GW SOLUTIONS
ASSESSMENT & PROTECTION OF GROUNDWATER

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Islands Trust Area Groundwater Availability Assessment

Prepared for: Islands Trust

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1 EXECUTIVE SUMMARY

As part of the Islands Trust Groundwater Sustainability Science program, GW Solutions has assessed the spatial variability of groundwater availability in the Islands Trust Area. This study focused on the Southern Gulf Islands (SGI) region, comprising Galiano, North Pender, South Pender, Saturna, Mayne Islands, hereafter referred to as the Study Islands.

GW Solutions recently developed 3D conceptual models for each Study Island, summarizing the geology, groundwater and well data ("Report 1") (GW Solutions, 2021a). Additionally, GW Solutions used a GIS-based methodology incorporating diffuse and localized recharge pathways to estimate the spatial variability of recharge potential throughout the Study Islands ("Report 2") (GW Solutions, 2021b). This report ("Report 3") brings together the results of Reports 1 & 2 to quantify groundwater availability throughout the Study Islands.

In this report, we apply a gridded water balance model to the Study Islands. The model estimates monthly potential evapotranspiration, soil moisture storage, actual evapotranspiration, soil moisture deficit, and soil moisture surplus (i.e., runoff and groundwater recharge). Using proxy data from a variety of sources, we also estimate surface and groundwater use across the Study Islands.

Using the results from the water balance model, we estimate the percentage of groundwater use relative to aquifer recharge, per groundwater region. The results reveal the regional disparities in groundwater use across the Study Islands. Use in some areas on Mayne Island, North Pender Island and Galiano Island reaches over 10% of groundwater recharge. This likely creates stress on environmental needs and may result in water conflicts.

2 GROUNDWATER AVAILABILITY ASSESSMENT

To quantify the amount of groundwater within the delineated groundwater regions, a methodology was developed based on climate variables, water demand, 3D conceptual models (Report 1), and groundwater recharge potential (Report 2).

The model inputs and methodology are illustrated by the flowchart in Figure 1.

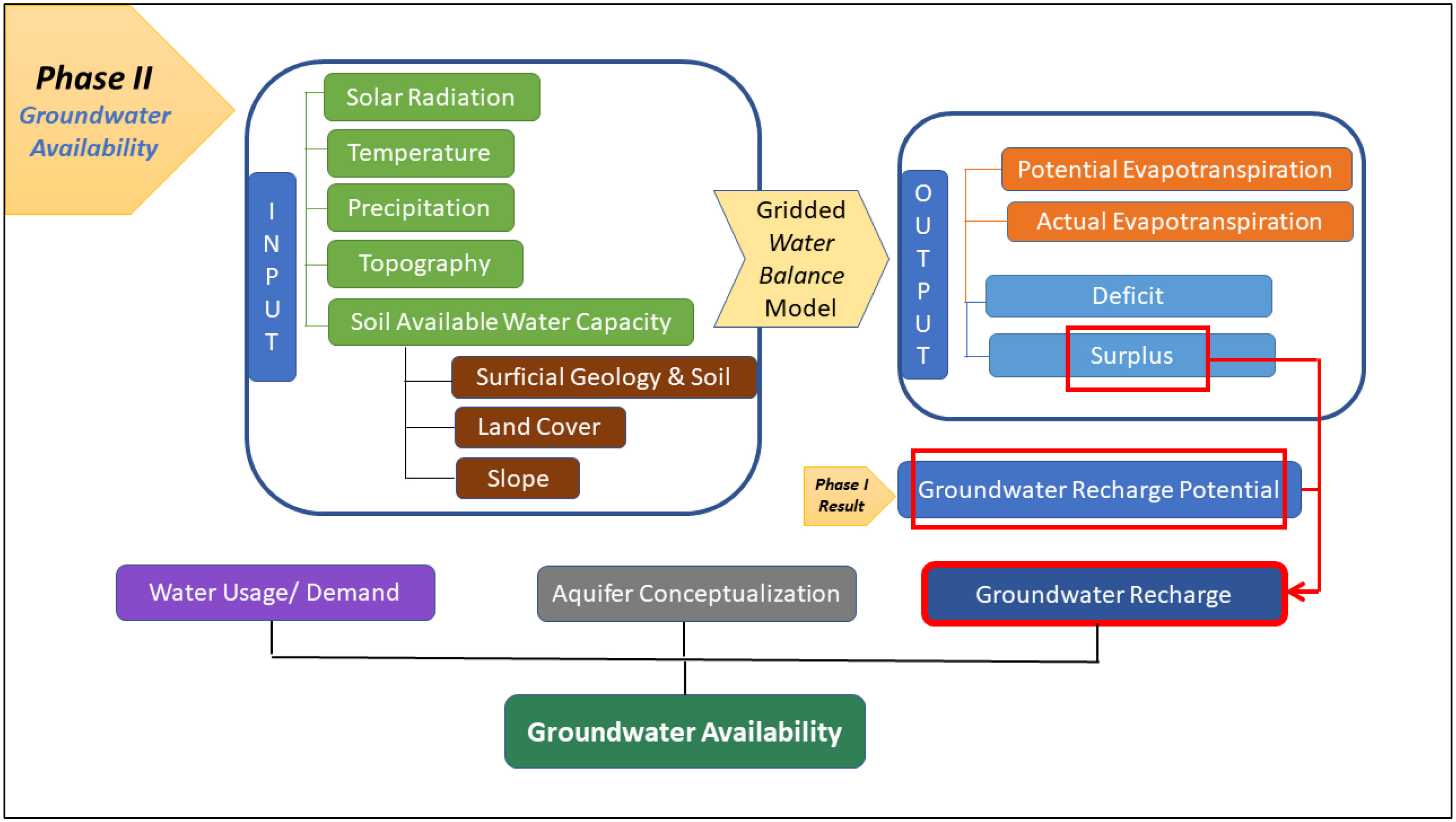

Figure 1: The water balance inputs and methodology to assess groundwater availability across the Study Islands.

2.1 Estimation of water use

2.1.1 Estimation of Surface Water Withdrawals

The water balance model requires an estimation of monthly and yearly surface water withdrawal volumes. The BC Points of Diversion (POD) database, which includes Water Licence information for surface water and springs, was used to estimate the surface water withdrawal volumes. A POD (i.e., spring, pond, or stream) can have multiple licenses; and each license can have one or more POD's. For each Water License, basic information is provided such as license status, expiry date, licensed volume and its corresponding unit and purpose.

Figure 2 shows the current licensed POD for the Study Islands, limited to withdrawals and classified by type of use (i.e., domestic, irrigation, industrial/commercial, institutional and water supply systems).

Methodology and Estimation of water volumes (surface water) for current PODs

Licensed volumes in the POD database are reported in yearly, monthly, daily, or hourly use rates. To normalize the licensed volumes to monthly rates, we applied coefficients that model seasonal patterns of water use. Coefficients were estimated based on monthly use trends for water supply systems on Vancouver Island (i.e., Salt Spring, Nanaimo), Ecofish Baseline Report and Rood and Hamilton (1995) (domestic), BC Ministry of Agriculture Livestock Watering Factsheets (livestock and irrigation), and the BC Agriculture Water Demand Model (irrigation).

Table 1 summarizes the monthly coefficients used for the conversion to monthly rates when the information was given in another unit. Monthly rates were then added to derive yearly water use for surface water and springs. The sum of the all the months equals to 12. The coefficient indicates months where greater water use happens and the proportion of water usage for each month . For instance, in *Irrigation: Private* there is not water usage from October to April (coefficient=0), the water usage in July and August (coefficient=3.6) is three times higher than in May and September (coefficient=1.2) and 33% more than the usage in June (coefficient=2.4).

