APPENDIX F

NORTH SALT SPRING WATER STUDY

POTENTIAL GROUNDWATER RESOURCES

Prepared by

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PROJECT 2458 NORTH SALT SPRING WATER STUDY
POTENTIAL GROUNDWATER RESOURCES

Seepage from Fractured Salt Spring Island Granite

Phase I: Supply and Demand Analysis

Part 1. Water Supply Options

Task 1. *Review all available resource materials related to water supply including existing surface sources,* ***potential groundwater aquifers****, supply system infrastructure, or other relevant information.*

GIGS has completed a review of potential groundwater aquifers within and adjacent to the supply/service areas of the NSSWD. No new field data is included in this compilation. The review encompassed a study of the following existing sources of information:

1/ Government Reports:
2/ Water Well Database (MELP)
3/ Reports on Well and Aquifer Evaluations (Islands Trust)
4/ Published Geological Maps, Victoria Area (GSC, Muller 1980)
5/ Published topographic maps:

October. Water table levels within the fractured bedrock reflect the precipitation pattern but lag somewhat behind rainfall events. The heavy precipitation of winter is usually more than sufficient to refill the available fracture voids each year. The fracture system is drained by gravity flow and well withdrawal during the period of low precipitation of spring and summer. The water table reaches its lowest levels at the end of the dry period.

The elevated area in the vicinity of Maxwell Lake southwest of Ganges offers by far the greatest potential for large reserves of high quality groundwater within or proximal to the service area of the North Salt Spring Water District. This is an extensive area which presently has only very limited demand on its groundwater reserves and is essentially pristine with respect to any form of contamination. We are confident that, with rational development following a program of study, this area could provide NSSWD with an additional source of water in excess of 200,000 cubic metres per year. Given the rate of current development on the island and the expected increase in demand for its water sources we conclude that an evaluation this resource should be carried out without delay.

A two-phase investigation of the groundwater resources of the Maxwell Lake upland is recommended:

Phase I will focus on the definition of surface features which can provide useful information related to water bearing fracture systems. Items to be addressed include: local geology, detailed topography, and hydrologic features. Geophysical traverses across areas of interest would provide insight into the location and extent of fracture systems at depth. The cost of this phase is estimated at $16,000 (see details below).

Phase II will include the drilling of 3 wells to depths of about 200 metres each and the pump testing of these to determine their long term capacities. The wells would be located in areas found to be the most suitable based on the results of Phase I and on considerations of access and infrastructure. Numerical modeling of aquifer response to pumping would provide a basis for rational development and management of the aquifer. The cost of this phase is estimated at $52,000.

Phase III which would encompass the development of the aquifer for production has not been considered in this preliminary review.

Phase I: Supply and Demand Analysis

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5/ Published topographic maps:
6/ Aerial Photographs:
7/ Field review.

The selection of target areas for groundwater exploration from existing resource material has considered the following criteria:

1/ Favorable geology (in order of decreasing favorability):
granites, conglomerates, volcanics, sandstones.
2/ Surface areas of favorable geological units within target areas.
3/ Average elevation of target areas. High elevation is a positive factor with respect to potential aquifer volume and cost of distribution.
4/ Volume of potential aquifers.
5/ Current demand on groundwater resource.
6/ Average depth of drilling required per unit of proven gal/min capacity.
7/ Demand/storage ratio
8/ Location relative to existing water supply facilities and infrastructure.

Early in the review process it became apparent that one target area, that of the Maxwell Lake uplands, completely eclipsed all other candidates. The Maxwell Lake area will therefore be the focus of the following discussion.

1/ Government Reports:

Hodge, W.S. 1995: Groundwater Conditions on Salt Spring Island (MELP)

At the request of Islands Trust, W.S. Hodge of the Groundwater Section (MELP) carried out a review of groundwater conditions on Salt Spring Island in the early 90s. His findings were presented in a report dated 1995. This report was based on existing topographic and geological mapping of the island and on the well data base which at that time (1992) included 1535 wells. It was noted that 30% of the population of about 8000-residents were serviced by groundwater in 1992.
In his study Hodge divided the island into a number of groundwater regions based on topographic divides between natural basins.

