Comox Valley
REGIONAL DISTRICT

Staff report

DATE: February 11, 2016

FILE: 5330-20

TO: Chair and Directors
Electoral Areas Services Committee

FROM: Debra Oakman, CPA, CMA
Chief Administrative Officer

RE: 2015 Saratoga Beach – Puntledge Black Creek (Area 'C') – Groundwater Monitoring Program

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Purpose
The purpose of this report is to provide the electoral areas services committee with a summary of the 2015 Saratoga Beach groundwater monitoring program findings. The monitoring program was carried out to evaluate the performance of onsite treatment systems in the Saratoga Beach settlement node based on the quality of the groundwater.

Policy analysis
Bylaw no. 2422, being the "Regional District of Comox-Strathcona Liquid Waste Management Planning Service Bylaw No. 2422, 2002" provides planning services to the rural areas with regard to liquid waste management.

Local Government Act (RSBC 2015 c. 1) section 306 states that a board may, by bylaw: (a) regulate and prohibit the design and installation of drainage and sewerage works provided by persons other than the regional district; and (b) require owners of real property to connect their buildings and structures to the appropriate sewer or drain connections in the manner specified in the bylaw.

Executive summary
Saratoga Beach is a rural residential and recreational area within Area 'C' of the Comox Valley Regional District (CVRD). The population in Saratoga Beach doubles in the summer months due to tourism and onsite wastewater treatment systems are utilized to treat sewage in this community. In response to concerns from residents regarding residential lot densities, variable soil conditions, and high water table in the area the CVRD commissioned a hydrological study to estimate the extent of failures of on-site wastewater treatment systems in the area.

The groundwater monitoring program was carried out by Payne Engineering Geology in March and April of 2015, when the subsurface water table was near its seasonal high. A study area that extends from the foreshore to Macaulay Road and from the Oyster River to Schulz Road was identified for this monitoring program.

The main objective of this monitoring program was to evaluate the overall failure rate of onsite treatment systems based on testing of groundwater quality downslope of the developed areas. Rather than investigating individual onsite treatment systems' conditions, Michael Payne broke the study area into sub areas and installed a monitoring well in each. Nitrate levels and *Escherichia coli* bacteria concentration in the monitoring wells were used as indicators for groundwater contamination due to failed onsite treatment systems.

The study shows an overall onsite treatment systems failure rate of 19 per cent based on groundwater quality for the entire study area. However, all of the failed wells were located within a densely populated zone roughly between the foreshore and the Saratoga Beach Estates property as illustrated in Figure 5 of appendix A, and referred to as the designate area. Six out of 12 testing wells within the designate area failed to meet or exceed the project specified water quality objectives. In addition to the possible presence of poorly maintained, ageing or undersized septic systems, these relatively high failure rates are exacerbated by high lot densities and a high water table. Based on these results, the study concludes that no urgent need exists for a larger area treatment system to service the entire settlement node. On the other hand, the study recommends connecting the properties within the designate area to a publicly owned communal treatment system if subsequent engineering studies demonstrate feasibility.

Recommendation from the chief administrative officer:
This report is presented for information only.

Respectfully:

D. Oakman

Debra Oakman, CPA, CMA
Chief Administrative Officer

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Attachments: Appendix A – "Report on the 2015 Saratoga Beach Groundwater Monitoring Program"

Appendix A

Draft # 7 for review and comment

Report on the 2015 Saratoga Beach Groundwater Monitoring Program

9 February 2016

Prepared for

Comox Valley Regional District

Courtenay, BC

Prepared by

Payne Engineering Geology

1230 Maple Road, North Saanich, BC, V8L 5P7

PEG File: CSR-3-1

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Contents

1. Introduction

1.1 Context

Saratoga Beach is a rural residential and recreational area in the Comox Valley Regional District (CVRD), generally located south of the Oyster River and north of Black Creek. Figure 1, Appendix 7, outlines the Saratoga Beach Study Area for this monitoring program. The following paragraphs outline the background and context for this consulting project, based on information provided by the Regional District.

In the summer months, this area experiences a doubling of population and an influx of day visitors. Currently, wastewater in the Saratoga Beach area is managed by onsite sewerage systems, including residential septic systems and a few communal or cluster sewage systems. One perception is that this limits the potential for residential and tourist development. Furthermore, many residents have expressed concern about residential densities and variable soil conditions in the area. Responding to this, the Regional District has commissioned studies to consider options for wastewater systems in the area. Since Saratoga Beach is isolated from large municipalities, the community is unable to join existing sewage infrastructure.

In February of 2015, the CVRD retained Payne Engineering Geology (PEG) to evaluate the performance of onsite sewage systems within the Saratoga Beach Study Area (or settlement node), by assessing groundwater quality within sub-areas of the node for evidence of contamination from failing onsite sewerage systems. This Study Area includes approximately 600 properties, with potential for further development. This study identifies areas within the Saratoga Beach settlement node where onsite systems are functioning as intended, and other areas experiencing a significant rate of failure. Section 2.2 of this report reviews relevant conclusions of the Regional District's Stage 1 Liquid Waste Management Plan (LWMP).

1.2 Purpose of the Monitoring Program

This groundwater monitoring program evaluates the overall effectiveness of onsite sewage systems within the Saratoga Beach Study Area. This information will inform Comox Valley Regional District decisions on how to best manage wastewater in this region. Specific objectives of this monitoring program were as follows:

(1) Identify the overall failure rate of onsite sewage systems in the Study Area, based on testing of groundwater quality down-slope from developed areas.

(2) Identify sub-areas with substantially different failure rates, compared with the overall Study Area.

(3) Evaluate the overall state of onsite sewage systems in the Study Area based on the results of this study.

(4) Discuss probable causes of onsite system failures.

(5) Recommend measures that the Regional District can consider when planning and managing sewage systems in the Saratoga Beach area.

The premise of this study is that shallow groundwater monitoring is a cost-effective way to measure the overall success or failure of onsite sewage systems, based on how well these systems protect groundwater quality. The basic premise is as follows:

(1) If shallow groundwater has been contaminated by sewage system pollutants, and exceeds water quality objectives, then this implies a general failure of onsite systems.

(2) In contrast, if most of the shallow groundwater meets applicable groundwater quality objectives, then this implies effective soil-based treatment of sewage by onsite sewage systems.

1.3 Limitations of this Review

This study reports on groundwater quality in 38 samples collected from 31 monitoring wells in the spring of 2015. The field and laboratory reports do not indicate groundwater quality at any other locations or at any other time. However, the results do provide a meaningful "snapshot in time" that supports the key report conclusions.

This report summarizes results of a regional study completed for the Comox Valley Regional District. The study focusses on overall success and failure of onsite sewage systems within the Saratoga Beach Study Area, for planning purposes. It does not evaluate the success or failure of any individual onsite systems on any particular properties within the Study Area, and is not intended to meet requirements of any wastewater regulation.

For convenience, the study included collecting water samples from two shallow, privately-owned water supply wells. The purpose was not to evaluate the water quality for use by the well owner. The purpose was to evaluate the overall effects of onsite systems on groundwater quality.

This report is subject to the attached Statement of General Conditions (Appendix 1).

1.4 Scope of PEG Services

In general, this review study included the following services and analysis (see Appendix 3 for methodology):

- Review background maps and reports, including the Regional District's Liquid Waste Management Plan. *See list in Appendix 2.*
- Select locations for sampling groundwater for this study, including new wells to be installed, pre-existing water supply wells, and pre-existing monitoring wells.
- Auger holes and log the soil profile.
- Install new monitoring wells.
- Purge and sample wells.
- Deliver samples to a laboratory for testing.
- Re-sample wells where appropriate, based on the first set of tests.
- Analyse the results and prepare this report.

We understand that the following parties will provide the following related services:

- The Regional District will remove monitoring wells from locations that might be disruptive or at-risk of damage.
- The RD will maintain one or more of the wells for potential future use for monitoring of the depth of the water table or sampling of groundwater.

2. Background

2.1 Summary of the Study Area and Project

The Saratoga Beach area is a rural residential area that is mainly serviced by communal water supply systems and individual onsite sewage systems. However, this area does include a few individual onsite water supply wells, and a few privately-owned communal sewage systems. The following table is a summary of the Saratoga Beach area and water and sewage systems.

Table 1: Summary of the Study Area

AREA SUMMARY	
Name:	Saratoga Beach Study Area or Settlement Node.
Map:	See Figure 1 in Appendix 7.
# of parcels:	Approximately 600 parcels on 570 hectares.
Parcel sizes: *approximate*	Average: 1.0 hectare. Range: 0.11 ha (1,100 sq.m.) to 30 ha. Public parks: 8 hectares total park area.
SEWAGE AND WATER SERVICES	
Land use:	Rural residential and commercial recreational
Sewage systems and regulations:	About 85% of the sewage is managed with onsite sewage systems. Depending on age, these will be either: (1) permitted under the 1985 ***Sewage Disposal Regulation*** (SDR); or (2) registered under the 2005 ***Sewerage System Regulation*** (SSR) (Note 1). The remaining 15% is managed via a few privately-owned communal sewage systems. Depending on age and size, these may be either: (1) permitted under the 1985 ***SDR***; or (2) registered under the 1999 ***Municipal Sewage Regulation***; or (3) registered under the 2012 ***Municipal Wastewater Regulation***. See below for a list of known systems.
Water supplies:	An estimated 98% of the existing dwellings are served by a Communal Water System: This includes two systems: (1) the Black Creek and Oyster Bay Water System, owned and operated by the Comox Valley RD; and (2) Watutco Enterprises Ltd. Approximately 2% of the existing dwellings, or about 10 properties, have a private onsite water system: These include dug wells and drilled wells.

Footnotes

(1) There could be one or more illegal onsite sewage systems, that is, systems that have not been permitted under the SDR or registered under the SSR.

In the Study Area, we found three privately-owned communal sewage systems:

- Pacific Playgrounds, 9082 Clarkson Avenue, serving 20 rental cottages, a campground with 201 campsites, and a 200-berth marina (details from www.pacificplaygrounds.com).
- Saratoga Beach Mobile Home Park, 2157 Regent Road, serving approximately 42 mobile homes (from aerial photograph).
- Driftwood Estates bare-land strata, Driftwood Road, serving approximately 14 residential properties (from CVRD iMap2.1).