Table 1. Monthly allocation coefficients for estimated water use from PODs

Group POD	Purpose	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
Domestic	DOMESTIC	0.85	0.85	0.85	0.85	0.95	1.00	1.50	1.50	1.10	0.85	0.85	0.85
Irrigation	IRRIGATION: PRIVATE	0.00	0.00	0.00	0.00	1.20	2.40	3.60	3.60	1.20	0.00	0.00	0.00
Irrigation	LAND IMPROVE: GENERAL	0.95	0.95	0.95	0.95	1.05	1.07	1.08	1.08	1.07	0.95	0.95	0.95
Irrigation	LIVESTOCK & ANIMAL: STOCK	0.85	0.85	0.85	0.85	0.95	1.00	1.50	1.50	1.10	0.85	0.85	0.85
Irrigation	LWN, FAIRWAY & GRDN: RES	0.00	0.00	0.00	1.20	2.40	2.40	2.40	2.40	1.20	0.00	0.00	0.00
Industrial	GRNHOUSE & NURSERY: GRNHO	0.00	0.12	0.12	0.24	1.20	1.68	2.88	2.88	2.04	0.72	0.12	0.00
Industrial	LWN, FAIRWAY & GRDN: WATE	0.00	0.00	0.00	1.20	2.40	2.40	2.40	2.40	1.20	0.00	0.00	0.00
Commercial	COMM. ENTERPRISE: ENTERPR	0.95	0.95	0.95	0.95	1.05	1.07	1.08	1.08	1.07	0.95	0.95	0.95
Institutional	MISC IND'L: FIRE PROTECTI	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Water Supply System	WATERWORKS (OTHER THAN LP	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Water Supply System	WATERWORKS: LOCAL PROVIDE	0.85	0.85	0.85	0.85	0.95	1.00	1.50	1.50	1.10	0.85	0.85	0.85

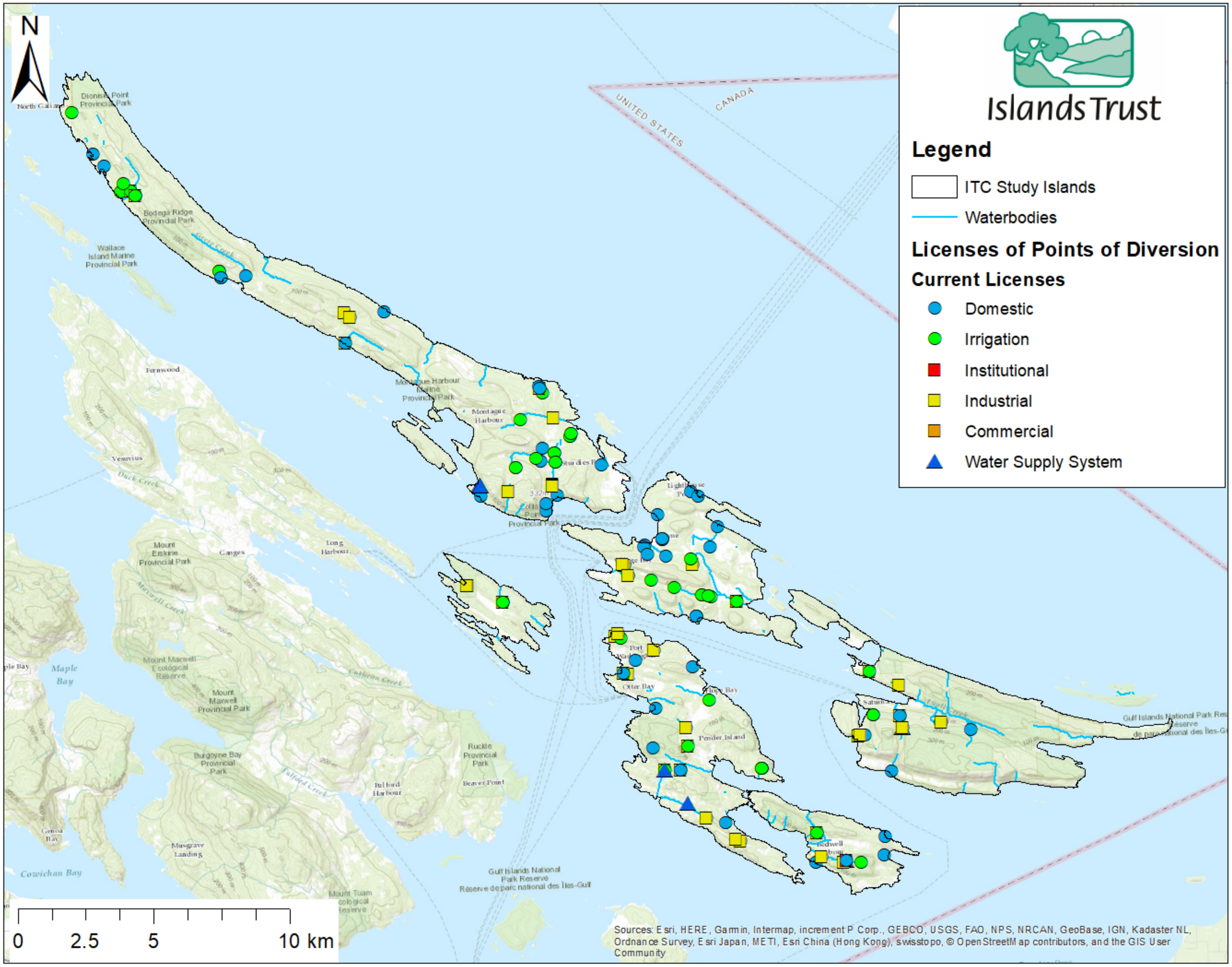

Figure 2. Current licences of Points of Diversion

2.1.2 Estimation of Groundwater Withdrawals

Water wells database, cadastral information, and water service areas

The BC water wells database (GWELLS), cadastral information and water service areas were used to estimate groundwater withdrawal. Unfortunately, the wells database does not include all wells since reporting to the Province was voluntary until the *Water Sustainability Act* in 2016 came into force. Additionally, dugs wells typically are not registered within GWELLS. The well use types were classified as: Water Supply System, Test Well, Private Domestic, Observation Well, Irrigation, Commercial and Industrial, Other and Unknown Well Use.

Wells that do not extract water were removed from the analysis, including abandoned, decommissioned, dry, test and observation wells.

The GWELLS database does not include information on pumped volumes. To estimate the water use from groundwater wells, we combined the following information:

- Parcel boundary and land use data from BC Assessment, provided by the Islands Trust staff (Figure 3).
- Active wells from the GWELLS database (Figure 4).
- Water service areas (Figure 5) whereby parcels are served by a communal water system. Domestic wells present in the services areas are likely not in use.

Water supply systems (Island Health Authority – IHA)

A water source is considered a “water supply system” if it serves two or more connections, and these are regulated by IHA. There are over 100 water supply systems throughout the Study Islands of which approximately 84% rely on groundwater (Figure 5). The number of connections for each water supply system is provided as a possible range.

2.1.3 Methodology

Groundwater wells database, cadastral information, and water service areas

Groundwater use was estimated based on joining active wells to the parcel’s land use (the “primary actual use” attribute from BC Assessment). Wells could then be classified by type of use: Water Supply System, Recreational, Irrigation, Institutional, Industrial, Domestic, Transportation and Commercial.

Average groundwater use for each land use type was estimated and adapted from Miles and Guy (2009) and is summarized in Table 2. The effects of seasonality and parcel size on water use were also taken into account. Three seasonality labels are used:

- “Area based”: volume estimation based on parcel area,
- “Seasonal use (May-Sep)”: volume estimation based on 5 months of water use (May to September); and
- “Area based and seasonal use (May-Sept)”: volume estimation based on combination of parcel area and period of use (May to September).

Coefficients from the BC Agricultural Water Demand Model (irrigation) and the BC Ministry of Agriculture’s Livestock Watering Factsheets (livestock and irrigation) were used for agricultural users (parcels with an irrigation use). Monthly and seasonal variations were estimated based on reported use for the domestic and water supply systems (Table 2). The coefficients are similar to those used for the POD water use estimation.

It is expected parcels within the Irrigation category will overestimate water demand. The method assumes 50% of the land is actively irrigated with volumes assigned in Table 2.

Domestic wells that are within water service areas were excluded in the estimation of groundwater volumes.

Water supply systems (Island Health Authority – IHA)

Only groundwater sources were taken from the IHA water supply system database since surface water and springs were captured in the POD database. Available information on individual water supply systems, including number of connections, population served and reported annual use is presented in Appendix 2.

GW Solutions assumed an average number of connections per source for water supply systems where no information was found (for example, if 2 wells provide water for the same water supply system) and applied an average minimum household use per dwelling of 250 litres per day (BC Water Sustainability Act). Seasonality was applied using the coefficients presented in Table 3.

Total groundwater use

The estimate of total groundwater use was calculated based on data from springs (POD), water wells (GWELLS database) and water supply systems (IHA database).

