Islands Trust

STAFF REPORT

File No.: SSI 6500-20
Water Sustainability

DATE OF MEETING:	October 29, 2019
TO:	Salt Spring Island Local Trust Committee
FROM:	William Shulba, P.Geo - Senior Freshwater Specialist Local Planning Services
COPY:	Jason Youmans, Island Planner
SUBJECT:	Salt Spring Island Groundwater Recharge Potential Report

RECOMMENDATIONS

1. That the Salt Spring Island Local Trust Committee receive the *Salt Spring Island Groundwater Recharge Potential Mapping* report.

2. THAT the Salt Spring Island Local Trust Committee direct staff to return with an analysis of land-use planning options for the protection of Community Aquifer Recharge Areas of Salt Spring Island based on the findings of the *Salt Spring Island Groundwater Recharge Potential Mapping* report.

3. THAT the Salt Spring Island Local Trust Committee direct staff to return with a proposed scope of work to action the recommendations of the *Salt Spring Island Groundwater Recharge Potential Mapping* report.

REPORT SUMMARY

The purpose of this staff report is to:

- present the Salt Spring Island Local Trust Committee (LTC) with the *Salt Spring Island Groundwater Recharge Potential Mapping* report;
- recommend that staff return with analysis of land-use planning options for the protection of Community Aquifer Recharge Areas of Salt Spring Island based on the findings of the report; and
- recommend that the LTC consider further groundwater preservation project to include determining recharge volumes and groundwater availability by way of water balance assessment of Community Aquifers of Salt Spring Island.

BACKGROUND

Groundwater supplies approximately half of the water needs of the Salt Spring Island community and is an ecological component of our watersheds. Groundwater supplies are recharged through freshwater networks with watershed ecosystems. Therefore, protecting groundwater recharge areas should be an integral component of land-use planning to protect these watershed ecosystems, preserve environmental flow needs, and manage groundwater resources for island communities.

The Salt Spring Island Local Trust Committee (LTC) has maintained Water Sustainability (formerly "Watershed Management") as a top priority since 2013. In 2016, the LTC supported a "Groundwater Supply" project, now called the "Groundwater Preservation Project" with on-going data stewardship and monitoring projects.

In February 2019 the LTC endorsed the expansion of the Groundwater Preservation Project to include *Community Aquifer Recharge Areas* and to maintain Water Sustainability as a top priority;

> **SS-2019-036**
> **It was MOVED and SECONDED,**
> That the Salt Spring Island Local Trust Committee amend the Groundwater Preservation Project Charter by allocating $5,000 from the Water Sustainability 2019/20 budget to identify Community Aquifer Recharge Areas on Salt Spring Island.
>
> **CARRIED**

Islands Trust retained hydrogeology consulting firm GW Solutions to determine groundwater recharge potential on Salt Spring Island in April 2019. GW Solutions returned with a report and GEOTIFF file on May 30, 2019.

At its October 2, 2019 meeting, the Local Trust Committee resolved to forward the *Groundwater Recharge Potential* Report to the Salt Spring Island Watershed Protection Alliance as follows:

> **SS-2019-174**
> **It was MOVED and SECONDED,**
> that the Salt Spring Island Local Trust Committee refer the community aquifer recharge area report to the Salt Spring Island Watershed Protection Alliance (SSIWPA) to coordinate a review by members and relevant agencies.
>
> **CARRIED**

ANALYSIS

Policy/Regulatory

Islands Trust Policy Statement:

Islands Trust Policy Statement Directive 3.3.1 holds that the freshwater wetlands, bodies of surface water, natural drainage patterns, water courses, fish-bearing streams, watershed and groundwater recharge areas of the Trust Area should be identified, protected and, where possible, restored or rehabilitated.

Work undertaken through the LTC's Groundwater Preservation Project is consistent with, and can help implement, the Islands Trust Policy Statement.

Issues and Opportunities

Salt Spring Island Groundwater Recharge Potential Report - Summary

The primary objectives of this part of the project was to retain consulting services to inventory geo-spatial data and groundwater related information, identify aquifer recharge potential, document the methodology, identify data gaps, and provide recommendations for future initiatives.

The deliverables of the consulting services established in the contract were limited to the technical report and groundwater recharge potential maps (including an ArcGIS-compatible Data Package).

Aquifer recharge occurs across most of the land in the Gulf Islands. However, due to changes in topography, geology, biogeography, climate and land-use, the magnitude and significance of recharge changes with the landscape. All aquifers have associated recharge zones to sustain groundwater use in the region.

A new approach has been developed to determine aquifer recharge potential and has been applied by GW Solutions here on Salt Spring. It considers spatial variability of precipitation, surplus, land cover, soil and geology, slope, and faults and contacts between bedrock strata. The potential for groundwater recharge for defined *Community Aquifers* has been investigated and reported on. Lithology, land use land cover, precipitation and slope are determined to be the most influential factors controlling recharge potential, followed by lineament density, soil type and drainage density. The aquifer recharge potential on Salt Spring has been mapped and shows a high contrast between areas with low recharge potential and areas with moderate to high recharge potential.

Further to its *Groundwater Recharge Potential Mapping* report, GW Solutions recommends:

1. *Groundwater level information from three ministry observation wells was available for this study. The integration of more wells with continuous water level monitoring would improve our understanding of the dynamics of the groundwater on Salt Spring and increase the confidence of the recharge potential mapping.*

2. *A detailed water budget study is recommended to properly manage the water resource on Salt Spring, combined with the improved knowledge gained from the completed aquifer recharge study. The scale at which water budgets should be completed must be selected based on the large variability in groundwater recharge across the Island. For instance, estimating a water budget at the groundwater sub-region scale might be adequate for the island.*

3. *The recharge potential map provides insights on understanding mountain block recharge for lowland areas; however, it does not estimate volumes. This could be achieved by completing a water budget study.*

<u>*Project Deliverables*</u>

When staff proposed this project to the LTC in February 2019, it included the following proposed deliverables:

- *Community Aquifer Recharge Areas* Base Maps;
- *Community Aquifer* demonstration data dashboard, and
- *Community Aquifer Recharge Area* demonstration three-dimensional hydrogeological model.

However, subsequent assessment indicated that all three deliverables could not be achieved for the $5,000 project budget. Therefore, the *Salt Spring Island Groundwater Potential Report* contains only the recharge area base maps of the first deliverable as per the consulting contract. Work on deliverables two and three could be included in a subsequent phases of the LTC's groundwater protection project such as a water balance assessment if the LTC chooses to pursue this work.

Consultation

The *Salt Spring Island Groundwater Recharge Potential* report will be forwarded for review to the members of the Salt Spring Island Watershed Protection Alliance (SSIWPA) in accordance with the LTC's October 2, 2019 resolution.

Agencies

Senior Freshwater Specialist is currently advancing water sustainability initiatives in the Islands Trust Area in coordination with provincial, regional, and local governments in consultation with local organizations and community members. The *Salt Spring Island Groundwater Recharge Potential* report was reviewed by Provincial ministry hydrogeologists and recommendations of potential outcomes of this work are beneficial to multiple government agencies.

First Nations

Through the Water Sustainability top priority, the LTC has an opportunity to hear from local First Nations regarding their knowledge, interests, and concerns regarding Salt Spring Island's water resources.

Staff will continue to work with Island Trust Senior Intergovernmental Policy Advisor on appropriate methods and approaches to engaging First Nations in the work of the Islands Trust.

Rationale for Recommendations

1) That the Salt Spring Island Local Trust Committee receive the Salt Spring Island Groundwater Recharge Potential Report.

LTC receipt of the *Salt Spring Island Groundwater Recharge Potential Report* helps fulfil a deliverable of the LTC's "Water Sustainability – Groundwater Preservation Project" and is consistent with the project charter.

2) THAT the Salt Spring Island Local Trust Committee request staff to return with analysis of land-use planning options for the protection of Community Aquifer Recharge Areas of Salt Spring Island.

Protection of Salt Spring Island's community aquifer areas through prudent land use planning can help maintain the resource for community and ecological needs.

3) THAT the Salt Spring Island Local Trust Committee direct staff to return with a proposed scope of work to action the recommendations of the Salt Spring Island Groundwater Recharge Potential Report.

In a time of climate change and development demand, the more the community and government agencies of jurisdiction know about groundwater resources, the better informed their land use planning decisions can be.

The recommendations in this report will build on the community's existing investment in coordinated watershed protection on Salt Spring Island. The Groundwater Preservation Project aligns with the Water Sustainability top priority and the recommendations in the report advance this initiative.

Through coordination and collaboration with government agencies, stakeholders, and community consultation, the LTC may receive additional information to support the Groundwater Preservation Project and to guide consideration of a different approach for addressing aquifer protection and groundwater resource preservation across multiple jurisdictions.

ALTERNATIVES

The LTC may consider the following alternatives to the staff recommendation:

1. *THAT the Salt Spring Island Local Trust Committee receive the report for information only.*

2. *THAT The Salt Spring Island Local Trust Committee defer consideration of the report and project expansion to a later date.*

NEXT STEPS

If the LTC chooses to carry the recommendations of this report, staff will:

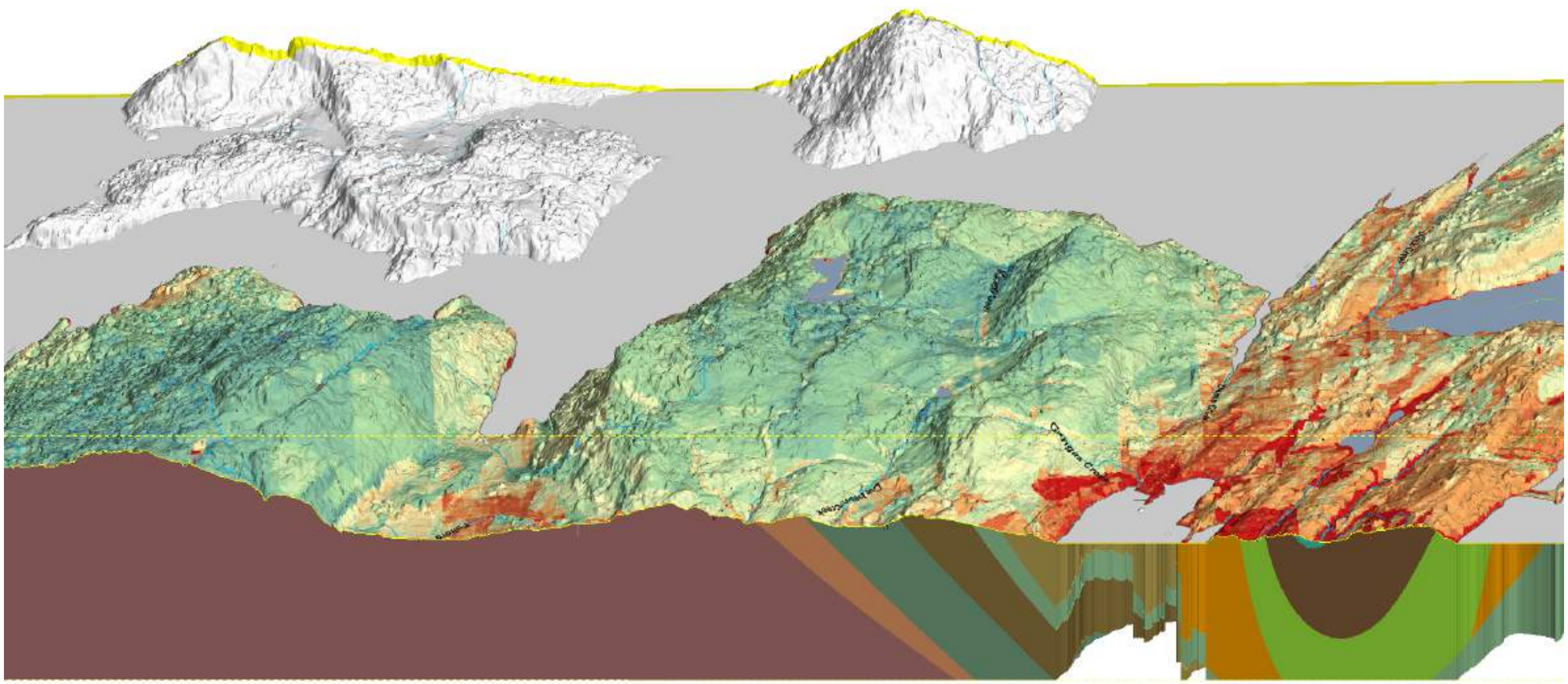
1. Forward the *Salt Spring Island Groundwater Recharge Potential* report to the Salt Spring Island Watershed Protection Alliance (SSIWPA) in accordance with the LTC’s October 2, 2019 resolution;
2. Explore analysis of land-use planning options for the protection of Community Aquifer Recharge Areas of Salt Spring Island; and
3. Create a scope of work to action the recommendations of the *Salt Spring Island Groundwater Recharge Potential* report.

Submitted By:	William Shulba, P.Geo Senior Freshwater Specialist	October 22, 2019
Concurrence:	Stefan Cermak, Regional Planning Manager	October 22, 2019

ATTACHMENTS

1. Salt Spring Island Groundwater Recharge Potential Report, GW Solutions 2019-17, May 30, 2019.
2. Groundwater Protection Project Charter

Salt Spring Island
Groundwater Recharge Potential Mapping



Prepared for: Islands Trust

Prepared by: GW Solutions Inc.

May 2019

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FIGURES[1]

[1] Cover image is of Leapfrog 3D conceptual model of Salt Spring Island bedrock geology overlain by recharge potential mapping from this project.

TABLES

APPENDICES

APPENDIX 1:

GW Solutions Inc. General Conditions and Limitations

1 BACKGROUND AND OBJECTIVES

1.1 Background

GW Solutions has been retained by Islands Trust to identify the potential groundwater recharge areas for Salt Spring Island. According to the BC MoE wells database, approximately 10% of wells within the database for Vancouver Island and the Gulf Islands are located on Salt Spring Island (further referred to as “Salt Spring” in this report). Within Salt Spring, approximately 74% of the wells are completed in bedrock aquifers, 20% in overburden aquifers, and 6% of the wells are classified as “unknown”, as shown in Figure 1.

1.2 Objectives

The primary objectives of this study include:

- Inventory geo-spatial data and groundwater related information;
- Identify Aquifer Recharge Potential; and
- Document the methodology, identify data gaps, and provide recommendation for future initiatives.

1.3 Deliverables

The deliverables of this project have been established in the contract and were limited to the following:

- This report;
- Groundwater recharge potential maps (including an ArcGIS-compatible Data Package);

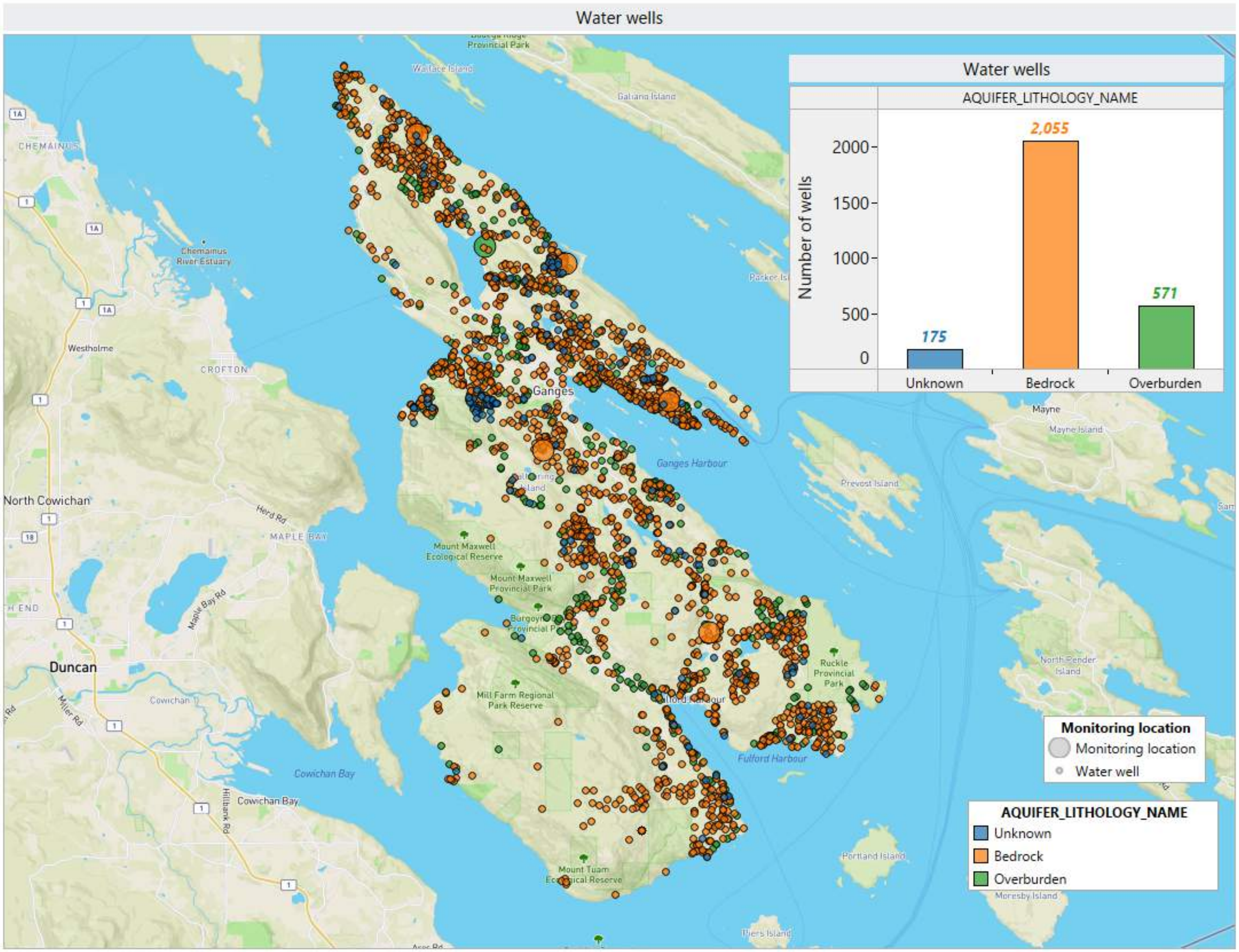

Figure 1. Water well type according to BC MoE wells database

2 FRAMEWORK AND STUDY AREA

Aquifer recharge analysis was completed for Salt Spring, covering an area of 185.5 km^2 (Figure 2). For reporting purposes, GW Solutions considered the 17 Aquifer subregions (shown in Figure 2) provided by the Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD). These aquifer subregions follow the drainage system as well as aquifer "regions" first identified by Hodge (1977), to include bedrock geology, fault systems and major groundwater divides.

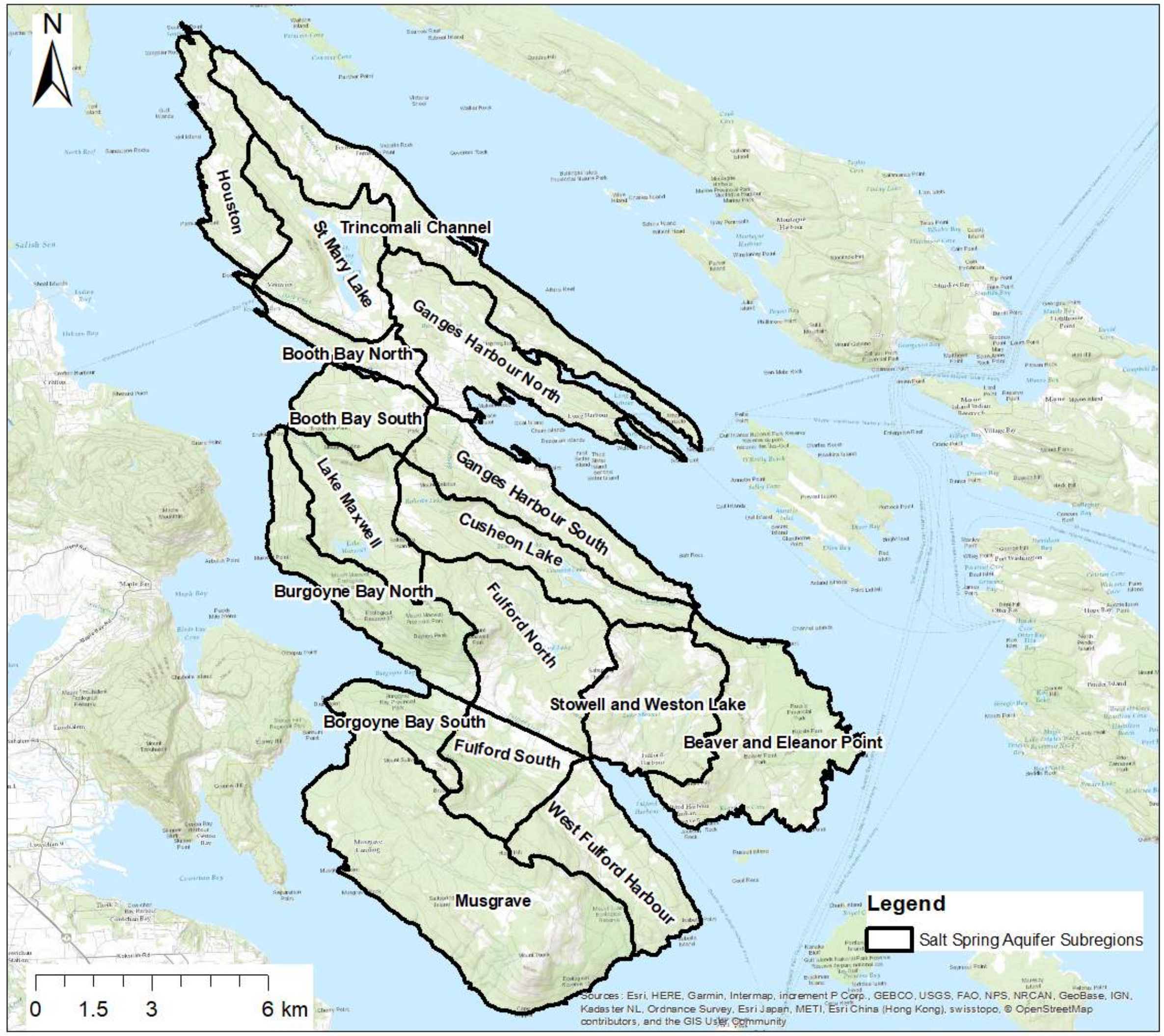

Figure 2. Study area for the aquifer recharge potential map showing Aquifer Subregions identified by FLNRORD and modified from Hodge (1977)

3 DATA COLLECTION AND REVIEW

GW Solutions has accessed and compiled the information summarized in Table 1.