2.2 Project History and Previous Reports

Table 2: A Brief Chronology of Events and Reports

Date (author)	Event or Report Title
Oct 1999 (RDC-S)	The Regional District (RD) adopts the first Saratoga Miracle Beach Local Area Plan.
Mar 2002 (RDC-S)	The RD completes a survey of 400 residents, regarding septic systems and considerations for a community sewage system. *This provides useful information about maintenance practices and about the average age of onsite systems in this area.*
Jan 2004 (RDC-S)	The RD completes a Liquid Waste Management Plan (LWMP) for the Saratoga and Miracle Beach areas, with assistance from engineering consultants. ***Report reference:*** Regional District of Comox – Strathcona, 2004. *Liquid Waste Management Plan, Stage 1, Final Report, Volume 1.* LWMP conclusions and recommendations, relevant to this Study, include: • Provides opinions that there are problems with failing septic systems, and that this Study Area has "poor soils". • The RD should develop a plan or program for managing onsite sewage systems. • Emphasize public education on using and maintaining onsite sewage systems. • The report presents three options, with each option relying on one or more publically-owned sewage systems, connected to and servicing most of the properties in the Study Area (90% - 95% of the properties). • The report recommends that a small number of larger properties, in Zone 3, continue to use onsite sewage systems. This is 5% to 10% of the properties.
Dec 2005 (RDC-S)	The Regional District develops a design concept for a publically-owned sewage system for the Saratoga Beach area, including the following features: • Gravity collection sewers connecting to most or all properties. • An advanced (Class A) wastewater treatment system; a membrane bioreactor was proposed. • Beneficial reuse of reclaimed water. The method and location of emergency or backup discharge (to river or ocean or ground) is not indicated. • Construction cost estimate of $23.1 million. ***Reference:*** *RDC-S slideshow presentation dated 1 Dec 2005.*

Feb 2006 (RDC-S)	The Regional District holds a referendum on borrowing of funds to design and build a publically-owned sewage system serving the entire of the Saratoga Beach development node. Voters defeat the borrowing proposal by a margin of 630 No to 349 Yes (from RDC-S News Release).
Nov 2006 (SBE)	On November 15, 2011, the Regional District board approved the master development agreement (MDA) for a 31-hectare parcel and 143 lot residential subdivision, located within Sub-Area 5 (see Figure 2, Appendix 7). *See footnote.*
Feb 2014 (IPS)	Community consultation for updating Official Community Plans. ***Report reference:*** Island Planning Services, February 2014. *Community Consultation, Rural Comox Valley OCP Review & Update.* This report is non-technical and focusses on common themes from community consultation including resident concerns regarding “failing septic systems”.
Nov 2014 (CVRD)	The RD invites proposals to complete this groundwater monitoring program.
2015 (PEG)	Payne Engineering Geology (PEG) completes this study.

Footnote

The Saratoga Beach Estates MDA is relevant to this study because the MDA requires the developer of Saratoga Beach Estates to construct a wastewater treatment plant, which will then be turned over to the CVRD to own and operate.

Reference: Comox Valley Regional District, November 2011. *SBE Master Development Agreement.* *http://www.comoxvalleyrd.ca/assets/Department/Documents/SBE_Master_Development_Agreement_November2011.pdf*

2.3 Surface Water Quality at Saratoga Beach

We are not aware of any previous monitoring of groundwater quality in this area. However, government agencies have monitored surface water in the Oyster River and nearshore ocean water quality at several locations.

2.3.1 Oyster River

BC Environment has established water quality objectives for the Oyster River, including the following objectives relevant to monitoring for sewage system contaminants (from Nagpal, 1990; Nordin et al, 2009):

- Fecal coliform bacteria: 90^{th} percentile less than 100 CFU/100mL (i.e.: no more than one sample, from every ten consecutive samples, must exceed a bacteria count of 100)
- NO_3 - Nitrate nitrogen: 30-day average less than 3.0 mg/L
- NO_2 - Nitrite nitrogen: 30-day average less than 0.02 mg/L

These water quality objectives recognise that the Oyster River supports aquatic life including fish, and is a direct or indirect source of drinking water.

For background, the following are selected relevant quotes from BC Ministry of Environment water quality reports for the Oyster River (Nagpal, 1990; Obee et al, 2010):

> *The Oyster River and its tributaries are a valuable resource for trout and salmon fisheries. They also serve as a source of drinking water supply and irrigation water. Although the recreational uses are confined primarily to the lower reaches of the main-stem Oyster River below Woodhus Creek, fishing may take place all the way to the confluence of Piggott Creek.*
>
> *In the upper watershed, forestry continues to be the main land use activity; however, rural residential development and agriculture are the main land use activities in the lower watershed. Most [water quality] parameters were well below the water quality objectives. ….*
>
> *The fecal coliform objective was met at Site 2 [Oyster River at Highway 1] in all sampling periods (2001-2008].*

In the quote above, the objective for fecal coliform bacteria is a density of less than 100 CFU/100mL. The Oyster River is also used as a source of drinking water, but the water is filtered through the river bed, and then disinfected, before distribution to residences (M. Herschmiller, 2015, *pers. comm.*). As a result, the applicable raw water criterion for drinking water would be nitrate-nitrogen less than 10 mg/L.

2.3.2 Black Creek

Black Creek is located outside of this Study Area. However, the southern edge of the Study Area, near Miracle Creek Drive, drains into Black Creek. As a result, Black Creek is part of the *receiving environment* for several onsite sewage systems along Miracle Creek Drive. The Stage 1 LWMP (RDC-S, 2004) reported that:

> *Black Creek is an important water body from a fisheries and agricultural perspective. Similar to the Oyster River, it traverses forest and agricultural lands. The lowest reaches of the Creek are developed but not to the extent of the Oyster River. In February of 2000 Black Creek was identified as one of fifteen streams in the province to be given a Sensitive Stream designation under the Fish Protection Act (FPA).*

The BC and Canada Water Quality web sites include water quality reports for several BC water bodies, but no reports on Black Creek.

2.3.3 Strait of Georgia

According to Fisheries and Oceans Canada (Thomson, 1981):

> *The Strait of Georgia is by far the most important marine region of British Columbia. More than 70% of the population of the province is located on its periphery and its shores provide a foundation for expanding development and industrialization. The Strait is a waterway for a variety of commercial traffic and serves as a receptacle for industrial and domestic wastes from the burgeoning urban centers of greater Vancouver. .... the Strait of Georgia constitutes a multiple-use aquatic environment that must be considered a national asset worthy of utmost consideration and protection.*

Appendix 6 lists the water quality objectives for this study, based on protecting public health and the environment, including shellfish and fisheries in the Strait of Georgia. The Government of Canada (Environment Canada) and the regional health authority (Island Health) both periodically monitor water quality near Saratoga Beach, although the monitoring is limited to indicator bacteria.

BC Environment has established the following water quality objectives for shellfish harvesting and swimming (from Waddington, 2001):

- *Escherichia coli (E. coli)* bacteria, for shellfish harvesting: 90th percentile less than 43 per 100mL and a median value of less than 14 per 100mL
- *E. coli*, for swimming: geometric mean less than 20 per 100 mL

During 2013-2014, Environment Canada sampled ocean water four times at Saratoga Beach, Station Number DP028, samples in May and October-November of each year. The laboratory reported a fecal coliform density of < 2 to 5 MPN/100mL in the four samples. These four results meet the water quality objectives for shellfish harvesting and swimming.

During 2014, Island Health reported safe saltwater quality for all samples collected from Saratoga Beach and Miracle Beach. Reported Enterococci densities were 5 or less than 5, per 100 mL, for a total of 28 samples collected from 4 sample locations. "Beaches are generally considered microbiologically safe to swim at when single sample results are less than 200 (fresh water) or 35 (salt water)" (Island Health, 2014).

3. Field Observations and Measurements

3.1 Geographic Setting and Terrain

The Study Area, for this groundwater monitoring program, is south of the Oyster River and north of Black Creek, as shown in Figure 1, Appendix 7. This is within the physiographic region known as the Nanaimo Lowland. In general, the surficial geology is dominated by a sandy glacio-marine deposits overlying glacial till at higher elevations, and by the Oyster River delta at lower elevations (from Fyles, 1959). The following tables summarize the climate and geographic setting and terrain of the Saratoga Beach region.

Table 3: Climate and Weather Summary for Comox

Precipitation:	Annual average 1,154 mm
Wettest months:	October – March have combined 78% of total precipitation.
March average:	Precipitation 105.7 mm.
March of 2015:	*Precipitation 101.9 mm (for comparison)*
Driest months:	April – September have combined 22% of total precipitation.
Moisture deficit:	The historical average moisture surplus is 89 mm/year. (Moisture deficit is negative 89 mm/year.)
Hottest month:	July: Average daily temperature 22.8°C
Coldest month:	December: Average daily temperature 3.5°C
Sources:	http://climate.weather.gc.ca/climate_normals http://farmwest.com/climate/et

Table 4: Geographic Setting and Terrain

Setting:	The biogeoclimatic zone is Coastal Western Hemlock.
Elevation:	0 to 80 m.
Surficial geology:	Geological Survey mapping shows three main areas: (1) Clarkson Avenue neighbourhood: Oyster River delta and shore drift deposits; typically sand with minor gravel, silt, clay, and peat. (2) South bank of the Oyster River, near Regent Rd and Catherwood Rd: River delta deposits; sand and gravel overlying glacial till. (3) Remainder of Study Area: Glacio-marine veneer overlying till; typically sand with minor gravel. (4) Underlying deposit: The Vashon till underlies most or all of the Study Area. This is typically a cemented, massive mixture of gravel, sand, silt and clay.
Soils:	The British Columbia Soil Survey has mapped two main soil groups: (1) Clarkson Avenue neighbourhood: Kye Soil Group; rapidly-drained loamy sand and sandy loam. (2) Remainder of the Study Area: Mostly Bowser Soil Group; imperfectly drained loamy sand and gravelly sandy loam, of variable depth, overlying silt loam or silty clay loam.
Aquifers:	There is one mapped aquifer in the study area, Aquifer 410. This is described as the southern bank of the Oyster River delta, and underlies the Clarkson Avenue neighbourhood. It is an unconfined sand and gravel aquifer this is productive and highly vulnerable, with moderate use (demand) as a supply of domestic water. No particular water quality or supply quantity concerns have been identified to date.
Sources:	BC Ministry of Forests, 1999. *Biogeoclimatic Zones of BC.* Comox Valley RD, 2015. *iMap2.1.* Fyles, 1959. *Map 49-1959, Surficial Geology, Oyster River.* Jungen, 1985. *Soils of Southern Vancouver Island.* Humphrey, 2000. *Regional District of Comox-Strathcona Aquifer Classification Project.* BC Water Resources Atlas, 2015.

These tables provide background information on the geographic setting; Sections 4 through 6 of this report discuss the implications.