Table 2. Average water use estimates based on parcel information

Group	Primary Actual Use	Estimation type and seasonality	L/day/parcel	Number per ha
Domestic	000 - Single Family Dwelling		625	
Domestic	002 - Property Subject to Section 19(8)		625	
Domestic	032 - Residential Dwelling with Suite		1250	
Domestic	033 - Duplex, Non-Strata Side by Side or Front / Back		625	
Domestic	038 - Manufactured Home (Not In Manufactured Home Park)		625	
Domestic	040 - Seasonal Dwelling	Seasonal use (May-Sep)	625	
Domestic	052 - Multi-Family (Garden Apartment & Row Housing)		2500	
Domestic	060 - 2 Acres or More (Single Family Dwelling, Duplex)		1250	
Domestic	062 - 2 Acres or More (Seasonal Dwelling)	Seasonal use (May-Sep)	1250	
Domestic	063 - 2 Acres or More (Manufactured Home)		1250	
Irrigation	110 - Grain & Forage	Area based and seasonal use (May-Sept)	18354	
Irrigation	120 - Vegetable & Truck	Area based and seasonal use (May-Sept)	11697.5	
Irrigation	130 - Tree Fruits	Area based and seasonal use (May-Sept)	24250	
Irrigation	140 - Small Fruits	Area based and seasonal use (May-Sept)	13892	
Irrigation	150 - Beef	Area based	50	1
Irrigation	170 - Poultry	Area based	30	180
Irrigation	180 - Mixed	Area based and seasonal use (May-Sept)	10000	
Irrigation	190 - Other	Area based and seasonal use (May-Sept)	10000	
Irrigation	610 - Parks & Playing Fields	Area based and seasonal use (May-Sept)	2000	
Irrigation	612 - Golf Courses (Includes Public & Private)	Area based and seasonal use (May-Sept)	20000	
Commercial	200 - Store(S) And Service Commercial		1129	
Commercial	202 - Store(S) And Living Quarters		1068	
Commercial	209 - Shopping Centre (Neighbourhood)		14355	
Commercial	233 - Individual Strata Lot (Hotel/Motel)		17500	
Commercial	237 - Bed & Breakfast Operation 4 Or More Units	Seasonal use (May-Sep)	4000	
Commercial	238 - Seasonal Resort	Seasonal use (May-Sep)	10000	
Commercial	239 - Bed & Breakfast Operation Less Than 4 Units	Seasonal use (May-Sep)	2000	
Commercial	270 - Hall (Community, Lodge, Club, Etc.)		2500	

Group	Primary Actual Use	Estimation type and seasonality	L/day/parcel	Number per ha
Commercial	273 - Storage & Warehousing (Closed)		1500	
Commercial	276 - Lumber Yard or Building Supplies		625	
Commercial	280 - Marine Facilities (Marina)		1128	
Commercial	300 - Stratified Operational Facility Areas		250	
Commercial	520 - Telephone		1500	
Commercial	580 - Electrical Power Systems (Including Non-Utility		6000	
Recreational	600 - Recreational & Cultural Buildings (Includes Curling		5000	
Institutional	615 - Government Reserves (Includes Greenbelts (Not in Farm		1500	
Institutional	620 - Government Buildings (Includes Courthouse, Post Office		2000	
Institutional	630 - Works Yards		500	
Institutional	650 - Schools & Universities, College or Technical Schools		7000	
Institutional	652 - Churches & Bible Schools		1800	

Table 3: Monthly seasonal variations for estimation of monthly pumped volumes

Month	No of days	Irrigation Distributed (%)	Water Supply System Increased by (%)	Domestic and others Increased by (%)
January	31		0%	0%
February	28		0%	0%
March	31		0%	0%
April	30		0%	0%
May	31	10%	15%	10%
June	30	20%	25%	12%
July	31	30%	80%	14%
August	31	30%	80%	14%
September	30	10%	20%	13%
October	31		0%	0%
November	30		0%	0%
December	31		0%	0%

