actual evapotranspiration (AET) represents the water lost by evaporation from soil and vegetative surfaces and used by plants from available soil moisture. AET varies from 3.9 mm up to 165 mm per month. The greatest evapotranspiration occurs in May, when plants are in active growth, temperatures are warmer, but soil moisture is still available for use. From June to August, AET is less because available soil moisture is used up and potential ET is less than can actually be used. Monthly data are shown in Figure 28.

Surplus: The water surplus presents the water available after losses to evapotranspiration. The greatest surplus occurs in the months of November to January, when rainfall is high, temperatures are lower, and plants are dormant. During the months of April to September very little surplus is available, as shown in Figure 29. In months when water surplus is available, a portion of the water infiltrates and contributes to groundwater recharge, The remaining surplus flows as runoff to surface water streams.

Recharge: The ability of surplus water to infiltrate into the ground depends on the recharge potential (controlled by factors such as slope, bedrock fractures and faults, soil and vegetation characteristics). Monthly groundwater recharge is shown in Figure 30, and ranges from 0 mm, in dry months (April to August), up to 130 mm in the wetter months (November to January).

Figure 31 shows the total estimated annual recharge for Gabriola Island per year. Some areas receive up to 500 mm of recharge, including higher elevation forested areas in the central island. For the majority of the island annual recharge ranges from 200 to 400 mm per year. Lower rates of recharge are expected in lower elevation discharge zones, and near the coast.

Water use: The spatial distribution of water use per parcel across the island is shown in Figure 32. No water use (0 mm per year) occurs in parks and protected areas, and undeveloped lots. Use for most residential lots is dependent on total lot size, ranging from les than 10 mm up to 100 mm per year in most areas. Higher water use is determined for lots with variable land use including water systems, commercial and market gardens, and multi-unit housing.

Aquifer Stress Ratio: Water use was compared to water availability across the island, shown in Figure 33. Most areas have a low water stress (water use is 5% or less of available recharge). Areas with high stress (10 to 20% of recharge is used for water demand), extreme (20-40% of available recharge is used) and very extreme stress (more than 40% of recharge is use) are observed in more developed areas with small lots and mixed commercial, institutional and residential use, such as in the village areas, and subdivisions in the north, northwest and northeast island. The stress categories are based on precautionary approach, and considering that a proportion of groundwater recharge is needed to maintain flux to the coastal areas, and to sustain baseflows in hydraulically connected surface water sources, such as creeks and wetlands.

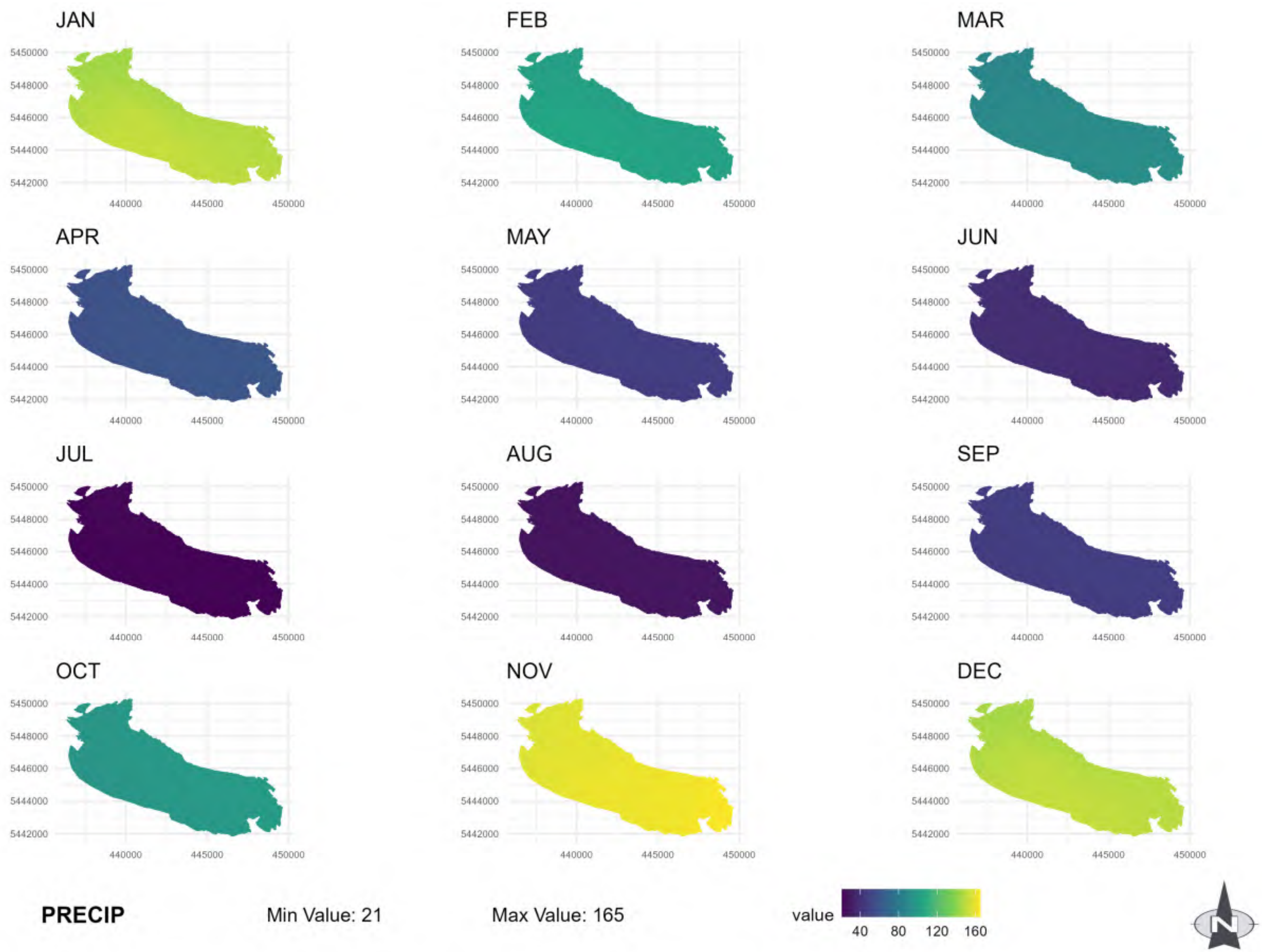


Figure 27: Gabriola Island monthly precipitation (mm)

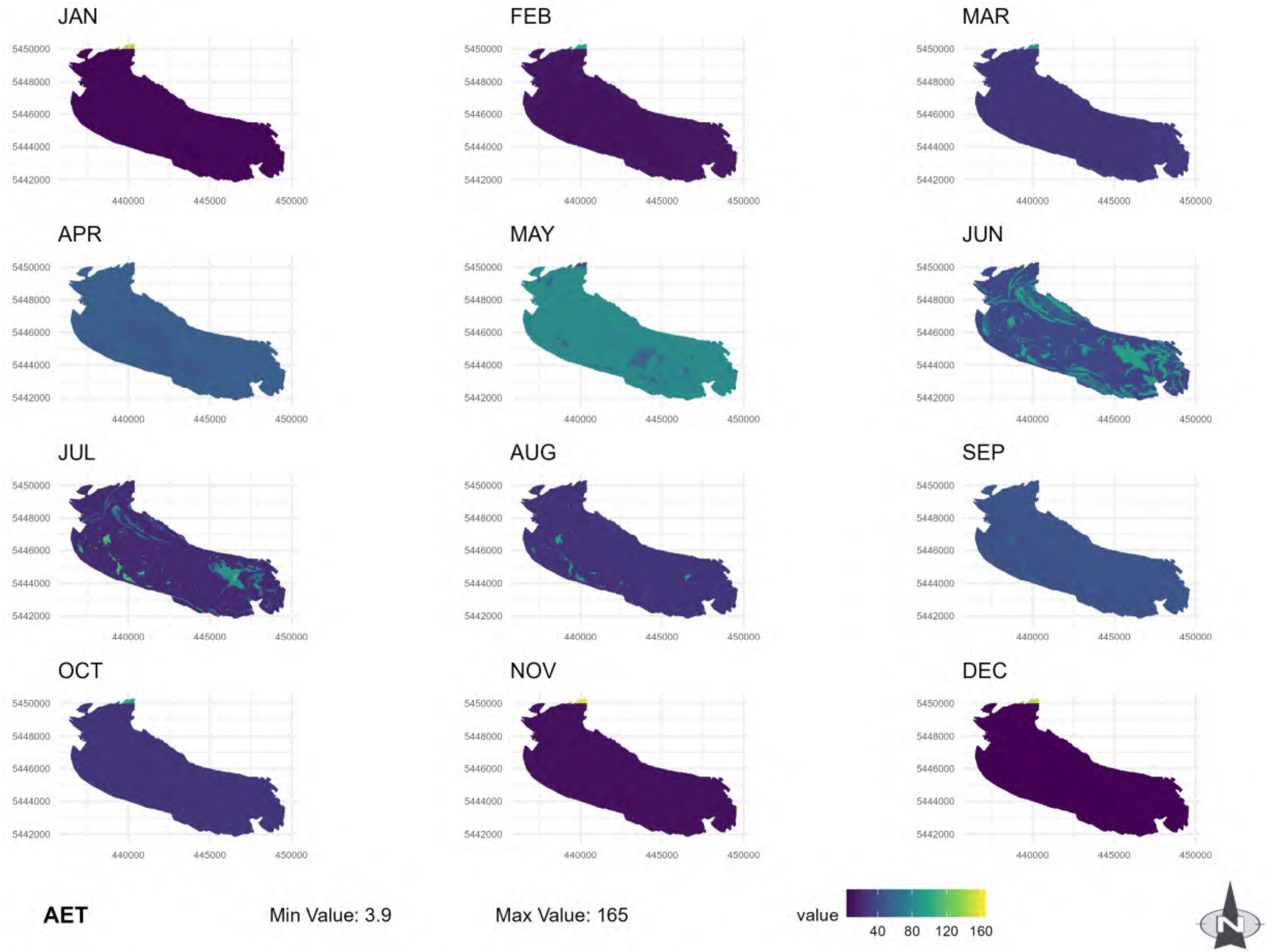


Figure 28: Gabriola Island monthly actual evapotranspiration (mm)

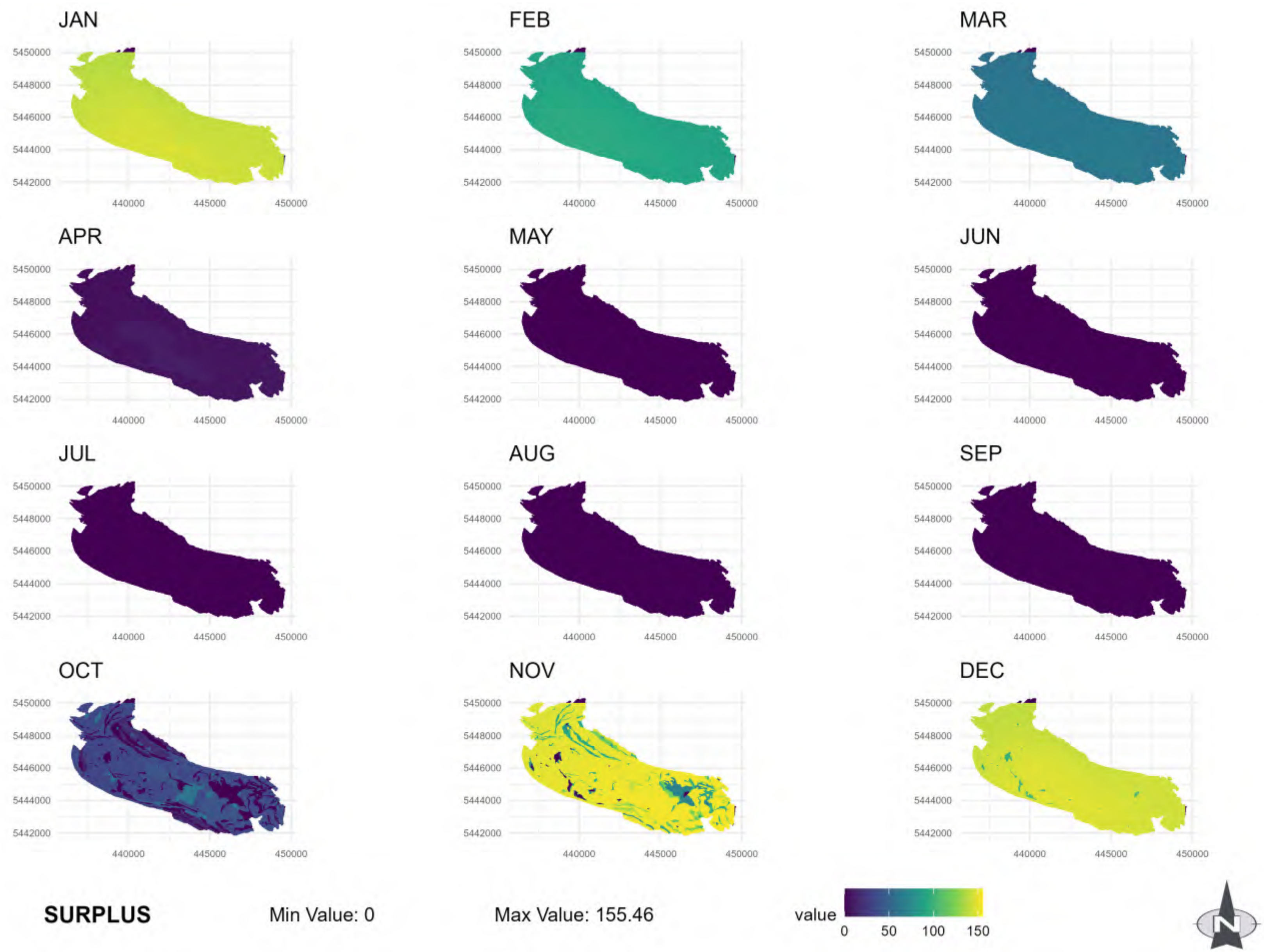


Figure 29: Gabriola Island monthly water surplus (mm)

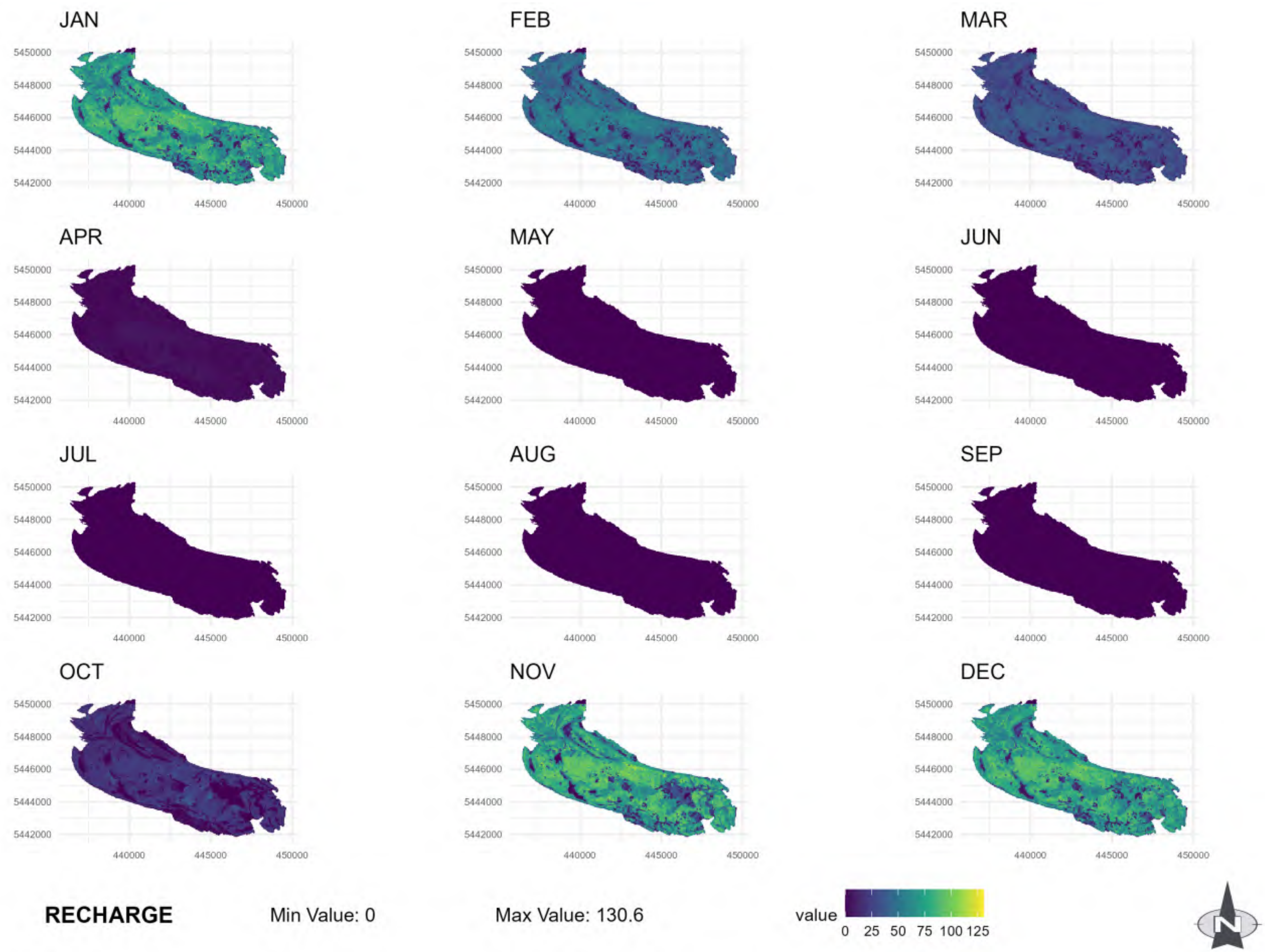


Figure 30: Gabriola Island monthly recharge (mm)

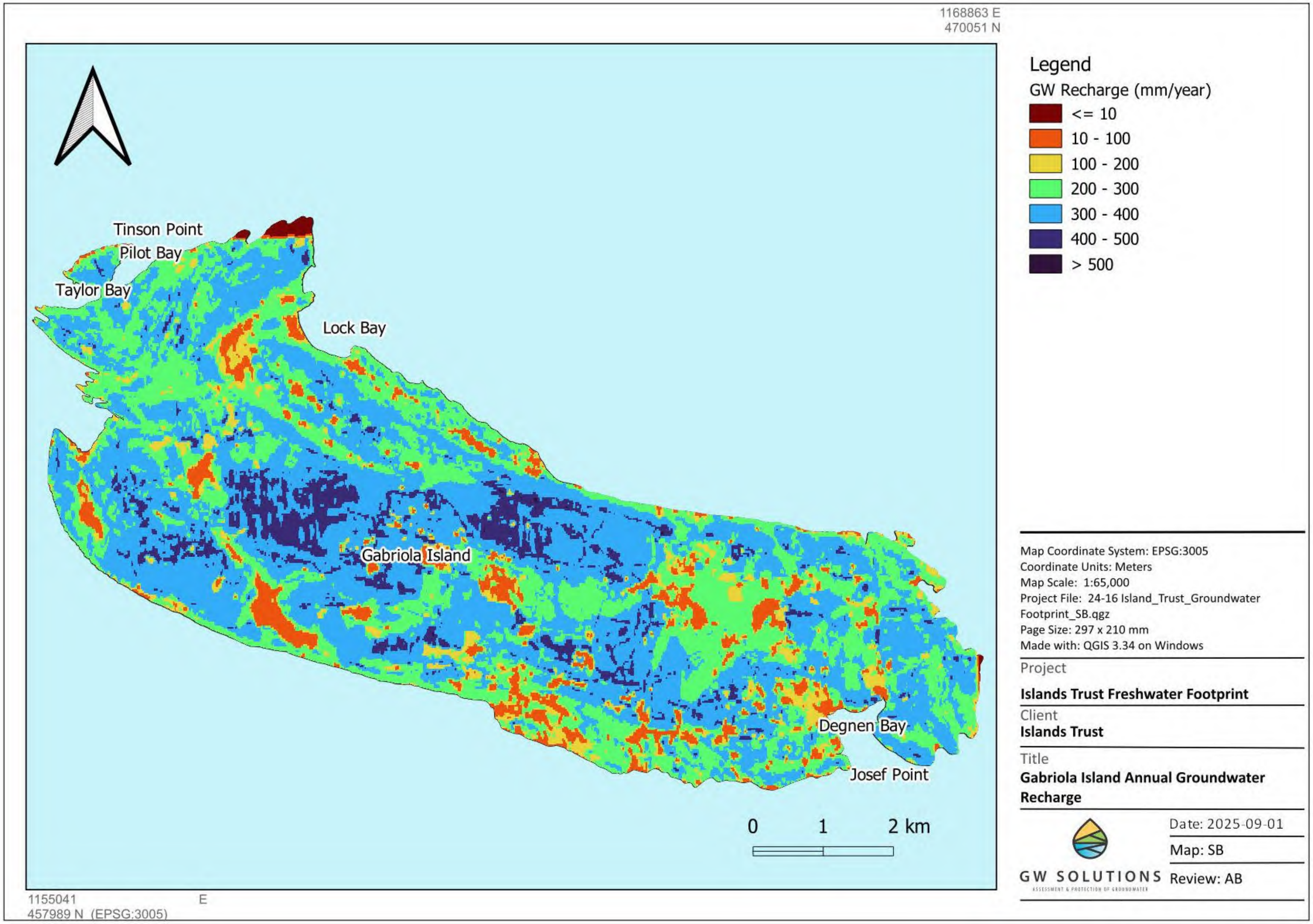


Figure 31: Gabriola Island annual groundwater recharge (mm/year).

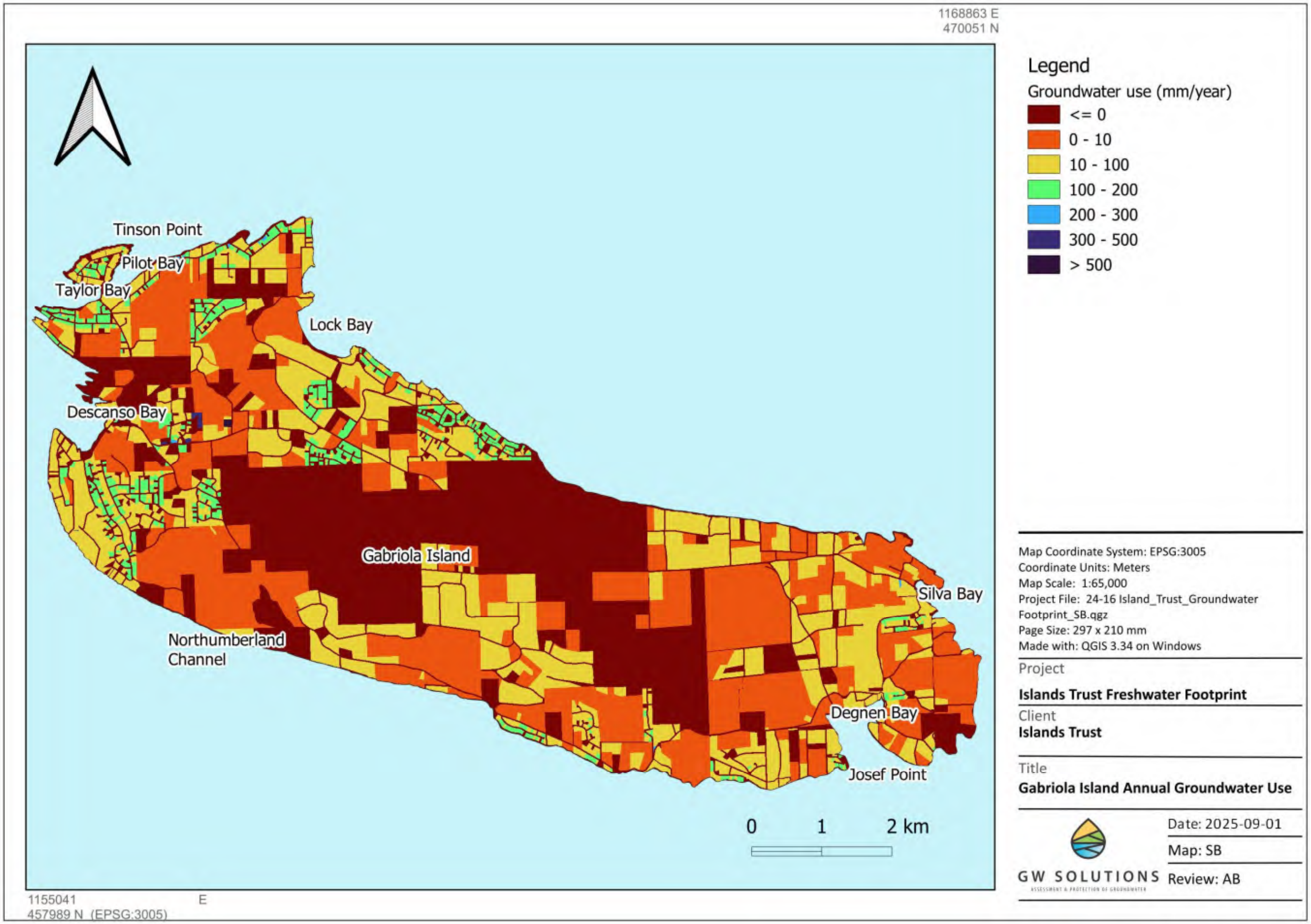


Figure 32: Gabriola Island annual groundwater use (mm/year).

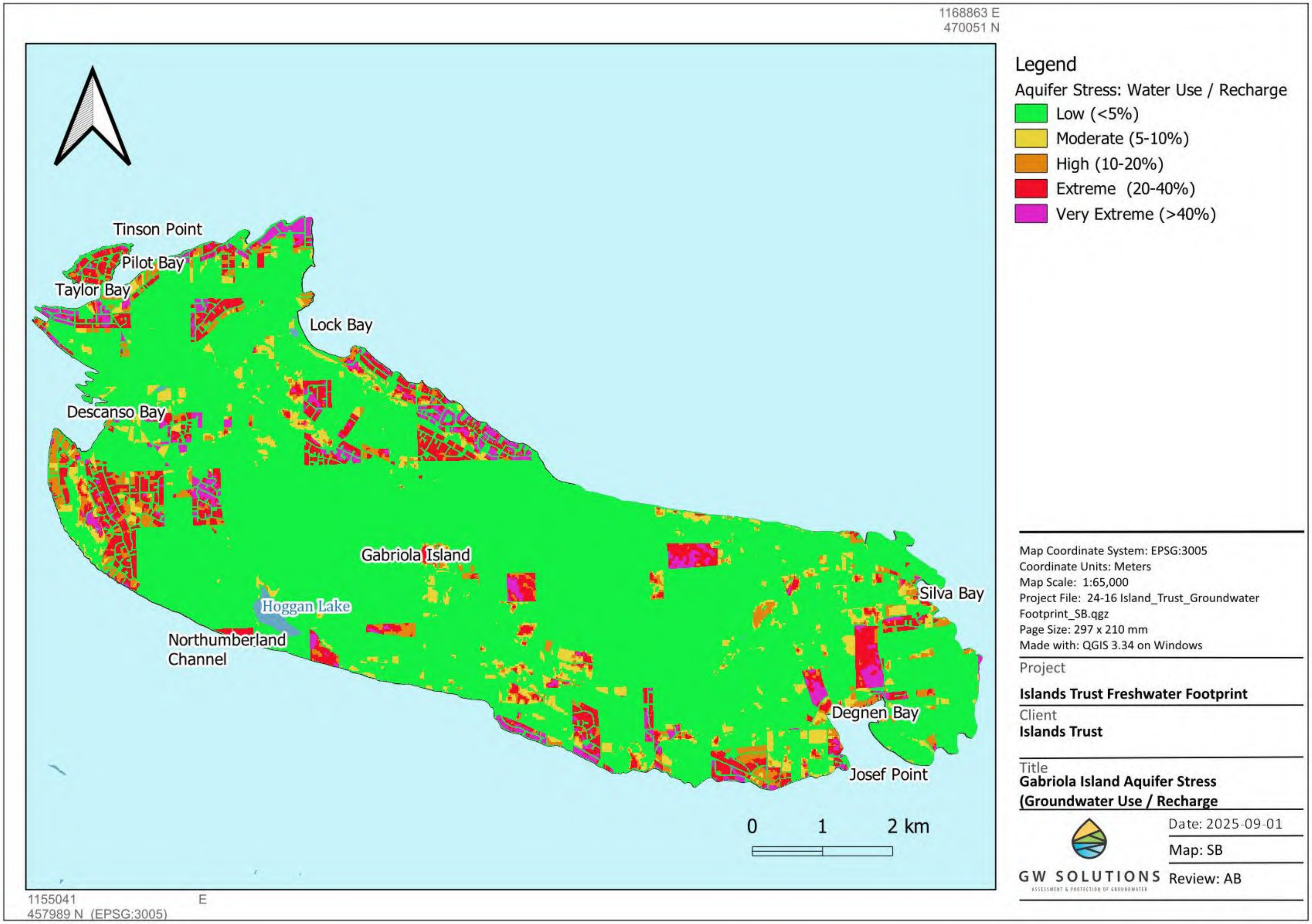


Figure 33: Gabriola Island Aquifer Stress, Ratio of Water Use/Recharge (mm).

6.4.5 Hydraulic Connectivity

The likelihood of hydraulic connectivity was assessed for streams across Gabriola Islands. Based on comparison of groundwater and stream levels, many of the streams across the island are likely to not be connected to the groundwater system. Where hydraulic connectivity was determined to be likely, both losing and gaining conditions were interpreted to occur.

There is currently a lack of monitoring data to validate the map assessment. Periodic monitoring has been completed by local groups such as Gabriola Streamkeepers on Mallet Creek and other sources, but there are no provincial or no long-term hydrometric sites. Mallet Creek, which has a dam to retain some storage in Peacock Lake, drains toward the west island north of Descanso Bay is reported as flowing year-round; other streams such as Columbia Creek and Winthuysen Creek are ephemeral, with diminished flows during the dry season (Doe, 2017).

Seasonal precipitation and runoff, rather than groundwater, are typically the dominant source of discharge in streams with low or no summer baseflow (Ward and Robinson, 2000). On Gabriola Island, insufficient data were available to estimate groundwater discharge to surface water bodies. It is likely that discharge to streams is a minor component of the annual water balance on the island. A previous water balance study of the island similarly did not incorporate analysis of groundwater-streams connectivity (SRK Consulting Inc., 2013).

Additional monitoring of streamflow and condition (i.e. when flow declines or stops in the spring and summer) on Gabriola Island is recommended to better quantify groundwater-surface water interrelationships. Monitoring of wetland level, temperature and seasonal drying-wetting patterns could also be useful to understand the interaction of these environments with groundwater systems. The focus of monitoring could include streams and areas identified as likely hydraulically connected and gaining, as shown in Figure 34.

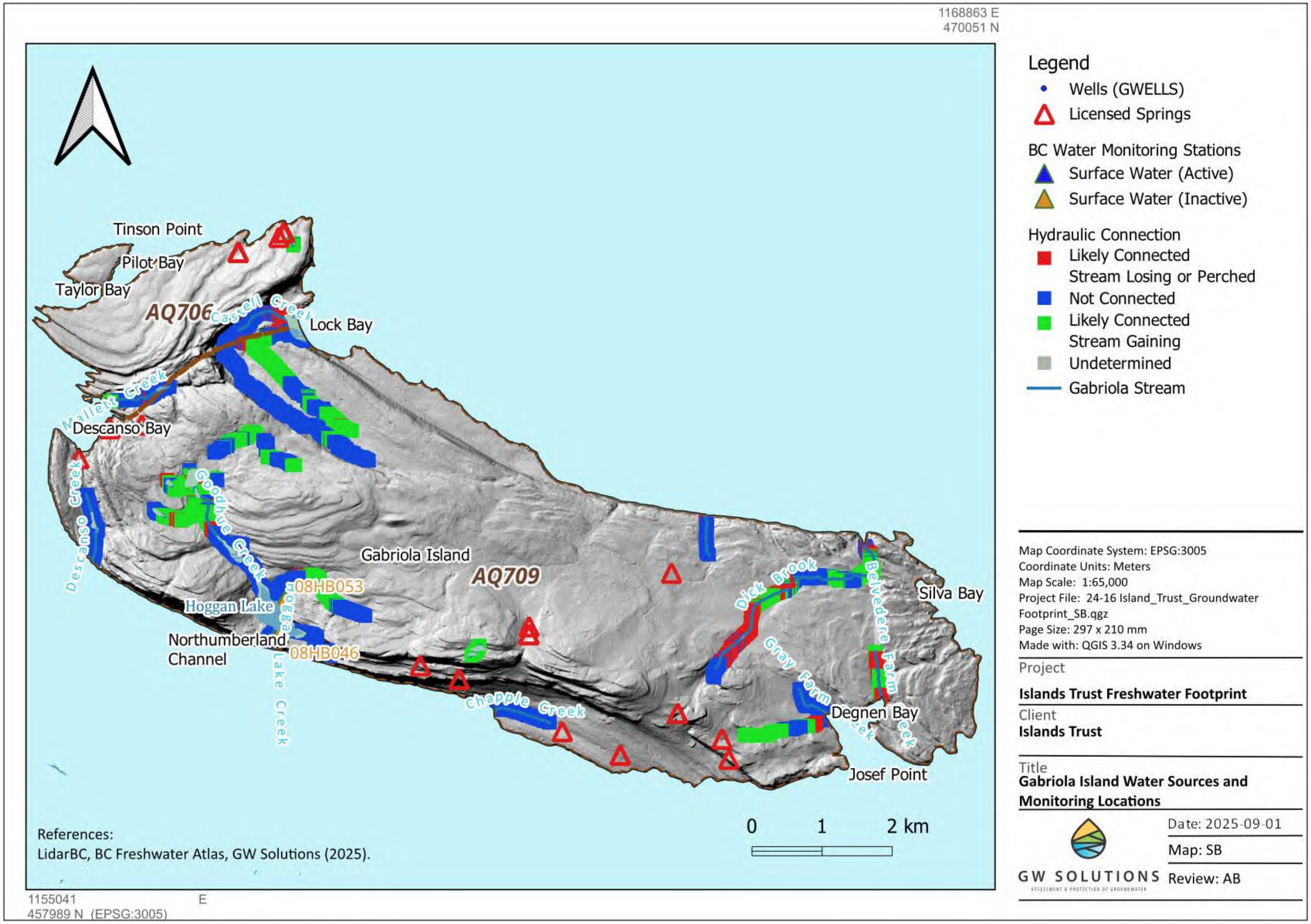


Figure 34: Gabriola Island streams potential hydraulic connection to groundwater.

6.5 Freshwater Hazard Assessment

6.5.1 Groundwater Monitoring Observations and Trends

In comparison to other islands in the Trust Area, Gabriola Island has the most active and long-term monitoring locations. Groundwater level and temperature are monitored in five dedicated Provincial Groundwater Observation Wells (PGOWN wells) and groundwater level, temperature and electrical conductivity (a measure of water salinity) are monitored in two RDN Volunteer Observation Wells. Long-term trends were assessed for wells with at least 10 years of monitoring, for the period from 2013-2025. In most locations there is a stable long-term trend, and groundwater levels have changes by less than 3 cm per year.

Observation Well (OW)197, in central Gabriola Island along North Road monitors groundwater conditions within a relatively undeveloped area, representative of ambient conditions in this area of the island; the hydrograph for OW197 exhibits a moderate declining trend, decreasing by approximately 5 cm per year over the period evaluated (Figure 36). In general, the observation well trends do not indicate significant aquifer stress, although the observed declining trend in OW197 may be related to climatic factors affecting groundwater recharge.

Table 27: Gabriola groundwater level trends, adapted from (Regional District of Nanaimo, 2025d)

RDN Water Region	Aquifer Number	Aquifer Material	Observation Well Number	Data Range (dataset)	Trend Result (cm per year) (Note 1)	Historical Groundwater Level Trend
WR7 - Gabriola Island	709	Bedrock	OW 196	2013 - 2025	-1.2	Stable
			OW 197	2013 - 2024	5.2	Moderate Decline
			OW 316	2013 - 2025	-2.1	Stable
			OW 385	2013 - 2025	1.4	Stable
			RDN VOW 07	2013 - 2025	-0.9	Stable
			RDN VOW 08	2013 - 2025	-1.3	Stable

Note 1: Groundwater level trends assessed by comparing long-term annual average in meters below ground level, therefore a positive trend indicates deepening water levels, and a negative trend indicates that the average groundwater level is increasing. Trend categories are defined in Table 13, based on (Environmental Reporting BC, 2024).

Although Gabriola has seven long-term monitoring locations, their siting and spatial distribution illustrate the challenge of obtaining representative datasets to assess long-term conditions and threats. For example, all of the active monitoring locations on Gabriola Island are situated in AQ709, and no monitoring locations are active in AQ706 on northwest Gabriola

Island. There are also no active monitoring locations in some of the more developed areas of the island, including the Sands, Descanso Bay and Silva Bay Regions, and in the village/commercial areas centred around North and South Road where many non-domestic water users are located. Further developing local networks including groundwater level monitoring by water systems and non-domestic well owners would help to improve understanding and tracking of long-term trends.

Compiled hydrographs and statistics for Gabriola groundwater monitoring locations are included in Appendix B, reproduced from (Regional District of Nanaimo, 2025d).

6.5.2 Seawater intrusion hazard

The estimated depth to the saltwater interface is shown in Figure 37. Areas where the interface is closest to sea level include the northwest island (Sands Region), in particular in the area of Twin Beaches Park peninsula. Other areas with shallow freshwater lens include the southwest island (Northumberland Channel) southeast and east island (False Narrows, Silva Bay). Although the map scale extends up to 500 m depth based on the model, freshwater is not anticipated to be found at depth in the centre of the island and deeper wells are likely to intersect fractures containing mature, highly mineralized water. Previous studies have indicated that fracture productivity likely decreases with depth in the aquifer, with limited flow below a depth 200 m (Burgess and Allen, 2016; Hodge, 1978).

The thickness of the freshwater lens below sea level is proportion to the groundwater elevation above sea level, therefore the depth of the interface is very sensitive to changes in groundwater elevation. For example, if the depth of the interface is less than 5 m below sea level, the available drawdown of freshwater above sea level will be approximately 1 m. For this reason, best management practices for prevention of sea water intrusion include avoiding drawdown of groundwater levels below sea level, as this will allow the freshwater-saltwater interface to move upward and inland, potentially affecting water quality in other adjacent wells.

Seawater intrusion hazard zones were identified by dividing coastal areas of the inland into zones or categories reflecting the relative hazard of seawater intrusion based the thickness of the freshwater lens (depth to the saline interface), shown in Figure 38. This hazard zone map was then used as an input for the final freshwater footprint spatial calculation.

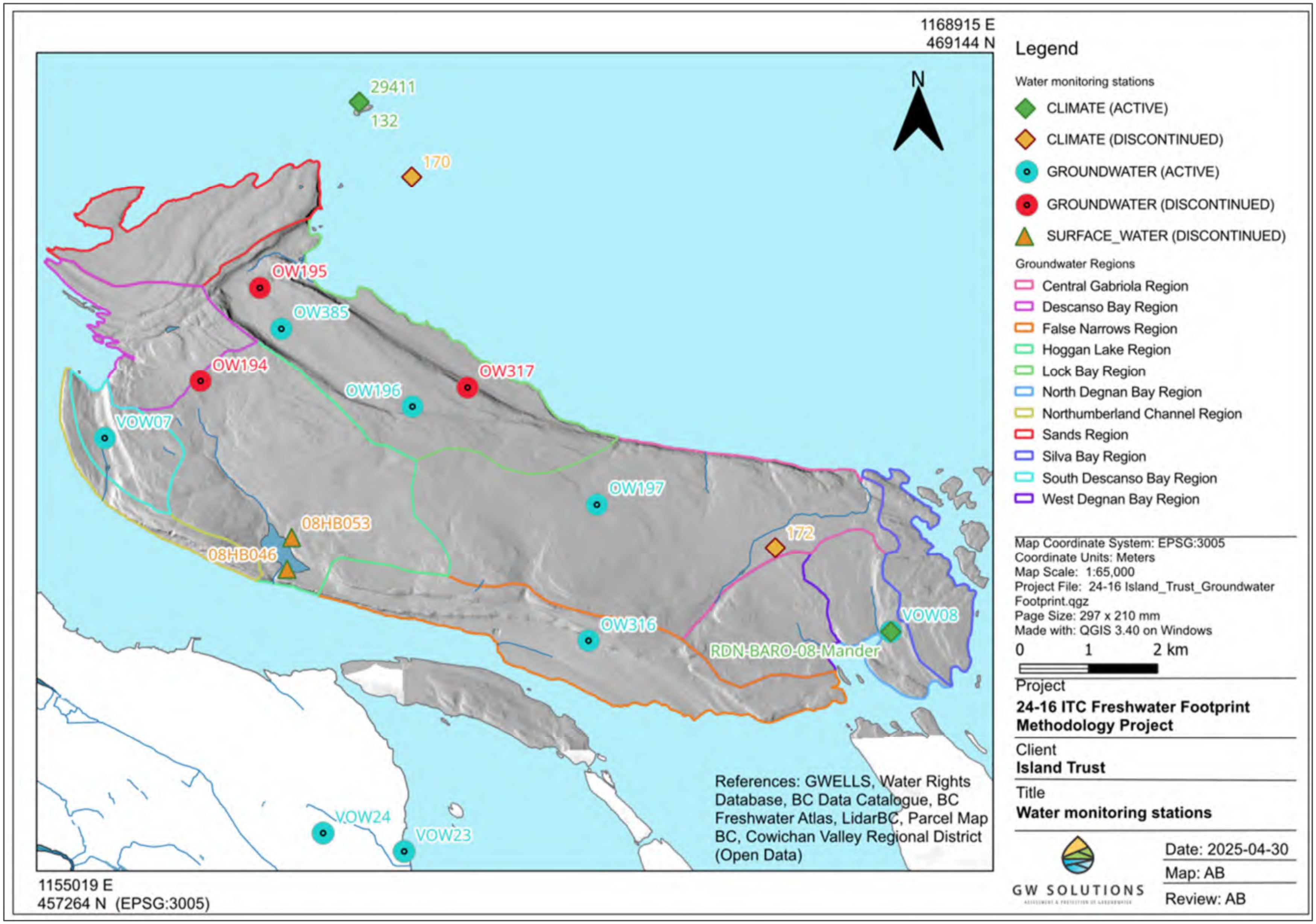


Figure 35: Gabriola Island monitoring locations.

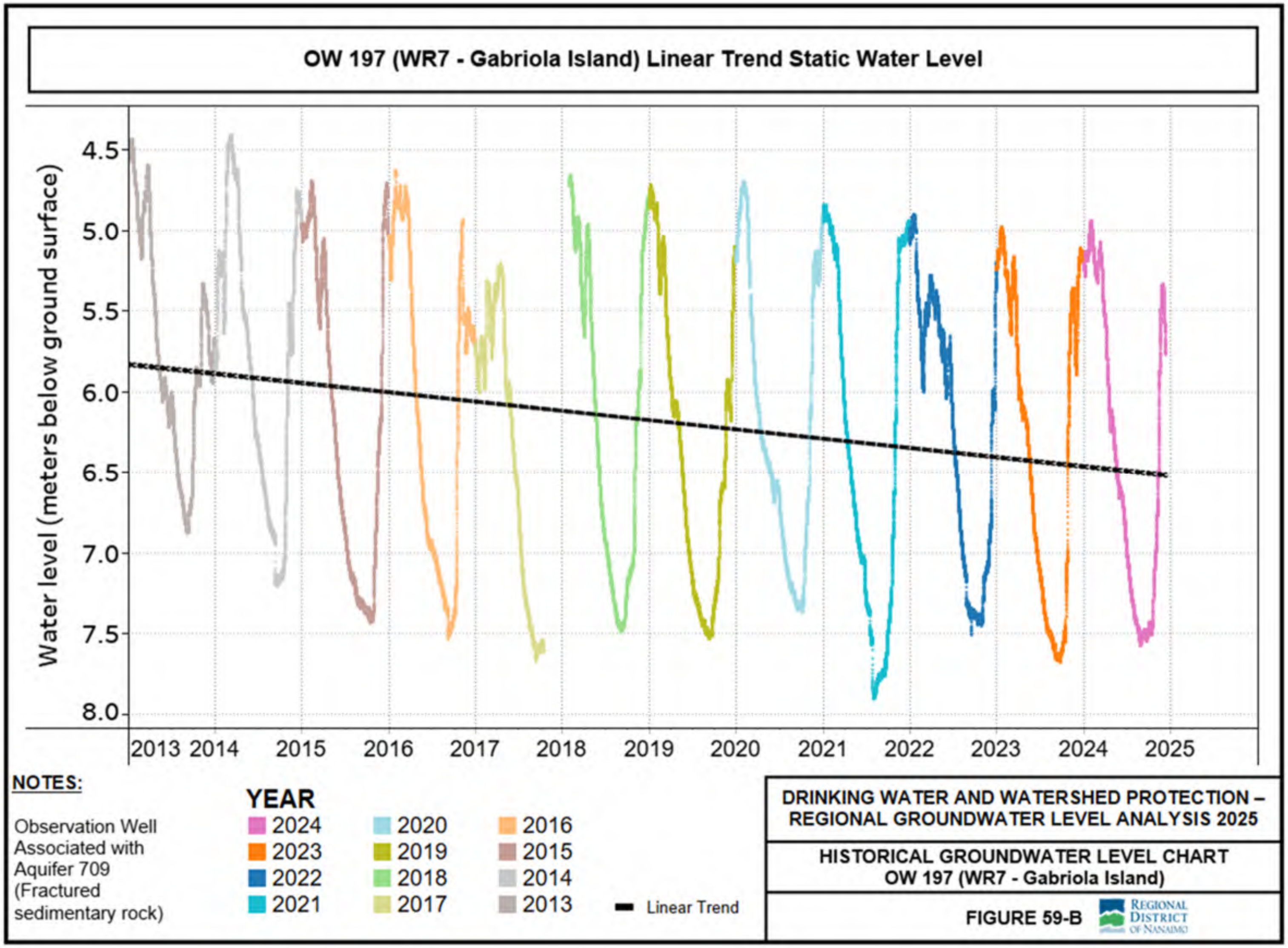


Figure 36: Gabriola Island Observation Well OW197 Long-term trend, reproduced from (Regional District of Nanaimo, Drinking Water and Watershed Protection, 2025).

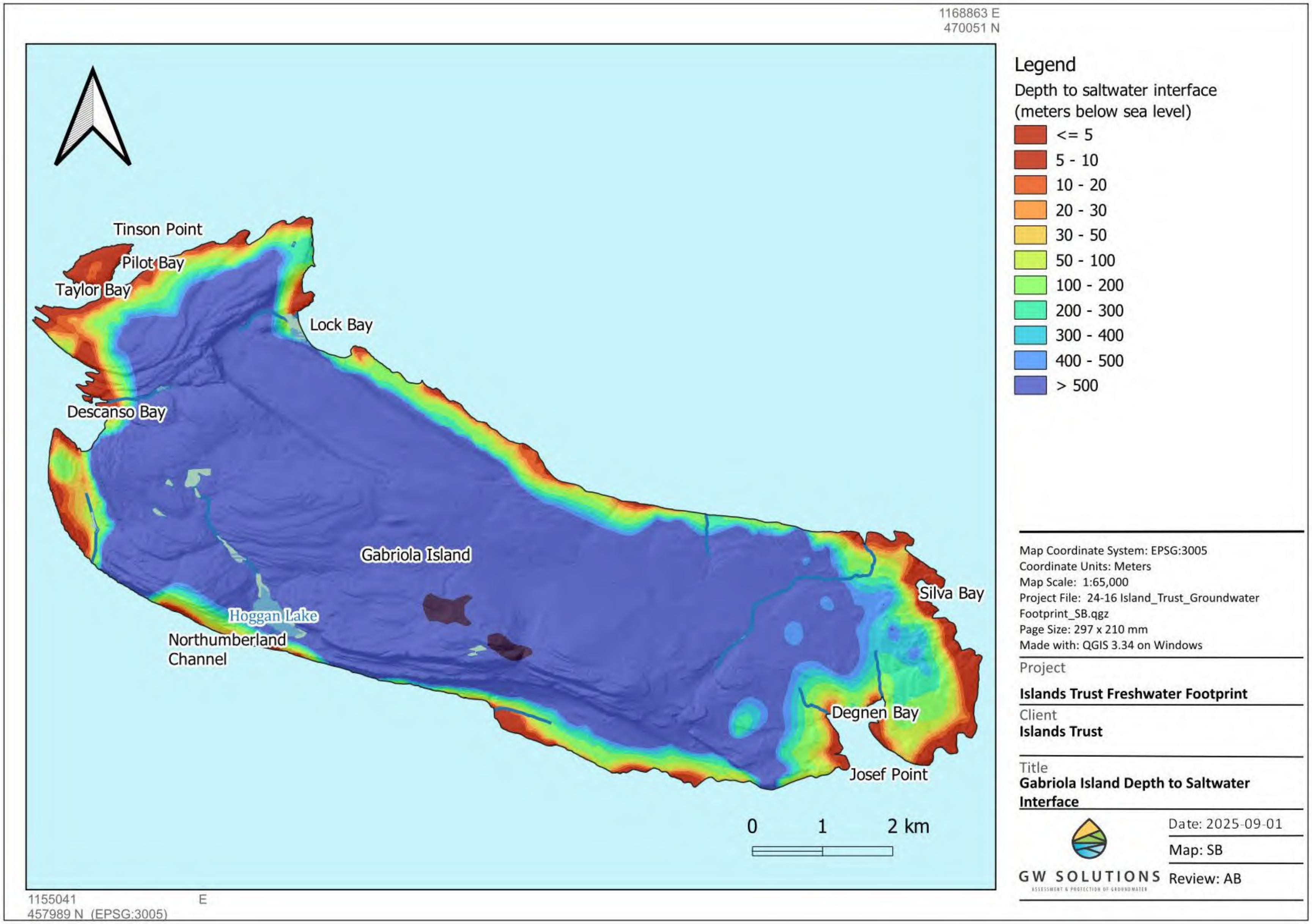


Figure 37: Gabriola Island depth to the saline interface meters below sea level (mbsl).