Table 1. Data type and source of information

Data Type	Data Source	Provided by
Groundwater levels	Observation Well Network (water levels) from the Province	BC Ministry of Environment
Climate	Pacific Climate Impacts Consortium (gridded meteorological information and precipitation data)	Pacific Climate Impacts Consortium
Watersheds	Salt Spring Watershed boundary	Islands Trust (CRD Boundaries)
Waterbodies	Lakes and wetlands	Islands Trust (CRD Boundaries)
Water wells	Wells database	BC Data Catalogue (GWells)
Surplus (groundwater and runoff)	GW Solutions water balance model	GW Solutions
Groundwater Chloride concentration for Salt Spring	Environmental Monitoring System	BC Data Catalogue
Precipitation Chemistry for Saturna Island	Environment and Climate Change Canada	Environment and Climate Change Canada Data
Aquifers	Salt Spring mapped aquifers	Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD)

Data Type	Data Source	Provided by
	Salt Spring aquifer subregions	FLNRORD
Elevation	30 m x 30 m digital elevation model	Natural Resources Canada - NRCAN
	2 m contour	Islands Trust
Soil, geology and land	BC Soil Information Tool (regional and local geology and soils information)	BC Soil Information Finder Tool and Islands Trust
	BC Land cover	BC Data Catalogue
	Salt Spring geology map, GIS files and notes	BCGS Open File 2009-11 by H.J. Greenwood with M.G. Mihalynuk

4 METHODOLOGY

GW Solutions has used a GIS approach based on recharge indexes to estimate groundwater recharge potential across Salt Spring.

4.1 Data Inputs

The following data sets were used for the GIS-based recharge index methodology:

4.1.1 **Slope and topography**

Slope was derived from the Digital elevation model and 2 m topographic contours at a grid size of 20 m x 20 m.

4.1.2 Soil and surficial geology

Soil related data was retrieved from the British Columbia Soil Information Finder Tool. The BC Soil database includes soil composition (mineral or organic), soil texture, coarse fragment content, drainage, soil layer thicknesses and characteristics, soil physical and chemical properties, as well as landform and parent material.

The available surficial geology mapping was joined to the soil layer and the resulting map is presented in Figure 4.

4.1.3 Land cover

GW Solutions used Land Cover mapping, circa 2000 vector polygons to derive land cover classes that were then converted to raster format. The resulting land cover raster is presented in Figure 4.

4.1.4 Bedrock geology

An exemplary bedrock geology map of Salt Spring is available, mapped by Greenwood and Mahalynuk (2009). The GIS files, PDF map and accompanying notes from BCGS Open File 2009-11 were provided by Islands Trust. The geology of the north half of Salt Spring is predominantly mudstone, sandstone and conglomerate of the Nanaimo Group. The sandstone/conglomerate units tend to be resistive to weathering and form topographic highs while the intervening valleys are dominated by shale/mudstone units. The shale units have preferentially eroded (recessive weathering) and correspond to topographic lows. The bedrock strata from Greenwood and Mahalynuk (2009) were grouped into their dominant rock textures and weathering profile:

- Fine-grained (Recessive weathering);
- Coarse-grained (Resistant weathering);
- Interbedded (Recessive Weathering); and
- Crystalline (Mixed weathering).

The strata on Salt Spring are steeply inclined and likely provide preferential pathways for groundwater infiltration to the subsurface. Bedding planes, faults, lineaments and geological contacts between the above groups were identified as potential recharge zones. Figure 5 shows the resulting interpreted bedrock geology.

4.1.5 Topographic Wetness Index

GW Solutions has generated the Topographic Wetness Index (TWI) using the 2 m topographic contour data. The TWI is commonly used to assess topographic effects on hydrologic processes. TWI is a function of the slope and the upstream contributing area. Figure 5 shows the resulting TWI map for Salt Spring. Large values of TWI are typically associated with lowlands having a larger contributing (catchment) area.

4.1.6 Precipitation

Annual total precipitation gridded data shown in Figure 6 were obtained from the Pacific Climate Impact Consortium (PCIC). The information corresponds to normal data for the 1981-2010 period.

4.1.7 Surplus

GW Solutions has developed a water balance model for Vancouver Island. The outputs of the model are described below:

- **Potential evapotranspiration (PE):** It represents moisture demand; it is the evaporative water loss from a vegetated surface in which water is not a limiting factor. It depends mainly on heat and radiation.
- **Actual evapotranspiration (AE):** It refers to water loss from a vegetated surface given water availability (precipitation and soil moisture storage). If water is not a limiting factor, actual evapotranspiration is equal to potential evapotranspiration.
- **Deficit:** It represents moisture stress and occurs when the evaporative demand is not met by available water. In other words, it is the difference between potential and actual evapotranspiration.
- **Surplus:** It is excess water (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 full.

GW Solutions has utilized the annual Surplus output raster file to aid in the determination of the aquifer recharge potential.