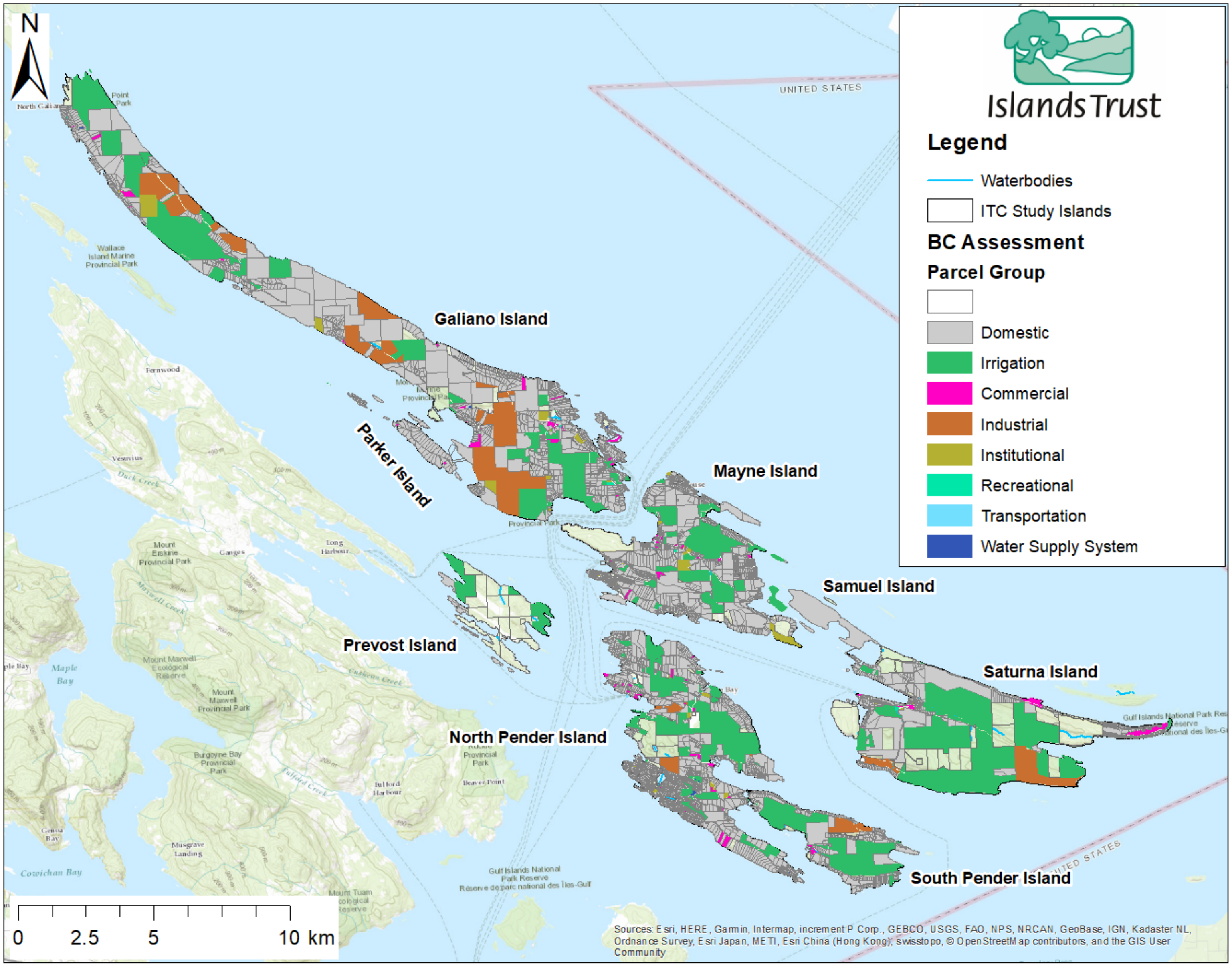

Figure 3: BC Assessment parcel type

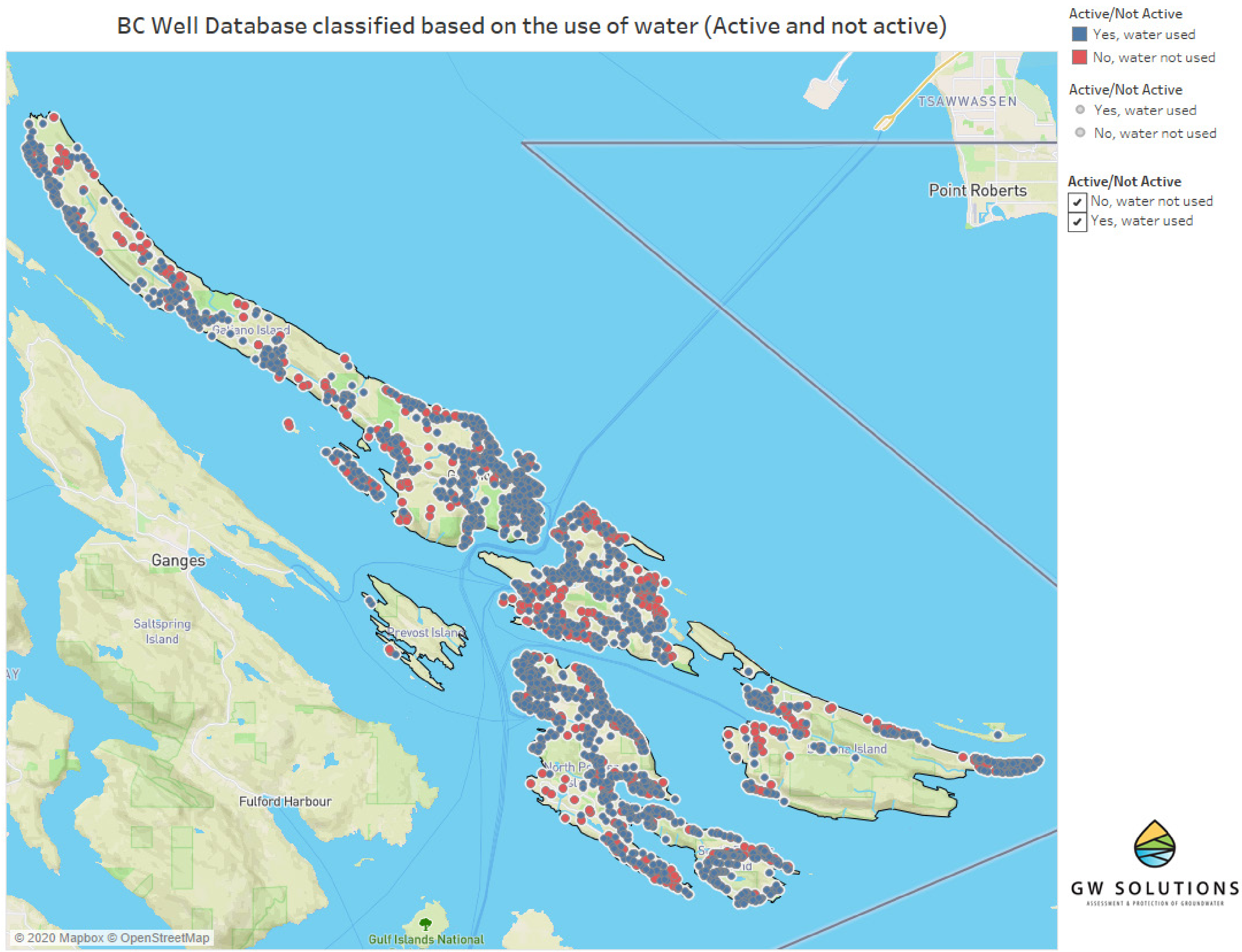

Figure 4. Wells withdrawing water and inactive wells

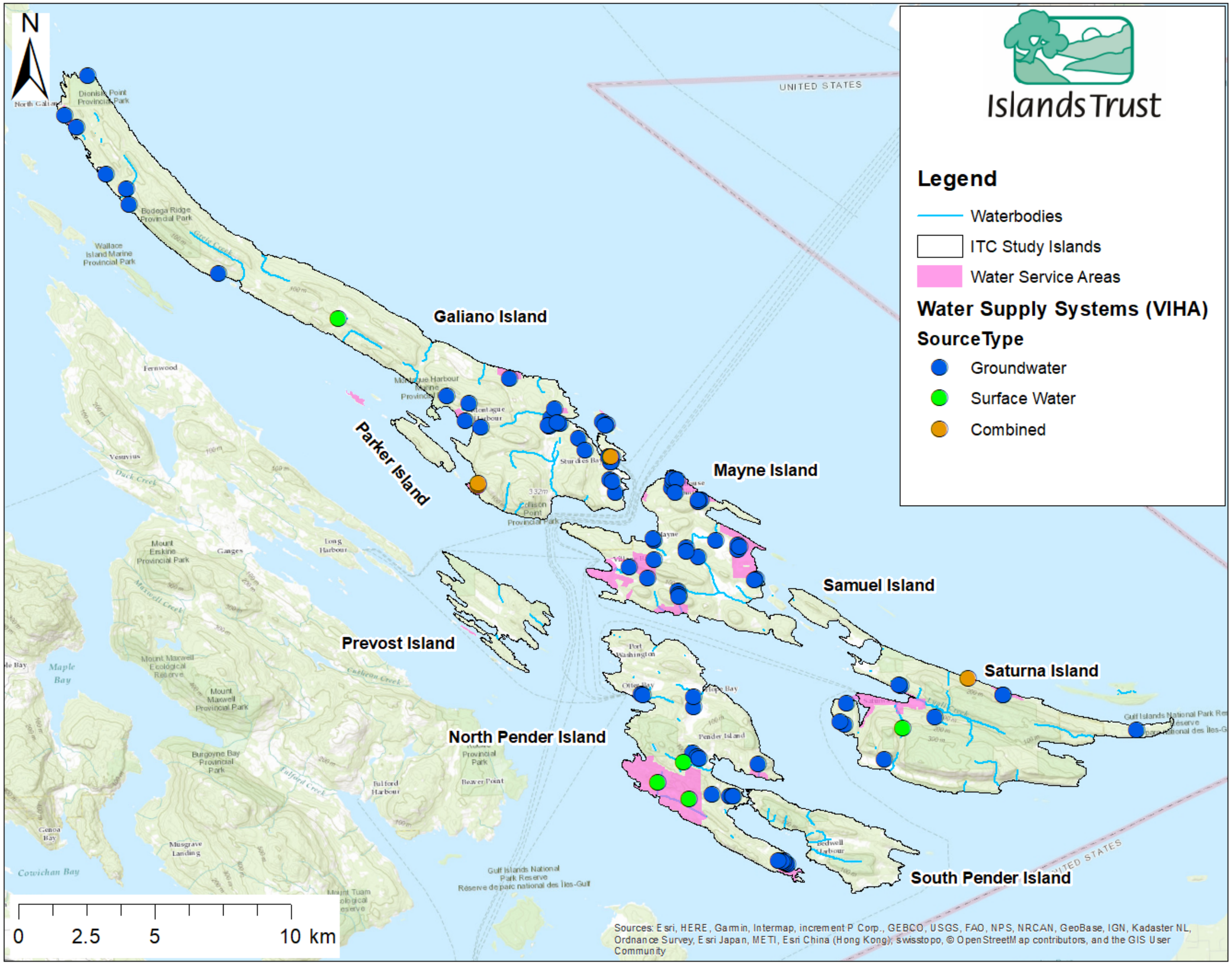

Figure 5.Service Areas and Water Supply Systems regulated by VIHA

2.1.4 Water Use Estimation Results

Appendix 3 summarizes the yearly estimated surface water and groundwater use for each island and aquifer, classified by type of use. Water use is estimated in cubic decameters, or dam^3 (1,000 m^3 (cubic meters) equals 1 dam^3).

Galiano Island

Most water users on Galiano Island obtain their water from groundwater wells (584 dam^3-bedrock aquifer 320) and uses include irrigation, domestic and water supply service.

Mayne Island

A majority of water users on Mayne Island obtain their water from groundwater (537 dam^3), specifically form Aquifer 447, Aquifer 620 and Aquifer 619. Surface water use is minimal compared to groundwater use (50 dam^3). Most of the water extractions are for irrigation and water supply purposes.

North Pender Island and South Pender Island

Surface water use (1370.70 dam^3) exceeds groundwater use (544 dam^3) for North Pender with most of the water extraction used for irrigation, water supply and private domestic use. Surface water is the main source for water supply systems.

Similar groundwater (120 dam^3) and surface water use (93 dam^3) is observed in South Pender. The main source of water use for irrigation and private domestic purposes is from groundwater source whereas the surface water is the main source for the water supply service for South Pender Island.

Saturna Island

Both surface water (148 dam^3) and groundwater (120 dam^3) are the main sources for water use for Saturna Island. Surface water is mainly used for water supply services and groundwater is mainly used for irrigation and water supply followed by private domestic use.

2.2 Water balance model

To estimate the water balance for the Study Islands, we used an ArcGIS-based model developed by James Dyer from the University of Ohio (Dyer, 2019, 2021). 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 a digital elevation model (DEM), soil available water capacity (AWC), monthly temperature (average), precipitation, and solar radiation.

The outputs of the model are:

- **Potential evapotranspiration (PE)** is estimated using the Turc method. PE is the evaporative water loss from a vegetation for which 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** 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** 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.

2.2.1 Model Methodology

The Thornthwaite-Mather water balance method uses the following logic:

A. Precipitation – potential evapotranspiration (P-PE):

   a. If supply (P) < demand (PE), plants utilize soil water.

   b. If supply (P) > demand (PE), there is more water than needed by vegetation.

   c. Available water is prioritized as follows:

i. Plants use what they need (first from precipitation, then from soil storage);

ii. If there is still excess water, it is used to recharge storage if recharge is not full;

iii. Any excess water becomes surplus.

B. The calculation begins with soil water storage (ST) assumed to be full (equal to soil available water capacity (AWC)) based on consecutive values of P-PE. It can be assumed that soil storage is fully recharged if the sum of consecutive positive P-PE values exceeds AWC.

C. Change in storage (ΔST) from month to month, resulting from water use by plants (i.e., negative change in storage) or excess water (positive change in storage).

D. Actual evapotranspiration (AE) is what plants can use. If water is not limited, plants use what they demand (AE=PE).

a. Whenever storage (ST) = AWC, AE = PE (water comes from Precipitation (P)).

b. As storage (ST) is depleted, it becomes increasingly difficult for plants to extract the water they need.

c. When ST < AWC, AE = P + $|\Delta ST|$.

E. Deficit (D) = PE - AE.

F. Surplus (S). If ST is full (ST = AWC), there is liable to be “excess precipitation” if plants do not use it all.

a. If ST < AWC, there can be no Surplus.

b. If ST = AWC, then S = P - AE.

c. Note that the month when ST equals AWC, S = P - AE - ΔST (excess first goes to fill storage).

G. The balance in water supply and demand at a site can be expressed in two relationships:

a. PE = AE + D (Moisture demand is equivalent to moisture transpired, plus the “shortfall.”).

b. P = AE + S (Moisture supply equates to moisture transpired plus excess beyond this need).

Note these checks will hold using annual totals (from December to January).