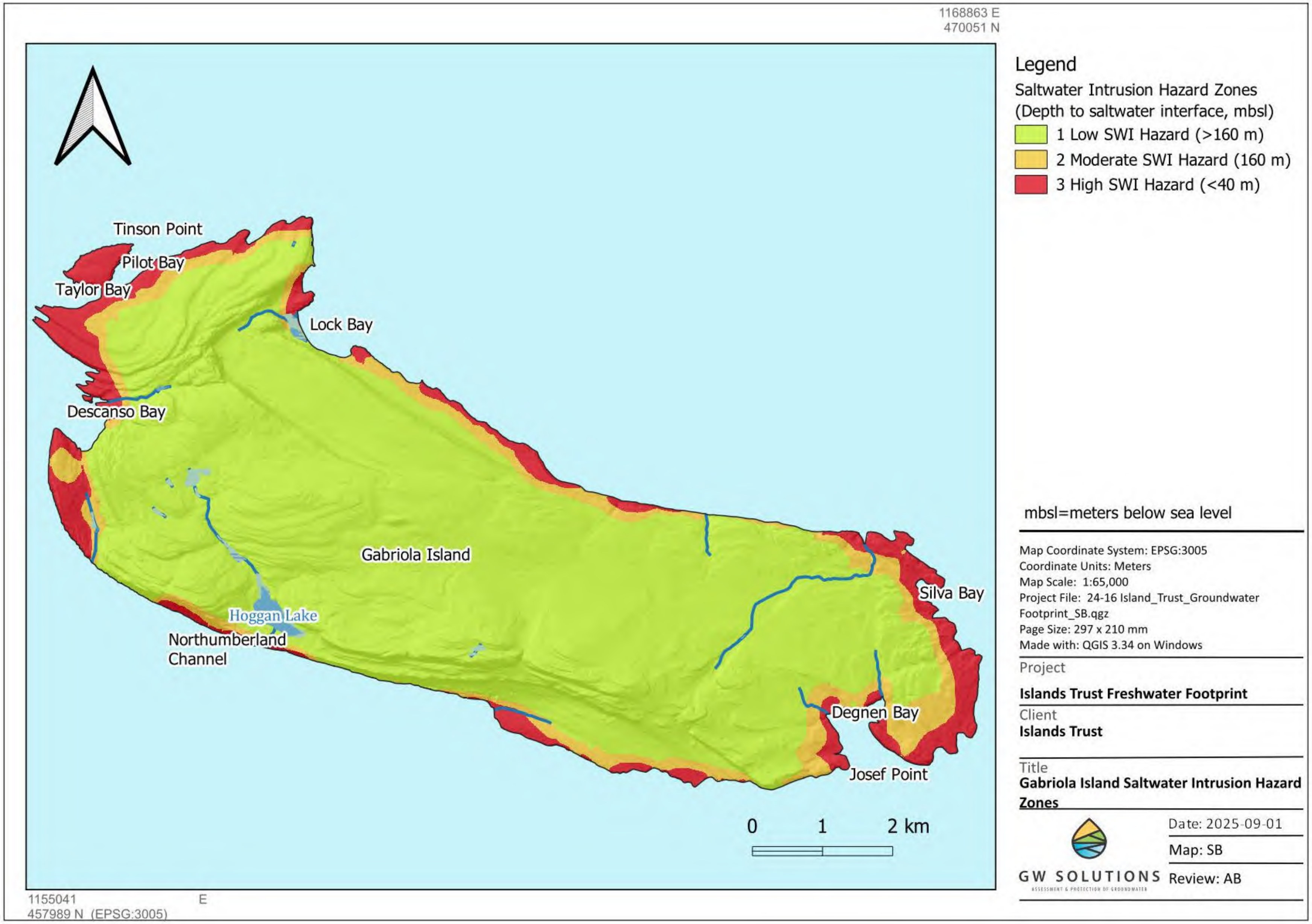


Figure 38: Gabriola Island seawater intrusion hazard zones.

6.5.3 Groundwater Quality Assessment

This project involved a comprehensive compilation and assessment of water quality data available for Gabriola Island. This was completed for several purposes:

- The presence of natural contaminants affects the usability of groundwater for drinking, therefore obtaining water of suitable quality is an important aspect of freshwater sustainability and security on the island.
- Water quality can indicate natural, climate-related, or other human caused factors influencing water quality. For example, if groundwater levels deepen during a long dry season or drought, the concentration of minerals and elements in the groundwater may increase as older, more mature groundwater is drawn from deeper fractures. In coastal areas, pumping can draw in saline water from a marine source, increasing the concentration of chloride or electrical conductivity in the water.
- Regional characteristics and trends in water quality may confirm or further validate of the water balance results and provide additional observations with respect to water stress and pressures affecting different areas of the island.

Water quality data were obtained from local studies (Earle and Krogh, 2006), and published sources including the Environmental Monitoring System database (Province of BC, 2025b). An invaluable source of data was obtained form the Regional District of Nanaimo well rebate program, which assists well owners with the cost of water quality lab analysis; participating well owners may indicate permission to share the data for research purposes. Additional data from sampling of permitted water systems on the island was obtained through a Freedom of Information request to Island Health from which select records were digitized to fill spatial data gaps or information in areas of interest. All available results were digitized and compiled into a master database for further analysis. Efforts were made to include recent data representative of current conditions (1985-2025); older historical data (Hodge, 1978) were not digitized due to time constraints, and differences in lab methods and reporting criteria. The water quality samples included results for both naturally occurring minerals, and parameters used to indicate aquifer stress, saltwater intrusion impacts, or contamination sources.

6.5.4 Water Quality Results

Data from a total of 540 laboratory analyzed samples from groundwater sources on Gabriola Island were compiled. The dates of sample collection ranged from 1985 to 2025 and included results for over 21,000 individual parameters. Figure 39-A shows the number of samples analyzed for each year, indicating that most samples were collected within the last decade (i.e. since 2013). The large number of samples collected in 2001 were associated with the Vancouver Island University study (Earle and Krogh, 2006). Figure 39-B shows the number of parameter results analyzed per year; the distribution reflects the number of samples available in each year, and changes in laboratory results e.g., in older samples the laboratory may have reported results for fewer parameters.

Table 23 shows the number of samples with concentrations of parameters below and above the Canadian Guidelines for Drinking Water Quality (GDWQ), and minimum and maximum (range) in concentration measured within each category. The results are compared to three types of drinking water guidelines: a Maximum Acceptable Concentration (MAC) for parameters related to health concerns, an Aesthetic Objective (AO) for parameters that affect the taste, odour and pleasantness of water for drinking, an Operational Guideline (OG), for parameters that influence the proper function of drinking water system disinfection or treatment, and As Low As Reasonably Achievable (ALARA) referring to recommendations for treatment to reduce concentrations of specific parameters in drinking water supplies (Health Canada, 2024a). A description of key parameters and their results are discussed below.

6.5.4.1 *Natural contaminants*

Elements such as fluoride, iron, and manganese are commonly present in groundwater in this region, due to the weathering and dissolution of rocks in contact with the groundwater (McGuigan et al., 2010).

Arsenic is a metalloid known to be naturally present at low to moderate concentrations within groundwater in some areas of Vancouver Island and the Gulf Islands, that originates from the weathering of arsenic-bearing minerals. Arsenic can also occur due to contamination from human activities (such as infiltration or runoff from mining or industrial effluent. In drinking water arsenic has no apparent smell or taste. It has been linked to both acute (toxic) and chronic health impacts including skin conditions, cardiological and neurological impacts and increased risk of some internal cancers (Health Canada, 2006b). The guideline for Canadian drinking water quality for arsenic is a Maximum Allowable Concentration (MAC) of 10 µg/L (Health Canada, 2024a). Arsenic can be removed using treatment technologies such as ion exchange, adsorption, coagulation/filtration, greensand filters or reverse osmosis (Health Canada, 2006b).

Results: Arsenic concentrations were below water quality guidelines in most samples (95%). A small number of samples had results above the limits, while the 95th percentile concentration was 3.317 mg/L, more than 300 times the drinking water limit of 0.01 mg/L. A map of arsenic concentration by sample site is shown in Figure 40.

Fluoride is an element present naturally in water. In groundwater fluoride comes from weathering of rocks and soil with fluoride containing minerals. Health Canada has established a Maximum Acceptable Concentration for fluoride of 1.5 mg/L (Health Canada, 2010). Drinking water containing higher concentrations of fluoride may be linked to harmful changes in the mineralization of bones and teeth, leading to problems such as skeletal fluorosis, bone density changes, and risk of fractures. Fluoride is also linked to potential impacts on reproductive health (Health Canada, 2010).

Result: A total of 32 samples (9%) had concentrations of fluoride above guidelines. For samples that exceeded 1.5 mg/L, the median concentration was 3.4 mg/L and the highest range (95th percentile) was 9.3 mg/L. The concentrations of fluoride by sample site are shown in Figure 41.

Iron and manganese are two metals often naturally present in groundwater, that can affect the aesthetic quality or pleasantness of water for drinking. The Health Canada Aesthetic Objective (AO) for iron is 100 µg/L; above this concentration the water may have a red colour, cause staining of plumbing or fixtures, and may be unpalatable for use (Health Canada, 2024b). Manganese is also commonly present in groundwater found on its own or in water that also has high iron concentration (Health Canada, 2024a). There are two Canadian guidelines for drinking water quality for manganese. The lower Aesthetic Objective (AO) is 20 µg/L, above this concentration the water may have a noticeable colour (e.g. visible black flecks or particulate), unpleasant taste and be less palatable for drinking, and can cause staining of household plumbing fixtures and laundry. A higher Maximum Allowable Concentration (MAC) for manganese of 120 µg/L has also been established; drinking water with manganese above this concentration may be associated with adverse health impacts including effects on neurological development in children. Both manganese and iron concentration can be reduced by water treatment using oxidation, adsorption with specialized granular media, and filtration (Health Canada, 2024b).

Results: Up to 19% of samples exceeded the GDWQ for iron, established based on aesthetic concerns (taste, colour). Manganese was notably higher than other metals, with 36% of samples exceeding the aesthetic objective (AO). Sample concentrations ranged from 0.01 mg/L up to 0.61 mg/L, with samples at higher concentrations exceeding both the AO and upper health related MAC (0.12 mg/L). A map of manganese concentrations by sample site is shown in Figure 42.

6.5.4.2 *Land use and contamination sources and indicators*

Bacteria including total coliforms and *Escherichia coli* are analyzed to indicate the vulnerability of a water source to potential pathogens (Health Canada, 2020a). Total coliform bacteria are found naturally in shallow soil and surface water sources such as lakes and ponds. The presence of total coliforms in a groundwater sample may indicate that surface water or water from a shallow source has entered the well, for example, from recharge transmitted to the well through shallow fractures. Surface water and shallow groundwater may contain harmful pathogens that can affect the health of people using the water for drinking. *Escherichia coli* (E. coli) are a type of fecal coliform bacteria present in the digestive systems of animals and humans; therefore if these bacteria are found, it indicates that the sample or the groundwater source has been contaminated with fecal matter, in which pathogens such as viruses or harmful bacteria may also be present (e.g., diarrhea causing *Giardia*) (Health Canada, 2020b).

Since 2005, wells constructed in BC are required to have a bentonite clay surface seal that prevents water from leaking into the well through the gap between the outside casing and the surrounding soil or rock (Province of BC, 2016a). If the surface seal material is eroded, removed, or is not present, such as in older wells, total coliforms or *E.coli* in a groundwater sample may indicate that surface water, or shallow drainage contaminated by sewage, is entering a well through the annular space around the casing. Therefore the well should be repaired to restore the surface seal. Wells are also protected from pathogens by ensuring a minimum setback distance of 30 m from potential contaminant sources, such as septic fields (Province of BC, 2011). Groundwater from a well, and water from a surface or groundwater source that is disinfected e.g. using chlorine or ultraviolet disinfection, should not contain any total or fecal coliforms, therefore the Drinking Water Quality Guideline is zero Colony Forming Units per hundred millilitres of water (0 CFU/100 mL) (Health Canada, 2020a, 2020b).

Results: From 45% to 60% of groundwater samples had total coliform above GDWQ (depending on the units or method of analysis). Approximately a third (16 of a total of 47) of the samples had fecal coliform bacteria, ranging up to a maxim of 782 CFU/mL. Fecal contamination can occur due to proximity of a well to sources of contamination (septic discharge, agricultural waste) and factors related to well construction, such as lack of a bentonite surface seal. Many wells on Gabriola Island are older (drilled before 2005), and do not have a surface seal. While the relatively shallow soil and overburden found in many areas allows for rapid infiltration and movement of drainage into the aquifer, with minimal filtration of bacteria and other pathogens.

Chloride (Cl) is a natural element abundant in rocks, soil and natural waters, and most abundant in the world's oceans (Health Canada, 1987). Chloride concentration is generally low in rain, surface water (rivers and lakes), and variable in groundwater depending on the processes occurring in the aquifer. For example, chloride concentration may be higher in water influenced by or mixed with water from marine sources. Other sources of chloride in groundwater include salt application to roadways, leachate from industry, and sewage effluent discharges, such as from septic systems. The drinking water guideline for chloride is an Aesthetic Objective of 250 mg/L. Water above this concentration water has a noticeable salty taste and can corrode water fixtures and distribution pipes (Health Canada, 1987).

Results: The concentration of chloride exhibited a wide range, from fresh (low, 6.6 mg/L) to an maximum of 2,600 mg/L. Only 5% of samples exceeded the drinking water limit of 250 mg/L. As shown in Figure 43, higher chloride samples were generally observed in wells closer to the coast, with some exceptions (e.g. deeper wells sited further inland).

Total Dissolved Solids (TDS) is a measure of the total concentration of dissolved minerals, metals, salts and organics in a sample, such as calcium, magnesium, sodium, bicarbonate, chloride and sulphate (Health Canada, 2025). The Health Canada operational guideline (OG) for TDS is 500 mg/L. At higher concentrations, TDS can cause scaling in home appliances and water fixtures such as hot water heaters. TDS can be higher in groundwater containing natural dissolved minerals, and in water contaminated by sewage, runoff and or industrial wastewater. Another commonly used measure of water salinity and mineral content is conductivity (EC), also referred to as electrical conductivity or specific electrical conductivity (corrected to a temperature of 25°C) (YSI Incorporated, 2009). Conductivity is correlated to the concentration of sodium and chloride and other major ions in the water. Both EC and Total Dissolved Solids (TDS), which can be calculated from EC, are easily measured in the field using a handheld meter to estimate the relative water salinity (US Environmental Protection Agency, 2025).

Results: Total dissolved solids concentration varied widely, from 100 mg/L up to 2,544 m/L, with a median of 240 mg/L for samples below guidelines. A total of 20 out of 256 samples (8%) exceeded the operational guideline. Higher TDS indicates more mineralized or saline groundwater, similar to chloride, which is present in samples from wells closer to the coast or in deeper wells. A map of TDS by site is shown in Figure 44.

Sodium (Na) is a component of salt (NaCl) dissolved in water from reactions with sodium containing minerals. It can also be present in wastewater and industrial discharges. Although non-toxic, sodium concentration above 200 mg/L can give water an unpleasant taste. Individuals with hypertension are also recommended to avoid ingestion of water with sodium above 20 mg/L (Health Canada, 1992). Sodium can be higher in water treated using a water softener to remove calcium and magnesium (i.e., hardness). In groundwater, sodium concentration can be an indicator of geochemical processes such as cation exchange or mixing of water from different sources (Allen and Suchy, 2001).

Results: A majority (95%) of samples contained sodium below the guideline, with only 16 samples exceeding 200 mg/L.

Nitrate (NO_3) is a water quality parameter that varies in concentration in water impacted by human activities and land use. Nitrate contamination from point and non-point sources is a significant environmental problem impacting both surface and groundwater quality in Canada and worldwide (Rivett et al., 2008; Rudolph et al., 2015). The ambient concentration of nitrate within groundwater in B.C. is typically very low, less than 0.1 mg/L (Wei et al., 2010). Nitrate concentrations greater than 1 mg/L in surface or groundwater are considered indicative of anthropogenic impacts associated with industry, agriculture and urban development (Dubrovsky and et al, 2010). More elevated nitrate concentrations (above 2 mg/L) in groundwater can often be attributed to pollution sources, such as infiltration of surface water or run-off containing residues of chemical fertilizers or animal manure, or from human waste discharges from septic tanks or sewage systems (Health Canada, 2013).

In water, nitrate has no colour, taste, or smell and it can only be measured by a laboratory or chemical test. The drinking water guideline for nitrate in drinking water is a Maximum Acceptable Concentration (MAC) of 10 mg/L (when measured as nitrate-nitrogen) (Health Canada, 2024a). Nitrate is a health concern as it can affect oxygen metabolism in the bloodstream, associated with adverse effects in young children (causing methaemoglobinaemia or “blue baby syndrome”) (Health Canada, 2013). Drinking water with nitrate at concentrations below current drinking water guidelines has also been linked to impacts on normal thyroid function, elevated risk of some cancers (colorectal, ovarian, thyroid, kidney and bladder), and adverse birth outcomes such as low birth rate and preterm birth (Schullehner et al., 2018; Temkin et al., 2019; Ward et al., 2018). Water treatment methods for removal of nitrate include anion exchange, reverse osmosis, biological denitrification, and distillation. However, boiling water can increase nitrate concentration (Health Canada, 2013).

Results: Nitrate concentrations ranged from 0.002 (the laboratory detection limit), up to 10.47 mg/L. Only 2 of 426 samples exceeded the nitrate guidelines. The median (and background concentrations of nitrate were relatively low (0.03 mg/L for samples below the limit). Although there is a general perception that nitrate from septic discharges is affecting local groundwater quality, based on this sample set, nitrate concentrations remain mainly near background or low levels (see discussion in 6.5.6). Figure 45 shows the nitrate concentrations by sample site.

In summary, the current review indicates that groundwater quality on the Gabriola Island is generally fresh, with generally low concentrations of natural minerals and contaminant indicators. Bacterial quality suggest that factors such as well construction and maintenance could be improved to protect well water quality. Metals such fluoride and manganese exceed guidelines in small to moderate proportion of sources, while the concentrations of chloride and TDS are variable.

6.5.5 **Water Type**

A Piper diagram showing the relative concentration of major ions in water samples from Gabriola Island is shown in Figure 46. The samples, symbolized by groundwater region and well depth show not obvious trends in water type by depth or region. Samples that are calcium-magnesium-bicarbonate water type (left purple segment of the diamond on the Piper plot) are considered fresh, and representative of younger, recently recharged groundwater. Older, more mature groundwater with higher concentrations of dissolved minerals is within the sodium bicarbonate water type (lower green segment of the upper diamond on the piper plot). Water of sodium chloride water type (red segment of the diamond), may be mixed with water from a saline source, such as from seawater intrusion water near the coast.

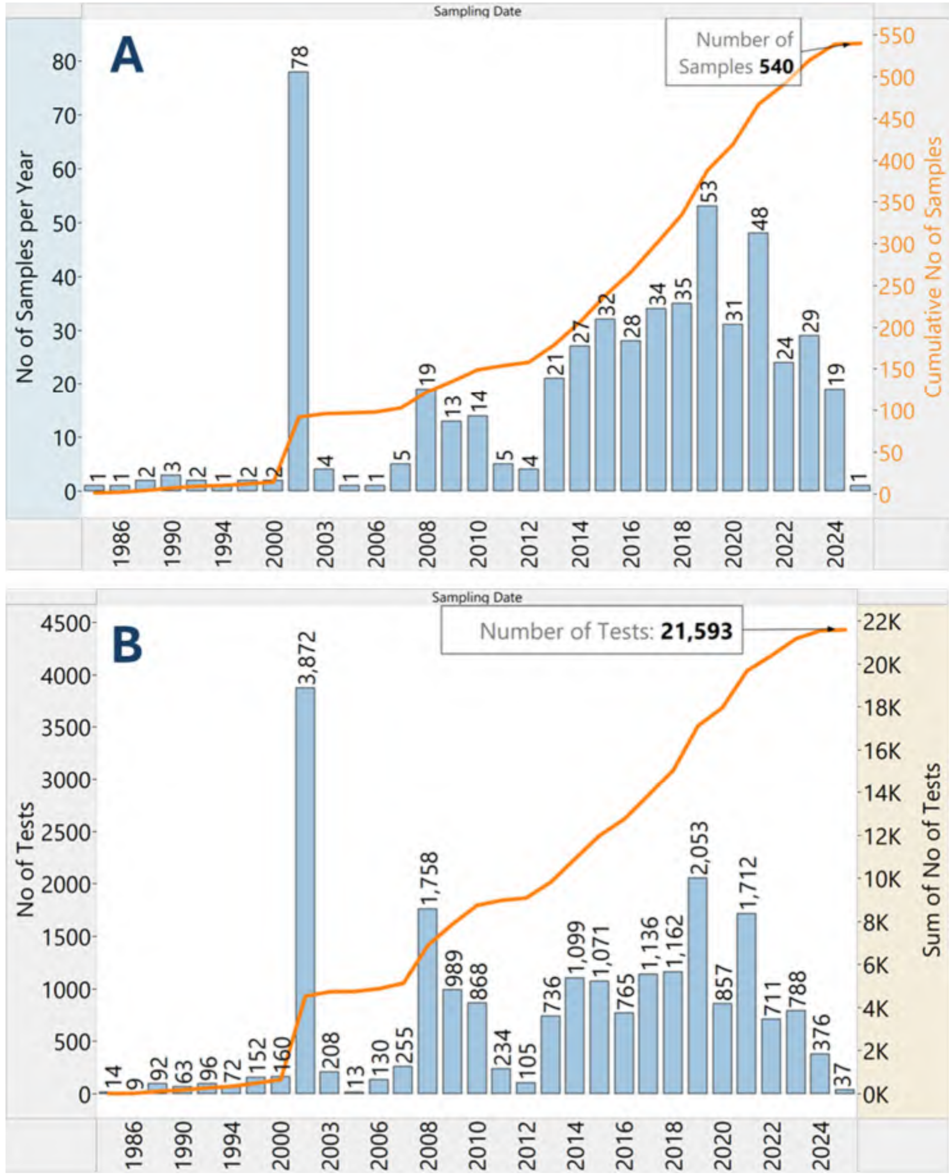


Figure 39: Gabriola Island water quality data compilation. A. Number of samples by year of collection. B number of parameter results by year of sample collection.

Table 28: Water quality results summary for bacteria, major ions, metals, nutrients and physical properties.

Parameter Group	Parameter Standard (Unit)	Min (Q5)	Median	Max (Q95)	Lower Limit Drinking water	Upper Limit Drinking water	Tye of Guideline	Exceedance Analysis	Number of samples
Bacteria	Coliform - Fecal (CFU/100mL)	0	0	0	0	0	MAC	Value does not exceed guideline	31
		1.75	5	782	0	0	MAC	Value exceeds guideline	16
	Coliform - Total (CFU/100mL)	0	0	0	0	0	MAC	Value does not exceed guideline	35
		2	62.5	4,615.00	0	0	MAC	Value exceeds guideline	50
	Coliform - Total (MPN/100mL)	0	0	0	0	0	MAC	Value does not exceed guideline	89
			11	182	0	0	MAC	Value exceeds guideline	73
Ions	Sulfate (mg/L)	1.54	14	36	0	500	AO	Value does not exceed guideline	437
	Sodium Total (mg/L)	12.4	78.95	161.1	0	200	AO	Value does not exceed guideline	300
		216	313	1,083.50	0	200	AO	Value exceeds guideline	16
	Fluoride (mg/L)	0.053	0.2	0.9	0	1.5	MAC	Value does not exceed guideline	320
		1.655	3.41	9.335	0	1.5	MAC	Value exceeds guideline	32
	Chloride (mg/L)	6.6	21	120	0	250	AO	Value does not exceed guideline	412
		360	808	2,600	0	250	AO	Value exceeds guideline	21
Metals	Arsenic Total (mg/L)	0.0001	0.0004	0.002691	0	0.01	MAC-ALARA	Value does not exceed guideline	400
		0.01144	0.013435	3.317025	0	0.01	MAC-ALARA	Value exceeds guideline	4
		0.042	0.06	0.06	0	0.01	MAC-ALARA	Detection limit greater than guideline	3
	Copper Total (mg/L)	0.00059	0.009765	0.2107	0	1	AO	Value does not exceed guideline	370

Parameter Group	Parameter Standard (Unit)	Min (Q5)	Median	Max (Q95)	Lower Limit Drinking water	Upper Limit Drinking water	Tye of Guideline	Exceedance Analysis	Number of samples
		1.06	2.51	151.5225	0	1	AO	**Value exceeds guideline**	**6**
	Lead Total (mg/L)	0.00014	0.00049	0.004148	0	0.01	MAC-ALARA	**Value does not exceed guideline**	**349**
		0.01097	0.03	0.683477	0	0.01	MAC-ALARA	**Value exceeds guideline**	**15**
		0.03	0.08	0.1	0	0.01	MAC-ALARA	**Detection limit greater than guideline**	**10**
	Cadmium Total (mg/L)	1.00E-06	1.00E-05	5.90E-05	0	0.005	MAC	**Value does not exceed guideline**	**364**
		0.006	0.01	0.01	0	0.005	MAC	**Detection limit greater than guideline**	**7**
		0.011	0.011	0.011	0	0.005	MAC	**Value exceeds guideline**	**1**
	Zinc Total (mg/L)	0.00186	0.0115	0.180505	0	5	AO	**Value does not exceed guideline**	**376**
		19.316	118.64	217.964	0	5	AO	**Value exceeds guideline**	**2**
	Manganese Total (mg/L)	0.001	0.00535	0.01729	0	0.02	AO	**Value does not exceed guideline**	**262**
		0.0227	0.0817	0.6086	0	0.02 0.12	AO MAC	**Value exceeds guideline**	**147**
	Chromium Total (mg/L)	0.0001	0.001	0.004961	0	0.05	MAC	**Value does not exceed guideline**	**327**
		0.06071	0.06071	0.06071	0	0.05	MAC	**Value exceeds guideline**	**1**
	Iron Total (mg/L)	0.00511	0.05375	0.22985	0	0.3	AO	**Value does not exceed guideline**	**344**
		0.31325	0.6195	14.23	0	0.3	AO	**Value exceeds guideline**	**66**
	Aluminum Total (mg/L)	0.003	0.0143	0.07144	0	0.1	OG	**Value does not exceed guideline**	**297**
		0.10975	0.206	1.33	0	0.1	OG	**Value exceeds guideline**	**76**

Parameter Group	Parameter Standard (Unit)	Min (Q5)	Median	Max (Q95)	Lower Limit Drinking water	Upper Limit Drinking water	Tye of Guideline	Exceedance Analysis	Number of samples
	Selenium Total (mg/L)	5.00E-05	0.0001	0.00541	0	0.05	MAC	**Value does not exceed guideline**	**361**
		0.06	0.06	0.096	0	0.05	MAC	**Detection limit greater than guideline**	**3**
		0.25093	0.25093	0.25093	0	0.05	MAC	**Value exceeds guideline**	**1**
	Barium Total (mg/L)	0.001	0.0064	0.09896	0	1	MAC	**Value does not exceed guideline**	**373**
		2.11	4	5.89	0	1	MAC	**Value exceeds guideline**	**2**
	Antimony Total (mg/L)	1.00E-05	0.0005	0.00052	0	0.006	MAC	**Value does not exceed guideline**	**361**
		0.02	0.04	0.09	0	0.006	MAC	**Detection limit greater than guideline**	**6**
		0.05576	0.5	0.5	0	0.006	MAC	**Value exceeds guideline**	**3**
	Uranium Total (mg/L)	1.00E-05	0.0001	0.000478	0	0.02	MAC	**Value does not exceed guideline**	**356**
		0.11	0.2	0.29	0	0.02	MAC	**Value exceeds guideline**	**2**
	Boron Total (mg/L)	0.05	0.2225	2.160415	0	5	MAC	**Value does not exceed guideline**	**370**
		5.608	8.29	134.929	0	5	MAC	**Value exceeds guideline**	**3**
	Mercury Total (mg/L)	1.90E-06	2.00E-06	5.00E-05	0	0.001	MAC	**Value does not exceed guideline**	**152**
		0.0019	0.00481	0.01	0	0.001	MAC	**Value exceeds guideline**	**5**
Nutrients	Nitrate as N (mg/L)	0.002	0.0315	1.9555	0	10	MAC	**Value does not exceed guideline**	**424**
		10.0	10.25	10.4689	0	10	MAC	**Value exceeds guideline**	**2**
	Nitrite as N (mg/L)	0.002	0.005	0.05	0	1	MAC	**Value does not exceed guideline**	**340**

Parameter Group	Parameter Standard (Unit)	Min (Q5)	Median	Max (Q95)	Lower Limit Drinking water	Upper Limit Drinking water	Tye of Guideline	Exceedance Analysis	Number of samples
Physical properties	pH (pH)	5.745	6.685	6.95	7	10.5	AO	**Value exceeds guideline**	**66**
		7.2	8.07	8.9	7	10.5	AO	**Value does not exceed guideline**	**326**
	Total Dissolved Solids (mg/L)	100	240	380	0	500	AO	**Value does not exceed guideline**	**236**
		520	1,140	2,544.50	0	500	AO	**Value exceeds guideline**	**20**
	Color True (Col.unit)	4.081	5	13.35	0	15	AO	**Value does not exceed guideline**	**107**
		19.195	28.4	80.99	0	15	AO	**Value exceeds guideline**	**20**
	Color Apparent (Col.unit)	5	5	14.1	0	15	AO	**Value does not exceed guideline**	**7**
		83.9	101	685.1	0	15	AO	**Value exceeds guideline**	**3**
	Sulfide Dissolved (mg/L)	0	0.002	0.0355	0	0.05	AO	**Value does not exceed guideline**	**67**
		0.0776	0.167	0.6375	0	0.05	AO	**Value exceeds guideline**	**7**
	Sulfide Total (mg/L)	0.00144	0.0025	0.02762	0	0.05	AO	**Value does not exceed guideline**	**17**
		0.0776	0.279	25.14	0	0.05	AO	**Value exceeds guideline**	**5**

Note: Type of Guideline: MAC=Maximum Acceptable Concentration, AO=Aesthetic Objective, OG=Operational Guideline, ALARA=As Low As Reasonably Achievable.(Health Canada, 2024a). Where noted, for some samples, the laboratory detection limit was higher than the drinking water guideline.

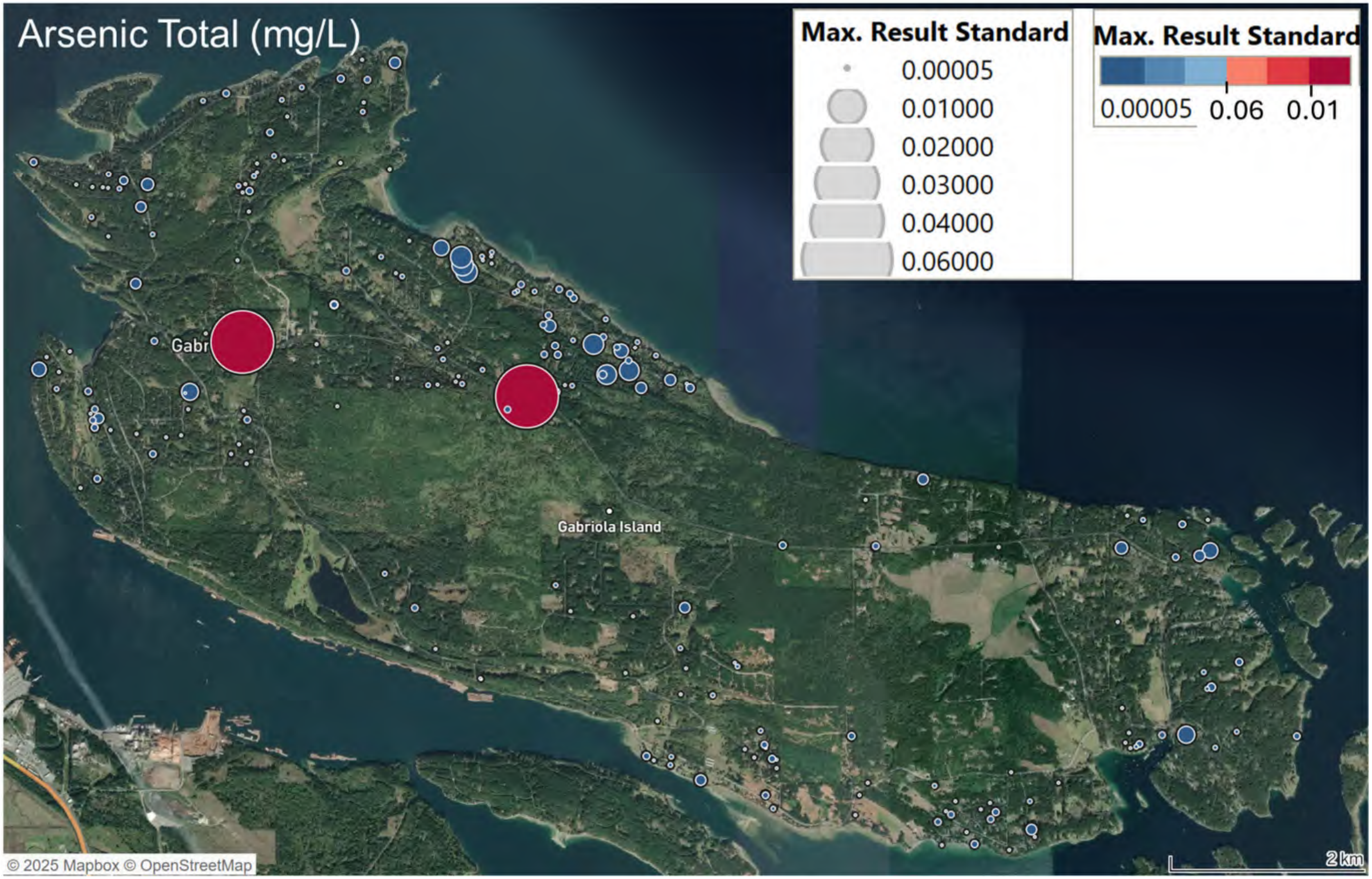


Figure 40: Gabriola Islands arsenic concentration by sample site.

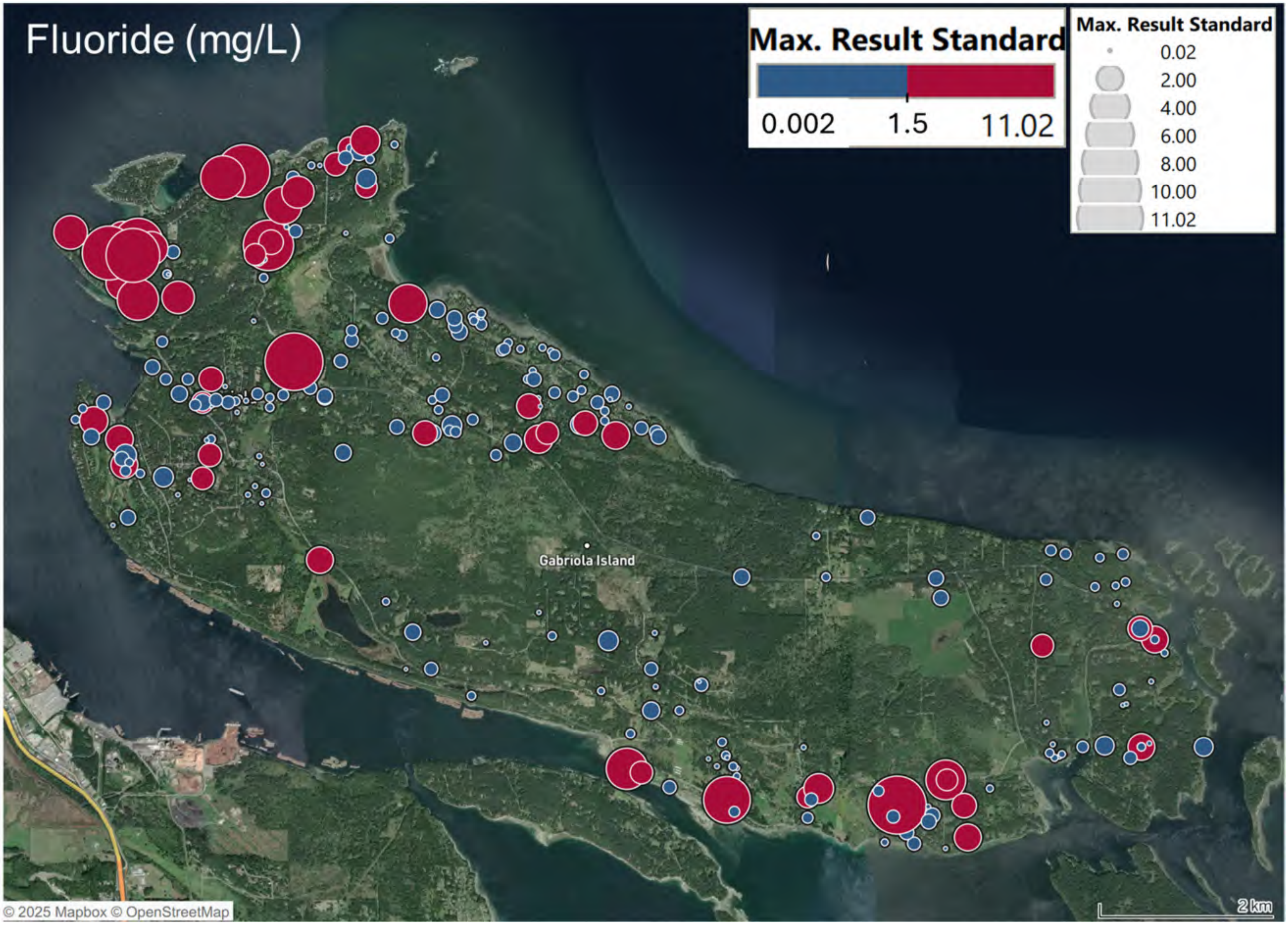


Figure 41: Gabriola Island fluoride concentration by sample site.

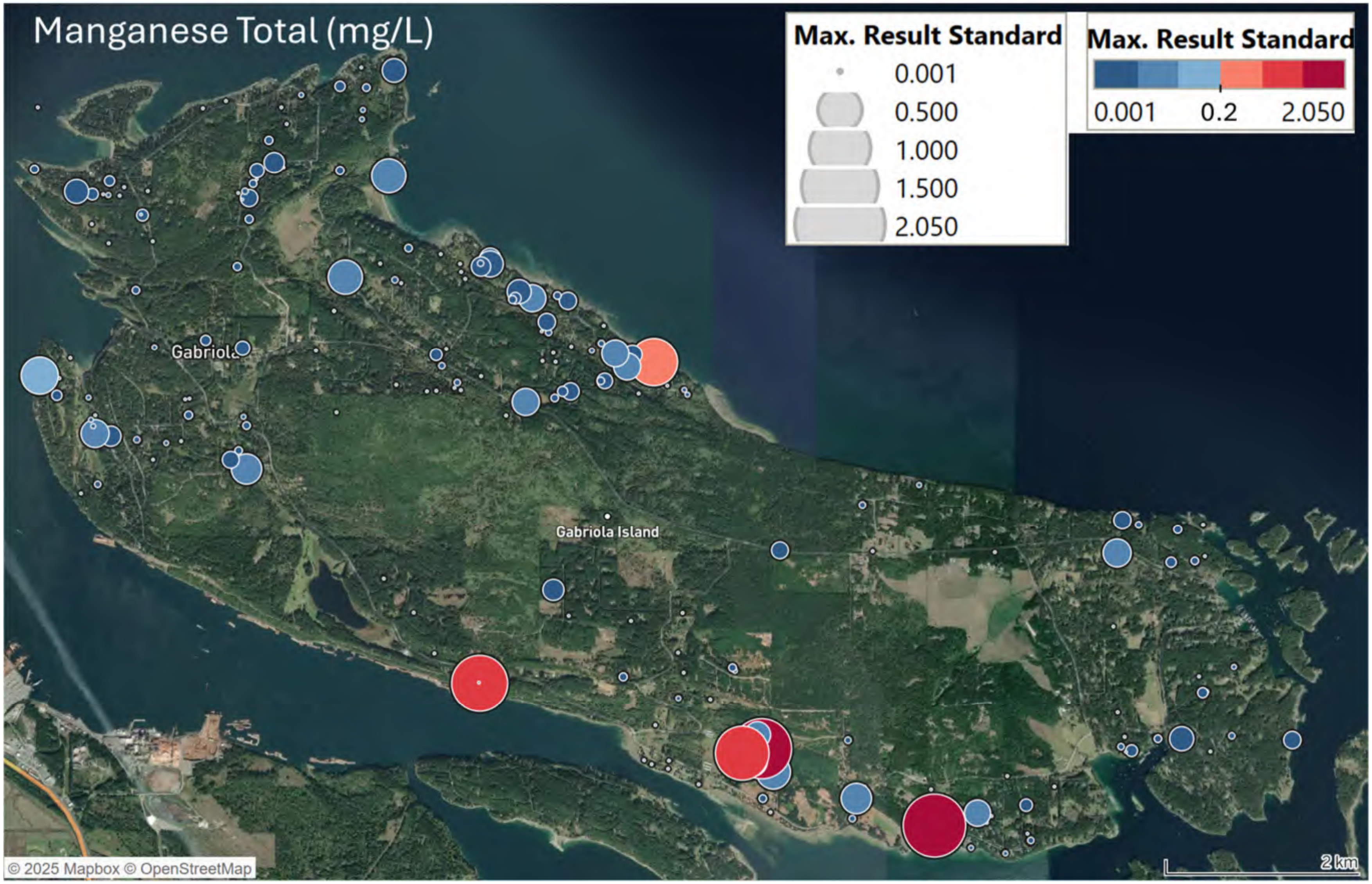


Figure 42: Gabriola Islands manganese concentration by sample site.

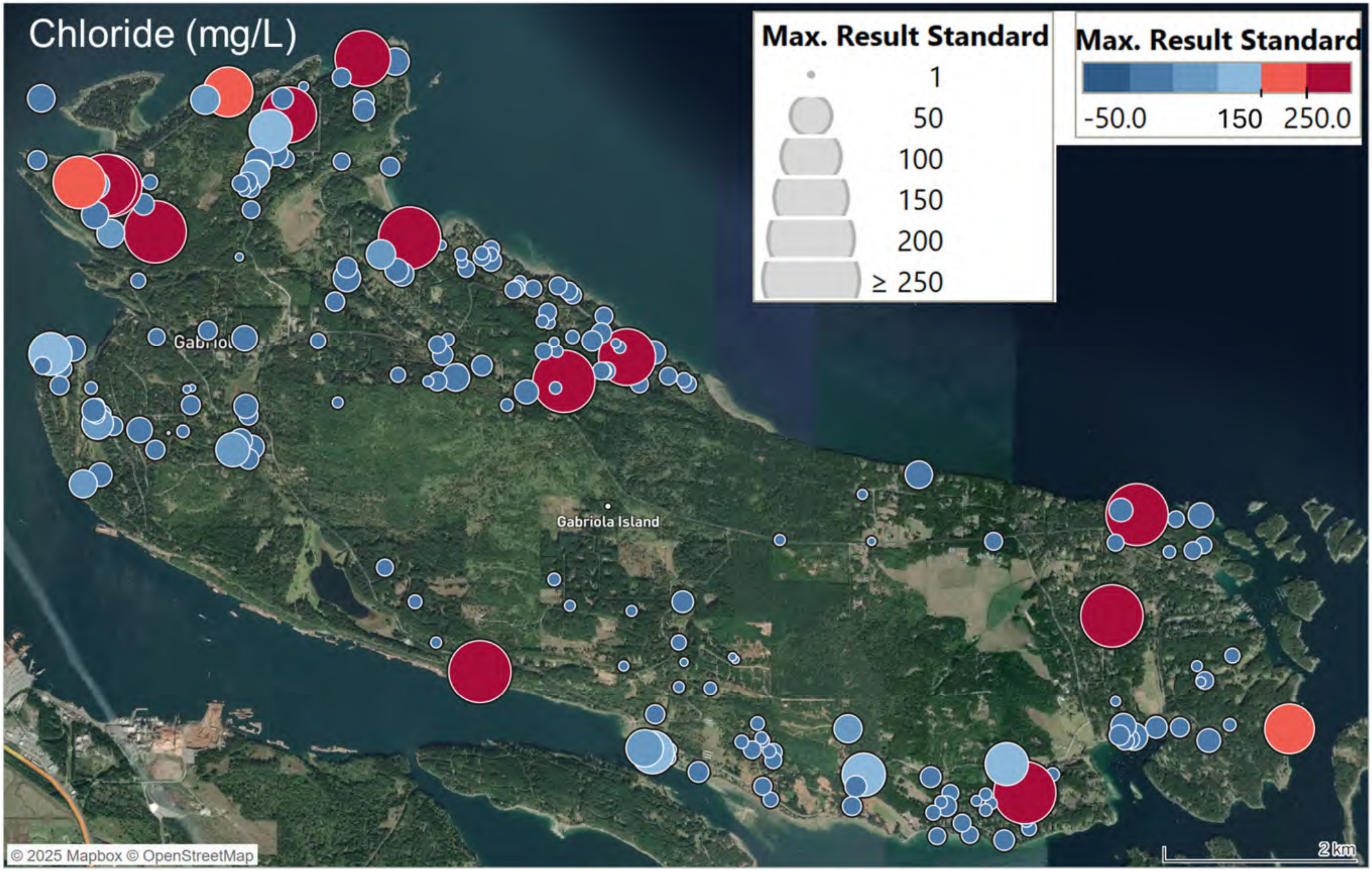


Figure 43: Gabriola Island chloride concentration by sample site.

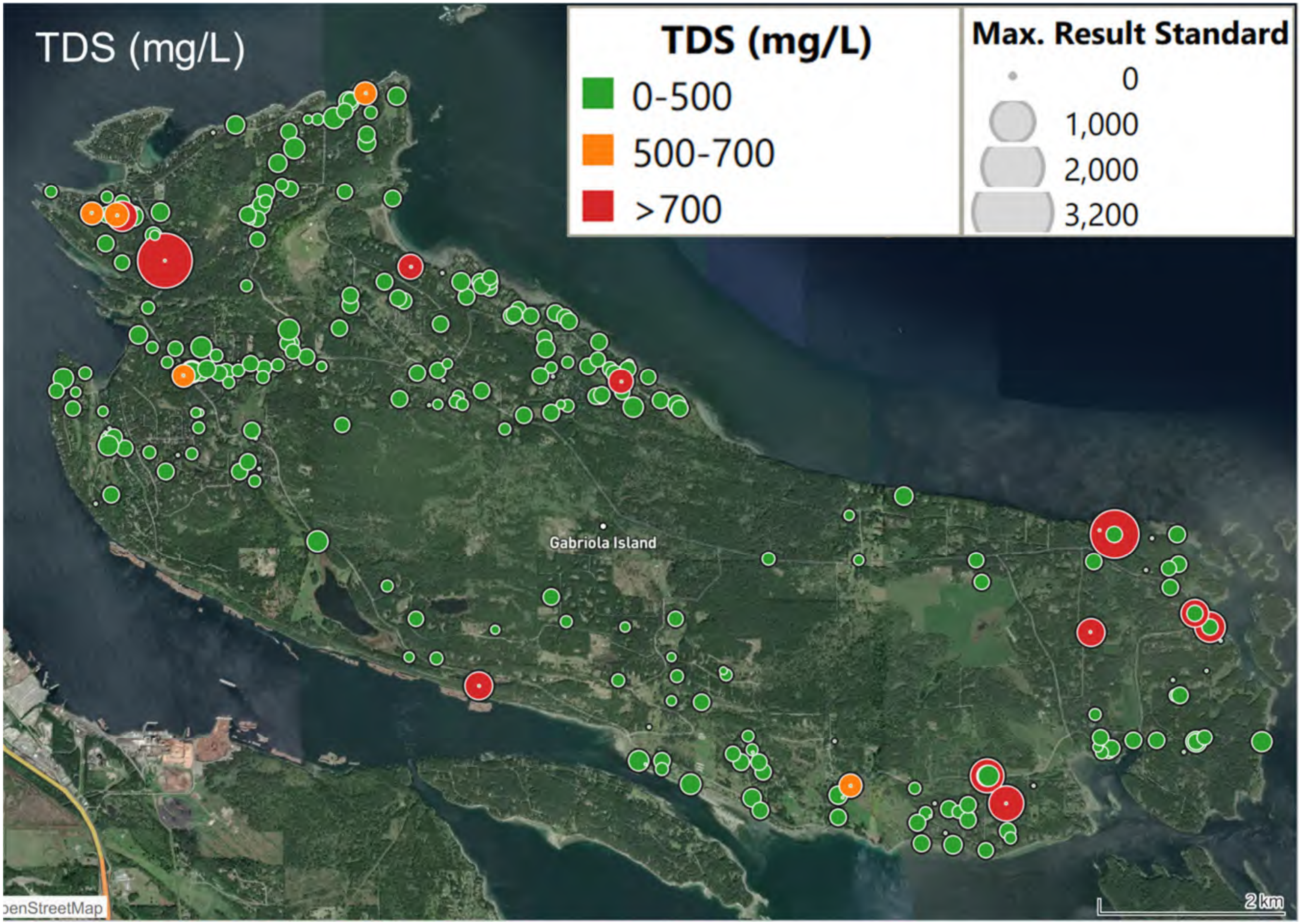


Figure 44: Gabriola Islands total dissolved solids (TDS) concentration by sample site.

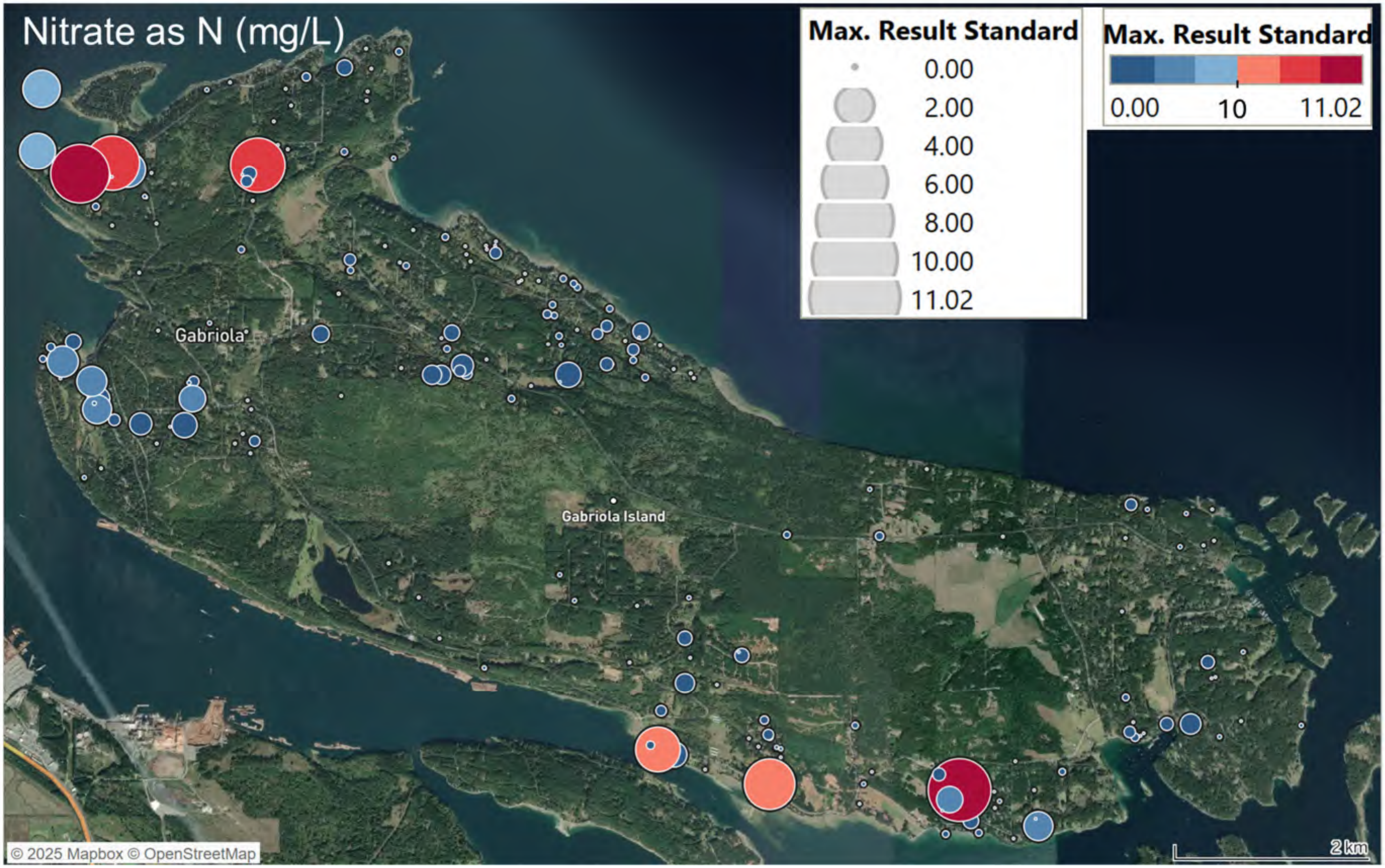


Figure 45: Gabriola Islands nitrate concentration by sample site.