3.2 Field and Laboratory Tests

For this monitoring program, field and laboratory testing included the following:

- Area reconnaissance and layout of monitoring well sites.
- Identifying pre-existing monitoring wells and water supply wells that were suitable for sampling.
- Checking locations of buried utilities.
- Hand augering 28 test holes, and installing 28 shallow groundwater monitoring wells. *See Figures 3 and 4 in Appendix 7.*
- Locating each well using hand-held GPS.
- Measuring the depth of the water table in 32 wells.
- Collecting 31 groundwater samples for laboratory testing (Set 1).
- Based on results from Set 1, collecting 7 repeat groundwater samples for lab testing (Set 2).

Appendix 3 is a summary of the field and laboratory dates, methods and rationale.

3.3 Observed Soil and Groundwater Conditions

The following is a summary of typical soil and groundwater conditions in the auger holes and monitoring wells (see also Appendices 4-2 and 4-3).

- Land slope: 4% to 12%
- Soil profile: Gravelly sand to sandy loam / OVERLYING / Silt loam.
- Bedrock: No bedrock found in auger holes.
- Depth of hand auger holes: 70 to 280 cm.
- Depth to soil mottling: 70 to 140 cm
- Depth of roots: 60 to 105 cm
- Measured depth of water table: 35 to 140 cm (31 March to 13 April 2015). *See Appendix 4-4.*
- Estimated depth to seasonal high water table: 60 to 120 cm
- Typical vertical thickness of perched water table (on flow restrictive layer): 10 to 20 cm

For this study, the typical soil B Horizon may was logged as follows:

- Soil texture: Gravelly sand to sandy loam.
- Structure: strong blocky or strong granular or single grain.
- Consistency: very friable or loose.
- Cementation: Not cemented.

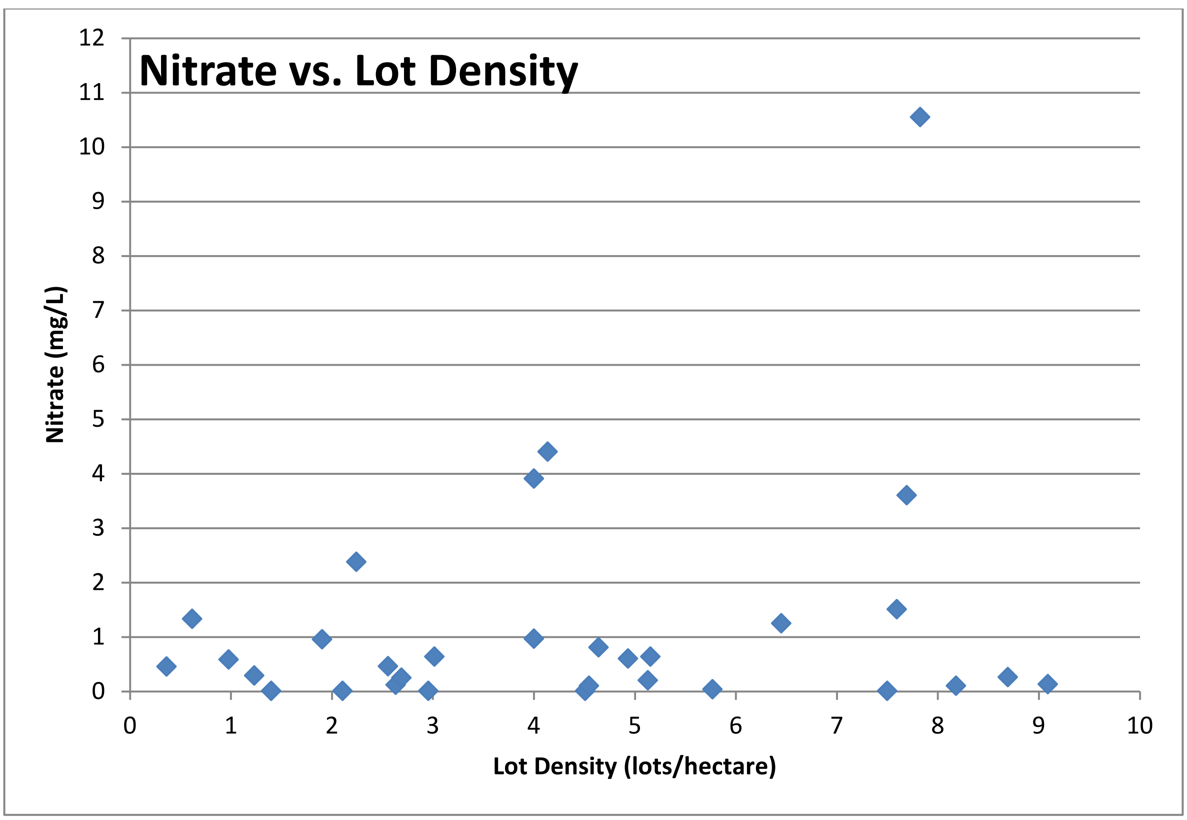
4. Hydrogeology and Engineering Analysis

4.1 Groundwater Quality in Monitoring Wells

From our review of background reports, we found little technical information about how well onsite sewage systems are working in the Study Area, or about their effect on groundwater quality. This groundwater monitoring program is the first technical study of this question. For analysis refer to the appendices. Appendix 3 reviews the methods used. Appendix 4 reports on field observations and measurements, including water quality. Appendix 5 is a summary of the laboratory testing results. Appendices 5 and 6 interpret the laboratory test results. Appendix 7 includes figures showing the location of the study area and monitoring wells.

4.2 Influence of Lot Size

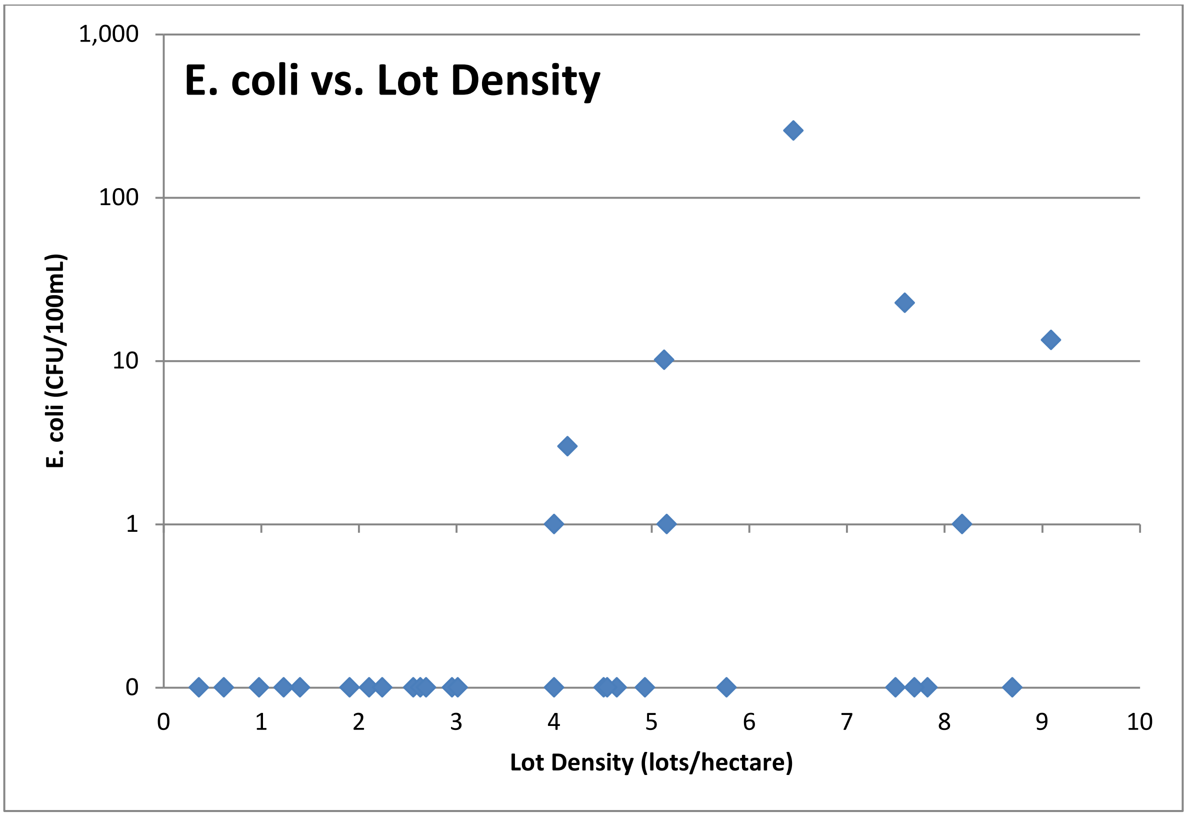
To analyse lot size versus groundwater quality, we looked at the average lot size (or septic system density) immediately up-slope from each of the monitoring wells. The following graph shows groundwater nitrate concentrations versus lot density.



For this project, the water quality objective for nitrate is 3.0 mg/L. This graph shows that all monitoring wells with a nitrate concentration exceeding 3.0 mg/L were located down-slope from areas with a higher residential density, with four or more lots per hectare.

This graph also shows that the monitoring wells located down-slope from lower density areas, with fewer than 4 lots per hectare, met the water quality objective. This shows a clear relationship between lot density and nitrate concentration. This is consistent with published research showing how residential lot size affects concentrations of nitrate in groundwater (Hantzsche and Finnemore, 1992; Gardner and Vogel, 2005).

The following graph shows groundwater E. coli density versus lot density.



This graph also shows how groundwater quality is influenced by lot density. For this project, the water quality objective for E. coli is less than 14 CFU/100mL. This graph shows that the wells that exceeded this value were located down-slope from areas with a lot density of more than 6 lots per hectare. Similarly, the wells located down-slope from lower density areas, with fewer than 6 lots per hectare, met the project objective.

Also, this graph shows that no E. coli bacteria were detected in any of the wells located down-slope of areas with a density of fewer than 4 lots per hectare.

Both of these graphs show a clear distinction between lower density areas of fewer than 4 lots per hectare, and higher density areas with more than 4 lots per hectare. This is equivalent to an average lot size of 0.25 hectare. For comparison only, the Island Health *Subdivision Standards* recommend a minimum lot size of 1.0 hectare, or a density of fewer than one lot per hectare, when the water table depth is 46 to 60 cm. The standards do allow for lots as small as 0.20 ha, when the water table is deeper than 90 cm (VIHA, 2013).

4.3 Influence of Depth of the Water Table

In general, septic systems work better where the water table is deeper. In this study, the monitoring wells with a water table deeper than 105 cm had a nitrate nitrogen concentration of less than 1.0 mg/L. Also, for the monitoring wells with a water table deeper than 90 cm, the reported E. coli density was less than 14 CFU/100mL. Considering both of these observations, the analysis shows a difference in groundwater quality in areas with a water table deeper than about 100 cm, when compared with areas with a water table shallower than 100 cm.