2.2.2 Data Inputs

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) provided by Island Trust. The DEM was up scaled to 20 m x 20 m resolution to match the water balance model scale.

Soil Available Water Capacity (AWC)

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. Soil mapping also includes available water holding capacity at different depths (0.15, 0.30, 0.45, 0.60, 0.75, 0.90, 1.05 and 1.20 m). In temperate forests, 95% of root mass occurs within the top 1 m of soil. Therefore, we have used the available water holding capacity at 0.90 m depth.

Geology (surficial geology, geomorphology)

Available surficial geology mapping for the Study Islands was integrated in the model (Province of British Columbia, 2020. BC Soil Information Finder Tool).

Average temperature and total precipitation

Gridded monthly total precipitation and maximum and minimum temperatures were obtained from the Pacific Climate Impact Consortium (PCIC). The information is based on climate normal data from 1981-2010. The information was checked against the climate station data in the study area.

Annual total precipitation for the Study Islands are presented in Figure 6.

Solar Radiation

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

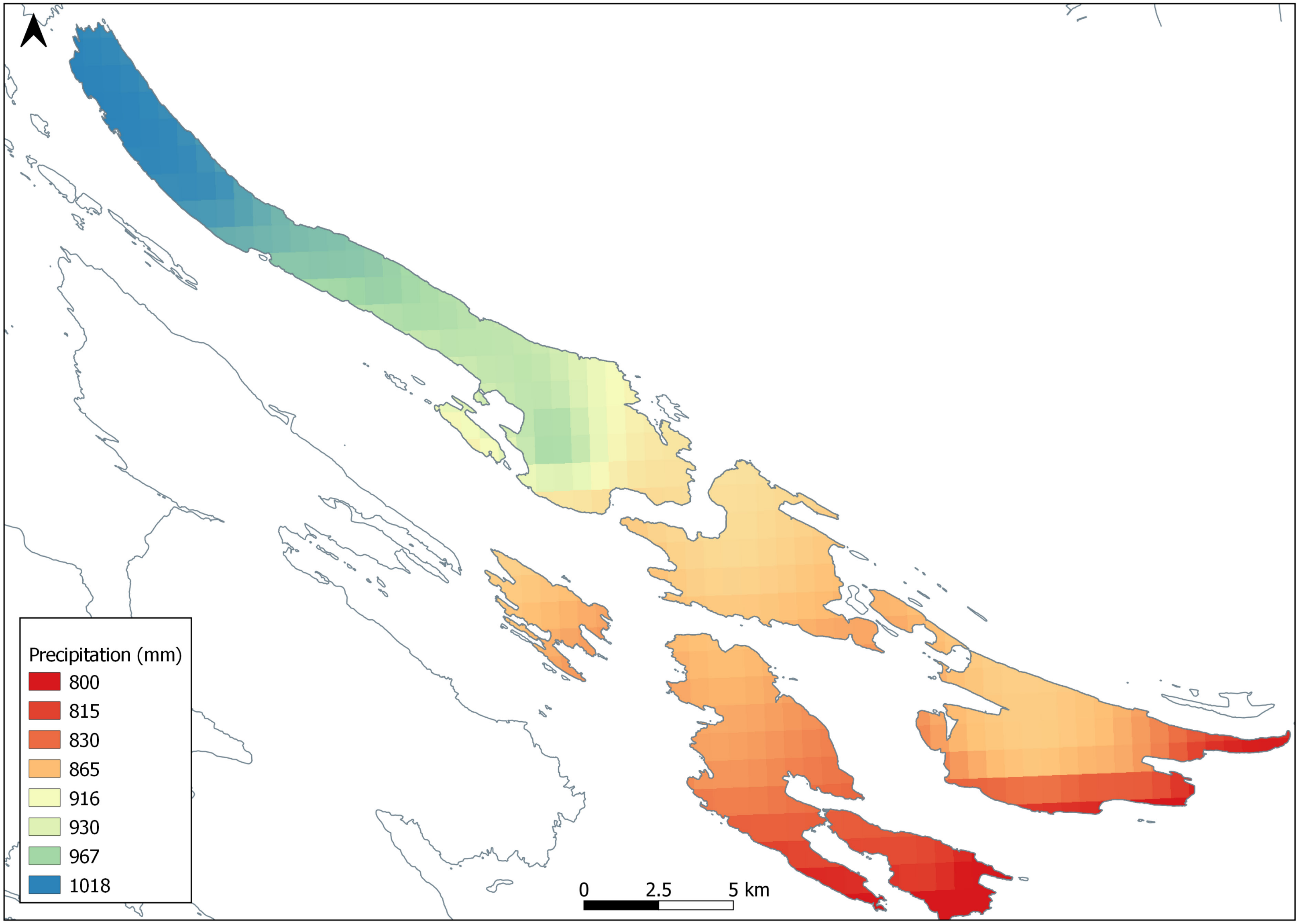

Figure 6: Annual total precipitation

2.2.3 Data Outputs

Estimation of Annual Actual Evapotranspiration

Actual evapotranspiration was estimated using the GIS based water balance tool (Dyer, 2019, 2021). Figure 7 shows the annual average actual evapotranspiration (Normal 1981-2010) for Study Islands.

Surplus (runoff and groundwater recharge)

Surplus is the remaining water (not evaporated or transpired) that leaves a site through runoff, subsurface flow, or a combination of both. There can be no surplus if soil storage is not full. Figure 8 presents the average annual water surplus.

2.2.4 Sensitivity Analysis Water Balance Model

The Sensitivity Analysis consisted of evaluating twelve scenarios which represent the range of possible variations for four input parameters:

- Precipitation
- AWHC Available Water Holding Capacity (water available to vegetation)
- Solar Radiation
- Temperature

The scenarios (Table 4) are designed to vary the inputs by either + or -15% from normal (i.e. long-term average). Precipitation was also varied by the most extreme values ever recorded (lowest and highest) at meteorologic stations NORTH PENDER ISLAND (Climate ID: 1015638) and SATURNA CAPMON (Climate ID: 1017098). Solar radiation was also varied for only the summer months when values are highest.

Table 4: Scenarios for Water Balance Sensitivity Analysis

Parameter	Scenario
AWHC	-15% from normal
AWHC	+15% from normal
Precipitation	-15% from normal
Precipitation	+15% from normal
Precipitation	driest year on record

Parameter	Scenario
	(1985 with 30% less precipitation)
Precipitation	wettest year on record (1997 with 50% more precipitation)
Solar radiation	summer months +15% from normal
Solar radiation	summer months -15% from normal
Solar radiation	all months +15% from normal
Solar radiation	all months -15% from normal
Temperature	+15% from normal
Temperature	-15% from normal

The results (Figure 9) show that for ITC Southern Gulf Islands Water Balance Model the most sensitive input parameter is precipitation affecting the recharge estimates by -50% to +20%. The remaining input parameters affect recharge by less than 5%. This highlights the importance of collecting additional precipitation data.

