May 30, 2019
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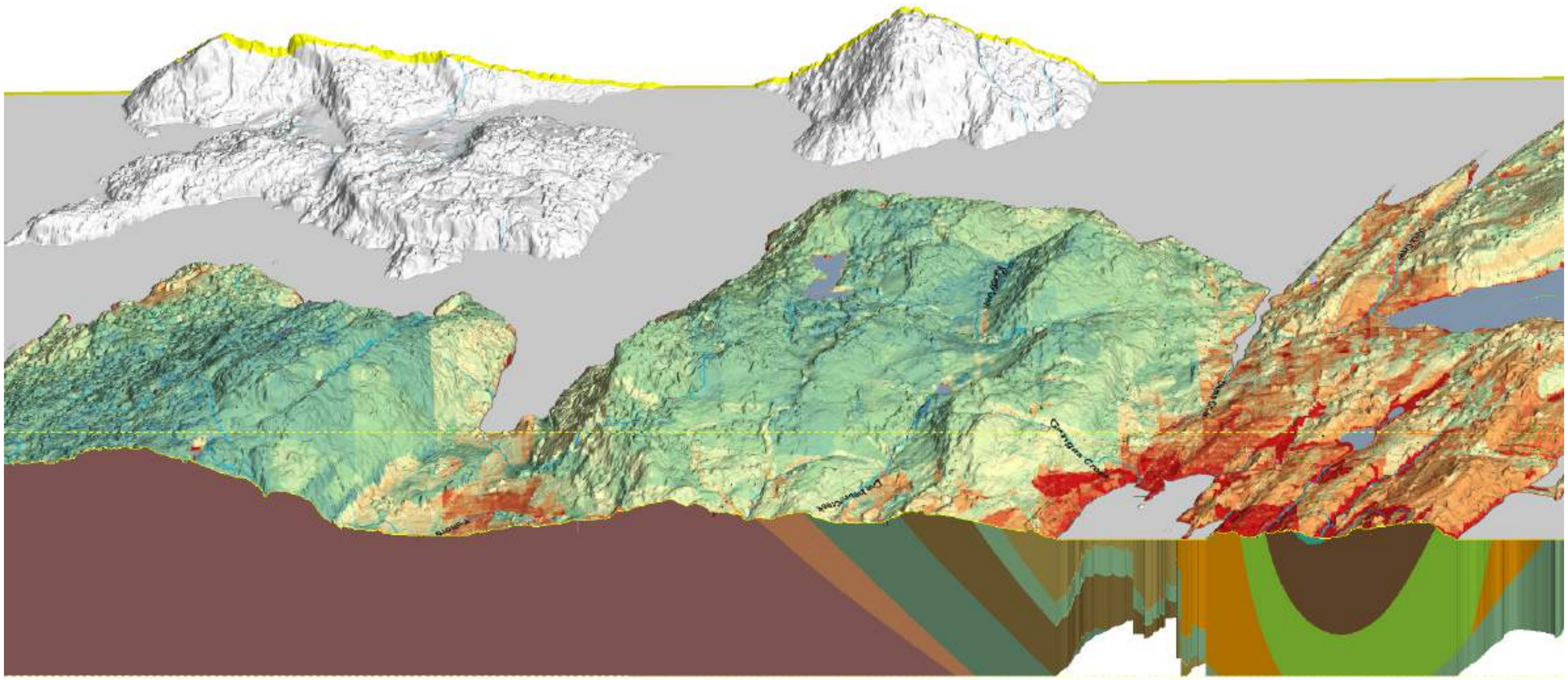
Salt Spring Island
Groundwater Recharge Potential Mapping



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

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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);

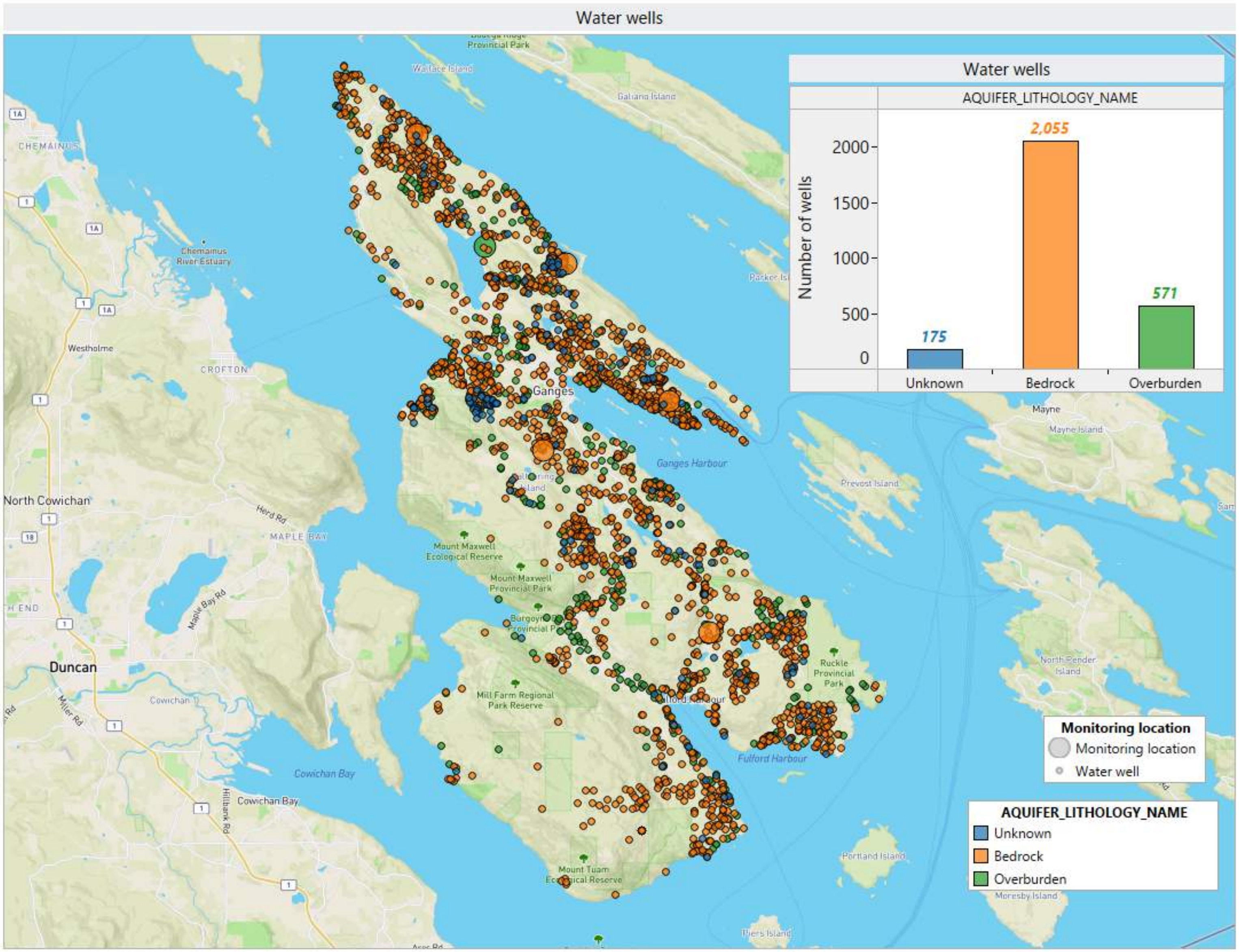

Figure 1. Water well type according to BC MoE wells database

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.