In his consideration of the fractured bedrock aquifer which underlies most of the island Hodge recognized that groundwater availability is limited by bedrock fracture porosity rather than by total annual precipitation. Lacking details of the variation of this parameter he used an average storage coefficient of 10^{-4}. Using the hydrograph method for estimating recharge (Kohut, 1987) Dodge gives a global estimate of 25.4 mm or about 3% of annual precipitation for recharge. Hodge states that this estimate is highly sensitive to the value assigned to the storage coefficient and that future studies should be directed toward more realistic evaluation of this parameter. Using the estimate of 10^{-4} for storage coefficient (effective porosity) and an arbitrary 60 metre thickness for the aquifer Dodge calculated the total available storage per unit area of aquifer.

On the demand side Dodge assumed that the average daily consumption would be 500 Igpd or 2.27 m^3/day per well. The total demand on each groundwater region was found by multiplying the 2.27m^3/d by the number of wells in the region (from the data base). This demand was extended over the 100 day dry period of summer.

The demand on each groundwater region was calculated as a percentage of the available storage for that region.

Dodge's figure for demand/storage ratio for the Maxwell Lake upland area is 8%. This reflects the very low density of wells in the area.

2/ Water Well Database (MELP)

The Groundwater Section of the B.C. Ministry of Environment maintains an internet accessible database on wells drilled in the province. This provides information of varying quality on well locations, depths, lithologies intersected, and estimates of well capacities. While this system provides a useful source of data for general considerations of groundwater exploitation it does not provide precise xyz data on well locations nor does it provide standardized descriptions of geological units intersected. An additional shortcoming of this database is its incompleteness; drillers submit logs to government only on a voluntary basis.

There are no sites listed in the well database within the area of interest Maxwell Lake upland.

Areas of similar geology on Salt Spring which are outside of the area of interest include:

- Lees Hill area
- Reginald Hill
- Mount Belcher

3/ Reports on Well and Aquifer Evaluations (Islands Trust)

The Official Community Plan of Salt Spring Island requires proof of potable water as part of the land subdivision process. Testing and reporting on wells is to be carried by Professional Engineers or Geologists with expertise in the area of groundwater hydrology. The reports are retained by Island Trust and are available for study by interested parties. These provide a growing source of detailed information on the groundwater resources of the island.

There are no detailed reports covering individual wells or areas within the Maxwell Lake uplands. There are however several which describe the hydrologic character of fractured granitoid and sedimentary rocks similar to those of the subject area.

- Lowen, D.A. 1999: Stuart Road Subdivision, Salt Spring Island, B.C.; Well Impact Report.
- Kohut, A.P.: Natural Seasonal Response of Groundwater Levels In Fractured Bedrock Aquifers of the Southern Coastal Region of British Columbia.
- Potter 1999: Pump Test and Analysis on Sparks Well, Lot B, Section 53, Plan 5556, Cowichan District (Fulford Harbour).

4/ Published Geological Maps, Victoria Area (GSC, Muller 1980)

GSC Map 1553A Victoria, Scale 1:100,000

Very general display of geological features. Field traverses required to provide useful detailed information.

5/ Published topographic maps:

- National topographic system:
  92B 13E, 1:50,000
- BC Surveys and Mapping Branch topographic maps
  Salt Spring Island, DWG #M234C, Sheet 2, 1"= 1320 '
  Provides general topographic features but no fine detail.
- Trim maps:
  92B083, 1:20,000
  The published 1:20,000 scale topographic map based on the Trim data shows only poor definition of topographic details in the Maxwell Lake area.