This result is generally consistent with the Island Health *Subdivision Standards,* which apply to proposed new residential subdivisions with individual onsite septic systems. These Standards recommend a minimum soil depth, to the seasonal high water table, of:

- at least 90 cm soil depth, when the lot size is 0.20 hectare or larger; and
- at least 76 cm of soil depth, when the lot size is 0.30 hectare or larger (for a lot with a slope of less than 15%)

4.4 Analysis of Onsite System Failures

This study indicates favourable treatment and dispersal of wastewater from onsite systems within the Study Area. However, analysis also reveals two problem areas (Figure 4).

(1) SARATOGA BEACH: Wells MW-7, MW-8, MW-9, and MW-31. This problem area does not extend as far inland as Clarkson Avenue, as indicted by favourable water quality in wells MW-27, MW-28, and MW-29.

(2) EAST SIDE OF McLAREY AVENUE: Wells MW-23 and MW-24. This second potential problem area does not extend to the west side of McLarey Avenue, as indicated by wells MW-6A, MW-6B, and MW-22.

Based on the location of the problem area, and based on locations of higher density areas with a shallow water table, Figure 5 identifies a *Designated Area* that, in our interpretation, has the least favourable conditions for on-site sewage systems. One implication of this is that, if the Regional District decided to connect some existing systems to a new communal sewage treatment system, these lots would be the higher priority for connection.

This study analyses probable causes of onsite sewage system treatment failures, as indicated by contaminated groundwater. Our analysis and interpretation provides good evidence of the following causes:

1. SMALL LOTS: Areas with smaller residential lots, especially lots smaller than 0.25 hectares, had an implied onsite system failure rate of 33%, compared with 0% for areas with lots larger than 0.25 ha. While this is only based on water quality in 32 locations in the spring of 2015, the results indicated a clear influence of lot size.
2. RECREATIONAL DENSITY: Higher density recreational developments, particularly when exceeding 12 cabins or RV campsites per hectare, contribute to onsite system failure. The expected wastewater flow rate from a cabin or RV campsite is approximately one third of that from a single family residence, on average.
3. SHALLOW WATER TABLE: Areas with a shallow water table, particularly areas with a water table shallower than 105 cm, had a higher failure rate. However, a shallow water table is not a reliable indicator of system failure in this Study Area. Even in areas with water table shallower than 60 cm, several of the monitoring wells indicated acceptable groundwater quality. This analysis is based on the seasonal high water table, as defined in the BC *Sewerage System Standard Practice Manual (SPM)*.
4. OLDER UNDERSIZED SYSTEMS: Many older onsite sewage systems are undersized relative to current regulations, and many will be overdue for maintenance or repair.

SOIL CONDITIONS IN THE STUDY AREA:

In this study area, the shallow soil type is generally favourable for onsite sewage systems, consisting mainly of loamy sand, sandy loam, and fine to medium-grained sand.

SEPTIC SYSTEM DESIGN AND INSTALLATION:

It is reasonable to expect that some onsite systems have failed or malfunctioned because of poor design or installation. However, while we have no details about individual onsite systems, we have no reason to expect many serious problem designs or installations.

4.5 Life Expectancy of Onsite Systems

Under favourable conditions, an onsite system may have a life expectancy of 40 to 80 years. Favourable conditions would include the following:

(1) favourable soil and groundwater conditions, especially an adequate depth to the water table;

(2) design and installation that complies with current standards, particularly the size of the septic tank and drainfield; and

(3) regular maintenance and repair by a qualified practitioner.

It is reasonable to expect that most of the onsite systems in the Saratoga Beach Study Area do not meet all three of the three longevity criteria listed above. Without the benefit of a comprehensive survey, we would expect that most systems in this Study Area would fail to meet one or two of these criteria.

There is no reliable way to estimate the life expectancy of an onsite system. However, based on our experience, we estimate that most of the onsite systems in this Study Area would have a life expectancy of 20 to 40 years. After reaching the end of this lifespan, a system should be replaced with a new onsite system or a new community sewage system. A previous survey of homeowners in the Saratoga Beach Area indicated an average system age of 11-21 years in 2004, or 22 to 32 years in 2015 (RDC-S, 2004).

Based on this analysis, we would then estimate that about 50% of the Saratoga Beach systems are now nearing their life expectancy, and will need a major upgrade or replacement within the next 10 years.

4.6 Costs of Sewage Systems at Different Scales

Over the last 20 years, several research studies have examined lifecycle costs of ***decentralized*** sewage systems, including onsite sewage systems (septic systems), and cluster systems. These studies show that *decentralized systems* have total lifecycle costs that are often lower than for larger ***centralized*** municipal sewage systems (see Appendix 2).

This distinction, between *centralized* and *decentralized* systems, is more a matter of the distances between the collection, treatment, and discharge components of the system. It is not a matter of who owns or manages the system. Indeed, many newer decentralized sewage systems are owned by, or managed by, a central government or agency. These are sometimes called *centrally-managed decentralized systems*. This concept is growing in popularity because these systems can offer both: (1) the advantages of small systems with distributed reuse or discharge of treated wastewater; and (2) advantages of reliable publically-funded management or maintenance.

Considering the example of Saratoga Beach, Section 6.2 of this report contemplates a cluster sewage system serving a portion of the area. Such a system would be considered a *decentralized* system if the treatment and discharge were located nearby.

5. Summary and Conclusions

5.1 Measured Success and Failure of Onsite Systems

In the Saratoga Beach Study Area, we monitored groundwater quality in March and April of 2015, when the water table was near its typical seasonal high. This monitoring shows that most of the onsite systems are functioning without causing serious groundwater pollution. However, the monitoring program did detect groundwater pollution in some areas, and failing onsite systems are the most probable cause of this pollution. The identified pollution includes nitrate nitrogen and *Escherichia coli* bacteria, both of which may be attributed to onsite sewage systems, although other pollution sources could also contribute to higher concentrations of nitrate or to higher densities of *E. coli*.

From this study, the onsite sewage system failure rate, for the entire Saratoga Beach Study Area, is 19%. The overall failure rate is expected to be lower in the summer and autumn.

On some or many of the higher density recreational properties, it is reasonable to expect higher failure rates in the summer, when considering nitrate-nitrogen concentrations in particular. This is because the deeper summertime water table is not expected to compensate for the higher occupancy and increased sewage discharge.

For comparison purposes, the Building Canada Fund states that: "*Normally, only onsite systems serving at least 25 lots, where there is a minimum 25 percent failure rate, will be considered for funding.*" (BC Ministry of Community Development, 2009) By this definition, an overall 19% failure rate could be considered manageable. However, as discussed below, we found that some parts of the Study Area are more prone to failures.

5.2 Problem Areas

Overall, six out of 31 monitoring wells, or 19%, failed to meet or exceed the project-specific water quality objectives (Appendices 5 and 6).

Two of these six wells failed to meet the E. coli objective. In particular, well MW-23 had an E. coli density of 23, and MW-31 has an E. coli density of 257 CFU/100mL.

Four of these wells had a nitrate concentration exceeding the project-specific objective; these four monitoring wells had a nitrate concentration in the range of 3.6 to 10.6 mg/L. Based on this, we identified two potential problem areas, as follows:

(1) SARATOGA BEACH: Wells MW-7, MW-8, MW-9, and MW-31.

(2) EAST SIDE OF McLAREY AVENUE: Wells MW-23 and MW-24.

Based on these results, Figure 5 shows an interpreted or inferred *Designated Area*. This is the area with the least favourable conditions for onsite sewage systems. Within this *Designated Area*, the overall failure rate, based on methods of this study, was 6 out of the 12 monitoring wells, for a 50% failure rate. This is a significant failure rate with reference to the Building Canada Fund standard listed above.

This study identified two main factors that influence how well onsite sewage systems function in this Study Area; (1) lot density; and (2) depth of the water table.

The first such factor is the lot density or lot size. The septic system failure rate was higher, 33%, in areas with lot sizes of 0.25 hectare or smaller. In contrast, in areas with an average lot size of larger than 0.25 hectares, the detected failure rate is zero.

The second factor is the depth of the seasonal high water table. In this study, all of the detected failures, based on measured groundwater quality, occurred in areas with a water table shallower than 105 cm. No failures were detected in areas with a water table deeper than 105 cm. This analysis is based on the depth of the water table measured at the time of this study, and is considered representative of the typical seasonal high water table.

Considering areas with a shallow water table, there are important differences between conventional below-grade drainfields and shallow or above grade dispersal systems, such as sand mounds. To the best of our knowledge, most of the existing onsite sewage systems in this Study Area use conventional below-grade drainfields, with infiltration trenches buried about 50 cm deep. However, on properties with a shallow water table, current standard practice calls for an at-grade or above grade drainfield, providing a vertical separation of at least 75 cm between the drainfield and the seasonal high water table (Ralston and Payne, 2014).

This implies that many of the treatment failures could be remedied by replacing existing below-grade drainfields with new above-grade drainfields built to current standards.

5.3 Overall State of Onsite Systems in this Area

This study indicates an overall onsite system success rate of 81%, or failure rate of 19%, based on groundwater quality in the Study Area. This result implies there is no immediate need for a publically-owned wastewater system to serve the entire Study Area or Development Node.

However, this study found a failure rate of 50% in the least favourable (or problematic) areas, particularly the *Designated Area* (Figure 5). The following table is a summary of the onsite system failure rates, for different areas or sub-areas, based on this study.

Table 5: Onsite System Failure Rates in Different Areas

AREA	Description	Failure rate
OVERALL STUDY AREA	Overall study area, or settlement node (see Figure 1)	19%
SMALL LOTS	Areas with lots smaller than 0.25 hectare.	33%
LARGE LOTS	Areas with lots larger than 0.25 hectare.	0%
DESIGNATED AREA	Lots in the *Designated Area* shown on Figure 5. In general, this sub-area has small lots and a shallow water table.	50%
BUILDING FUND CANADA (BFC)	For comparison only, BFC refers to a minimum failure rate of 25% for areas that will be considered for funding (see report Section 5.1).	25%

This study implies there would be some benefit to a new approach for wastewater systems for the problem areas. Section 6, below, discusses potential solutions for these areas.

5.4 Causes of Onsite System Failures

The probable causes of onsite system failures, within the Saratoga Beach Study Area, are as follows:

- small residential lots, especially lots smaller than 0.25 hectare;
- high-density recreational properties, especially those with more than 12 cabins or RV campsites per hectare;
- areas with a shallow water table, especially shallower than 105 cm; and
- emerging problems with operation and maintenance of aging undersized septic systems.

6. Recommendations

This study has implications for how the Comox Valley Regional District manages wastewater in the Saratoga Beach Study Area, including existing systems and new developments.