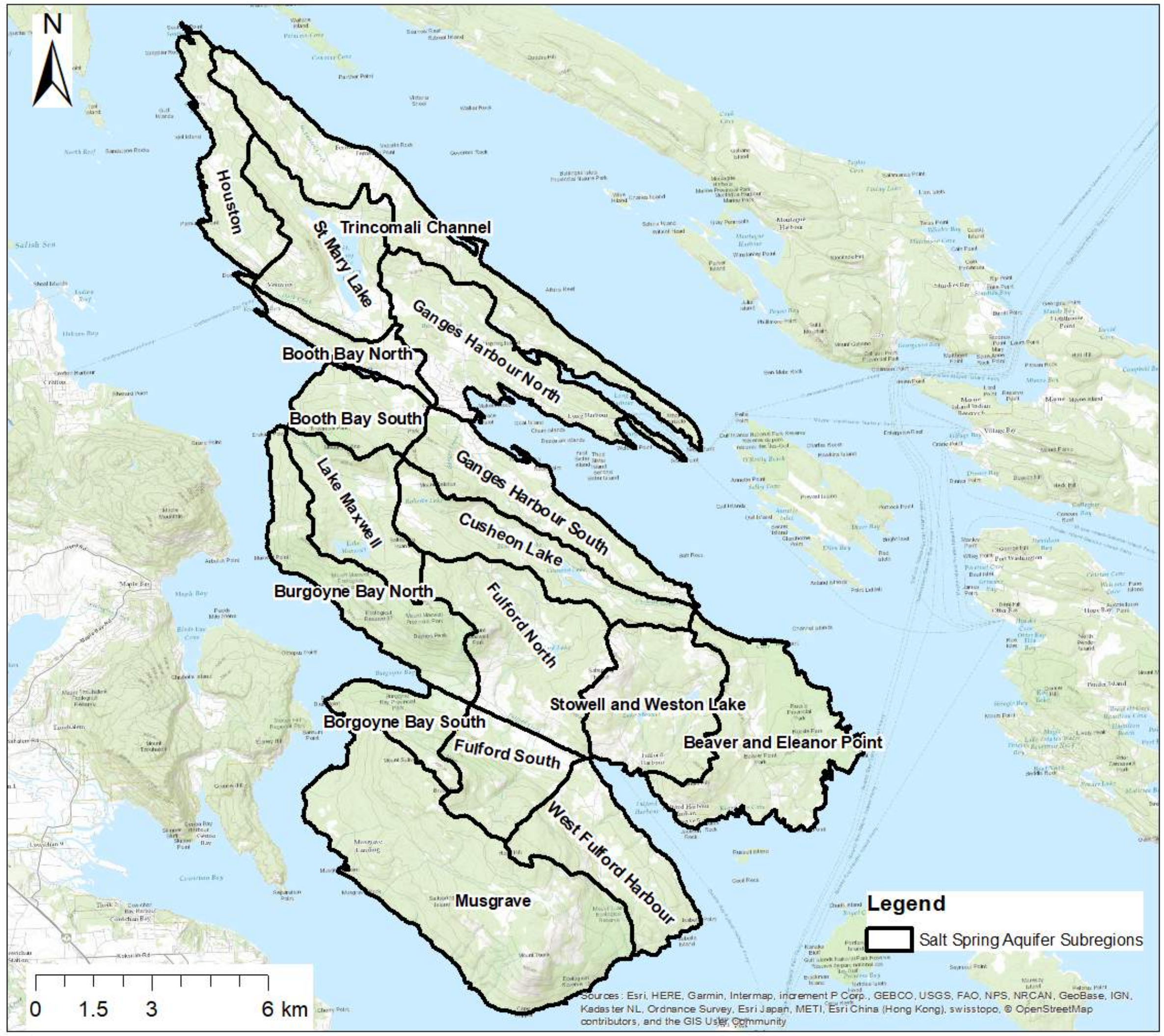

Figure 2. Study area for the aquifer recharge potential map showing Aquifer Subregions identified by FLNRORD and modified from Hodge (1977)

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.