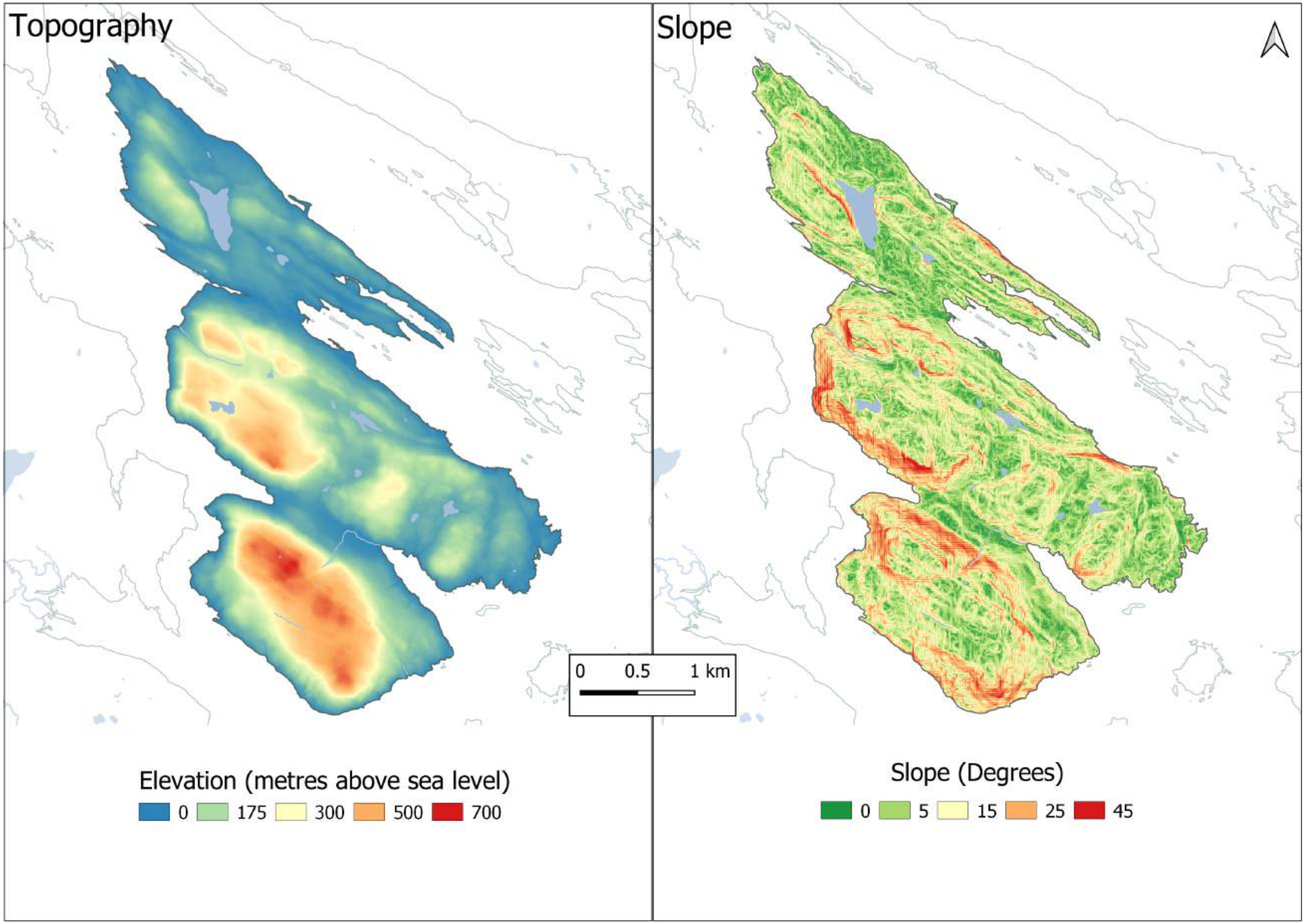

Figure 3. Slope and topography

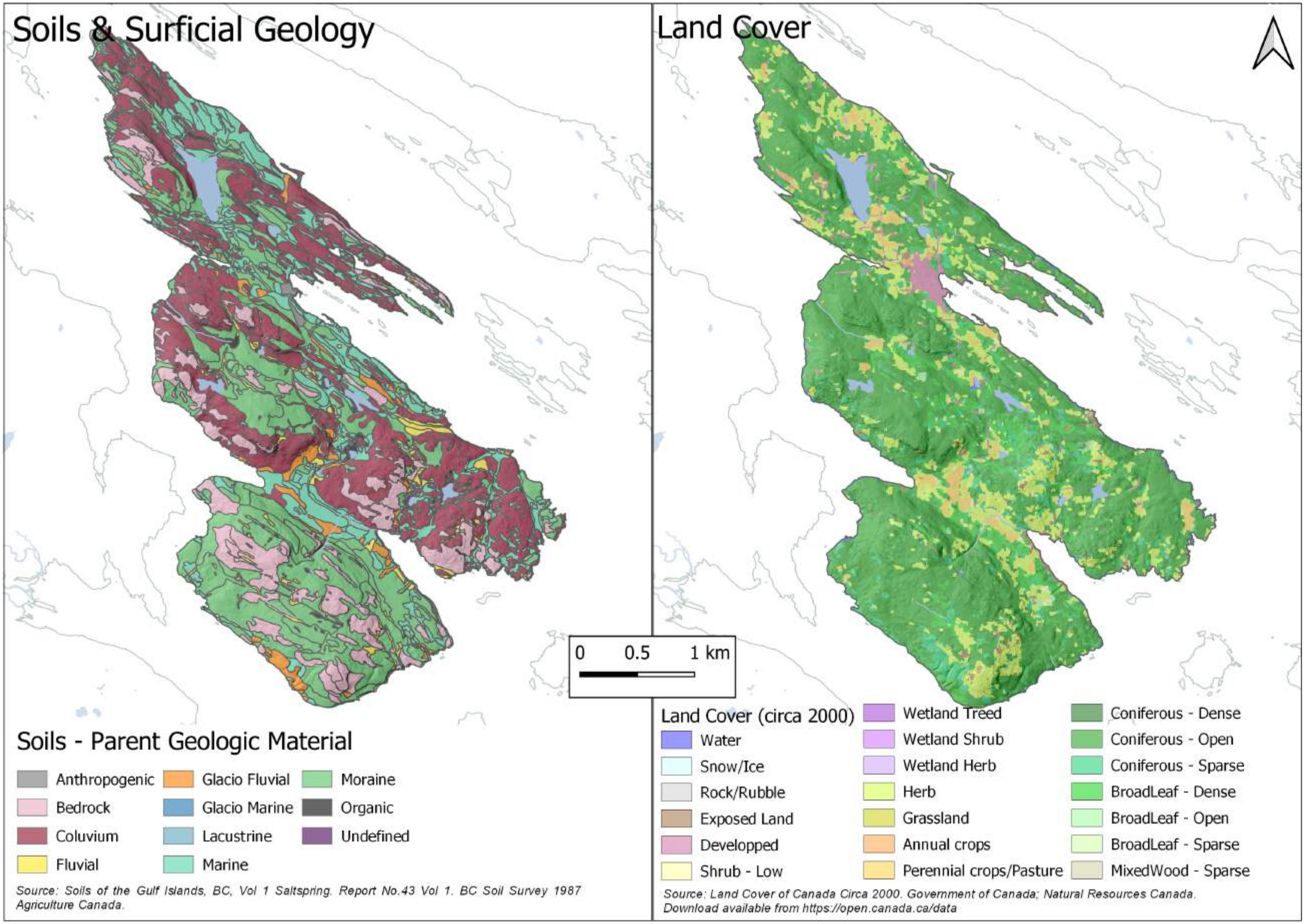

Figure 4. Soils, surficial geology and land cover

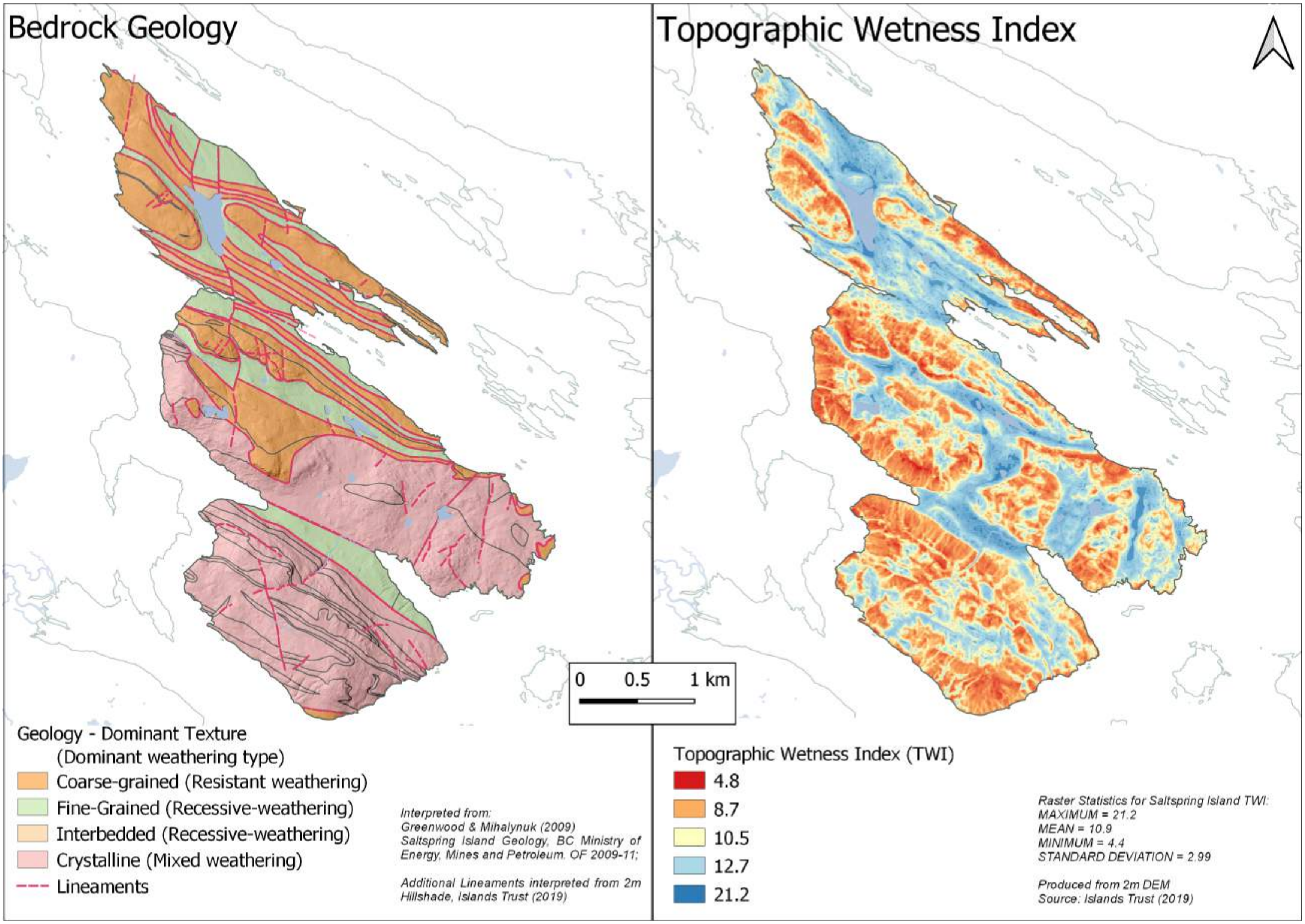

Figure 5. Bedrock geology, fine-coarse grained contacts, lineaments and Topographic Wetness Index

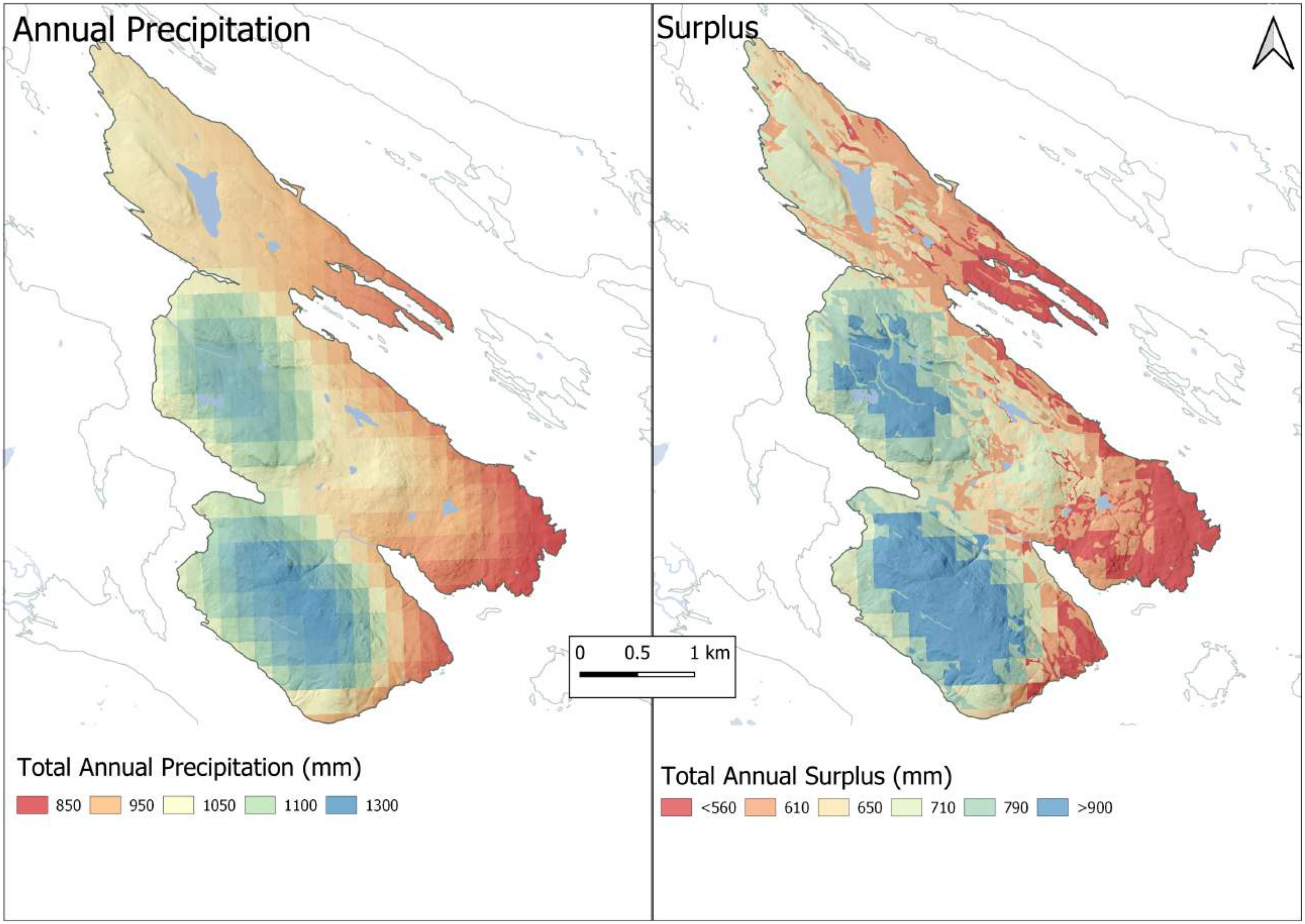

Figure 6. Precipitation and modeled surplus

4.2 Estimation of Infiltration Factors

An infiltration coefficient factor was calculated from the sum of individual infiltration coefficients considering five factors:

1. Land cover;
2. Soils;
3. Slope;
4. Faults, bedrock lineaments and geological contacts; and
5. Water surplus.

These factors are determined based on relevant reference information and the statistical distribution values for Salt Spring. A 20 m x 20 m grid cell was used.

4.2.1 Land cover infiltration factor

Land cover has significant effects on the groundwater recharge by way of evapotranspiration, interception, and dispersion by foliage, which prevents or slows precipitation from reaching the ground leading to longer exposure to the atmosphere and increased evaporation. Table 2 summarizes the land cover infiltration factors considered for the study area. Figure 9 shows the land cover infiltration factor.

