GALIANO GROUNDWATER STUDY

Submitted To:

Islands Trust

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Submitted By:

Waterline Resources Inc.
Nanaimo, BC

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WL11-1755

Waterline Resources Inc.

EXECUTIVE SUMMARY

Galiano Island and other Gulf Islands pose unique challenges in terms of sustainable development of fresh water resources in conjunction with future land use planning initiatives. Galiano has a relatively small landmass and land development will undoubtedly impact the groundwater resource in some way through reduced volumes of infiltrated rainwater and subsequent recharge to underlying aquifers and increased water supply demands. In addition, surface activities have the potential to affect the quality of recharging water, and therefore must be approached in a careful and thoughtful manner. These issues are further complicated by the possibility of salt water intrusion common to coastal environments.

Over the last few decades, a considerable amount of hydrogeological work has been conducted on Galiano Island. Although individual hydrogeological studies reference previous studies, historical data is not easily integrated so that groundwater use and aquifer response can be easily assessed over time.

Although theoretical calculations can be made to predict potential impacts, assumptions and uncertainties can lead to incorrect or ambiguous predictions. Furthermore, no requirement for follow up groundwater monitoring exists, and no verification of predictive estimates occurs. Municipal planning could be greatly improved if there were an opportunity to assess the current health of groundwater supply aquifers and to accurately predict the long-term cumulative effects of existing groundwater extraction activities, or activities related to potential future land development.

Approximately 1050 water wells are registered with BC MoE on Galiano Island. These wells service domestic households, businesses, and industrial operations, yet very few of these wells are being monitored in terms of groundwater diversion, water level, or quality. Only two wells (<0.2%) are currently being monitored for water level by the BC Ministry of Environment in the Sturdies Bay area. No other data is readily available to the public from which to assess current groundwater conditions.

Continuous long-term monitoring of aquifer response to natural phenomenon such as precipitation events and tidal fluctuations, or human activities such as groundwater pumping and diversion, is fundamental to developing an understanding of groundwater systems. To understand the "plumbing system" within the aquifers, extending from the recharge to discharge areas, it is important to assess the cause and effect relationship of these key elements by implementing a continuous, long-term monitoring program. Such an approach provides an early-warning system for aquifer management and the needed information for future land use planning. It would also allow for quick mitigative response so that corrective action can be implemented if adverse impacts are identified so that safe and reliable groundwater supply can be preserved for future generations.

Waterline has developed an approach that we believe will maximize the understanding of aquifers on Galiano so that they may be protected for generations to come.

- As a first step, Waterline recommends that all existing water wells be catalogued on the Islands Trust GIS system so that planning initiatives can be considered in the context of existing groundwater users and aquifers. As new subdivisions or developments requiring additional groundwater extraction are proposed, groundwater testing and long-term monitoring should be required such that it can be integrated into an existing groundwater database for future consideration. Although past activities and groundwater data cannot entirely be compiled in this manner, any future data collected can be integrated and, over time, accurate conceptual models of aquifers within identified groundwater regions can be established.

- Groundwater conservation practices such as the use of cisterns need to be encouraged and community outreach programs are needed so that residents understand the importance of groundwater protection measures and the need for participation. Concepts such as best management practices and groundwater conservation measures need to be explained so that all present and future people who live on the island adopt sustainable practices to conserve and protect fresh groundwater sources.

- Hydrogeology assessments related to proposed subdivisions and developments requiring additional groundwater extraction should be clearly outlined in bylaws to include field verification of existing, nearby wells, an assessment of the transmissivity and storage coefficient for the aquifer being proposed for development, and some prediction of the cumulative drawdown impact that could occur to the aquifer and existing users over a reasonable timeframe (20-30 years). This approach is in accordance to standard hydrogeological practices and will help to tailor new developments to accommodate the very unique environments that occur across Galiano. This approach should update the existing subdivision servicing requirements.

- Aquifer mapping and particularly aquifer vulnerability mapping should be updated once baseline groundwater data is available across the island. Land use planning and activities can then be fully developed for each groundwater region and informed decision can then be made on a site-specific, or project by project basis. Mitigative strategies may be set in place to reduce impacts where possible through low impact development practices, water conservation, capture and infiltration measures, establishing communal well systems, and through other measures.

Managing groundwater resources will undoubtedly present unique challenges but also presents a unique opportunity for innovation and setting the template for the approach to aquifer management in an island environment.

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1.0 INTRODUCTION

Galiano Island is located on the outer edges of the Southern Gulf Islands in Southwestern British Columbia (Figure 1). It has a rural island community and like many of the Gulf Islands, water supply issues relating to quantity and quality have become an increasing concern with growing development pressures.

The Galiano Local Trust Committee (LTC) is currently reviewing and evaluating the Official Community Plan (OCP) for Galiano with the intent, among other issues, of balancing the water supply requirements for area growth against environmental needs and future sustainability. As part of the OCP review, a Galiano Water Advisory Committee was tasked with reviewing available water supply related information and to identify recommendations that could be implemented by the LTC.

Based on the Water Advisory Committee's findings, the Islands Trust commissioned Waterline Resources Inc. (Waterline) to complete the enclosed groundwater study. The purpose of the study is to provide additional research into the state of water supply on Galiano Island and to clarify specific groundwater issues and concerns. This information will be submitted to the LTC to assist with the ongoing OCP review and update.

1.1 Objectives and Scope of Work

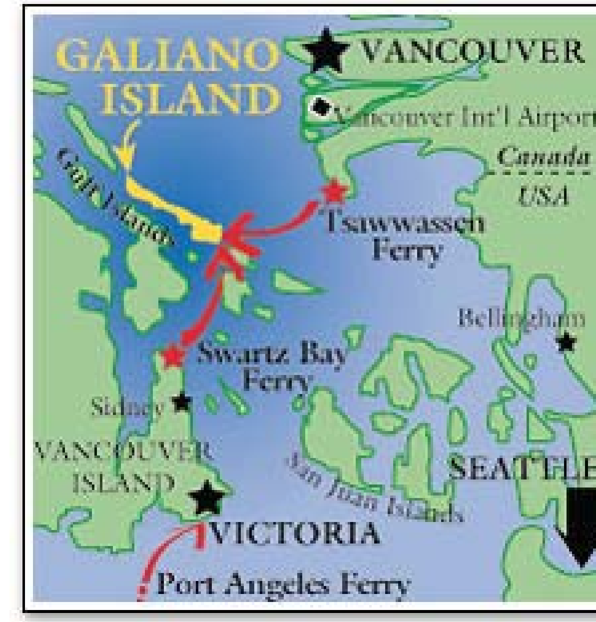
Groundwater resource sustainability is recognised as a significant issue in this area for the following reasons:

- Very low recharge rates during the summer dry season cause groundwater levels to drop, thereby reducing supply. At the same time, annual summer populations increases significantly causing demand to increase.
- Ongoing development pressures exist, and there is a concern that if development is managed poorly it could adversely impact groundwater resources in the region which could have a detrimental effect on existing residents and businesses.
- Problems with saltwater intrusion, particularly in areas with high population density, appear to be increasing with time.
- Potential climate change impacts are uncertain and could put increased pressure on the groundwater resource sustainability.

A thorough understanding of the groundwater resource potential beneath Galiano Island is required to anticipate and mitigate problems related to groundwater extraction. As such, the study's objectives were as follows:

- To review available information and to recommend methods for identifying critical groundwater areas including recharge and water deficient areas;
- To perform a data gap analysis and to propose a program for collecting the data; and,
- To assess the existing and potential land use impacts on critical groundwater areas and to propose management strategies to mitigate or prevent further impacts.

Galiano Island
Aerial Photography



N

Legend

- River
- Wetland
- Lake

0 1 2 3 4 5
Kilometres

Source: Adapted from Islands Trust GIS Database

PROJECT	**Galiano Groundwater Study** **Galiano Island, British Columbia** **Islands Trust**
TITLE	**LOCATION MAP**

Waterline Resources Inc.

PREPARED BY: Waterline Resources Inc.	
PROJECT: WL11-1755	
COMPILED BY: CGD	**FIGURE 1**
DATE ISSUED: February 2011	
REVISED: --	

To meet these objectives, Waterline's scope of work included the review of available reports and references provided by the Islands Trust and other research sources. This information was considered within the context of nine specific questions outlined within the Invitation to Quote (ITQ-2010-.013, Appendix A) that pertained to characterizing critical groundwater areas, groundwater quality issues, critical groundwater area management and future steps. The report enclosed herein has been prepared to address the specific questions and to provide recommendations for the LTC.

Waterline recognizes that some of the recommendations provided herein may not appear to be within the mandate of the LTC at this time, however, the ideas have been presented for consideration and the means to implement them may yet be found.

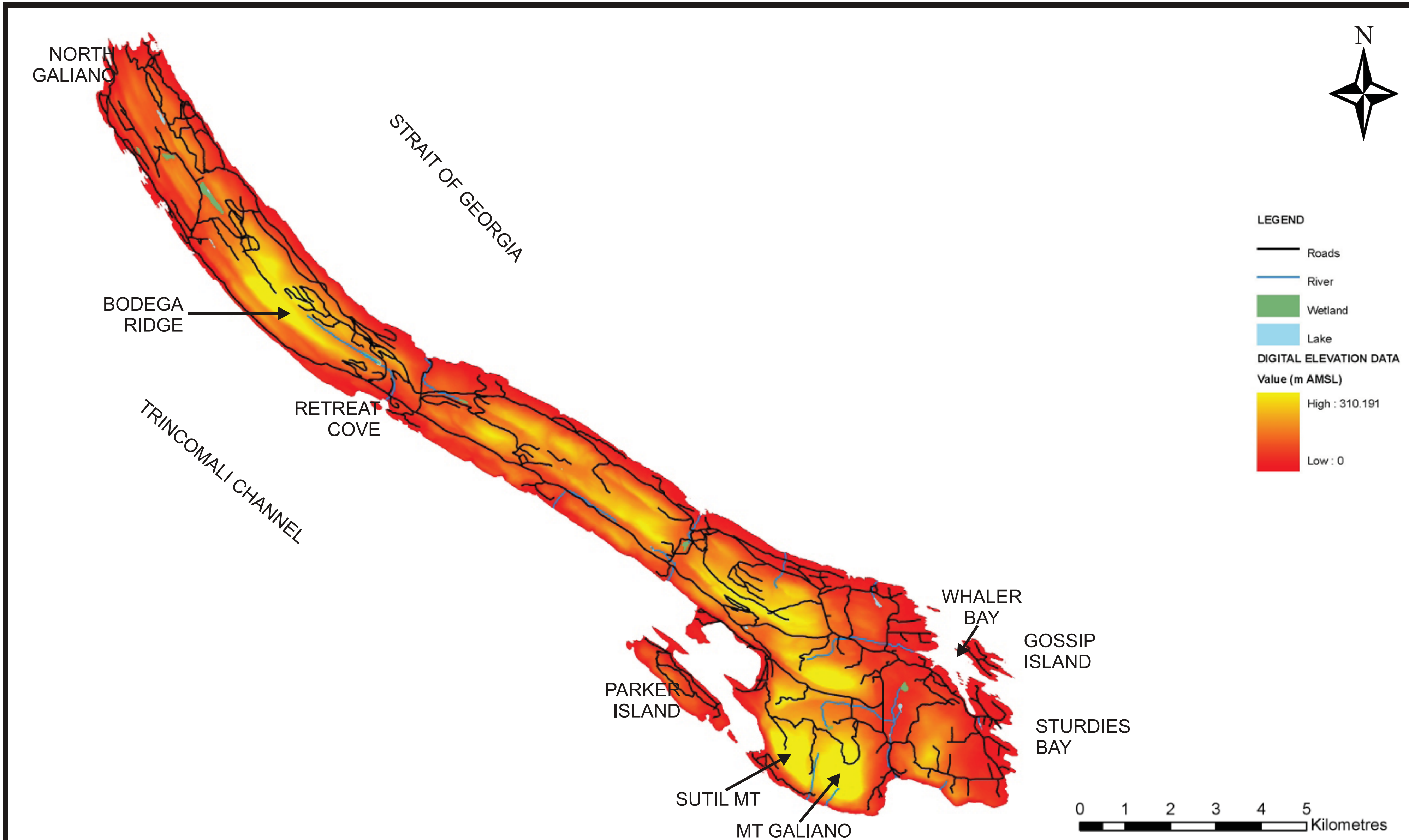
2.0 GALIANO ISLAND PHYSIOGRAPHY AND GEOLOGY

Galiano Island is a long, narrow island with elevations ranging from sea level to 311 m above sea level at Mount Galiano (Figure 1). The island is broken up into a series of geologically controlled ridges and valleys, which control local drainage patterns. Small wetlands, bogs and creeks are common across the island. A digital elevation map is presented as Figure 2 with yellow coloured areas indicating higher elevation and red coloured areas indicating lower elevation.

Quaternary deposits on Galiano Island comprise either thin, compact glacial till or fluvial sands and gravels deposited by meltwater (Mordaunt and Hodge, 1983). Based on provincial soils mapping, more than 60% of the soils on Galiano Island are classified as well drained (Greene, et al., 1989) suggesting coarse-grained sedments (eg: sand and gravel). The deposits are typically thin and with poor groundwater potential except in limited, topographic trough areas (Kohut and Johansson, 1997).

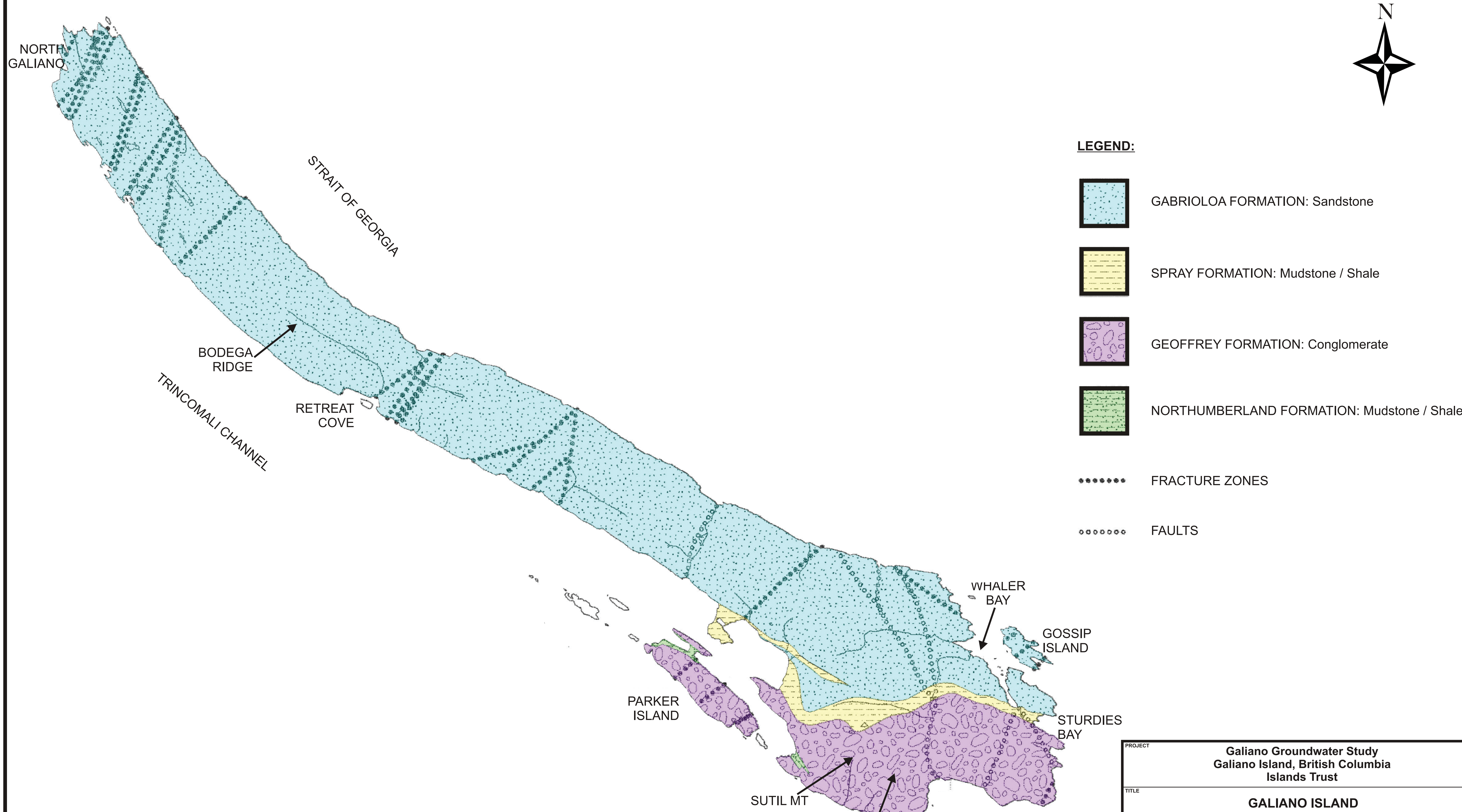
The bedrock geology beneath Galiano Island comprises fractured sedimentary rocks of the Late Cretaceous Nanaimo Group complex, which consists of alternating sequences of northeast dipping, inter-bedded sandstone/siltstone-dominant and mudstone/shale sequences. Four formations have been mapped on Galiano Island and include the Gabriola Formation (sandstone), the Spray Formation (mudstone/shale), the Geoffrey Formation (conglomerate) and the Northumberland Formation (mudstone/shale) (Muller and Jeletsky, 1970). The bedrock geology of Galiano Island is shown on Figure 3.