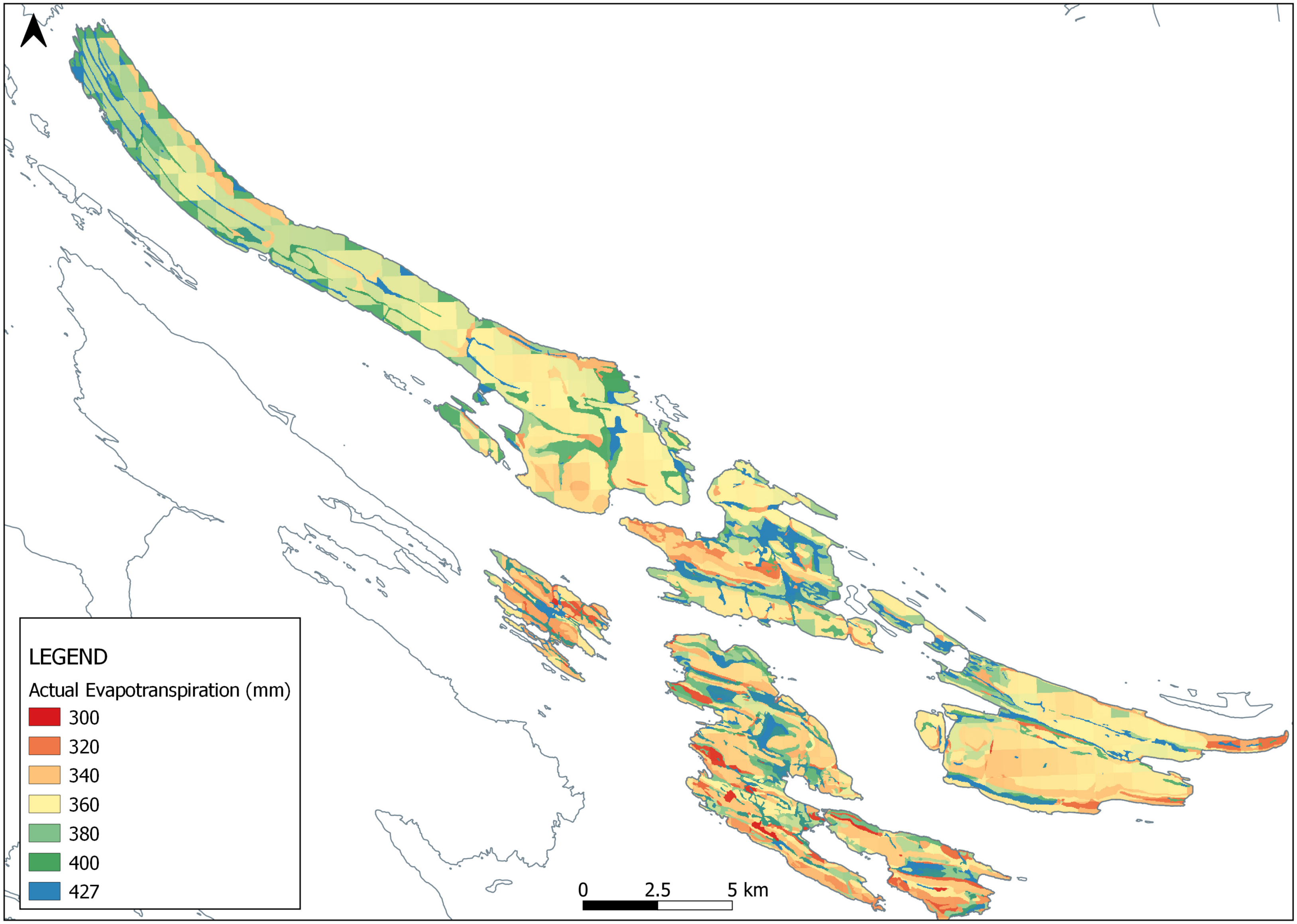

Figure 7: Annual actual evapotranspiration

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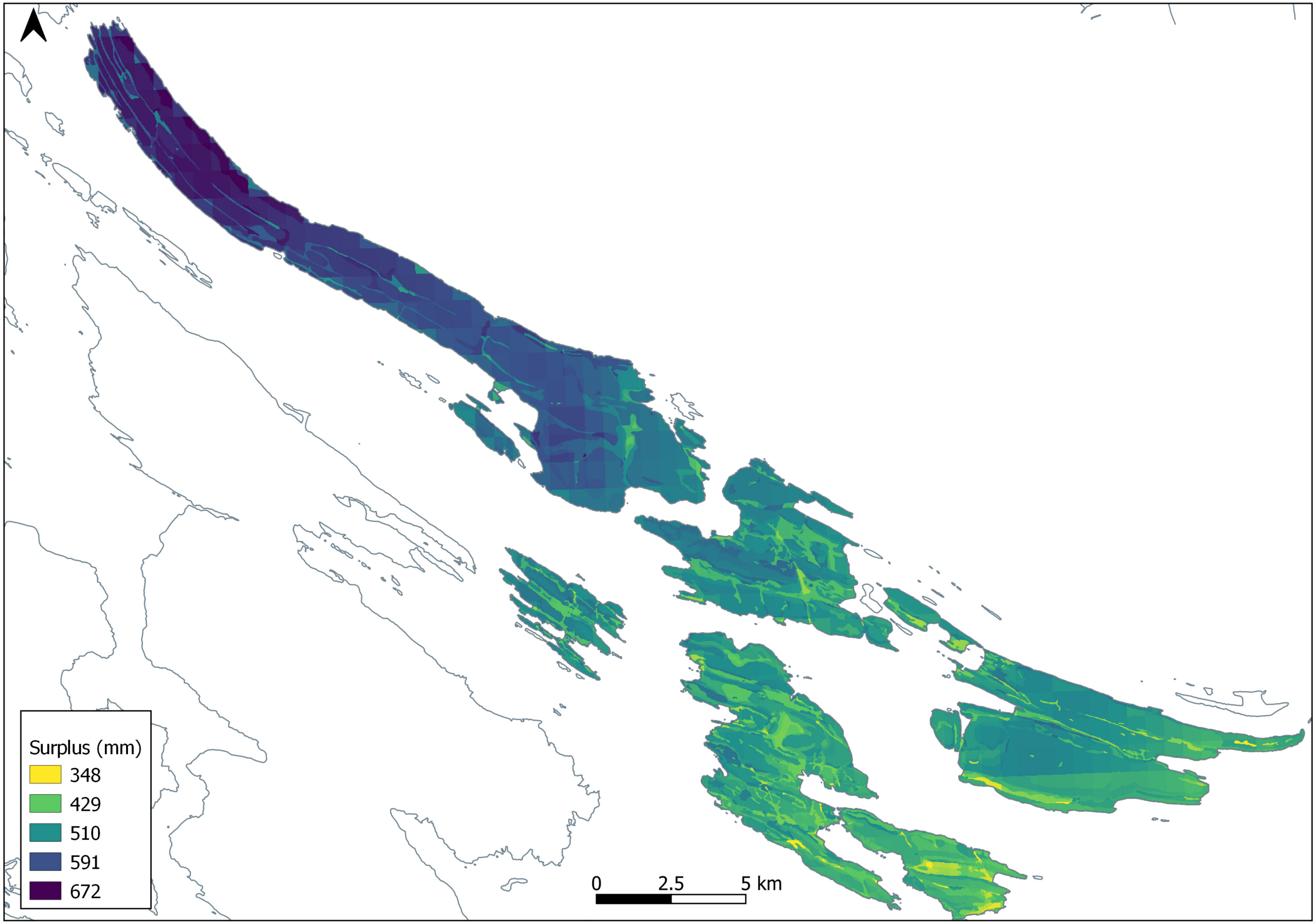

Figure 8: Calculated annual water surplus

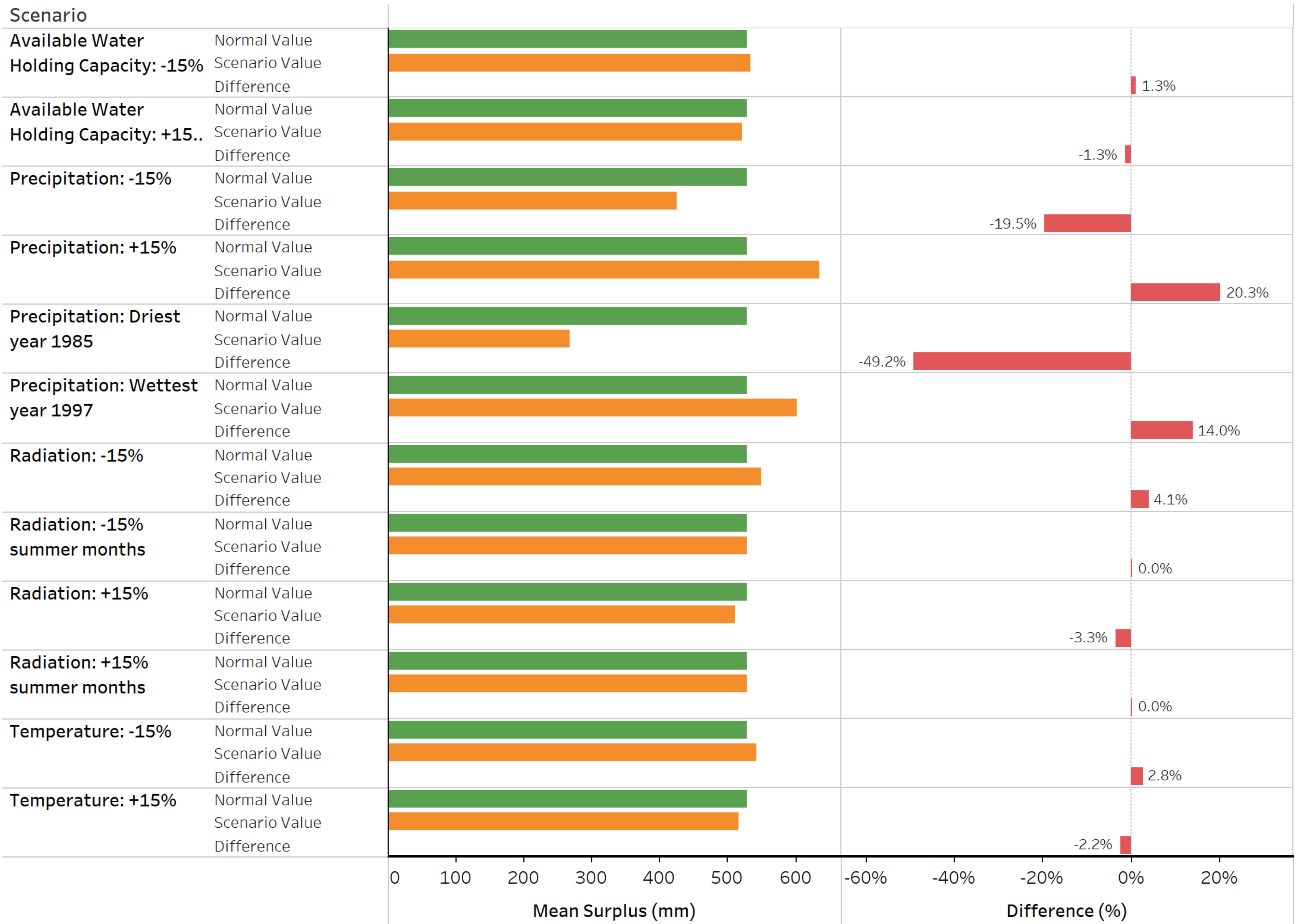

Figure 9. Results of sensitivity analysis for Southern Gulf Islands

2.3 Estimation of groundwater recharge

To estimate the amount of surplus able to infiltrate to the ground, the resulting Groundwater Recharge Potential (Report 1) was multiplied by the surplus across the Study Islands. Figure 10 shows the estimated average annual groundwater recharge across the Study Islands.