Water type	Groundwater process interpretation
Calcium-magnesium-bicarbonate	Younger, recently recharged
Sodium-bicarbonate	Older, more mature
Sodium-chloride	Mixed with saline source e.g. seawater intrusion

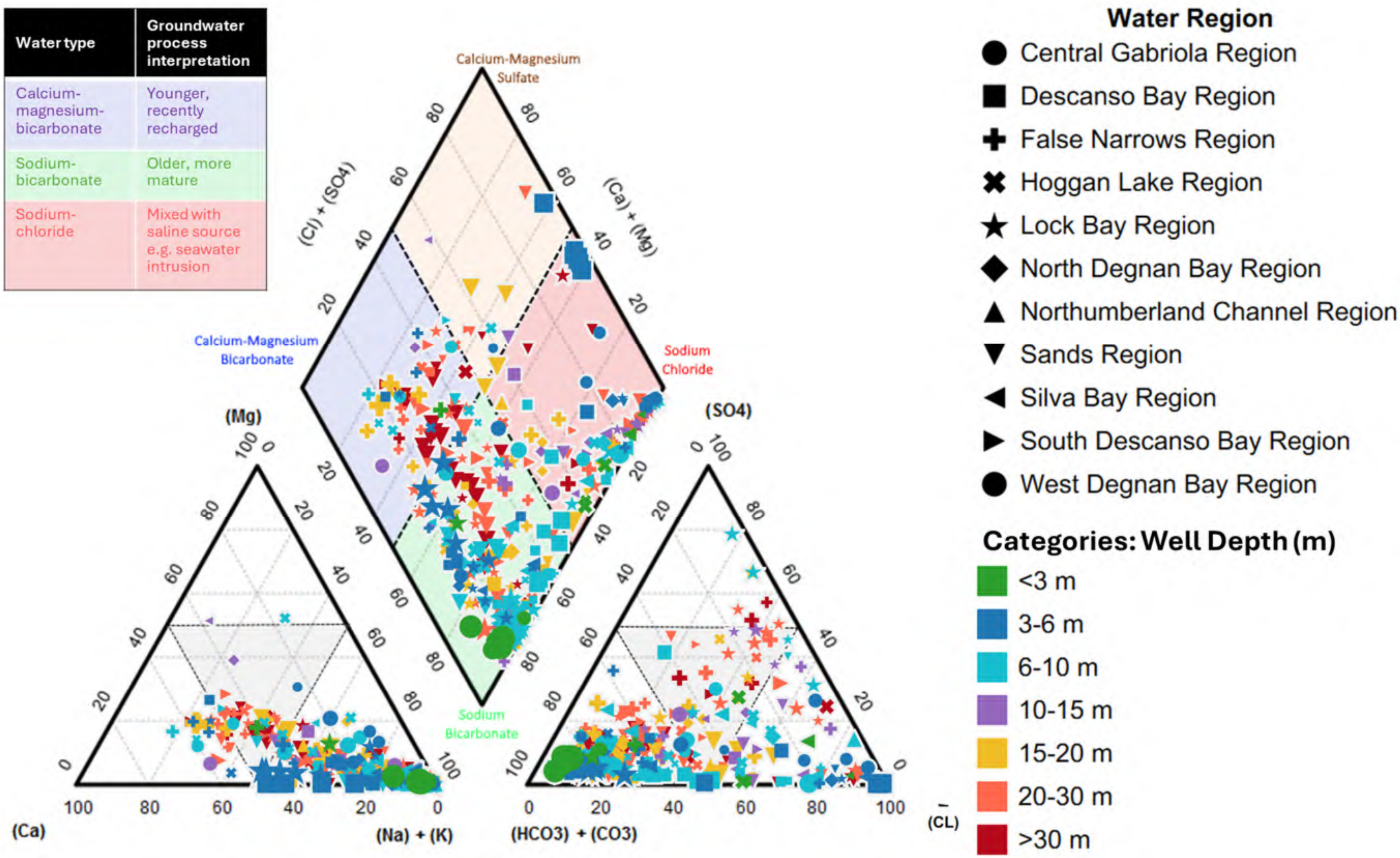


Figure 46: Piper diagram illustrating concentration of major ions in water samples. Symbols indicate region, and colours indicate the well depth.

6.5.6 Background concentrations and regional trends

The freshwater footprint method considered whether the groundwater quality measured in different areas could provide an indication of aquifer stress or the impact of different types of land use. For example, in an area with a large number of wells close to the coast, a higher than average concentration of chloride in groundwater samples could indicate that groundwater quality was being impacted by high water use or other factors contributing to seawater intrusion. Similarly, nitrate concentrations might be higher in areas with a high density of small lots with their own septic systems. To consider these potential indicators, the background concentrations and regional trends for chloride, total dissolved solids and nitrate were examined. Observed changes over time, and the relationship with spatial factors such as well distance from the coast, and well depth were also evaluated.

To estimate the background concentration of chloride, total dissolved solids and nitrate in groundwater samples from Gabriola Island, a probabilistic approach was used based on methods adapted from mineral exploration and applied to drinking water studies (Panno et al., 2006; Kelly and Panno, 2008; Barroso and Melnechenko, 2019). Environmental variables such as water quality concentrations often have a log-normal distribution, i.e., a larger number of values centred around the lower end of the measurement scale. When concentrations of a parameter are plotted on a cumulative frequency plot (probability curve), datasets with log-normal distribution will plot as a straight line. If there are multiple straight segments, variations in the slope of the line highlight thresholds that define the boundaries between different populations or groups within the data set.

Aquifers receive recharge that originated first as rain or snowmelt. This water infiltrates into the subsurface undergoing various physical and chemical processes, such as dissolving natural minerals or mixing with water or elements from contamination sources. Rainfall in the south coast of BC is characterized by low concentrations of major ions such as chloride, sodium and nitrate. For example, long-term monitoring of rain chemistry at the Saturna Island station, operated by the Canadian Air and Precipitation Monitoring Network, are shown in Figure 47 (Environment and Climate Change Canada (ECCC), 2024). A seasonal effect is observed in the rain chemistry, in which concentrations of chloride and sodium are higher in precipitation during the winter, when sea spray particulates are captured in rainfall during winter storms. Conversely, the median concentration of nitrate in rain is low (median 0.2 mg/L) but higher in the spring and summer compared to winter, due to the presence of dust and soil particles containing nitrate from decomposed organic materials and agricultural fertilizers applied to fields and wind-borne during this time of year.

In comparison to fresh rainwater, the concentration of chloride, TDS and nitrate can vary in groundwater depending on factors such the time of travel, how long the water has been stored in the aquifer or impacts from land use and sources of contamination.

Background water quality results

Chloride (Cl): Figure 48-A shows a cumulative frequency plot of chloride concentrations in 433 groundwater samples from Gabriola Island (1985 to 2025). The labels indicate the inflection points in the curve that define different categories or sample populations containing chloride concentration within a similar range. From this diagram we observe:

- There are two inflection points in the curve, one at 6 mg/L and a second at 74 mg/L. Most samples from Gabriola Island fall within this range.
- Concentrations of chloride less than 6 mg/L are very fresh. This could be from a source that is hydraulically connected to surface water e.g. a spring or shallow well.
- Groundwater with chloride above 74 mg/L have a higher than background concentration, and may be affected by different processes, for example, mixing with water sources that are higher in chloride, such as deeper, more mature groundwater, seawater, or recharge from septic effluent. The maximum concentration measured was 4,500 mg/L chloride.
- In terms of regional trends, Figure 49 shows that the median chloride concentration was higher in samples from the Descanso Bay (median 62 mg/L) and Northumberland Channel Regions (median 54 mg/L). Although the median in the Sands region was lower than this (28 mg/L) the box plot indicates a wider range between minimum and maximum sample concentrations.

Total dissolved solids (TDS): TDS is a relative measure of the total mineral content of water. TDS (calculated from electrical conductivity) is easily measured in the field using a hand-held meter, making it a useful indicator. Figure 48-B shows the cumulative frequency of TDS in 313 groundwater samples from Gabriola Island (2001-2025).

- Two inflection points define the boundaries between three groups in the dataset.
- Below 126 mg/L the groundwater is fresh, such as from shallow, recently recharged sources that have not had a long contact time with sediments and rock.
- The majority of samples have a concentration in the range form 126 mg/L to 514 mg/L.
- Above 514 mg/L are samples from sources that are either more highly mineralized (deep groundwater) or influenced by a source of salinity, such as seawater intrusion. TDS 500 mg/L is the Health Canada operational guideline, above this limit water may have a salty taste, or cause scaling and corrosion of plumbing fixtures, etc.

Nitrate (NO_3): Nitrate concentration in groundwater is generally low, but can be elevated if introduced from agricultural runoff, leachate from sewage discharges (septic systems, sewage treatment plants) (Health Canada, 2013). Figure 48-C shows a cumulative frequency plot of nitrate concentrations in 607 groundwater samples from Gabriola Island (1985 to 2024). From this it is noted:

- There are three inflection points in the curve.
- Samples below the inflection point at 0.001 mg/L reflect samples for which the concentration was at or close to the laboratory detection limit.
- The second inflection point is at 0.01 and the third at 0.96 mg/L. The majority of groundwater sampled on Gabriola Island fall within range between these points.
- Groundwater samples with concentrations greater than 1.0 mg/L have a higher than background concentration. These may be impacted by a source of nitrate, such as septic discharge.
- The regional trends show that median nitrate concentrations are very low throughout the island. However a larger range is observed in samples from the False Narrows and Sands regions.

Fluoride

Fluoride is a natural groundwater contaminant present from dissolution of minerals such as in sedimentary rock. A potential correlation between TDS and fluoride was observed, as shown in Figure 48-D. Mature groundwater from deeper fractures has a generally higher concentration of TDS, associated with higher concentrations of minerals such as fluoride, which are known to occur within the sedimentary bedrock on the island. Figure 52 shows statistics for fluoride concentration in Gabriola Island groundwater by region. Median fluoride concentrations relatively consistent (below 0.3 mg/L) in most areas. The median fluoride concentration is higher in the Descanso Bay area.

Well Depth

A preliminary assessment of the influence of finished well depth (elevation of well bottom) on regional water quality was completed. For example, Figure 53 shows statistics from the GWELLS database on well construction for the different water regions. Higher median chloride concentrations in groundwater samples were observed in areas in which wells were drilled deeper below sea level, such as the Northumberland Channel and Sands Regions. Higher average TDS and fluoride are found in in groundwater recharge zones with deep wells, such as Descanso Bay and Descanso Bay areas. Higher average nitrate concentrations are observed in discharge areas, areas with high well density, and where the average well depth is shallower, such as in the Lock Bay area.

In summary, the analysis of the statistical variability, including background concentrations of key parameters, shows that groundwater quality sampled from Gabriola Island sources generally falls within a consistent range. Data within the upper bounds of probability (90th percentile or higher) indicate samples falling outside of the usual range, potentially connected to regional differences in groundwater processes--i.e., recharge or discharge zones—well construction characteristics and other factors. The geochemistry dataset could be further examined to identify relationships between the different parameters and the significance to describing aquifer processes.

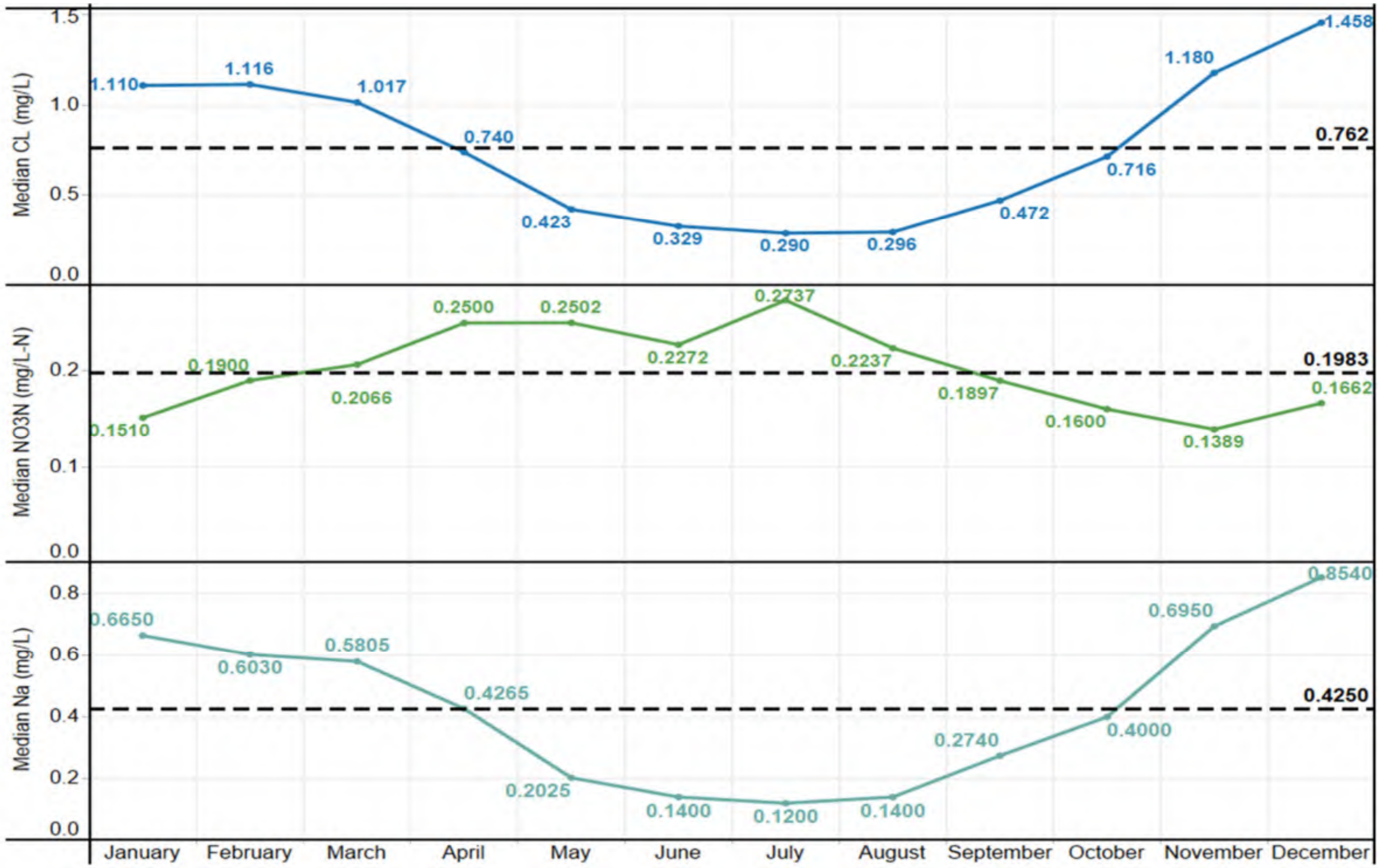
6.5.7 Chloride vs electrical conductivity and other indicators

The relative concentration of chloride compared to electrical conductivity of a water sample can be used to identify groundwater that is impacted by a source of salinity, such as seawater intrusion (Klassen et al., 2014). Groundwater samples with chloride greater than 250 m/L (the drinking water quality guideline) have a notably salty taste, and high likelihood of being impacted by intrusion or other processes (wells drilled into deeper formations, or intersecting fractures connected to the sea). Groundwater with chloride greater than 100 mg/L, and electrical conductivity above 1000 has a higher than background or average salinity, which could indicate the effect of mixing of fresher groundwater with water from a saline source, such as from within the mixed transition zone between saline and fresh groundwater in coastal areas.

Figure 55 shows groundwater chloride concentration (interpolated) compared to depth to saline interface for the northern Gabriola Island Region. Chloride concentration is higher in areas with shallow groundwater levels above sea level, shallow depth to saltwater interface and wells drilled deeper below sea level and into the transition zone between fresh and saline water. In these areas at high risk of seawater intrusion, it is recommended to avoid over pumping, and limit groundwater level drawdown below sea level. Other best management practices to prevent seawater intrusion are included in Appendix A.

6.5.8 Lot size and population density

Gabriola Island has a population of approximately 4500 residents, most (78%) of whom are live on the island full-time . Population statistics for the island are summarized in Table 29. Spatial population data layers were obtained from Statistics Canada and used to determine the freshwater footprint hazard for this criteria. Cadastral lot boundaries and land use categories were obtained from Islands Trust and BC Assessment Authority (BC Assessment, 2025). There are more than 3300 lots on Gabriola Island, as summarized in Table 30. The parcels in each water management region are shown in Figure 56 and Figure 57, and land use categories are shown in Figure 58.



Saturna Island Site ID CAPMCABC1SAT) 1983-2015

Analyte (mg/L)	January	February	March	April	May	June	July	August	September	October	November	December
Sodium	0.6650	0.6030	0.5805	0.4265	0.2025	0.1400	0.1200	0.1400	0.2740	0.4000	0.6950	0.8540
Chloride	1.110	1.116	1.017	0.740	0.423	0.329	0.290	0.296	0.472	0.716	1.180	1.458
Nitrate-N	0.1510	0.1900	0.2066	0.2500	0.2502	0.2272	0.2737	0.2237	0.1897	0.1600	0.1389	0.1662

Figure 47: Saturna Island (Site CAPMCABC1SAT) monthly rainwater chemistry (chloride, sodium, nitrate) 1985- 2015.

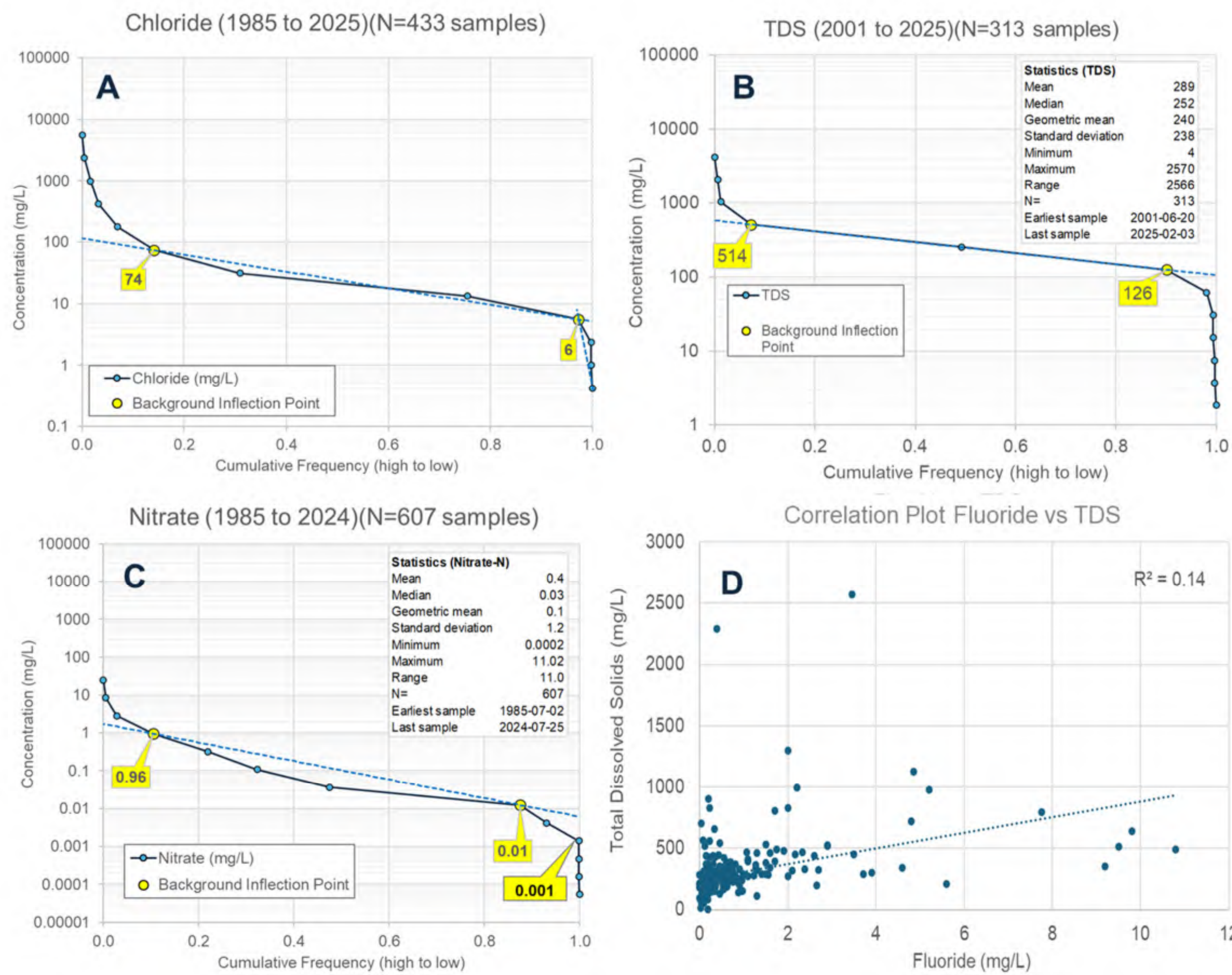


Figure 48: Gabriola Island groundwater background concentration analysis for A. Chloride, B. Total Dissolved Solids (TDS) and C. Nitrate. D. Correlation plot of Fluoride vs TDS.

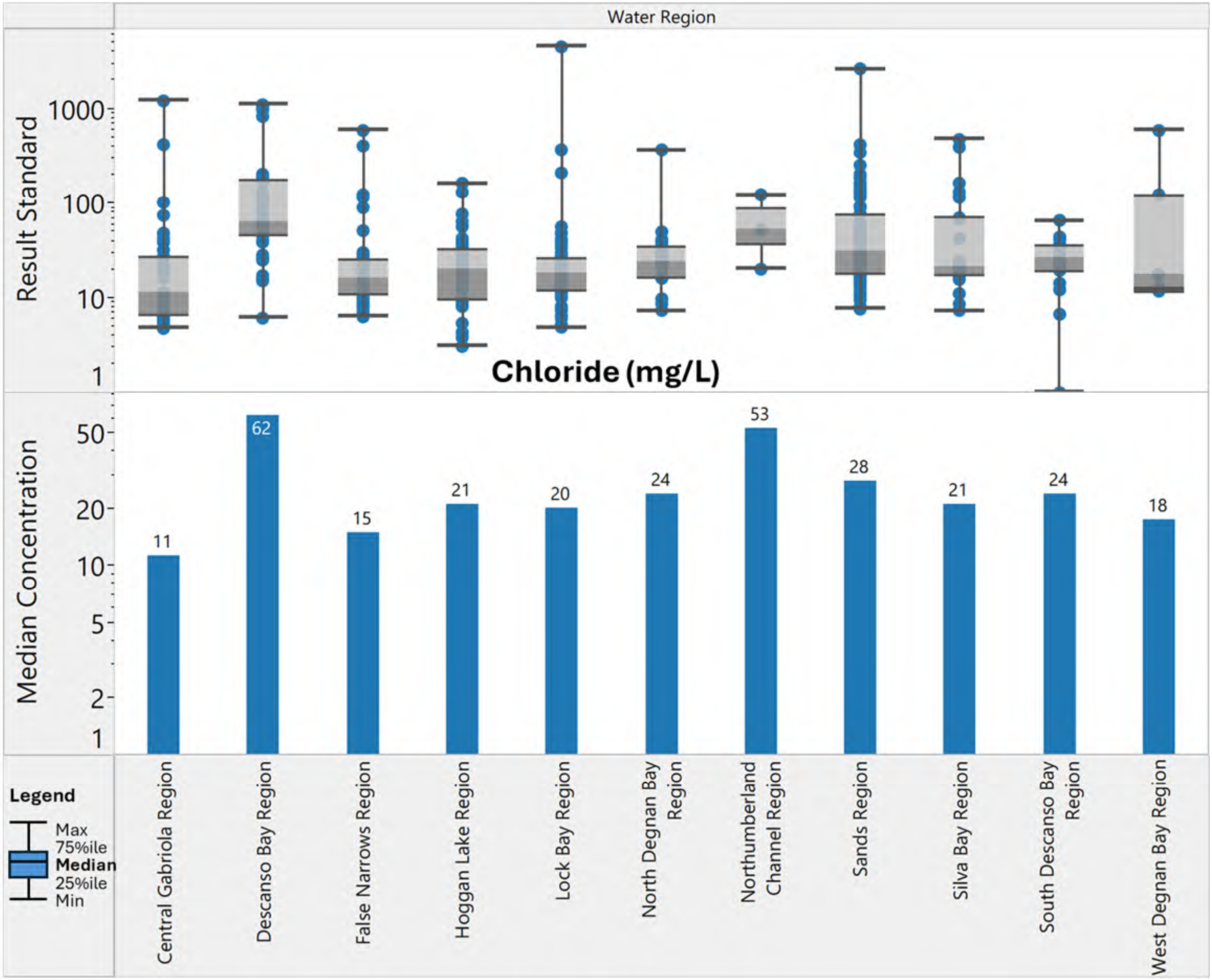


Figure 49: Gabriola Island median chloride concentration by groundwater management region.

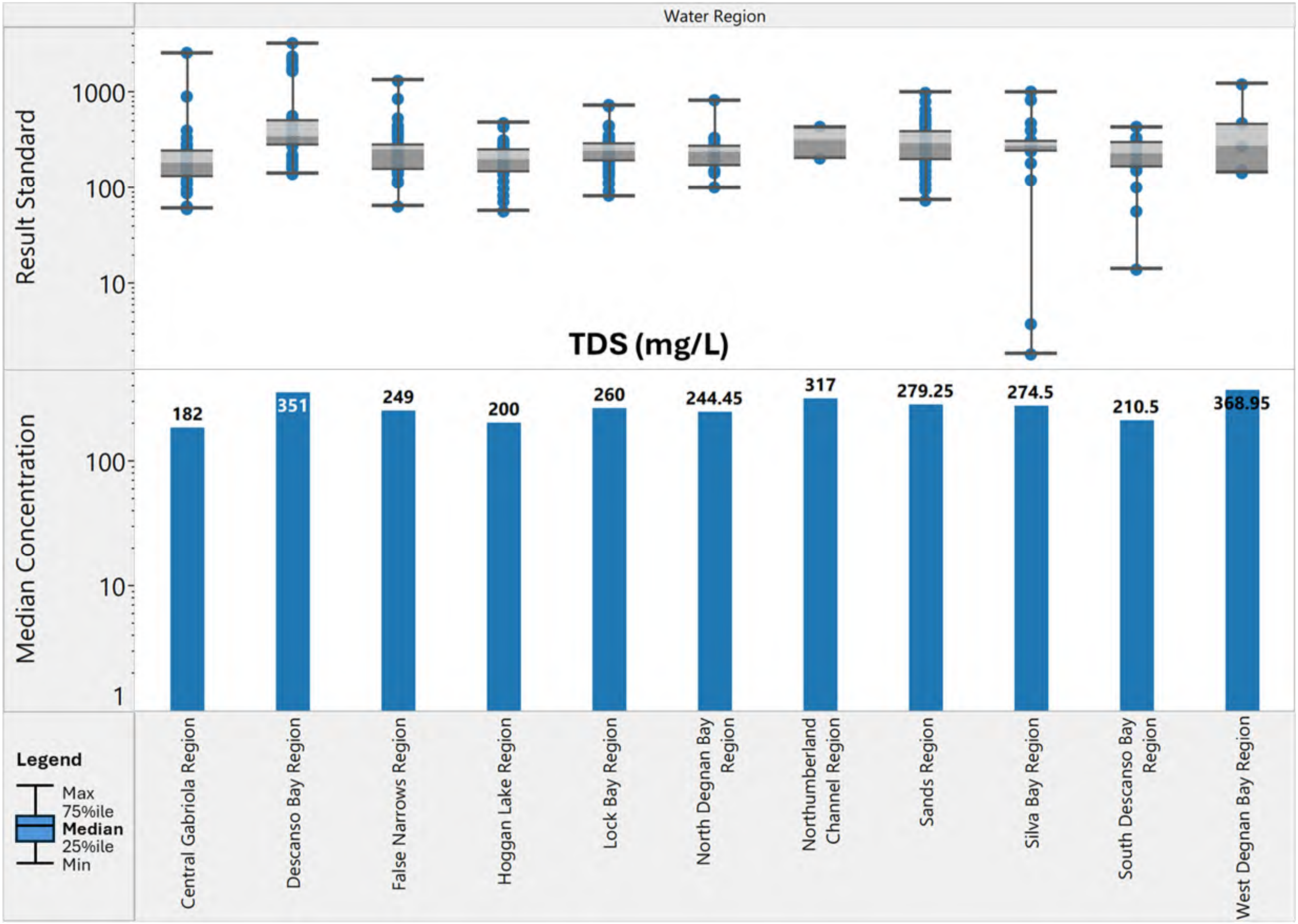


Figure 50: Gabriola Island median chloride concentration by groundwater management region.

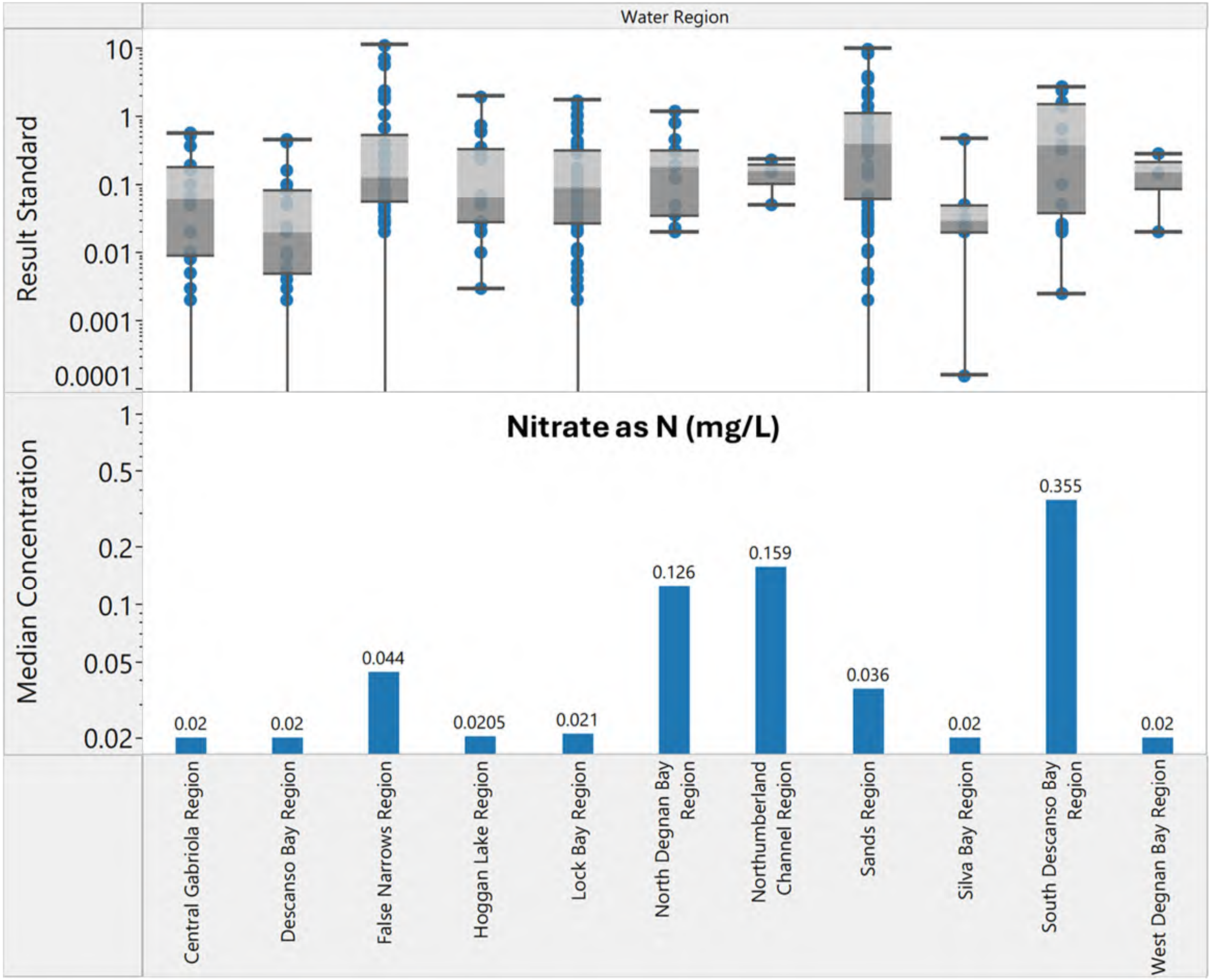


Figure 51: Gabriola Island median nitrate concentration by groundwater management region.

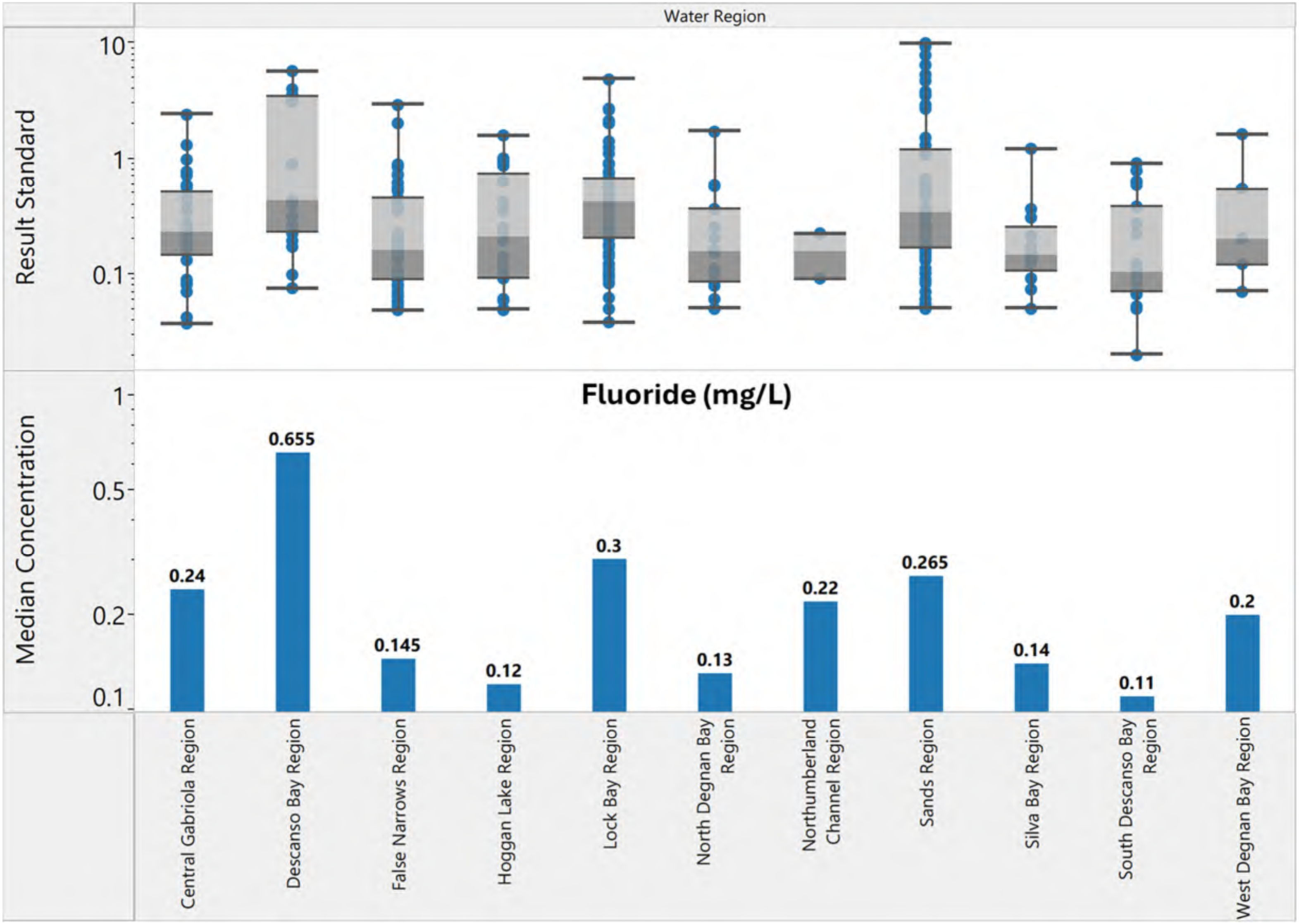


Figure 52: Gabriola Island median nitrate concentration by groundwater management region.

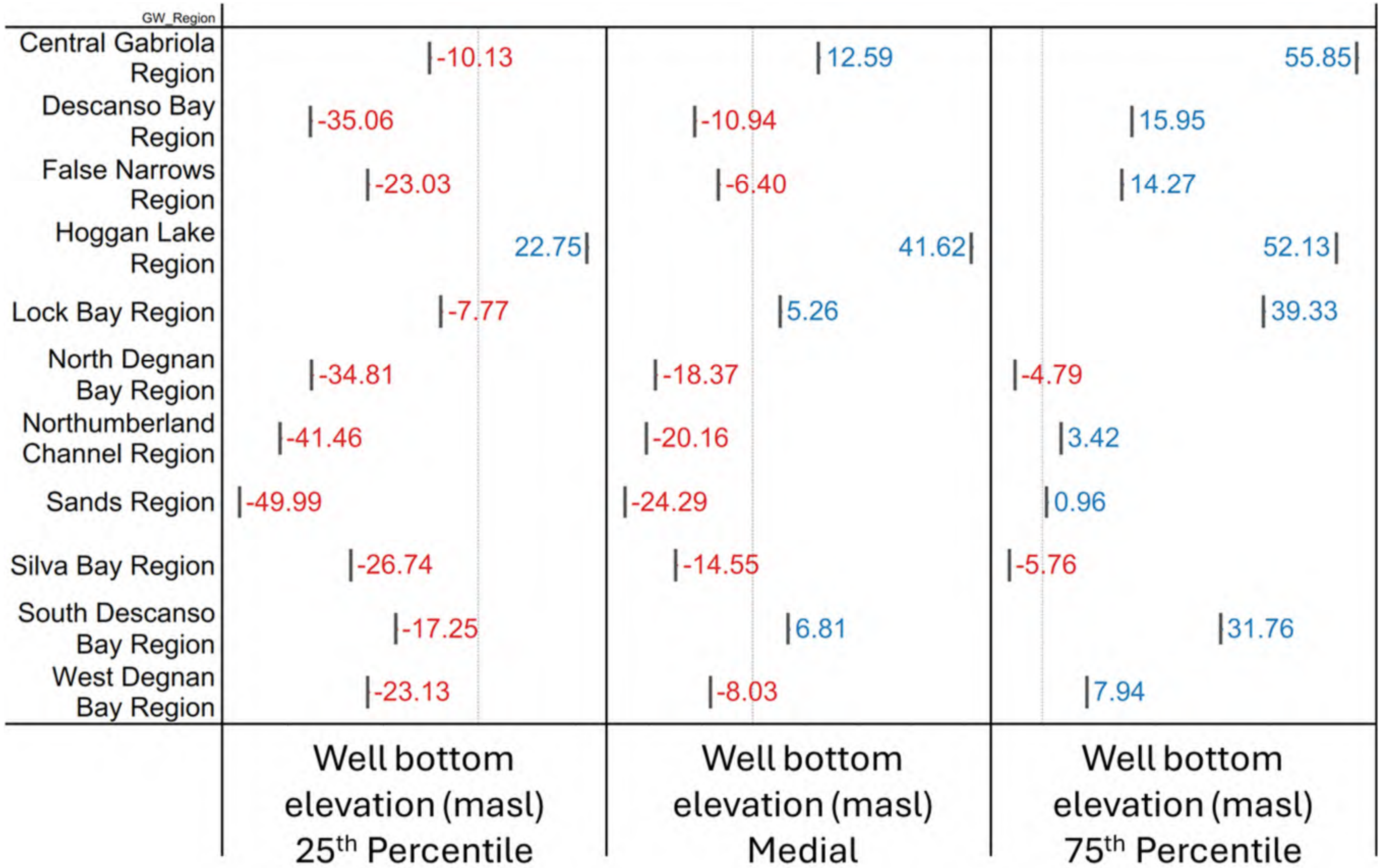


Figure 53: Gabriola Island 25th percentile, median, and 75th percentile well bottom elevation (masl) by region.

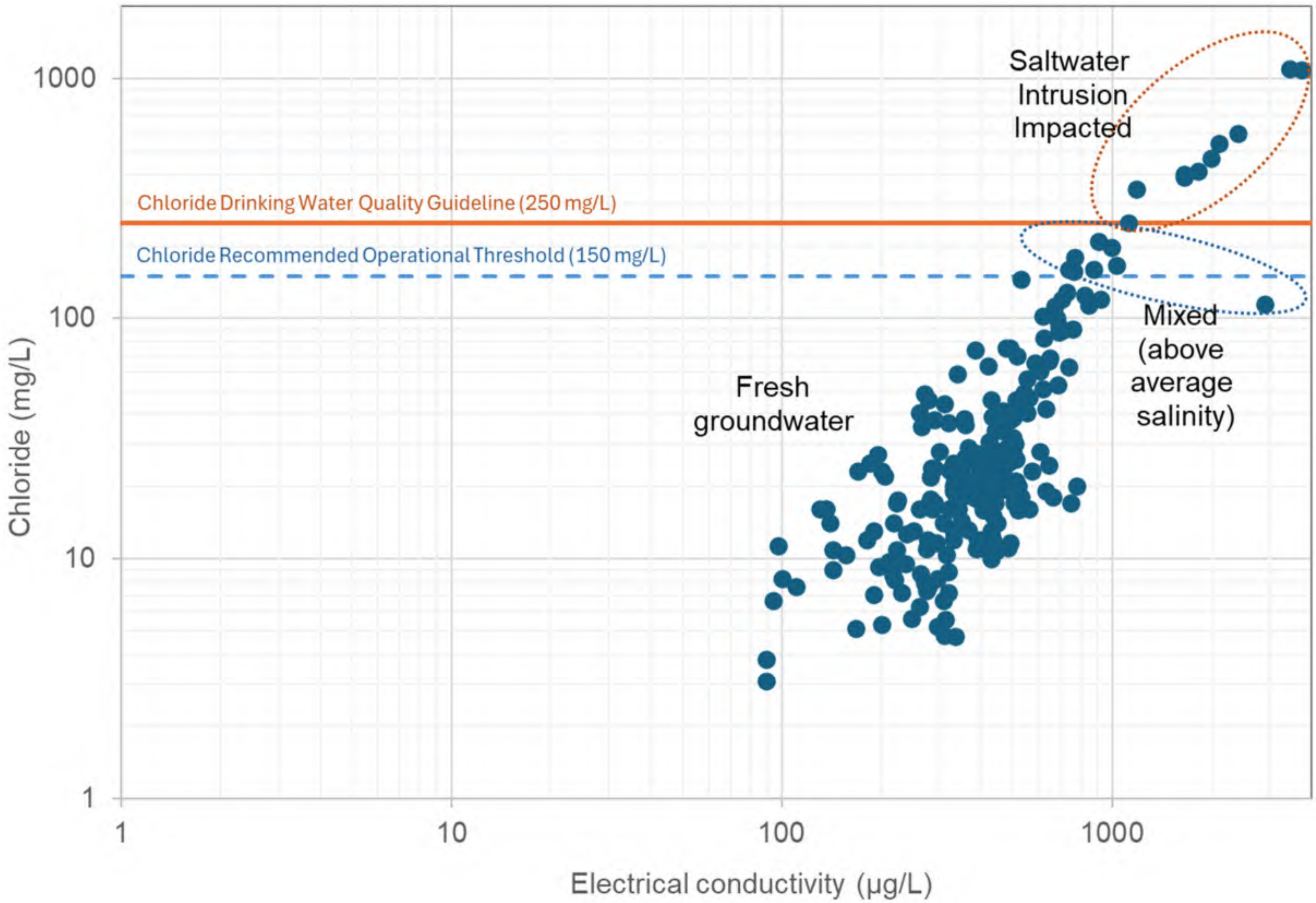


Figure 54: Chloride versus electrical conductivity (EC) for Gabriola Island groundwater samples. Samples with chloride greater than 250 mg/L and EC are likely impacted by seawater intrusion or water from a deeper, more saline groundwater source. Cl >100 mg/L is above background and in the higher range (>90th percentile) of samples.

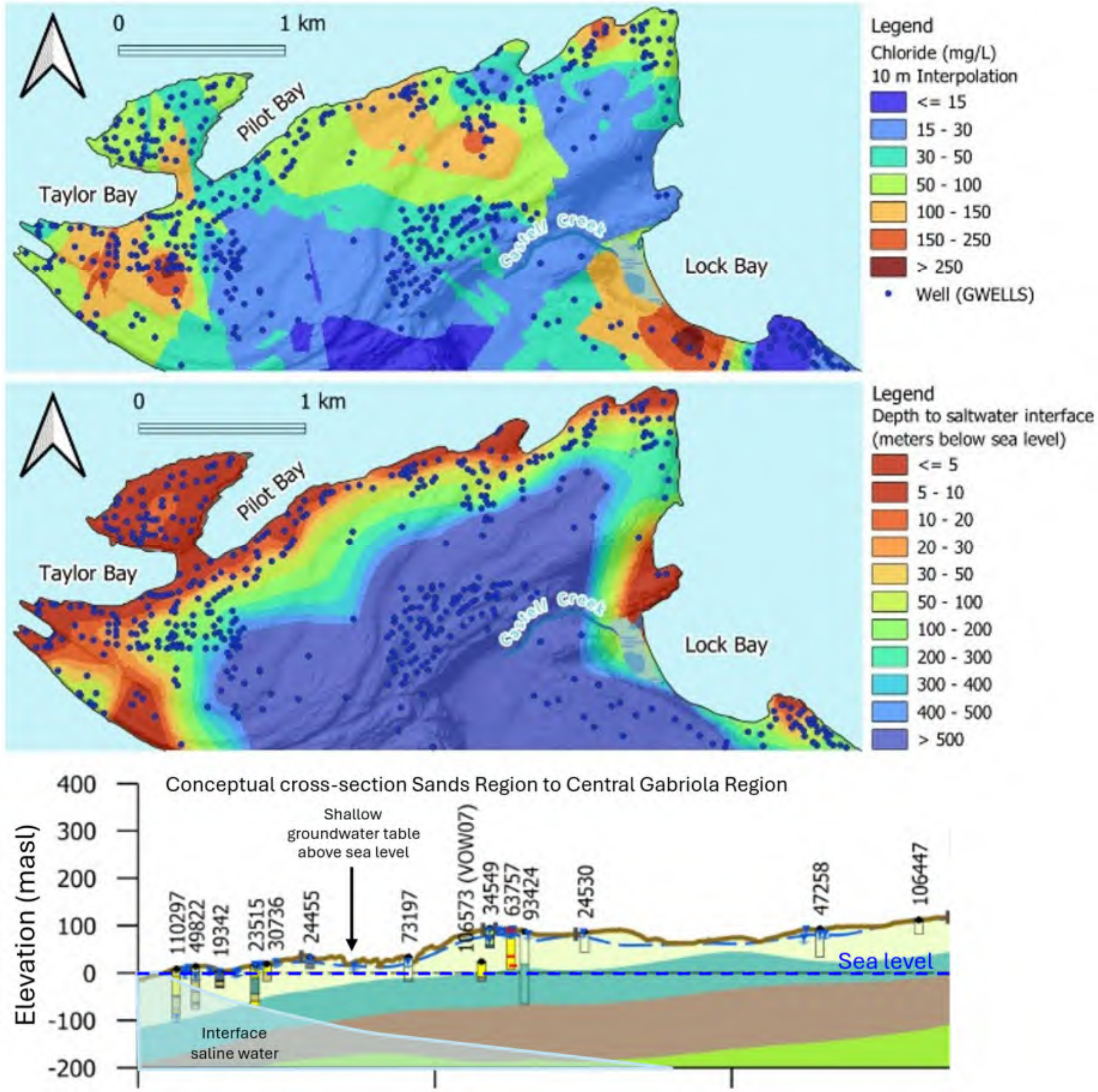


Figure 55: Northern Gabriola Island interpolated chloride concentration compared to depth to saline interface, and conceptual cross-section showing shallow groundwater table and wells drilled into the freshwater-saltwater transition zone.

Table 29: Gabriola Island population statistics (Statistics Canada, 2023b).

Gabriola Island Census Profile	Total
Population, 2021	4500
Population, 2016	4033
Population percentage change, 2016 to 2021	11.6
Total private dwellings	3062
Private dwellings occupied by usual residents	2375
Percentage dwellings occupied by usual residents	78%
Number of persons in private households	4495
Average household size	1.9
Population density per square kilometre	77.4
Land area in square kilometres	58.12

Table 30: Gabriola Island parcels.