Table 2. Land Cover Infiltration Factors

Value	Description	Group	Infiltration Factor
0	No Data	No Data	0
11	Cloud	Cloud	0
12	Shadow	Shadow	0
20	Water	Water	0
31	Snow/Ice	Non-Vegetated Land	0
32	Rock/Rubble	Non-Vegetated Land	0.1
33	Exposed Land	Non-Vegetated Land	0.08
34	Developed	Non-Vegetated Land	0.01
52	Shrub - Low	Shrubland	0.15
81	Wetland Treed	Wetland	0.05

Value	Description	Group	Infiltration Factor
82	Wetland Shrub	Wetland	0.05
83	Wetland Herb	Wetland	0.05
100	Herb	Herb	0.14
110	Grassland	Herb	0.13
121	Annual crops	Herb	0.12
122	Perennial crops and Pasture	Herb	0.12
211	Coniferous - Dense	Forest/Trees	0.2
212	Coniferous - Open	Forest/Trees	0.19
213	Coniferous - Sparse	Forest/Trees	0.18
221	BroadLeaf - Dense	Forest/Trees	0.17
222	BroadLeaf - Open	Forest/Trees	0.16
223	BroadLeaf - Sparse	Forest/Trees	0.15
233	MixedWood - Sparse	Forest/Trees	0.14

4.2.2 Soil infiltration factor

The soil infiltration factor relates to three soil characteristics: drainage (weighting factor 70%), texture (30%) and geology (10%). These three characteristics were weighted to obtain the soil infiltration factor. Table 3 lists the drainage, texture and geology factors considered for the estimation of the soil infiltration factor. Figure 7 presents the soil infiltration factor.

Table 3. Drainage, texture and geology factors

Group	Code	Description	Factor
Drain	P	Poorly Drained	0.1
Drain	I	Imperfectly Drained	0.15
Drain	MW	Moderately Well Drained	0.2
Drain	W	Well Drained	0.3
Drain	R	Rapidly Drained	0.4
Texture	SICL	Silty Clay Loam	0.1
Texture	SIL	Silt Loam	0.15
Texture	SL	Sandy Loam	0.2
Texture	L	Loam	0.3

Group	Code	Description	Factor
Texture	LS	Loamy Sand	0.35
Texture	S	Sand	0.4
Geology		Anthropogenic	0.01
Geology		Bedrock	0.2
Geology		Colluvium	0.2
Geology		Fluvial	0.3
Geology		Glacio Fluvial	0.4
Geology		Glacio Marine	0.2
Geology		Ice	0
Geology		Lacustrine	0.1
Geology		Marine	0.1
Geology		Moraine	0.1
Geology		Organic	0.1
Geology		Undefined	0.01
Geology		Undifferentiated	0.2

4.2.3 Slope infiltration factor

Topography greatly influences the potential for water infiltration to the subsurface. Low slopes promote infiltration whereas steep slopes promote runoff and decreased infiltration. Table 4 summarizes the slope infiltration factors. Figure 7 shows the resulting slope infiltration factor map.

Table 4. Slope infiltration factors

Groundwater recharge potential	Slope degree	Infiltration factor
Minimum	>24.04	0.01
Very poor	8.46 - 24.04	0.02
Poor	4.51-8.46	0.05
Moderate	2.7-4.51	0.1
Good	1.8-2.7	0.15
Very good	0.22-1.8	0.2
High	<0.22	0.3

4.2.4 Bedrock Contact/Lineament infiltration factor

In order to determine the bedrock infiltration factors, the Topographic Wetness Index (TWI) and bedrock contacts/lineaments were integrated. Values with high TWI suggest a higher possibility for groundwater recharge. The recharge potential values corresponding to the combined TWI and bedrock contacts/lineament zones are listed in Table 5 and summarized in Figure 8.

Table 5. TWI/Bedrock Contact/Lineament recharge potential

Groundwater recharge potential	TWI range	TWI Recharge Potential
Low	< 8	0.25
Moderate	8 - 11	0.5
High	11 - 14	0.75
Very High	14 - 21	1

4.2.5 Water surplus

Surplus is the available water in the ground (not evaporated or transpired) that exits a site through runoff or subsurface flow or a combination of both. The surplus will be the dominant factor when identifying recharge areas. The surplus index is shown in Figure 9.

Table 6. Surplus recharge potential

Groundwater recharge potential	Surplus range (mm)	Recharge Potential
Minimum	< 560	0.15
Poor	560 - 610	0.35
Moderate	610 - 650	0.5
Good	650- 710	0.65
Very good	710 - 790	0.8
High	790 - 960	1

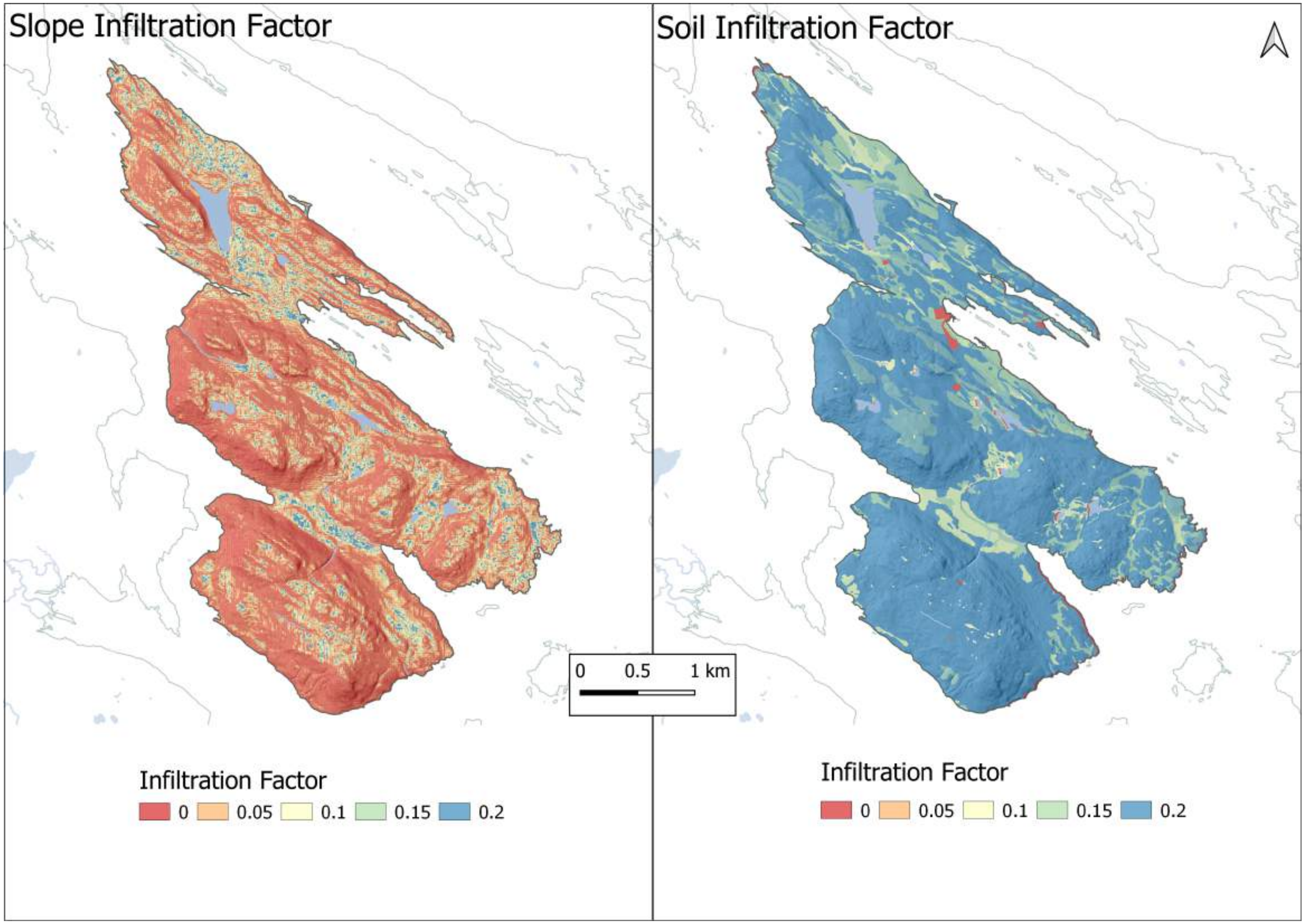

Figure 7. Slope and soil infiltration factor

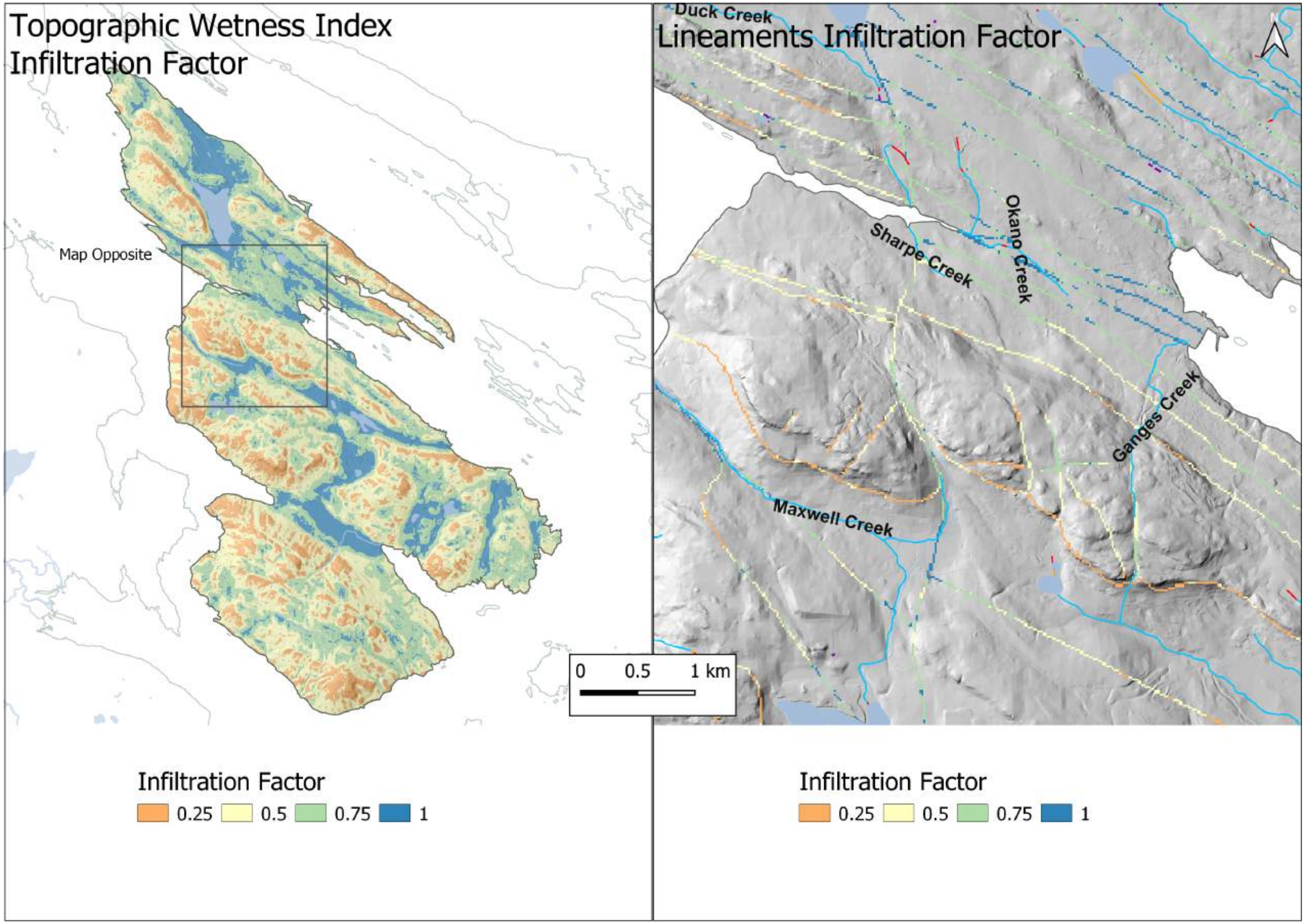

Figure 8. Topographic Wetness Index and bedrock contact/lineament infiltration factor