Figure 4 shows a schematic of groundwater flow in fractured bedrock typical of the Gulf Islands environment (Allen et al., 2009). The orientation or the strike of dominant fault systems is northeast across and approximately perpendicular to the long axis of Galiano Island (Figure 3). These fracture or faults systems are generally found to be steeply dipping. According to Allen et al., (2002), many observed fractures at surface are open and may be very important from an aquifer recharge perspective. However, at depth the fractures have smaller widths or apertures and are occasionally mineralized and sealed which reduces the bedrock permeability and the corresponding yield of aquifers in the subsurface.



REFERENCE: adapted from Islands Trust GIS Database

PROJECT	**Galiano Groundwater Study** **Galiano Island, British Columbia** **Islands Trust**
TITLE	**GALIANO ISLAND** **DIGITAL ELEVATION MODEL**
Waterline Resources Inc.	**PREPARED BY:** Waterline Resources Inc. **PROJECT:** WL11-1755 **COMPILED BY:** JAM **DATE ISSUED:** February 2011 **REVISED:** –
	FIGURE 2



MAP REFERENCE: from *Bedrock Lithology and Structure* after: Foweraker (1973), Carter (1976), Muller (1980); and *Assessment of Groundwater Availability and Quality, Galiano Island*, Kohut & Johanson (1998)

PROJECT
Galiano Groundwater Study
Galiano Island, British Columbia
Islands Trust

TITLE
GALIANO ISLAND
BEDROCK GEOLOGY

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PROJECT: WL11-1755
COMPILED BY: JAM
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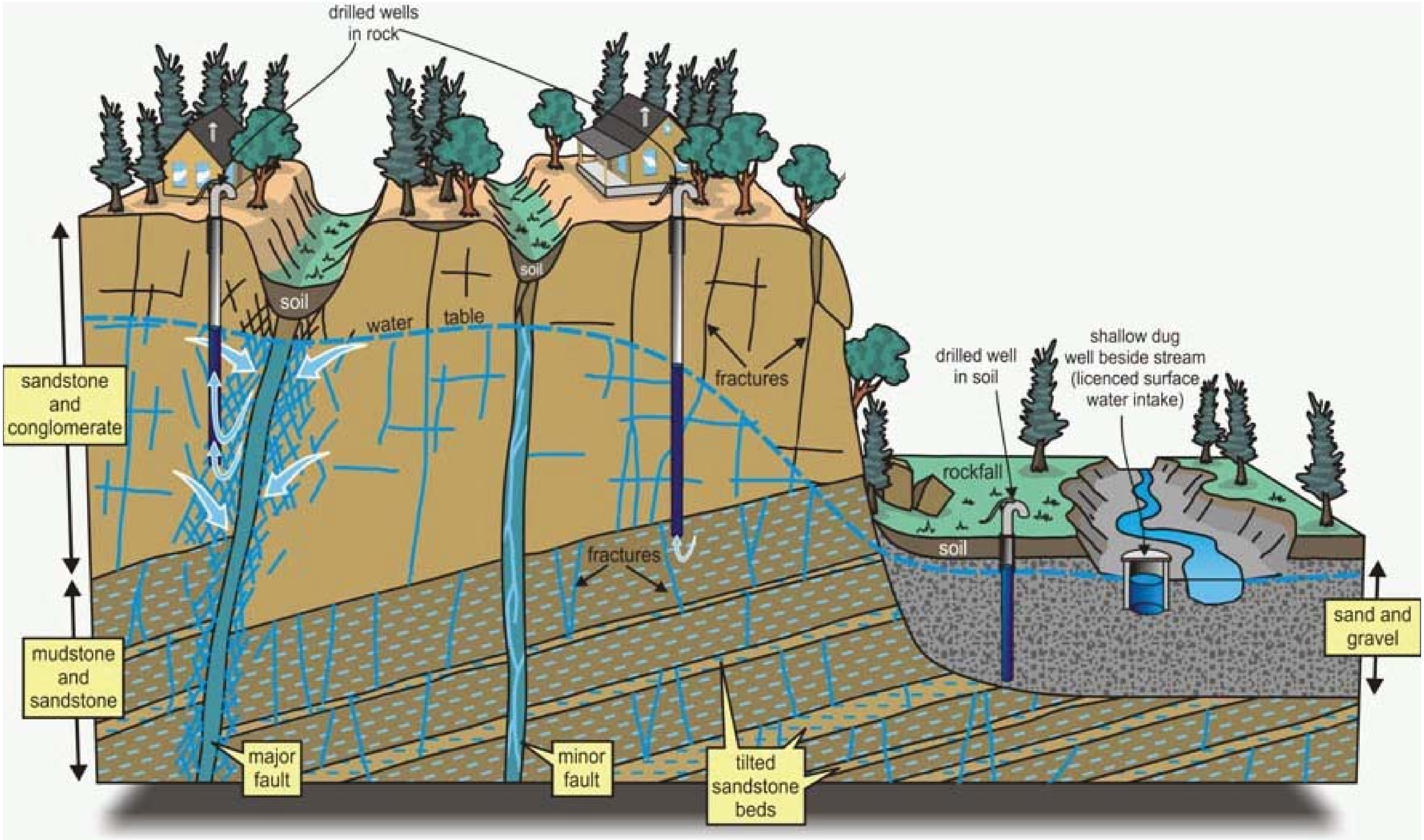
FIGURE 3



REFERENCE: Allen et al., 2009

PROJECT	Galiano Groundwater Study Galiano Island, British Columbia Islands Trust
TITLE	**SCHEMATIC SHOWING GROUNDWATER IN FRACTURED BEDROCK**
Waterline Resources Inc.	**PREPARED BY:** Waterline Resources Inc. **PROJECT:** WL11-1755 **COMPILED BY:** CGD **DATE ISSUED:** February 2011 **REVISED:** –
	FIGURE 4

Figure 5 shows the water well distribution across Galiano Island based on data from the BC Water Resources Atlas (MoE, 2011). As shown, the wells are predominantly located along coastal areas in southern Galiano. Each well has been classified in terms of completion depth. As shown, while the well completion depths vary across Galiano, many of the wells are completed at depths between 100 and 150 m below ground level, which are likely below sea level. This will be discussed further in Section 5.

Figure 6 presents three cross-section transects through Galiano at the locations shown on the inset map and also shown on Figure 5. The approximate ground surface, well depths and piezometric surfaces are indicated. As shown, the piezometric surface mimics topography in a muted manner and is highest in the central portion of the island and lowest near the coast. Based on the topographic relief and measured water levels in existing water wells, groundwater flow across Galiano Island is from the inland areas towards the south and north coastal areas (see cross-sections A-A', B-B', and C-C', Figure 6).

The Gabriola Formation sandstones, which cover about two thirds of the island, have an aquifer transmissivity, or the ability of rock to transmit groundwater, of approximately $3x10^{-5}$ m^2/s (Surrette et. at., 2008). Such values are generally considered low for sandstone aquifers suggesting moderate to low permeability and well yield in the Gabriola Formation sandstone. The mudstone dominant Spray Formation exhibited a geometric mean transmissivity of $2.7x10^{-5}$ m^2/s (Surrette et. at., 2008), which is less that half of that observed for the Gabriola sandstone and typical for mudstone/shale rock mass.

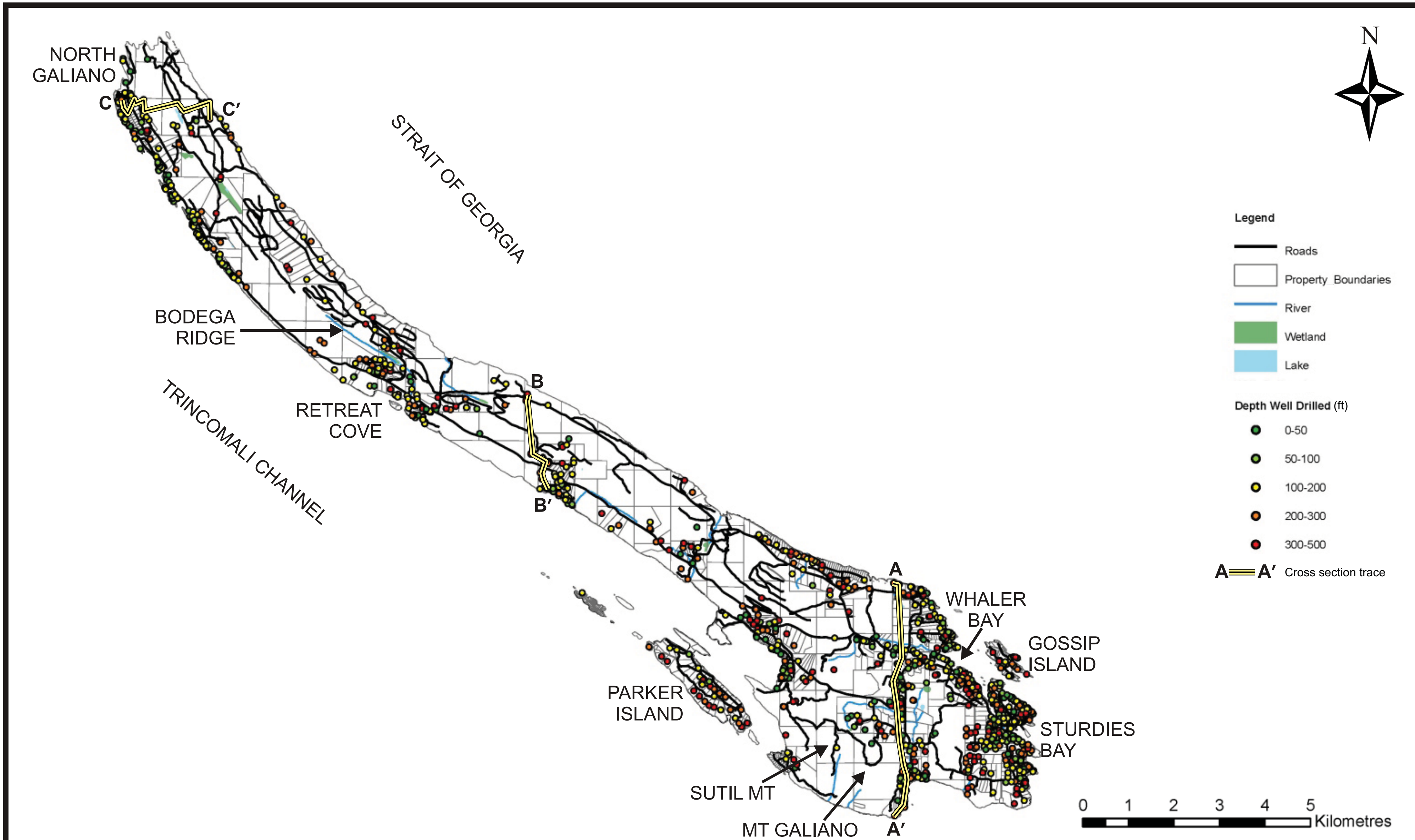
3.0 CHARACTERIZING CRITICAL GROUNDWATER AREAS (CGWA)

In accordance with the terms and conditions, the following sections will address specific questions 1 through 4.

3.1 Existing Watershed Mapping

Q1) Assess the utility of using existing Islands Trust Watershed mapping to delineate/revise groundwater regions.

The Kohut and Johanson (1998) groundwater region mapping effort was to provide a means for describing and comparing key groundwater areas across the island. As stated in their report, groundwater regions should reflect more than topographic relief and surface drainage features. A groundwater region should also incorporate subsurface geologic and structural conditions, the relative land areas, topographic slope, groundwater use, and similar aquifer characteristics.