6/ Aerial Photographs:

Air photo library, Victoria

B.C. Assessment Authority, Victoria

The following photos were reviewed at B.C. Assessments:

SRS 4853; 100 to 110 and 130 to 140

1:10,000 scale (1992)

Moderate resolution shows areas of bedrock exposure and Pleistocene drainage channel northwest of Maxwell Lake which may be aligned along major fracture zone. Photos provide areas of focus for ground traverses.

7/ Field Review:

A preliminary field traverse of the area northwest of Maxwell Lake carried out by GIGS on July 22, 2001 revealed information on local lithology and numerous topographic details of the area which are related to geological structure. It is evident that surface traverses in the area of interest could be used to upgrade the geological database and provide additional information to the Trim database and thereby improve the digital terrain model of the area.

There are a number of existing roads which provide access to the areas of interest. Most of these cross private land and their use would be subject to easement agreements with local landowners. Existing access easements of interest include those of NSSWD to Maxwell Lake and the BC Hydro access to its power-line right of way.

Task 2. *Quantify the long term potential for development of groundwater resources within or proximate to the service area.*

The Maxwell Lake upland area offers the greatest potential for groundwater resources within or proximate to the NSSWD service area and probably within the whole of Salt Spring Island (see figure 1). The following key elements contribute to this potential:

- Large area (approximately 8 km^2)
- High elevation (average height about 300 m ASL): This in combination with the area translates to a large potential aquifer volume with water stored at height being a net benefit vis-à-vis distribution costs.
- Favorable geology: Massive granite, volcanics, and conglomerate. All capable of supporting open fracture systems.
- Sparsely developed: Little anthropogenic contamination risk or competition for groundwater water reserves.
- Favorably located with respect to existing infrastructure (pipeline, roads, power)

An added long-term advantage to the development of groundwater reserves in the Maxwell Lake upland area would be its added support to the case for protection of the Maxwell Lake watershed. Aquifers and lakes are linked hydraulically and benefit from the same primary water source (precipitation) and suffer from the same sources of contamination. A fully protected aquifer in this area would extend beyond the limits of the surface watershed.
Figure 1 shows features of interest within the Maxwell Lake upland including topography, cadastral features, geology, and access.

AREA

The approximate surface limits of the potential aquifer in the Maxwell Lake area. This has an area of about 8 km^2. Note the existence of only large property blocks here (little development). Access to the area is via Cranberry Road. NSSWD has an existing pipeline here which supplies the Ganges area with Maxwell Lake water.

ELEVATION

Elevations within the area of interest range from about 200 to 500 metres above sea level, with an average of about 300 metres. The area is characterized topographically by a broad relatively flat ridge which is flanked to the southwest by steep slopes which drop toward Burgoyne Bay and to the northeast by ground which slopes moderately toward the valleys of Maxwell and Cusheon Creeks. Maxwell Lake occupies a depression located about midway along the ridge.

GEOLOGY

Large areas of Palaeozoic metagranitic and volcanic rocks, and Upper Cretaceous conglomerates are found along the crest and southwesterly slopes of the Maxwell Lake upland area. There are few wells in this area but elsewhere on the island these rocks provide a source of abundant high quality groundwater. Porosity of these rocks is limited to numerous fracture zones and faults. Their total bulk porosities probably range between 1×10^{-4} and 1×10^{-3}

Rock Type	Porosity	Area Km^2	Volume Km^3	Porous Vol to 200m (m^3)*
Granite	.001	3.26	.78	$.78 \times 10^6$
Volcanic	.001	1.90	.46	$.46 \times 10^6$
Conglom/ss	.001	2.84	.36	$.36 \times 10^6$
Totals		8.0	1.6	1.6×10^6**

Table 1 Estimated Characteristics of Maxwell Uplands Aquifer

* Assuming a bulk porosity of 10^{-3}

** Total estimated storage volume is about 3x the volume of Maxwell Lake

EXISTING DEVELOPMENT

There is very little land or groundwater development within the Maxwell Lake upland area. The provincial well database has no entries for this area.