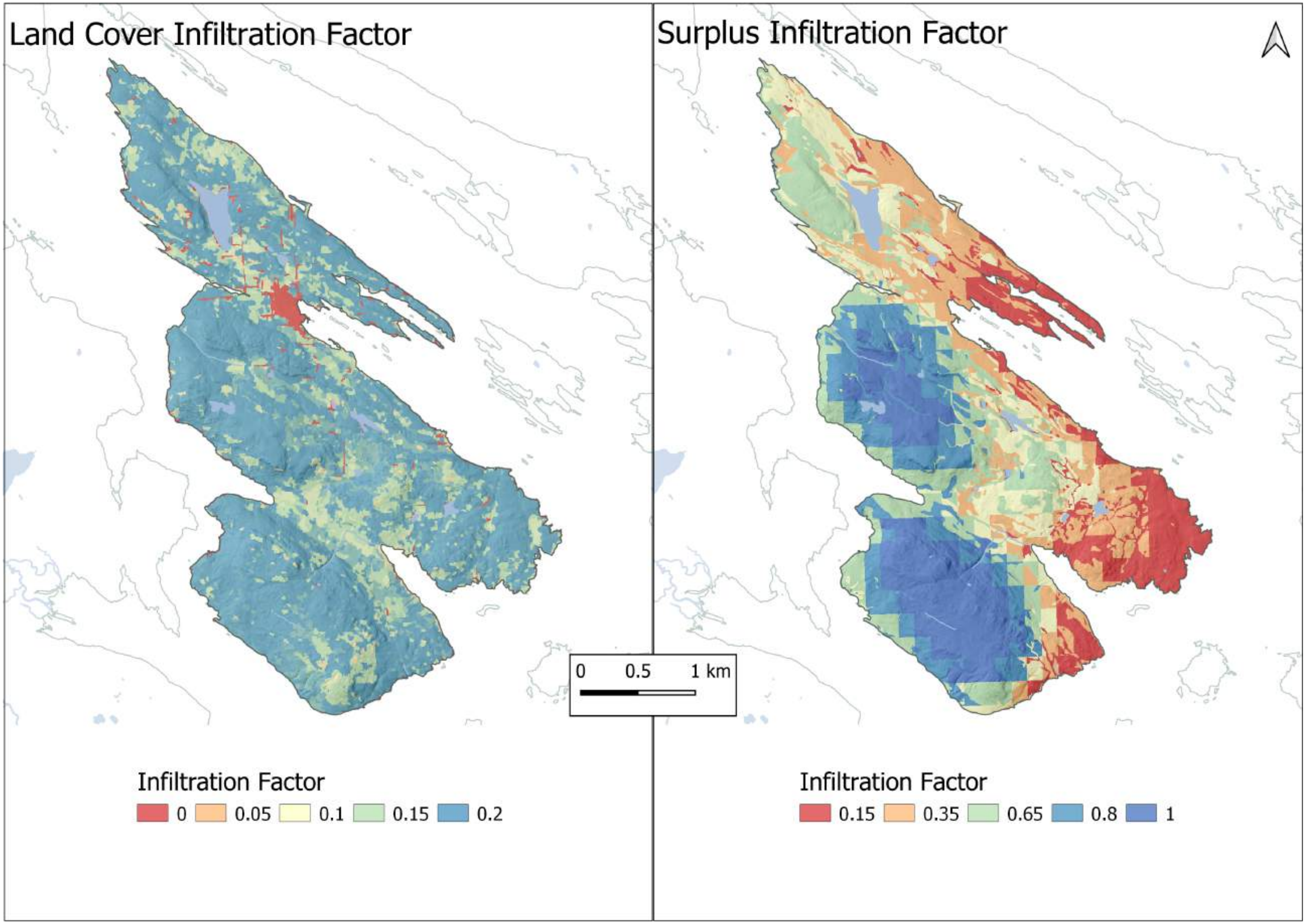

Figure 9. Land Cover infiltration factor and surplus index

4.3 Recharge Potential

In most systems, the sum of slope, soil and land cover factors will determine the percentage of surplus that will recharge the groundwater systems. However, in a bedrock dominant environment, the faults, geologic contacts and lineaments will also play an important role. GW Solutions proposes the following equation to estimate the groundwater recharge potential:

$$RP=[85\%*(IF_{soil}+IF_{landcover}+IF_{slope})+15\%*(IF_{faults})]*SI$$

Where:

RP= Recharge potential (0.0 - 0.73)

IF_{soil} = Soil infiltration factor (0.0 - 0.4)

$IF_{landcover}$ = Land cover infiltration factor (0.0 - 0.2)

IF_{slope} = slope infiltration factor (0.01 - 0.3)

IF_{faults} = bedrock contacts/lineaments infiltration factor (0.25 - 1.0)

SI = Surplus Index (0.15 - 1.0)

The equation was finalized based on trial and error from varying the different infiltration factors. For instance, IF_{faults} was varied the effect on recharge potential from 0% to 50%. Surplus has been considered as the multiplication factor in the equation to generate a contrast in recharge potential map. If no surplus is present, there will be no potential for recharge even though the infiltration factors will suggest the opposite.

The resulting recharge potential map is presented in Figure 10. A map was also produced (Figure 11) taking into account the aquifer subregions presented in Figure 2 with six classification groups. Musgrave and Lake Maxwell present very good and high potential for recharge compared to the rest of the Island. Additionally, the east side of the Island shows low to poor recharge potential.

Figure 12 shows the monthly average mean depth to water for three provincial observation wells. OW373 has the largest groundwater fluctuation (6.5 m) followed by OW438 (5 m) and the lowest groundwater fluctuation corresponds to OW281 with only 0.7 m. Based on the assumption that the amplitude of the piezometric fluctuation is related to aquifer recharge, we observe a correlation between the observed amplitude and the groundwater recharge potential as summarized in Table 7.

Table 7. Relationship between recharge potential and groundwater amplitude

Observation well	Groundwater amplitude	Recharge potential	Recharge potential group
OW281	0.7	0.06	Low
OW438	5	0.2	Moderate
OW373	6.5	0.35	High

Figure 13 shows a simplification of Chloride mass balance approach (Wood and Sanford, 1995). Data used for producing Figure 13 includes chloride concentration for groundwater wells (Environmental monitoring system-EMS) and chloride concentration of precipitation (Saturna Island- Environment and Climate Change Canada Data). The first graph shows the approximate percentage of precipitation that is considered recharge. Recharge as a percentage of precipitation varies from 1% to 29% suggesting a large variability of recharge across the Island. The second graph of Figure 13 provides the recharge flux in mm/year assuming the precipitation will reach the water table. The equation used for estimating the aquifer recharge flux is presented below:

$$q = \frac{P * Clp}{Clgw}$$

where q is groundwater recharge flux (mm/year), P is average annual precipitation (mm/year), Clp average precipitation-weighted chloride concentrations (1.313 mg/L for precipitation on Saturna Island) and Clgw is the average chloride concentration in groundwater (mg/L). Using this method, the calculated aquifer recharge flux for Salt Spring varies from 9 to 285 mm/year, suggesting that the mechanism for recharge on Salt Spring is complex and spatially variable.