REFERENCE: adapted from BC Water Resources Atlas (MoE, 2011)

PROJECT

Galiano Groundwater Study
Galiano Island, British Columbia
Islands Trust

TITLE

GALIANO ISLAND
WATER WELL LOCATIONS AND DEPTHS

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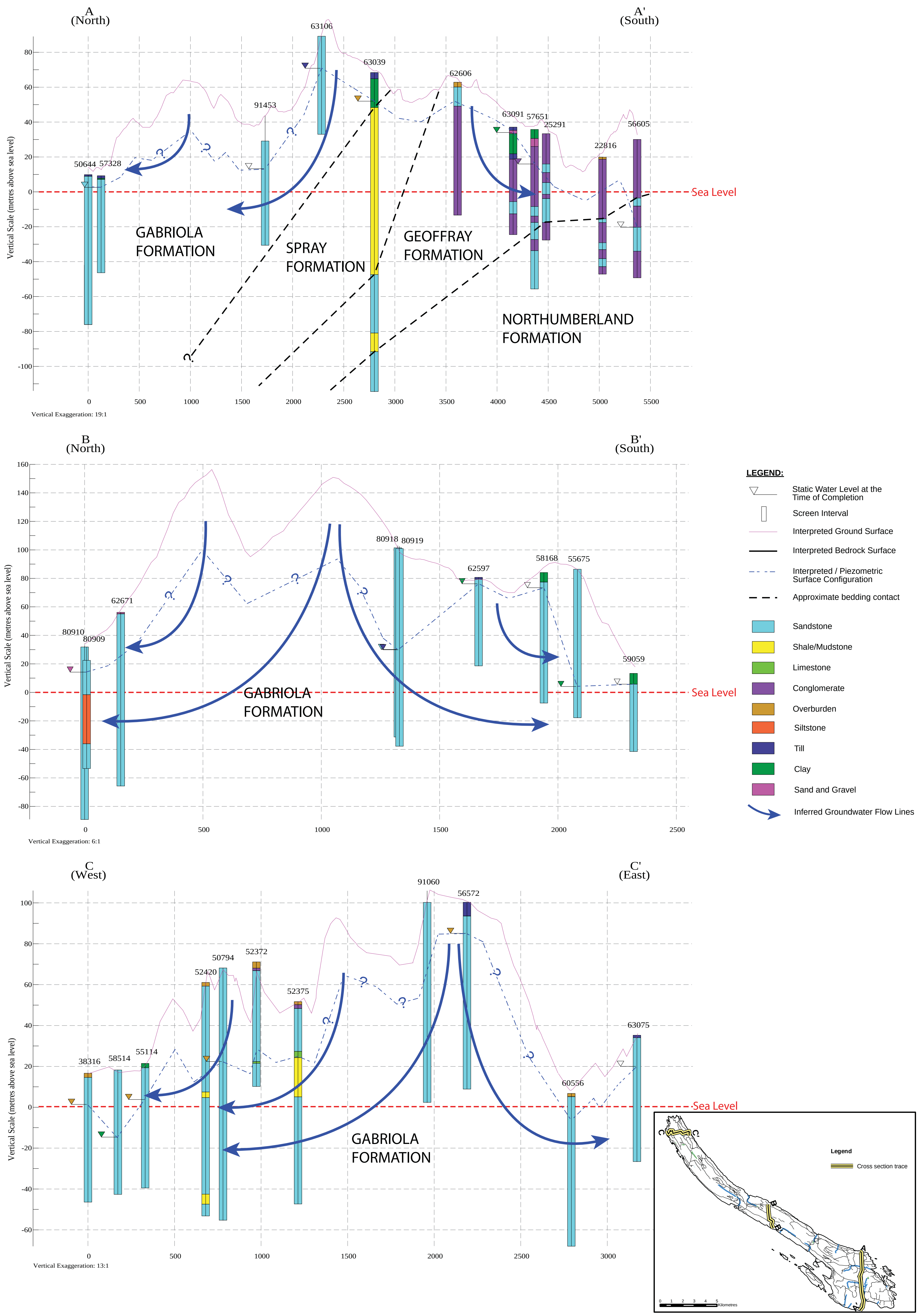
FIGURE 5



NOTES:

- Water levels estimated based on known water levels and ground elevations.
- Water levels shown are those taken during the drilling of the borehole.
- Data concerning the various strata have been obtained at the borehole locations only. The soil stratigraphy between boreholes has been inferred from geological evidence and so may vary from that shown.
- Freshwater/Seawater interface is unknown.

PROJECT

Galiano Groundwater Study
Galiano Island, British Columbia
Islands Trust

TITLE

HYDROGEOLOGICAL CROSS SECTIONS

Waterline Resources Inc.

PREPARED BY: Waterline Resources Inc.
PROJECT: WL11-1755
COMPILED BY: CGD
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REVISED: --

FIGURE 6

Boundaries related to groundwater regions are not necessarily the same as surface water boundaries that correspond to the watershed boundaries identified in the Islands Trust GIS database. This is because subsurface geology may cross from one watershed to another. This is shown in Figure 6 (A-A') where groundwater that is recharged on the south slope of the island could flow to the north coast of the island as it follows the Gabriola Formation to the north.

The boundaries identified by Kohut and Johanson (1998) provide a reasonable approach to compartmentalize island groundwater resources and appear to be based on sound hydrogeological principles. Waterline does not recommend using the watershed mapping to delineate or revise the established groundwater regions.

Please note that regardless of the regional division of groundwater areas, pumping impacts can cross the boundaries so caution should be exercised when applying groundwater regions as a management tool to subdivision or development planning.

3.2 Digital Elevation Mapping

Q2) Assess the utility of using existing Islands Trust Digital Elevation Mapping (DEM) to delineate or revise recharge and discharge areas.

In a natural fractured bedrock aquifer system, rainwater percolates downward through the soil and rock at the ground surface and recharges underground fractures which form the aquifer. The water continues to flow down through the fractures until the fracture is exposed along a slope as a seep or a spring, it is pumped out by a well that intersected the fracture, or it discharges to along the coast. To understand this process, geology, geological structure (bedding, folding, faulting), vegetation, topographic slope, and known hydrogeological characteristics must also be considered when attempting to characterize recharge and discharge areas.

Digital Elevation Mapping is a powerful tool that can be used in hydrogeology to provide better estimates of ground elevation from which groundwater elevation levels and hence flow models may be derived. On its own, however, it does not adequately represent the environmental conditions that influence groundwater recharge and discharge in the subsurface aquifers and has little utility in their delineation.

3.3 Standards and Criteria for Critical Groundwater Areas

Q3) Review and comment on standards/criteria for identifying critical groundwater areas in previous reports, including commenting on the utility of the following groundwater supply measures: Demand/storage ratio, demand estimates, recharge rates, storage coefficients, water balance modeling and analysis of topography, soils and geologic structure.

The following sections summarize a review completed for standards or criteria used to identify critical groundwater areas from previous reports.

3.3.1 Demand Storage Ratio

Demand storage ratio by definition is the ratio of the water supply demand in a region versus the estimated amount of groundwater that is stored in a defined aquifer. Although the ratio can be useful in certain environments where the storage of groundwater can be accurately determined, fractured bedrock environments pose a particular challenge due to the variability of aquifer storage.

Fundamental assumptions need to be made in order to complete the demand storage calculation:

- Number of wells – This reflects the number of wells based on BC Water Resources Atlas records which may not accurately reflect all wells in use. Field verification would be required for confirmation;
- Daily well use – See discussion in Section 3.3.2.
- Thickness - The ability to assess aquifer thickness in a fractured bedrock system, whereby dominant fractures may be near vertical, is difficult.
- Storage coefficient – See discussion in Section 3.3.4.

Theoretically, a demand storage ratio of greater than 50% means that 50% of the groundwater resources are being utilized. A demand storage ratios of 100% means that groundwater resources are being fully utilized. In such a case, groundwater use restrictions and perhaps even a moratorium on groundwater extraction activities should be put into effect in order to ensure sustainable management of the resource.

Uncertainty in the values used to calculate the demand storage ratio can result in significant variability in the estimates. For example, the demand storage ratio calculations prepared by Harrison (1994) and Mordant and Hodge (1983) were an order of magnitude different than those prepared by Kohut and Johanson (1998) due to differing opinions on appropriate storage coefficients. In the absence of accurate data relating to the fundamental assumptions, this tool has little benefit or meaning and caution needs to be exercised when developing planning guidelines based on such uncertain calculations.

3.3.2 Demand Estimates

Various approaches have been considered to estimate water demand on Galiano Island. Table 1 summarizes a selection of demand estimates for consideration.

Table 1: Demand Estimates

Source	***Demand***
Previous Demand Estimates for Galiano	(m^3/day)
Mordaunt and Hodge (1983)	1.89
Harrison (1994)	0.9-2.3
Kohut (1988)	0.9
Thurber (1993)	0.9-1.89
Other sources	
Islands Trust Land Use 127 Bylaw (1999)	2.3
Capital Regional District (CRD, 2007)	1.2
Salt Spring Island Water Council (SSI, 2010)	0.8
Harrison (1994) community systems on Galiano	0.18-1.16
Galiano Water Advisory Committee (2010) Galiano Estates and Parker Island resident	0.27-0.6

The Galiano Water Advisory Committee (2010) indicated that permanent residents are, for the most part, aware of measures for conserving water; however, the summer influx of visitors may not be as sensitive to the need to conserve water. The seasonal change in demand has been estimated, but still carries uncertainty. As can be seen from the variety of references in Table 1, there is no strong agreement of representative water use values that can be applied universally across the Island.

In the absence of local monitoring data, a conservative value of 0.9 m^3/day (200 igpd) is considered a reasonable estimate for average residential usage based the more recent studies cited in Table 1. The existing potable water supply standard volume should not be reduced; however, due to expected variability in demand seasonally and potential well production losses with time.

Agricultural activities may be consuming water. Commercial and industrial businesses may also have varying water requirements. Some individual water service areas or systems may already be collecting this information, but it is not being undertaken universally for all systems, nor all users. Where water consumption data is being collected (CRD or private systems on Galiano), the data should be compiled and tracked. Where the data is not already being collected, it is possible to confirm the actual water use in communities if simple water metering devices were installed for any new wells. This would remove some of the uncertainty in the water demand estimate for specific areas. More information on this subject will be provided in Section 6.

Recharge Rates

Recharge to aquifers occurs from the infiltration of precipitation. The amount of precipitation that infiltrates and recharges aquifers is a function of the permeability of ground cover, climatic conditions, topographic slope, and the fracture porosity of the bedrock near the surface. Approximately 80% of Galiano Island has been defined as probable recharge area and only a thin strip around the coastline situated below approximately 50 m above sea level has been defined as probable discharge areas (Kohut and Johanson, 1998).

Estimates of recharge rates applied to Galiano in the previous reports have ranged from 0.1% (Mordaunt and Hodge, 1983) to 12% (Piteau Associates, 1994). Kohut and Johanson (1998) estimated recharge on Galiano Island to be less that 10%. Dr. Allen et al. (2009) used numerical modelling to derive recharge estimates between 16-45%, on the Gulf Islands. However, based on more recent research findings, Dr. Allen has indicated that the higher end recharge estimate was highly unlikely. In her opinion, recharge is probably between 10 and 20% on the Gulf Islands (Dr. Allen, pers. comm., 2011).

As can be seen, hydrogeologists don't often agree on recharge numbers because they do range from one area to another and it is not always the best practice to select one number and apply it to an entire island. In Waterline's opinion the recharge number itself is not effective when used as a management tool to assess critical groundwater regions in terms of potentially available water volumes for extraction because there is too much potential variability.

Recharge is still import to the aquifer and to maintain natural recharge rates, potential land use impacts should be minimized, where possible and artificial recharge, or rainwater infiltration practices should be encouraged in any development activity that is likely to adversely impact natural recharge. The potential for adverse impact to recharge should be determined based on site specific information.

3.3.3 Storage Coefficients

A storage coefficient describes the volume of water that will be released from storage with a decline in hydraulic head in a particular aquifer. Typical storage coefficients used for demand storage calculations ranged from 0.001 to 0.0001. These were based on previous groundwater evaluations in the Gulf Islands by Foweraker (1974), Hodge (1978), Chwojka (1979) and Kohut and Johanson (1998) and may or may not apply to Galiano. Site specific aquifer testing would need to be completed while monitoring numerous observation wells in order to confirm the local storage parameter and its variability within the region. As indicated in Section 3.3.1, it can be difficult to predict aquifer storage in a fractured bedrock environment.

Storage coefficient values can be estimated from pumping tests if an observation well is monitored. However, based on our review of available groundwater assessment reports for Galiano Island, storage coefficients are not being evaluated by hydrogeologists conducting assessments for new developments. The site specific data collected during pumping tests should be used determine local storage coefficients and to better define the critical groundwater areas.

3.3.4 Water Balance Modelling

Regional water balance models are most commonly used to assess surface water flow systems. Analytical and numerical water balance models also exist for groundwater, however, water balance models require the similar input criteria to the demand-storage ratio described above. In the absence of good data, water balance modeling can become an exercise in assumptions and realistically, no more effective than demand-storage estimates in the absence of solid data. Water balances, or budgets on a regional scale should also be used with caution when applied to groundwater because they may not accurately reflect what is available through the ground to a particular well or specific area. This is particularly true in a complex bedrock aquifer environment.

A water balance model can be helpful for use in planning and implementing green infrastructure and rainwater management systems for smaller scale new developments to ensure that recharge to the subsurface is not significantly reduced. In this case, site specific data would be collected and applied to the model. Many areas are implementing a `no net increase in runoff` policy for new developments. This encourages the use of rainwater infiltration features to support recharge to the aquifers and to maintain baseflow to local stream systems. From this perspective, there are some definite benefits to water balance modelling.

3.3.5 Topography, Soils and Geology

The analysis of topography, soils and geological structure are key factors that should be considered in identifying critical groundwater areas such as recharge. As indicated in Section 3.2, elevation should not be used on its own to define recharge areas.

In summary, little new data is available to improve the standards or criteria used to identify critical groundwater areas from previous reports and in most cases, a degree of uncertainty will remain with the estimated standards or criteria used even with further information available.

3.4 Methodology for Delineation of CGWA

To define recharge and discharge areas on Galiano Island, Kohut and Johanson (1998) reviewed:

- Topographic features (elevation and slope) on a 1:12,000 scale, surface drainages and air photos;
- Known geologic conditions including structural features;
- Presence of flowing artesian wells, springs and wetlands;
- Changes in topographic slope;
- Available groundwater level information from wells and springs, inferred hydraulic gradients and probable directions of groundwater flow; and,
- Phreatophytic vegetation and changes in vegetation and distribution.

Based on our review of the work by Kohut and Johanson (1998), Waterline concurs with their approach to delineating these critical groundwater areas; with the addition of water quality data as well. In our opinion, Galiano Island has been appropriately segregated into numerous groundwater regions and groundwater management and planning efforts needs to be focused on a more local scale.

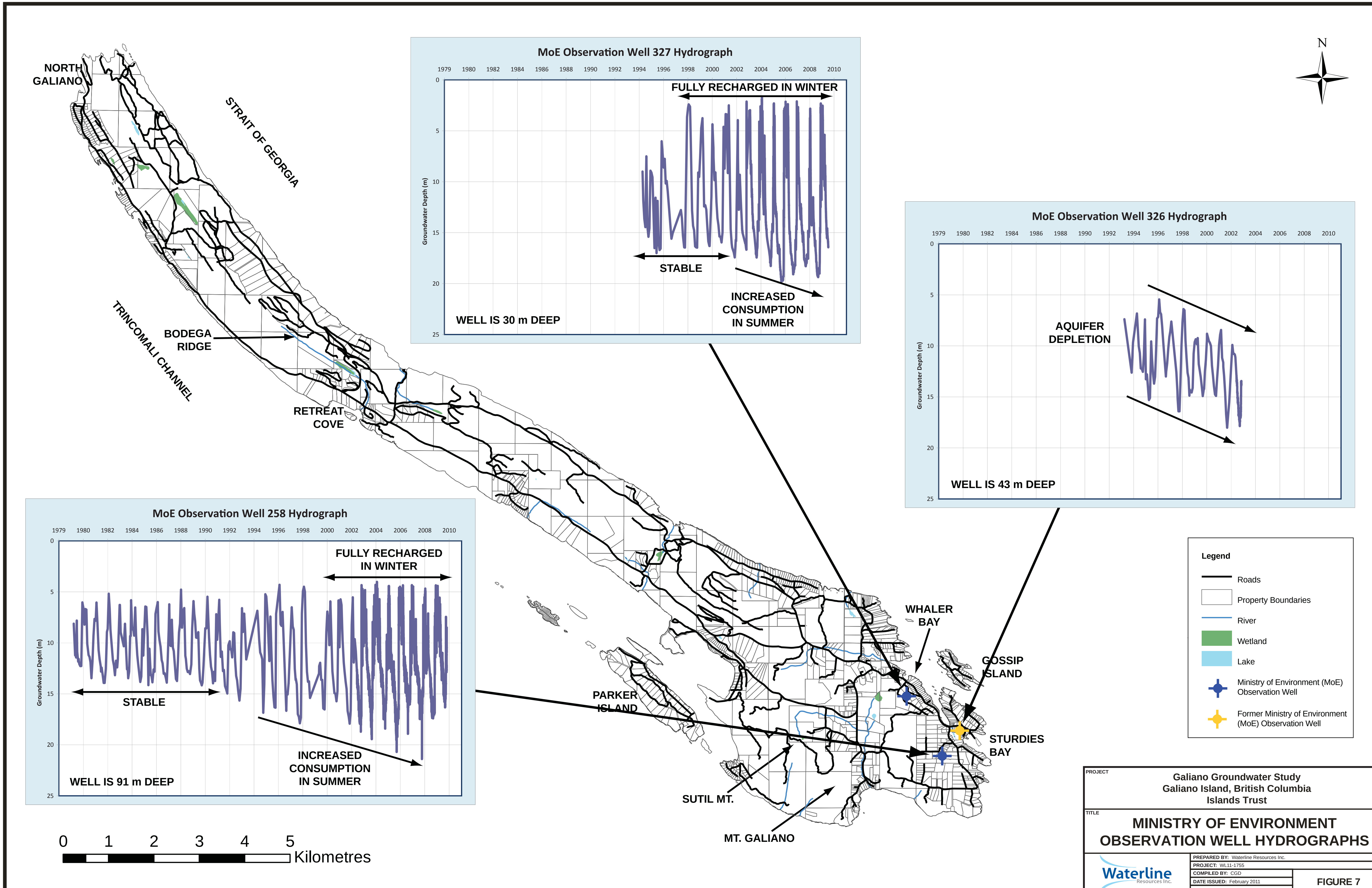
As shown on Figure 5, approximately 1050 water wells are registered with BC MoE on Galiano Island. These wells service domestic households, businesses, and industrial operations, yet very few (if any) of these wells are being monitored in terms of groundwater diversion, water level, or quality. Only two wells (<0.2%) are currently being monitored for water level by the BC Ministry of Environment in the Sturdies Bay area. No other data is readily available to the public from which to assess current groundwater conditions.