RECHARGE POTENTIAL

Average annual precipitation: 0.8 m

Total volume of water available for recharge: $8 \times .8 \times 10^6 = 6.4 \times 10^6$ m^3

This is 4 times the estimated porous volume of the aquifer down to -200 m depth (and about 12 times the estimated volume of Maxwell Lake).

DEVELOPMENT POTENTIAL

There are no wells within the area of interest to provide direct evidence of its groundwater potential. Areas of similar geology on Salt Spring Island which have a relatively high density of wells and for which data is available have been selected to provide indirect measures of the expected capacity of the Maxwell Lake upland area. Five areas included in this review include three areas of Salt Spring underlain by granitic rocks (Lees Hill, Stuart Road, and Reginald Hill); one of coarse Cretaceous clastic rocks (Mount Belcher conglomerates); and by way of comparison one of granitic rocks on the Sanich peninsula.

The Lees Hill area provides data on 20 wells drilled into fractured granite immediately to the southeast of the subject area. Reginald Hill offers data on 5 wells also drilled in granites of the Fulford Harbour area. The Stuart Road subdivision offers 24 wells in granite of the upland area immediately west of Stuart Road for which formal pump testing results give sound evidence of long term well capacities. The Belcher Heights subdivision above Ganges utilizes 12 wells drilled into Cretaceous conglomerates and sandstones. An area of Sanich with wells in Jurassic granites which has been reviewed by Kohut is also included.

Table 2 summarizes details of the areas reviewed which offer insight into the groundwater potential of the Maxwell Lake upland. For purposes of this discussion the term specific capacity used in this table is defined as the average long term capacity of wells in gallons per minute per 1000 feet of drilled well. For each area reviewed the specific capacity was determined by dividing the sum of the individual well capacities by the total length of the wells. With the exception of the Stuart Road subdivision, all of the reviewed areas provided well capacity estimates established by their respective drill contractors using short term air lift tests. These driller's estimates are generally higher than the capacities defined by formal pump tests. In table 2 the specific capacities given are based on driller's capacities conservatively reduced by a factor of 2.

Well Field	No of Wells	Rock Type	Specific Capacity*	Data source
Lees Hill, SSI	20	Granite	22.00	MOE database
Stuart Road, SSI	24	Granite	8.60	Lowen
Reginald Hill, SSI	5	Granite	21.54	MOE database
Belcher Heights	12	Cong/sandst	17.67	MOE database
Sanich	29	Granite	38.34	Kohut