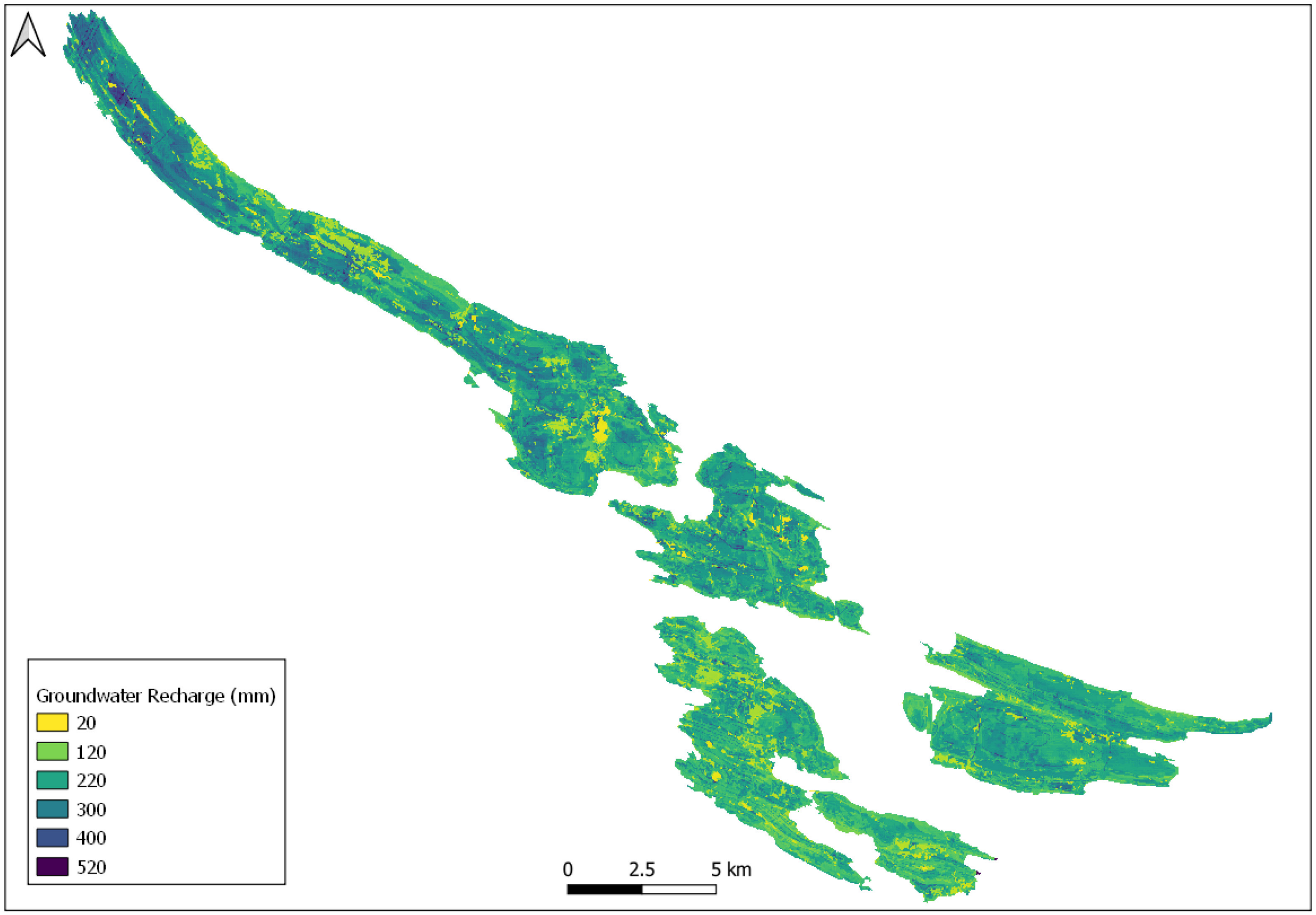

Figure 10: Calculated annual groundwater recharge

2.4 Groundwater recharge and groundwater use

To assess the groundwater availability within each groundwater regions, the estimated groundwater recharge was compared to the estimated groundwater use for each region. Most groundwater use occurs from May to September whereas groundwater recharge occurs in from October to April.

Table 5 and Figure 11 summarize the percentage of groundwater use compared to recharge taking into account normal data (1981-201) and the driest scenario (1985). Groundwater regions for which the use is less than 5% of the recharge are highlighted in green, percentages beteen5 to 10% are highlighted in orange and groundwater regions with groundwater use exceeding 10% of the recharge are highlighted in red. The former regions are likely already under stressed conditions.

The monthly water budget summary for each groundwater region is included in Appendix 4 and the annual water budget summaries for all defined groundwater regions are provided in Appendix 5. Additionally, Appendix 6 summarizes the monthly and annual water budget for all the groundwater regions using the driest climate scenario (1985).

Table 5. Summary of groundwater recharge and groundwater use

Island	Groundwater Region ID	Groundwater Region Name	Groundwater Recharge-Normal (dam^3)	Groundwater Recharge-Driest (dam^3)	Groundwater Use (dam^3)	% of Use from Recharge-Normal	% of Use from Recharge-Driest	% of Use from Recharge (Normal-Driest)
Galiano Island	GAL01	North Galiano_Spanish Hills	642	328	22	3.4%	6.7%	3-7%
	GAL02	Dionisio Point	477	253	0.4	0.1%	0.2%	0.1-0.2%
	GAL03	North Georgia Strait	402	216	1	0.2%	0.4%	0.2-0.4%
	GAL04	North Trincomali Channel	1345	700	18	1.4%	2.6%	1-3%
	GAL05	West Galiano	527	272	19	3.6%	7.0%	4-7%
	GAL06	East Galiano	732	392	3	0.4%	0.7%	0.4-0.7%
	GAL07	Greig Creek	583	303	8	1.3%	2.5%	1-3%
	GAL08	Central Georgia Strait	666	348	2	0.3%	0.6%	0.3-0.6%
	GAL09	Quadra Hill_East	614	322	0.5	0.1%	0.2%	0.1-0.2%
	GAL10	Quadra Hill_West	1211	623	10	0.9%	1.7%	1-2%
	GAL11	South Trincomali Channel	261	135	3	1.1%	2.1%	1-2%
	GAL12	Cook Cove	760	397	3	0.5%	0.9%	0.5-0.9%
	GAL13	Finlay Lake	782	411	37	4.7%	9.0%	5-9%
	GAL14	Montague Harbour	759	389	38	5.0%	9.8%	5-10%
	GAL15	Winstanley Point	131	68		0.0%	0.0%	0-0%

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ASSESSMENT & PROTECTION OF GROUNDWATER

Island	Groundwater Region ID	Groundwater Region Name	Groundwater Recharge-Normal (dam^3)	Groundwater Recharge-Driest (dam^3)	Groundwater Use (dam^3)	% of Use from Recharge-Normal	% of Use from Recharge-Driest	% of Use from Recharge (Normal-Driest)
	GAL16	Sutil Mountain	477	246	17	3.5%	6.9%	4-7%
	GAL17	Georgeson Bay	365	188	9	2.5%	4.9%	3-5%
	GAL18	Matthews Point	88	45	2	2.0%	3.8%	2-4%
	GAL19	South Galiano	760	391	69	9.1%	17.7%	9-18%
	GAL20	Cain Peninsula	111	57	13	11.5%	22.4%	12-22%
	GAL21	Murchison- Whaler Bay	1828	930	75	4.1%	8.1%	4-8%
Mayne Island	MAY01	Georgina Pt_HallHill_North	888	455	75	8.5%	16.5%	8-17%
	MAY02	Center1_East	909	446	31	3.4%	6.9%	3-7%
	MAY03	Center1_West	871	449	24	2.8%	5.4%	3-5%
	MAY04	Center2_East	1185	584	33	2.8%	5.6%	3-6%
	MAY05	Center2_West	439	219	35	8.1%	16.2%	8-16%
	MAY06	Navy Channel_Westside	632	321	16	2.6%	5.0%	3-5%
	MAY07	Navy Channel_Eastside	170	86	1	0.7%	1.5%	0.7-1.5%
North Pender Island	NP01	North Pender I	476	237	13	2.7%	5.4%	3-5%
	NP02	North Pender II	1486	726	44	3.0%	6.1%	3-6%
	NP03	North Pender III	481	240	41	8.5%	17.1%	9-17%
	NP04	North Pender IV	1171	575	67	5.7%	11.7%	6-12%
	NP05	North Pender V	41	21		0.0%	0.0%	0-0%
	NP06	North Pender VI	393	195	0.4	0.1%	0.2%	0.1-0.2%
	NP07	North Pender VII	769	375	24	3.1%	6.4%	3-6%
	NP08	North Pender VIII	256	128	7	2.7%	5.3%	3-5%
South Pender Island	SP01	South Pender I	512	253	11	2.1%	4.2%	2-4%
	SP02	South Pender II	636	304	12	1.8%	3.8%	2-4%
	SP03	South Pender III	88	43	0	0.0%	0.0%	0-0%
	SP04	South Pender IV	373	183	10	2.7%	5.5%	3-5%
Saturna Island	SAT01	Boot Cove	519	262	20	3.8%	7.5%	4-7%
	SAT02	Brown Ridge	1346	678	4	0.3%	0.6%	0.3-0.6%
	SAT03	Lyall Harbour	2201	1137	13	0.6%	1.2%	0.6-1.2%
	SAT04	Narvaez Bay	1293	654	2	0.2%	0.3%	0.2-0.3%
	SAT05	Tumbo Channel	1323	685	25	1.9%	3.6%	2-4%