Establishing a water level monitoring program in key aquifers could provide actual data to assess if groundwater levels are declining over time and would be more effective in defining critical groundwater areas. To demonstrate the benefits, Figure 7 shows three hydrographs of Ministry of the Environment (MoE) Observation Wells. All three wells are located in southeastern Galiano in areas where high demand-storage ratios had been calculated by Mordaunt and Hodge (1983) and Harrison (1994). The information interpreted from these monitoring wells is described below.

- Well 327 is located in the Whaler Bay groundwater region and completed at approximately 30 m depth. The water level hydrograph indicates that the groundwater demand increased significantly between 1996 and 2010. Notwithstanding the apparent increase in groundwater use, the data indicates that water levels generally recovered back to static conditions each year during the winter rainy season. If the MoE observation well is representative of all water supply wells in the region then it can be concluded that the aquifer in the region is not being over exploited and therefore groundwater diversion activities would appear to be sustainable.

- Well 258 is located on Sturdies Road in the South Galiano groundwater region and completed at a depth of 91 m. The hydrograph for this observation well shows a similar trend to well 327 and indicates that the groundwater demand increased significantly between 1996 and 2010. However, as with well 327, water levels generally recovered back to static conditions each year during the winter rainy season indicating good recharge to the aquifer. Please note, even though the winter hydraulic heads are remaining relatively constant, the seasonal lows during the summer potentially could induce saltwater intrusion to occur.

- This well is completed in the Cain Peninsula area at a depth of 43 m. The hydrograph for well 326 shows that up to 2003 both summer and winter water levels were exhibiting a declining trend suggesting that the aquifer was being actively mined or over-exploited. Because the monitoring ceased in 2003, insufficient information is available to determine the current status of the aquifer in this location. According to Graeme Henderson, the MoE Groundwater Technician, the new well owner decided to use the well and it was no longer available for monitoring. Identification of a new observation well is highly recommended in the Cain Peninsula area to replace Well 326 as the data from this area indicates water level decline was occurring before monitoring was terminated.



NORTH GALIANO
STRAIT OF GEORGIA
TRINCOMALI CHANNEL
BODEGA RIDGE
RETREAT COVE
WHALER BAY
GOSSIP ISLAND
STURDIES BAY
PARKER ISLAND
SUTIL MT.
MT. GALIANO
N
MoE Observation Well 327 Hydrograph
FULLY RECHARGED IN WINTER
STABLE
INCREASED CONSUMPTION IN SUMMER
WELL IS 30 m DEEP
Groundwater Depth (m)
MoE Observation Well 326 Hydrograph
AQUIFER DEPLETION
WELL IS 43 m DEEP
Groundwater Depth (m)
MoE Observation Well 258 Hydrograph
FULLY RECHARGED IN WINTER
STABLE
INCREASED CONSUMPTION IN SUMMER
WELL IS 91 m DEEP
Groundwater Depth (m)
0 1 2 3 4 5
Kilometres
Legend
Roads
Property Boundaries
River
Wetland
Lake
Ministry of Environment (MoE) Observation Well
Former Ministry of Environment (MoE) Observation Well
PROJECT
Galiano Groundwater Study
Galiano Island, British Columbia
Islands Trust
TITLE
MINISTRY OF ENVIRONMENT OBSERVATION WELL HYDROGRAPHS
Waterline Resources Inc.
PREPARED BY: Waterline Resources Inc.
PROJECT: WL11-1755
COMPILED BY: CGD
DATE ISSUED: February 2011
REVISED: --
FIGURE 7

As was shown in Figure 7, groundwater level monitoring is far more important in groundwater management planning as it indicates whether recharge is in fact occurring (or not) and provides verification as to whether groundwater pumping activities are adversely depleting the aquifer.

4.0 GROUNDWATER QUALITY ISSUES

Q5) Identify and comment on potential or confirmed groundwater quality issues, including (but not limited to): saline intrusion, naturally occurring chemical constituents which may be a risk to human health (e.g. Arsenic), risk of contamination due to surface sources and poorly functioning septic systems.

The following sections summarize the water quality review completed relative to the above referenced question.

4.1 Potential Saline Intrusion

In coastal aquifers, the volume of aquifer recharge can significantly affect the position of the fresh-saltwater interface as follows:

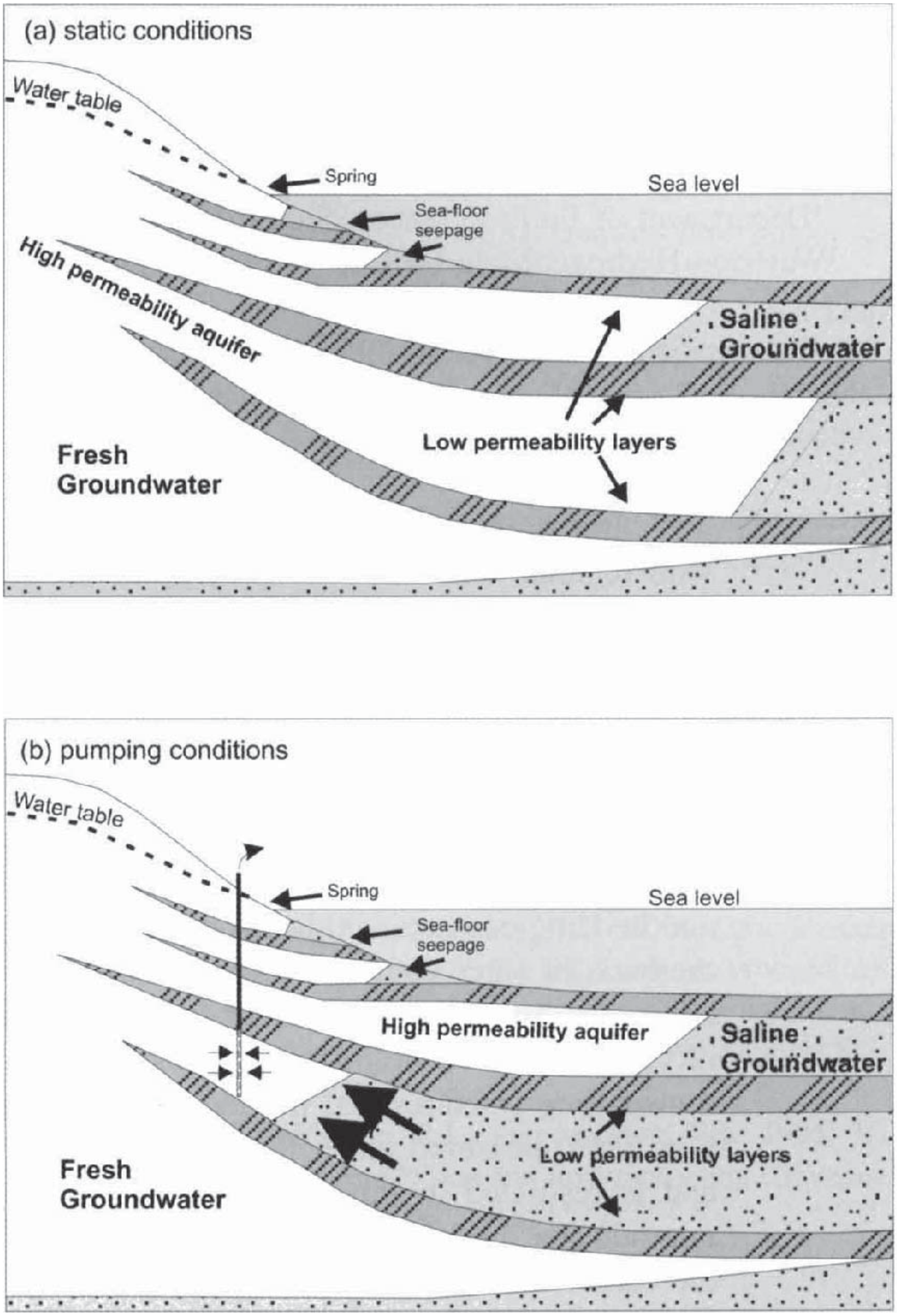
- Decreasing recharge will result in the fresh-saltwater interface moving inland.
- Increasing sea level will result in the fresh-saltwater interface moving inland.
- Increased pumping may cause the fresh-seawater interface to shift inland.

Groundwater regions such as the south Galiano, Whaler Bay, Cain Peninsula located near the coastline have experienced lower seasonal water levels, or perhaps groundwater mining and, as such, may be at risk for salt water intrusion. Furthermore, large permeable fractures orientation across the long axis of the island can also create conduits for rapid entry of saltwater to a water supply aquifer (Figure 8).

Water chemistry data collected by the MoE was reviewed for these wells to screen for potential saltwater intrusion indicators. Figure 9 presents Piper Plots for each well. As shown, the groundwater chemistry from samples collected from Well 258 has changed from a calcium-sulphate area to a sodium-bicarbonate over time as the summer water level dropped lower, drawing on deeper fractures. The deeper fractures have older water chemistry that indicates cation exchange. None of the water chemistry results indicate mixing with sea water.

Well 326 and 327 Piper Plots have variable water quality that may indicate a cation exchange mixing process is occurring, but insufficient data is available to confirm this. The additional MoE water quality data for the three observation wells indicated a slight increase in electrical conductivity with time.

Kohut and Johanson (1998) reported at least 13 groundwater regions had evidence of saltwater intrusion, poor water quality and deteriorating water quality. Unfortunately, aside from the three MoE observation wells with water quality data presented, no other current geochemical data was available for review.



REFERENCE: from Allen et al. (March 2002)

PROJECT	Galiano Groundwater Study Galiano Island, British Columbia Islands Trust
TITLE	SALT WATER INTRUSION IN A FRACTURED BEDROCK AQUIFER

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COMPILED BY: JAM
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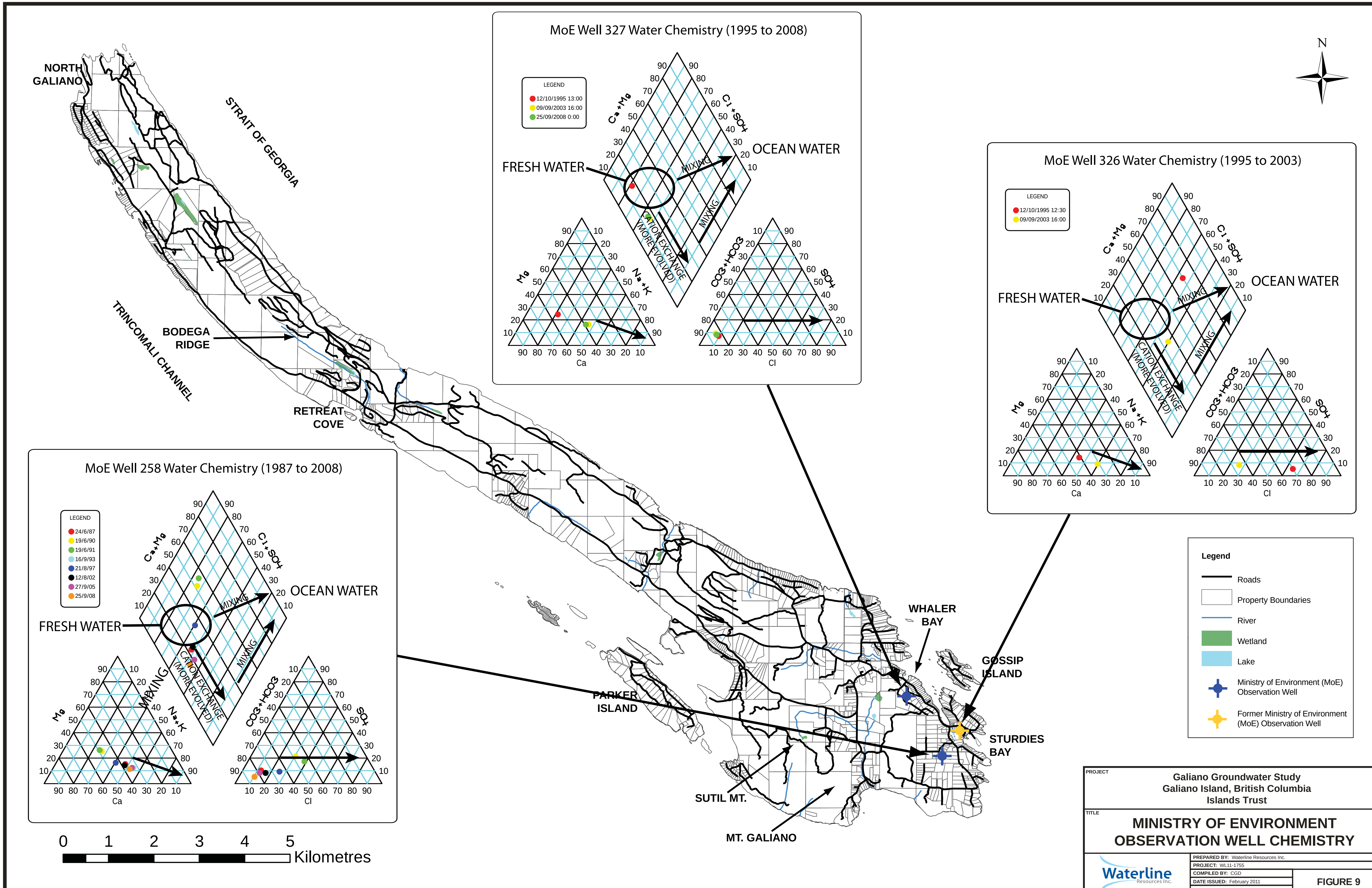
FIGURE 8



NORTH GALIANO
STRAIT OF GEORGIA
TRINCOMALI CHANNEL
BODEGA RIDGE
RETREAT COVE
WHALER BAY
GOSSIP ISLAND
PARKER ISLAND
STURDIES BAY
SUTIL MT.
MT. GALIANO
N
MoE Well 327 Water Chemistry (1995 to 2008)
LEGEND
12/10/1995 13:00
09/09/2003 16:00
25/09/2008 0:00
MoE Well 326 Water Chemistry (1995 to 2003)
LEGEND
12/10/1995 12:30
09/09/2003 16:00
MoE Well 258 Water Chemistry (1987 to 2008)
LEGEND
24/6/87
19/6/90
19/6/91
16/9/93
21/8/97
12/8/02
27/9/05
25/9/08
FRESH WATER
OCEAN WATER
MIXING
CATION EXCHANGE (MORE EVOLVED)
Ca+Mg
Cl+SO4
Mg
Na+K
Ca
CO3+HCO3
SO4
Cl
Legend
Roads
Property Boundaries
River
Wetland
Lake
Ministry of Environment (MoE) Observation Well
Former Ministry of Environment (MoE) Observation Well
0 1 2 3 4 5 Kilometres
PROJECT
Galiano Groundwater Study
Galiano Island, British Columbia
Islands Trust
TITLE
MINISTRY OF ENVIRONMENT OBSERVATION WELL CHEMISTRY
Waterline Resources Inc.
PREPARED BY: Waterline Resources Inc.
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COMPILED BY: CGD
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FIGURE 9

4.2 General Water Quality Concerns

Historical water quality problems have included groundwater impacts from saltwater intrusion resulting in increased sodium and chloride concentrations in the groundwater. Other water quality parameters of concern included iron, manganese, fluoride, hydrogen sulphide and coliform bacteria. Many of these parameters occur naturally in the Nanaimo Group sedimentary rocks. Historically, arsenic had been reported at concentrations exceeding the Guidelines for Canadian Drinking Water Quality in only two wells across Galiano (Kohut and Johanson, 1998).