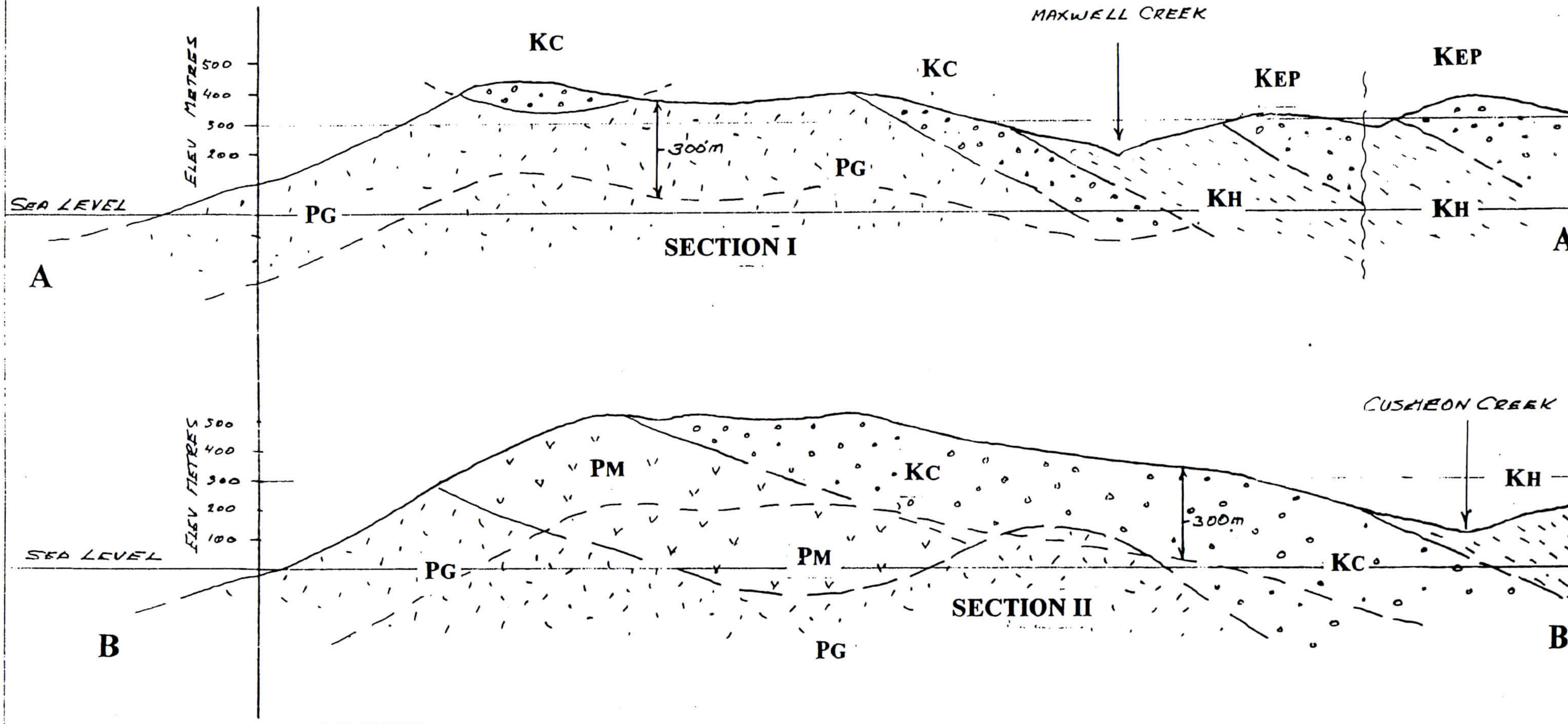
Table 2: Specific Capacities of Comparable Local Well Fields in Fractured Rocks
* Average Long Term Capacity per 1000 ft of drilling based on pump test results or 50% of drillers estimates.

It should be noted that the subsurface structures which are the most productive water sources are open fracture zones which provide both storage volume and high hydraulic conductivity. These features may be recognizable on surface or may be detectable by applied geophysical methods. They constitute the prime targets for exploration in fractured rock aquifers.

The average figures for specific capacities given above are based on data from wells drilled at random locations, within their respective areas, without the benefit of hydrogeological studies. We would submit that an investigation designed to locate major fracture zones may significantly improve the expected capacities of wells drilled in Maxwell upland area.

WATER QUALITY

Bacterial contamination is generally absent from the deep fracture systems of granites and conglomerates. Bacteria are usually introduced to the system by drilling, testing, and pump installation. This contamination can readily be eliminated by short-term chlorine treatment. Community use of water wells will require some form of ongoing treatment as per the regulations of the health act. In the case of wells exploiting pristine aquifers this treatment requirement is usually justified due to inadequacies of the distribution system rather than those of the aquifer.



LEGEND

KEP	**Extension - Protection Formation** Conglomerate, Sandstone, Minor shale	
KH	**Haslam Formation** Shale, Minor sandstone	
KC	**Comox Formation** Conglomerate, Sandstone, Minor shale	
PG	**Salt Spring Intrusions** Meta Quartz Porphyry, Meta Granodiorite	
PM	**Myra Formation** Altered Basalt and Andesite	

FIGURE 2
GULF ISLANDS GEOTECHNICAL SERVICES
PROJECT 2458 NSSWD STUDY, GRO UNDWATER SECTIONS
Scale 1: 20,000 R.Potter P.Eng. July 6 , 2001

It is expected that the water from some wells drilled in granites and conglomerates of the Maxwell Lake upland area will have concentrations of iron and/or manganese in excess of the limits set by the Guidelines for Canadian Drinking Water Quality. The limits for iron and manganese are set as "aesthetic objectives" in that they are not considered to be toxic but may impart objectionable taste to the water and cause staining of laundry and plumbing fixtures. The risk of encountering other metallic contaminants in the groundwater of these rocks is very low.