BC Assessment Actual Land Use (2025 Roll Year)	
Land parcels (non-vacant)	2892
Land parcels (vacant)	492
Total parcels	3384
Lots with registered wells	2020
Total registered wells (GWELLS)	2762
Wells per km^2	48

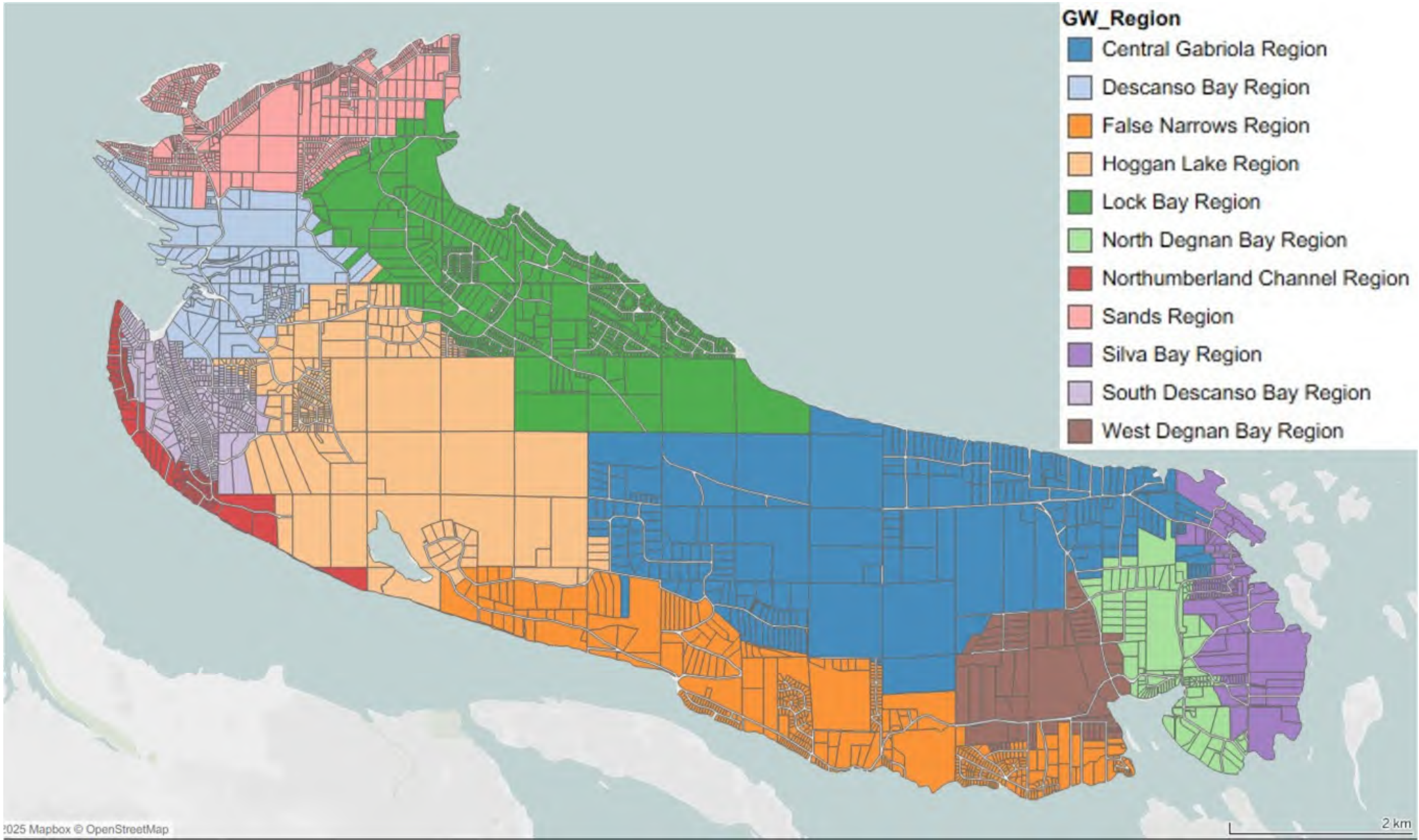


Figure 56: Gabriola Island parcels by Groundwater Management Region.

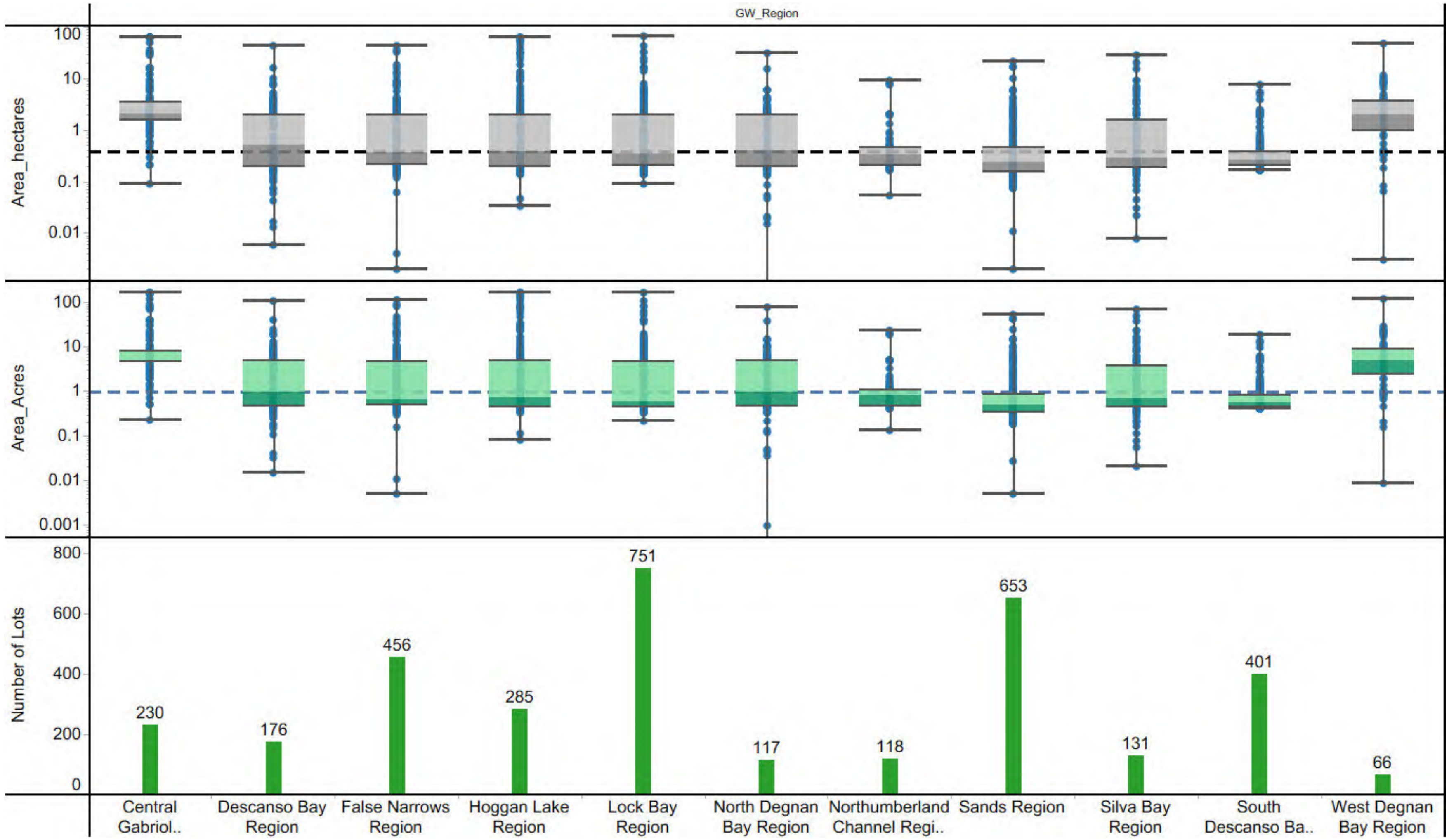


Figure 57: Gabriola Island parcels size and number by Groundwater Management Region.

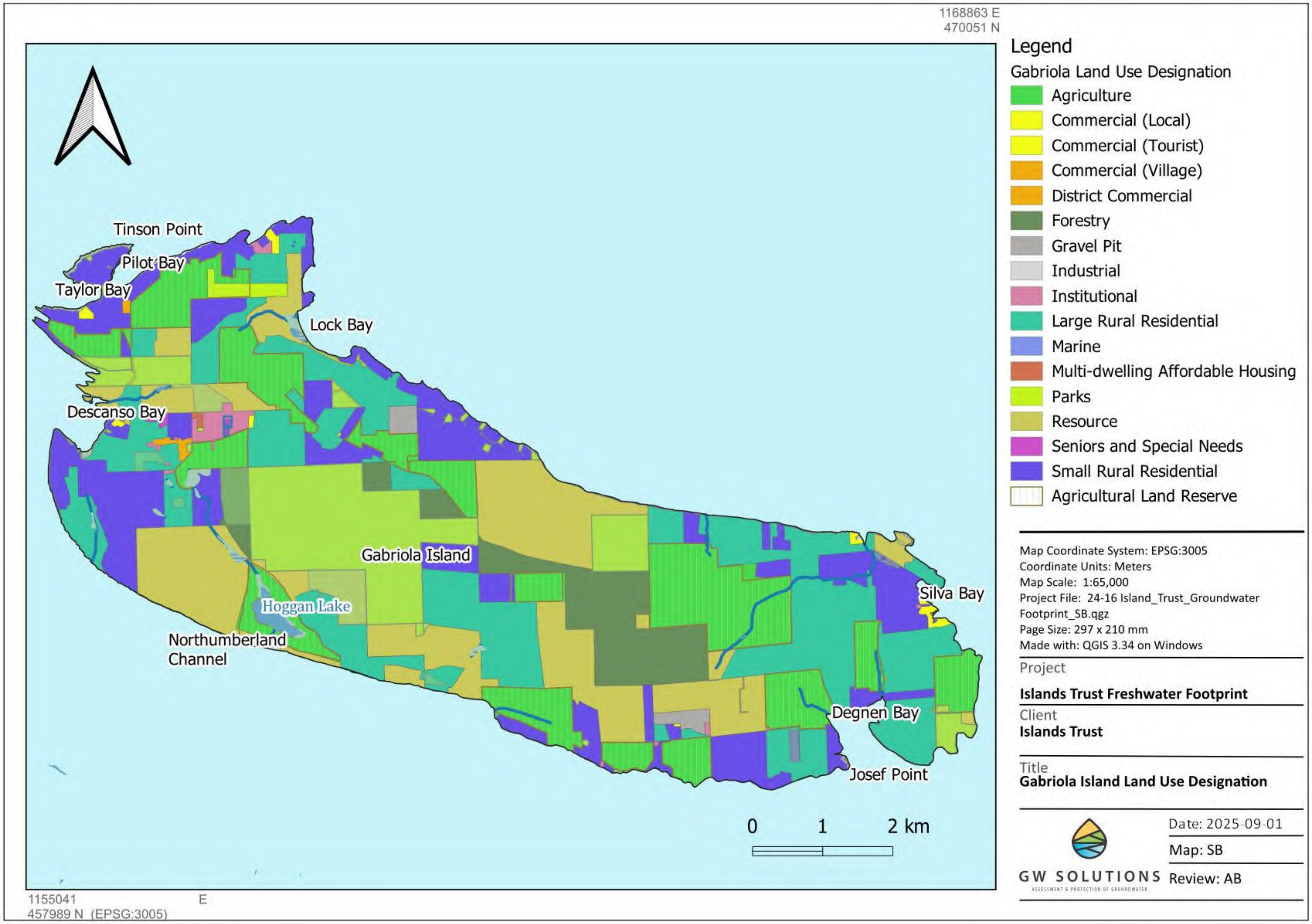


Figure 58: Gabriola Island land use designation.

6.6 Gabriola Water Footprint – Combined Criteria

The freshwater footprint combined the following groundwater assessment criteria:

- Water demand versus recharge, representing aquifer stress;
- Water quality indicators including chloride, and total dissolved solids;
- Groundwater hazards including depth to the saline interface, lot density, and population density.

The combined freshwater footprint criteria mapped over Gabriola Island are shown in Figure 59. Observations:

- A very high freshwater footprint was observed along the northeast side of the island including in the Sands and Descanso Bay regions. The population density, lot size and water quality indicators are highest in these areas, while seawater intrusion risk is also high due to the low groundwater gradient and shallow depth to the saltwater interface.
- Other areas of very high hazard were observed close to the coast, in the Silva Bay and Lock Bay regions, and along False Narrows and Northumberland Channel. High footprint hazard was observed to extend inland bordering very high risk areas, including zones with greater density of lots and population.
- The SWI hazard (based on the depth to saltwater interface) and combined footprint hazard indicates that higher hazards can extend from 200 to greater than 500 m inland from the coast. Despite this, the water quality results show that many existing wells in higher hazard areas produce fresh water and have not been impacted by intrusion. Anecdotally and based on local information, there is a potential relationship with higher SWI hazard areas such as in the Sands region, and use of alternate water sources such as bulk water hauling or rainwater catchment.
- Areas such as the South Descanso Bay and Northumberland Channel Regions are considered preferential groundwater recharge zones. In these areas groundwater levels are relatively deep, and there is a very shallow freshwater lens above sea level, therefore wells may intersect fractures containing both mature, mineralized groundwater, or water mixed with a marine source, as shown by higher TDS concentrations in groundwater samples from these zones.
- Development and population density have a strong effect on the footprint hazard, as shown by inter-regional variability. Protected areas in the central island that have a low development density have very low to low freshwater footprint.
- The freshwater footprint and water demand compared to availability is lower in the Central Gabriola, West Degnan Bay and North Degnan Bay groundwater regions, where more agricultural operations are located on large lots. Water demand for farming is still considered low, as most agricultural lots are not irrigated over their entire area, if at all. However as climate change influences temperature and evapotranspiration patterns, the freshwater footprint for the Central Gabriola, North and West Degnan Bay regions would be expected to increase.

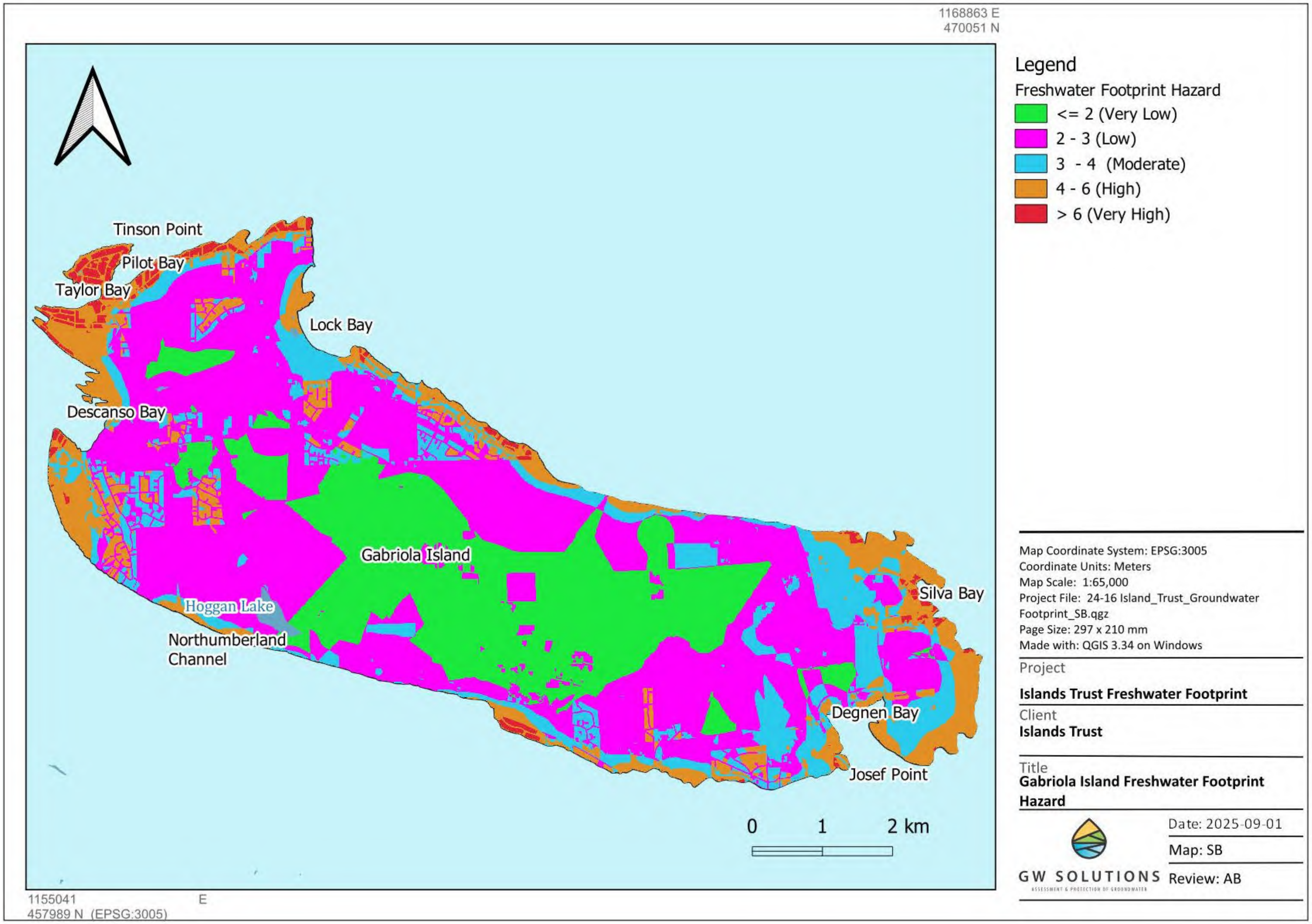


Figure 59: Freshwater Footprint Hazard map.

6.7 Implications for Groundwater Management Policies and Regional Growth

A significant driver of this work was the desire to develop island communities strategically, increasing density where appropriate, protecting critical recharge areas and avoiding overdevelopment in areas exhibiting water stress. Historical subdivision of the island created neighbourhoods with relatively small lots (e.g. parcel area in the range of 1000 m^2 or 0.25 acres) each with their own well and septic system. With increased property values, and need for housing, comes the pressure to add residential density including as secondary suites and cottages in already highly developed areas.

- The freshwater footprint analysis provides a guide to factors that could be considered when developing growth strategies that minimize further pressure in highly stressed areas.
- Areas with a very high freshwater footprint are likely not appropriate for development beyond current density or require policies to guide land use changes and rezoning specific to the hazards in these areas, such as saltwater intrusion.
- Additional development on the island could focus in areas with very low, to moderate footprint.
- The southeast island is an area of established farmland and large parcels suitable for agriculture. Considering ways to support this type of land use and ensure adequate quantity and quality of water for local food production, will increase community resiliency.

7 CONCLUSIONS AND RECOMMENDATIONS

A freshwater footprint methodology was developed to assess water security and sustainability within the Islands Trust area, in which groundwater is the primary water source. Water supplies on the islands are limited and vulnerable to depletion and impacts from land use and natural hazards. Building on the concepts of an ecological carrying capacity and aquifer stress assessment, the objective was to evaluate groundwater sustainability on the islands, considering factors related to water supply and demand, land use and water quality indicators.

Managing groundwater sustainably means maintaining water of adequate quality and quantity for community needs (energy, water supply, food production, industry), while maintaining stable levels, flows and quality in aquifers, and groundwater dependent ecosystems. It also requires governance models that allow for equitable, long-term planning, and protection of water for future generations.

The freshwater footprint method incorporated criteria related to:

- Aquifer stress (groundwater use compared to recharge);
- Groundwater level monitoring and long-term trends);

- Population and lot density;
- Saltwater intrusion hazard based on depth to the saltwater interface; and
- Groundwater quality parameters—chloride and total dissolved solids (TDS)—as indicators of fresh groundwater or the impacts of seawater intrusion or mixing with deeper, mineralized water sources.

In an island setting, all of the water available in streams and aquifers comes from precipitation over the island's footprint. Surrounded by sea water with high salinity, island aquifers are vulnerable to changes in recharge, groundwater pumping, and climate-change related sea level rise and storm surges which increase the hazard of seawater intrusion. Fractured sedimentary bedrock (subtype 5a) aquifers, common in the Trust Area, have a low productivity, and wells with low to moderate yields. Groundwater development and drilling of deeper wells can intersect fractures with more mature, mineralized groundwater with higher concentrations of natural contaminants such as manganese, fluoride and arsenic. Human land use and activities, such as discharges from septic systems and agricultural waste, can also introduce nutrients such as nitrate and other contaminants. For these reasons, measures of water sustainability focused solely on a water balance approach may fail to consider important indicators of the impacts of groundwater use and land development.

The freshwater footprint methodology was developed and applied to a case study for Gabriola Island, in the Regional District of Nanaimo (RDN). Gabriola Island was considered an ideal location to test the method because the hydrogeology of the island has been well studied. Long-term (10+ years) groundwater level monitoring data were available for six sites. While a large water quality dataset was compiled from water system operational sampling, and domestic well testing subsidized through the RDN Drinking Water and Watershed Protection Program. Despite this, data gaps were identified, including lack of groundwater level monitoring near community centres and in the areas of high well density and higher water demand, including for non-domestic (licensable) use, and lack of monitoring data from surface streams and lakes.

Aquifer stratigraphic model: A conceptual model of Gabriola Island aquifers was developed, and detailed information on soils, surficial geology, weather, climate, and groundwater conditions was compiled into a geospatial database.

Gridded water balance model

A GIS-based water balance model was developed, using 10 by 10 m grid cells to characterize water inputs and outputs in different areas of Gabriola Island.

> **Climate:** The Gabriola Islands climate is characterized by mild, wet winters and warm dry summers. Most annual precipitation is received during the months of November to January.

Water sources and demand: Most water on Gabriola Island is obtained from wells. However, surface water, rainwater collection and bulk water hauling are also relied on for potable use, to augment groundwater supplies or backup water source. A comprehensive estimate of water use was prepared, based on an inventory of registered wells, water licenses, and non-domestic water users on the island. Annual and monthly water demand was determined for different land use categories (e.g. residential, commercial, industrial) considering regional water use patterns and peaking factors, based on long-term monitoring in representative water systems (RDN water services). Annual water demand on the island is up to 740,000 m3/year, with higher demand in the summer months due to increased occupancy and outdoor use.

Groundwater recharge potential: The ability of precipitation to infiltrate into the ground and recharge local aquifers was assessed based on factors such as soil depth and material, bedrock fractures, topography, slope, and vegetative cover. Topography and bedrock fractures, indicated by mapped lineament features, had the largest influence on groundwater recharge, with high elevation areas in the southwest and central island identified as areas of highest recharge potential.

Groundwater recharge: The amount of groundwater that is replenished into the island aquifers annually and per month, was estimated considering precipitation inputs, and water losses from evapotranspiration and runoff. Most groundwater recharge occurs during the winter when evapotranspiration from soil and plants is less, and surplus water is available from precipitation.

Aquifer stress: The proportion of annual recharge used to supply residential, institutional commercial and industrial water demand (including agriculture) was calculated. The aquifer stress index—water use compared to availability—was divided into five categories: Low (<5% of groundwater recharge is used annually), Moderate (5-10%), High (10-20%), Extreme (20-40%), Very Extreme (>40% of recharge is used). Densely developed areas with smaller lots such as in the Sands (north island), central village and Descanso Bay areas had extreme to very extreme aquifer stress. However most areas of the island have a low to moderate stress. The stress index thresholds are considered precautionary, to ensure that groundwater is preserved to maintain coastal ecosystems, and groundwater dependent baseflows in creeks and wetlands.

Hydraulic connectivity: Groundwater discharge is essential for thermal regulation and maintenance of base flows in hydraulically connected surface water sources including streams, creeks and wetlands. Although many of the streams on Gabriola Island are ephemeral, and surface water flow data were not available, mapping methods were used to determine areas of probable hydraulic connectivity, which could be targeted for future monitoring.

Freshwater Hazard Assessment

Groundwater monitoring trends: Long-term monitoring data from six sites including four provincial observation wells, and two volunteer wells monitored by Regional District of Nanaimo were evaluated. Most sites show stable trends, while a moderate declining trend water observed in one well. More monitoring is needed by water systems and in volunteer or dedicated wells to assess conditions in highly developed areas of the island.

Seawater intrusion hazard: Deterioration of freshwater quality due to seawater intrusion in coastal areas is considered the most significant hazard for the island's aquifers. The depth to the saltwater interface was mapped to indicate the depth of the freshwater lens. Seawater intrusion hazard is greatest in coastal areas with low topographic gradient and high density of wells, but high risk areas can extend up to 500 m inland, and are sensitive to drawdown of groundwater levels below sea level.

Groundwater quality: A comprehensive database of groundwater quality results was compiled from over 500 samples collected from 1985 to 2025. Water quality was good overall, with the results for most parameters meeting drinking water quality guidelines. A small proportion of samples had concentrations of fluoride or arsenic above health related guidelines. Similarly, concentrations of manganese, chloride and total dissolved solids (TDS) were higher than aesthetic objectives and operational guidelines in some samples. Concentration of nitrate was below drinking water guidelines in all samples. Background concentrations of chloride, total dissolved solids and nitrate were determined, to highlight areas that could have higher than average concentration due to land use or other impacts. Chloride and electrical conductivity are considered useful to indicate wells that are impacted by seawater intrusion and mixing of fresh groundwater with saline water sources. Higher concentrations of TDS indicate highly mineralized water, such as obtained from deeper fractures, including in the central island at further distance from the coast.

Bacteria: Total coliform bacteria were present in up to 60% of samples, indicating groundwater recharge from surface water sources, soil layers and shallow fractures. *E. coli* bacteria were present in a third of samples, indicating groundwater contamination with fecal matter which could contain other pathogens such as viruses. Well vulnerability to contamination is related to well maintenance and construction characteristics, such as lack of a surface seal in older wells, and proximity of wells to septic systems. Further education on well maintenance, and support for upgrading wells to prevent introduction of bacterial contaminants and other pathogens is recommended.

Freshwater Footprint

The freshwater footprint combined the results of the water quantity and quality indictors including aquifer stress, seawater intrusion hazard, population and lot density, and water quality criteria (TDS and chloride). Areas in central and southern

Gabriola island had a lower freshwater footprint, while high footprint was observed near Descanso Bay and the community centres. Very high freshwater footprint was determined in the Sands region on the north island, reflecting the increased hazard of seawater intrusion in this area.

The overall hazard reflects the relative vulnerability freshwater due to natural hazards (precipitation and recharges, thickness of the freshwater lens below the island, groundwater mineralization) and human influenced factors (groundwater use, development density, drilling of wells into deeper aquifer zones in coastal and inland areas).

The footprint assessment results could be used to guide land use planning and policy development to ensure protection of Gabriola Islands freshwater resources.

The following recommendations could be considered on Gabriola Island and in other areas:

Groundwater monitoring networks: Review and enhance local groundwater monitoring by identifying and implementing monitoring in additional locations. Gabriola Island benefits from having multiple active provincial and volunteer observation wells, however information is lacking in village centres and areas of higher well density and water demand such as the northwest island. Monitoring strategies could include establishing locations for ambient monitoring of inactive wells (purpose built). However in the short-term, establishing monitoring within existing and active wells such as those operated by water systems would likely be most cost effective.

Support water systems to implement or enhance operational monitoring and reporting: Water systems should be encouraged and supported to implement monitoring of groundwater conditions (water level and temperature), water use (metering) and water quality monitoring. Monitoring provides valuable information for operational and planning purposes, e.g., to evaluate seasonal changes in water availability and use, to predict and respond during periods of drought and water shortage, to plan and implement water conservation strategies. Water system monitoring could be prioritized in areas where current groundwater monitoring data are lacking. Additional monitoring workshops focussed on the needs and responsibilities of water system operators could be offered in the local area, to encourage monitoring and data sharing. A repository for shared information could be established or opportunities sought to increase participation and use of existing data collection and sharing tools, including Aquarius (Ministry of Environment and Parks, 2025b), Depth2Water (Regional District of Nanaimo, 2025a), or other data compilation software and web-tools.

Develop surface water (hydrometric) and climate monitoring networks: Gabriola Island and other islands in the Trust Area, have numerous small streams with limited active monitoring, although historical programs have collected periodic data. Islands Trust could seek opportunities to collaborate with provincial agencies, and conservation groups to establish and maintain monitoring stations in key watersheds. Priority for monitoring could be given to streams and wetland areas where there is a high likelihood of hydraulic connectivity between groundwater and surface water, to assess groundwater baseflow contributions, and the timing of seasonal streamflow declines. Similarly, local climate monitoring stations could be re-initiated or to capture representative data on precipitation, temperature and other climate-related parameters.

Improve data sharing and availability for decision-making: Develop a local or regional water information repository, to assist with collection and sharing of monitoring information including water level monitoring, and water usage. Provide training and standards for monitoring and data collection methods and standards to ensure good quality data are collected. Regional and local users could work with the province to include appropriate datasets in provincial data portals. For example, the provincial Real-Time water data portal (Ministry of Environment and Parks, 2025b) includes data from community monitoring networks including those operated by the Regional District of Nanaimo; however public use of the data in provincial data hubs could benefit from the inclusion of more metadata and documentation regarding the monitoring location characteristics, and methods used for data collection, validation, and compensation (i.e., correction to manual readings and adjusting for barometric pressure variation). There is currently no data collection tool or repository for water use data, a significant gap that hinders research and resource management.

Collect statistics on bulk water hauling: Where bulk water is provided to augment water supplies, this information can provide insight into seasonal or long-term stresses and resource limitations in particular areas. For Gabriola Island, on-island water use for bulk delivery is metered. Water sourced from Nanaimo and brought to Gabriola Island is not specifically tracked. A simple tracking system could be implemented by City of Nanaimo and Regional District of Nanaimo to collect information on the general region (e.g., island, electoral area) where water is being delivered. Statistics on changes in bulk delivery patterns over time could provide insight into where water scarcity or drought pressures are occurring.

***Water Sustainability Act* and groundwater licensing:** Although it is difficult to verify using available datasets, it appears that a significant proportion of non-domestic groundwater users in the study area do not have a groundwater license despite the Act being in force for a decade (although an unknown number of licenses may be in process). Non-domestic groundwater users should be encouraged to apply for a groundwater license to secure their water rights, if they have not yet applied. The Ministry of Water, Land and Resource Stewardship should work with the local community to improve understanding and awareness of groundwater licensing requirements. Regulation of non-domestic users is an important management tool. Water license terms should include conditions related to water metering, monitoring and water quality testing, in particular within areas with the highest vulnerability to saltwater intrusion.

Integrate Water Quality Databases: The challenge of compiling water quality for this study highlighted the need for greater integration and co-operation between regulatory agencies including Island Health and the Ministry of Water, Land and Resource Stewardship. Current methods for tracking water quality are antiquated, frequently require manual digitization, and there is limited ability to evaluate trends. GWELLS registration was incomplete or missing for many water systems, and sample site naming conventions were inconsistent. Provincial agencies should ensure all permitted water system wells are registered and cross-referenced in GWELLS and establish a shared unique numbering system (EMS ID and referenced Well Identification Plate) for field validation of groundwater sites, for all water system and sample sites. Laboratories should be required to upload digital data to a provincial database. Ideally there should be shared water quality database managed between agencies that would allow for permitted access for other levels of government and researchers.

Field surveys: Community surveys, including field evaluation of electrical conductivity, could be conducted in areas of higher seawater intrusion risk to validate model assumptions and refine understanding of regional water quality.

Water Quality Objectives: Aquifer water quality objectives and thresholds could be developed under the *Water Sustainability Act*, to prevent the drilling and operation of wells that produce saline water, and wells impacted by sea water intrusion or mixing of highly mineralized water groundwater from deep fractures.

Further develop and apply the methodology in other areas: Further work could be completed in the Islands Trust Area to assess the feasibility of the water footprint approach, determine applicability to other areas, and ways in which the methodology could be improved.

Traditional knowledge and First Nations values: Islands Trust is in the process of building collaborative working relationships with First Nations governments, including the Snunemuxw First Nation whose traditional territory and lands encompass Gabriola Island. Although First Nations involvement was a desired component of the project that was not possible to include within the first phase but is something that could be further explored in future.

Study Limitations

This document was prepared for the exclusive use of Islands Trust. The inferences concerning the data, site and receiving environment conditions contained in this document are based on information obtained during investigations conducted at the site by GW Solutions and others, and are based solely on the condition of the site at the time of the site studies. Soil, surface water and groundwater conditions may vary with location, depth, time, sampling methodology, analytical techniques and other factors.

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The produced graphs, images, and maps, have been generated to visualize results and assist in presenting information in a spatial and temporal context. The conclusions and recommendations presented in this document are based on the review of information available at the time the work was completed, and within the time and budget limitations of the scope of work.

Islands Trust may rely on the information contained in this memorandum subject to the above limitations.

8 CLOSURE

Conclusions and recommendations presented herein are based on available information at the time of the study. The work has been carried out in accordance with generally accepted engineering practice. No other warranty is made, either expressed or implied. Engineering judgement has been applied in producing this letter-report.

This report was prepared by personnel with professional experience in the fields covered. Reference should be made to the General Conditions and Limitations attached in Appendix 1.

GW Solutions was pleased to produce this document. If you have any questions, please contact me.

Yours truly,

GW Solutions Inc.
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APPENDIX A

BEST PRACTICES FOR PREVENTION OF SEAWATER INTRUSION

Table A1. Best practices for prevention of seawater intrusion.

Well Drillers	Research local conditions and plan when drilling in areas at risk of seawater intrusion Site wells a minimum of 30 m from seashore Test for salinity indicators during drilling (electrical conductivity (EC) or total dissolved solids (TDS)) If saline groundwater is encountered stop drilling and test the water quality Backfill and seal off saline zones Educate well owners regarding the hazards and prevention of SWI
Well Pump Installers	Install well pump at shallower depth and include automated shutoffs to limit groundwater level drawdown below sea level Set pump to operate for timed shorter cycles at a low pumping rate to refill water storage (“well sipping”) Install meters and alarms to identify and quickly fix uncontrolled leaks A datalogger can be installed that monitors groundwater level, temperature and EC, to develop an understanding of changes in water quality during pumping Install monitoring equipment to measure EC or TDS while pumping, and to shut off pumping if water quality exceeds an identified limit (e.g. operational threshold or drinking water guideline) (Note: Cost for this type of monitoring would be relatively high and only recommended for a water supply systems or higher capacity production wells in which SWI impacts are being managed)
Well Owners	Record observations that could indicate changes in water quality over time (salty taste, observed corrosion or discolouration of pipes and fixtures) Purchase a low-cost water quality monitor (e.g. pen style conductivity or TDS meter) and record periodic measurements of groundwater quality, making note of trends, seasonal differences, or changes during periods of higher water use Collect samples for lab analysis of geochemical water quality annually or semi-annually, and include analysis of salinity indicators (chloride, EC, TDS) Install low water use fixtures (low flush or suction toilets, low flow shower heads and faucets) Practice water conservation, limit non-essential water use including limiting outdoor irrigation in areas at highest risk of intrusion Consider options for water re-use in the home or outdoors Check for and fix uncontrolled leaks, hoses left open, etc. which could draw down water levels in the well Educate residents and guests regarding low water use practices Use water cisterns to store water from the well or other backup supplies (e.g., rainwater collection). Observing tank storage and drawdown is also an easy way to measure and manage water demand. If well produces salty water seasonally or periodically, use an alternate supply, investigate the cause and seek advice from a driller, pump installer or other qualified person Properly decommission (backfill) unused wells that could provide a pathway for circulation and movement of saline water from deeper to shallower aquifer zones In multi-well systems, alternate the pumping of each well to allow water levels to recover

References:(Province of BC, 2016b; US Geological Survey, 2000; Werner et al., 2013).

APPENDIX B

FRESHWATER FOOTPRINT ADDITIONAL TABLES

Table B-1: Gabriola Island Non-Domestic Groundwater Users

Count	Facility Name	Address	Facility Category (Island Health)	Water use purpose	License (YESES, NO, UNKNOWN NOWN, APPLIED, NA)	Water source type - well, spring, stream, other
1	Arbutus Building Supply	785 Ross Way	2-14 (DWS)	Industrial-commercial enterprise	UNKNOWN	Well
2	Camp Miriam	835 Berry Point Road	2-14 (DWS)	Industrial-camp and public facility	UNKNOWN	Well
3	Christ Church Gabriola (Gabriola United Church)	2600 South Road	1 (DWQ)	Industrial-camp and public facility	UNKNOWN	Well
4	Descanso Bay Regional Park	595 Taylor Bay Road	2-14 (DWS)	Industrial-camp and public facility	YES (AQ706)	Well (non-potable only)
5	Dragon's Lodge	2950 Dragons Lane	1 (DWQ)	Industrial-commercial enterprise	UNKNOWN	Well
6	BC Ferries Terminal (Fiddlehead Spring)	350 North Road	2-14 (DWS)	BC Ferries water supply (terminal bathrooms)	YES	Spring
7	Folk Life Village	575 North Road	2-14 (DWS)	Industrial-commercial enterprise	UNKNOWN	Well
8	Gabriola Agricultural Hall Water System	465 South Road	1 (DWQ)	Industrial-camp and public facility	UNKNOWN	Well
9	Gabriola Commons Foundation	675 North Road	2-14 (DWS)	Industrial-camp and public facility, Irrigation	YES	Stream, well?
10	Gabriola Community Health Centre	695 Church Street	1 (DWQ)	Industrial-camp and public facility	UNKNOWN	Well
11	Gabriola Garden Homes Vis 5013	500 Argyle Lane	2-14 (DWS)	Waterworks-strata	UNKNOWN	Well
12	Gabriola Golf and Country Club	825 South Road	1 (DWQ)	Industrial-commercial enterprise	YES	Stream, well
13	Gabriola Island Community Hall	2200 South Road	1 (DWQ)	Industrial-camp and public facility	NO	Well
14	Gabriola Island School	680 North Road	1 (DWQ)	Industrial-camp and public facility	UNKNOWN	Well
15	Gabriola Professional Centre	1 590 North Road	2-14 (DWS)	Industrial-commercial enterprise	UNKNOWN	Well

Count	Facility Name	Address	Facility Category (Island Health)	Water use purpose	License (YESES, NO, UNKNOWN NOWN, APPLIED, NA)	Water source type - well, spring, stream, other
16	Gabriola Retirement Village - Well #1 (Meadowood)	22 745 Church Street	15-300 (DWC)	Waterworks	UNKNOWN	
17	Giro Water Supply	700 Tin Can Alley	2-14 (DWS)	Industrial-camp and public facility	UNKNOWN	Unknown
18	Haven Foundation	240 Davis Road	15-300 (DWC)	Industrial-commercial enterprise	UNKNOWN	Hauled, rainwater
19	Hope Centre	790 North Road	1 (DWQ)	Industrial-camp and public facility	UNKNOWN	Well
20	Hope House	790 North Road	1 (DWQ)	Industrial-camp and public facility	UNKNOWN	Well
21	Islands Trust Northern Office (Gabriola Island)	700 North Road	1 (DWQ)	Industrial-camp and public facility	UNKNOWN	Well
22	Madrona Market Place	500 North Road	1 (DWQ)	Industrial-commercial enterprise	UNKNOWN	Well
23	Madrona Market Place West	480 North Road	2-14 (DWS)	Industrial-commercial enterprise	UNKNOWN	Well
24	Meadow Wood	22 745 Church Street	2-14 (DWS)	Industrial-camp and public facility	UNKNOWN	Well
25	Mid Island Consumer Services Co-Op	548 North Road	1 (DWQ)	Industrial-commercial enterprise	UNKNOWN	Well
26	Pages Inn On Silva Bay	3415 South Road	2-14 (DWS)	Industrial-commercial enterprise	UNKNOWN	Well
27	Pages Resort and Marina	3350 Coast Road	2-14 (DWS)	Industrial-commercial enterprise	UNKNOWN	Well
28	Ravenskill Cidery	1240 Coats Road	2-14 (DWS)	Industrial-commercial enterprise	UNKNOWN	Well
29	Robert's Place	560 North Road	1 (DWQ)	Industrial-commercial enterprise	UNKNOWN	Well
30	Rollo McClay Community Park Water	1100 McClay Way	2-14 (DWS)	Industrial-camp and public facility	NA	Hauled
31	Rollo Senior Center	685 North Road	1 (DWQ)	Industrial-camp and public facility	UNKNOWN	Well
32	Silva Bay Resort & Marina/Sterling Res.	3383 South Road	2-14 (DWS)	Industrial-commercial enterprise	UNKNOWN	Well

Count	Facility Name	Address	Facility Category (Island Health)	Water use purpose	License (YESES, NO, UNKNOWN NOWN, APPLIED, NA)	Water source type - well, spring, stream, other
33	Slow Rise Bakery	2500 Coho Drive	2-14 (DWS)	Industrial-commercial enterprise	UNKNOWN	Well
34	Somerset Farm	RR 7 2585 North Road	2-14 (DWS)	Poultry, beef, veggie farm stand	UNKNOWN	Well
35	Summer Rain Water Hauler Truck # 1	3153 Whalley Road	Hauler (DWH)	Waterworks-Water delivery	UNKNOWN	Well, hauled
36	Summer Rain Water Hauler Truck # 2	3153 Whalley Road	Hauler (DWH)	Waterworks-Water delivery	UNKNOWN	Well, hauled
37	Summer Rain Water Hauler Truck # 3	3153 Whalley Road	Hauler (DWH)	Waterworks-Water delivery	UNKNOWN	Well, hauled
38	Summer Rain Water System	3153 Whalley Road	2-14 (DWS)	Waterworks-Water delivery	UNKNOWN	Well
39	Surf Water System	885 Berry Point Road	2-14 (DWS)	Industrial-commercial enterprise	UNKNOWN	Well
40	Sweeney - North Road Water System	815 North Road	2-14 (DWS)	Waterworks	UNKNOWN	Well
41	Twin Beaches Shopping Center	377 Berry Point Road	2-14 (DWS)	Industrial-commercial enterprise	UNKNOWN	Well
42	Gabriola Village Plaza	580 North Road	2-14	Industrial-commercial enterprise	UNKNOWN	Well
43	Fellowship Church	775 North Road	1	Industrial-camp and public facility	UNKNOWN	Rainwater, well (backup)
44	BC Ambulance Service Station 153	721 Church Street	1	Industrial-camp and public facility	UNKNOWN	Well
45	Gabriola #1 Fire Hall	730 Church Street	1	Industrial-camp and public facility	APPLIED	Well, rainwater catchment
46	Gabriola #2 Fire Hall	2400 South Road	1	Industrial-camp and public facility	APPLIED	Well
47	Wild Rose Garden Centre	750 Tin Can Alley	1	Industrial-commercial enterprise	UNKNOWN	Well
48	Bypass Holdings Ltd.	893 Berry Point Road	2-14 (DWS)	Industrial-commercial enterprise	UNKNOWN	Well
49	Paisley Place Water System	529 Paisley Place	15-300	Waterworks	UNKNOWN	Well

Count	Facility Name	Address	Facility Category (Island Health)	Water use purpose	License (YESES, NO, UNKNOWN NOWN, APPLIED, NA)	Water source type - well, spring, stream, other
50	Gabriola Post Office	470 South Road	1	Industrial-camp and public facility	UNKNOWN	Well
51	Gabriola Arts and Heritage Centre	476 South Road	1	Industrial-camp and public facility	UNKNOWN	Well
52	Good Earth Farm	600 South Road	1	Irrigation	UNKNOWN	Well
53	The Garden Bed Organic Farm	565 South Road	1	Irrigation	UNKNOWN	Well
54	RCMP (South Road)	525 South Rd	1	Industrial-camp and public facility	UNKNOWN	Well
55	Gabriola Museum	505 South Rd	1	Industrial-camp and public facility	UNKNOWN	Well
56	Twin Cedars Veterinary Services	885 Buttercup Rd	1	Industrial-livestock and animal	UNKNOWN	Well
57	Heart and Soil Organics	2260 South Rd	1	Irrigation	UNKNOWN	Well
58	Wheelbarrow Nursery	2280 South Rd	1	Industrial-greenhouse, nursery	UNKNOWN	Well
59	Skol Pub (Currently closed)	355 North Road	2-14 (DWS)	Industrial-commercial enterprise	UNKNOWN	Well
60	Crofters Gleann Enterprises	1055 South Road	1	Industrial, irrigation	UNKNOWN	Well

APPENDIX C

MONITORING WELL HYDROGRAPHS

APPENDIX D

HYDROGEOLOGIC CROSS-SECTIONS

APPENDIX E

GABRIOLA WATER USE SURVEY

APPENDIX F

GW SOLUTIONS INC. GENERAL CONDITIONS AND LIMITATIONS

This report incorporates and is subject to these "General Conditions and Limitations".

1.0 USE OF REPORT

This report pertains to a specific area, a specific site, a specific development, and a specific scope of work. It is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation from the site or proposed development would necessitate a supplementary investigation and assessment. This report and the assessments and recommendations contained in it are intended for the sole use of GW SOLUTIONS's client. GW SOLUTIONS does not accept any responsibility for the accuracy of any of the data, the analysis or the recommendations contained or referenced in the report when the report is used or relied upon by any party other than GW SOLUTIONS's client unless otherwise authorized in writing by GW SOLUTIONS. Any unauthorized use of the report is at the sole risk of the user. This report is subject to copyright and shall not be reproduced either wholly or in part without the prior, written permission of GW SOLUTIONS. Additional copies of the report, if required, may be obtained upon request.

2.0 LIMITATIONS OF REPORT

This report is based solely on the conditions which existed within the study area or on site at the time of GW SOLUTIONS's investigation. The client, and any other parties using this report with the express written consent of the client and GW SOLUTIONS, acknowledge that conditions affecting the environmental assessment of the site can vary with time and that the conclusions and recommendations set out in this report are time sensitive. The client, and any other party using this report with the express written consent of the client and GW SOLUTIONS, also acknowledge that the conclusions and recommendations set out in this report are based on limited observations and testing on the area or subject site and that conditions may vary across the site which, in turn, could affect the conclusions and recommendations made. The client acknowledges that GW SOLUTIONS is neither qualified to, nor is it making, any recommendations with respect to the purchase, sale, investment or development of the property, the decisions on which are the sole responsibility of the client.

2.1 INFORMATION PROVIDED TO GW SOLUTIONS BY OTHERS

During the performance of the work and the preparation of this report, GW SOLUTIONS may have relied on information provided by persons other than the client. While GW SOLUTIONS endeavours to verify the accuracy of such information when instructed to do so by the client, GW SOLUTIONS accepts no responsibility for the accuracy or the reliability of such information which may affect the report.

3.0 LIMITATION OF LIABILITY

The client recognizes that property containing contaminants and hazardous wastes creates a high risk of claims brought by third parties arising out of the presence of those materials. In consideration of these risks, and in consideration of GW SOLUTIONS providing the services requested, the client agrees that GW SOLUTIONS's liability to the client, with respect to any issues relating to contaminants or other hazardous wastes located on the subject site shall be limited as follows:

(1) With respect to any claims brought against GW SOLUTIONS by the client arising out of the provision or failure to provide services hereunder shall be limited to the amount of fees paid by the client to GW SOLUTIONS under this Agreement, whether the action is based on breach of contract or tort;

(2) With respect to claims brought by third parties arising out of the presence of contaminants or hazardous wastes on the subject site, the client agrees to indemnify, defend and hold harmless GW SOLUTIONS from and against any and all claim or claims, action or actions, demands, damages, penalties, fines, losses, costs and expenses of every nature and kind whatsoever, including solicitor-client costs, arising or alleged to arise either in whole or part out of services provided by GW SOLUTIONS, whether the claim be brought against GW SOLUTIONS for breach of contract or tort.

4.0 JOB SITE SAFETY

GW SOLUTIONS is only responsible for the activities of its employees on the job site and is not responsible for the supervision of any other persons whatsoever. The presence of GW SOLUTIONS personnel on site shall not be construed in any way to relieve the client or any other persons on site from their responsibility for job site safety.

5.0 DISCLOSURE OF INFORMATION BY CLIENT

The client agrees to fully cooperate with GW SOLUTIONS with respect to the provision of all available information on the past, present, and proposed conditions on the site, including historical information respecting the use of the site. The client acknowledges that in order for GW SOLUTIONS to properly provide the service, GW SOLUTIONS is relying upon the full disclosure and accuracy of any such information.

6.0 STANDARD OF CARE

Services performed by GW SOLUTIONS for this report have been conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions in the jurisdiction in which the services are provided. Engineering judgement has been applied in developing the conclusions and/or recommendations provided in this report. No warranty or guarantee, express or implied, is made concerning the test results, comments, recommendations, or any other portion of this report.

7.0 EMERGENCY PROCEDURES

The client undertakes to inform GW SOLUTIONS of all hazardous conditions, or possible hazardous conditions which are known to it. The client recognizes that the activities of GW SOLUTIONS may uncover previously unknown hazardous materials or conditions and that such discovery may result in the necessity to undertake emergency procedures to protect GW SOLUTIONS employees, other persons and the environment. These procedures may involve additional costs outside of any budgets previously agreed upon. The client agrees to pay GW SOLUTIONS for any expenses incurred as a result of such discoveries and to compensate GW SOLUTIONS through payment of additional fees and expenses for time spent by GW SOLUTIONS to deal with the consequences of such discoveries.

8.0 NOTIFICATION OF AUTHORITIES

The client acknowledges that in certain instances the discovery of hazardous substances or conditions and materials may require that regulatory agencies and other persons be informed and the client agrees that notification to such bodies or persons as required may be done by GW SOLUTIONS in its reasonably exercised discretion.

9.0 OWNERSHIP OF INSTRUMENTS OF SERVICE

The client acknowledges that all reports, plans, and data generated by GW SOLUTIONS during the performance of the work and other documents prepared by GW SOLUTIONS are considered its professional work product and shall remain the copyright property of GW SOLUTIONS.

10.0 ALTERNATE REPORT FORMAT

Where GW SOLUTIONS submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed GW SOLUTIONS's instruments of professional service), the Client agrees that only the signed and sealed hard copy versions shall be considered final and legally binding. The hard copy versions submitted by GW SOLUTIONS shall be the original documents for record and working purposes, and, in the event of a dispute or discrepancies, the hard copy versions shall govern over the electronic versions. Furthermore, the Client agrees and waives all future right of dispute that the original hard copy signed version archived by GW SOLUTIONS shall be deemed to be the overall original for the Project. The Client agrees that both electronic file and hard copy versions of GW SOLUTIONS's instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except GW SOLUTIONS. The Client warrants that GW SOLUTIONS's instruments of professional service will be used only and exactly as submitted by GW SOLUTIONS. The Client recognizes and agrees that electronic files submitted by GW SOLUTIONS have been prepared and submitted using specific software and hardware systems. GW SOLUTIONS makes no representation about the compatibility of these files with the Client's current or future software and hardware systems.