Other recent well tests submitted to Islands Trust in support of subdivision applications were reviewed to assess potential water quality issues. The parameters that did not meet the Guidelines for Canadian Drinking Water Quality include:

- Coliform and non-coliform bacteria in groundwater near Georgeson Bay (GIGS, 2000);
- Non coliform bacteria, iron and manganese in groundwater from 1 well located near the middle of Galiano Island (GIGS, 2001a);
- Iron and manganese in groundwater from 1 well near Montague Harbour (GIGS, 2001b);
- Iron in groundwater from one well located in South Galiano (GIGS, 200c);
- Iron, manganese, fluoride and pH in groundwater from four wells located in South Galiano (GIGS, 2002a);
- Coliform and non-coliform bacteria in groundwater from 1 well located in South Galiano (GIGS, 2002b)
- Coliform bacteria, iron and manganese in groundwater from 1 well located near the middle of Galiano Island (GIGS, 2003)
- Turbidity, iron and manganese in groundwater from one well in South Galiano (Lowen, 2005);
- Iron in groundwater from two wells located in South Galiano (GIGS, (2006);
- Iron and manganese in groundwater from one well located in South Galiano (GIGS, 2007a);
- Turbidity, iron and manganese in groundwater from one well near Retreat Cover (Hodge, 2007);
- Iron and manganese in groundwater from one well near the middle of Galiano Island (GIGS, 2007b);
- Manganese in groundwater from one well (Hodge, 2009);
- Total coliform, turbidity and pH, in all wells, antimony, arsenic, iron, fluoride and lead for wells located on Lots 1, 2 and 4 (Hodge, 2006).
- Chloride, sodium and total dissolved solids in one well and iron and manganese in one well located in Sturdies Bay (Thurber, 2010).

Waterline also confirmed the data with Mr. Erwin Dyck, Supervisor of Environmental Health with the Vancouver Island Health Authority in Victoria. Mr. Dyck used to oversee the water systems on Galiano for many years and is very familiar with the water quality issues. Mr. Dyck indicated that he was aware of saline intrusion occurring in Montague Harbour and in Sturdies Bay. He also indicated that to his knowledge, iron and manganese were a common water quality issue for residents on Galiano. Arsenic had never been an issue for a community water system, but on occasion, concentrations of arsenic exceed the applicable water use guidelines (Hodge

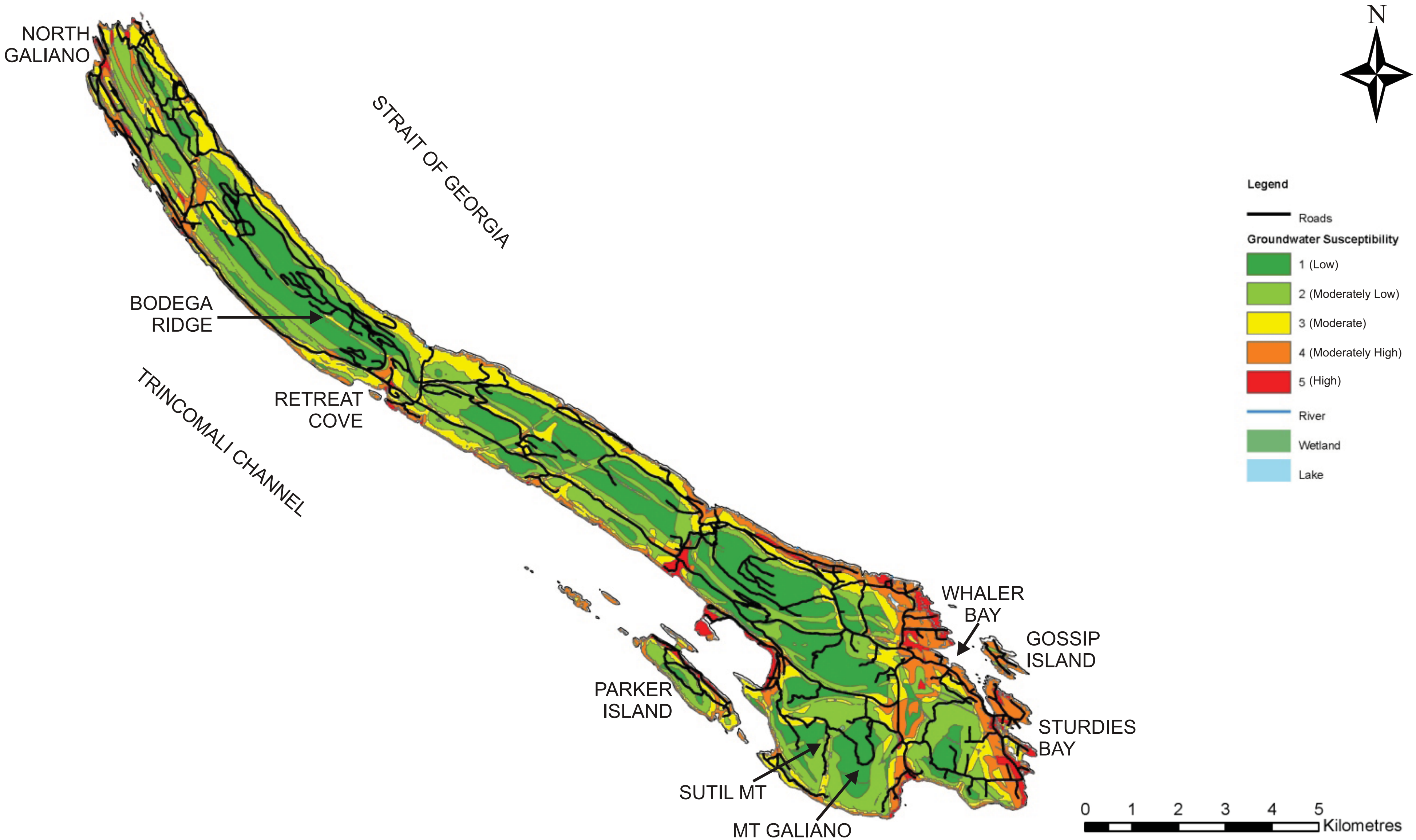
2006, Kohut and Johanson, 1998). Fluoride on rare occasions was reported at levels exceeding the applicable limits. Lead was detected at elevated levels in one community well, but it became no longer detectable after one or two sampling events (Erwin Dyck, pers. comm.).

4.3 Potential for Surface or Shallow Contamination

Figure 10 presents the intrinsic vulnerability map for Galiano Island (Denny et al. 2007). This map was developed using a modified DRASTIC methodology which presents a spatial and semi-quantifiable susceptibility index from surface sources. The groundwater vulnerability mapping should be used with caution. It shows that only the coastal areas are mapped as having high vulnerability due to the permeability of the fractures and shallow depth to groundwater (two key parameters in the DRASTIC methodology). While this may be correct in terms of the probability of salt water intrusion, the areas mapped as having low vulnerability are generally less developed and very little data is available to verify the risks to aquifers. According to Dr. Allen (pers. comm.), DRASTIC works best on flatter topography and the extreme topography present on Galiano can under represent the potential vulnerability of the higher elevation terrain.

The intrinsic vulnerability mapping also does not account for potentially poor well completions on aging wells, which are most common in the densely populated southern Galiano region. Mr. Dyck stated that the fractured bedrock and poor well sealing has likely created a pathway for surface water contamination to enter into the aquifer from shallow groundwater and surface water that may have been contaminated by septic discharges. Mr. Dyck also indicated that in his former position he received many complaints about water quality changing seasonally, or after large storm events.

Mr. Dyck reported that coliforms are fairly common in the bedrock wells. This is consistent with Kohut and Johanson's 1998 findings. He indicated that occasionally, elevated E.Coli levels in wells have been detected in the past. During Waterline's review of the historic water quality data and water quality from the three MoE observation wells, it appears that typical septic contamination indicators such as nitrates, nitrites and ammonia were present at low to non-detectable levels. No other new data is currently publically available to evaluate potential surface or shallow contamination impacts.



REFERENCE: adapted from Denny et al. 2007 and Islands Trust GIS Database

PROJECT

Galiano Groundwater Study
Galiano Island, British Columbia
Islands Trust

TITLE

GALIANO ISLAND
INTRINSIC GROUNDWATER SUSCEPTIBILITY

Waterline Resources Inc.

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FIGURE 10

5.0 CRITICAL GROUNDWATER AREAS IMPACTS DISCUSSION

5.1 Unique Groundwater Conditions

Galiano Island and other Gulf Islands pose unique challenges when it comes to sustainable development of fresh water resources. Galiano has a relatively small landmass and the development of the land will undoubtedly impact recharge to aquifers in some way. Dense development such as that which occurs in southeast Galiano Island can reduce permeable surfaces which can reduce recharge. This combined with a high density of pumping wells will increase the stress on the aquifer. Where there is no requirement for monitoring volume of groundwater extracted, or water levels in the aquifer, there is no opportunity to adequately track and verify the impact to the aquifers. Furthermore in coastal areas, increased groundwater diversion increases the risk of induced salt water intrusion further complicating groundwater management strategies.

There is also the potential for creating point sources of contamination by introducing new developments. The data reviewed by Waterline suggests that recharge rates on Galiano are relatively high due to increased fracturing of the bedrock near the surface and the presence of thin, moderately high permeability soil cover. Although this is a positive feature to ensure subsurface aquifers recharge, it causes some concerns when considering potential contaminant sources that may be introduced when a new development is approved.

A better understanding of the hydrogeological environment is required in order to properly assess vulnerability and to allow for a balanced approach to development planning and groundwater resource protection. This can only be achieved if groundwater monitoring (level, flow, and quality) is implemented in the various groundwater regions identified for Galiano. Although this may be difficult (not impossible) to implement for existing developed areas, the approach must be changed in the future if a sustainable future is desired.

The following discussion is intended to specifically respond to the ITQ's questions 6 through 8.

5.2 Land Use Impacts – Current and Potential Future

Q6) Assess the potential impact of land use activities, current and permitted future, on critical groundwater areas, including the following: small-lot residential development, large-lot residential development, land alteration activities, including vegetation and tree removal and road construction, commercial, industrial and home occupation uses.

Galiano Island hosts a varied mixture of land use activities, some of which may already exist and some of which have yet to be developed. As discussed above in regard to land development, Waterline considers that each type of the development has the potential to adversely impact the groundwater resources. As there is insufficient data available to evaluate current conditions in the critical groundwater areas and their sensitivities to different land use activities, the potential impacts are discussed in Table 2, below, for the land-use activities requested.

Table 2: Potential Land Use Impacts

Land Use Activity	***Potential Impacts on Critical Groundwater Areas***

Small-lot residential development	• Higher proportionate land area developed leaving less potential permeable surfaces.
	• Higher density groundwater extraction increases stress on aquifer leading to:
	  ○ declining water levels,
	  ○ increased well to well interference,
	  ○ potential for dry wells leading to deeper wells drilled,
	  ○ increased potential to draw water from deeper fractures that may have less desirable water quality, and
	  ○ risk of saltwater intrusion.
	• Higher density septic disposal fields and other potential sources of contamination potentially increases contaminant load on aquifer.
	• Construction of basements (full or partial), foundations, roads, etc. may change the shallow groundwater flow regime and lead to flooding or subsidence issues.

Large-lot residential development	• Potential for the same impacts as above, but typically to a lesser degree as the impacts are less concentrated.
Commercial, industrial and home-based businesses (will depend on site specific activities)	• May use a higher portion of land area thereby decreasing potential permeable surfaces. • May have a higher water demand which will increase aquifer stress leading to same or higher related potential impacts as those listed above for small-lots. • May result in larger septic flows which may increase contaminant load on aquifer. • May store and handle chemicals that could spill and leak into the aquifer.
Land alteration – vegetation and tree removal	• Can both positively and negatively impact groundwater levels depending on the site specific conditions. Evapotranspiration is reduced with tree removal which can result in an increase in groundwater levels; however, increased runoff may reduce overall recharge and thereby reduce groundwater levels with time. • Where increases in groundwater levels occur, the increased pore pressure may adversely impact slope stability.
Road construction	• May impact shallow groundwater flows depending on road cuts and create zones for groundwater discharge. • Depending on traffic levels, may increase risk of contaminants from road runoff entering the aquifer. • Road salt and other de-icing chemicals, if used, may enter into the aquifer.

In all cases, the degree of land use impact vary depending on site specific conditions. In many cases, low impact development and water conservation practices may mitigate adverse impacts from land use activities. This will be discussed further in Section 6.5.

5.3 Effectiveness of Regulations

There is a lack of provincial regulatory guidance related to specific requirements for hydrogeological assessments for land development projects. For instance, the BC Water Act does not require licensing of groundwater diversion, nor does it specify the scope of groundwater studies necessary to protect groundwater resources. In Waterline's opinion, this is a serious flaw in the BC legislation as, in the absence of any guidance; a minimal investigative approach is taken when new developments are proposed.

In other jurisdictions in Canada, municipal planning is approached on a watershed basis as there is a recognition that sustainability of communities depends greatly on the ability to provide safe and reliable water supply. Where provincial legislation is lacking, municipal/local governments may have to assume the responsibility to ensure that the land can be developed sustainably from a groundwater resource perspective. This is of particular importance in an island environment where the landmass is smaller and resources are subject to different environmental conditions more common to mainland environments. Therefore, there is a need for local governments to incorporate more groundwater management guidelines and investigative procedures into local bylaws including the subdivision servicing regulations of the Land Use Bylaw and the Official Community Plan Bylaw No. 108 (Islands Trust, 1995).

Q7) Review and comment on effectiveness of existing relevant regulations, specifically: Subdivision servicing regulations, requirement for cisterns in new construction in Water Management Areas, Development Permit Area 4 – Elevated Groundwater Catchment Areas.

5.3.1 Subdivision Servicing Requirements (Islands Trust, 1999, Section 13.23)

Based on our review of the subdivision servicing requirements, a good base exists; however, more specific wording with respect to the hydrogeological assessment may be merited due to the unique environment found on Galiano. Table 3 presents a summary of the challenges facing the sustainability of groundwater resources on Galiano under the existing Land Use Bylaw and bylaw regulations and suggestions for a new approach. The issues discussed will also apply to developments not requiring subdivision, but that will require one or more new water sources.