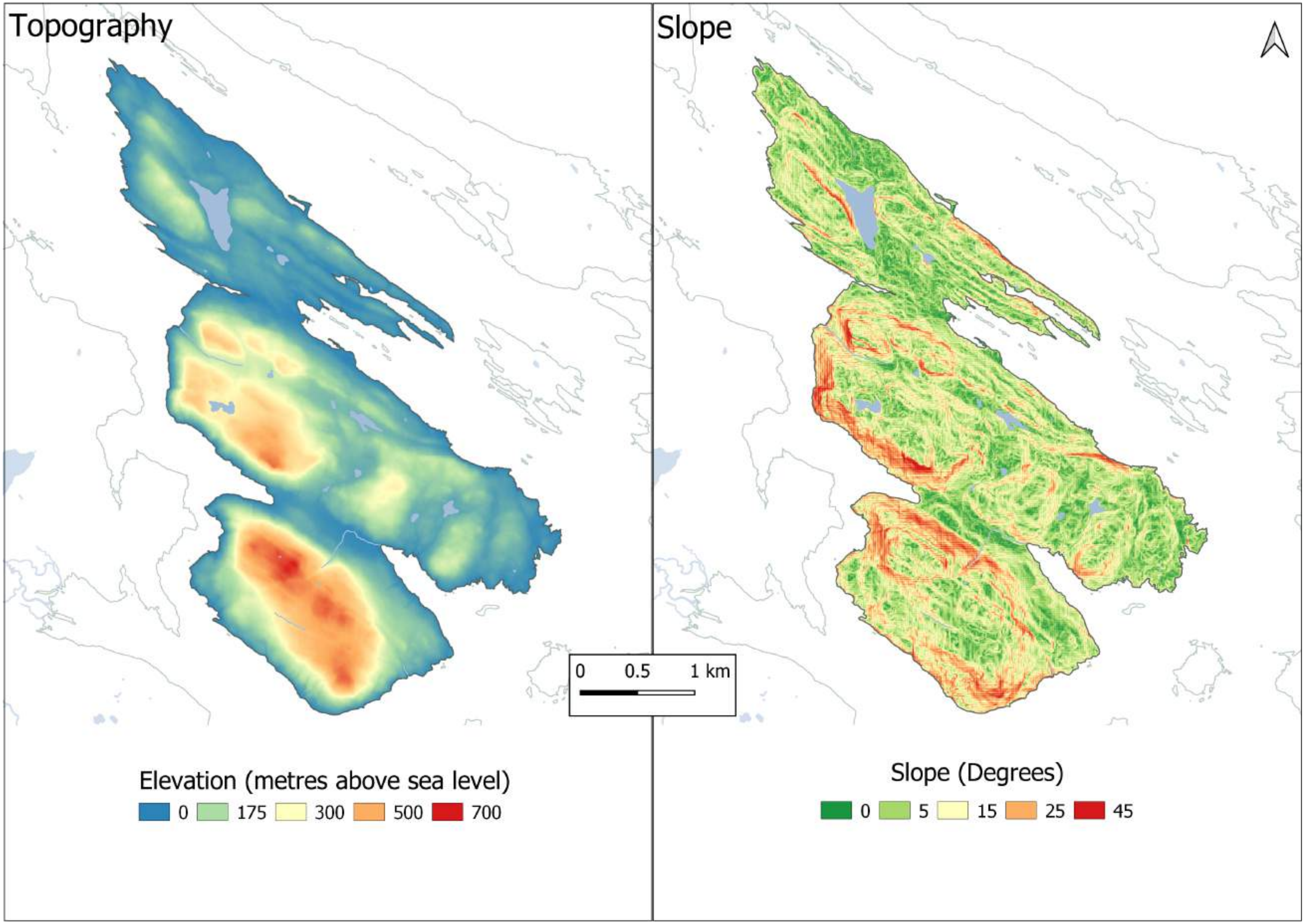

Figure 3. Slope and topography

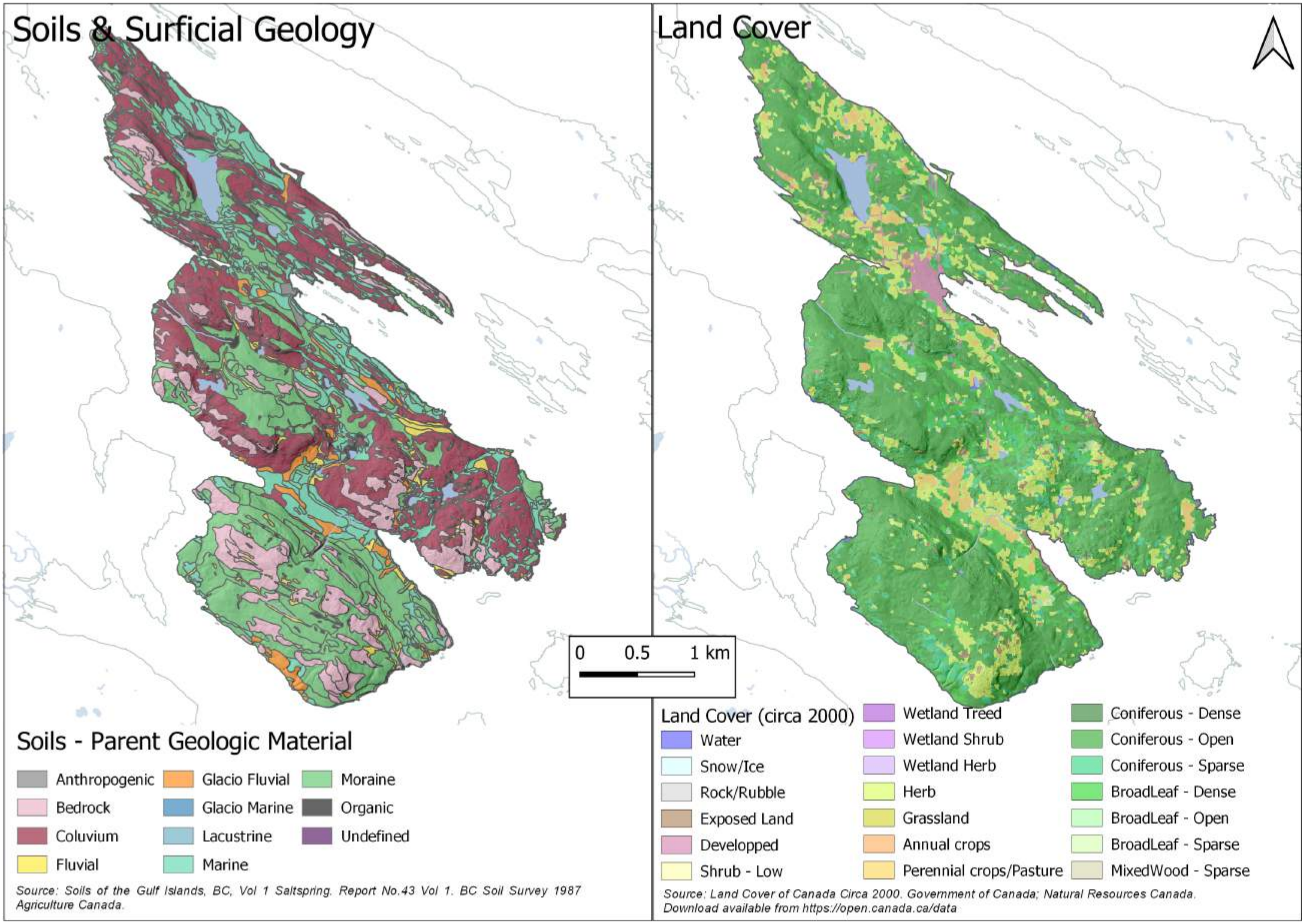

Figure 4. Soils, surficial geology and land cover