The Permian volcanic rocks of the subject area belong to the Sicker volcanic assemblage. On a regional scale these rocks are host to metallic mineralization at a number of sites on Vancouver Island (eg: Mount Sicker near Duncan, Buttle Lake in Strathcona Park). There is a recognized potential for metallic contamination of water circulating within fractures in these rocks.

PROPOSED INVESTIGATION OF GROUNDWATER RESOURCE

PHASE I

Review of surface features existing within the area of interest including:

- Geology/Hydrology/Topographic field review: Collection of data on topography, lithologies, structures, streams, springs etc. This will provide site specific details such as location, orientation, and character of fracture zones to be used in locating optimal well locations.
- Surface Geophysics: An electromagnetic (EM) survey to locate major fracture zones.
- Land ownership review: Availability of access, drilling sites, water pipeline routes.

PHASE II (Details to be modified as per the results of phase I)

Preliminary drilling program:

- A minimum of three, 200 metre holes, spaced approximately 500 metres apart, located within the fractured granites northwest of Maxwell Lake.
- Each well to undergo a 72 hour pump test to be carried out at pumping rates of about 60% of driller's estimated capacity.
- Sampling and analysis of water for bacteriological, chemical, and physical parameters.
- Analysis of pumping data.
- Engineering reporting on test results.
- Simulation modeling of aquifer to provide the following preliminary feasibility estimates:
    1) Overall capacity of aquifer.
    2) Number and optimal spacing of wells required to exploit the aquifer.
    3) Drawdown predictions for the area.

PHASE III

Development of the aquifer.

- Land base: Land purchases or easements for well sites, roads, pipelines, storage.
- Infrastructure: Roads, power supply to well sites, pipelines.
- Well drilling and completion.
- Engineering and capacity testing. Continuous monitoring of pumping rates and water levels within the fracture system.
- Upgrading of simulation model to incorporate all new data and improve the predictive capacity of the model.
- Management and monitoring. Emphasis should be placed on the acquisition of data required to maintain volume and quality objectives.

BUDGET ESTIMATE FOR PHASES I AND II

PHASE I				
Geology/Hydrology Review: 10 days @ $700/day			$7000	
EM Survey : MaxMin or EM34				
15 km @ 3 km/day				
Crew, equip rental, field expenses				
	5 days @ $1200/day	$6,000		
	Shipment and insurance	$ 500		
			$6500	
Land ownership review (Trust in-house) Estimate			$2500	
TOTAL PHASE I				$16,000
PHASE II				
Drilling: 600 m @ $50/m			$30,000	
Capacity Testing:	Equipment rentals	$ 1,100		
	Pump installations	$ 1,500		
	Pumping 72 h x 3 x $50	$10,100		
	Recovery 12 x 3 x $50	$ 1,800		
	Total capacity testing		$14,500	
Laboratory Analyses			$ 1,000	
Reporting			$ 3,000	
Modeling			$ 3,500	
TOTAL PHASE II				$52,000
Contingencies (10%)				$ 7,000
TOTAL PHASES I &II				$75,000

This report labeled 2458-3 and dated July 24, 2001 has been prepared by Gulf Islands Geotechnical Services for Islands Trust and the North Salt Spring Waterworks District as part of a study undertaken by Aqion Water Technologies Ltd.

If you have any questions or require further information please contact the writer.

Gulf Islands Geotechnical Services

Per: Robert Potter, P.Eng.