A revised hydrogeological assessment program is provided in Section 6.3.

Table 3: Existing Subdivision Servicing Bylaw – Challenges and Solutions

Challenges with the Existing Subdivision Servicing Requirements	***Possible Solutions***
• Property owner focussed on own property and personal development concerns. Each subdivision test is reviewed as an individual piece.	• 'BIGGER PICTURE' approach needed to protect long-term community concerns. The identification of already existing wells through a field verified survey and the tracking and evaluation of cumulative effects will better guide development planning and approvals.
• Pumping test typically minimal duration as is a residential dwelling requiring only 0.35 igpm. In certain environments four to 12 hour pumping test lengths may not extend long enough to adequately test the sustainability of the resource and potential/risk for saline intrusion. Testing is imperative to understand impacts to the groundwater regime.	• Test lengths or other specific requirements could be set by the LTC based on specific concerns for that groundwater region. Investigations need to consider existing density, cumulative effects if pumping, sea water intrusion, and declining water levels if monitoring data is available.
• Well testing program focuses on proving quantity of the individual well rather than assessing hydraulic properties of the aquifer that can be used to predict future impact.	• Require additional aquifer parameters (transmissivity and storage coefficient) as part of the report. This information can be added to a central database and used for future testing program planning.
• Often one observation well monitored during a test and data not interpreted beyond reporting interference.	• Extend monitoring area depending on specific groundwater region and the perceived well density.
• Once the testing program is completed, no follow up monitoring is being required to verify hydrogeological predictions and to determine whether or not impacts are occurring.	• Owners could be required to install a monitoring well and have it monitored with the findings reported for a specified length of time. Alternatively access to the monitoring well could be required for future monitoring. The monitoring well requirement could be dependent on the size of the proposed development.
• Subdivision Servicing Bylaw sets same standards for all sites.	• Classify critical groundwater regions and apply different requirements based on known issues.
• Local aquifer characteristic, hydraulic property, water quality data, or number of existing wells in use in area may not be available to the public.	• LTC should incorporate the data from each report into a GIS based tracking system to share information and facilitate better management of groundwater resources across the island. Each time a new development application is submitted for consideration and approval, the proponent should be provided with existing groundwater data for a region to ensure that cumulative impacts to the aquifer are being considered.

5.3.2 Subdivision Servicing Requirements (Islands Trust, 1999, Section 13.22)

The effectiveness of a cistern can depend on the regularity of precipitation, which is significantly reduced over the summer months. Apparently most systems are between 75% and 90% efficient with evaporation losses occurring out the roof opening during the summer period. The use of cisterns is appropriate as it encourages water conservation and reduces the demand for groundwater. Education and community outreach would be beneficial to help with the success of this program if it is implemented.

Once additional understanding of current groundwater conditions is gained in each of the critical groundwater areas and the cistern use effectiveness is determined in the areas currently designated (Schedule C in the Land Use Bylaw), it may be appropriate to revise the areas where this requirement applies.

5.3.3 Official Community Plan Bylaw No. 108 (Islands Trust, 1995, Section 3.0)

The OCP currently identifies lands situated above 140 m elevation as groundwater catchment areas that need to be protected and designates this as a land use development permit area (DPA #4). The guidelines associated with DPA #4 state:

- *Buildings and structures may be sited only where development approval information provided by the permit applicant indicates that such structures can be accommodated without impairing the quantity or quality of groundwater in the local groundwater region.*

- *The construction of roads and utility corridors and other activities involving the disturbance of the soil, must be conducted in such a manner that the productivity of the local groundwater recharge area is not impaired through soil compaction, altered surface drainage patterns, siltation, erosion, or salt water intrusion.*

- *The layout of subdivision must ensure that building sites are located and are of sufficient area that development permitted by the Land Use Bylaw may fully comply with these guidelines.*

The DPA #4 states that the 140 m elevation contour was identified and mapped in the 1998 Kohut and Johanson study. The 1998 report by Kohut and Johansson actually stated that any areas above approximately 50 m elevation represent potential recharge areas and should be protected, or managed appropriately. The area covered by DPA#4 is considered inadequate to sufficiently protect the groundwater resources on Galiano.

The developed guidelines under DPA#4 relate to building and road structures and their siting rather than eventual land use activities and the potential impacts involved (water extraction, potential impacts to water quality, etc.). The guidelines do not set any requirements for site specific characterization or groundwater assessment. The special conditions referring to ‘only those portions of the catchment areas having shallow soils and being particularly sensitive to development’ is considered vague. Waterline considers that DPA #4 should be abandoned, or revised. Further recommendations are discussed in Section 6.4.

6.0 RECOMMENDED GROUNDWATER MANAGEMENT PLANNING

To protect the quantity and quality of the groundwater resource on Galiano Island, Waterline recommends that the Islands Trust implement the following groundwater management and data acquisition measures.

6.1 Groundwater Monitoring Program

Waterline recommends that area specific groundwater data is collected (water level, use, water quality) through long-term groundwater monitoring initiatives. The monitoring data should then be compiled in a central database for reference and use when new developments are being proposed or regional/municipal planning is being considered. By improving the data collection and assessment requirements during the subdivision approval process, the Islands Trust will gain the means to make planning decisions with a certain degree of confidence that ensure that groundwater resources are sustainably developed and managed.

If at least one observation well was available in each region some determination of active groundwater recharge could be confirmed rather than relying on recharge estimates based assumed surface characteristics. Waterline understands that the Islands Trust has had some initial discussions with MoE regarding possible new monitoring wells on the island.

Monitoring data be compiled in a central database for reference. Armed with this real information on local groundwater conditions, and data from individual pumping tests that are required each time a development is proposed, development planning for an area based on actual groundwater availability provides the greatest opportunity for sustainability.

6.2 Community Outreach Program

Living in an island environment has all the obvious benefits of being close to the ocean and nature but requires a sense of stewardship. This is not only true for surface water resources that can be plainly seen at the surface, but it is also true for subsurface groundwater resources that cannot be seen.

Community outreach programs are also very useful so that residents understand the importance of groundwater protection measures and the need for change. Fresh water supply is required to sustain life and it belongs to everyone. There is often a misconception that the landowner owns the groundwater beneath the land when in actual fact the groundwater is owned by the crown and it’s everyone’s responsibility for its continued management and protection. To a large degree, the value of the land is contingent on the opportunity to develop a suitable water supply. Other concepts such as best management practices and groundwater conservation measures need also be explained so that all present and future people who live on the island adopt sustainable practices to conserve and protect fresh groundwater source.

6.3 Revised Subdivision Servicing Requirements

The current bylaw wording requires that a hydrogeological assessment subdivision application include the requirement for a pumping test that is in accordance with generally accepted hydrological engineering practice to establish the long-term reliability of the source and that does not adversely impact any neighbouring wells. Based on our review of available hydrogeological reports prepared in support of subdivision applications, these tests are typical relatively brief (less than 24 hours) and involve a 100 day projection of drawdown to predict the sustainable well capacity.

In Waterline’s opinion, the 100 day well capacity prediction that is applied to determine a well’s suitability for supplying water supply to a newly proposed development may not be sufficient to protect the groundwater resource from over exploitation. The intent of this calculation is to predict water level drawdown over the peak summer demand period and not intended for assessment of long-term (20+ years) of drawdown in an aquifer.

Cumulative effects of groundwater extraction activities can be estimated using standard hydrogeological techniques that are available in analytical models used to evaluate the same pumping test data which is already being collected as part of a subdivision application on Galiano. The cumulative effects approach allows for the prediction of drawdown impacts in existing water wells within an appropriate radius and over the projected life of the proposed development. Typically, predictive estimates of water level drawdown are evaluated based on population growth estimates and planning timeframes which often look 20-30 years into the future. These estimates should be made mandatory for any new proposed subdivision or groundwater extraction project, and monitoring data provided to the Islands Trust so that it can be considered each time a new subdivision or groundwater extraction project is proposed.

Although BC does not have specific guidelines relating to groundwater use, in Alberta for example, the drawdown in an aquifer is typically restricted to 50% of the available head as measured in an observation well 150 m away from a pumping well (Alberta Environment, 2006). Regulating the actual measured drawdown in a well or an aquifer is an appropriate approach to ensure that over-pumping does not occur.

Follow up monitoring should also be completed to determine actual impacts to recharge and from groundwater diversion activities. As a condition of development approval for a new subdivision, for example, a monitoring well could be established for this purpose and groundwater level data collected and submitted to the Islands Trust for inclusion into an information database (GIS system). This data could subsequently be made available to other future applicants for consideration when planning their developments. In this manner, each time a new development is proposed it requires that the new applicant consider all previous groundwater data collected in a region and for the proponent to provide an update so that the Islands Trust so that informed decisions can be made with respect to groundwater supply availability and its protection. In Waterline’s view this is the best way to ensure future sustainability of the groundwater supply for generations to come.

An example of hydrogeological assessment guidance is attached in Appendix C for reference.

6.4 Aquifer Protection Planning

Most of Galiano Island is considered a recharge area and that which is not is predominantly located close to the coast in areas at risk from saltwater intrusion. Since it is not practicable to limit development across the entire island, the assessment of land use impacts should consider the land use activities and the potential aquifer vulnerability on a site-specific, project by project basis. Mitigative strategies may be set in place to reduce impacts where possible. Best management practices can act to guide land development depending on the proposed activity and to set measures in place to protect the groundwater resource.

Other communities apply development permit areas for lands that overlie aquifers. As such, a development permit process that encourages groundwater management and protection may be more appropriate. For instance, the following items should be considered/incorporated or referenced in the OCP for both subdivision and additional development:

- Development and implement of Best Management Practices for road building, land clearing, and other land use activities;
- Emphasis on green development;
- Incorporating rainwater harvesting and infiltration/recharge enhancement into rainwater management and consider the requirement to balance impacts to runoff with these measures so there is 'no net increase in runoff';
- Focus on site specific data collection to identify sensitive areas with no soil cover, highly permeable soil cover, or intense fracturing or fault zones could be considered;
- Where additional water supply is required, require appropriate assessment and testing standards with follow up monitoring as described in section 6.3;
- Limit the use of potential groundwater contaminants such as road salt and pesticides and herbicides and setting requirements for storage of other chemicals (fuels, etc.) above set volumes; and,
- Within the critical groundwater areas where saline intrusion is identified as a concern, develop requirements well construction and operation practices to reduce the potential for drawing in saltwater.

With the benefits of feedback from a groundwater monitoring program, it will be possible to adjust the development strategies, or mitigate impacts when they are perceived on an island-wide, or critical groundwater area basis.

7.0 CLOSURE

This report and the information included were compiled exclusively for the Islands Trust and presents results of the Galiano Groundwater Study. This work was carried out in accordance with the scope of work for this project and accepted hydrogeological practices. No other warranty, expressed or implied, is made as to the professional services provided to the client. Any use which a third party makes of this report, or any reliance on or decisions to be made based upon it, are the responsibility of such third parties. Waterline accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

Respectfully submitted,

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APPENDIX A

INVITATION TO QUOTE

ISLANDS TRUST INVITATION TO QUOTE

GALIANO GROUNDWATER STUDY

Invitation to Quote Number: ITQ-2010.013
Issue date: November 5, 2010
Closing Time: Proposal must be received **before 12:00 noon** Pacific Time on
Monday, November 22, 2010

THE ISLANDS TRUST CONTACT PERSON: All enquiries from proponents that are related to this Invitation to Quote (ITQ) including any requests for information and clarification are to be directed, in writing, to the following person who will respond if time permits. Information obtained from any other source is not official and should not be relied upon. Enquiries and any responses will be recorded and may be distributed to all Proponents at the option of Island Trust. Enquiries will be received from proponents until **noon on Thursday, November 18, 2010.**

Robert Kojima
Islands Trust
Island Planner
Email: rkojima@islandstrust.bc.ca

Quotes must NOT be sent by facsimile or email. Quotes are to be submitted to the closing location as follows:

Proposal envelopes should be clearly marked with the name and address of the Bidder, the Invitation to Quote **Number ITQ-2010-.013**, and the name of the Invitation to Quote. The envelope MUST contain the Quote form as included on Page 7 of this Invitation to Quote document, and must be delivered by hand, mail or courier to:

Islands Trust
Suite 200 – 1627 Fort Street
Victoria, BC
V8R 1H8
Attention: **Robert Kojima**

CONTENTS

THE ISLANDS TRUST

INVITATION TO QUOTE
Terms and Conditions

1 BACKGROUND:

The Galiano Local Trust Committee (LTC) is undertaking a review and update of its Official Community Plan (OCP) and has identified the need for additional research on groundwater issues as a priority. A Water Advisory Committee has provided a report and recommendations to the LTC on issues and concerns related to water on the island. Based on the recommendation of that committee, the LTC has resolved to use available funding to support additional research into the state of the water supply on Galiano Island.

2 **SUMMARY OF REQUIRED GOODS:** The Islands Trust is seeking quotations for the following deliverables:

Objectives

With the overall goal of protecting groundwater resources, the objectives of the research are:

1. To review existing reports and recommend an optimal method for identifying critical groundwater areas, including recharge areas and water deficient areas

2. To identify data gaps and propose a program of future data gathering

3. To assess the impacts of various existing and potential land uses on critical groundwater areas and recommend management strategies.

Specific Questions to be Addressed

1. Assess the utility of using existing Islands Trust watershed mapping to delineate/revise groundwater regions

2. Assess the utility of using existing Islands Trust Digital Elevation Mapping (DEM) to delineate/revise recharge/discharge areas.

3. Review and comment on standards/criteria for identifying critical groundwater areas in previous reports, including commenting on the utility of the following groundwater supply measures:

   a. Demand/storage ratio
   b. Demand estimates
   c. Recharge rates
   d. Storage coefficients
   e. Water balance modeling
   f. Analysis of topography, soils and geologic structure

4. Assess the adequacy of current estimates based on reports in item 3 above and propose a methodology for delineating or revising critical

groundwater areas, including recharge areas and water deficient areas, using current data and mapping

5. Identify and comment on potential or confirmed groundwater quality issues, including (but not limited to):

a. Saline intrusion
b. Naturally occurring chemical constituents which may be a risk to human health (e.g. Arsenic)
c. Risk of contamination due to surface sources
d. Poorly functioning septic systems

6. Assess the potential impact of land use activities, current and permitted future, on critical groundwater areas, including the following:

a. Small-lot residential development
b. Large lot residential development
c. Land alteration activities, including vegetation and tree removal, and road construction
d. Commercial, industrial and home occupation uses

7. Review and comment on effectiveness of existing relevant regulations, specifically:

a. Subdivision servicing regulations
b. Requirement for cisterns in new construction in Water Management Areas
c. Development Permit Area 4 - Elevated Groundwater Catchment Areas

8. Provide recommendations on additional appropriate groundwater management measures to address current and potential land use impacts on critical areas.

9. Identify issues where additional, reasonably attainable data could improve understanding or identification of critical areas. Recommend a program of future data acquisition.

Data Sources

There are a number of existing reports and data sources that should be used in the analysis and would be provided to the success proponent by the Islands Trust:

1. Existing Galiano groundwater reports: Kohut and Johansen, 1998; Harrison, 1994; Thurber, 1993; Mordaunt and Hodge, 1983, Water Advisory Committee, 2010.
2. Mapping: Groundwater vulnerability mapping, watershed modeling, Digital Elevation mapping, soils mapping, zoning and build-out.
3. Subdivision hydrology reports.
4. Current bylaws, regulations and DPA.