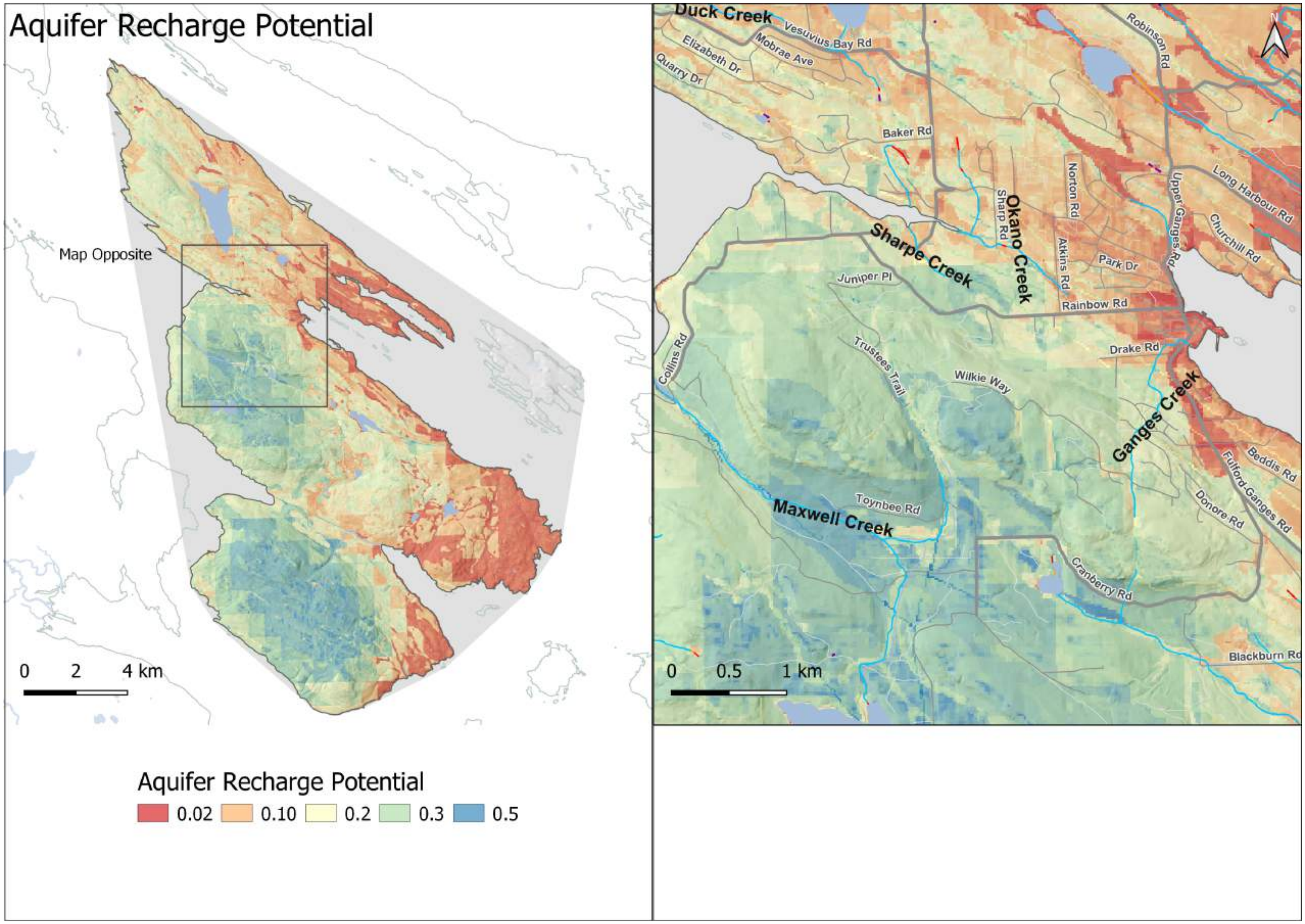

Figure 10. Recharge potential map

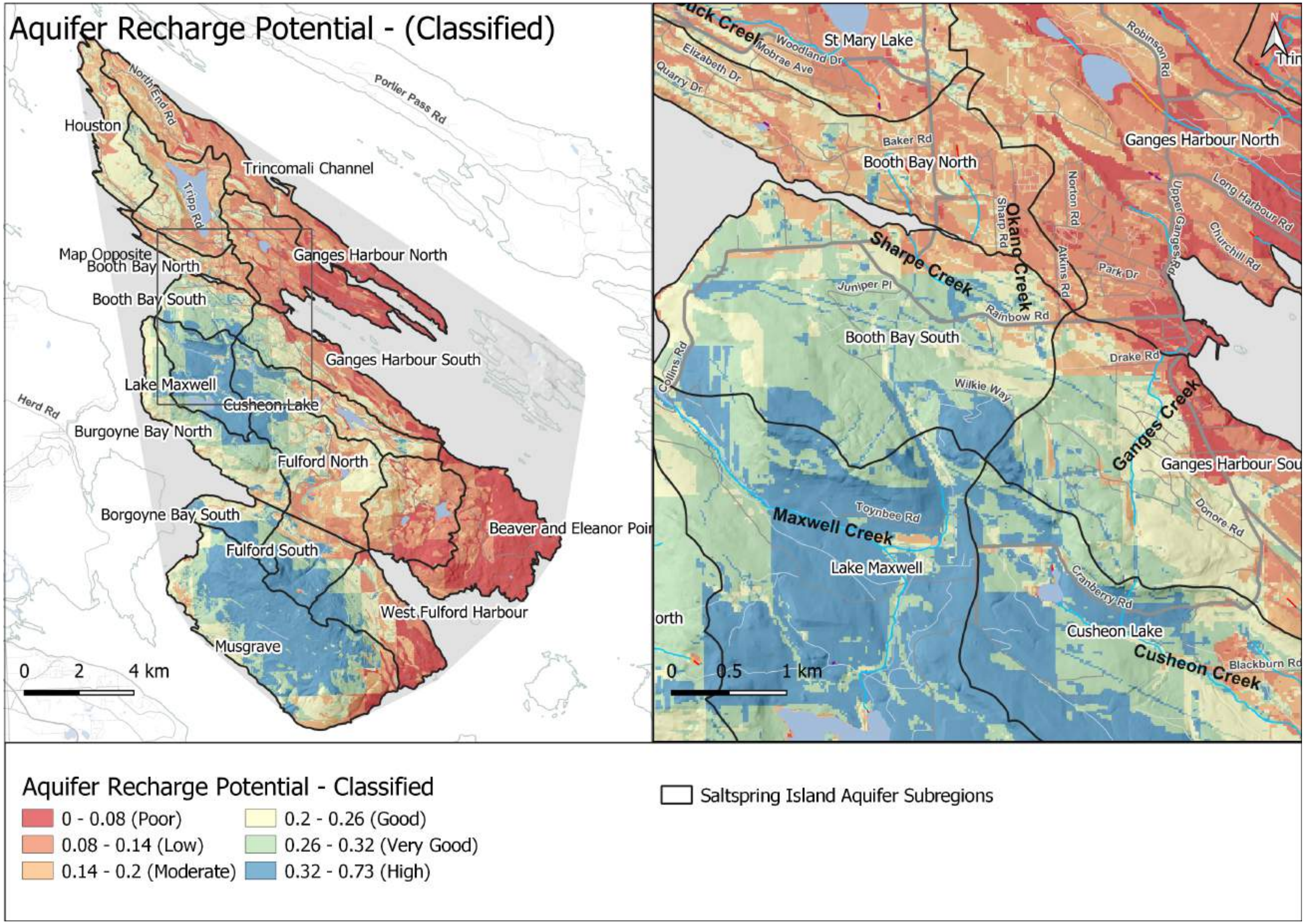

Figure 11. Classified recharge potential map

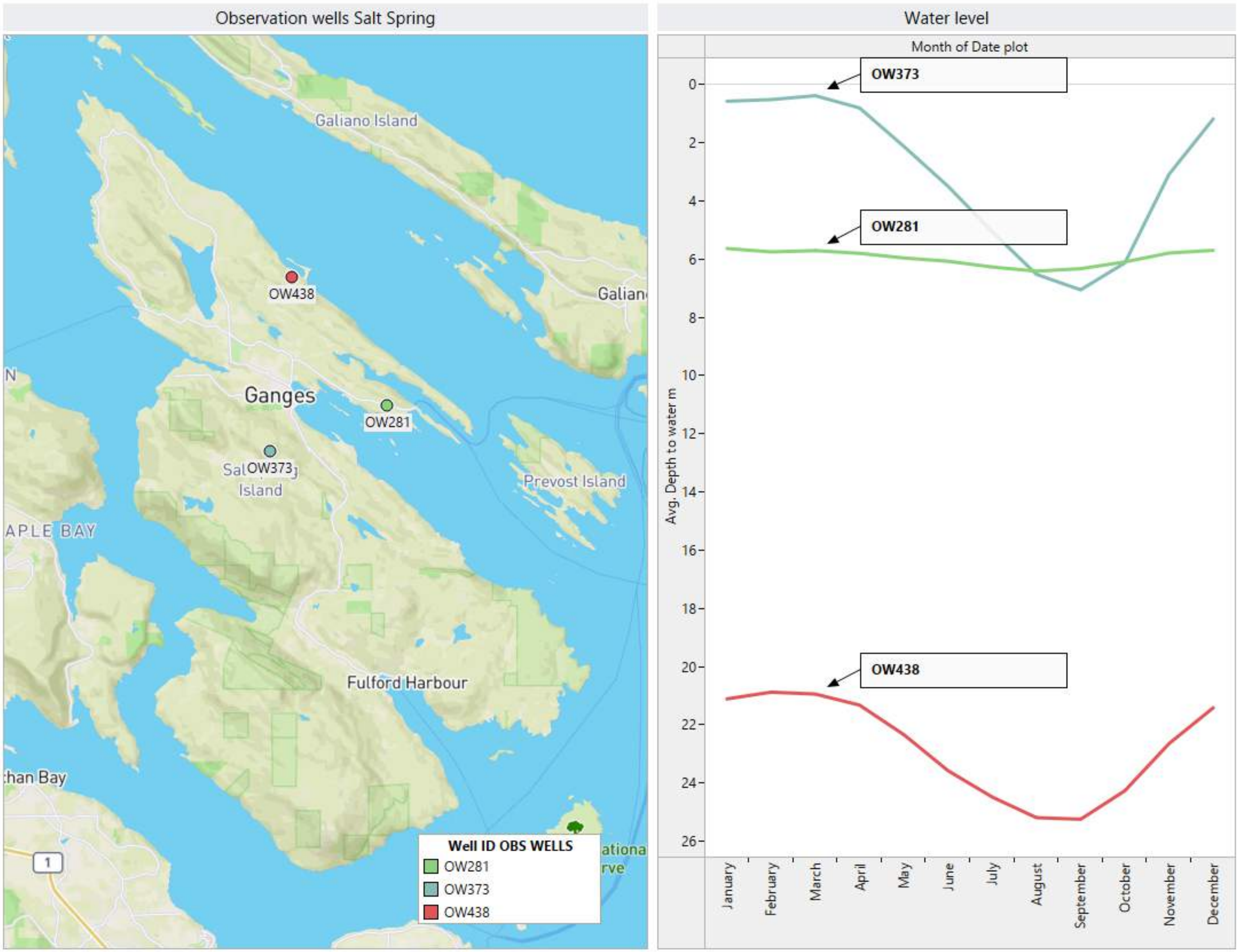

Figure 12. Monthly average depth to water for the provincial observation wells on Salt Spring