GW SOLUTIONS
ASSESSMENT & PROTECTION OF GROUNDWATER

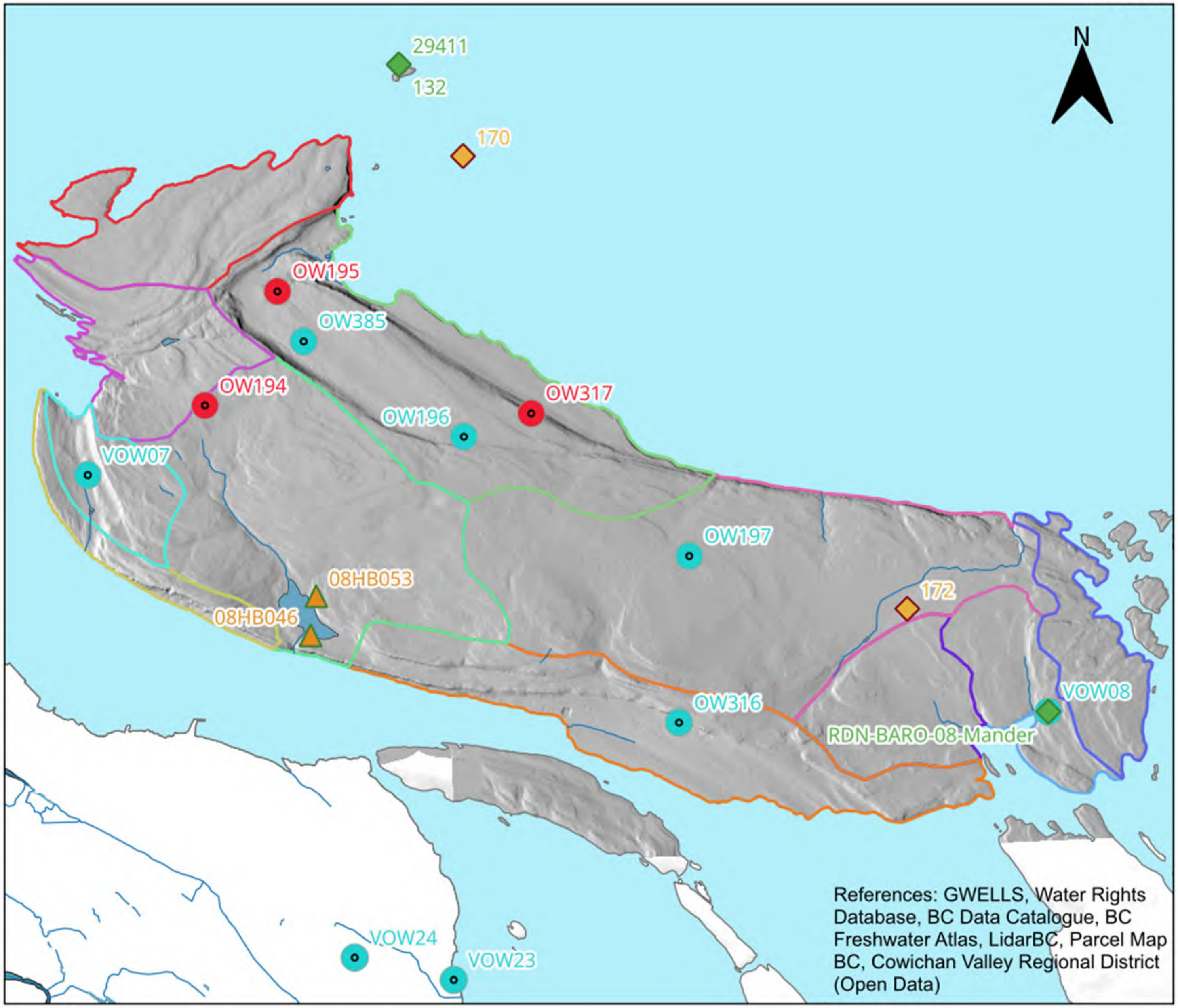
Islands Trust Freshwater Footprint

Methodology Development and Gabriola Case Study

September 2025

Appendix C: Gabriola Island Observation Well Hydrographs

1168915 E
469144 N



1155019 E
457264 N (EPSG:3005)

Legend

Water monitoring stations

- CLIMATE (ACTIVE)
- CLIMATE (DISCONTINUED)
- GROUNDWATER (ACTIVE)
- GROUNDWATER (DISCONTINUED)
- SURFACE_WATER (DISCONTINUED)

Groundwater Regions

- Central Gabriola Region
- Descanso Bay Region
- False Narrows Region
- Hoggan Lake Region
- Lock Bay Region
- North Degnan Bay Region
- Northumberland Channel Region
- Sands Region
- Silva Bay Region
- South Descanso Bay Region
- West Degnan Bay Region

Map Coordinate System: EPSG:3005
Coordinate Units: Meters
Map Scale: 1:65,000
Project File: 24-16 Island_Trust_Groundwater Footprint.qgz
Page Size: 297 x 210 mm
Made with: QGIS 3.40 on Windows

0 1 2 km

Project
24-16 ITC Freshwater Footprint Methodology Project

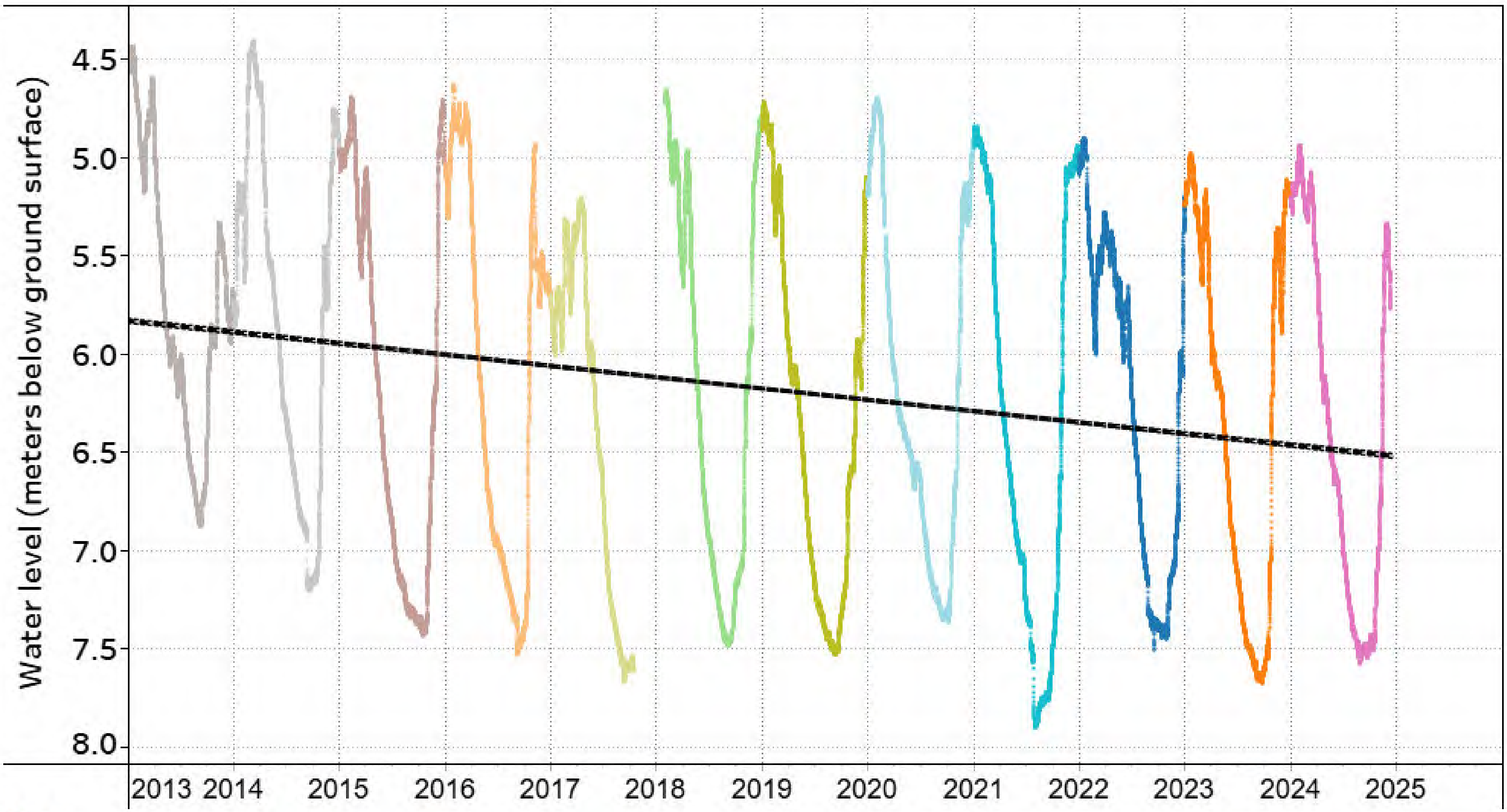
Client
Island Trust

Title
Water monitoring stations

GW SOLUTIONS

Date: 2025-04-30
Map: AB
Review: AB

OW 197 (WR7 - Gabriola Island) Linear Trend Static Water Level



NOTES:

Observation Well Associated with Aquifer 709 (Fractured sedimentary rock)

YEAR

2024 2020 2016
2023 2019 2015
2022 2018 2014
2021 2017 2013

Linear Trend

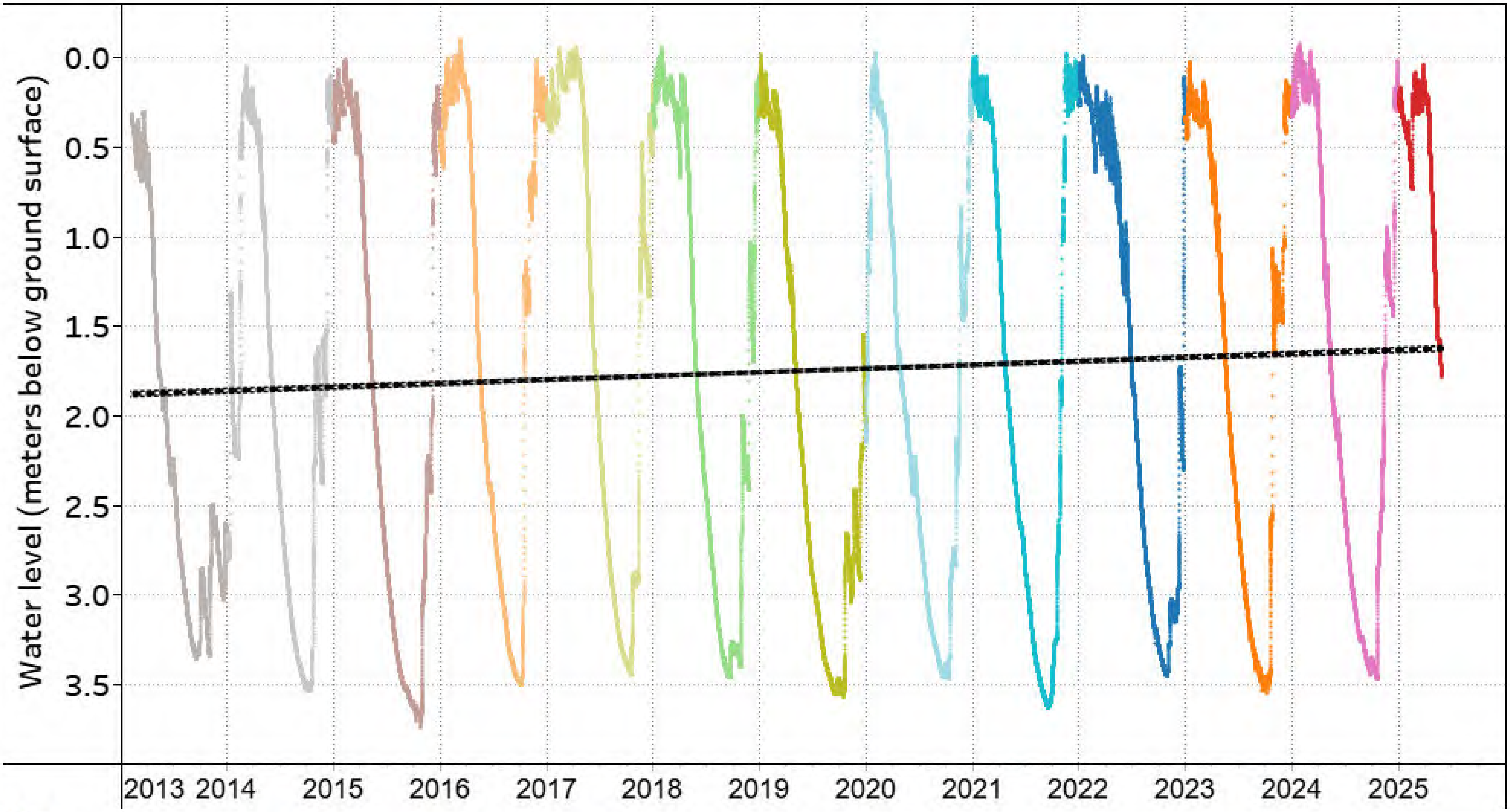
DRINKING WATER AND WATERSHED PROTECTION – REGIONAL GROUNDWATER LEVEL ANALYSIS 2025

HISTORICAL GROUNDWATER LEVEL CHART OW 197 (WR7 - Gabriola Island)

FIGURE 59-B

Regional District of Nanaimo

OW 316 (WR7 - Gabriola Island) Linear Trend Static Water Level



NOTES:

Observation Well Associated with Aquifer 709 (Fractured sedimentary rock)

YEAR

2025	2021	2017	2013
2024	2020	2016	
2023	2019	2015	
2022	2018	2014	Linear Trend

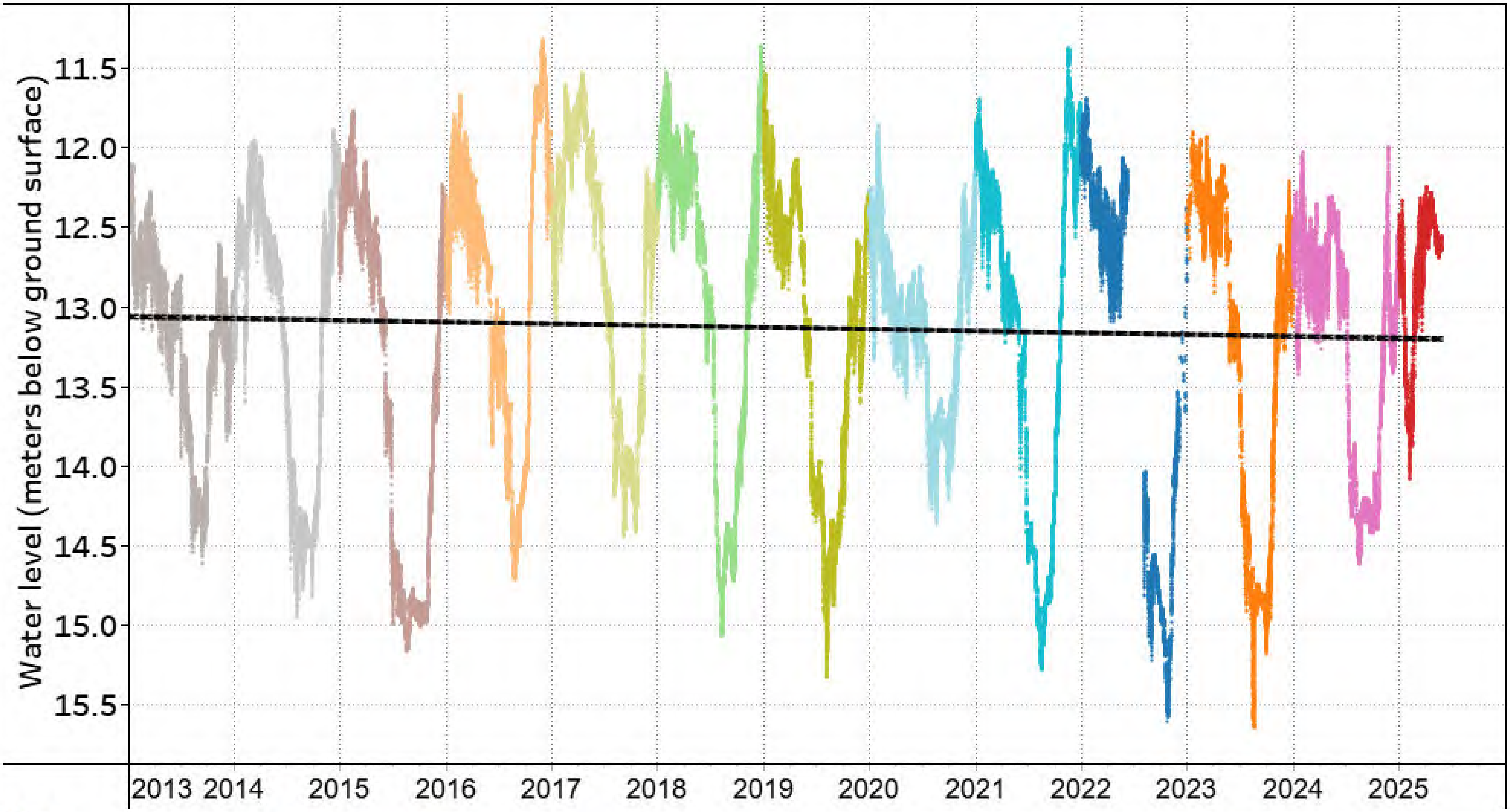
DRINKING WATER AND WATERSHED PROTECTION – REGIONAL GROUNDWATER LEVEL ANALYSIS 2025

HISTORICAL GROUNDWATER LEVEL CHART
OW 316 (WR7 - Gabriola Island)

FIGURE 60-B

Regional District of Nanaimo

OW 385 (WR7 - Gabriola Island) Linear Trend Static Water Level



NOTES:

Observation Well Associated with Aquifer 709 (Fractured sedimentary rock)

YEAR

2025, 2024, 2023, 2022, 2021, 2020, 2019, 2018, 2017, 2016, 2015, 2014, 2013

Linear Trend

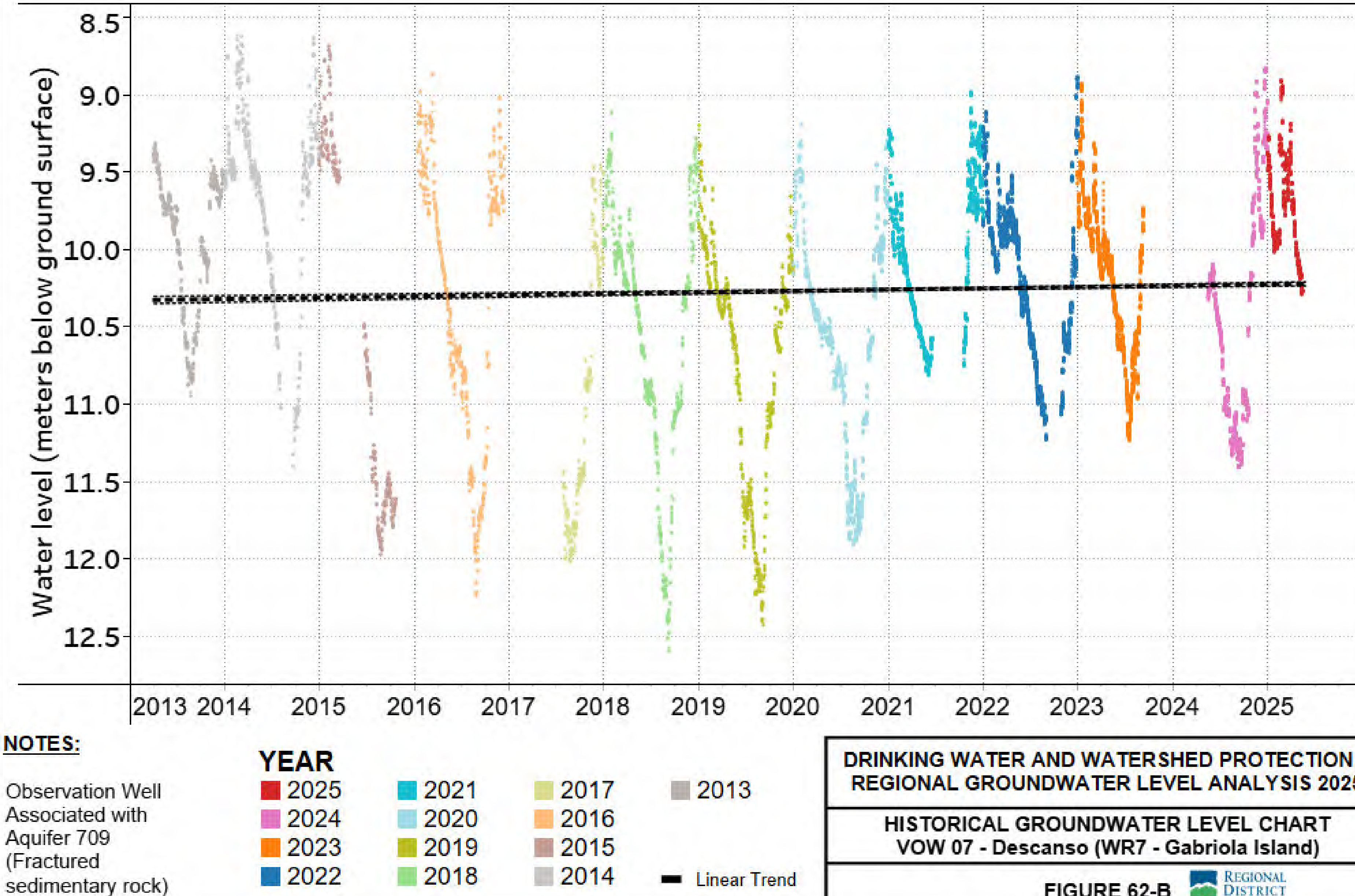
DRINKING WATER AND WATERSHED PROTECTION – REGIONAL GROUNDWATER LEVEL ANALYSIS 2025

HISTORICAL GROUNDWATER LEVEL CHART OW 385 (WR7 - Gabriola Island)

FIGURE 61-B

Regional District of Nanaimo

VOW 07 - Descanso (WR7 - Gabriola Island) Linear Trend Static Water Level



NOTES:

Observation Well Associated with Aquifer 709 (Fractured sedimentary rock)

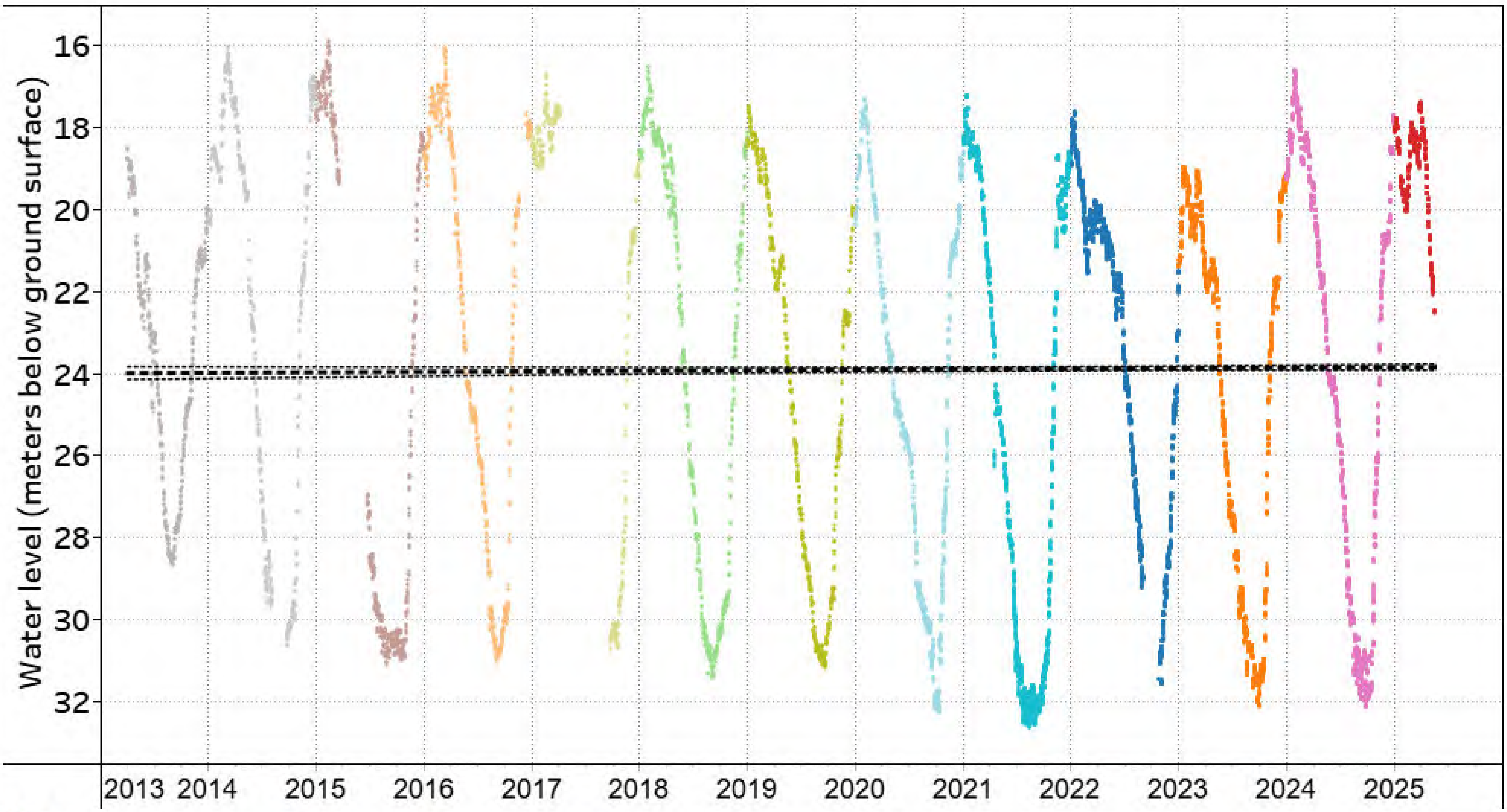
DRINKING WATER AND WATERSHED PROTECTION – REGIONAL GROUNDWATER LEVEL ANALYSIS 2025

HISTORICAL GROUNDWATER LEVEL CHART
VOW 07 - Descanso (WR7 - Gabriola Island)

FIGURE 62-B

Regional District of Nanaimo

VOW 08 - Mander (WR7 - Gabriola Island) Linear Trend Static Water Level



NOTES:

Observation Well Associated with Aquifer 709 (Fractured sedimentary rock)

YEAR

2025, 2024, 2023, 2022, 2021, 2020, 2019, 2018, 2017, 2016, 2015, 2014, 2013

Linear Trend

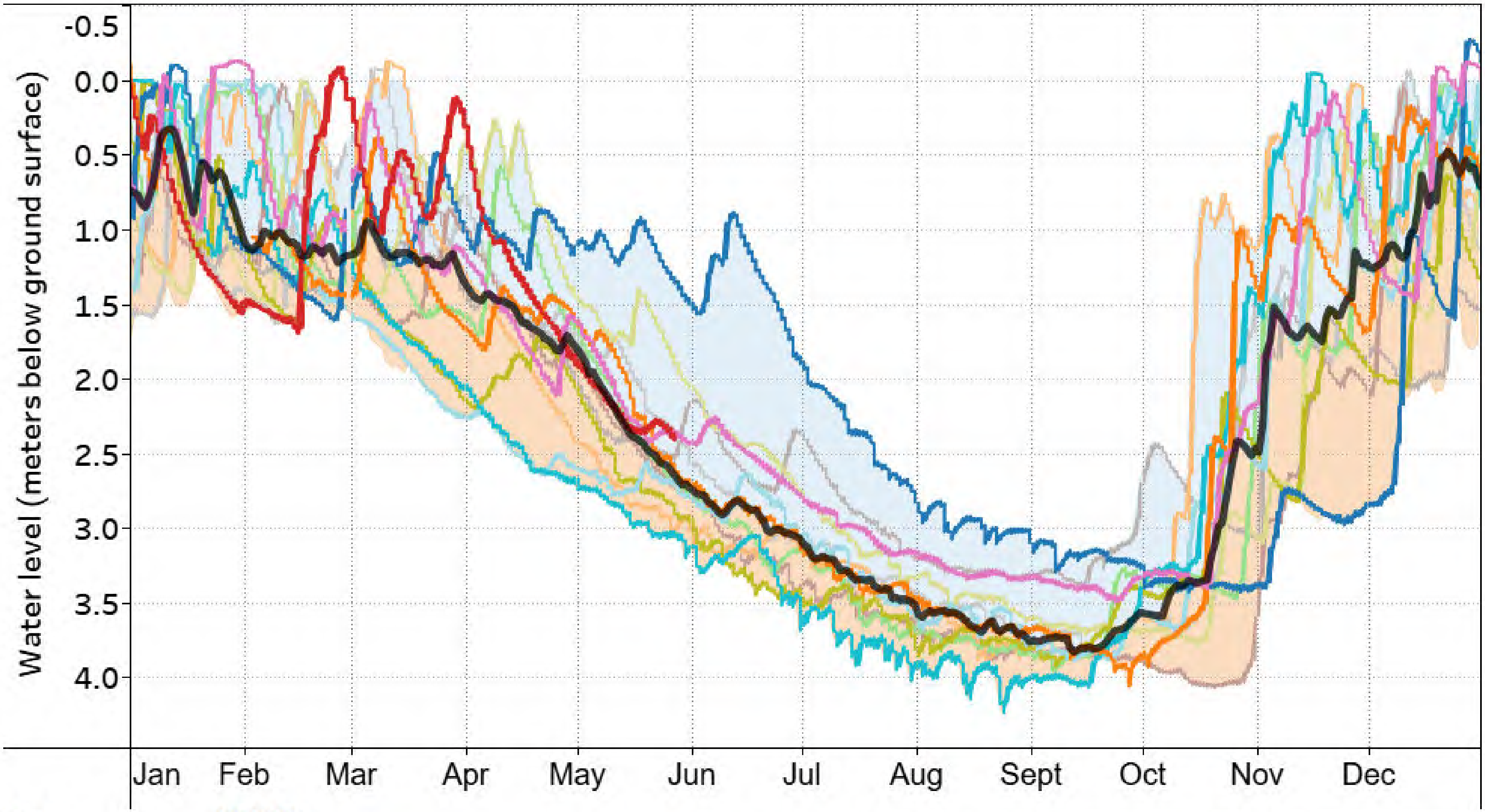
DRINKING WATER AND WATERSHED PROTECTION – REGIONAL GROUNDWATER LEVEL ANALYSIS 2025

HISTORICAL GROUNDWATER LEVEL CHART
VOW 08 - Mander (WR7 - Gabriola Island)

FIGURE 63-B

Regional District of Nanaimo

OW 196 (WR7 - Gabriola Island) Seasonal Static Water Level



NOTES:

Observation Well Associated with Aquifer 709 (Fractured sedimentary rock)

YEAR

2025, 2024, 2023, 2022, 2021, 2020, 2019, 2018, 2017, 2016, 2015, 2014, 2013

Seasonal Trend
Above Median
Below Median

Median Groundwater Level

Data included from January 2013 to December 2024

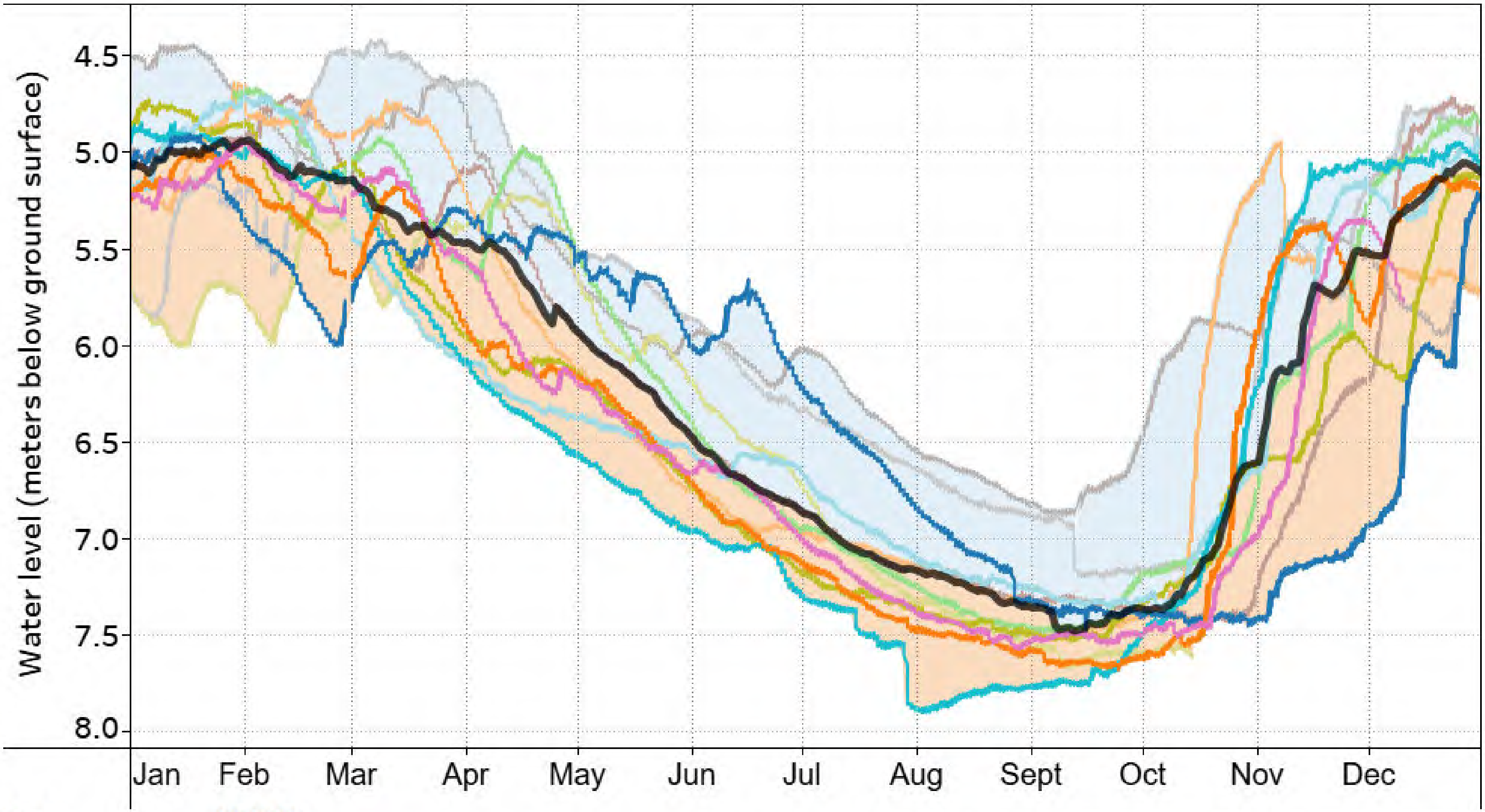
DRINKING WATER AND WATERSHED PROTECTION – REGIONAL GROUNDWATER LEVEL ANALYSIS 2025

SEASONAL GROUNDWATER LEVEL CHART
OW 196 (WR7 - Gabriola Island)

FIGURE 51-C

Regional District of Nanaimo

OW 197 (WR7 - Gabriola Island) Seasonal Static Water Level



NOTES:

Observation Well Associated with Aquifer 709 (Fractured sedimentary rock)

YEAR

2024
2023
2022
2021
2020
2019
2018
2017
2016
2015
2014
2013

Seasonal Trend
Above Median
Below Median

Median Groundwater Level

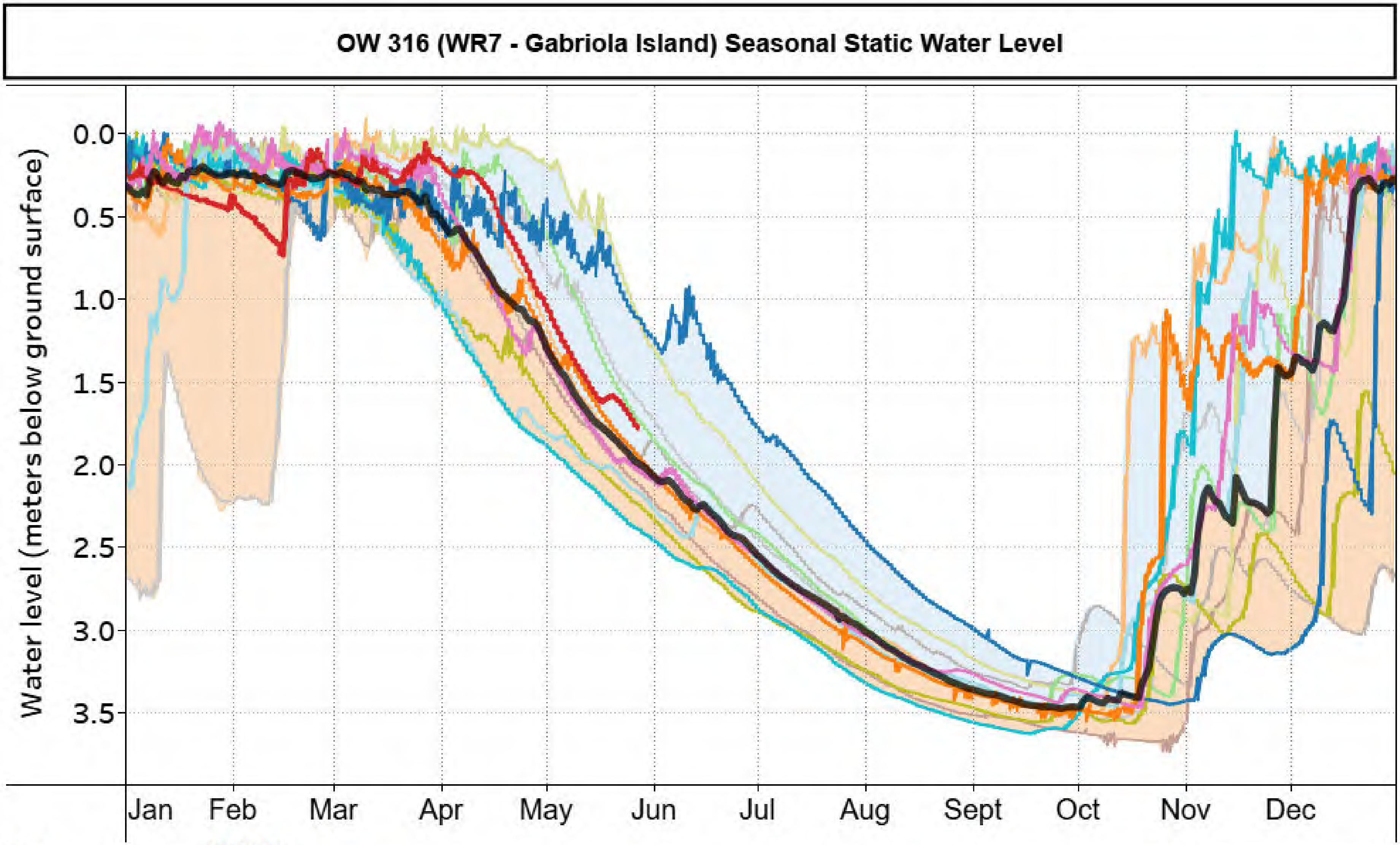
Data included from January 2013 to December 2024

DRINKING WATER AND WATERSHED PROTECTION – REGIONAL GROUNDWATER LEVEL ANALYSIS 2025

SEASONAL GROUNDWATER LEVEL CHART
OW 197 (WR7 - Gabriola Island)

FIGURE 52-C

Regional District of Nanaimo



NOTES:

Observation Well Associated with Aquifer 709 (Fractured sedimentary rock)

YEAR

2025, 2024, 2023, 2022, 2021, 2020, 2019, 2018, 2017, 2016, 2015, 2014, 2013

Seasonal Trend

Above Median

Below Median

Median Groundwater Level

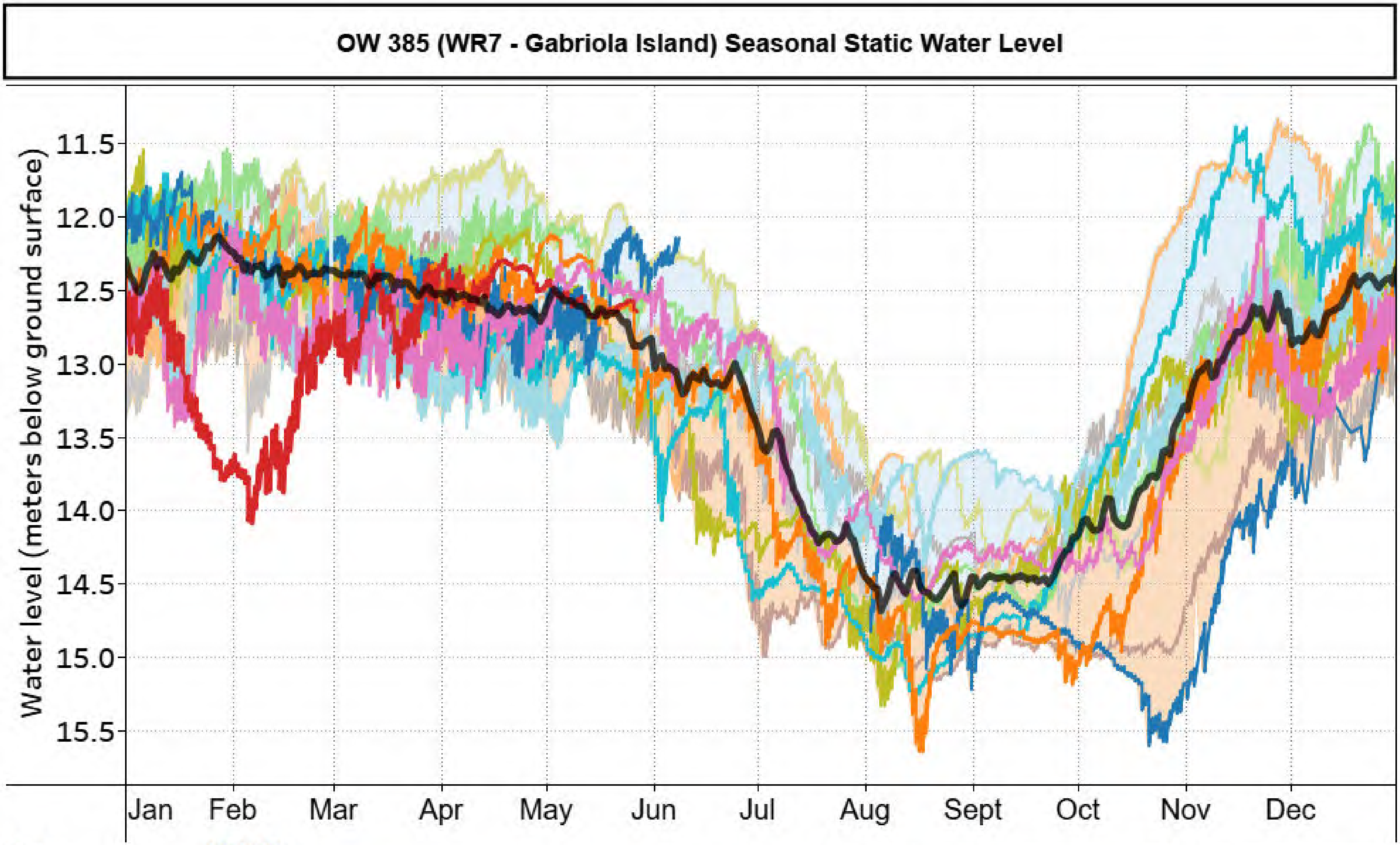
Data included from February 2013 to December 2024

DRINKING WATER AND WATERSHED PROTECTION – REGIONAL GROUNDWATER LEVEL ANALYSIS 2025

SEASONAL GROUNDWATER LEVEL CHART
OW 316 (WR7 - Gabriola Island)

FIGURE 53-C

Regional District of Nanaimo



NOTES:

Observation Well Associated with Aquifer 709 (Fractured sedimentary rock)

YEAR

- 2025
- 2024
- 2023
- 2022
- 2021
- 2020
- 2019
- 2018
- 2017
- 2016
- 2015
- 2014
- 2013

Seasonal Trend

- Above Median
- Below Median
- Median Groundwater Level

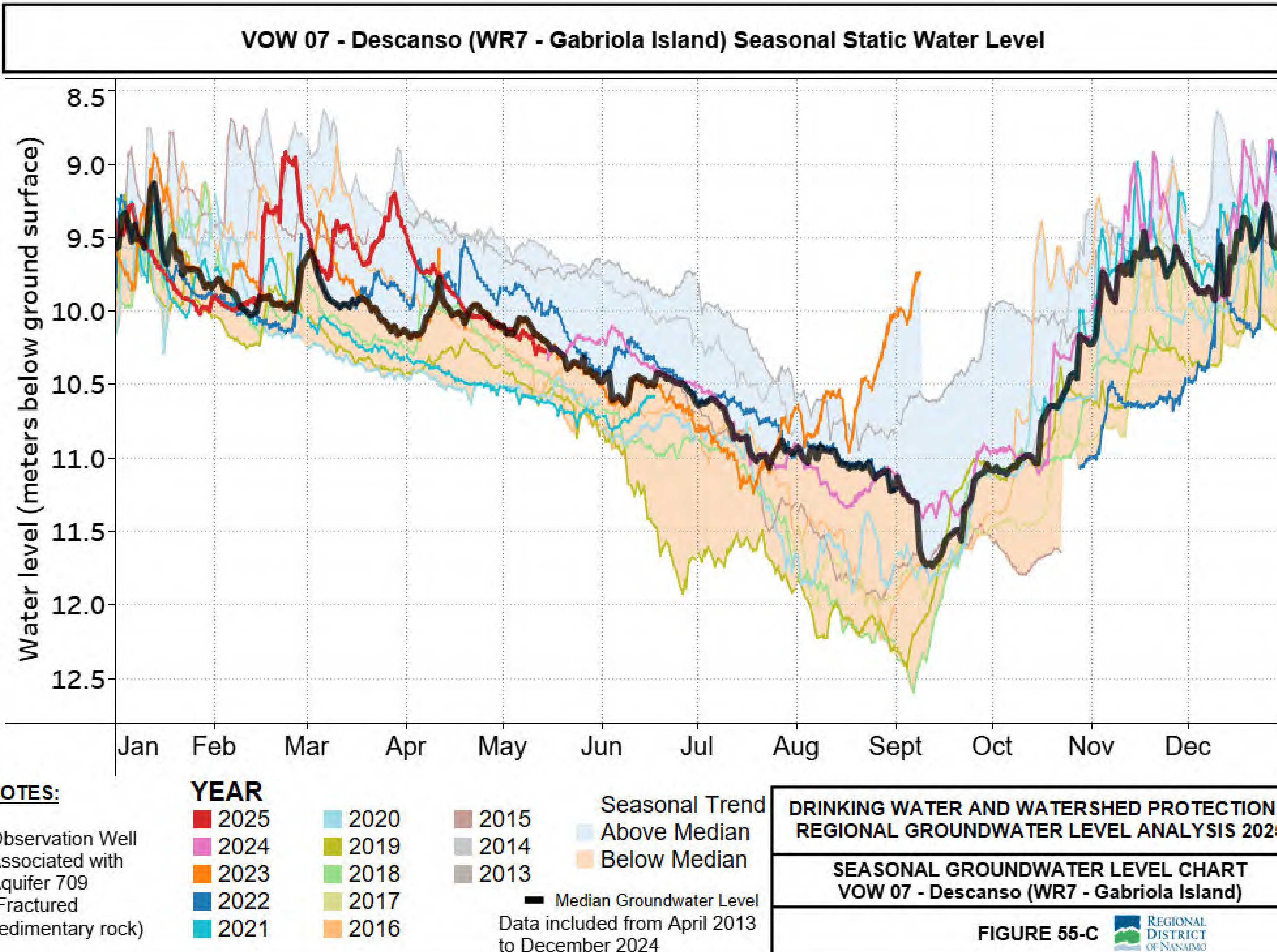
Data included from January 2013 to December 2024

DRINKING WATER AND WATERSHED PROTECTION – REGIONAL GROUNDWATER LEVEL ANALYSIS 2025

SEASONAL GROUNDWATER LEVEL CHART
OW 385 (WR7 - Gabriola Island)

FIGURE 54-C

Regional District of Nanaimo



NOTES:

Observation Well Associated with Aquifer 709 (Fractured sedimentary rock)

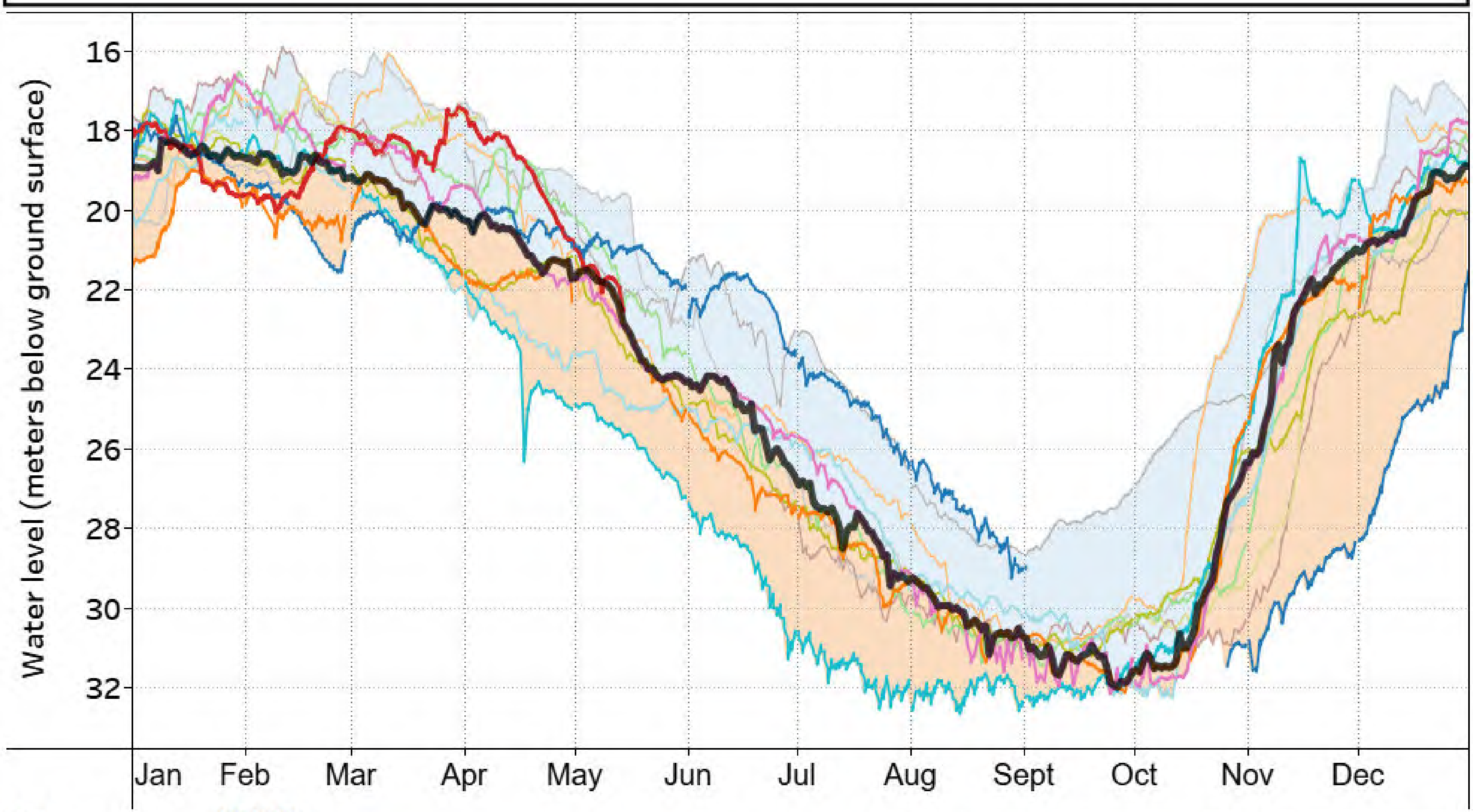
DRINKING WATER AND WATERSHED PROTECTION – REGIONAL GROUNDWATER LEVEL ANALYSIS 2025

SEASONAL GROUNDWATER LEVEL CHART
VOW 07 - Descanso (WR7 - Gabriola Island)

FIGURE 55-C

REGIONAL DISTRICT OF NANAIMO

VOW 08 - Mander (WR7 - Gabriola Island) Seasonal Static Water Level



NOTES:

Observation Well Associated with Aquifer 709 (Fractured sedimentary rock)