In addition, the following reports and data should be used in the analysis and obtained independently by the proponent:

1. Ministry of Environment WELLs database, provincial aquifer mapping, provincial observation well data.
2. Best practices documents, such as the Groundwater Bylaws Toolkit.
3. Other relevant documents or sources

Deliverables

1. A report addressing the objectives and specific questions as outlined above providing recommendations for management strategies.

2. The expectation is that this would not be a field study, but would be a review of existing reports, information and data. It would not involve providing a mapping product, mapping would be carried out by Islands Trust, based on recommendations of this review

3. Attend one Local Trust Committee meeting on Galiano Island to provide a summary of finds and answer questions.

4. Attend on meeting with Islands Trust staff in Victoria, BC.

3 CONTRACT TERM/WORK SCHEDULE:

Draft report by March 1, 2011

Final report with edits by **March 31, 2011.**

4 ENQUIRIES:

All enquiries pertaining to this ITQ shall be directed in writing only to:

Robert Kojima
Islands Trust
Island Planner
Email: rkojima@islandstrust.bc.ca

Enquiries will be responded to until noon on Thursday, November 18, 2010

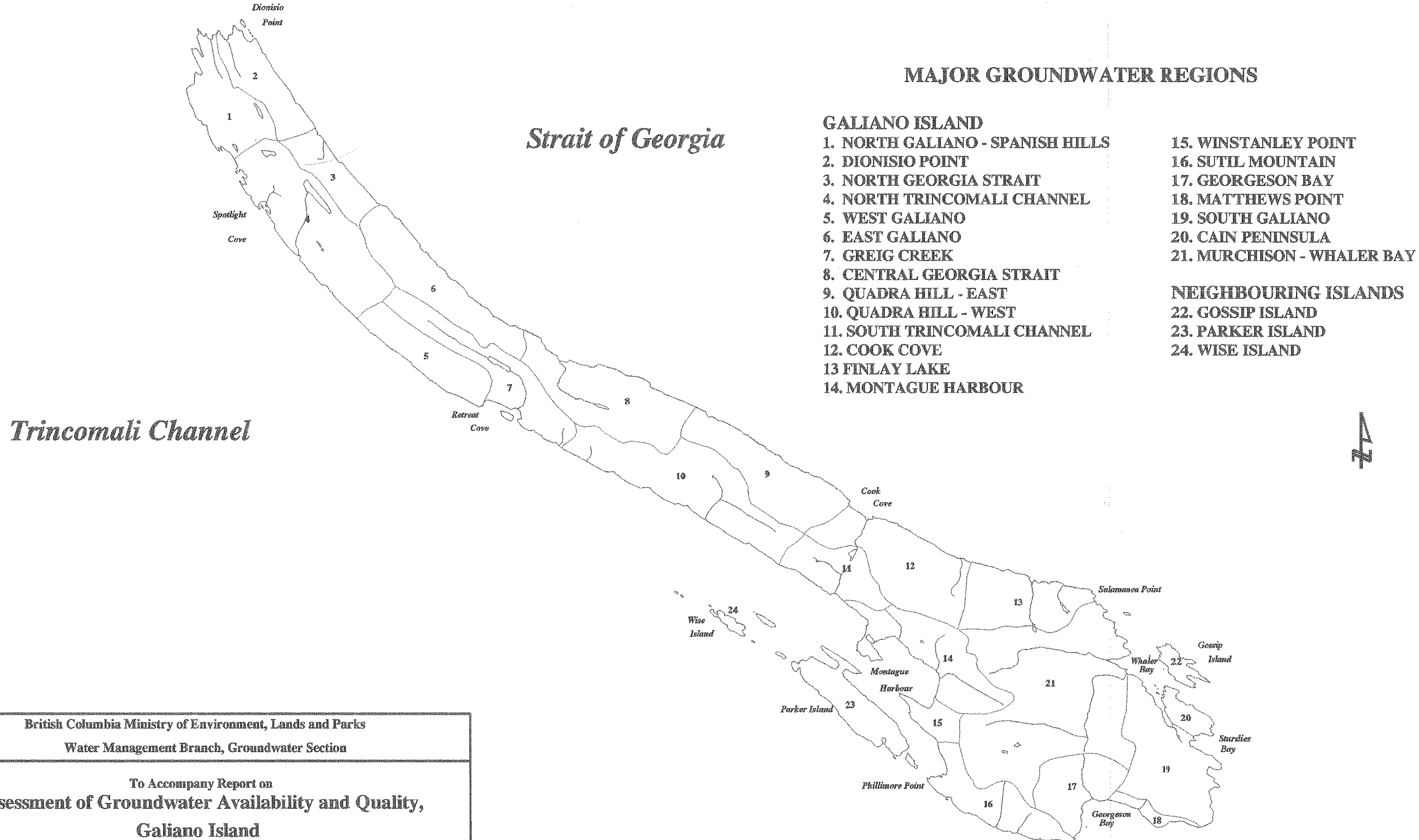
5 ELIGIBILITY REQUIREMENTS:

Bidders must meet the Islands Trust requirements for experience. The Islands Trust will disqualify any bidder who cannot provide the following, when requested:

(a) adequately demonstrate that they have the ability to provide the necessary expertise and resources to satisfactorily complete the contract.

APPENDIX B

GROUNDWATER REGION AND GIS WATERSHED MAPS



British Columbia Ministry of Environment, Lands and Parks

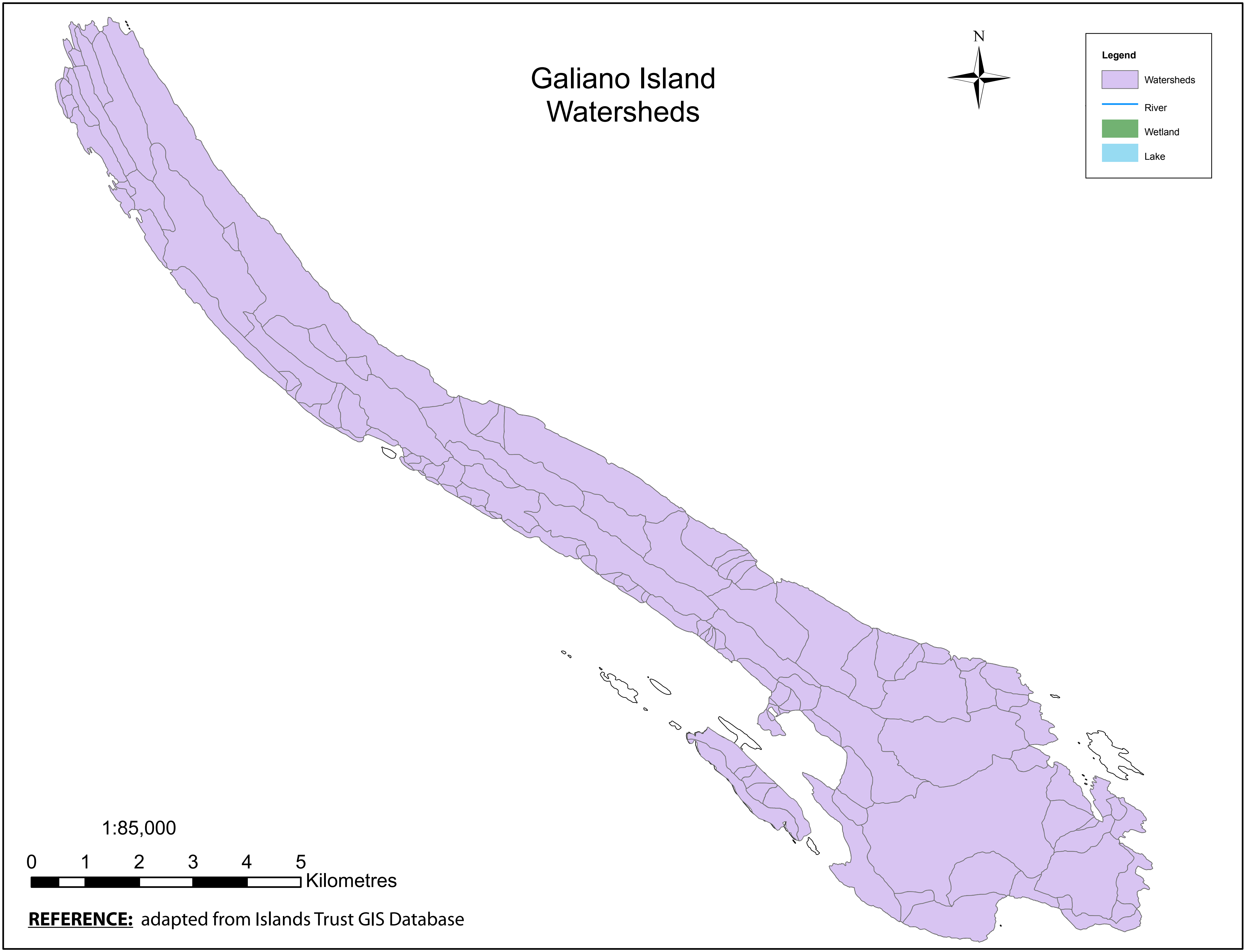
Water Management Branch, Groundwater Section

To Accompany Report on

Assessment of Groundwater Availability and Quality, Galiano Island

Figure 5 : Groundwater Regions

Scale : 1 : 75,000 Date : October 1997


Galiano Island
Watersheds
N
Legend
Watersheds
River
Wetland
Lake
1:85,000
0 1 2 3 4 5
Kilometres
REFERENCE: adapted from Islands Trust GIS Database

APPENDIX C

EXAMPLE HYDROGEOLOGICAL ASSESSMENT GUIDANCE

(Source: Alberta Environment, 2003, Groundwater Evaluation Guideline)

Part 2: Best Management Practice

The applicant/consultant shall have an evaluation program designed, including a field-verified survey of water users, a pumping test(s) using observation well(s) and/or existing household well(s), if warranted, among other things. The applicant shall submit a report, in support of an application to obtain a licence, demonstrating sufficient groundwater of a suitable quality is available for the intended purpose.

The following criteria identify the department's best management practice for information required with an application:

2.01 Description of Geology and Hydrogeology

The applicant or consultant shall submit a description of the geology and hydrogeology at the proposed project site based on information from:

(a) Alberta Research Council hydrogeological reconnaissance maps, cross-sections and reports, and any other report,

(b) Descriptions and aquifer parameters reported in other projects requiring licences or approvals, and

(c) Water well drilling reports and chemical analyses.

2.02 Field-Verified Survey

The radius of the field-verified survey shall be one kilometre or more according to the geologic and hydrogeologic conditions, the quantity of groundwater required by the proposed project and the number of water users in the area.

The field-verified survey shall consist of a

(a) Plan(s) showing the ownership and locations of all water wells, springs and/or dugouts within an appropriate radius of the project site, and

(b) Table containing (see Schedule 3 for an example)
  - (i) owner's/lessee's names,
  - (ii) legal land location and surface elevation,
  - (iii) type of water source (e.g. wells, springs, dugouts, etc.)
  - (iv) well status (e.g. producing, standby, observation, abandoned, etc.),
  - (v) well depth,
  - (vi) original non-pumping water level and date, and current non-pumping water level,
  - (vii) well completion details, completion interval (open hole, perforated or screened),
  - (viii) depth to the top of the aquifer and the amount of available head,
  - (ix) pump intake depth,
  - (x) maximum pumping rate,
  - (xi) purpose of use (household/livestock/industrial, etc.) and current water daily/annual requirements,
  - (xii) distance from the proposed groundwater diversion or drainage site, and
  - (xiii) summary of historical chemical analyses

Notes: **Most of the information above should be obtained directly from the water source users. Water well drilling records should only be used to confirm communicated water source data or to complete the information if it is unknown to the users. If the user is absent during the survey, an effort must be made to obtain the information at a later date.**

When the field survey is properly conducted, any potential conflict among neighbours can be prevented early. Where a history of conflict exists, the consultant should consider monitoring neighbouring well(s) during the test.

Where water level measurements are difficult to obtain, an observation well may be constructed

(A) with the same water-bearing zone as the proposed production well or drainage site and

(B) in close proximity to the sites

- **of non-obtainable measurements or**
- **where measurements are required from a large subdivision/municipality).**

2.03 Pumping Test

The pumping test(s) shall be conducted on the proposed water well(s) to determine the hydraulic properties of the aquifer to enable determination of the extent and the sustainable yield of the aquifer.

During the pumping test, the proponent shall

(a) obtain water samples as identified in **2.07 (c)** and shall submit

(i) water temperature, date, and time of sampling,
(ii) date the analyses were performed, and
(iii) results of the analyses,

(b) have the flow rate at not less than the anticipated maximum production rate,

(c) have the maximum variation in pump rate at ± 5%,

(d) have the pumping continue for a period of time sufficient to identify any limiting boundary conditions (see Schedule 1 for standard lengths of pumping test),

(e) take recovery measurements for at least the same length of time as the proposed production well(s) was pumped,

(f) not deposit any substance at the pumping test site or in any water body receiving discharge which will adversely affect the water body, and

(g) not discharge groundwater to the land surface where it may adversely affect soils or vegetation, or cause any other environmental damage.

2.04 Water Level Monitoring Schedule

Water levels measured in the production well(s) and observation wells shall be recorded to the nearest one (1.0) centimetre during the pumping and recovery phases of the pumping test. The monitoring frequency and the accuracy of the water level measurements must be suitable to determine aquifer parameters.

The last water level during the pumping period should be taken just prior to the pump being turned off.
After the pump is turned off, the depth to water in the well(s) must also be measured while the water level "recovers" from the pumping

Monitoring frequency, during the recovery period, should be similar to the frequency during the pumping period.

Recovery measurements should be taken for at least the same length of time as the well was pumped or until the water level has recovered to within 90% of the pre-test non-pumping water level, which ever comes first.

The following water level monitoring schedule is an example of a suitable frequency:

From 0 to 10 minutes	every minute
From 10 to 30 minutes	every 5 minutes
From 30 to 60 minutes	every 10 minutes
From 1 to 2 hours	every 15 minutes
From 2 to 4 hours	every 30 minutes
From 4 to 12 hours	every hour
From 12 to 24 hours	every 2 hours
From 24 to 36 hours	every 4 hours
From 36 to 48 hours	every 6 hours
After 48 hours	every 8 to 12 hours

2.05 Observation Wells

When appropriate to the scale and potential impact of the project, an observation well(s) should be installed at a suggested distance of 15 and 150 metres from the proposed production well. The distance should be considered based on the aquifer type (e.g. confined, unconfined), intended pumping rate, anticipated drawdown based on the drilling reports, or any Policy/Regulation specifying other requirements.

The observation well(s) should be completed in the same aquifer as the proposed production well.

It may also be necessary to monitor household or previously licensed groundwater diversion and/or observation wells in other subsurface units depending on the geologic and hydrogeologic conditions and the proposed groundwater withdrawal rate at the diversion sites. Installation of additional observation wells may be required for monitoring purposes.

Water levels in the observation well(s) should be monitored on a schedule similar to monitoring schedule of water levels in the pumped well.