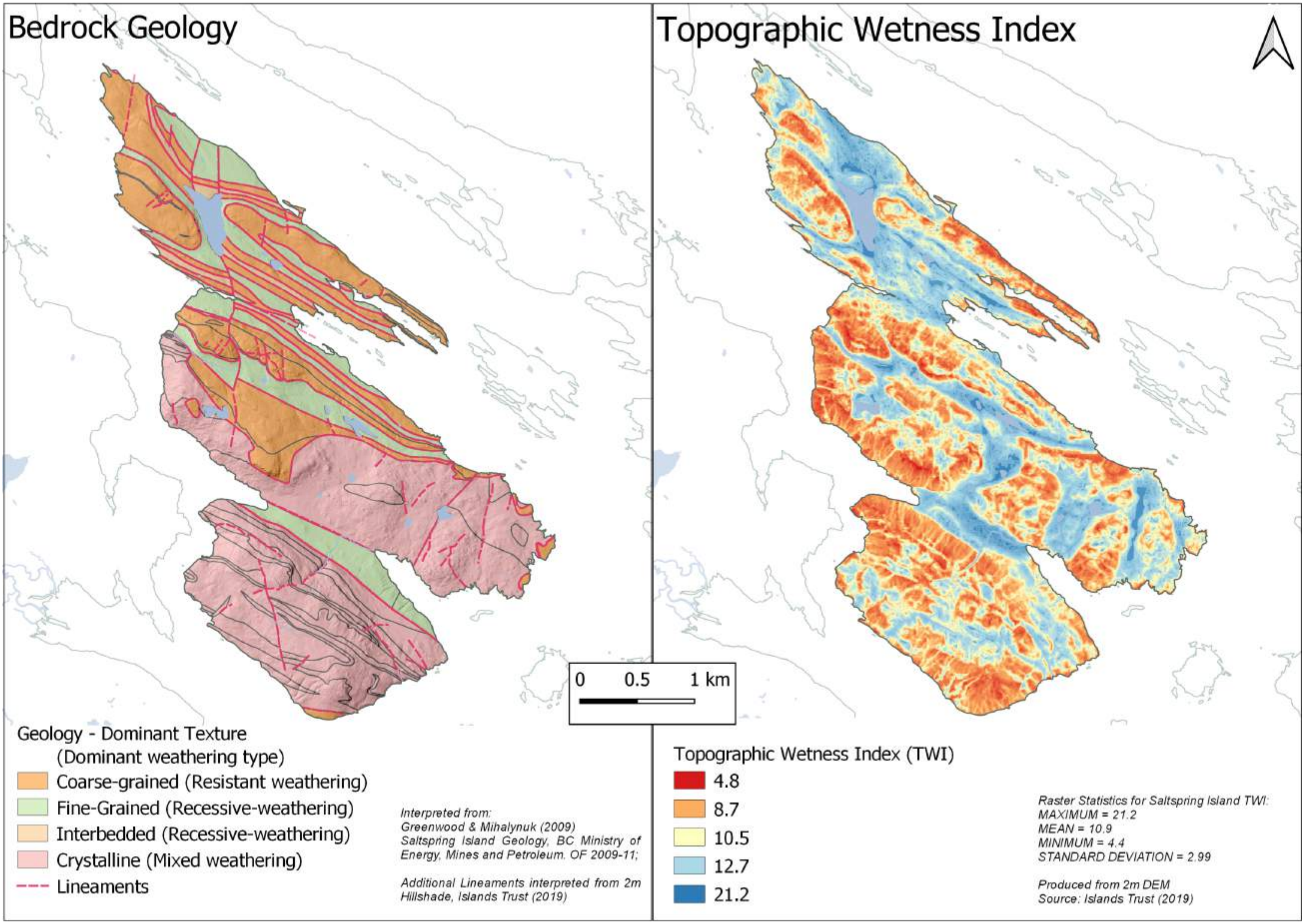

Figure 5. Bedrock geology, fine-coarse grained contacts, lineaments and Topographic Wetness Index