6.1 Managing Existing Wastewater Systems

As discussed above, a significant number of older existing septic systems contribute to groundwater pollution because of a combination of: (1) system components that are undersized relative to current standards; (2) drainfields that are too deep in the soil profile relative to the depth of the water table; and (3) incomplete system maintenance and repair by some homeowners.

Over the next five years, these existing systems should be upgraded to current standards. This change would better protect health and environment, even in areas with smaller lots and a shallower water table. As an example only, a viable system for a small lot might use an upgraded system with a sand mound, drainage improvements, or custom-design by a professional. Typically, these types of onsite sewage systems are more expensive than a conventional gravity septic system.

In this context, the best management practice, at least for some parts of the Study Area, will include continued use of individual onsite sewage systems, but with more effective management. To this end, the Regional District may consider how to better enforce the Sewerage System Regulation. This could potentially include measures to limit or prevent illegal installations and repairs, and programs to encourage or enforce regular maintenance of systems by registered practitioners.

This could include one or more of the following measures:

(1) working with Island Health to improve enforcement of the Sewerage System Regulation;

(2) directly involving the CVRD in improving the frequency and quality of maintenance and repair of existing onsite wastewater systems;

(3) monitoring changes in groundwater quality over time;

(4) reporting known or suspected problems to Island Health for investigation.

In support of these measures, the Regional District may wish to initiate an onsite system management program, supported regional bylaws. The 2004 LWMP discusses potential structures for such a management program. We recommend providing a copy of this report to Island Health (Gary Anderson, EHO) for review and comment.

6.2 Managing Wastewater for New Construction

For new land development in the Saratoga Beach area, the Comox Valley RD and property owners could consider the following viable alternatives:

(1) individual onsite wastewater systems (septic systems) on lots that are larger than 0.25 hectares, and have a seasonal high water table deeper than 100 cm; or

(2) a privately-owned cluster wastewater system, potentially collecting wastewater from smaller size lots, with a septic tank or treatment system, and with effluent discharge to a communal drainfield; or

(3) a publically-owned community wastewater system, with a septic tank or wastewater treatment system, with discharge to a communal drainfield or method of reuse.

Considering Option (1) above, a new subdivision based on individual septic systems should comply with Island Health (VIHA) *Subdivision Standard*s. This would lead to large lots in areas with a shallow water table. For example, the Island Health *Standards* specify a minimum building lot size of 1.0 hectare when the high water table is 46 to 60 cm deep. For this reason, a developer contemplating a subdivision in an area with a shallow water table might contemplate Options (2) and (3), to allow for smaller building lots.

Considering Option (3) above, the master development agreement between the CVRD and Saratoga Beach Estates, provides potential for a new clustered system built for this development to be subsequently handed over for management by the regional district.

For all three options, wastewater systems must comply with the applicable wastewater regulation, either the Sewerage System Regulation, or the Municipal Wastewater Regulation, depending on the design wastewater flow rate for the system.

Also, under each of the options listed, the wastewater system owner could consider an advanced treatment system that produces reclaimed water suitable for reuse. Based on analysis and design by a qualified professional, potentially viable options for reuse of reclaimed water include irrigation and landscaped water features.

6.3 Connecting Existing Parcels to a Communal System

Where possible, houses located in higher density areas with septic system problems, particularly the *Designated Area* in Figure 5, could be connected into cluster sewage systems being built for new construction. One such example is the Saratoga Beach Estates development referred to in section 6.2. Additional engineering analysis would be required to determine the technical and economic feasibility of retrofitting existing neighbourhoods for connection to such a community wastewater system.

6.4 Long-term Monitoring of Groundwater

The Regional District's aquifer mapping report (Humphrey, 2000) concluded that:

> *Water quality does not appear to be a pressing issue in the Regional District at the moment. However, baseline data has not been recorded for several of the aquifers identified. In order to monitor fluctuations in groundwater quantity and quality a network of observation wells is advised. This network may provide the baseline quality data required to identify contamination and also provide an early response to contamination, if it should occur.*

The shallow monitoring wells installed for this study may be used for long-term monitoring of shallow groundwater quality, focussed on the effects of onsite sewage systems.

Appendices

Appendix 1: Statement of General Conditions

Scope of this Report

This review report satisfies only those objectives stated in the introduction. Payne Engineering Geology (PEG) has not conducted a *Site Investigation*, *Hydrogeology Study* or *Environmental Impact Assessment*.

Use of this Report

This Payne Engineering Geology (PEG) report pertains only to a specific project. If the project is modified, then our client will allow us to confirm that the report is still valid. We prepared this report only for the benefit of our Client and those agencies authorized by law to regulate our Client's activities. No others may use any part of this report without our written consent. To understand the content of this report, the reader must refer to the entire, signed report. We cannot be responsible for the consequences of anyone using only a part of the report, or referring only to a draft report. This report reflects our best judgement based on information available at the time. Any use of this report, or reliance on this report, by a third party is the responsibility of that third party. We accept no responsibility for damages, if any, suffered by a third party as a result of decisions made or actions taken based on this report.

Reliance on Provided Information

PEG has relied on the accuracy and completeness of information provided by its client and by other professionals. We are not responsible for any deficiency in this document that results from a deficiency in this information.

Logs of Test Holes or Wells and Subsurface Interpretations

Ground and ground water conditions always vary across a site and vary with time. Test hole and well logs show subsurface conditions only at the locations of the test hole or well. The precision with which geological and geotechnical reports show subsurface conditions depends on the method of excavation or drilling, the frequency and methods of sampling and testing, and the uniformity of subsurface conditions.

Descriptions of Geological Materials and Water Wells

This report includes descriptions of natural geological materials, including soil, rock, and ground water. PEG based these descriptions on observations at the time of the study. Unless otherwise noted, we based the report's conclusions and recommendations on these observed conditions.

Changed Conditions

Conditions encountered by others at this site may differ significantly from what we encountered, either due to natural variability of subsurface conditions, or as a result of construction activities. Our client will inform us about any such changes, and will give us an opportunity to review our recommendations. Recognizing changed soil and rock conditions, or changed well conditions, requires experience. Therefore, during construction or remediation, a qualified professional should be employed to visit the site with sufficient frequency to observe whether conditions have changed significantly.

Risks and Liability

We recommend that our client engage PEG to review all design drawings and constructed works that are based on our conclusions and recommendations. This is a requirement of the *Association of Professional Engineers and Geoscientists of BC.*

Standard of Care

We exercise a standard of care consistent with that level of skill and care ordinarily exercised by professionals currently practising under similar conditions.

Appendix 2: References

References

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Costs of Sewage Systems

This appendix reviews conclusions from research studies that examine the lifecycle costs of decentralized sewage systems.

Study 1: US Environmental Protection Agency

This landmark US EPA study, and report to the United States Congress, concluded that:

> *Adequately managed decentralized wastewater systems are a cost-effective and long-term option for meeting public health and water quality goals, particularly in less densely populated areas.*
>
> *One area of concern is failing or obsolete wastewater systems in less densely populated areas. When these systems were first built, common practice was to install the least costly solution, which was not necessarily the most appropriate solution for the conditions. For a variety of reasons, these systems are failing. Both centralized and decentralized system alternatives need to be considered in upgrading failing systems to provide the most appropriate and cost-effective solutions to wastewater treatment problems.*
>
> *Decentralized onsite and cluster wastewater systems can be the most cost-effective option in areas where developing or extending centralized treatment is too expensive (e.g., rural areas, hilly terrain).*
>
> *Reference: US EPA, 1997.*

Study 2: Rocky Mountain Institute, Colorado

In 2004, the Rocky Mountain Institute completed a research study for the US EPA entitled *Valuing Decentralized Wastewater Technologies*. Relevant conclusions include the following:

> *Smaller [wastewater] systems lose the advantages of economies of scale that are possible in wastewater treatment capital costs and Operation and Maintenance costs. However, smaller systems also avoid diseconomies of scale that are inherent in sewer systems. Given that collection system costs can be 80 percent or more of total system costs, collection diseconomies of scale can overwhelm treatment economies of scale, resulting in decentralized systems being the more economical choice. However, high effluent standards tend to favor centralization, although it is possible to produce high quality effluent with some decentralized technologies. Some of these technologies, such as small-scale constructed treatment wetlands, may be more land-intensive.*
>
> *Reference: Pinkham et al, 2004.*

Study 3: Water Environment Research Foundation

In 2007, WERF completed a final report on evaluation and use of decentralized wastewater technologies. This 182-page report includes the following conclusion relevant to planning for the Saratoga Beach area:

> *Decentralized systems are reasonable alternatives in many situations. Nonetheless, it has been the experience of the authors, and many of the people interviewed for this report, that decentralized alternatives are ignored or cursorily dismissed in situations where they may be at least as cost effective as any centralized alternative.*
>
> *Reference: Etnier et al, 2007.*

Other Information Retained on File

In addition to the references listed above, Payne Engineering Geology has retained the following documents on file:

- field notes
- photographs of monitoring wells
- original laboratory reports
- measurements and estimate of chloride concentrations in groundwater and surface water
- maps showing locations of buried utilities

Appendix 3: Study Methodology

Step (date, 2015)	Procedure and Rationale (including references)
Select sub-areas for monitoring (March)	PROCEDURE Divide the entire Study Area into 30-35 sub-areas. *See Figure 2 in Appendix 7.* RATIONALE The number of sub-areas, 30 to 35, was carefully selected to allow for installation and sampling within the project budget, while still providing an adequate number of samples for a statistically representative sampling of groundwater quality. Sub-areas were selected to have: (1) similar geology and soil types, (2) similar land use and density, and (3) similar number of lots in each sub-area. Sub-areas do not coincide with drainage basins or watersheds.
Select locations for monitoring wells (March)	PROCEDURE Select one or more prospective locations for each sub-area. Arrange access to private properties. Mark locations in the field while checking for ease of access and locations of buried utilities. RATIONALE The selected monitoring well locations are: (1) at a relatively low elevation for the sub-area, that is, within the receiving environment for onsite systems; (2) located on public property, or on accessible private property; (3) down-slope of a residential density that is representative of that area; and, (4) avoiding buried utilities, where feasible.
Hand auger holes (March)	PROCEDURE Use a hand shovel and auger to excavate 28 holes. Log the soil profile. RATIONALE The holes were excavated by hand to avoid damaging buried utilities and reduce excavation safety risks. Where feasible, the auger holes were excavated to approximately 30 to 60 cm below the water table. John Langard, ROWP, and Michael Payne, P.Geo., logged the soil profile to USDA standards (Schoeneberger et al, 2012).