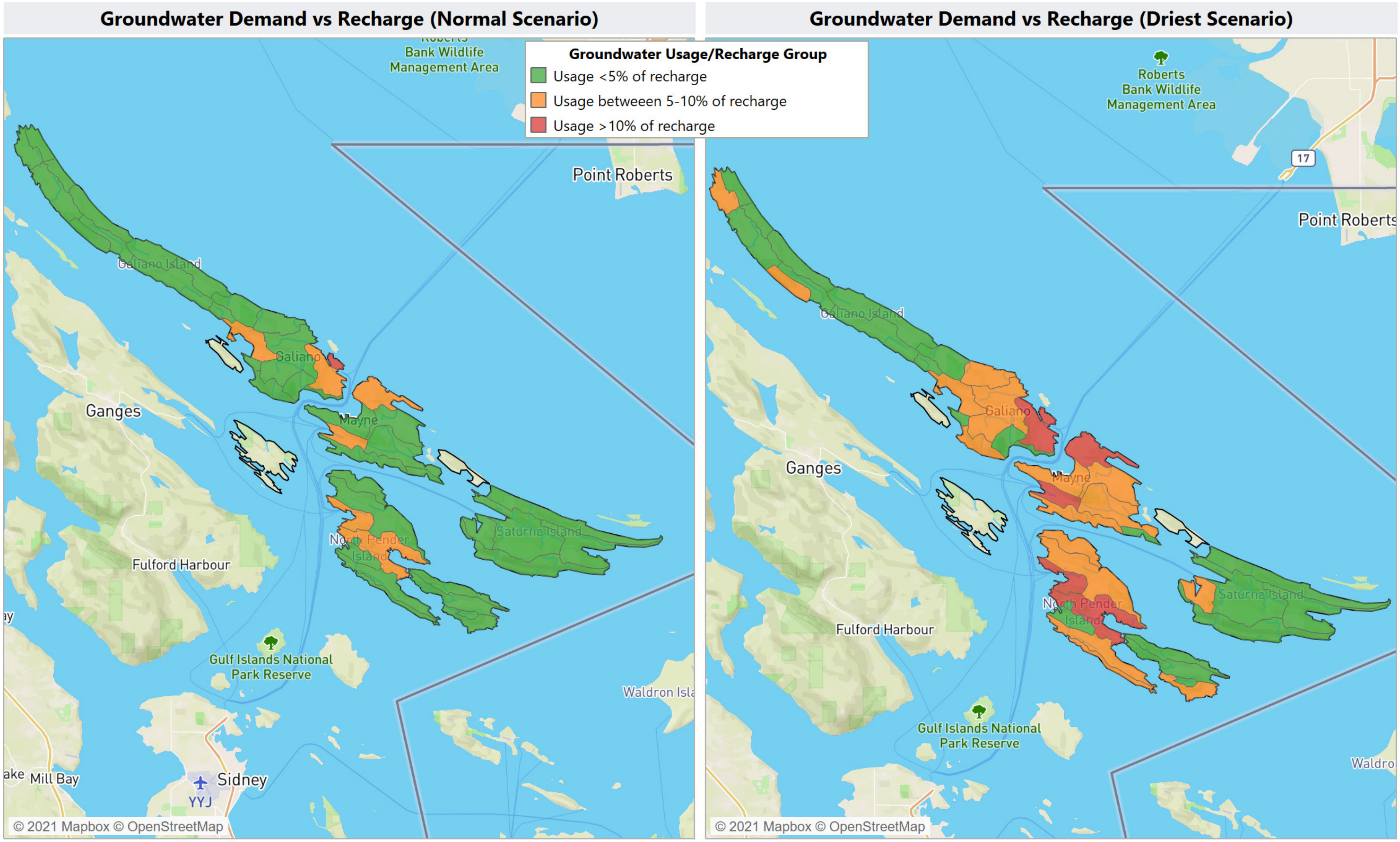

Figure 11: Groundwater recharge and groundwater use per groundwater regions (normal and driest scenario)

3 CONCLUSIONS

1. Quantifying the *focused* component of groundwater recharge was achieved by analyzing high-resolution LiDAR topography for linear, bedrock features (lineaments), which play an important role in recharge of bedrock aquifers. Lineament mapping was previously only possible from geological field investigations or analysis of aerial imagery (report 2).

2. Groundwater regions have been delineated based on catchments, bedrock geology, mapped aquifers, and the distribution and attributes of water wells. A total of 48 groundwater regions have been defined for the Study Islands.

3. A gridded water balance model was developed for the Study Islands. Model output includes surplus, runoff and groundwater recharge. Total annual precipitation ranges between 800 and 1020 mm/year and surplus between 292 and 683 mm/year for the normal data (1981-210) and surplus between 65 and 377 mm/year during the year with the minimum precipitation (1985).

4. Water use for surface water and groundwater sources has been estimated with a methodology developed by GW Solutions. The estimated volumes could be used for comparison when metered data is obtained.

5. Using results from the water balance model, we estimate the percentage of groundwater use relative to aquifer recharge, per groundwater region. The results reveal the regional disparities in groundwater use across the Study Islands. Use in some areas on Mayne Island, North Pender Island and Galiano Island reaches greater than 10% of groundwater recharge. This likely creates stress on environmental needs and may result in water conflicts.

6. If the Southern Gulf Islands experience drought condition such as in 1985, the groundwater recharge could be reduced by up to 50%.

4 RECOMMENDATIONS

GW Solutions makes the following recommendations:

1. To better characterize, monitor, protect water resources, the ITC should initiate a community-based monitoring program that focuses on data collection. This program should include:

    a. Monitoring of the groundwater levels in priority groundwater regions where a large portion of recharge is allocated. This should be achieved either through the use of dedicated monitoring wells, or of privately-owned wells that are equipped with devices that measure water level and electrical conductivity (a proxy for salinity). These monitoring efforts should focus on early detection and mitigation of the risks of salt-water intrusion.

b. Actual water use is a major uncertainty and must be estimated using information from proxy models. ITC should implement a pilot water metering program to collect real-world water use on the Gulf Islands. Additionally, a water use survey is highly recommended specially in water regions highlighted in orange and red.

c. Define local environmental flow needs for surface water bodies and implement measures to preserve them.

d. Better define the relationship between land development and groundwater use and availability to make land development and land management decisions that do not jeopardize the water resource.

2. Currently there is not active hydrometric station on the Study Islands. ITC should install hydrometric stations to monitor surface water level and flow. These data could be used to further calibrate the water balance model.

3. The effects of climate on aquifer recharge and groundwater availability should be estimated and modeled. Several climate stations should be installed because large changes in temperature and precipitation are expected in the coming decades, and this will have a large impact on aquifer recharge.

5 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.

In evaluating the subject study area and water data, GW Solutions has relied in good faith on information provided. The factual data, interpretations and recommendations pertain to a specific project as described in this document, based on the information obtained during the assessment by GW Solutions on the dates cited in the document, and are not applicable to any other project or site location. GW Solutions accepts no responsibility for any deficiency or inaccuracy contained in this document as a result of reliance on the aforementioned information.

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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If new information is discovered during future work, including excavations, sampling, soil boring, water sampling and monitoring, predictive geochemistry or other investigations, GW Solutions should be requested to re-evaluate the conclusions of this document and to provide amendments, as required, prior to any reliance upon the information presented herein. The validity of this document is affected by any change of site conditions, purpose, development plans or significant delay from the date of this document in initiating or completing the project.

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.

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7 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,

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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.

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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.

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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.

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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.

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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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