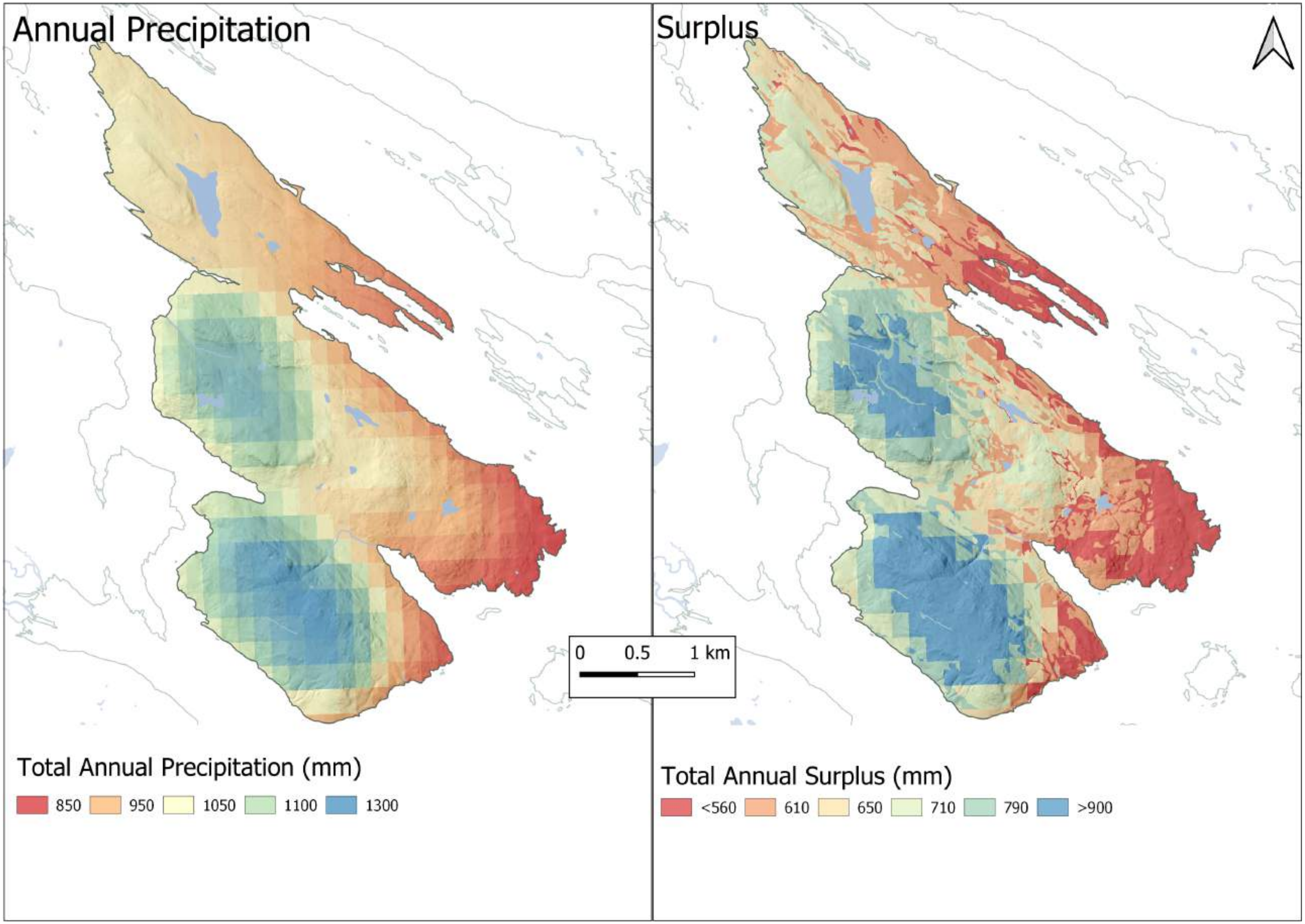

Figure 6. Precipitation and modeled surplus

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

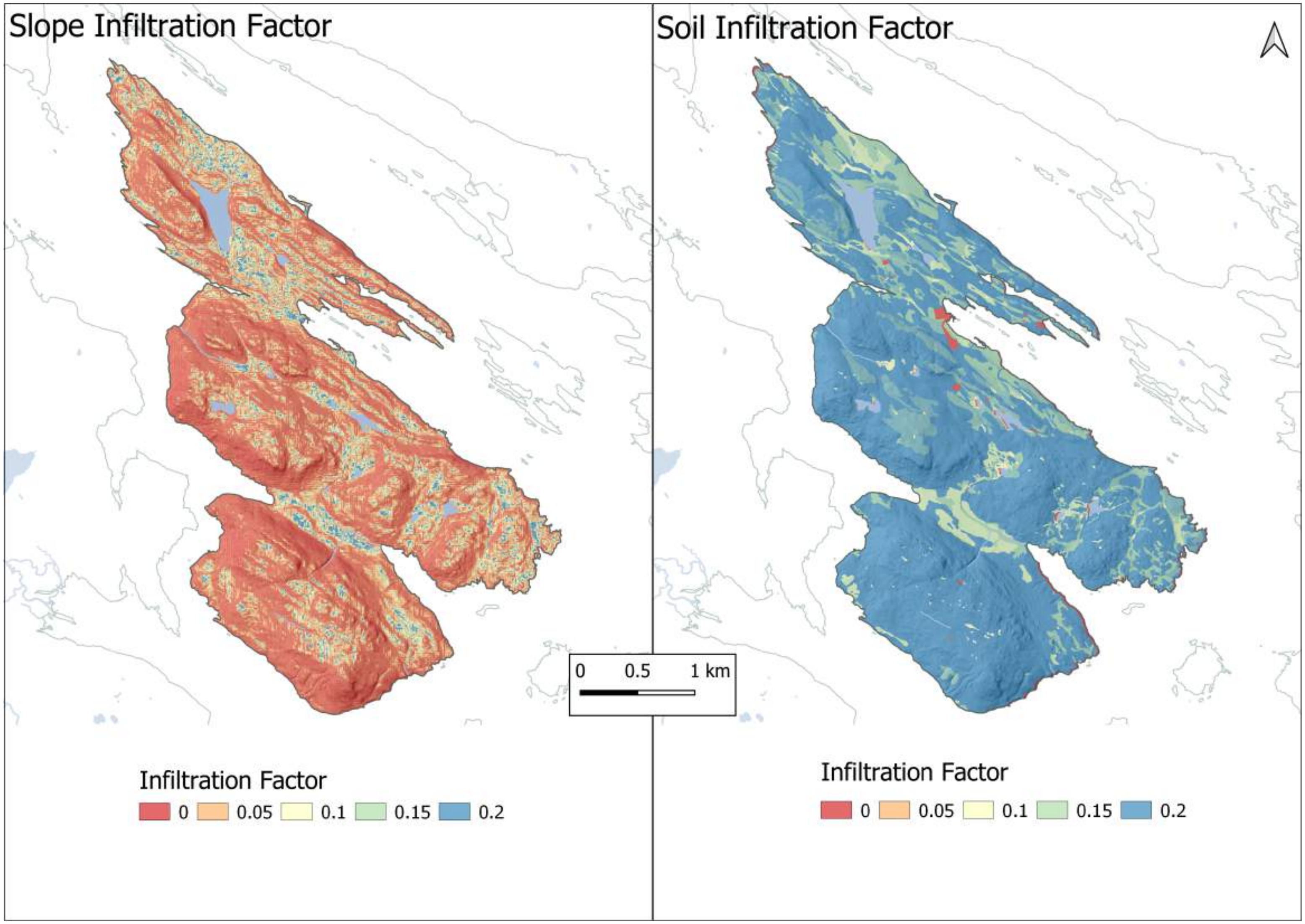

Figure 7. Slope and soil infiltration factor

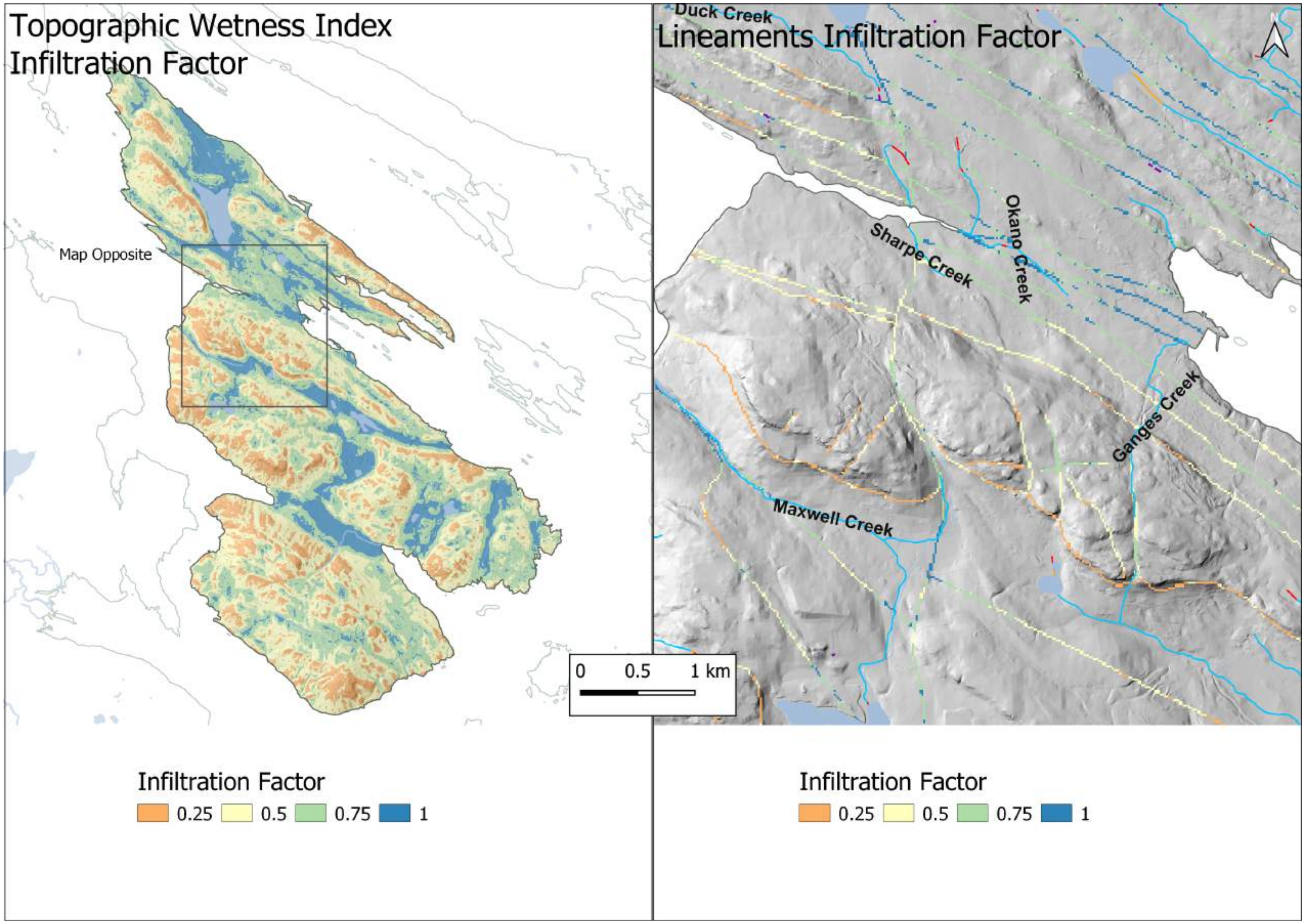

Figure 8. Topographic Wetness Index and bedrock contact/lineament infiltration factor