Install monitoring wells (March)	PROCEDURE Install 50-mm diameter PVC monitoring wells in the hand auger holes. Confirm access to privately-owned monitoring wells and water supply wells. Each monitoring well consisted of, from bottom to top: bottom cap, 50-mm diameter PVC well screen of length 300 to 400 mm and slot size 0.25 mm (0.010 inch), 50-mm diameter PVC well casing extending above-grade, 50-mm threaded cap. We do not have information about the length of well screen on pre-existing, privately-owned wells. Wells MW-2 and MW-3 were installed with a bentonite seal located above the well screen and below grade; the seals vertical thickness was 200 to 300 mm. Record the well coordinates using a hand-held GPS (Garmin GPSmap 60Cx, accuracy +/- 5 m). RATIONALE The well design and construction is consistent with applicable standards (Nielsen, 1991), with some modifications appropriate for shallow temporary monitoring wells. The monitoring wells were located where no surface water infiltration was anticipated, so bentonite seals were not installed. The exceptions were at MW-2 and MW-3, installed near the base of a relatively deep drainage ditch where surface water infiltration is expected at times.
Select project-specific water quality objectives (March)	PROCEDURE Select project-specific objectives for E. coli, nitrate-nitrogen, and nitrite-nitrogen in groundwater, based on water uses in the Study Area, and applicable provincial water quality objectives, considering effects of dilution where considered relevant (see Appendix 6). RATIONALE Appendix 6 is a summary of the water quality objectives, including identifying uses of groundwater, river water, and ocean water within the Study Area. Surface water quality objectives for nitrite depend on the concentration of dissolved chloride ions in the surface water, as this affects toxicity to aquatic life. For this reason, we used two approaches to select the water quality objective for nitrite (NO2). First, we considered chloride concentrations in shallow groundwater, which tend to be high, largely as a result of chloride contributions from septic systems. Second, we considered the chloride concentrations, and dilution effects, in surface water, where chloride concentrations are relatively low.

Select dates for well sampling (March)	PROCEDURE Sampling dates: We selected sampling dates to follow 1 to 4 days after rainy periods of 1-2 week duration. RATIONALE The date of sampling, at the end of March, was a suitable for the purpose of this study. Table 3, Section 3.1, shows that the rainfall during March of 2015 was more than 100 mm, and was within 5% of normal rainfall for this month. The latter part of the rainy season, mid-January through mid-April, is often preferred for this type of study because this is the time when soil oxygen levels are typically the lowest, responding to sustained high water tables. To confirm that the groundwater sampling dates corresponded to the time of the high water table, we checked the water table measurements in the nearest government Observation Well, #369. This is a shallow well, 7.3 m deep, located west of the Study Area, near to the Inland Island Highway. Records show a water table elevation that is within 20 cm of the typical seasonal high, from approximately January through mid-April of 2015. Additional checks showed that of the depth of the water table, during sampling, was comparable to the typical seasonal high water table. Appendix 4-2 shows that the depth of soil mottling and depth of roots were comparable to the depth of the water table in most monitoring wells in late March. The soil mottling and roots are good indicators of the depth of the seasonal high water table in geologic environments with a seasonal perched water table in southwestern BC.

Purge and sample monitoring wells (March 31 – April 2)	PROCEDURE Bailers and pumps: For each 50-mm diameter monitoring well, install a new Waterra clear PVC single-sample bailer and twine. The two pre-existing, privately-owned monitoring wells (MW-10 and MW-32) did not have bailers, so we installed new bailers in those wells. Bailers were secured inside each well to avoid contamination between sampling. For privately-owned water supply wells, we collected the sample using the pre-installed well pump. Sampling procedure: At each monitoring well, including the privately-owned wells, purge the stagnant water from the well. Record the field quality of the purged water (temperature, electrical conductivity, pH) using a Hanna Combo HI 98129. *See Appendix A4-5.* Use the bailer to collect a sample for laboratory testing. Place the sample in a cooler. To reduce risks of well-to-well contamination, and as a worker safety precaution, samplers washed their hands before and after each sample. Wells were secured by over-tightening the threaded caps. RATIONALE The monitoring wells were purged to stabilize field water quality parameters and to either: (1) purge at least 3 well volumes if the well recharged quickly, or (2) purge the well dry if the well recharged slowly (based on Neilsen, 1991).
Submit samples to Maxxam Laboratories	PROCEDURE Deliver the water samples to Maxxam Laboratories, Courtenay, within 24 hours of sampling. RATIONALE The laboratory provided the sample delivery time requirements.

Re-sample and re-test monitoring wells (April 13)	PROCEDURE Identify the MWs where the first sample exceeded the pre-set project-specific water quality objective. Re-purge and re-sample each of those wells. RATIONALE The intent is to confirm the water quality in situations where the first test result exceeded the project re-sampling criterion. We were unable to resample monitoring well MW-9 because it had been removed between April 2 and April 13. The groundwater quality, as indicated by the laboratory reports, is considered to represent the end result of all effective subsurface wastewater treatment processes, including dilution. The effects of dilution were not analysed separately; dilution is one of several natural subsurface processes which, in combination, may result in partial or full subsurface reduction or removal of sewage pollutants.
Provide MW locations to the RD for removal or future use (April)	PROCEDURE Provide the Regional District with maps, UTM coordinates, and photographs of each of the wells. Identify wells that may be suitable for longer-term use, and wells that should be removed soon to avoid nuisance to neighbours. It was agreed that the Regional District would remove the wells. Most or all wells can be removed by hand or using a simple level system. The hole can be backfilled with native soil or fill sand. In situations where the well cannot be conveniently removed, it may be cut off at grade and backfilled with fill sand. RATIONALE All of these monitoring wells were intended as temporary monitoring wells, installed for the purpose of this study only. However, several wells are “out of the way” and may be suitable for longer-term use. The remainder of the wells should be removed to avoid nuisance to neighbours and risk of damage to the well.

Refer to Appendix 2 for full references.

Appendix 4: Field Reports

A4-1: GPS Locations of Monitoring Wells

Grid: UTM, Datum: NAD83		
MW	Position (+/- 5 m)	Description
1	10 U 345629 5525559	01-APR-15 3:57:42PM
2	10 U 346087 5526030	01-APR-15 2:59:19PM
3	10 U 346084 5525953	01-APR-15 3:26:57PM
4	10 U 346651 5525790	01-APR-15 2:07:42PM. Corrected 07-JUL-15.
5	10 U 347273 5525966	07-JUL-15 6:22:53PM, +/- 4 m.
6A	10 U 347532 5525972	31-MAR-15 12:35:40PM. Corrected 07-JUL-15.
6B	10 U 347513 5525946	02-APR-15 11:52:38AM. 2103 Saratoga Road.
7	10 U 348008 5525877	01-APR-15 9:01:16AM. Beach.
8	10 U 348015 5525729	01-APR-15 9:21:00AM. Beach.
9	10 U 348350 5525115	31-MAR-15 6:50:17PM. Beach.
10	10 U 348595 5524838	31-MAR-15 5:37:33PM. Driftwood Estates.
11	10 U 348954 5524455	01-APR-15 11:01:23AM
12	10 U 348690 5524220	01-APR-15 12:07:48PM
13	10 U 348624 5524132	01-APR-15 12:01:07PM. Corrected 07-JUL-15.
14	10 U 348128 5524347	01-APR-15 6:37:50PM
15	10 U 347731 5524654	01-APR-15 7:26:08PM
16	10 U 347467 5524354	01-APR-15 7:52:36PM
17	10 U 347638 5525020	31-MAR-15 5:06:48PM. 8820 Olund Road.
18	10 U 346622 5525036	31-MAR-15 4:46:21PM
19	10 U 345890 5525029	01-APR-15 4:49:24PM
20	10 U 345838 5525431	01-APR-15 4:23:22PM
21	10 U 346303 5525804	01-APR-15 2:32:19PM. Corrected 07-JUL-15.
22	10 U 347480 5525512	31-MAR-15 1:03:31PM
23	10 U 347603 5525870	31-MAR-15 1:54:24PM
24	10 U 347590 5525733	31-MAR-15 2:16:35PM
25	10 U 347685 5525733	31-MAR-15 3:06:19PM
26	10 U 347791 5525159	07-JUL-15 6:53:55PM, +/- 3 m
27	10 U 347872 5525760	01-APR-15 9:45:56AM
28	10 U 347924 5525324	01-APR-15 10:03:33AM
29	10 U 347964 5525084	31-MAR-15 7:43:27PM
30	10 U 348103 5525269	31-MAR-15 7:17:15PM
31	10 U 348354 5525029	31-MAR-15 6:21:00PM
32	10 U 347614 5526293	02-APR-15 11:21:54AM

A4-2: Auger Hole and Monitoring Well Summary

Auger Hole Summary *depths in cm below natural ground surface*

MW #	Soil type B Horizon *(1)* Soil description: texture, structure, consistency	Land slope *(2)*	Flow restrictive layer *Depth in cm*	Flow restrictive layer *type*	Depth of soil mottling *cm*	Root depth *cm*	Measured water table depth *(3)* *cm*	Seasonal high water table *(4)* *cm*	MW depth *cm*	Auger Hole depth *cm*
1	Gravelly loamy sand, moderate blocky, very friable.	5%	50	Silt loam	50	50	22	30	80	80
2	Loamy sand, strong blocky, very friable.	3%	> 220		> 220	165	171	170	215	220
3	Gravelly sand, single grain, loose.	4%	> 280		> 280	170	138	155	270	280
4	Sandy loam, strong blocky, very friable.	8%	30	Loam	> 70	30	25	30	65	70
5	Gravelly loamy sand, single grain, loose.	9%	> 190		120	100	123	120	190	190
6A	Very gravelly loamy sand, strong granular structure, loose.	4%	> 150		> 150	90	> 150	160	150	150
6B	N/A	4%	N/A		N/A	N/A	158	160	500	N/A
7	Gravelly sand, single grain, loose.	14%	> 130		> 130	N/A	82 - 84	80	130	130
8	Very gravelly sand, single grain, loose.	12%	> 120		> 120	N/A	82 - 91	80	120	120
9	Extremely gravelly sand, single grain, loose.	14%	> 110		> 110	N/A	101	100	110	110
10	N/A	N/A	N/A		N/A	N/A	198	200	387	N/A
11	Sandy loam, moderate blocky, very friable.	3%	> 130		> 130	80	92	85	125	130
12	Gravelly loamy sand, strong blocky, very friable.	9%	> 105		> 105	85	34	60	100	105
13	Gravelly loamy sand, strong granular structure, very friable.	4%	140	SiCL	115	115	89	100	160	170
14	Gravelly loamy sand, strong granular structure, very friable.	7%	> 110		> 110	70	70	70	110	110
15	Gravelly loamy sand, weak-moderate blocky, firm.	10%	45	WCLS	45	40	35	40	95	95
16	Sandy loam, strong granular structure, very friable.	4%	60	SCL	60	60	24	40	145	150