2.06 Interpretation of Pumping Test Data

A quantitative assessment of aquifer parameters (Transmissivity, Storativity, etc.), potential drawdown, and long-term yield is based on the

(a) Aquifer type and assumptions common to most analytical methods:
- (i) aquifer is assumed to have an infinite areal extent,
- (ii) water is bounded by a less permeable bed below in the case of an unconfined aquifer, and above and below in the case of a confined aquifer,
- (iii) aquifer is homogeneous, isotropic, and of uniform thickness,
- (iv) flow is laminar,
- (v) water is released from storage instantaneously with a decline in head, and
- (vi) aquifer is pumped at a constant discharge rate,

(b) Identification and location of any aquifer boundary causing a divergence of the test data from the straight-line and the type curve, Jacob and Theis methods respectively – the following conditions may cause departures resembling an aquifer response to either recharge or discharge (barrier) boundaries:
- (i) leakage from adjacent aquifers,
- (ii) an increase (or decrease) in the thickness of the aquifer,
- (iii) an increase (or decrease) in the permeability of the producing aquifer,
- (iv) cessation (or the initiation) of pumping from a nearby well,
- (v) decrease (or increase) in the rate of discharge from the well,
- (vi) facies change,
- (vii) secondary porosity (e.g. fracture porosity),
- (viii) delayed yield in unconfined aquifers (resembling recharge),
- (ix) mining effect, and
- (x) barometric effects – significant where minimal drawdown is incurred,

(c) Aquifer shall be analyzed (hydraulic conductivity, transmissivity and storativity coefficient) using
- (i) analytical solutions (type of analyzes used is a function of the aquifer and its geological and hydrogeological settings)
- (ii) numerical and computer models – type of analysis used is a function of the aquifer and its geological and hydrogeological settings, and
- (iii) the most appropriate method, however the applicant or representative is responsible for providing specified data and be prepared to defend the choice

(d) Pumping test data and data interpretation by various methods of which two (2) most commonly used are:
- (i) Theis method which determines the aquifer parameters from the production well data (transmissivity only) and observation well data (transmissivity and storativity) – it is also used for assessing the amount of potential drawdown, at various times and selected distances from the water well, and
- (ii) Cooper-Jacob method which is a modified Theis method when certain conditions are met,

(e) Determination of aquifer boundaries which is essential before the long-term yield of the aquifer can be determined,

(f) Theoretical long-term yield of a proposed production well determined by using either the

Farvolden Method

$$Q_{20} = (0.68)(T)(H_A) \times (0.7)$$

or the

Moell Method

$$Q_{20} = \frac{Q(H_A)}{s_{100} + 5\triangle s} \times 0.7$$

where

H_A = available head (in metres)
s_{100} = the drawdown at 100 minutes (in metres)
Q = well pumping rate during the pumping test (in cubic metres per day [m^3/d])
Q_{20} = sustainable yield for a 20-year period (in m^3/d)
$\triangle s$ = drawdown per log cycle of time
T = transmissivity (in square metres per day [m^2/d])
0.7 = 70% safety factor

The Moell formula is commonly used where large drawdowns occur at the beginning of the pumping period.

For confined aquifers, the available head (H_A) is equal to the distance between the non-pumping water level in the well prior to the pumping test and the top of the aquifer or the top of the completion interval, which ever is less.

For unconfined aquifers, the available head (H_A) is chosen to be equal to 2/3 of the difference between the base of the aquifer and the non-pumping water level in the well (or 2/3 of the saturated thickness of the aquifer).

2.07 Water Quality Assessment

The following will be required:

(a) Impact of effluent/discharge (return flow) from industrial, municipal, aquaculture, and livestock projects, etc. on the aquifer, nearby streams and water bodies which must be considered – suitable effluent management plans regulated through other agencies may be required,

(b) Reference to the "Surface Water Quality Guidelines For Use in Alberta" and consideration of flow rates and timing of discharge into receiving water bodies, and

(c) In most cases it will be sufficient to have the water sample, collected from the production well near the end of the pumping period, analysed for the parameters and constituent identified as "Routine Analysis" ("Detailed Analysis" should be submitted for central distribution water supply systems for municipal/household purposes).

List of Parameters for Routine and Detailed Analysis

Routine Analysis:

(i) Bicarbonate (HCO_3)
(ii) Calcium (Ca)
(iii) Carbonate (CO_3)
(iv) Chloride (Cl)
(v) Fluoride (F)
(vi) Iron (Fe)
(vii) Magnesium (Mg)
(viii) Manganese (Mn)
(ix) Nitrite + Nitrate ($NO_2 + NO_3$)
(x) pH
(xi) Potassium (K)
(xii) Sodium (Na)
(xiii) Sulphate (SO_4)
(xiv) Total Dissolved Solids
(xv) Total Alkalinity
(xvi) Total Hardness

Additional constituents may be analyzed as deemed necessary (i.e. in accordance with the surface water quality guidelines, etc.).

Note: Groundwater remediation projects may require additional parameters

Detailed Analysis:

(i) Arsenic (As)
(ii) Bicarbonate (HCO_3)
(iii) Calcium (Ca)
(iv) Carbonate (CO_3)
(v) Chloride (Cl)
(vi) Colour (TCU)
(vii) Copper (Cu)
(viii) Fluoride (F)
(ix) Iron (Fe)
(x) Lead (Pb)
(xi) Magnesium (Mg)
(xii) Manganese (Mn)
(xiii) Mercury
(xiv) Metals (total and dissolved)
(xv) Nitrite & Nitrate ($NO_2 + NO_3$)
(xvi) Nitrogen – Ammonia
(xvii) Total Kjeldahl Nitrogen(TKN)
(xviii) pH
(xix) Phenols
(xx) Phosphorus (P)
(xxi) Potassium (K)
(xxii) Sodium (Na)
(xxiii) Sulphate (SO_4)
(xxiv) Sulphide (H_2S)
(xxv) Total Alkalinity
(xxvi) Total Dissolved Solids(TDS)
(xxvii) Total Hardness
(xxviii) Turbidity (NTU)
(xxix) Zinc (Zn)

Bacteriological Analysis

(xxx) Coliforms – **Fecal** (mpn/100mL)
(xxxi) Coliforms – **Total** (mpn/100mL)

2.08 Effects on the Aquifer, Other Users, Other Water Bodies, and the Aquatic Environment

The following shall be considered in the assessment of both short-term and long-term impacts:

(a) Aquifer characterization determined from the analysis of pumping test data, chemical data, field-verified survey data and other hydrogeological reports and data (e.g. fracture dominated flow, limited areal extent, strong dynamic flow regime, extensive diversion from other projects, strong natural discharge, limited or abundant recharge, confined / unconfined conditions, etc.),

(b) Any interference with other local groundwater and surface water users,

(c) Proximity of surface water bodies (e.g. springs, dugouts, dams, sloughs, creeks, rivers, etc.),

(d) Evaluation of distance/time drawdown graphs and the calculation of the potential well interference effects,

(e) Predicted drawdown in the water well compared to amount of available head (the top of the aquifer and/or top of completion interval which ever is less) and to the pump intake depth in area wells,

(f) Evaluation of technical / hydrogeological or other valid concerns expressed in any response to public consultation regarding the proposed diversion and use of groundwater by the project,

(g) Identification of other environmental / hydrogeological issues requiring referral to other agencies – specific monitoring requirements may be required to address the specific concerns,

(h) Suitable analytical solutions or computer numerical models to properly represent "realistic" groundwater flow systems, which will include the entire length of time of groundwater diversion and use,

(i) Evaluation of impacts on watersheds at full water allocation limits or with other allocation controls (e.g. water management plans, licensing moratoria, apportionment limitations, etc.),

(j) Local sub-basins with sensitive water bodies (i.e. small contributing area to surface area ratios) or rare plants or animal species which must be specifically identified and protected,

(k) Areas adjacent to protected wetlands or "special places" which must be specifically identified and evaluated as a sensitive area,

(l) Evaluation of erosion potential and changes in fish habitat which may be required for large-scale mine or pit drainage projects,

(m) Evaluation of large diversions for effects caused by increased groundwater recharge which may be needed in recharge dominated flow systems or for drought sensitive local water bodies, and

(n) Changes in water quality as a result of the diversion or drainage (e.g. increased metal mobility, anaerboci/aerobic changes, salinity increase, etc.).

Note: It is assumed, when a licensee or approval holder cannot prove beyond a reasonable doubt the water diversion or drainage caused an alleged unreasonable impact, the water diversion or drainage did cause the unreasonable impact

2.09 Water Well Construction

Water wells must be constructed in accordance with the methods outlined in the *Water (Ministerial) Regulation* (the "Regulation").

2.10 Technical Report

Where applicable, the applicant is responsible for submitting the supporting information together with an application which may in a form of a groundwater evaluation report prepared by a qualified groundwater specialist who is a member of the Association of Professional Engineers, Geologists and Geophysicists of Alberta (the "APEGGA").

The report should provide, among other things, the

(a) Results from the field-verified water well survey of surrounding water well, spring, and dugout users,

(b) Pumping test program, and

(c) Historical monitoring data and any other aspect of the groundwater exploration program

Conclusions reached in the report should be based on an interpretation and conceptualization of the geology / hydrogeology in the area through the construction of cross-sections and interpretation of pumping test, monitoring, and water quality data.

The report shall confirm the proposed diversion or drainage of groundwater will not

(a) Unreasonably interfere with other water users or water sources,

(b) Negatively impact the aquifer or other aquifers and surface water bodies, and

(c) Harm the environment in general.

The report shall

(a) Identify the necessary remedial measures if unreasonable impact is anticipated, and

(b) Identify alternative sources of supply in case of potential water shortages.

2.11 Assessment of information

2.11.01 Why is Assessment Necessary?

Information is assessed to determine the feasibility of allocating groundwater in a manner based on "first in time first in right principles", and to manage and sustain the groundwater resources for future generations.

The assessment of pumping test data and other information is necessary to determine the aquifer parameters. In the process of evaluating, the aquifer will be assessed if it is capable of providing the quantity and quality of groundwater required for the proposed project on an ongoing basis without unreasonably/negatively impacting the aquifer(s), existing water supplies, and surrounding water bodies.

If the assessment concludes there is sufficient groundwater for the proposed project, then the proponent will have an additional degree of assurance that the requested quantity of groundwater can be removed without impacting the aquifer or surrounding water bodies.

However if the available data indicate there is insufficient groundwater available to meet the proposed project's requirements, alternative water sources (such as another aquifer or surface water) can be assessed to determine suitability.

The following questions should be considered when conducting a groundwater assessment:

(a) Is the proposed diversion technically feasible (e.g. well design, available head, maximum pumping rate, long-term yield, appropriate quality, etc.)?

(b) Is the proposed diversion sustainable throughout the life of the project, without damage to the aquifer?

(c) Will the proposed diversion have an adverse effect on other groundwater users in the area? Can the predicted effect(s) be mitigated?

(d) Will the proposed diversion have an adverse effect on other components of the environment, and especially on the aquatic environment?

(e) What monitoring conditions will provide data required to confirm initial predictions and to identify potential adverse effects in the future? This includes consideration of what information might be required to successfully conduct an investigation into an allegation(s) of well interference against the licensee or approval holder.

2.11.02 What is Assessed?

The technical report(s) filed in support of an application to divert or drain groundwater is assessed to determine if the aquifer is capable of supplying both the quantity and quality of groundwater required by the project on an ongoing basis.

Consultants preparing these reports are expected to use scientific methods and procedures providing the technical basis on which groundwater can be allocated. Factors limiting the diversion or use of groundwater required by the project must be identified in the report.

Groundwater availability in an area can vary from less than 10 cubic metres per day (m^3/d) to several thousands cubic metres per day depending on the aquifer characteristics. Pumping test data are assessed to determine the aquifer parameters at the project site and the sustainable rate at which groundwater can be withdrawn from the aquifer without causing either aquifer depletion or unreasonable impact to other aquifers or other groundwater users in the surrounding area. The effects of boundary conditions must also be taken into consideration during the evaluation process.

With the establishment of surface water restrictions (in-stream objectives, minimum flow levels, moratoria, etc.) the hydraulic relationship between groundwater and surrounding surface water sources must also be considered as part of the submission for review. One of the challenges of assessing a groundwater project in a restricted water basin is quantifying the hydraulic relationship between surface water and groundwater resources.

2.12 Multiple-Aquifer Completions

Where wells were constructed with multiple completion intervals prior to the Regulation governing well construction, there is no legislation to force well owners to reconstruct these wells according to the Regulation before obtaining a licence.

However where pumping test is required and in order to conduct a proper evaluation, the well must be re-completed in such a manner to isolate one aquifer interval. This will allow for proper testing of the interval and provide a more accurate assessment of the aquifer parameters. Thus for any application to obtain a licence and where testing is required, the owners may be directed to have the well re-completed or isolated with a single aquifer prior to the testing.

2.13 Replacement and Supplementary Water Wells

2.13.01 What is a Replacement Water Well?

A replacement water well is a new well constructed to replace an older (existing) well and shall be

(a) Installed with a drawdown and cone of depression similar to or better than the drawdown and cone of depression of the existing well,

(b) Installed near and in the same aquifer as the existing well, and

(c) Completed in accordance with the Regulation governing well completion interval length at the time of the replacement,

and the existing well shall be abandoned in accordance with the Regulation.

Any licence for the existing well may be amended to reflect changes to the pumping rate and production interval.

Should an additional quantity of water be needed (operation expansion) at the time of drilling the replacement well, a new licence will be required.

2.13.02 What is a Supplementary Water Well?

A supplementary water well is a new well in addition to older (existing) wells and shall be

(a) Installed near the existing well where drawdown and the cone of depression is similar to or better than the drawdown and cone of depression of the existing well,

(b) Installed in the same aquifer as the existing well, and

(c) Completed in accordance with the Regulation governing well completion interval length at the time of the replacement.

The supplementary water well will be identified on any licence for the existing water well and will share the current allocation and priority number of the existing well if there is no additional quantity of water required.

Should an additional quantity of water be needed (operation expansion) at the time of drilling the supplementary well, a new licence will be required.

2.14 Water Level Below the Top of the Aquifer or the Completion Interval

The pumping water level in a water well should not be allowed to decline below the top of a confined aquifer or the top of the completion interval, which ever is nearer to the top of the well casing, during either normal or peak water use periods.

To prevent mining (de-watering) of confined aquifers, each water well completed in a confined aquifer shall be equipped with a low-level shut-off switch. Alternatively if a water well is not equipped with a low-level shut-off switch, the pump installer shall provide the Director with the position of the pump intake in the well relative to the top of the well casing.

2.15 Monitoring Requirements and Conditions for Licences and Approvals

Conditions and monitoring requirements are based on the

(a) Size of the diversion or drainage project,

(b) Type of water well supply system (e.g. multiple-well system, etc.),

(c) Potential impact on surrounding water users, in which case the conditions may include, but not limited to,
   (i) frequent or continuous water-level monitoring of the production well with automatic digital recording,
   (ii) frequent or continuous water-level monitoring of observation wells,
   (iii) installation of low-level shut-off switch in each production well, and
   (iv) depending on location and production intervals, specific allocation to each well (instead allowing the licensee/approval holder the option to pump various quantities from each well providing total withdrawal does not exceed the total allocation).

(d) Uncertainty regarding the Transmissivity (T) and Storativity Coefficient (S) values calculated from pumping test data (variations due to fracture permeability, limited aquifer extent, etc.), and the resulting uncertainty in predictions of impacts,

Note: Observation wells, re-evaluation by consultants in annual water use reports, increased frequency of monitoring, and low-level shut-off requirements are common licence conditions warranted by such uncertainty.

(e) Discharge or return flow for remediation and aqua-culture projects which require specific conditions to monitor quality and quantity.

Multiple large groundwater diversion or drainage in the same area and development of groundwater diversion or drainage with high potential for increases in population or industrial use may warrant monitoring conditions to confirm or update impact predictions.

Monitoring conditions may include

(a) monitoring household wells in the area,

(b) constructing and monitoring additional wells,

(c) continuous or frequent monitoring production volume and water level , and

(d) annual water use evaluation reports.