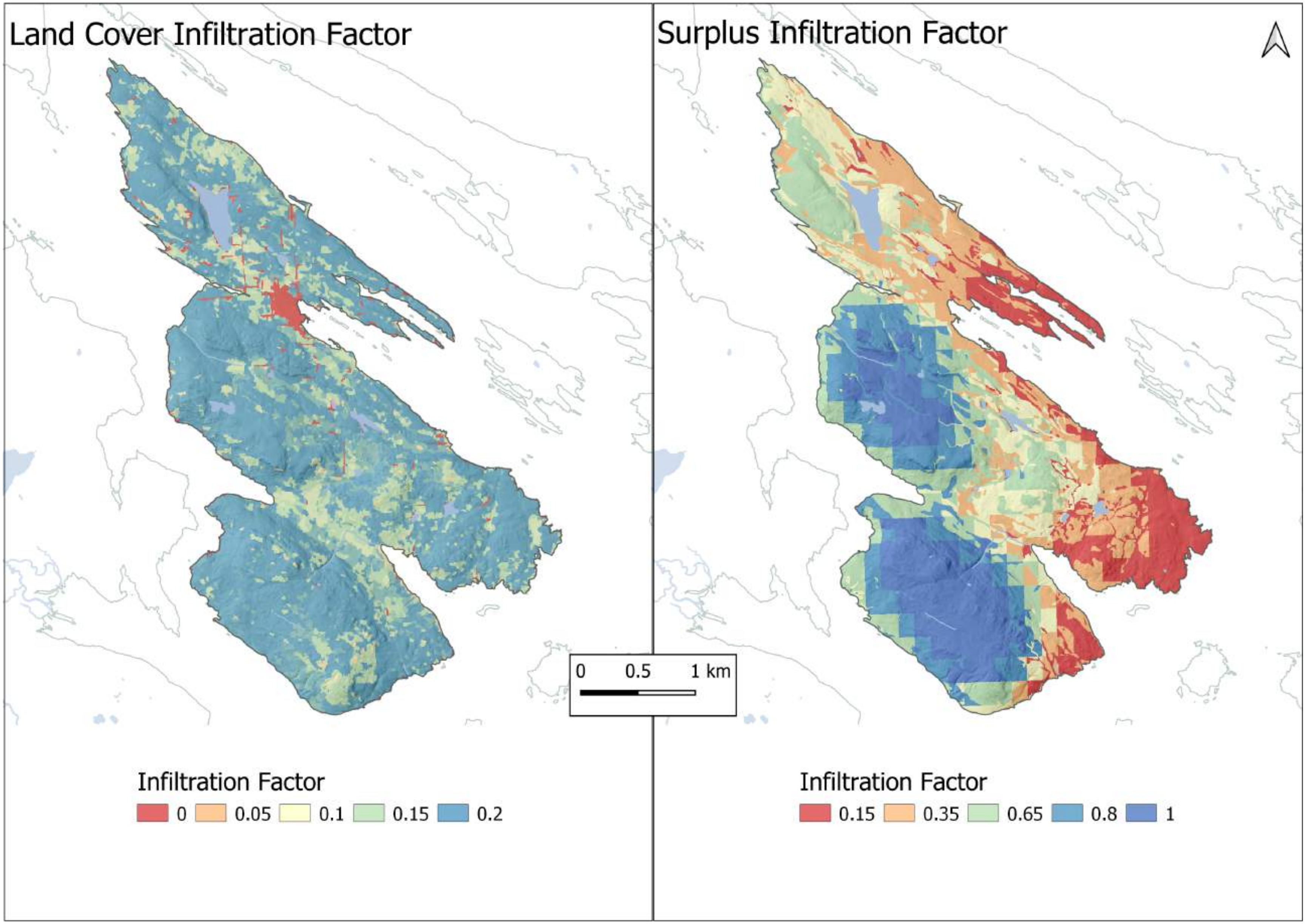

Figure 9. Land Cover infiltration factor and surplus index

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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.