MW #	Soil type B Horizon Soil description: texture, structure, consistency	Land slope	Flow restrictive layer *depth in cm*	 *type*	Depth of soil mottling *cm*	Root depth *cm*	Measured water table depth *cm*	Seasonal high water table *cm*	MW depth *cm*	Auger Hole depth *cm*
17	N/A	N/A	N/A		N/A	N/A	90	90	500	(5)
18	N/A	N/A	N/A		N/A	N/A	75	75	490	(5)
19	Gravelly loamy sand, single grain, firm.	7%	> 115		70	70	52	60	110	115
20	Sandy loam, strong granular structure, friable.	3%	65	Silt loam	65	50	55	55	100	100
21	Loamy sand, strong granular structure, very friable.	6%	> 120		> 120	90	66	75	120	120
22	Gravelly loamy sand, strong granular structure, very friable.	4%	> 190		> 190	120	> 185	190	185	190
23	Sandy loam, moderate blocky structure, very friable.	18%	105	Silt loam	105	105	85 – 89	90	125	125
24	Gravelly loamy sand, moderate blocky, very friable.	14%	> 90		> 90	50	55 – 68	60	90	90
25	Sandy loam, moderate granular structure, very friable.	5%	> 150		35	90	62	60	150	150
26	Gravelly loamy sand, strong granular structure, very friable.	5%	60	Silt loam	60	60	20	40	105	105
27	Very gravelly sand, single grain, loose.	4%	> 120		> 120	90	74	80	125	125
28	Gravelly loamy sand, strong granular structure, very friable.	6%	> 115		> 115	80	52	65	105	115
29	Gravelly loamy sand, single grain, very friable.	8%	120	Silt loam	> 180	130	66 – 93	95	165	180
30	Very gravelly sand, single grain, loose.	5%	> 110		70	70	52	60	115	115
31	Very gravelly sand, single grain, loose.	12%	> 100		> 100	60	55 – 69	60	100	100
32	N/A	N/A	N/A		N/A	N/A	100 – 140	120	620	N/A

RANGE AND TYPICAL VALUES (all depths in cm below natural ground surface)

	Soil type B Horizon Soil texture	Land slope	Flow restrictive layer	Depth of soil mottling	Root depth	Measured water table depth	Seasonal high water table	MW depth	Auger Hole depth
RANGE	Extremely gravelly sand to sandy loam	3-18%	30-300	35-300	30-170	22-200	30-200	65-500	70-280
TYPICAL	Gravelly sand to sandy loam	4-12%	100-140	70-140	60-105	35-140	60-120 *(6)*		

Footnotes

*(1) Soil classification is based on the USDA **Field Book** (Schoeneberger et al, 2012).*

(2) Slope measured with Suunto PM-5/360 PC hand-held inclinometer, +/- 2%.

(3) Water table below ground surface, measured during the period of 31 March to 13 April 2015.

(4) Seasonal High Water Table (SHWT) is defined as the highest water table that is sustained for more than two consecutive weeks (Ralston and Payne, 2014). The SHWT is estimated from the other depths shown.

(5) In water supply wells, MW-17 and MW-18, the depth of the water table was estimated from nearby excavations.

(6) Typical vertical thickness of seasonal perched water table, on top of flow restrictive layer, is 10 to 20 cm.

MW – Monitoring Well. N/A – Not Applicable.

WCLS – Weakly Cemented Loamy Sand SiCL – Silty Clay Loam SCL – Sandy Clay Loam

A4-3: Auger Hole Logs

General Information

Site:	Saratoga Beach Study Area (settlement node)
Dates:	17 – 19 March 2015.
Excavator:	Hand auger.
Weather:	Variable cloud and sun
Logged by:	J.P. Langard and M.I. Payne.
Locations:	See Figures in Appendix 7 and GPS locations in Appendix A4-1.
Reference:	Depths measured below existing finished grade. Where noted, this level is below the pre-existing or natural ground surface.
Wells:	See Appendix 3 for typical monitoring well construction.

Auger Hole Logs

MW – 1

Depth *cm*	Colour *(2)*	USDA texture *(1)*	gravel	Structure type, grade		USDA consistence	Roots Max. depth	Roots quant, size	Mottles depth	Mottles quant, contrast	Moisture
0 - 10	Red brown	Loamy sand	12%	GR	3	very friable		mf			W
10 - 30	Yellow brown	Gravelly loamy sand	15%	ABK	2	very friable	30	ff			S
30 - 60	Olive	Gravelly silt loam	15%	ABK	1	very firm			30-60	cD	S
60	BOTTOM	Existing grade, at MW-1, is 20 cm lower than pre-existing ground surface.							Seepage below 22 cm		

MW – 2

Depth *cm*	Colour	USDA texture	gravel	Structure type, grade		USDA consistence	Roots Max. depth	Roots quant, size	Mottles depth	Mottles quant, contrast	Moisture
0 - 90		Existing ditch; Depth 90 cm									
90 - 110	Dark brown	Loamy sand	5%	SBK	3	very friable		Cm			M
110 - 190	Red brown	Gravelly sand and loamy sand	25%	SG	0	soft to loose	165	fm			D
190 - 220	Brown	Very Gravelly sand	40%	SG	0	loose				None	W – S
220	BOTTOM								No seepage		

MW – 3

Depth				Structure		USDA consistence	Roots		Mottles		
Cm	Colour	USDA texture	gravel	type, grade			Max. depth	quant, size	depth	quant, contrast	Moisture
0 - 120		Existing ditch; depth 120 cm									
120 - 190	Yellow brown	Gravelly sand	20%	SG	0	loose	170	ff			M
190 - 280	Grey brown	Very gravelly sand	40%	SG	0	loose				None	W – S
280	BOTTOM								No seepage		

MW – 4

Depth				Structure		USDA consistence	Roots		Mottles		
Cm	Colour	USDA texture	gravel	type, grade			Max. depth	quant, size	depth	quant, contrast	Moisture
0 - 30	Red brown	Sandy loam	10%	ABK	3	very friable		cm			M
30 - 70	Dark brown	Gravelly loam	20%	ABK	1	very friable	30	ff		None	S
70	BOTTOM								Seepage below 35 cm		

MW – 5

Depth				Structure		USDA consistence	Roots		Mottles		
Cm	Colour	USDA texture	gravel	type, grade			Max. depth	quant, size	depth	quant, contrast	Moisture
0 - 10	Dark brown	Gravelly sandy loam	%	GR	3	very friable		mm			M
10 - 60	Yellow brown	Gravelly loamy sand	%	SG	0	loose		mm			M
60 - 120	Olive	Gravelly sand	%	SG	0	loose	100	fm			M
120 - 190	Olive grey	Gravelly sand	%	SG	0	loose			120	gleyed	W – S
190	BOTTOM								Seepage below 150 cm		

MW – 6A

Depth Cm	Colour	USDA texture	gravel	Structure	USDA consistence	Roots		Mottles		Moisture
				type, grade		Max. depth	quant, size	depth	quant, contrast	
0 - 25	Dark brown	Gravelly sandy loam	5%	GR 3	very friable		cm			M
25 - 70	Red brown	Very gravelly loamy sand	10%	GR 3	loose		fm			M
70 - 150	Grey brown	Very gravelly sand and loamy sand	25%	SG 0	loose	90	ff		None	M – W
150	BOTTOM							No seepage		

MW – 6B

500 cm deep, privately-owned irrigation water supply well. Saratoga Road.

MW – 7

Depth Cm	Colour	USDA texture	gravel	Structure	USDA consistence	Roots		Mottles		Moisture
				type, grade		Max. depth	quant, size	depth	quant, contrast	
0 - 130	Grey	Gravelly sand	25%	SG 0	loose		None		None	M – S
130	BOTTOM	(Beach sand)						seepage below 100 cm		

MW – 8

Depth Cm	Colour	USDA texture	gravel	Structure	USDA consistence	Roots		Mottles		Moisture
				type, grade		Max. depth	quant, size	depth	quant, contrast	
0 - 90	Grey	Gravelly sand	40%	SG 0	loose					M
90 - 120	Grey	Extremely gravelly sand	90%	SG 0	loose		None		None	S
120	BOTTOM	(Beach sand)						seepage below 100 cm		

MW – 9

Depth Cm	Colour	USDA texture	gravel	Structure	USDA consistence	Roots		Mottles		Moisture
				type, grade		Max. depth	quant, size	depth	quant, contrast	
0 - 90	Grey	Extremely gravelly sand	70%	SG 0	loose					M
90 - 110	Red brown	Extremely gravelly sand	70%	SG 0	loose		None		None	S
110	BOTTOM	(Beach sand)						seepage below 90 cm		

MW – 10

390 cm deep, privately-owned groundwater monitoring well. Driftwood Road.

MW – 11

Depth cm	Colour	USDA texture	gravel	Structure		USDA consistence	Roots		Mottles		Moisture
				type, grade			Max. depth	quant, size	depth	quant, contrast	
0 - 25	Light brown	Loam	10%	ABK	2	very friable		cm			M
25 - 45	Olive	Sandy loam	10%	ABK	2	very friable		ff			M – W
45 - 110	Grey	Extremely gravelly sand	75%	SG	0	loose	60	ff		None	W
110	BOTTOM	Existing grade is ~ 20 cm lower than pre-existing natural ground surface.							seepage below 80 cm		

MW – 12

Depth cm	Colour	USDA texture	gravel	Structure		USDA consistence	Roots		Mottles		Moisture
				type, grade			Max. depth	quant, size	depth	quant, contrast	
0 - 20	Dark brown	Gravelly loamy sand	25%	GR	3	very friable		cm			M
20 - 40	Red brown	Gravelly loamy sand	25%	GR	2	very friable		cm			M – W
40 - 85	Grey	Extremely gravelly sand	65%	SG	0	loose	65	fm		None	S
85	BOTTOM	Existing grade is 20 cm lower than pre-existing natural ground surface.							seepage below 60 cm		

MW – 13

Depth cm	Colour	USDA texture	gravel	Structure		USDA consistence	Roots		Mottles		Moisture
				type, grade			Max. depth	quant, size	depth	quant, contrast	
0 - 10	Dark brown	Gravelly loamy sand	15%	GR	3	very friable		cm			M
10 - 40	Red brown	Gravelly loamy sand	20%	GR	2	very friable	40	cm			M
40 - 65	Grey	Sand	5%	SG	0	very friable			40-65	fF	W
65 - 95	Olive	Silty clay loam	15%	ABK	1	friable				gleyed	S
95	BOTTOM	Existing grade @ MW-13 is 75 cm lower than pre-existing ground surface; in side wall of drainage ditch.							seepage below 60 cm		