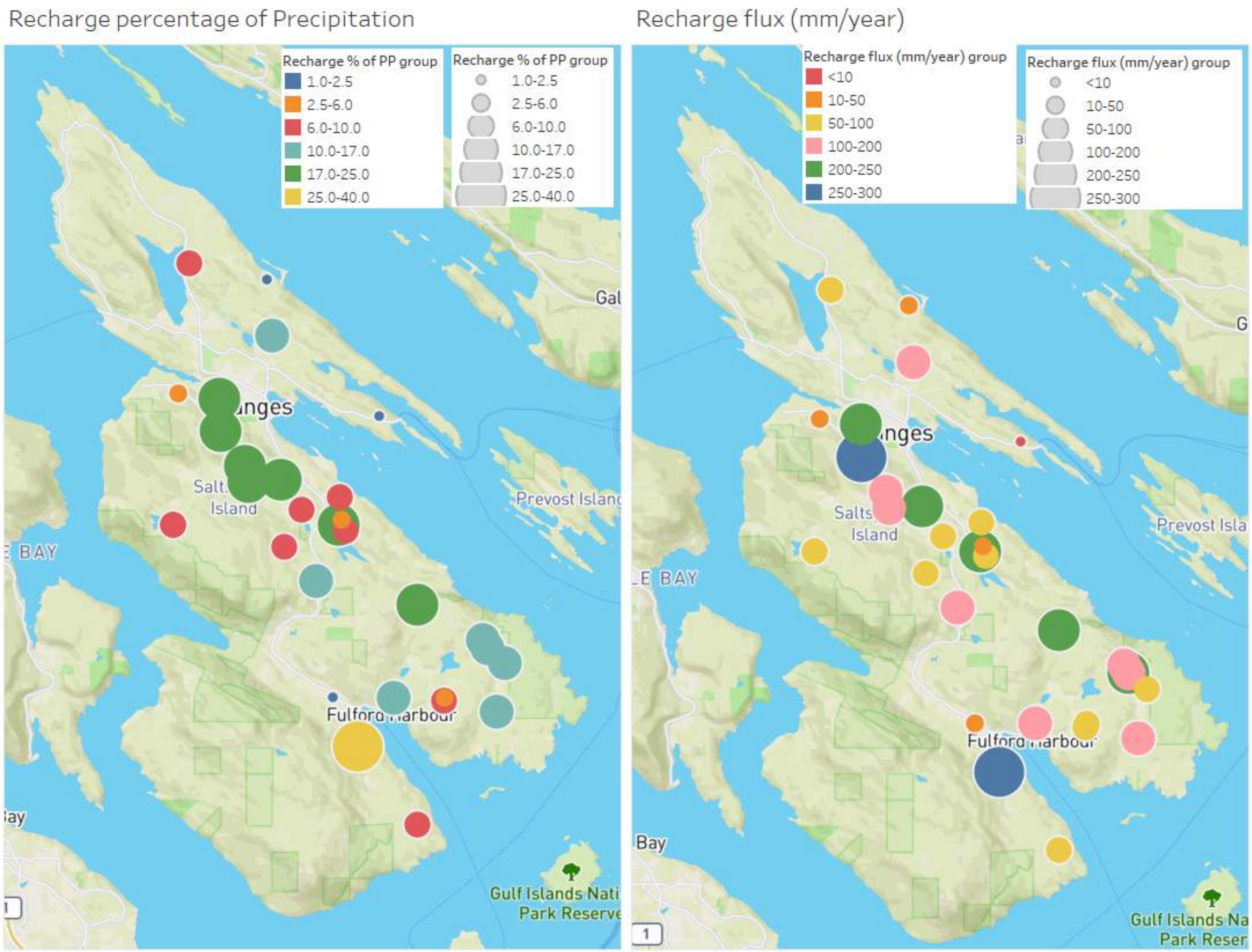

Figure 13. Recharge as a percentage of precipitation and recharge as flux (mm/year)

5 CONCLUSIONS

Based on the completed work, GW Solutions draws the following conclusions:

1. A new approach has been developed to determine the aquifer recharge potential. It considers spatial variability of precipitation, surplus, land cover, soil and geology, slope, and faults and contacts between bedrock strata.

2. Total annual precipitation varies from 830 to 1300 mm/year and surplus varies from 410 to 960 mm/year.

3. The surplus has the largest effect on the aquifer recharge potential followed by soil properties and land cover.

4. Faults/bedrock contacts do not dominate the recharge mechanism at the scale of the island; however, they will have an effect more locally, at the aquifer sub-region scale.

5. The aquifer recharge potential on Salt Spring has been mapped. It clearly shows a high contrast between areas on Salt Spring with low recharge potential (northern and eastern island, including the peninsulas), and areas with moderate to high recharge potential (west central and southern part of the highland).

6. Aquifer recharge systems are complex and vary greatly across the Island.

6 DATA GAPS AND RECOMMENDATIONS

GW Solutions makes the following recommendations:

1. Groundwater level information from three ministry observation wells was available for this study. The integration of more wells with continuous water level monitoring would improve our understanding of the dynamics of the groundwater on Salt Spring and increase the confidence of the recharge potential mapping.

2. A detailed water budget study is recommended to properly manage the water resource on Salt Spring, combined with the improved knowledge gained from the completed aquifer recharge study. The scale at which water budgets should be completed must be selected based on the large variability in groundwater recharge across the Island. For instance, estimating a water budget at the groundwater subregion scale (Figure 2) might be adequate for the island.

3. The recharge potential map provides insights on understanding mountain block recharge for lowland areas; however, it does not estimate volumes. This could be achieved by completing a water budget study.

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8 STUDY LIMITATIONS

This document was prepared for the exclusive use of Islands Trust (the client). 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 findings and conclusions documented in this document have been prepared for the specific application to this project, and have been developed in a manner consistent with that level of care normally exercised by hydrogeologists currently practicing under similar conditions in the jurisdiction.

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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 report subject to the above limitations.

9 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 letter 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 us.

Yours truly,

GW Solutions Inc.

K. Antonio Barroso	Matt Vardal, Msc.	Gilles Wendling, Ph.D., P.Eng.
MSc in Hydrogeology	MSc in Geology	President

APPENDIX 1

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 $10,000, 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.

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Water Sustainability: Groundwater Preservation Project

Project Charter v8.2

Salt Spring Island Local Trust Committee

Date: February 26, 2019

Purpose

This project addresses the need for information inventory, mapping, and data analysis to preserve groundwater use and protect aquifers through land-use planning and coordination function of the SSI LTC. Islands Trust staff and the LTC are supporting this project through project management, coordinating funding, and cooperating with other governments and organizations to inform groundwater resource management decisions through evidence-based groundwater-use planning and aquifer protection strategies. *Community Aquifer* ecosystem mapping is essential to determining aquifer protection strategies and groundwater well monitoring is a primary variable in calculating carrying-capacity of groundwater resources on Salt spring Island. Surface water resource monitoring has been recommended to further understand interactions between groundwater and surface water to further define calculations of aquifer water budgets.

Background

The Salt Spring Local Trust Committee has advanced water sustainability as a top priority including coordinating the Salt Spring Island Watershed Protection Alliance (SSIWPA). Through the SSIWPA strategic planning process in 2018, the Salt Spring Island Water Sustainability Framework was established to address projects relating to *Watershed Protection* and *Freshwater Preservation* identifying aquifers. The Ministry of Forest Lands and Natural Resources (FLNRO) is an active member of SSIWPA that has funded a two year program to revise the aquifer mapping (2016-17) and develop island-scale aquifer water budgets (2017-18); with mutual outcomes linked and benefited by this project. The Capital Regional District CRD is an active member in SSIWPA and is supporting this project through the lake monitoring component of this project. With the assistance of grants manager at Islands Trust and support from CRD and FLNRO, SSIWPA acquired a freshwater sustainability grant from the Real Estate Foundation of BC for the *SSI Groundwater Wells Monitoring Pilot Project (2017-2019)*.

Objectives

- *Inventory groundwater quantity and quality information to inform land use planning decisions.*
- *Identify priority areas of groundwater recharge and targeted investigation.*
- *Supplement existing Provincial GWELLS inventory.*
- *Inventory and review well reports on file at Islands Trust and survey targeted private well owners.*
- *Receive Real Estate Foundation grant for groundwater monitoring pilot program.*
- *Establish a community well monitoring program to supplement provincial observation well network.*
- *Identify locations for surface water monitoring including lake level monitoring stations.*
- *Identify aquifer ecosystem types and areas.*

In Scope

- *Coordination with various Islands Trust staff, FLNRO staff and SSIWPA coordinator.*
- *Procurement and contract management for well data review, inventory, and well-owner survey.*
- *Map project results; cross reference well data to WELLS database and enter new records.*
- *SSI LTC application for funding (REFBC).*
- *Pilot program to monitor changes in water levels in 12 groundwater wells and several lakes.*
- *Investigation of long-term monitoring strategy*
- *Development analysis framework to determine of Community Aquifer Recharge Areas*
- *Development of a data framework to explore groundwater data and information.*

Out of Scope.

- *Consumption metering*
- *Drilling of new wells*
- *Decommissioning of wells*
- *Monitoring wells outside of identified priority areas.*

Project Team

Jason Youmans, Islands Trust Island Planner	*Program Manager*
William Shulba, Islands Trust Senior Freshwater Specialist	*Project Lead*
Sylvia Barroso, FLNRO Hydrogeologist	*FLNRO/TWG Project Lead*
Mike Richards, Islands Trust Grants Administrator	*Grant Administrator*
Mark Van Bakel, Islands Trust Information Systems Specialist	*Information Coordinator*
Shannon Cowan, SSIWPA Coordinator	*Project Coordinator*
Dale Green, CRD, Senior Environmental Science Officer	*Project Technical Support*

Budget

Budget Source: SSI LTC Watershed Management - 4014

Fiscal	Item	Cost
2018-19	Community Aquifer Recharge Area Analysis and Demonstration Watershed Data Dashboard	5,000.00
2018-19	**Total**	**5,000.00**

RPM Approval:

Stefan Cermak

Date: February, 19, 2019

LTC Endorsement:

Resolution #:

Date:

Work plan Overview

Deliverable/Milestone	Lead	Staff Time	Target Date
Process to issue contract the well inventory/survey.	William Shulba, Nancy Roggers, Islands Trust; Shannon Cowan, SSIWPA; Sylvia Barroso, FLNRO; .	14 hours	Complete
Project management, coordination between leads.	Jason Youmans, Island Planner and Shannon Cowan, SSIWPA.	35 hours	On-going
Identify priority areas for inventory and monitoring.	William Shulba, Islands Trust; Shannon Cowan, SSIWPA; Sylvia Barroso, FLNRO	2 hours	Complete
Wells Inventory: Review of Islands Trust well reports, survey of well owners, data gathering and compilation.	Contractor, supervised by Sylvia Barroso, (FLNRO); coordinated by Shannon Cowan (SSIWPA), IT file orientation by SSI Staff.	2 hours (SSI Staff)	Complete
Final well inventory and report to Local Trust Committee	Contractor with assistance from: William Shulba, Islands Trust; Shannon Cowan, SSIWPA; Sylvia Barroso, FLNRO	14 hours	Complete
Facilitate Real Estate Foundation Grant Application	Shannon Cowan (SSIWPA) /Mike Richards (Islands Trust)	5 hours	Complete
Evaluate List of Potential Monitoring Locations.	William Shulba, Islands Trust; Shannon Cowan, SSIWPA; Sylvia Barroso, FLNRO	1 hour	Complete
Establish agreements with well owners and dock owners for monitoring.	William Shulba, Islands Trust; Shannon Cowan, SSIWPA; Sylvia Barroso, FLNRO	7 hours	May 2018— Dec 2018
Fieldwork to install monitoring equipment.	William Shulba, Islands Trust	100	Aug 2018— March 2019
Data collection, transfer and analysis.	William Shulba, Islands Trust	100	Spring 2018— Dec 2019
Process and interpret data.	Contractor supervised by: William Shulba, Islands Trust	100	After 4-6 months of data collection at regular intervals.
GIS Data Input and Analysis	Islands Trust GIS Staff in consultation with Sylvia Barroso, FLNRO and William Shulba, Islands Trust	Freshwater specialist : 100 hrs	November, 2019
Community Aquifer Recharge Area mapping and demonstration watershed data dashboard	William Shulba, Islands Trust Groundwater Sciences Consultant	40 hours	February 2019— March 2019.
Final Project Report and presentation of work result to Salt Spring Island Local Trust Committee.	Jason Youmans, Islands Trust; William Shulba, Islands Trust; Shannon Cowan, SSIWPA; Sylvia Barroso, FLNRO	7 hours	Update before Oct 31 2018; Final Dec, 2019.
		TOTAL: 527 hours	