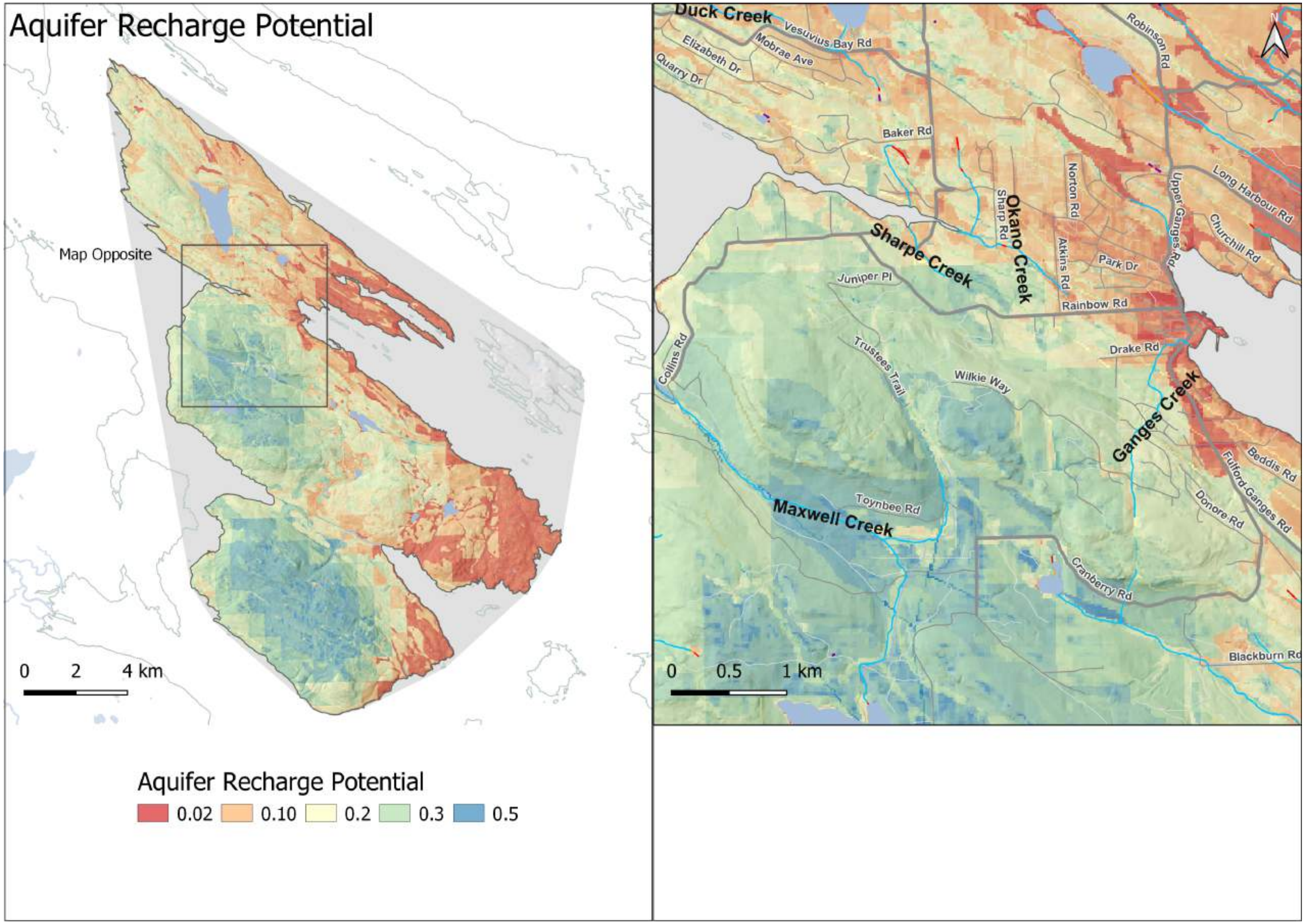

Figure 10. Recharge potential map

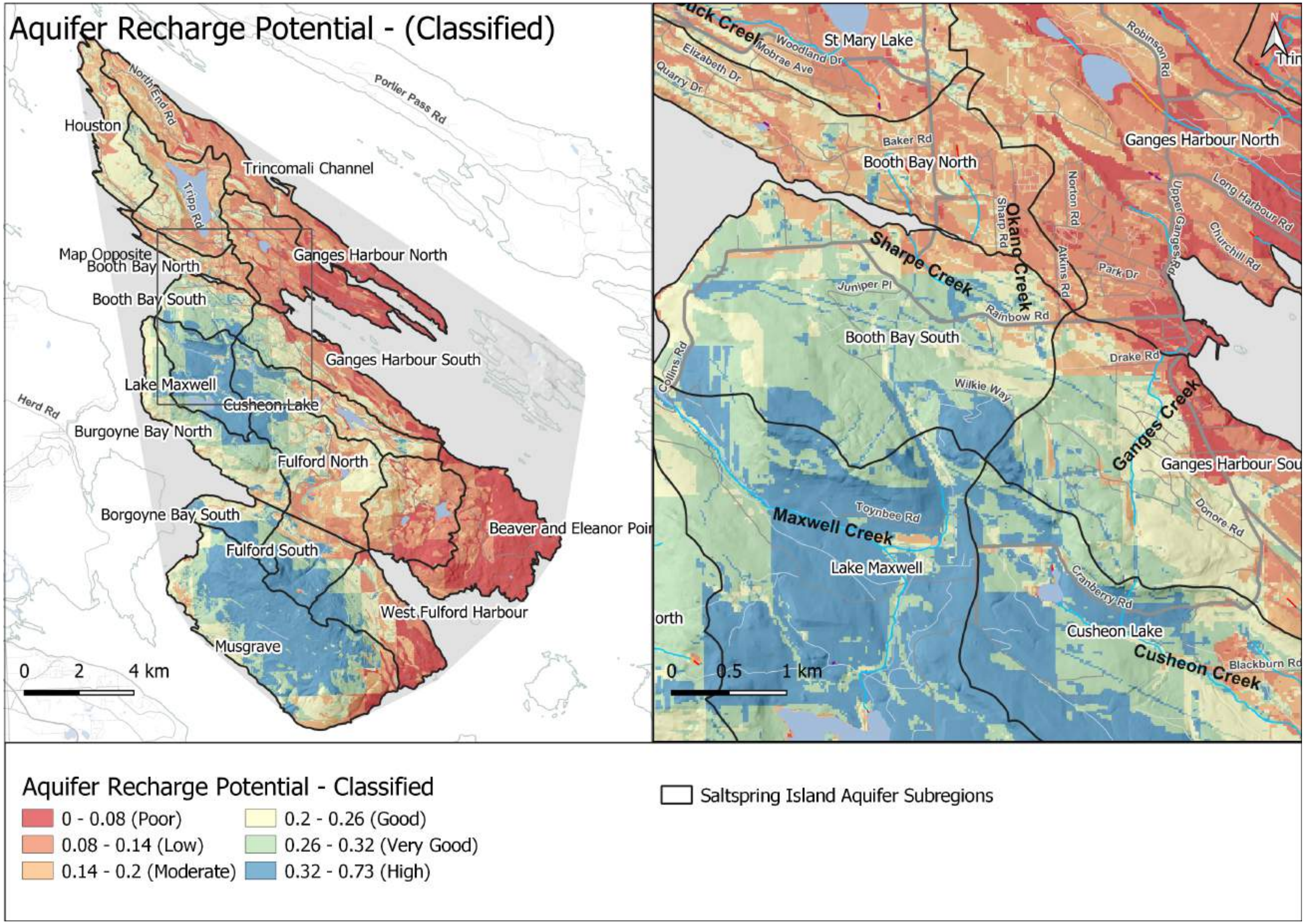

Figure 11. Classified recharge potential map

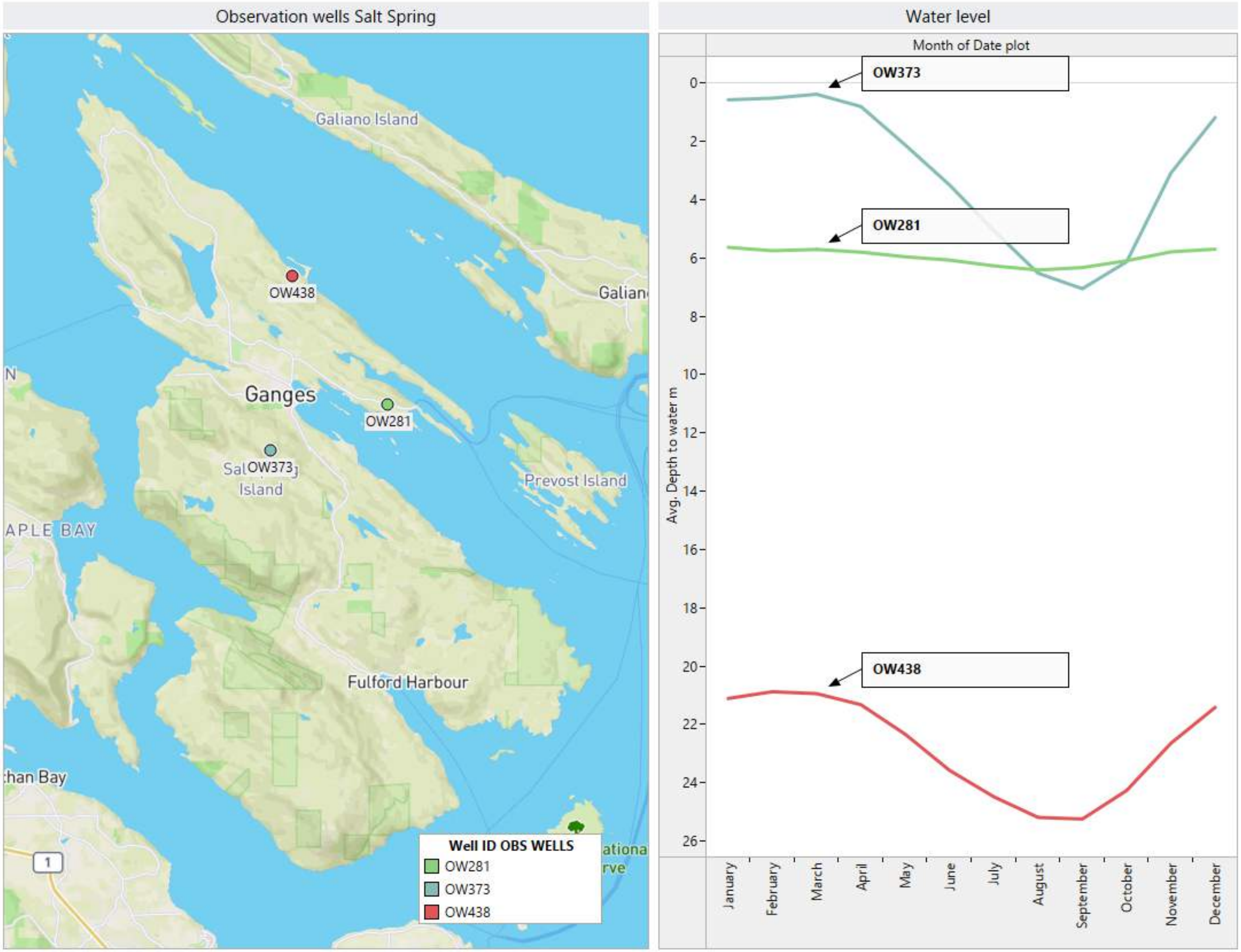

Figure 12. Monthly average depth to water for the provincial observation wells on Salt Spring

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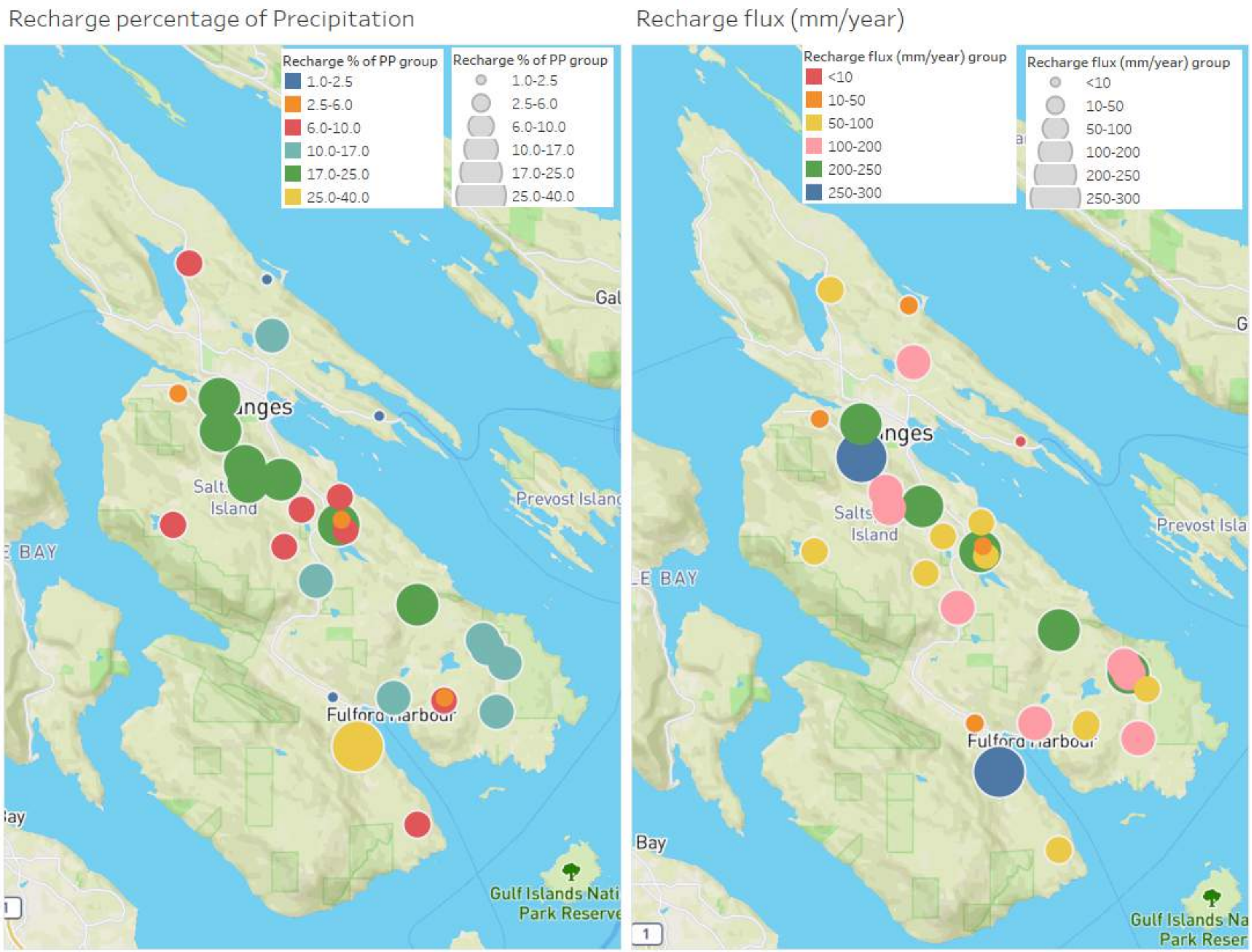

Figure 13. Recharge as a percentage of precipitation and recharge as flux (mm/year)

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.

7 REFERENCES

- Quiroz Londoño, Orlando Mauricio, Asunción Romanelli, María Lourdes Lima, Héctor Enrique Massone, and Daniel Emilio Martínez. "Fuzzy Logic-Based Assessment for Mapping Potential Infiltration Areas in Low-Gradient Watersheds." *Journal of Environmental Management* 176, (2016): 101-111.

- Harris, M. and S. Usher, 2017. Preliminary groundwater budgets, Cobble Hill / Mill Bay area, Vancouver Island, B.C. Water Science Series, WSS2017-01. Prov. of B.C., Victoria, B.C.

- Hodge, W. S. 1977. A Preliminary Hydrogeological Study of Salt Spring Island. Groundwater Section Hydrology Division Water Investigations Branch Ministry of the Environment.

- Galvão, Paulo, Ricardo Hirata, and Bruno Conicelli. "Estimating Groundwater Recharge using GIS-Based Distributed Water Balance Model in an Environmental Protection Area in the City of Sete Lagoas (MG), Brazil." *Environmental Earth Sciences* 77, no. 10 (2018): 1-19.

- Greenwood, H.J. and Mihalynuk, M.G. 2009. Salt Spring Island Geology; (Map, GIS files, and notes); BCGS Open File 2009-11. BC Ministry of Energy Mines and Petroleum Resources.

- Mahmoud, Shereif H., A. A. Alazba, and Amin M. T. "Identification of Potential Sites for Groundwater Recharge using a GIS-Based Decision Support System in Jazan Region-Saudi Arabia." *Water Resources Management* 28, no. 10 (2014): 3319-3340.

- MOEE, 1995. Hydrogeological technical information requirements for land development applications. Victoria, BC: Ministry of Environment and Energy.

- BCGS 2009-11 by H.J. Greenwood with M.G. Mihalynuk.

- Wood, Warren W. "Use and Misuse of the Chloride-Mass Balance Method in Estimating Ground Water Recharge." Ground Water 37, no. 1 (1999): 2-3.

8 STUDY LIMITATIONS

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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.

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.