YEAR

2025
2024
2023
2022
2021
2020
2019
2018
2017
2016
2015
2014
2013

Seasonal Trend
Above Median
Below Median

Median Groundwater Level

Data included from April 2013 to December 2024

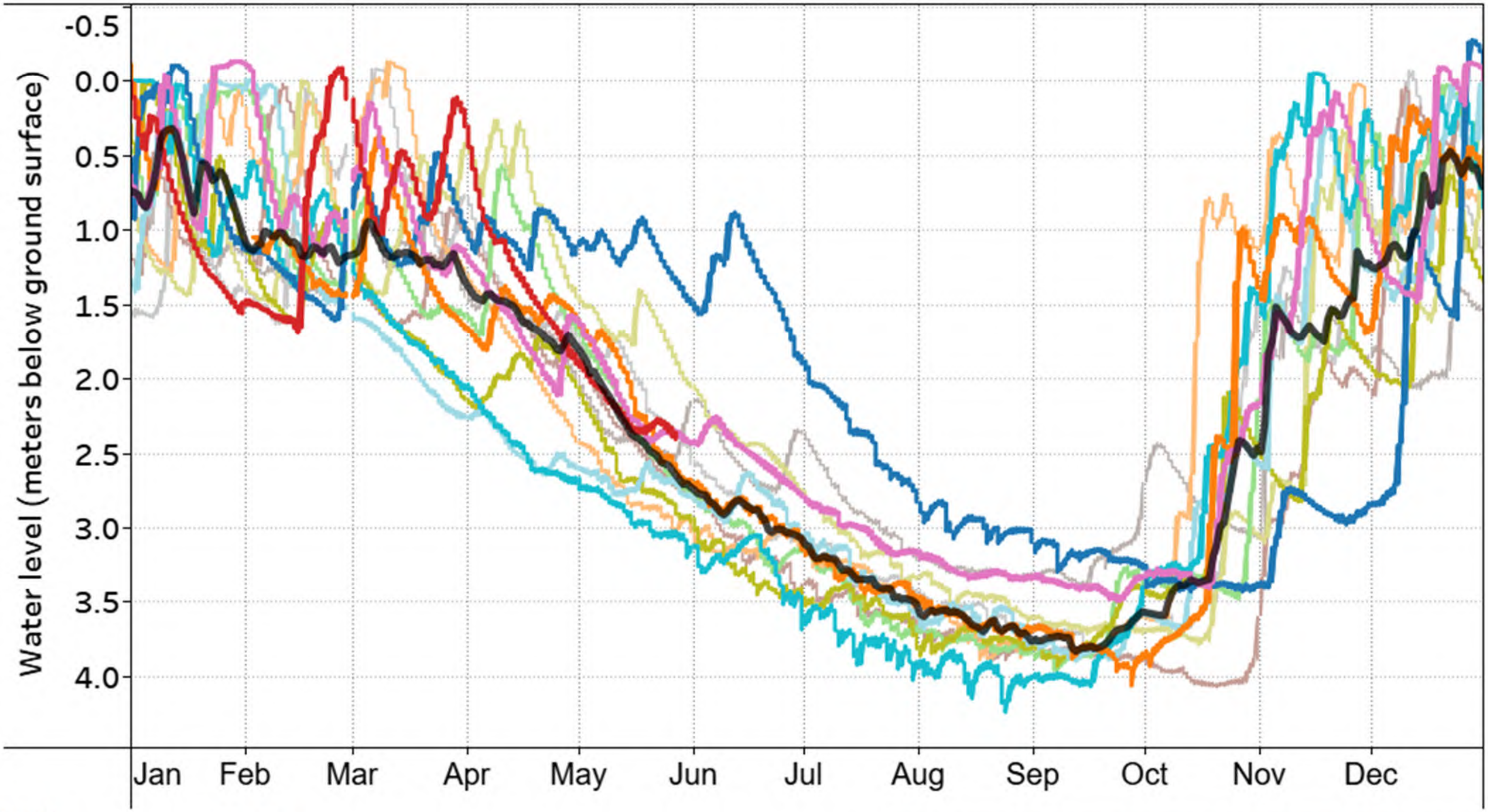
DRINKING WATER AND WATERSHED PROTECTION – REGIONAL GROUNDWATER LEVEL ANALYSIS 2025

SEASONAL GROUNDWATER LEVEL CHART VOW 08 - Mander (WR7 - Gabriola Island)

FIGURE 56-C

Regional District of Nanaimo

OW 196 (WR7 - Gabriola Island) Seasonal Static Water Level



NOTES:

Observation Well Associated with Aquifer 709 (Fractured sedimentary rock)

Data included from January 2013 to December 2024

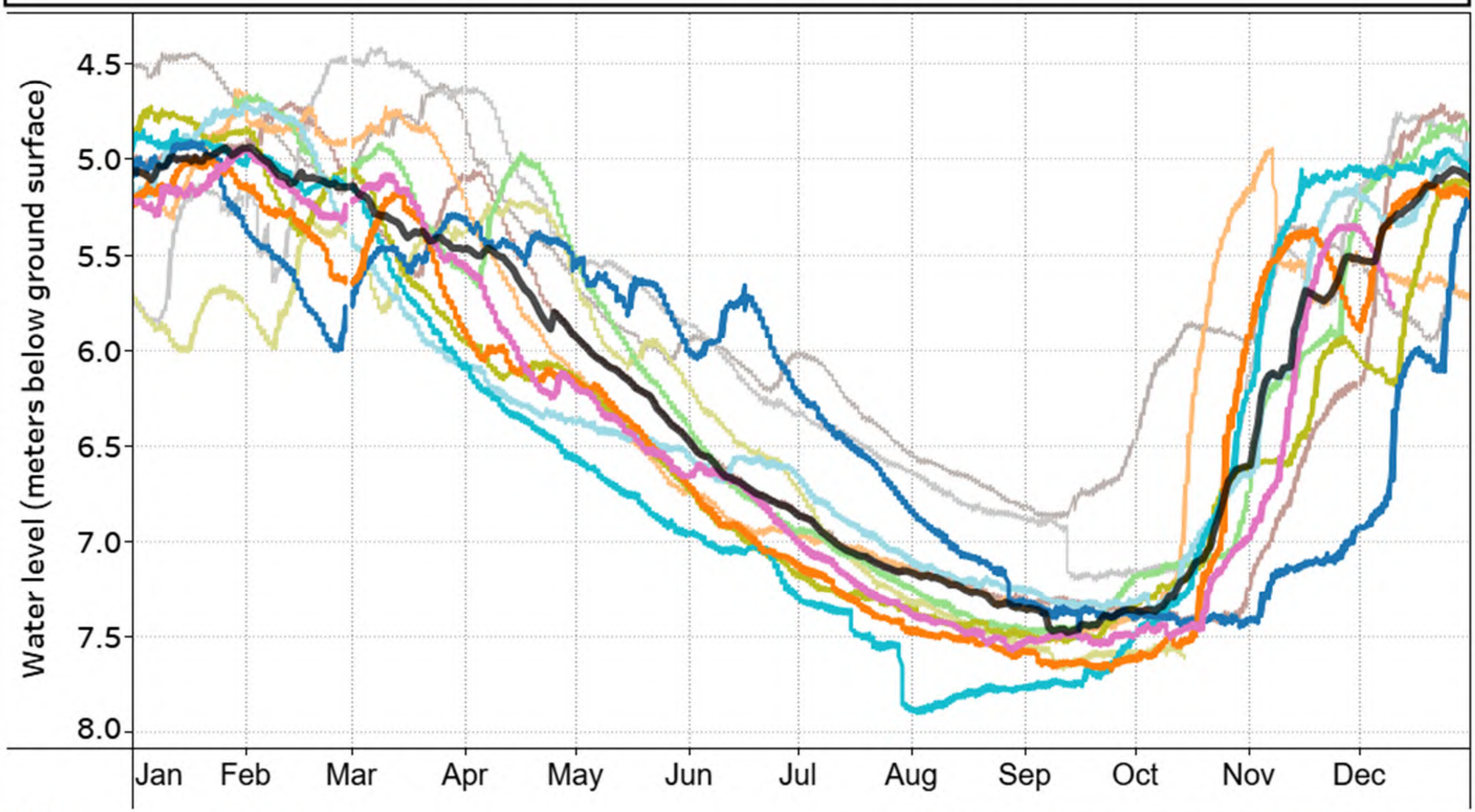
DRINKING WATER AND WATERSHED PROTECTION – REGIONAL GROUNDWATER LEVEL ANALYSIS 2025

SEASONAL GROUNDWATER LEVEL CHART
OW 196 (WR7 - Gabriola Island)

FIGURE 58-C

REGIONAL DISTRICT OF NANAIMO

OW 197 (WR7 - Gabriola Island) Seasonal Static Water Level



NOTES:

Observation Well Associated with Aquifer 709 (Fractured sedimentary rock)

YEAR

2024, 2023, 2022, 2021, 2020, 2019, 2018, 2017, 2016, 2015, 2014, 2013

Median Groundwater Level

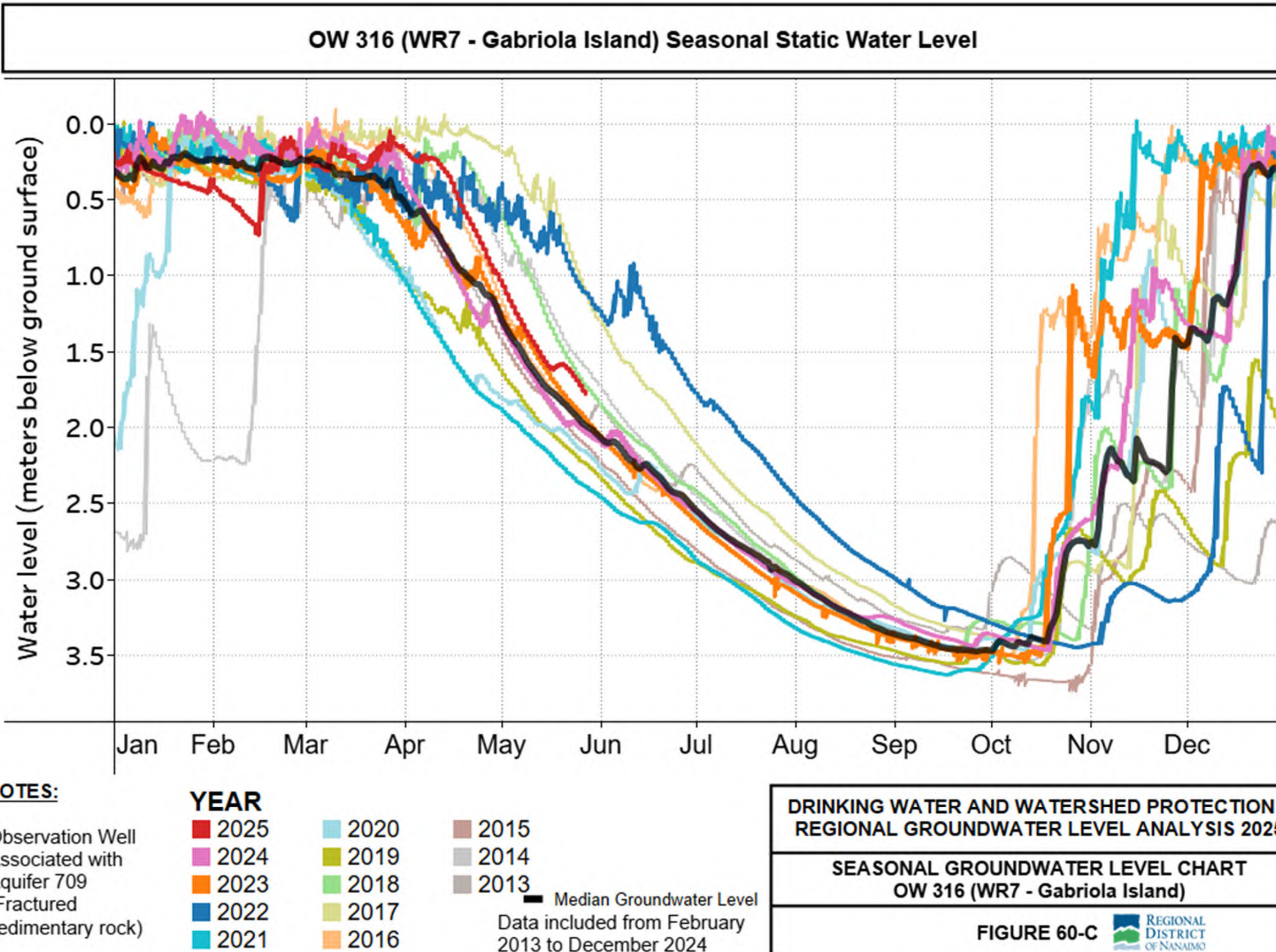
Data included from January 2013 to December 2024

DRINKING WATER AND WATERSHED PROTECTION – REGIONAL GROUNDWATER LEVEL ANALYSIS 2025

SEASONAL GROUNDWATER LEVEL CHART OW 197 (WR7 - Gabriola Island)

FIGURE 59-C

Regional District of Nanaimo



NOTES:

Observation Well Associated with Aquifer 709 (Fractured sedimentary rock)

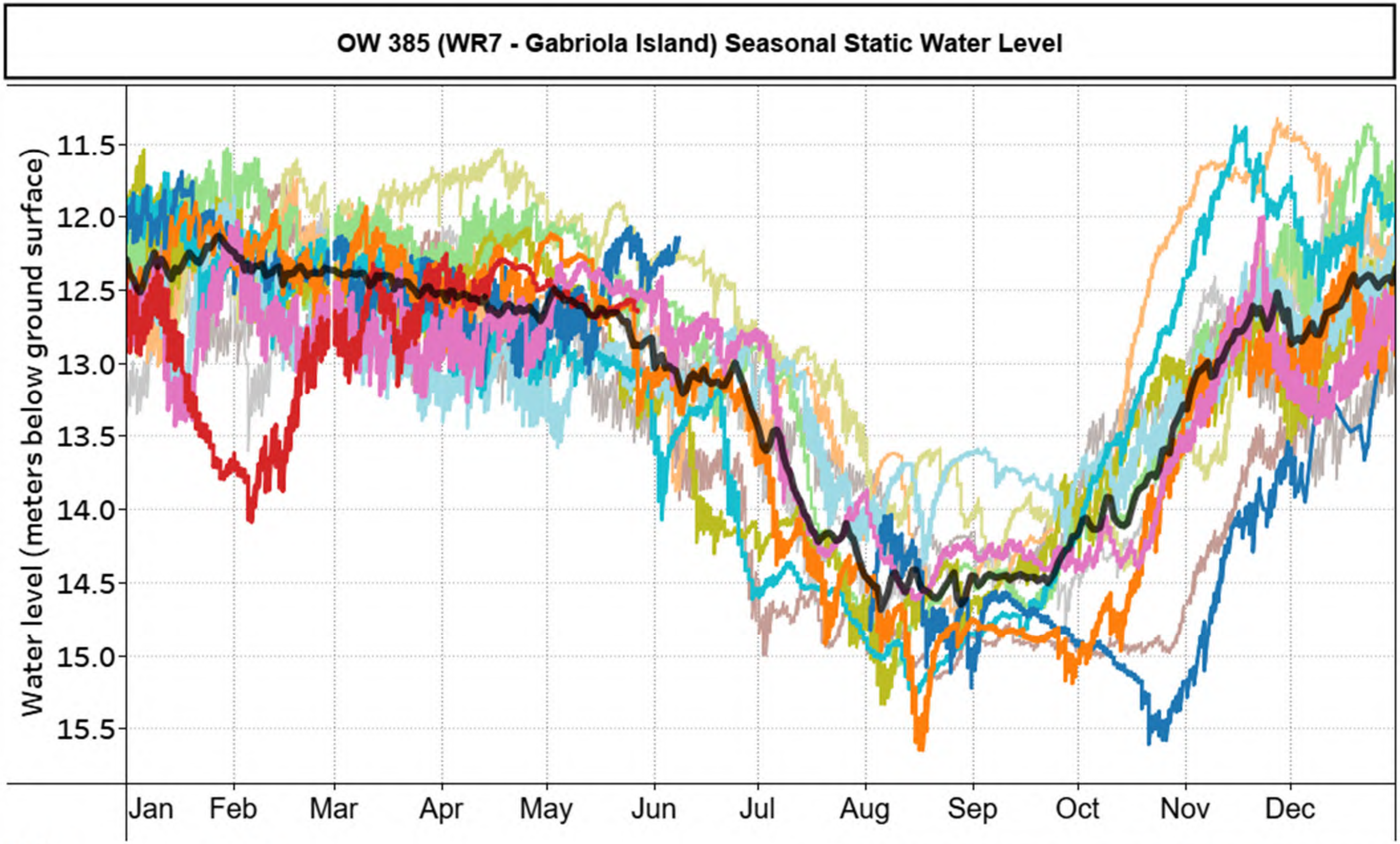
Data included from February 2013 to December 2024

DRINKING WATER AND WATERSHED PROTECTION – REGIONAL GROUNDWATER LEVEL ANALYSIS 2025

SEASONAL GROUNDWATER LEVEL CHART
OW 316 (WR7 - Gabriola Island)

FIGURE 60-C

Regional District of Nanaimo



NOTES:

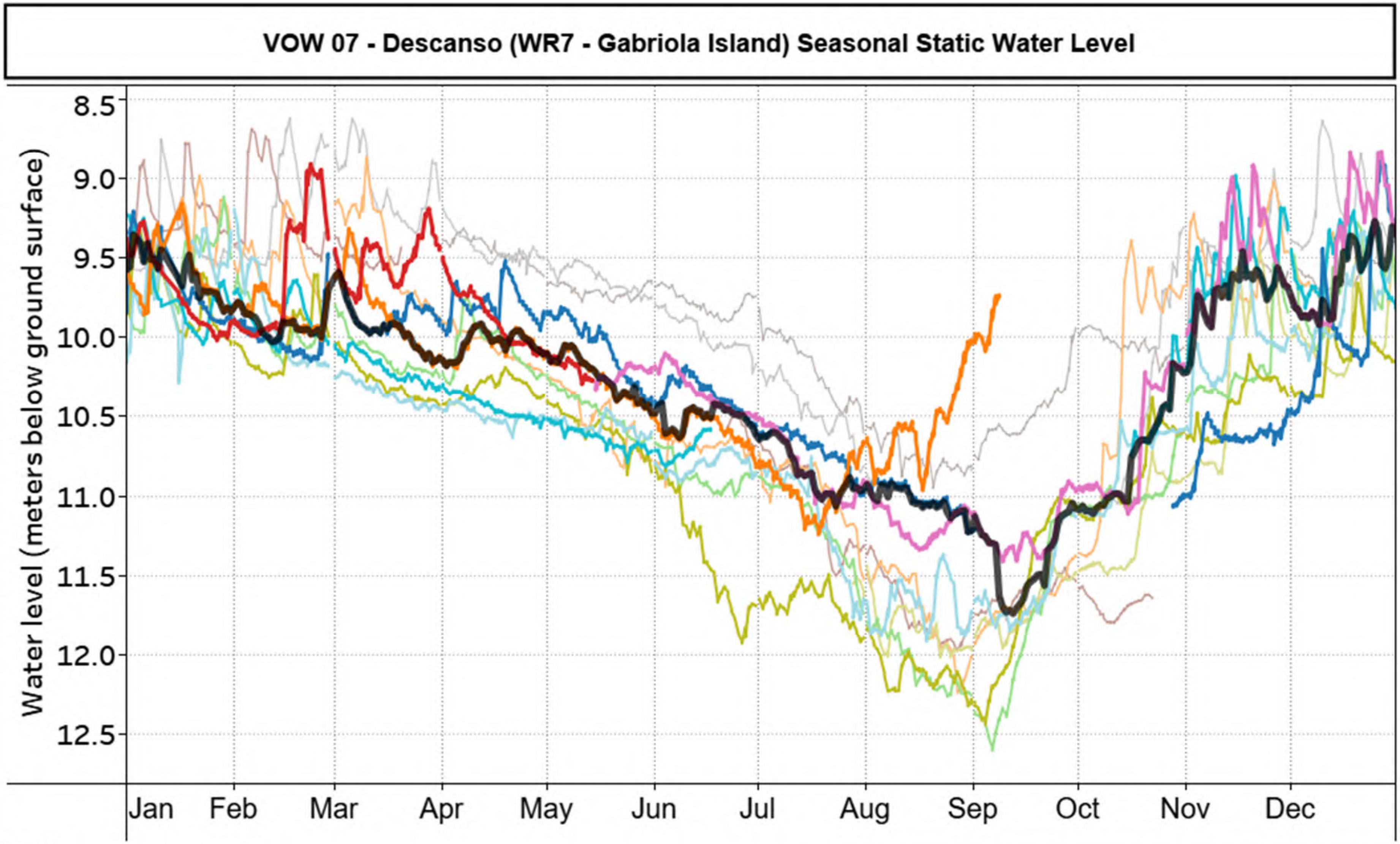
Observation Well Associated with Aquifer 709 (Fractured sedimentary rock)

DRINKING WATER AND WATERSHED PROTECTION – REGIONAL GROUNDWATER LEVEL ANALYSIS 2025

SEASONAL GROUNDWATER LEVEL CHART
OW 385 (WR7 - Gabriola Island)

FIGURE 61-C

Regional District of Nanaimo



NOTES:

Observation Well Associated with Aquifer 709 (Fractured sedimentary rock)

YEAR

2025
2024
2023
2022
2021
2020
2019
2018
2017
2016
2015
2014
2013

Median Groundwater Level

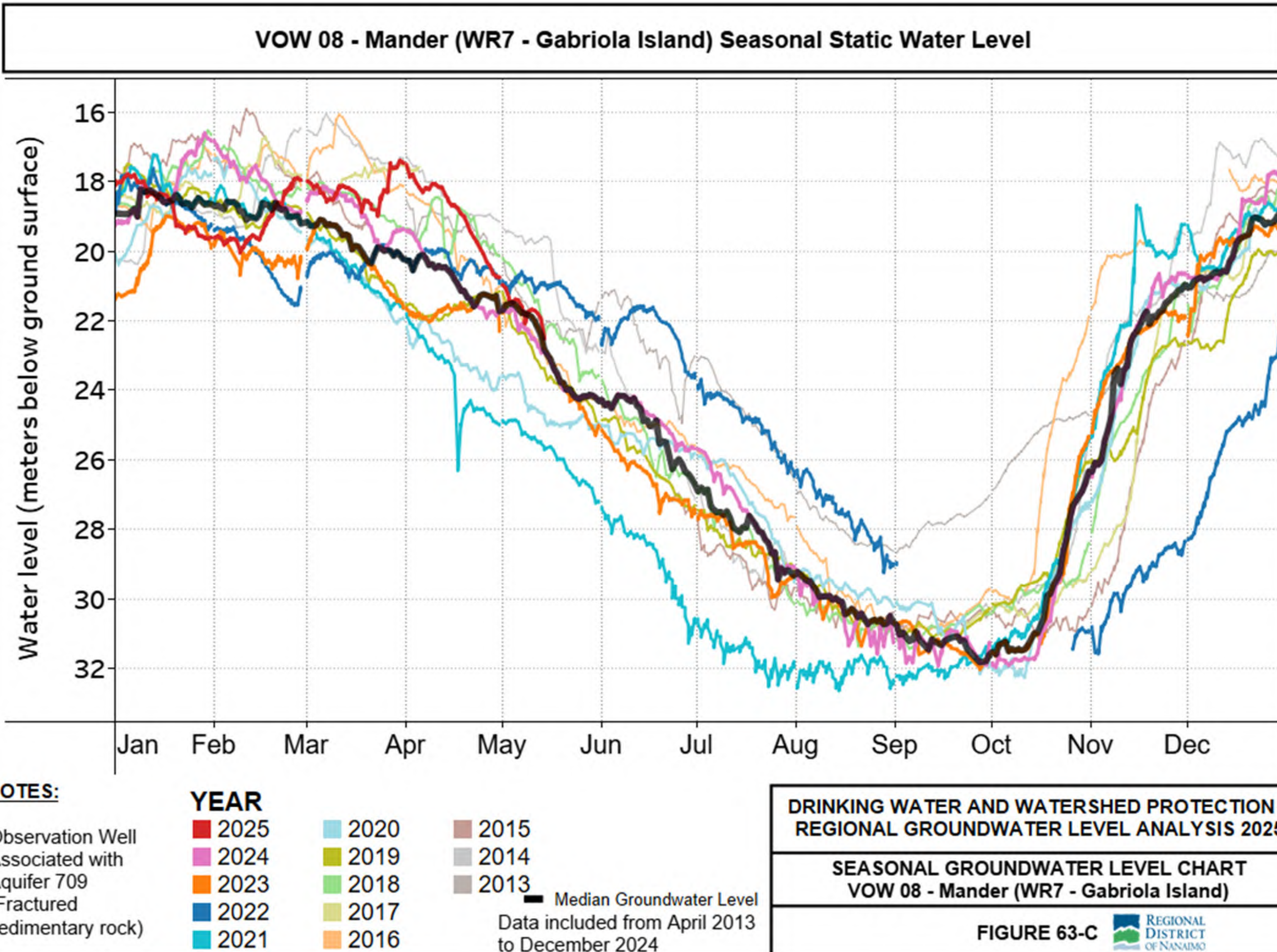
Data included from April 2013 to December 2024

DRINKING WATER AND WATERSHED PROTECTION – REGIONAL GROUNDWATER LEVEL ANALYSIS 2025

SEASONAL GROUNDWATER LEVEL CHART VOW 07 - Descanso (WR7 - Gabriola Island)

FIGURE 62-C

Regional District of Nanaimo



NOTES:

Observation Well Associated with Aquifer 709 (Fractured sedimentary rock)

DRINKING WATER AND WATERSHED PROTECTION – REGIONAL GROUNDWATER LEVEL ANALYSIS 2025

SEASONAL GROUNDWATER LEVEL CHART VOW 08 - Mander (WR7 - Gabriola Island)

FIGURE 63-C

Regional District of Nanaimo

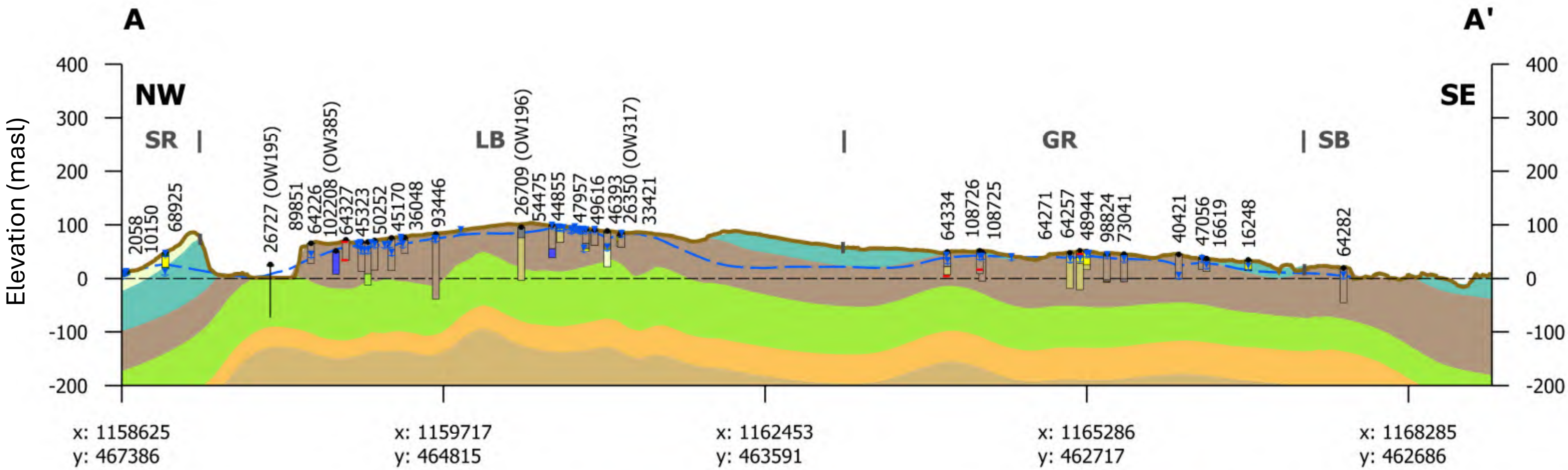
GW SOLUTIONS
ASSESSMENT & PROTECTION OF GROUNDWATER

Islands Trust Freshwater Footprint

Methodology Development and Gabriola Case Study

September 2025

Appendix D: Hydrogeologic Model Cross-sections



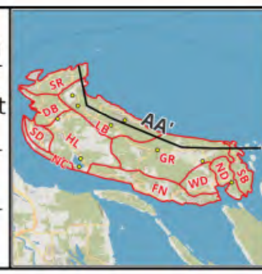
GW SOLUTIONS
ASSESSMENT & PROTECTION OF GROUNDWATER

Title:
Hydrogeological Cross Section

Project:
24-16 ITC Freshwater Footprint Methodology Project

Client:
Islands Trust

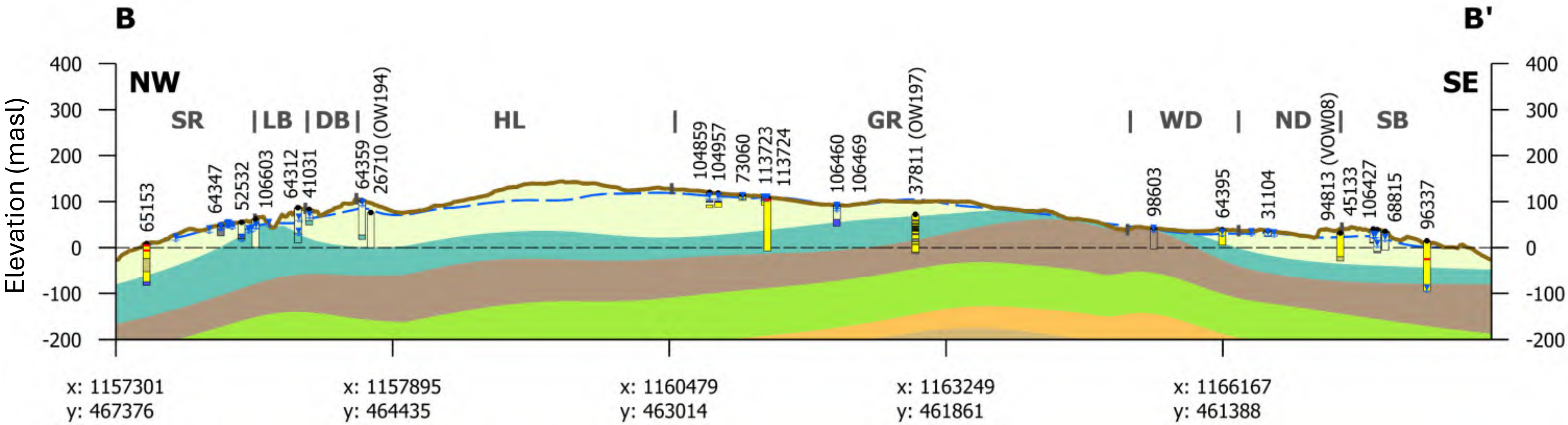
Date: June 2025
Creator: AZ
Review: AB



ESPG: 3005
A: 1158625, 467386
A': 1169064, 462692
Scale: 1:53,000
Vertical exaggeration: 5x
0m 1500m

Legend
Groundwater
Fracture
Water Level Measurement
Quaternary (overburden)
Gabriola Fm.
Spray Fm.
Geoffrey Fm.
Northumberland Fm.
DeCourcy Fm.
Cedar District Fm.

Note:Includes projected wells, labelled with their GWELLS Well Tag Number, located within **50** m of the cross-section line.



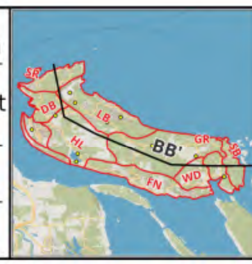
GW SOLUTIONS
ASSESSMENT & PROTECTION OF GROUNDWATER

Title: Hydrogeological Cross Section

Project: 24-16 ITC Freshwater Footprint Methodology Project

Client: Islands Trust

Date: June 2025 **Creator:** AZ **Review:** AB



ESPG: 3005

B: 1157301, 467376

B': 1169080, 461392

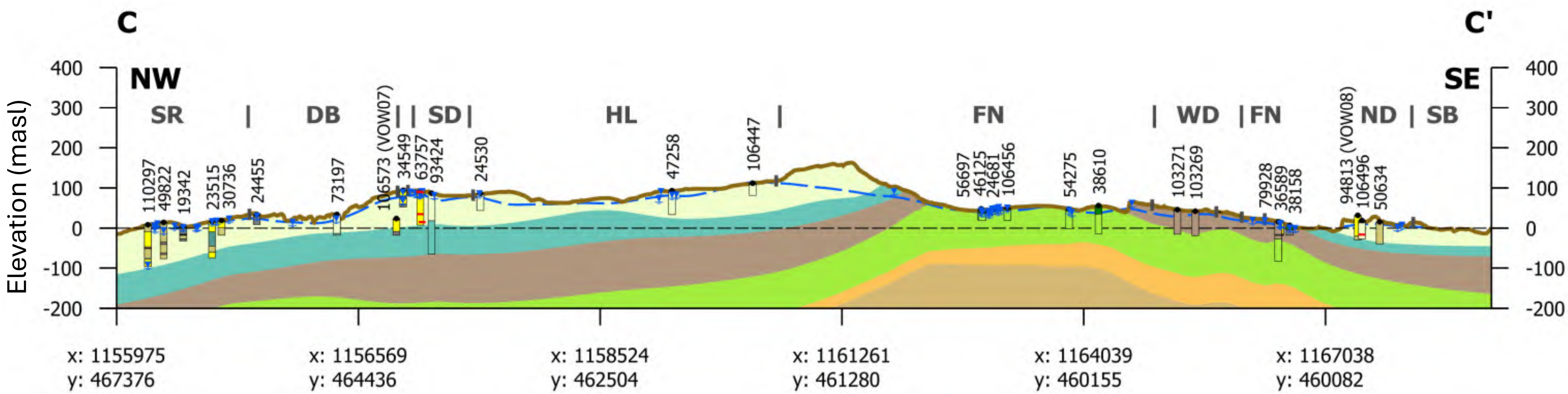
Scale: 1:62,000

Vertical exaggeration: 5x

0m 1500m

Legend
- Groundwater
- Fracture
- Water Level Measurement
- Quaternary (overburden)
- Gabriola Fm.
- Spray Fm.
- Geoffrey Fm.
- Northumberland Fm.
- DeCourcy Fm.
- Cedar District Fm.

Note: Includes projected wells, labelled with their GWELLS Well Tag Number, located within 50 m of the cross-section line.



GW SOLUTIONS

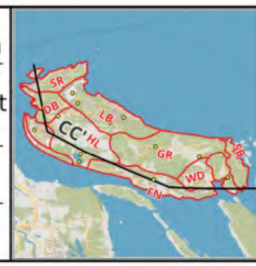
ASSESSMENT & PROTECTION OF GROUNDWATER

Title: Hydrogeological Cross Section

Project: 24-16 ITC Freshwater Footprint Methodology Project

Client: Islands Trust

Date: June 2025 **Creator:** AZ **Review:** AB



ESPG: 3005

C: 1155975, 467376

C': 1169097, 460092

Scale: 1:71,000

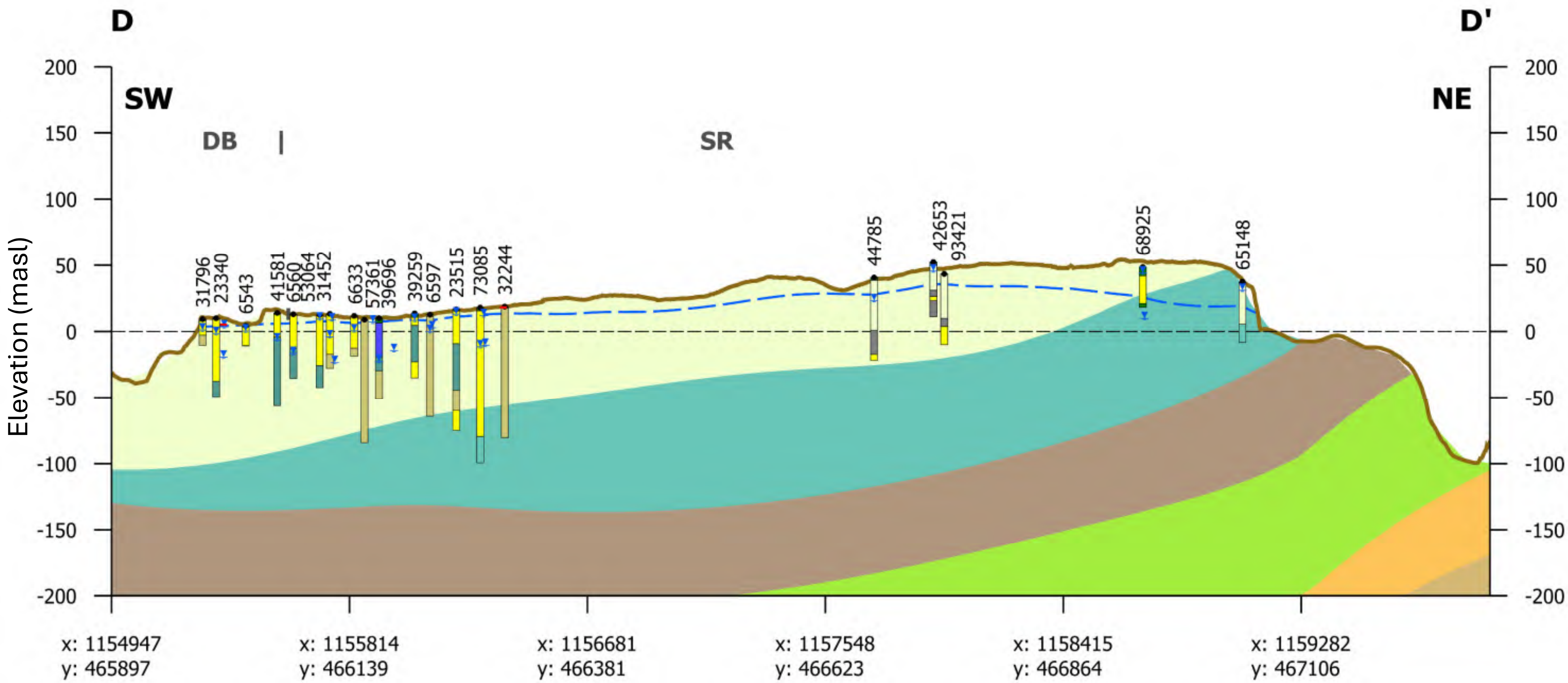
Vertical exaggeration: 5x

0m 1500m

Legend

- Groundwater
- Fracture
- Water Level Measurement
- Quaternary (overburden)
- Gabriola Fm.
- Spray Fm.
- Geoffrey Fm.
- Northumberland Fm.
- DeCourcy Fm.
- Cedar District Fm.

Note: Includes projected wells, labelled with their GWELLS Well Tag Number, located within **50 m** of the cross-section line.



GW SOLUTIONS

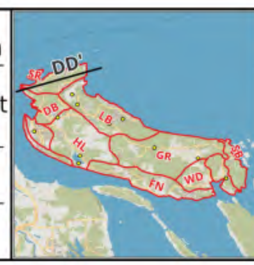
ASSESSMENT & PROTECTION OF GROUNDWATER

Title: Hydrogeological Cross Section

Project: 24-16 ITC Freshwater Footprint Methodology Project

Client: Islands Trust

Date: June 2025 **Creator:** AZ **Review:** AB



ESPG: 3005

D: 1154947, 465897

D': 1159970, 467298

Scale: 1:22,000

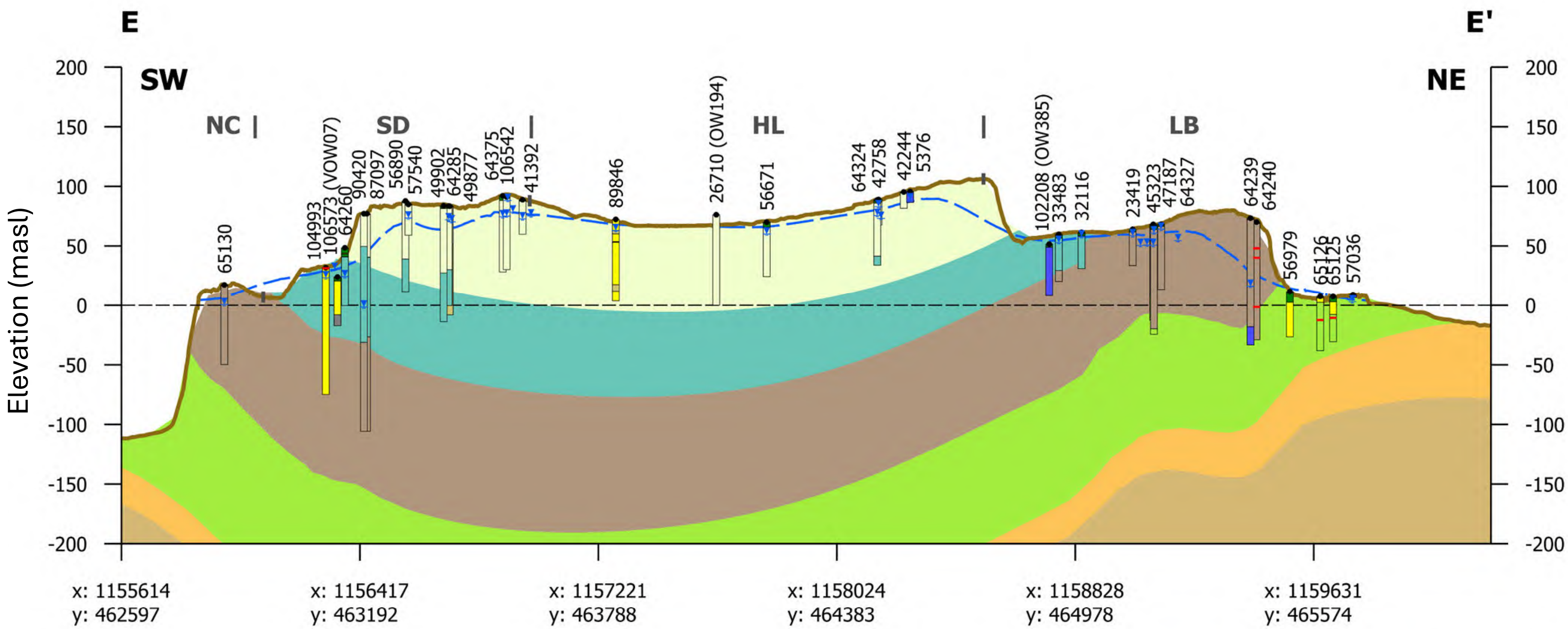
Vertical exaggeration: 5x

0m 500m

Legend

- Groundwater
- Fracture
- Water Level Measurement
- Quaternary (overburden)
- Gabriola Fm.
- Spray Fm.
- Geoffrey Fm.
- Northumberland Fm.
- DeCourcy Fm.
- Cedar District Fm.

Note: Includes projected wells, labelled with their GWELLS Well Tag Number, located within **50** m of the cross-section line.



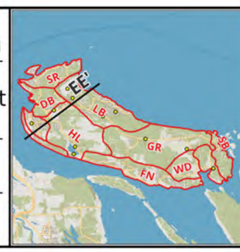
GW SOLUTIONS
ASSESSMENT & PROTECTION OF GROUNDWATER

Title: Hydrogeological Cross Section

Project: 24-16 ITC Freshwater Footprint Methodology Project

Client: Islands Trust

Date: June 2025 | **Creator:** AZ | **Review:** AB



ESPG: 3005

E: 1155614, 462597

E': 1160228, 466016

Scale: 1:24,000

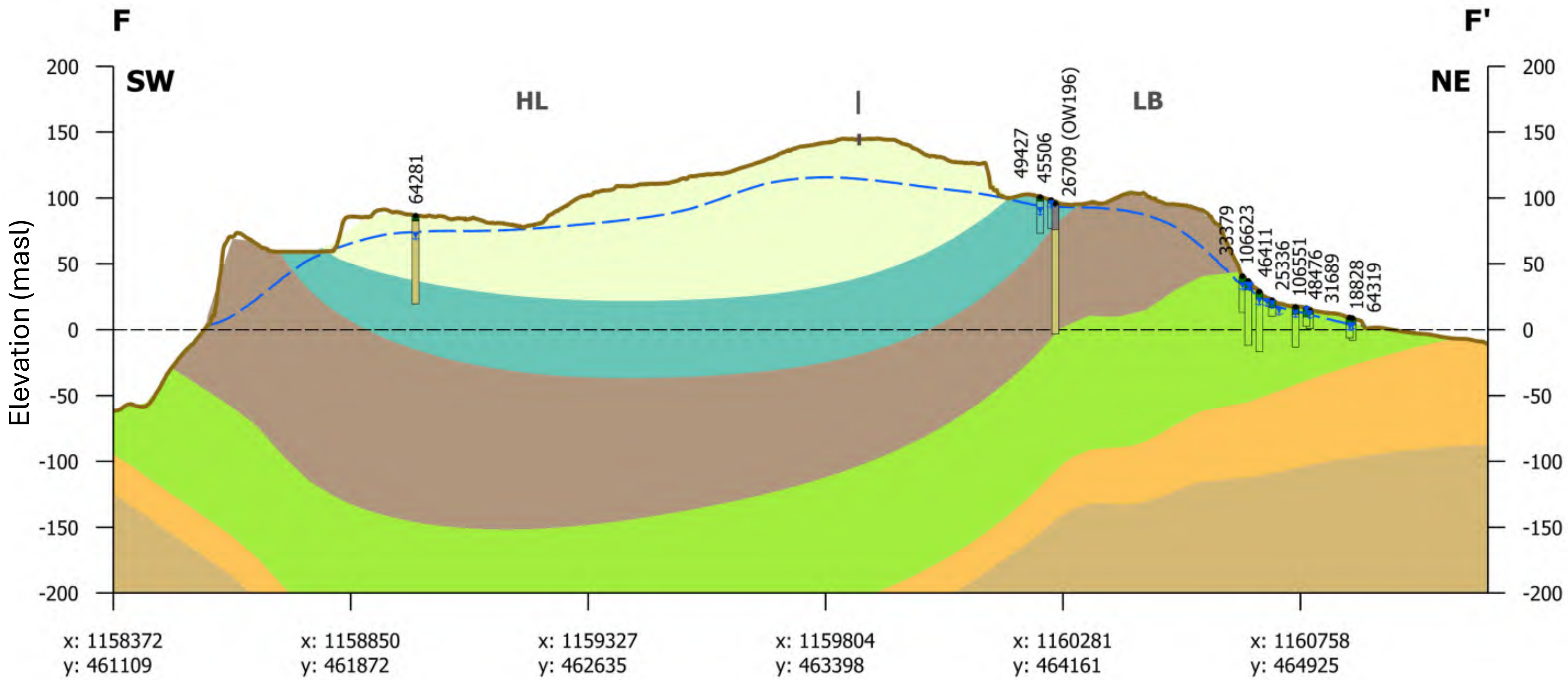
Vertical exaggeration: 5x

0m 500m

Legend

- Groundwater
- Saline Interface
- Fracture
- Water Level Measurement
- Quaternary (overburden)
- Gabriola Fm.
- Spray Fm.
- Geoffrey Fm.
- Northumberland Fm.
- DeCourcy Fm.
- Cedar District Fm.

Note: Includes projected wells, labelled with their GWELLS Well Tag Number, located within 50 m of the cross-section line.



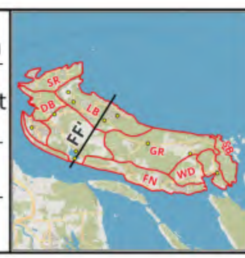
GW SOLUTIONS
ASSESSMENT & PROTECTION OF GROUNDWATER

Title:
Hydrogeological Cross Section

Project:
24-16 ITC Freshwater Footprint Methodology Project

Client:
Islands Trust

Date: June 2025
Creator: AZ
Review: AB



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F': 1161135, 465527
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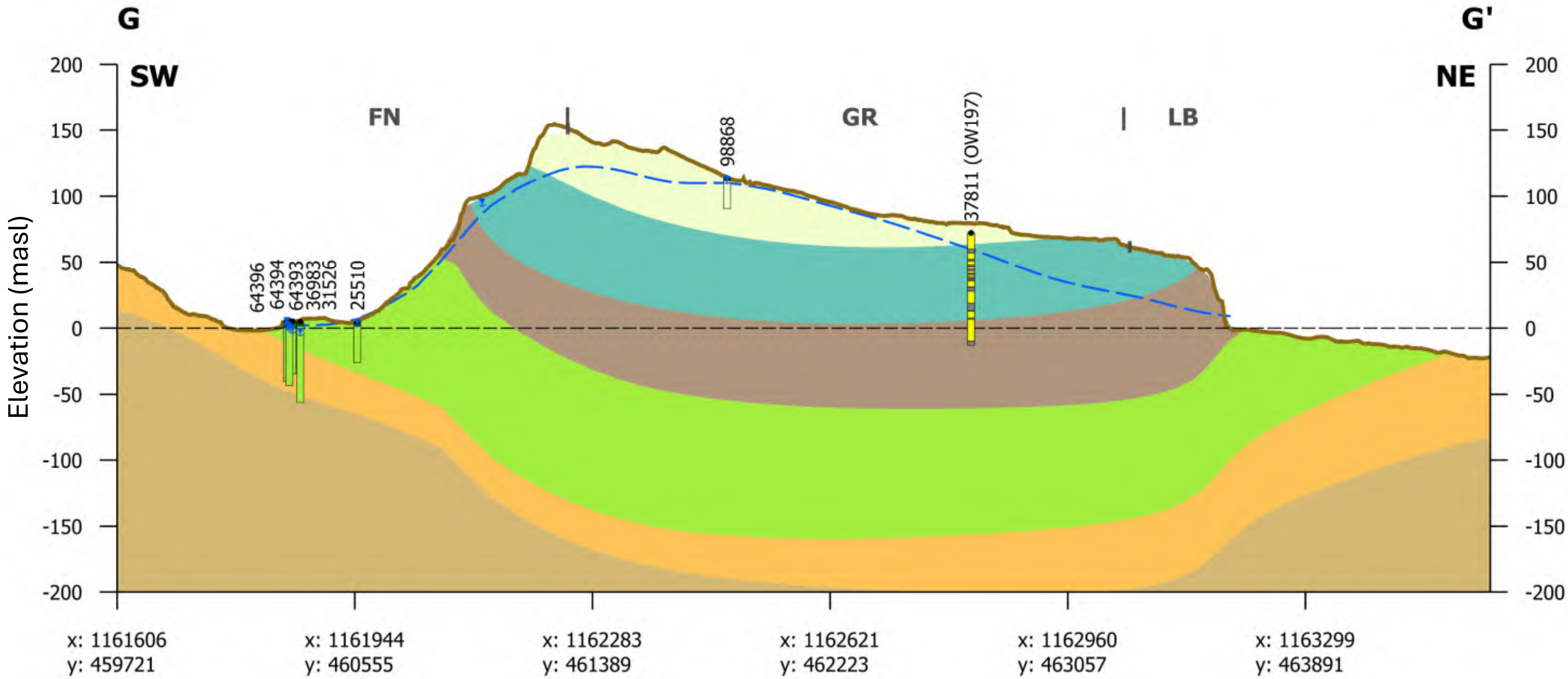
Vertical exaggeration: 5x
0m 500m

Legend
- Groundwater
- Fracture
- Water Level Measurement
- Quaternary (overburden)
- Gabriola Fm.
- Spray Fm.
- Geoffrey Fm.
- Northumberland Fm.
- DeCourcy Fm.
- Cedar District Fm.

Note: Includes projected wells, labelled with their GWELLS Well Tag Number, located within **50 m** of the cross-section line.



GW SOLUTIONS
ASSESSMENT & PROTECTION OF GROUNDWATER

Title: Hydrogeological Cross Section

Project: 24-16 ITC Freshwater Footprint Methodology Project

Client: Islands Trust

Date: June 2025

Creator: AZ

Review: AB

ESPG: 3005

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G': 1163562, 464539

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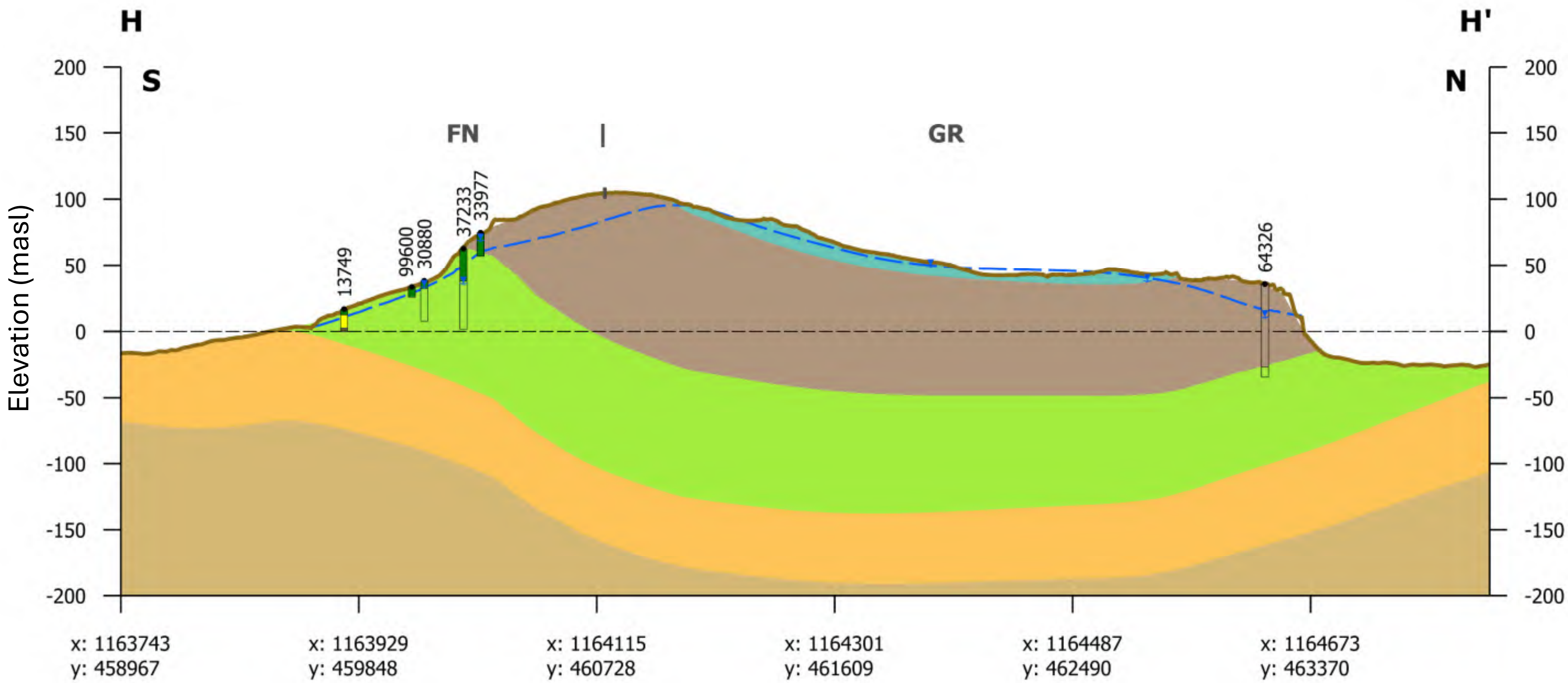
Vertical exaggeration: 5x

0m 500m

Legend

- Groundwater
- Fracture
- Water Level Measurement
- Quaternary (overburden)
- Gabriola Fm.
- Spray Fm.
- Geoffrey Fm.
- Northumberland Fm.
- DeCourcy Fm.
- Cedar District Fm.

Note: Includes projected wells, labelled with their GWELLS Well Tag Number, located within 50 m of the cross-section line.



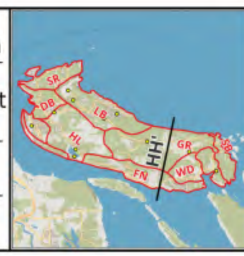
GW SOLUTIONS
ASSESSMENT & PROTECTION OF GROUNDWATER

Title:
Hydrogeological Cross Section

Project:
24-16 ITC Freshwater Footprint Methodology Project

Client:
Islands Trust

Date: June 2025
Creator: AZ
Review: AB



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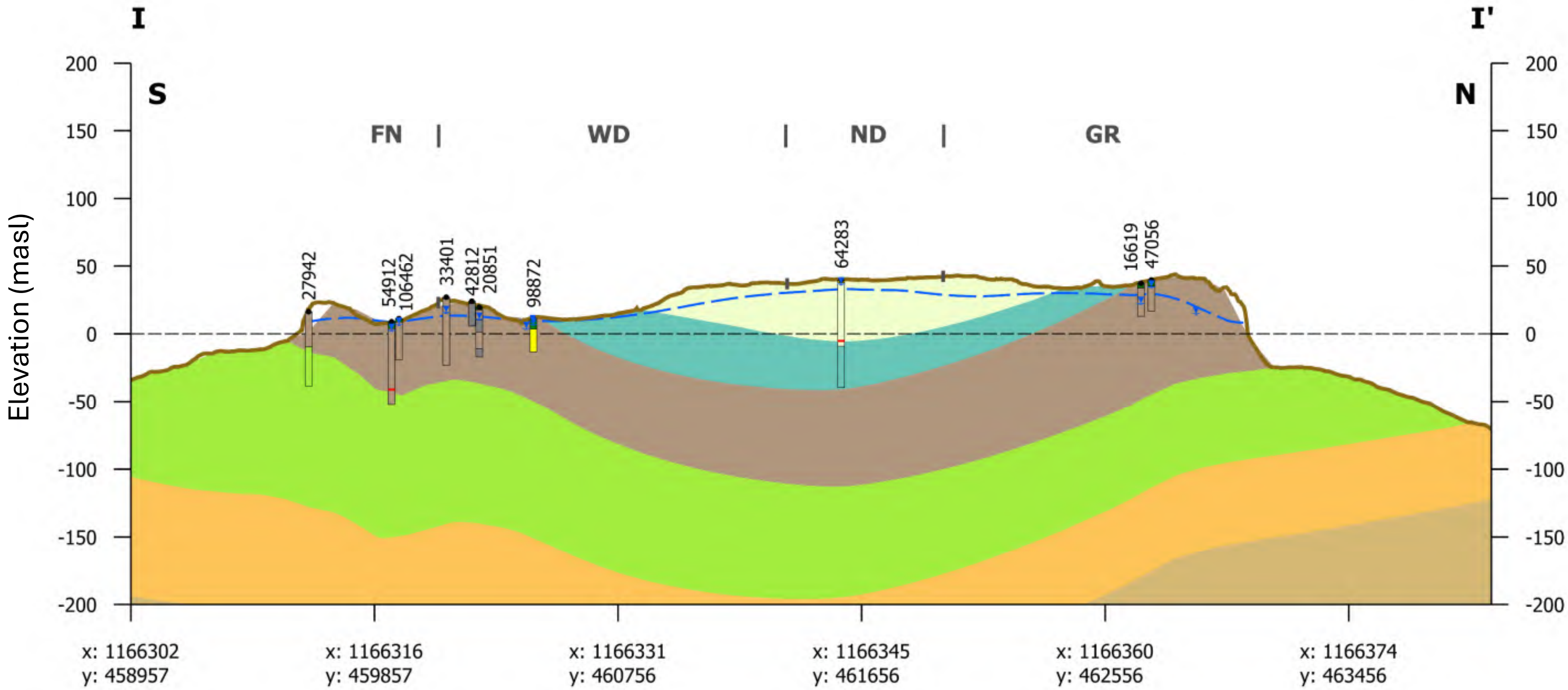
Vertical exaggeration: 5x
0m 500m

Legend
- Groundwater
- Fracture
- Water Level Measurement
- Quaternary (overburden)
- Gabriola Fm.
- Spray Fm.
- Geoffrey Fm.
- Northumberland Fm.
- DeCourcy Fm.
- Cedar District Fm.

Note:Includes projected wells, labelled with their GWELLS Well Tag Number, located within **50 m** of the cross-section line.



GW SOLUTIONS
ASSESSMENT & PROTECTION OF GROUNDWATER

Title:
Hydrogeological Cross Section

Project:
24-16 ITC Freshwater Footprint Methodology Project

Client:
Islands Trust

Date: June 2025
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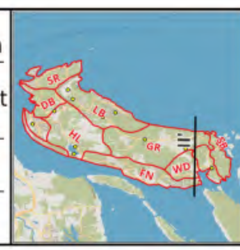
Review: AB



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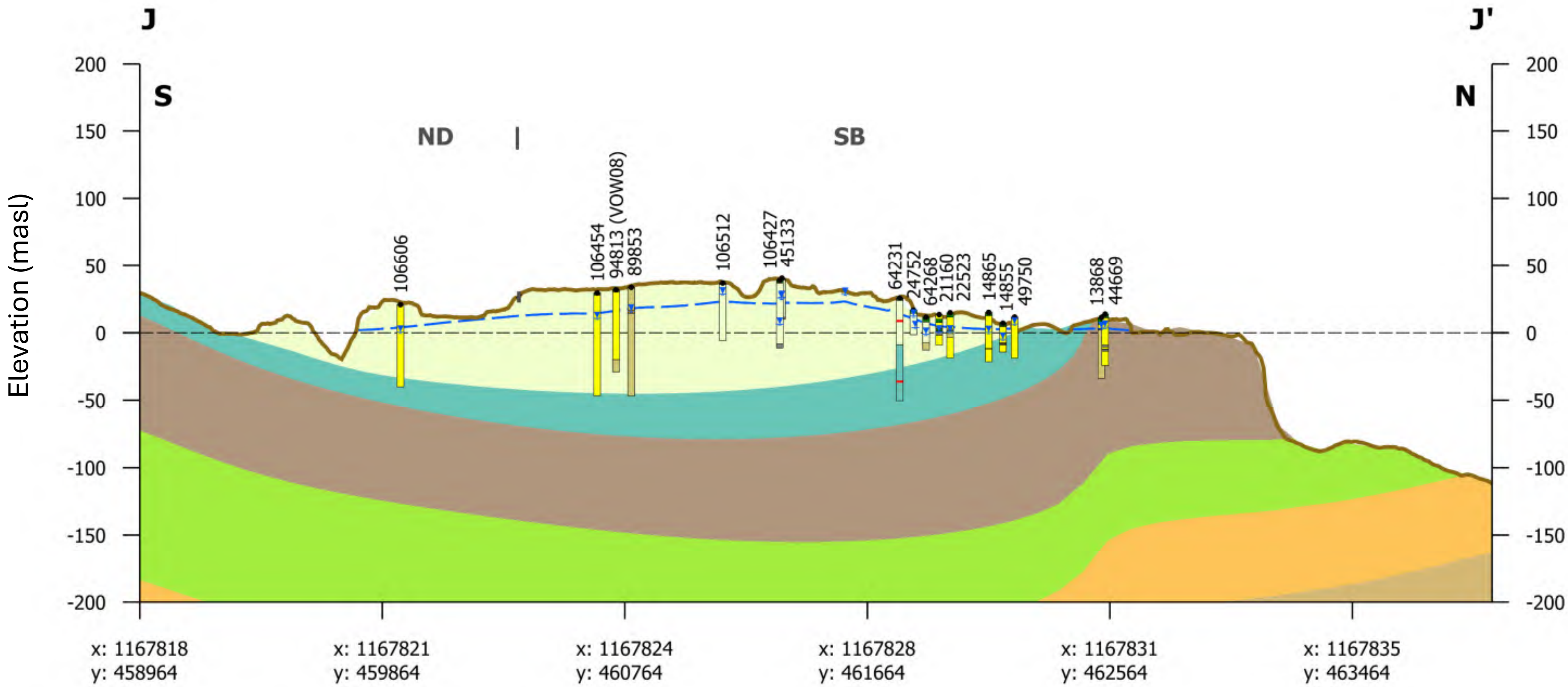
0m 500m

Legend
Groundwater
Fracture
Water Level Measurement
Quaternary (overburden)
Gabriola Fm.
Spray Fm.
Geoffrey Fm.
Northumberland Fm.
DeCourcy Fm.
Cedar District Fm.

Note:Includes projected wells, labelled with their GWELLS Well Tag Number, located within **50 m** of the cross-section line.



GW SOLUTIONS

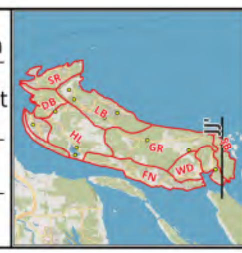
ASSESSMENT & PROTECTION OF GROUNDWATER

Title: Hydrogeological Cross Section

Project: 24-16 ITC Freshwater Footprint Methodology Project

Client: Islands Trust

Date: June 2025 | **Creator:** AZ | **Review:** AB



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Scale: 1:21,000

Vertical exaggeration: 5x

0m 500m

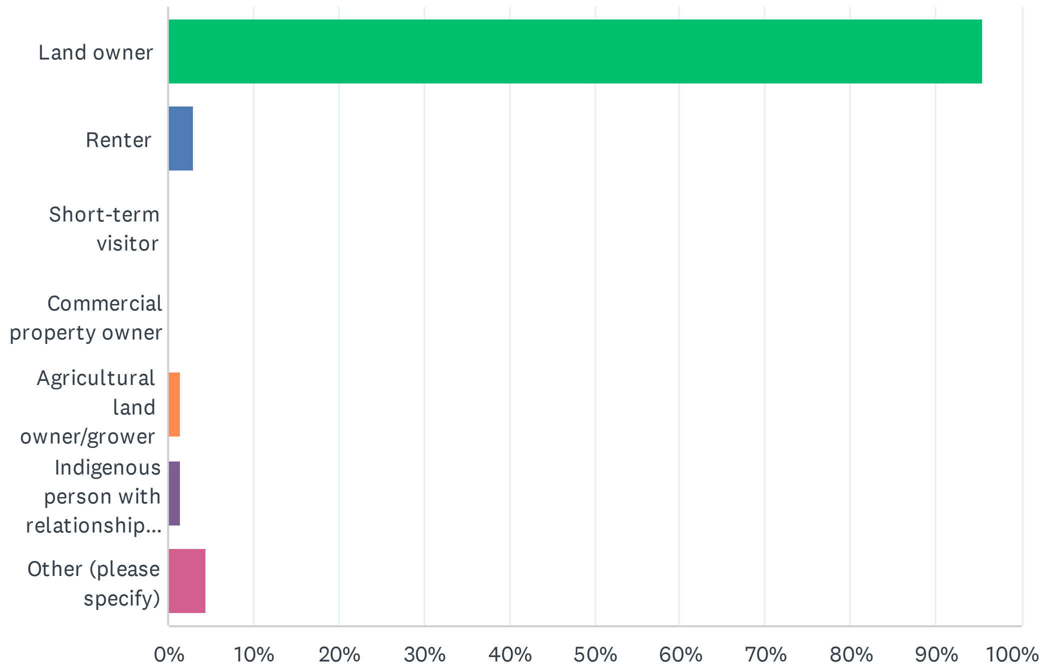
Legend

- Groundwater
- Fracture
- Water Level Measurement
- Quaternary (overburden)
- Gabriola Fm.
- Spray Fm.
- Geoffrey Fm.
- Northumberland Fm.
- DeCourcy Fm.
- Cedar District Fm.

Note: Includes projected wells, labelled with their GWELLS Well Tag Number, located within **50 m** of the cross-section line.

Q1 Which of the following best describes your connection to Gabriola Island? Select all that apply.

Answered: 66 Skipped: 1

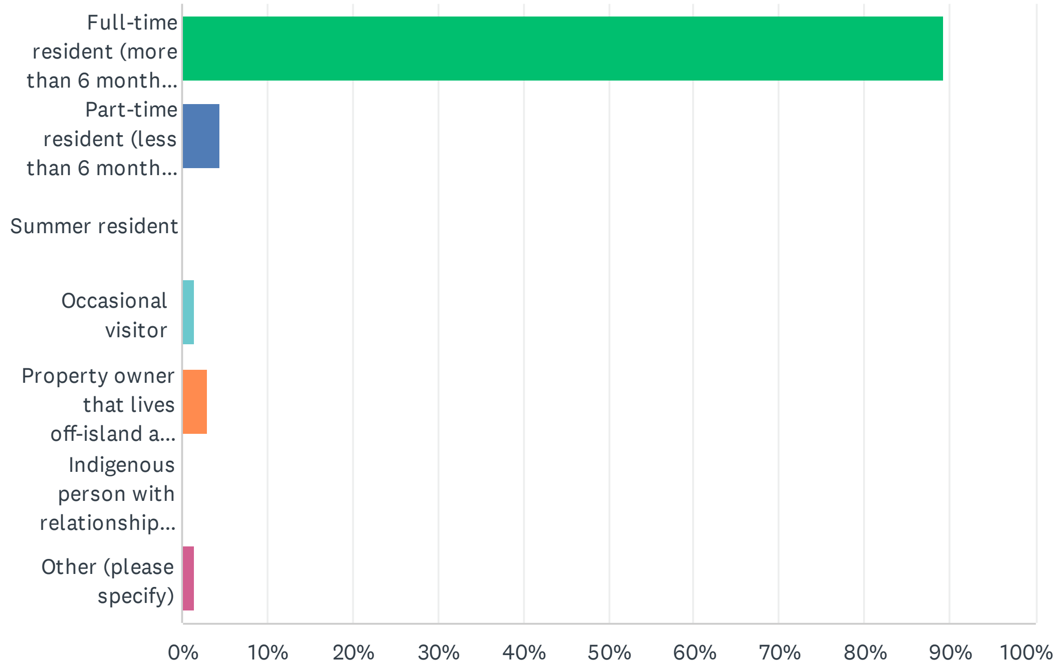


ANSWER CHOICES	RESPONSES	
Land owner	95.45%	63
Renter	3.03%	2
Short-term visitor	0.00%	0
Commercial property owner	0.00%	0
Agricultural land owner/grower	1.52%	1
Indigenous person with relationships to the Islands Trust Area	1.52%	1
Other (please specify)	4.55%	3
Total Respondents: 66		

#	OTHER (PLEASE SPECIFY)	DATE
1	Chair of the Society that owns the Gabriola Commons	4/29/2025 6:47 PM
2	Partner of owner	4/8/2025 12:30 PM
3	tourist	3/20/2025 2:26 PM

Q2 I am a...

Answered: 66 Skipped: 1

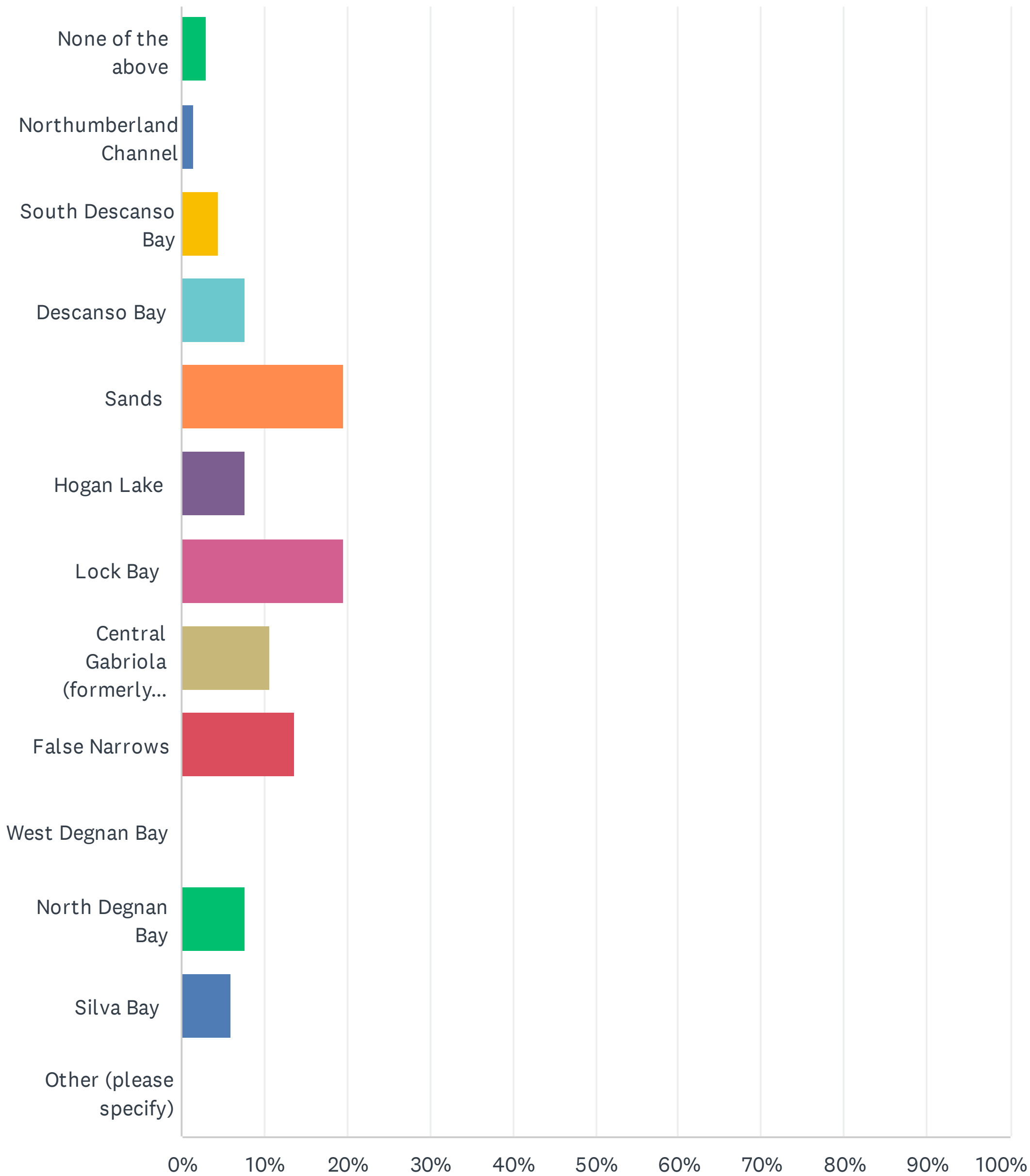


ANSWER CHOICES	RESPONSES	
Full-time resident (more than 6 months per year)	89.39%	59
Part-time resident (less than 6 months per year)	4.55%	3
Summer resident	0.00%	0
Occasional visitor	1.52%	1
Property owner that lives off-island and visits infrequently	3.03%	2
Indigenous person with relationships to the Islands Trust Area	0.00%	0
Other (please specify)	1.52%	1
TOTAL		66

#	OTHER (PLEASE SPECIFY)	DATE
1	Property owner who resides 6 months a year	4/22/2025 3:38 PM

Q3 Based on the map of water management areas on Gabriola Island, in which general area is your property located (select one):

Answered: 66 Skipped: 1



ANSWER CHOICES	RESPONSES	
None of the above	3.03%	2
Northumberland Channel	1.52%	1
South Descanso Bay	4.55%	3
Descanso Bay	7.58%	5
Sands	19.70%	13
Hogan Lake	7.58%	5
Lock Bay	19.70%	13
Central Gabriola (formerly "Gabriola Region")	10.61%	7
False Narrows	13.64%	9
West Degnan Bay	0.00%	0
North Degnan Bay	7.58%	5
Silva Bay	6.06%	4
Other (please specify)	0.00%	0
Total Respondents: 66		

#	OTHER (PLEASE SPECIFY)	DATE
	There are no responses.	

Q4 What is the average number of people residing on the property? Please enter a number.

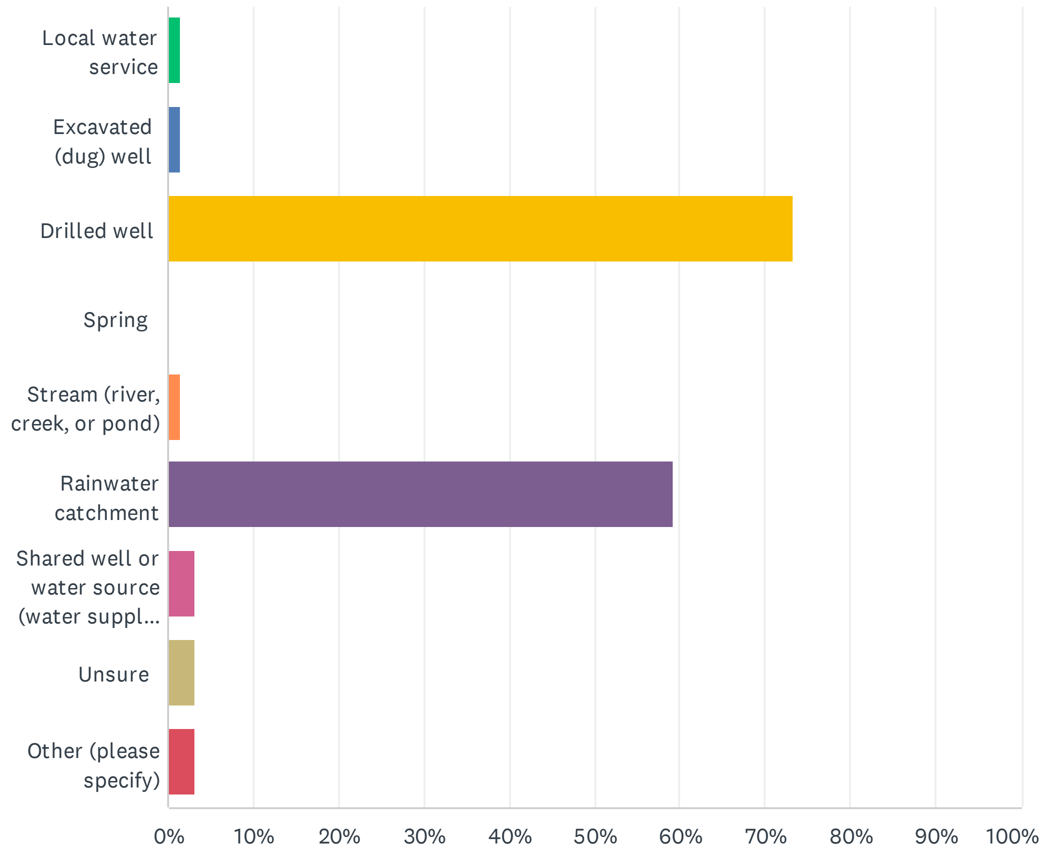
Answered: 66 Skipped: 1

#	RESPONSES	DATE
1	6	5/18/2025 9:34 PM
2	2	5/17/2025 11:11 AM
3	7	5/15/2025 7:17 PM
4	7	5/15/2025 6:03 PM
5	2	5/15/2025 3:46 PM
6	2	5/15/2025 12:17 PM
7	2	5/15/2025 11:26 AM
8	9	5/14/2025 4:54 PM
9	2	5/14/2025 2:00 PM
10	2	5/13/2025 10:45 PM
11	2	5/13/2025 10:39 PM
12	2	5/13/2025 9:28 PM
13	4	5/13/2025 5:15 PM
14	1	5/13/2025 4:53 PM
15	2	5/13/2025 3:45 PM
16	2	5/9/2025 11:16 AM
17	1	5/7/2025 9:00 PM
18	3	5/3/2025 11:37 AM
19	2	5/1/2025 6:07 PM
20	20	4/29/2025 9:42 PM
21	0ne	4/29/2025 6:47 PM
22	8	4/25/2025 8:14 AM
23	0	4/23/2025 9:01 AM
24	2	4/22/2025 3:38 PM
25	2	4/21/2025 2:50 PM
26	2	4/19/2025 8:34 AM
27	1	4/15/2025 3:50 PM
28	2	4/14/2025 8:28 PM
29	2	4/14/2025 12:40 PM
30	Three	4/12/2025 2:17 PM
31	3	4/12/2025 9:28 AM

32	2	4/11/2025 5:37 PM
33	4	4/11/2025 9:53 AM
34	2	4/10/2025 5:56 PM
35	3	4/10/2025 6:40 AM
36	2	4/9/2025 4:15 PM
37	2	4/9/2025 12:01 PM
38	2	4/9/2025 9:12 AM
39	4	4/9/2025 9:06 AM
40	2	4/9/2025 8:47 AM
41	2	4/9/2025 6:31 AM
42	2	4/8/2025 10:32 PM
43	2	4/8/2025 9:53 PM
44	2	4/8/2025 9:27 PM
45	1	4/8/2025 8:44 PM
46	2	4/8/2025 8:15 PM
47	3	4/8/2025 8:14 PM
48	2	4/8/2025 7:35 PM
49	2	4/8/2025 7:14 PM
50	1	4/8/2025 6:58 PM
51	2	4/8/2025 6:32 PM
52	1	4/8/2025 6:30 PM
53	one	4/8/2025 5:58 PM
54	two	4/8/2025 5:43 PM
55	2	4/8/2025 5:37 PM
56	3	4/8/2025 5:05 PM
57	2	4/8/2025 4:58 PM
58	2	4/8/2025 4:45 PM
59	2	4/8/2025 12:30 PM
60	2	3/28/2025 5:09 PM
61	1	3/27/2025 6:14 AM
62	2	3/20/2025 5:58 PM
63	2	3/20/2025 3:36 PM
64	4	3/20/2025 2:26 PM
65	2	3/19/2025 10:01 AM
66	2	3/18/2025 10:43 AM

Q5 What is the source of water supply for the property? Select all that apply.

Answered: 64 Skipped: 3



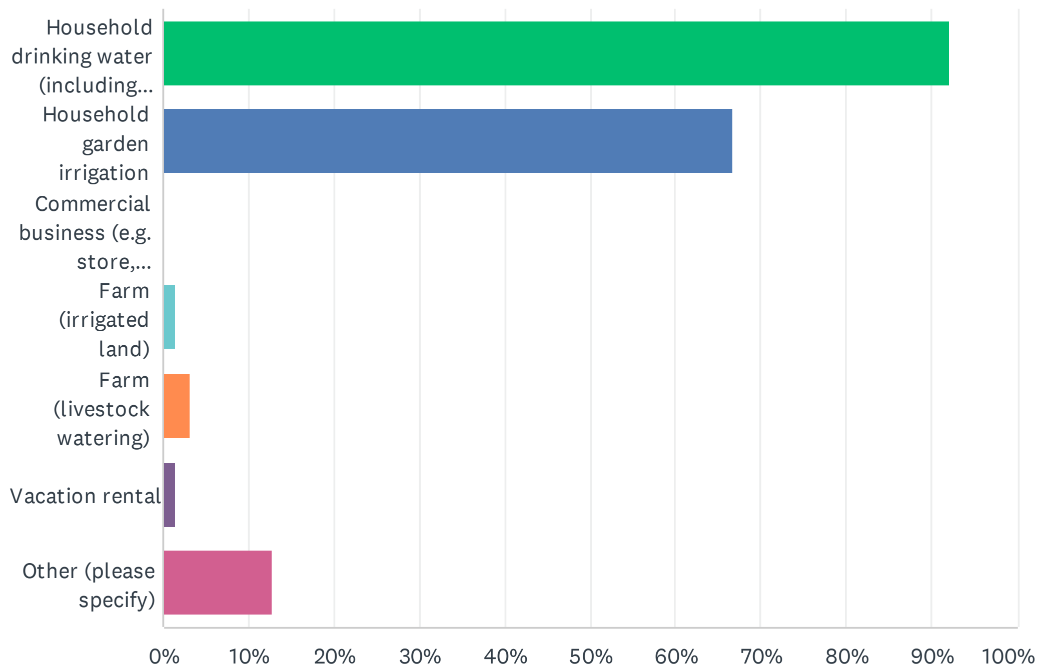
ANSWER CHOICES	RESPONSES	
Local water service	1.56%	1
Excavated (dug) well	1.56%	1
Drilled well	73.44%	47
Spring	0.00%	0
Stream (river, creek, or pond)	1.56%	1
Rainwater catchment	59.38%	38
Shared well or water source (water supply shared between multiple land parcels/households)	3.13%	2
Unsure	3.13%	2
Other (please specify)	3.13%	2
Total Respondents: 64		

#	OTHER (PLEASE SPECIFY)	DATE

1	well water stored in large cisterns - I live in the only condo on Gabriola	4/29/2025 9:45 PM
2	There is nothing on this small property	4/23/2025 9:03 AM

Q6 What is the purpose of water use on the property? Select all that apply.

Answered: 63 Skipped: 4



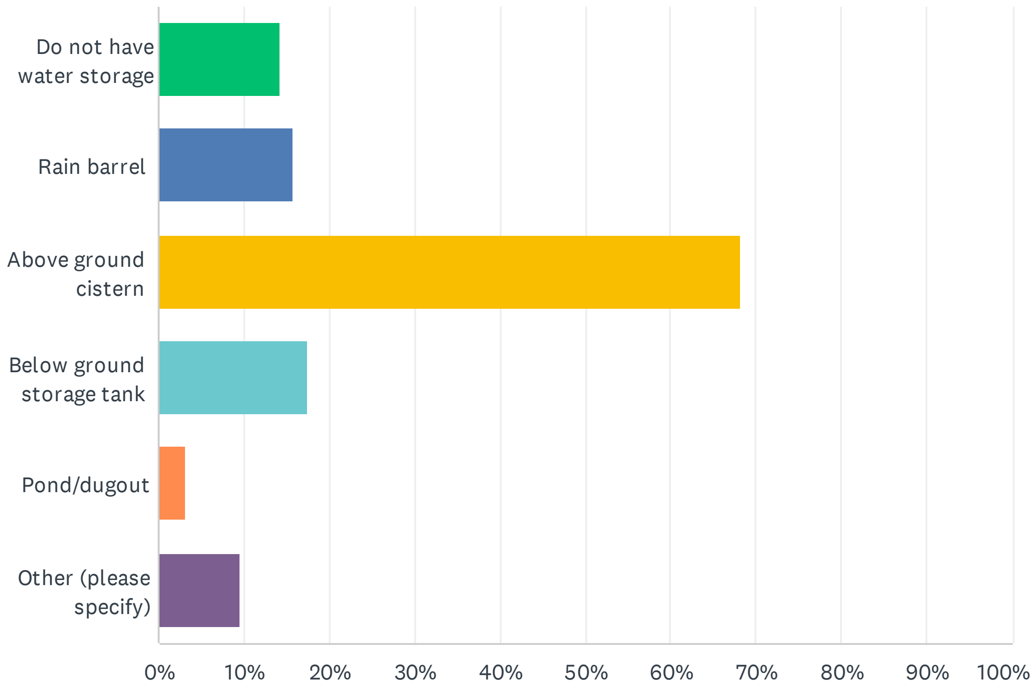
ANSWER CHOICES	RESPONSES	
Household drinking water (including domestic pets)	92.06%	58
Household garden irrigation	66.67%	42
Commercial business (e.g. store, restaurant, hotel)	0.00%	0
Farm (irrigated land)	1.59%	1
Farm (livestock watering)	3.17%	2
Vacation rental	1.59%	1
Other (please specify)	12.70%	8
Total Respondents: 63		

#	OTHER (PLEASE SPECIFY)	DATE
1	Household non drinking water	5/13/2025 10:47 PM
2	Dishes showers laundry	5/13/2025 5:18 PM
3	household domestic chores - laundry etc.	4/29/2025 9:45 PM
4	There is nothing on this small property	4/23/2025 9:03 AM
5	power washing decks	4/8/2025 9:59 PM
6	Household water not for drinking	4/8/2025 7:15 PM
7	Household use but I don’t drink it.	4/8/2025 6:32 PM

8	clothes washing, bathroom needs	3/27/2025 6:16 AM

Q7 What types of water storage do you have on the property? Select all that apply.

Answered: 63 Skipped: 4



ANSWER CHOICES	RESPONSES	
Do not have water storage	14.29%	9
Rain barrel	15.87%	10
Above ground cistern	68.25%	43
Below ground storage tank	17.46%	11
Pond/dugout	3.17%	2
Other (please specify)	9.52%	6
Total Respondents: 63		

#	OTHER (PLEASE SPECIFY)	DATE
1	Cistern in basement (concrete)	5/15/2025 7:19 PM
2	Cisterns for shower dishes, barrels and cistern for garden rain water	5/13/2025 5:18 PM
3	There is nothing on this small property	4/23/2025 9:03 AM
4	additional above ground cistern for well water storage/offgassing	4/21/2025 2:58 PM
5	Above ground holding	4/12/2025 2:20 PM
6	built in 15,000 gal cistern	3/20/2025 6:01 PM

Q8 If you have water storage, please indicate the approximate volume of storage (including measurements):

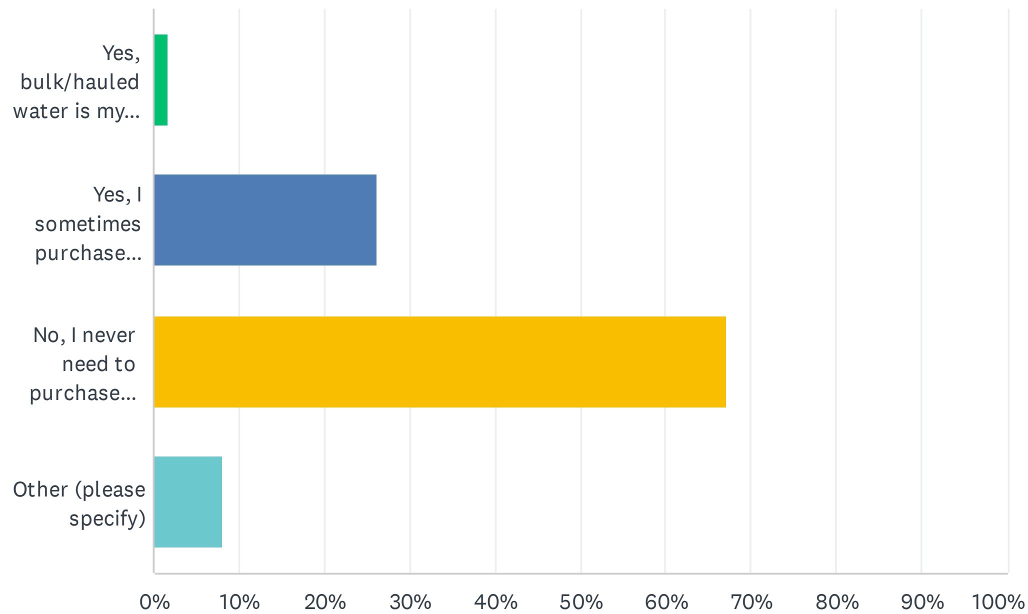
Answered: 47 Skipped: 20

#	RESPONSES	DATE
1	1500 gal	5/18/2025 9:36 PM
2	1250 gal	5/17/2025 11:13 AM
3	7000 gallons or so	5/15/2025 7:19 PM
4	1000 gal	5/15/2025 6:05 PM
5	10,000 gallons	5/15/2025 3:48 PM
6	10,000 gal	5/15/2025 12:19 PM
7	4 x 1800 gallon	5/15/2025 11:34 AM
8	8000 gallons	5/14/2025 4:56 PM
9	5000 gallons	5/14/2025 2:02 PM
10	5000 gallons	5/13/2025 10:47 PM
11	2500 gallons	5/13/2025 10:41 PM
12	5000 gallons	5/13/2025 9:34 PM
13	1000L 4 large cisterns and 1 under house	5/13/2025 5:18 PM
14	2500 gallons	5/13/2025 4:57 PM
15	5000L	5/13/2025 3:46 PM
16	18000 gals	5/9/2025 11:18 AM
17	16000 gallons; irregular shape	5/3/2025 11:41 AM
18	7000 gallons in three tanks	5/1/2025 6:09 PM
19	10,000 gals	4/29/2025 9:45 PM
20	1500 gallons	4/29/2025 6:49 PM
21	3 @ 750 gallons each	4/22/2025 3:39 PM
22	1,200 Imperial gallons for each cistern. Standard Century Plastics size for volume. Approx. 8' diameter x 5.5' high	4/21/2025 2:58 PM
23	?	4/15/2025 3:52 PM
24	4 cisterns total volume 3600 gallons	4/14/2025 8:31 PM
25	30,000 gallon concrete cistern. 5,000 gallons are reserved for fire suppression.	4/14/2025 12:43 PM
26	5000 us gal	4/12/2025 9:29 AM
27	8000 gal im	4/11/2025 5:40 PM
28	5000 gallons	4/11/2025 9:55 AM
29	5,000 gallons cistern and several water barrels for garden	4/10/2025 6:00 PM
30	5000 gallons	4/9/2025 4:16 PM
31	14,000 gallons	4/9/2025 12:04 PM

32	3 x 1000 gal cisterns	4/9/2025 8:50 AM
33	14,000 USgal	4/9/2025 6:39 AM
34	7000	4/8/2025 10:35 PM
35	2000 gallons	4/8/2025 9:29 PM
36	7000 gallons	4/8/2025 9:00 PM
37	7500l	4/8/2025 8:15 PM
38	10,000 gallons	4/8/2025 6:34 PM
39	2500 gallons	4/8/2025 6:32 PM
40	775 gals	4/8/2025 5:48 PM
41	5000 litres	4/8/2025 5:40 PM
42	41,000 litres	4/8/2025 5:09 PM
43	X	4/8/2025 12:32 PM
44	10,000 gallons in 5 black polly cisterns	3/28/2025 5:10 PM
45	15,000 built in cistern	3/20/2025 6:01 PM
46	10000 litres	3/20/2025 3:38 PM
47	it's big like 10k L or so	3/19/2025 10:02 AM

Q9 Do you purchase bulk water (hauled water) for your water source:

Answered: 61 Skipped: 6

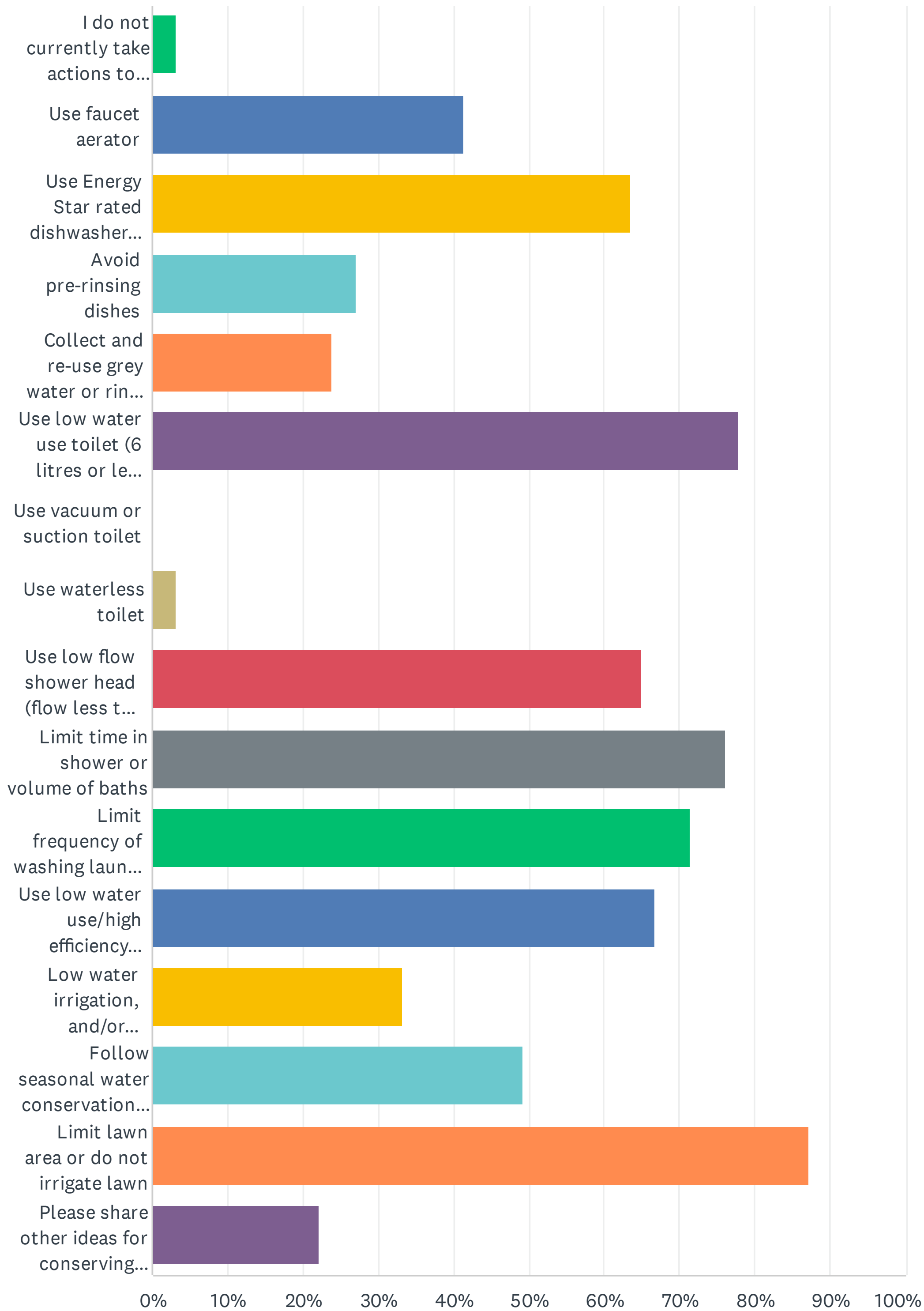


ANSWER CHOICES	RESPONSES	
Yes, bulk/hauled water is my primary water source	1.64%	1
Yes, I sometimes purchase bulk/hauled water to augment my water supply seasonally or during dry years	26.23%	16
No, I never need to purchase bulk/hauled water	67.21%	41
Other (please specify)	8.20%	5
Total Respondents: 61		

#	OTHER (PLEASE SPECIFY)	DATE
1	Very rarely need to purchase hauled water	5/3/2025 11:41 AM
2	There is nothing on this small property	4/23/2025 9:03 AM
3	New build and plan to use rainwater only-should never have to purchase water hopefully.	4/14/2025 12:43 PM
4	I have purchased water when I have the cistern cleaned	4/10/2025 6:00 PM
5	Rarely purchase water in summer only if we have many visitors	4/9/2025 6:39 AM

Q10 What actions do you take to conserve water on your property. Select all that apply.

Answered: 63 Skipped: 4



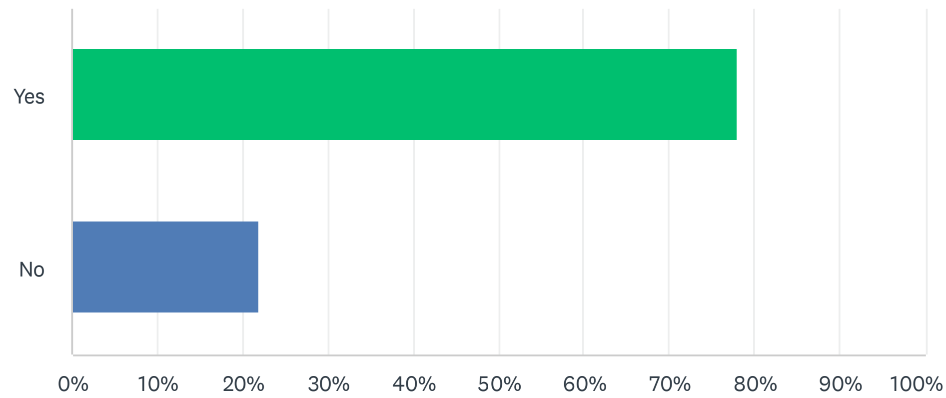
ANSWER CHOICES	RESPONSES	
I do not currently take actions to conserve water	3.17%	2
Use faucet aerator	41.27%	26
Use Energy Star rated dishwasher (water use <16 litres per cycle)	63.49%	40
Avoid pre-rinsing dishes	26.98%	17
Collect and re-use grey water or rinse water	23.81%	15
Use low water use toilet (6 litres or less per flush)	77.78%	49
Use vacuum or suction toilet	0.00%	0
Use waterless toilet	3.17%	2
Use low flow shower head (flow less than 7.6 Litres per minute)	65.08%	41
Limit time in shower or volume of baths	76.19%	48
Limit frequency of washing laundry and/or full loads only	71.43%	45
Use low water use/high efficiency washing machine	66.67%	42
Low water irrigation, and/or automatic timers	33.33%	21
Follow seasonal water conservation advice and advisories (e.g., Regional District of Nanaimo or BC drought conservation levels)	49.21%	31
Limit lawn area or do not irrigate lawn	87.30%	55
Please share other ideas for conserving water:	22.22%	14
Total Respondents: 63		

#	PLEASE SHARE OTHER IDEAS FOR CONSERVING WATER:	DATE
1	timers on all irrigation systems	5/18/2025 9:36 PM
2	When you live on an island you know what to do to conserve water!	5/15/2025 12:19 PM
3	Use stored rainwater to wash cars or pressure wash. Use thin towels that air dry to extend periods between washing. Mulch heavily. Plus limit chemical use so it doesn't go in groundwater!	5/15/2025 11:34 AM
4	Bathing in winter shower in summer, if it’s yellow let it mellow	5/13/2025 10:41 PM
5	Japanese Bath	5/13/2025 9:34 PM
6	flush only when necessary	4/29/2025 9:45 PM
7	hand watering and lawn not watered at all	4/14/2025 8:31 PM
8	Collect rain	4/11/2025 5:40 PM
9	no lawn, and landscape with native plants and trees, use rinse water for plants, save water in buckets when running shower and use for toilet flushing	4/10/2025 6:00 PM
10	careful attention to rainwater catchment	4/8/2025 9:00 PM
11	do not use a dushwasher	4/8/2025 6:00 PM
12	do not wash vehicles	4/8/2025 5:48 PM
13	composting toilet in guest accommodation on property as well as our 8 gal / minute well trickles to 2,000 gallon cistern on timer and float valve so well is never ever stressed	3/28/2025 5:10 PM

14	shower only every other day	3/27/2025 6:16 AM

Q11 Do you have an active well on your property?

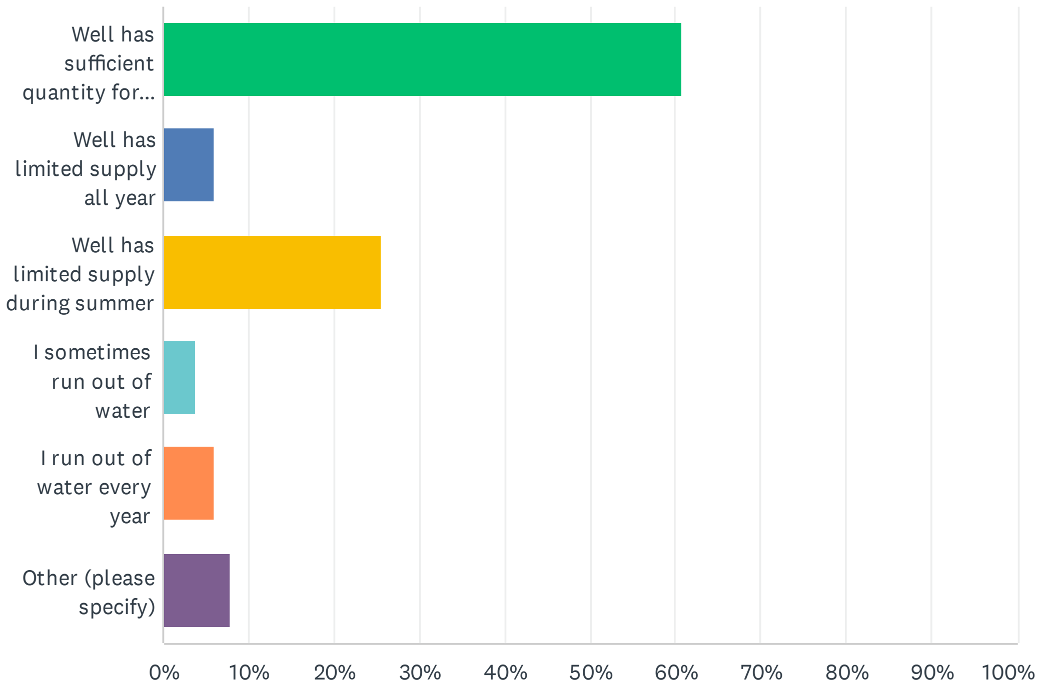
Answered: 64 Skipped: 3



ANSWER CHOICES	RESPONSES	
Yes	78.13%	50
No	21.88%	14
TOTAL		64

Q12 Does your well have any problems related to water QUANTITY? Select all that apply.

Answered: 51   Skipped: 16

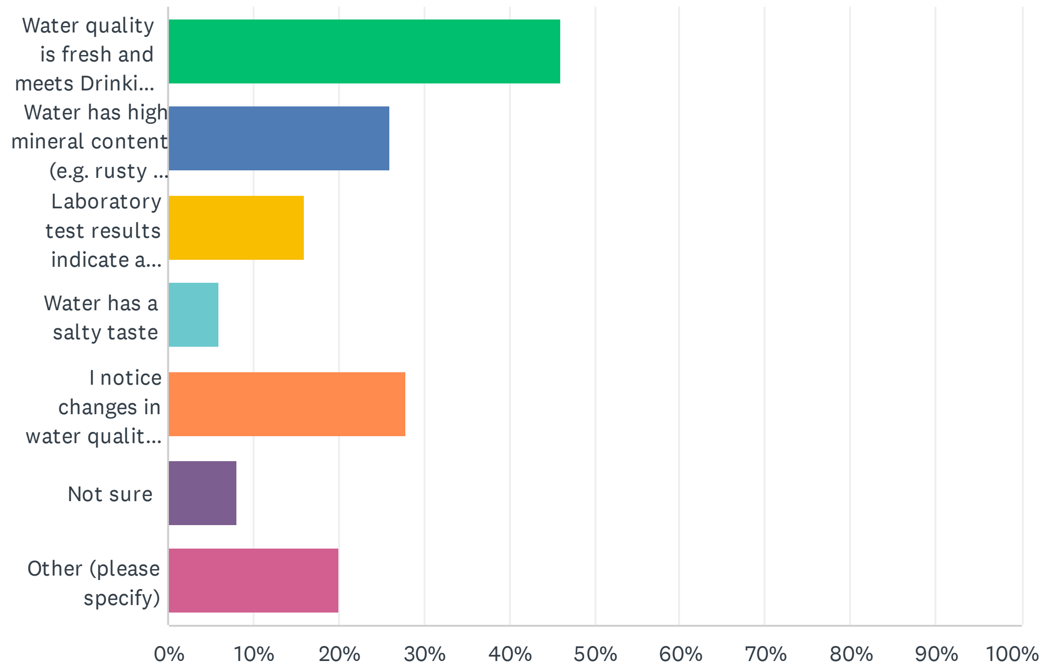


ANSWER CHOICES	RESPONSES	
Well has sufficient quantity for my needs year-round	60.78%	31
Well has limited supply all year	5.88%	3
Well has limited supply during summer	25.49%	13
I sometimes run out of water	3.92%	2
I run out of water every year	5.88%	3
Other (please specify)	7.84%	4
Total Respondents: 51		

#	OTHER (PLEASE SPECIFY)	DATE
1	We pump water from winter and store in summer	5/13/2025 5:19 PM
2	recharge well rate is 1/4 gallon per minute (15 gallons per hour), the depth of the well is the saving grace	4/14/2025 8:36 PM
3	Switch to collected rain water in summer to avoid straining well	4/8/2025 10:03 PM
4	No problems, but we go out of our way to be gentle with our use anyway.	3/28/2025 5:19 PM

Q13 Does your well have any problems related to water QUALITY? Check all that apply.

Answered: 50 Skipped: 17



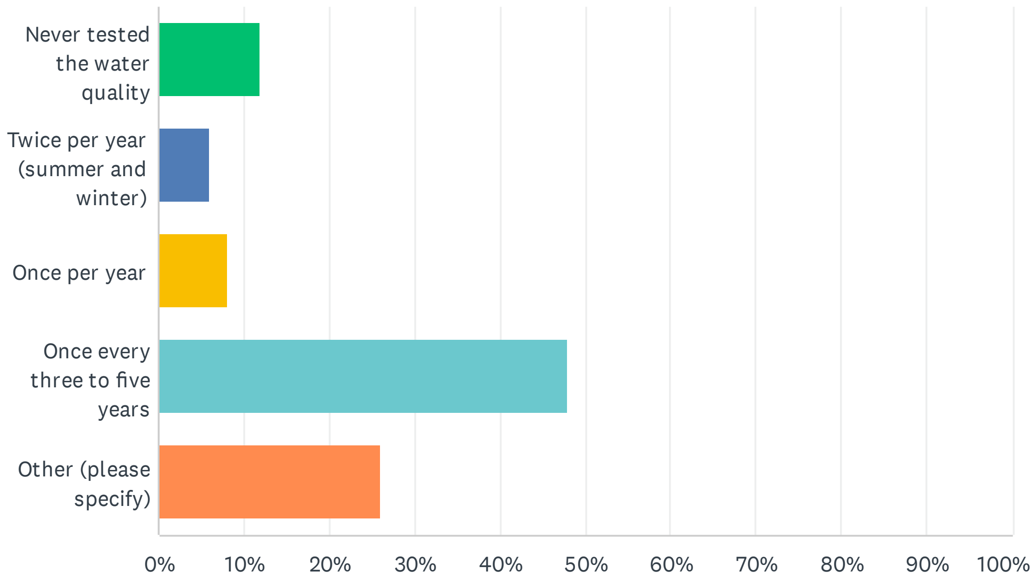
ANSWER CHOICES	RESPONSES	
Water quality is fresh and meets Drinking Water Quality Guidelines	46.00%	23
Water has high mineral content (e.g. rusty or dark colour, sulfur odor)	26.00%	13
Laboratory test results indicate a water quality concern e.g. bacteria or water quality parameters with concentrations above Drinking Water Guidelines	16.00%	8
Water has a salty taste	6.00%	3
I notice changes in water quality during different times of year	28.00%	14
Not sure	8.00%	4
Other (please specify)	20.00%	10
Total Respondents: 50		

#	OTHER (PLEASE SPECIFY)	DATE
1	Was tested a few years back was fine. We have 5 filters and uv	5/13/2025 5:19 PM
2	sulfur with the change of seasons, and Mn levels that cause aesthetic issues. Solution was employed - spray into cistern.	4/21/2025 3:04 PM
3	using a UV light and filter	4/14/2025 8:36 PM
4	high salinity (likely due to ocean water incursion), lead content possible local contamination from industry or property uphill (Twin Beaches Mall, road), sulphur smell	4/14/2025 12:47 PM

5	high in heavy metals so only use for watering gardens (mostly in containers)	4/8/2025 9:02 PM
6	very high toxic manganese level	4/8/2025 6:05 PM
7	High manganese	4/8/2025 5:01 PM
8	We have high levels of manganese and some other minerals in our water. For that reason as well as water management, we trickle pump from the well to a cistern and then filter water to less than 1 mil before treating with a UV light.	3/28/2025 5:19 PM
9	I have a UV system in place that is cleansing the water	3/27/2025 6:18 AM
10	I was told it can get worse in drought times (tannins)	3/19/2025 10:04 AM

Q14 How often do you test the quality of water from your well i.e., collect a sample for laboratory analysis?

Answered: 50   Skipped: 17



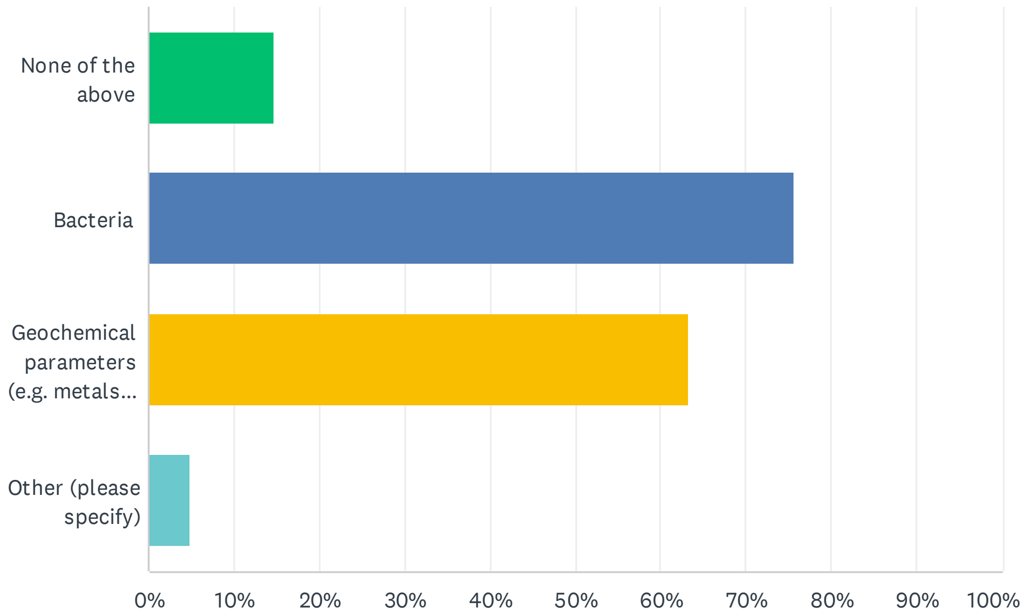
ANSWER CHOICES	RESPONSES	
Never tested the water quality	12.00%	6
Twice per year (summer and winter)	6.00%	3
Once per year	8.00%	4
Once every three to five years	48.00%	24
Other (please specify)	26.00%	13
TOTAL		50

#	OTHER (PLEASE SPECIFY)	DATE
1	Hasn't been tested for 15 years	5/14/2025 2:04 PM
2	several times a year; building has r/o filters but we send the water for testing anyway	4/29/2025 9:46 PM
3	Tested seven years ago.	4/29/2025 6:51 PM
4	Tested before we put a UV system	4/25/2025 8:17 AM
5	Have done 3 tests over 25 years, most recently in 2025 under the RDN well testing rebate program.	4/21/2025 3:04 PM
6	have not tested it recently	4/15/2025 3:54 PM
7	Tested several times per year for two years to confirm it is non-potable and non-suitable for irrigation	4/14/2025 12:47 PM
8	Monthly	4/11/2025 9:56 AM
9	Tested when first purchased property in 2017	4/8/2025 10:03 PM

10	rarely	4/8/2025 9:02 PM
11	I don’t drink it so don’t test it	4/8/2025 6:34 PM
12	We have only tested our water once or twice for minerals and bacteria in the 17 years we have been using the well.	3/28/2025 5:19 PM
13	havent lived there long enough for another test	3/19/2025 10:04 AM

Q15 If you collect water samples for laboratory analysis, what water quality parameters are tested. Select all that apply.

Answered: 41 Skipped: 26

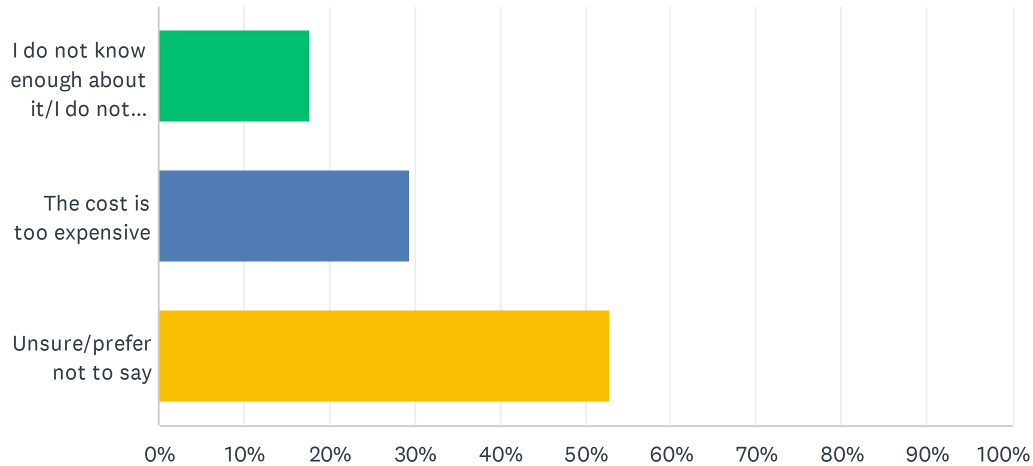


ANSWER CHOICES	RESPONSES	
None of the above	14.63%	6
Bacteria	75.61%	31
Geochemical parameters (e.g. metals, general drinking water quality parameters)	63.41%	26
Other (please specify)	4.88%	2
Total Respondents: 41		

#	OTHER (PLEASE SPECIFY)	DATE
1	no longer use well (probably never will again) and so no longer will test	4/14/2025 12:47 PM
2	complete test	3/20/2025 6:04 PM

Q16 If you do not collect water samples for laboratory analysis, what prevents you from doing so? Select all that apply.

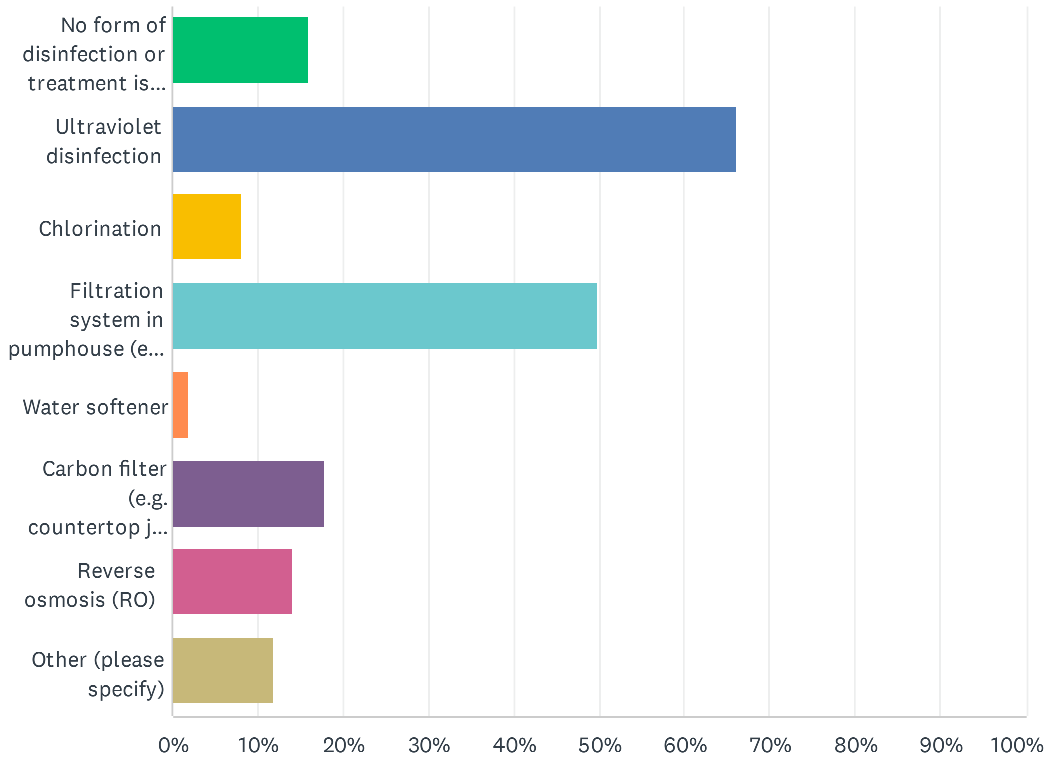
Answered: 17 Skipped: 50



ANSWER CHOICES	RESPONSES	
I do not know enough about it/I do not know how to find information about it	17.65%	3
The cost is too expensive	29.41%	5
Unsure/prefer not to say	52.94%	9
TOTAL		17

Q17 What form of water treatment do you use for your groundwater supply? Select all that apply.

Answered: 50 Skipped: 17



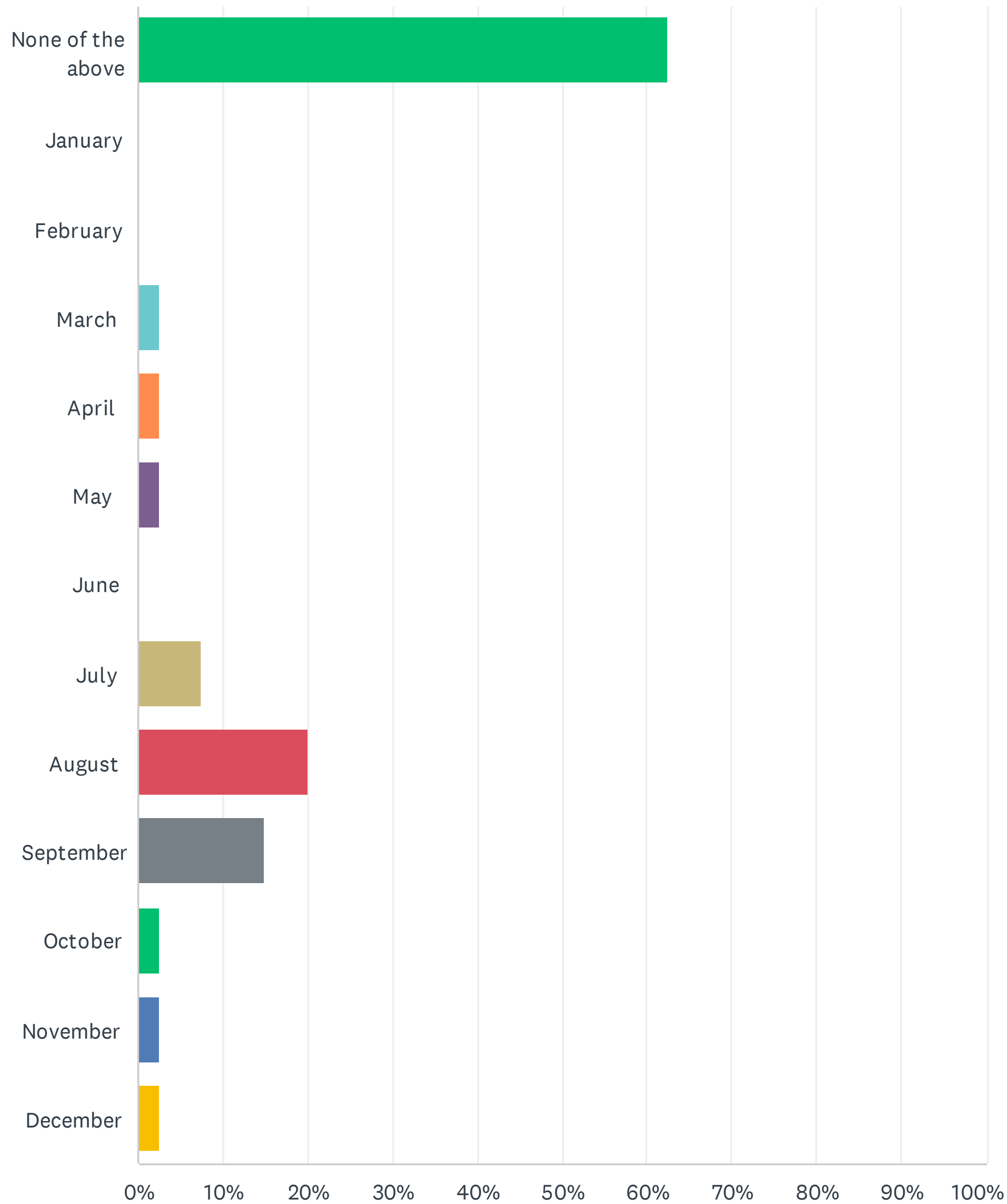
ANSWER CHOICES	RESPONSES	
No form of disinfection or treatment is used	16.00%	8
Ultraviolet disinfection	66.00%	33
Chlorination	8.00%	4
Filtration system in pumphouse (e.g. ceramic filter, greensand filter or specialized adsorption media)	50.00%	25
Water softener	2.00%	1
Carbon filter (e.g. countertop jug or tap mounted cartridge)	18.00%	9
Reverse osmosis (RO)	14.00%	7
Other (please specify)	12.00%	6
Total Respondents: 50		

#	OTHER (PLEASE SPECIFY)	DATE
1	We also don't drink it. We buy drinking water at the store	5/15/2025 7:20 PM
2	two prefilters before UV, and Brita filter (pitcher style) occasionally	4/21/2025 3:04 PM
3	for our RAINWATER (don't use well) we use sediment filters and UV disinfection	4/14/2025 12:47 PM

4	None only use well water for flushing toilet	4/8/2025 9:31 PM
5	also 5 and 1 micron filters before RO and house plumbing	4/8/2025 6:05 PM
6	trickle well water to 2,000 gal cistern to allow aeration so that bacteria cause " sulphur" smell can off gas.	3/28/2025 5:19 PM

Q18 If your well has limited supply or runs out of water, either occasionally or every year, when do you typically run out of water?

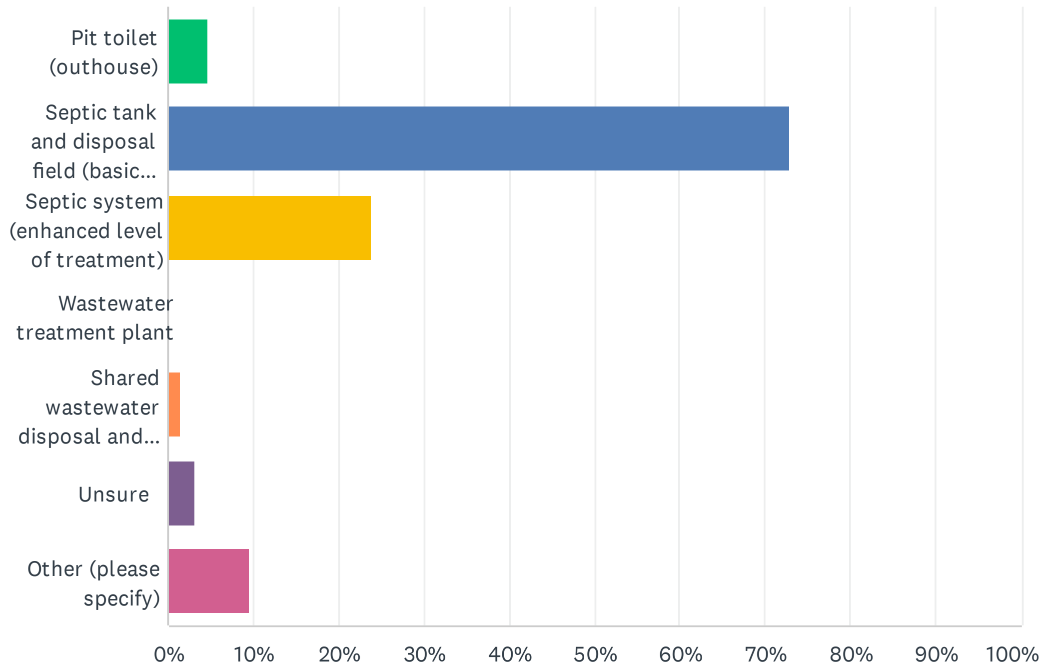
Answered: 40 Skipped: 27



ANSWER CHOICES	RESPONSES	
None of the above	62.50%	25
January	0.00%	0
February	0.00%	0
March	2.50%	1
April	2.50%	1
May	2.50%	1
June	0.00%	0
July	7.50%	3
August	20.00%	8
September	15.00%	6
October	2.50%	1
November	2.50%	1
December	2.50%	1
Total Respondents: 40		

Q19 How is wastewater and sewage treated and disposed of on the property? Select all that apply.

Answered: 63 Skipped: 4

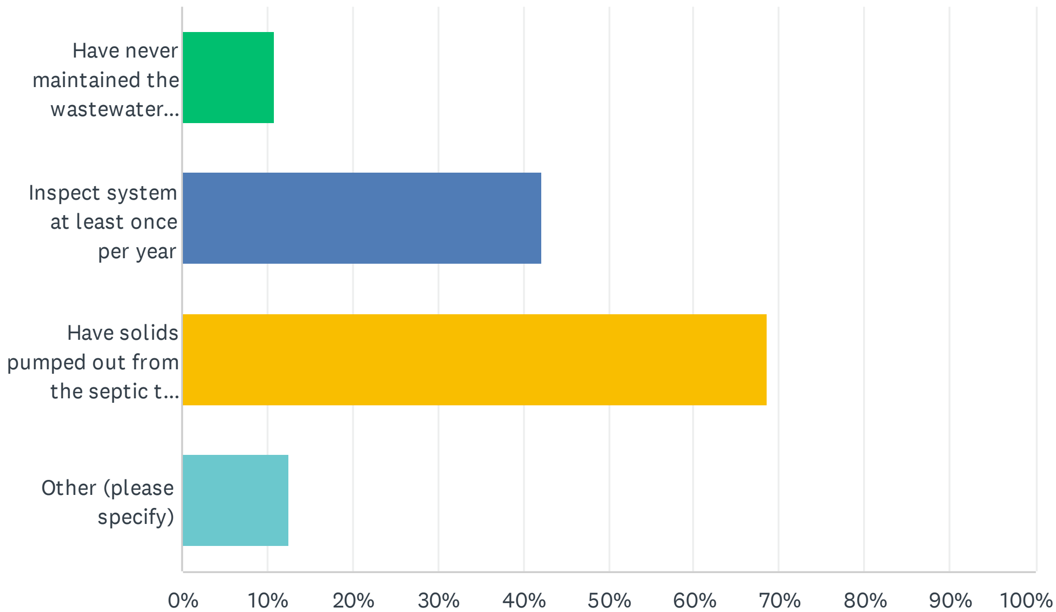


ANSWER CHOICES	RESPONSES	
Pit toilet (outhouse)	4.76%	3
Septic tank and disposal field (basic level of treatment)	73.02%	46
Septic system (enhanced level of treatment)	23.81%	15
Wastewater treatment plant	0.00%	0
Shared wastewater disposal and treatment system between multiple parcels or households	1.59%	1
Unsure	3.17%	2
Other (please specify)	9.52%	6
Total Respondents: 63		

#	OTHER (PLEASE SPECIFY)	DATE
1	Composting toilet, waste is bagged and disposed of	5/15/2025 7:21 PM
2	There is nothing on this small property	4/23/2025 9:03 AM
3	Im not sure of the difference between basic and enhamced levels of treatment	4/22/2025 3:42 PM
4	Graywater mulch basin to plants for washing machine	4/21/2025 3:05 PM
5	Grey water pit for laundry and kitchen water	4/19/2025 8:40 AM
6	composting toilet	3/28/2025 5:21 PM

Q20 How frequently do you check and perform maintenance on your wastewater management system? Select all that apply.

Answered: 64   Skipped: 3



ANSWER CHOICES	RESPONSES	
Have never maintained the wastewater system (e.g. septic tank and field)	10.94%	7
Inspect system at least once per year	42.19%	27
Have solids pumped out from the septic tank every 3 to 5 years	68.75%	44
Other (please specify)	12.50%	8
Total Respondents: 64		

#	OTHER (PLEASE SPECIFY)	DATE
1	Pump septic 2x per year (small old tank)	5/15/2025 7:21 PM
2	Had it inspected once in 4 years	5/13/2025 5:20 PM
3	Also have it inspected at time of pumpout	4/25/2025 8:17 AM
4	There is nothing on this small property	4/23/2025 9:03 AM
5	had it checked 5yrs ago	4/15/2025 3:55 PM
6	As needed	4/11/2025 9:57 AM
7	I have only pumped septic tanks once in 17 years and septic pump people have confirmed that system is working properly with no issues.	3/28/2025 5:21 PM
8	just got the place but had major service when we bought	3/19/2025 10:04 AM

Q21 Do you have any other comments on Gabriola Island water issues?

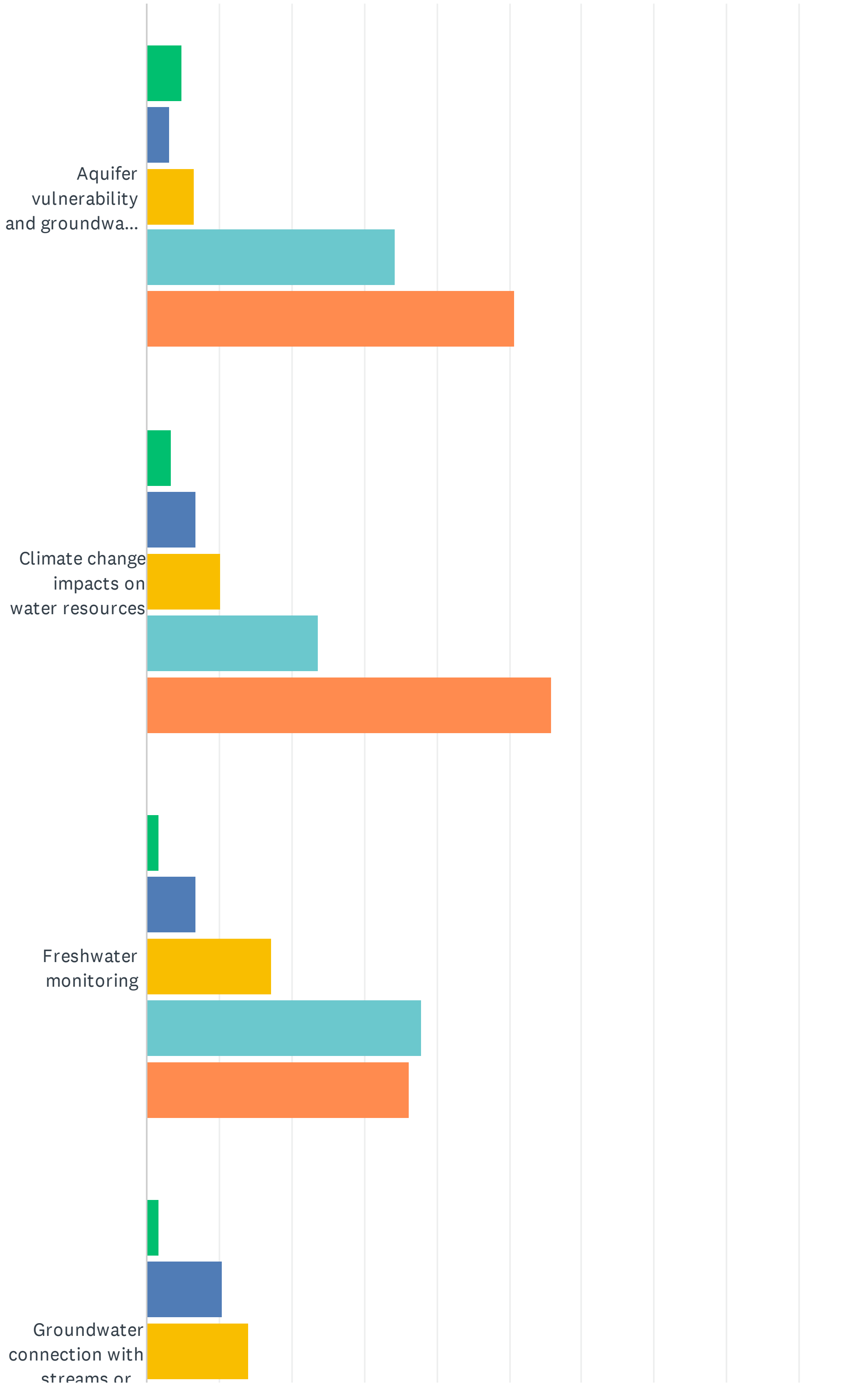
Answered: 29 Skipped: 38

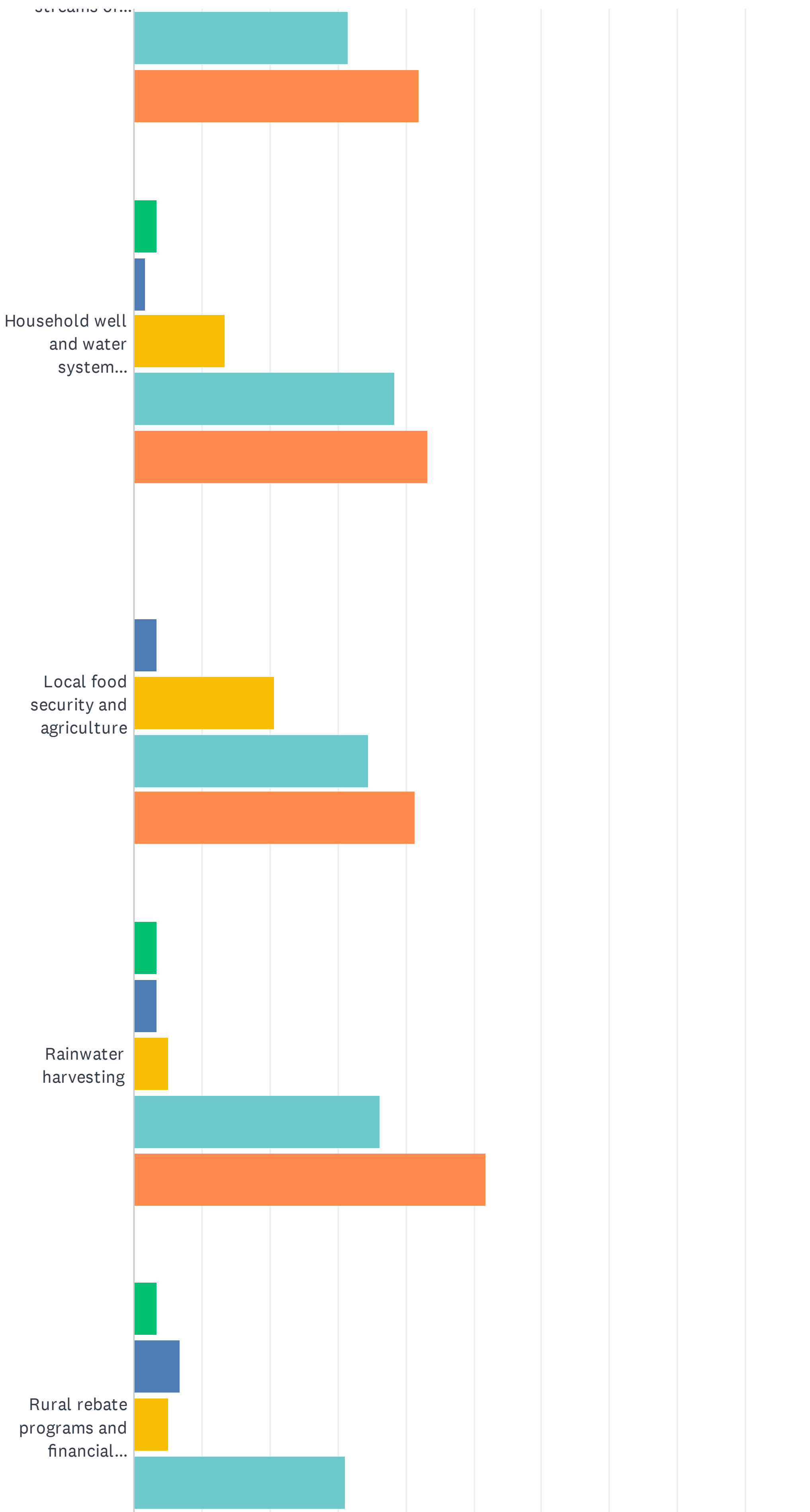
#	RESPONSES	DATE
1	We should not have commercial leases that allow water collection to be used for sale to other users.	5/18/2025 9:43 PM
2	Ground water is climate sensitive and studies have shown that there should be only limited additional residential and commercial/industrial development on Gabriola . Increased density will imperil all groundwater users . Increased density for commercial business or worker accomodations (low wage workers) which are championed by the Chamber of Commerce , should be avoided .	5/17/2025 11:24 AM
3	I've heard several people talk about having a good well that was then contaminated with ecoli from a new neighbour's new septic.	5/15/2025 7:23 PM
4	People should be required to have rainwater collection	5/15/2025 6:07 PM
5	Water is a limited resource on the island and development should only be done in areas with water	5/15/2025 3:52 PM
6	We should require all new construction to be rainwater catchment only! Subdivision should be stopped and only allowed as a rezoning. Proof of water for subdivision is causing deeper wells and more damage.	5/15/2025 12:25 PM
7	I am very concerned about the property used to source water to the Silva Bay marina/resort property, as it is a neighbouring property and would impact our supply if that resort is over-built. I would like to know the effects on groundwater of the materials sprayed on the roads to contain dust, as our well is very close to the road.	5/15/2025 11:44 AM
8	New builds should not be allowed to drill wells lower than neighbours.	5/14/2025 2:06 PM
9	Encourage collection of water	5/13/2025 10:45 PM
10	I think we should allow approved grey water systems	5/13/2025 5:22 PM
11	Rainwater collection is the most environmentally friendly water system by far.	5/3/2025 11:44 AM
12	I have never understood why any building permits and occupancy permits are issued in the absence of the property also having an installed rainwater collection system. I also want to see allowable density limited by groundwater capacity.	5/1/2025 6:14 PM
13	I worry about the number of very big water trucks going back & forth on the ferry for several months during the months of water shortages on Gabriola - GHG emissions, ferry space, etc.	4/29/2025 9:49 PM
14	Water on Gabriola issues are primarily of distribution: some areas have high water table and excellent water quality; others should never have had wells drilled. Rainwater for household water use should have been permitted, regulated/best practices explained and encouraged by local health authority and gov'ts years ago!!	4/21/2025 3:10 PM
15	Poor understanding of aquifer interconnection in the village area in the face of increasing development and density allowances (i.e. Paisley development)	4/19/2025 8:44 AM
16	no other than increased population creates decrease water levels and strain on water table	4/15/2025 3:57 PM
17	The aquifers on the south end and Whalebone area seem to have much more abundant water, and better water quality (from talking to people who live there and looking at properties through real estate). Quality of groundwater varies highly geographically, even within a small neighbourhood. I've heard that some aquifers are drying up in the summer now due to overuse from new wells from new development. Rainwater use and cistern use is not as common as it should be to protect the groundwater reserves.	4/14/2025 12:52 PM
18	Our groundwater resupply is not being protected. In many areas of our aquifer due to over-demand the supply is stressed. During the dry season we are trucking millions of litres of	4/12/2025 2:40 PM

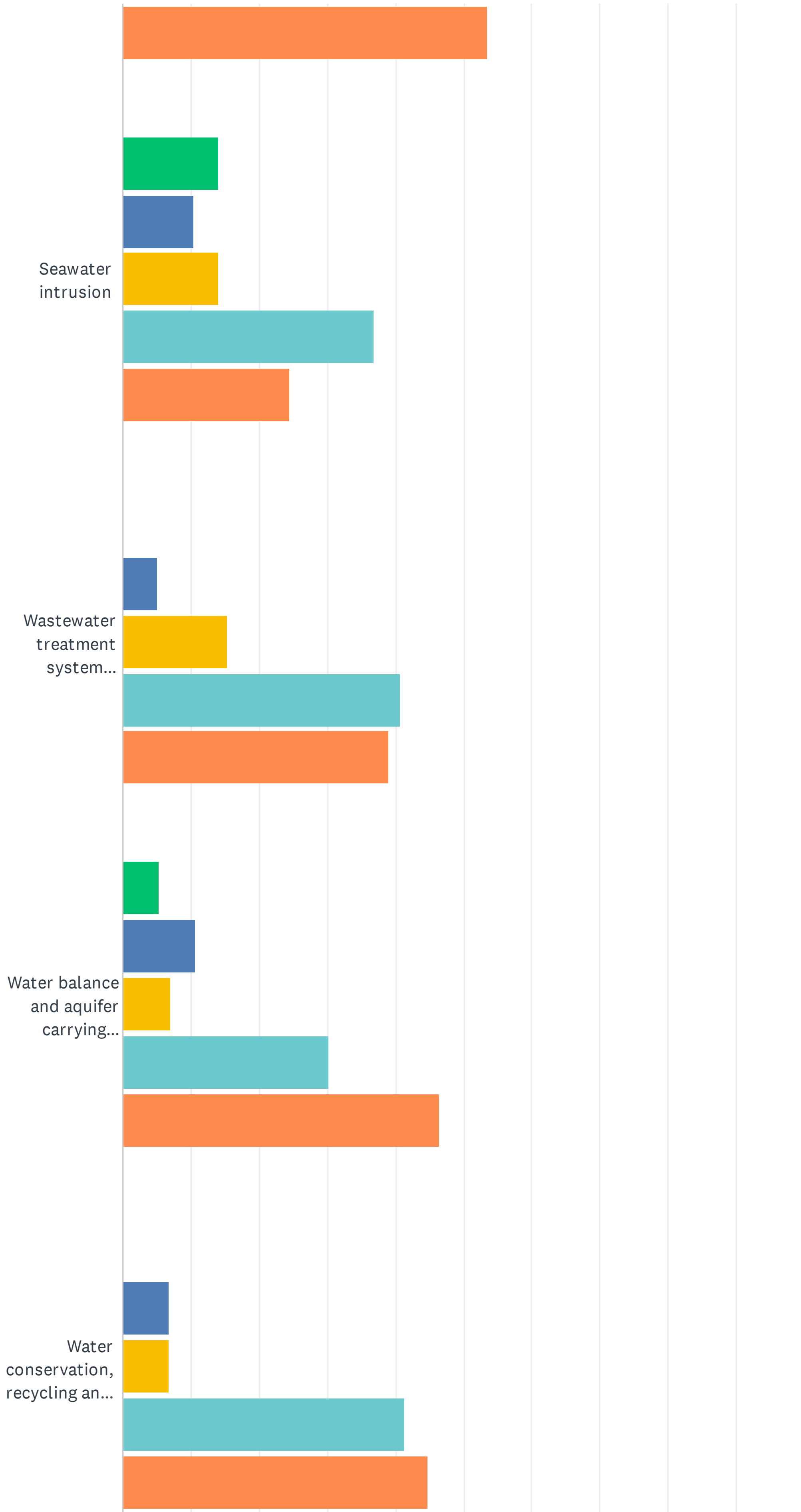
	potable water to households on the island from Nanaimo. When it comes to the water level being classified as “variable” this is a problem for many of us. Ten plus years ago we had an ample supply of groundwater and currently many wells in our area are going dry . We notice a considerable downward trend with groundwater levels. The aquifer here our watershed is noticeably in large decline.	
19	Over population	4/11/2025 5:46 PM
20	There are areas on the Island where there is an abundance of water. Others have no water.	4/11/2025 12:13 PM
21	mandate that a minimum number of native trees must be left on every property, to help lower the number of exotics that need extra water (and also may be detrimental to environment)	4/10/2025 6:03 PM
22	Yes illegal suites over population in areas designated single family dwellings	4/10/2025 6:46 AM
23	know some people have wells run low or gone dry. others high level of sulphur smell. Concern about impact of growing number of households on island that may overburden water supplies	4/8/2025 10:08 PM
24	Gabriola has ongoing water issues	4/8/2025 6:08 PM
25	No	4/8/2025 5:42 PM
26	Please refer to Dvid Coutts 2020 Geology PHD Thesis: Deciphering the Controls on Deep-Water Sediment-Routing Systems, Upper Nanaimo Group, BC: Integration of Geochronology and Stratigraphy. An entire section on Gabriola As well, revisit the Trust Counsel policy concerning RO treatment. The current policy is not based in science!	4/8/2025 4:53 PM
27	No	4/8/2025 12:34 PM
28	We have kept detailed rainwater and precipitation records since 2014 and notice that annual average precipitation has been increasing from less than 40 inches to an average of 46 inches overall with last year 2024 showing 68.35 inches! With rainwater collection and storage, Gabriola appears to have more than enough water to sustain human needs. Gabriola does not have a water shortage problem. It has a water management issue.	3/28/2025 5:28 PM
29	time to legislate rainwater colletion/filtration	3/20/2025 6:06 PM

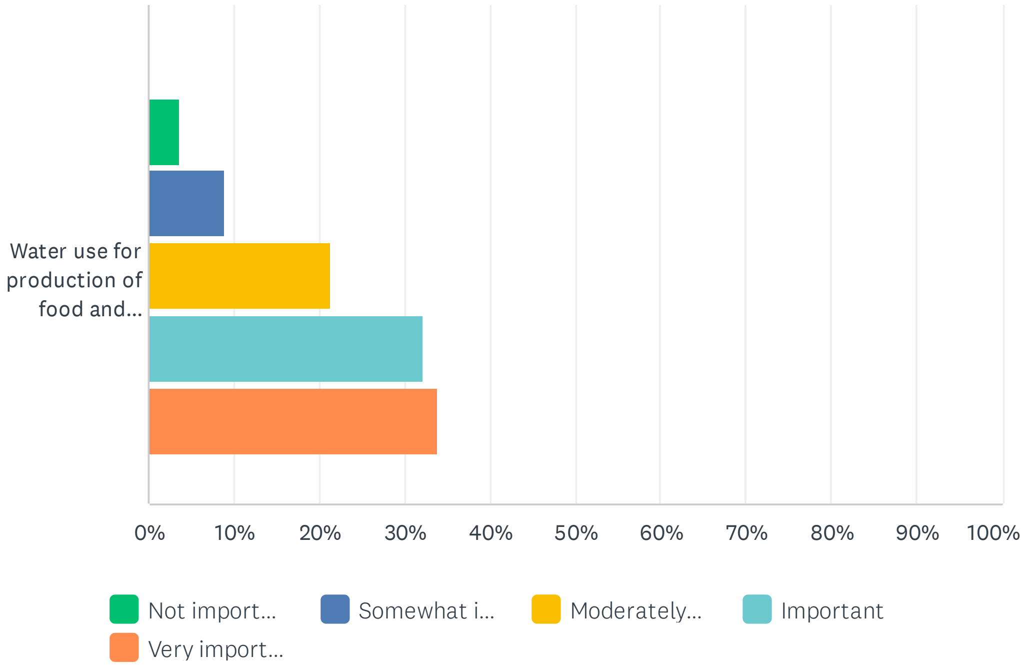
Q22 For the water topics listed below, please rank each, based on the level of importance to you.

Answered: 61 Skipped: 6




streams on...
Household well and water system...
Local food security and agriculture
Rainwater harvesting
Rural rebate programs and financial...

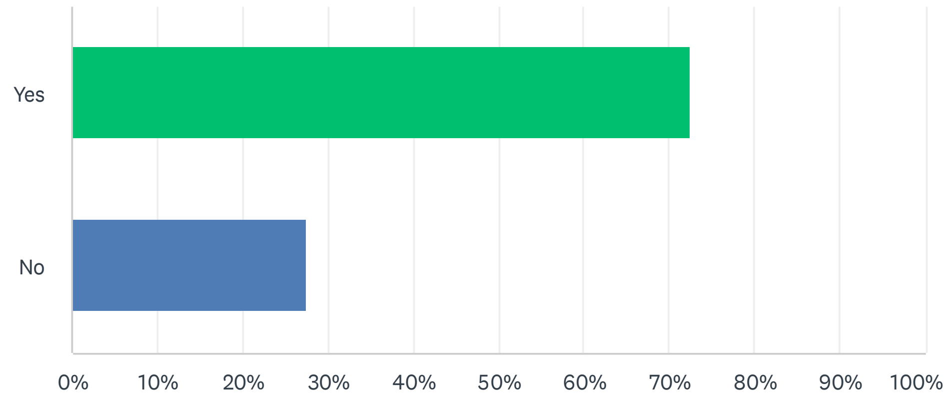

Seawater intrusion
Wastewater treatment system...
Water balance and aquifer carrying...
Water conservation, recycling an...


Water use for production of food and...
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Not import...
Somewhat i...
Moderately...
Important
Very import...

	NOT IMPORTANT	SOMEWHAT IMPORTANT	MODERATELY IMPORTANT	IMPORTANT	VERY IMPORTANT	TOTAL	WEIGHTED AVERAGE
Aquifer vulnerability and groundwater contamination	4.92% 3	3.28% 2	6.56% 4	34.43% 21	50.82% 31	61	4.23
Climate change impacts on water resources	3.39% 2	6.78% 4	10.17% 6	23.73% 14	55.93% 33	59	4.22
Freshwater monitoring	1.72% 1	6.90% 4	17.24% 10	37.93% 22	36.21% 21	58	4.00
Groundwater connection with streams or coastal ecosystems	1.75% 1	10.53% 6	14.04% 8	31.58% 18	42.11% 24	57	4.02
Household well and water system construction, operation and maintenance	3.33% 2	1.67% 1	13.33% 8	38.33% 23	43.33% 26	60	4.17
Local food security and agriculture	0.00% 0	3.45% 2	20.69% 12	34.48% 20	41.38% 24	58	4.14
Rainwater harvesting	3.45% 2	3.45% 2	5.17% 3	36.21% 21	51.72% 30	58	4.29
Rural rebate programs and financial supports (e.g. for well repairs, quality testing, water storage, or low water use fixtures)	3.45% 2	6.90% 4	5.17% 3	31.03% 18	53.45% 31	58	4.24
Seawater intrusion	14.04% 8	10.53% 6	14.04% 8	36.84% 21	24.56% 14	57	3.47
Wastewater treatment system construction, operation and maintenance	0.00% 0	5.08% 3	15.25% 9	40.68% 24	38.98% 23	59	4.14
Water balance and aquifer carrying capacity	5.36% 3	10.71% 6	7.14% 4	30.36% 17	46.43% 26	56	4.02
Water conservation, recycling and reuse	0.00% 0	6.90% 4	6.90% 4	41.38% 24	44.83% 26	58	4.24
Water use for production of food and consumer goods (i.e., including goods supplied from outside the community)	3.57% 2	8.93% 5	21.43% 12	32.14% 18	33.93% 19	56	3.84

Q24 I would like to receive emails regarding the Freshwater Footprint project.

Answered: 40 Skipped: 27



ANSWER CHOICES	RESPONSES	
Yes	72.50%	29
No	27.50%	11
TOTAL		40