MW – 14

Depth cm	Colour	USDA texture	gravel	Structure type, grade	USDA consistence	Roots Max. depth	Roots quant, size	Mottles depth	Mottles quant, contrast	Moisture
0 - 15	Dark brown	Gravelly loamy sand	20%	GR 3	very friable		cm			M
15 - 50	Red brown	Sand and loamy sand	10%	GR 3	very friable	50	cm			W
50 - 90	Grey	Gravelly Sand	25%	SG 0	loose				None	S
90	BOTTOM	Existing grade @ MW-14 is 20 cm lower than pre-existing ground level.						No seepage noted		

MW – 15

Depth cm	Colour	USDA texture	gravel	Structure type, grade	USDA consistence	Roots Max. depth	Roots quant, size	Mottles depth	Mottles quant, contrast	Moisture
0 - 10	Dark brown	Sandy loam	10%	GR 2	very friable	10	ff			W
10 - 65	Olive brown	Gravelly loamy sand	25%	SBK 1	firm, very weakly cemented			15	cD	W – S
65	BOTTOM	Existing grade @ MW-15 is 30 cm lower than pre-existing ground level.						seepage below 20 cm		

MW – 16

Depth cm	Colour	USDA texture	gravel	Structure type, grade	USDA consistence	Roots Max. depth	Roots quant, size	Mottles depth	Mottles quant, contrast	Moisture
0 - 10	Light brown	Sandy loam	5%	GR 3	very friable		cm			M
10 - 40	Brown	Sandy clay loam	10%	ABK 1	friable	40	ff			M – W
40 - 130	Olive	Gravelly sandy clay loam	20%	ABK 1	friable			40 +	fF	W – S
130	BOTTOM	Existing grade is 20 cm lower than pre-existing ground level.						seepage below 40 cm		

MW – 17

Privately-owned, dug water well. Olund Road.

MW – 18

490-cm deep, privately-owned, dug irrigation water well. Finlay Road.

MW – 19

Depth cm	Colour	USDA texture	gravel	Structure type, grade		USDA consistence	Roots Max. depth	Roots quant, size	Mottles depth	Mottles quant, contrast	Moisture
0 - 20	Brown	Loamy sand	5%	GR	2	very friable	20	ff			W
20 - 65	Light brown	Gravelly loamy sand	30%	SG	0	firm, very weakly cemented			20-65	cD	W – S
65	BOTTOM	Existing grade is 50 cm lower than pre-existing ground level.							seepage below 30 cm		

MW – 20

Depth cm	Colour	USDA texture	gravel	Structure type, grade		USDA consistence	Roots Max. depth	Roots quant, size	Mottles depth	Mottles quant, contrast	Moisture
0 - 30	Dark brown	Gravelly sandy loam	15%	GR	3	friable	30	cm			M
30 - 45	Olive	Sandy loam	5%	ABK	2	firm					W
45 - 50	Olive	Silt loam	5%	ABK	2	very firm			45-80	mD	W – S
80	BOTTOM	Existing grade is 20 cm lower than pre-existing ground surface.							No seepage noted		

MW – 21

Depth cm	Colour	USDA texture	gravel	Structure type, grade		USDA consistence	Roots Max. depth	Roots quant, size	Mottles depth	Mottles quant, contrast	Moisture
0 - 30	Red brown	Loamy sand	10%	GR	3	very friable		cf			M
30 - 90	Red brown	Sand and loamy sand	5%	SG	0	very friable	90	cf			M – W
90 - 120	Grey brown	Very gravelly sand	40%	SG	0	loose				None	S
120	BOTTOM								seepage below 85 cm		

MW – 22

Depth *cm*	Colour	USDA texture	gravel	Structure type, grade	USDA consistence	Roots Max. depth	Roots quant, size	Mottles depth	Mottles quant, contrast	Moisture
0 - 10	Dark brown	Loamy sand	10%	GR 3	very friable		cm			M
10 - 60	Red brown	Gravelly loamy sand	20%	GR 3	very friable		cm			M
60 - 160	Grey	Extremely gravelly sand	65%	SG 0	loose	90	fm		None	M - W
160	BOTTOM	Existing grade is 30 cm lower than pre-existing ground surface; in a ditch side wall.						seepage below 160 cm		

MW – 23

Depth *cm*	Colour	USDA texture	gravel	Structure type, grade	USDA consistence	Roots Max. depth	Roots quant, size	Mottles depth	Mottles quant, contrast	Moisture
0 - 45	Dark brown	Gravelly sandy loam	15%	ABK 2	very friable	45	mm			S
45 - 65	Olive	Silt loam	5%	SBK 1	very friable			45-65	cD	S
65	BOTTOM	In cut bank with existing grade ~ 60 cm lower than natural ground surface.						seepage below 30 cm		

MW – 24

Depth *cm*	Colour	USDA texture	gravel	Structure type, grade	USDA consistence	Roots Max. depth	Roots quant, size	Mottles depth	Mottles quant, contrast	Moisture
0 - 20	Dark brown	Sandy loam	15%	GR 3	very friable		cm			M
20 - 70	Red brown	Gravelly sand and loamy sand	30%	SBK 2	very friable	30	ff		None	S
70	BOTTOM	Existing ground surface is ~ 20 cm lower than pre-existing ground surface.						seepage below 40 cm		

MW – 25

Depth *cm*	Colour	USDA texture	gravel	Structure type, grade	USDA consistence	Roots Max. depth	Roots quant, size	Mottles depth	Mottles quant, contrast	Moisture
0 - 35	Dark brown	Sandy loam	15%	GR 2	very friable		ff			M
35 - 90	Olive	Silt loam	5%	SBK 1	very friable	90	ff	30-90	cD	M
90 - 150	Grey	Sand	15%	SG 0	loose			90 +	gleyed	S
150	BOTTOM							seepage below 110 cm		

MW – 26

Depth *cm*	Colour	USDA texture	gravel	Structure type, grade	USDA consistence	Roots Max. depth	Roots quant, size	Mottles depth	Mottles quant, contrast	Moisture
0 - 60	Dark brown	Gravelly loamy sand	20%	GR 3	very friable	60	cf			M
60 - 105	Olive	Silt loam	5%	SBK 1	friable			60 +	cD	S
105	BOTTOM							seepage below 70 cm		

MW – 27

Depth *cm*	Colour	USDA texture	gravel	Structure type, grade	USDA consistence	Roots Max. depth	Roots quant, size	Mottles depth	Mottles quant, contrast	Moisture
0 - 10	Brown	Gravelly sand and loamy sand	20%	GR 3	very friable		cm			M
10 - 90	Grey	Very gravelly sand	45%	SG 0	loose	90	ff			M – W
90 - 125	Grey	Very gravelly sand	50%	SG 0	loose				None	W – S
125	BOTTOM							seepage below 100 cm		

MW – 28

Depth *cm*	Colour	USDA texture	gravel	Structure type, grade	USDA consistence	Roots Max. depth	Roots quant, size	Mottles depth	Mottles quant, contrast	Moisture
0 - 20	Dark brown	Gravelly loamy sand	15%	GR 3	very friable		cm			M
20 - 85	Grey	Gravelly sand	30%	SG 0	loose	50	fm		None	S
85	BOTTOM	Existing grade is ~ 30 cm lower than pre-existing ground surface.						seepage below 45 cm		

MW – 29

Depth *cm*	Colour	USDA texture	gravel	Structure type, grade	USDA consistence	Roots Max. depth	Roots quant, size	Mottles depth	Mottles quant, contrast	Moisture
0 - 20	Dark brown	Gravelly loamy sand	15%	GR 3	very friable		mf			M
20 - 80	Red brown	Gravelly sand and loamy sand	20%	SG 0	loose		ff			M
80 - 110	Olive	Silt loam	5%	SBK 1	very friable	90	ff			W
110 - 140	Grey	Very gravelly sand	35%	SG 0	loose				None	S
140	BOTTOM	Existing grade is 40 cm lower than pre-existing ground surface.						seepage below 110 cm		

MW – 30

Depth *cm*	Colour	USDA texture	gravel	Structure type, grade		USDA consistence	Roots Max. depth	Roots quant, size	Mottles depth	Mottles quant, contrast	Moisture
0 - 10	Dark brown	Gravelly sandy loam	20%	GR	3	very friable		cm			M
10 - 70	Grey	Very gravelly sand and loamy sand	50%	SG	0	loose	70	ff			M – S
70 - 115	Grey	Gravelly sand	20%	SG	0	loose			70 +	gleyed	S
115	BOTTOM								seepage below 90 cm		

MW – 31

Depth *cm*	Colour	USDA texture	gravel	Structure type, grade		USDA consistence	Roots Max. depth	Roots quant, size	Mottles depth	Mottles quant, contrast	Moisture
0 - 5	Dark brown	Gravelly loamy sand	15%	GR	3	very friable		cm			M
5 - 80	Grey	Extremely gravelly sand	70%	SG	0	loose	40	ff		None	S
80	BOTTOM	Existing grade is 20 cm lower than pre-existing ground surface.							seepage below 50 cm		

MW – 32

620 cm (6.2 m) deep, privately-owned, drilled monitoring well. Completed at-grade. Pacific Playgrounds.

Footnotes

(1) Soil classification is based on ***Field Book for Describing and Sampling Soils, Version 3.0*** (Schoeneberger et al, 2012).

(2) Codes shown in brackets refer to ***Munsell Soil Colour Charts*** (2000).

Abbreviations used on test pit logs

USDA Texture	Structure	Cementation	Mottles
S - sand	sg - single grain	NC - non-cemented	fF - few faint mottles
LS - loamy sand	m - massive	EW - extr. weakly	fD - few distinct
SL - sandy loam	gr - granular	cemented	mottles
L - loam	abk - angular blocky	VW - very weakly	fP - few prominent
SiL - silt loam	sbk - subangular blocky	cemented	mottles
Si - silt	pl - platy	W - weakly cemented	cF - common faint
SCL - sandy clay loam	pr - prismatic	M - moderately	cD - common distinct
CL - clay loam	cpr - columnar	cemented	cP - common
SiCL- silty clay loam			prominent
SC - sandy clay	USDA Consistence (moist)	Roots	mF - many faint
SiC - silty clay	L - loose	ff - few fine roots	mD - many distinct
C - clay	VFR - very friable	fm - few medium-size	mP - many prominent
	FR - friable	roots	
USDA Texture Prefixes	FI - firm	fc - few coarse roots	Moisture
G - Gravelly	VFI - very firm	cf - common fine	S - saturated
VG - Very Gravelly	EF - extremely firm	cm - common	W - wet
Cb - Cobbly	SR - slightly rigid	medium-size	M - moist
VCb - Very Cobbly	R - rigid	cc - common coarse	D - dry
	VR - very rigid	mf - many fine	
		mm - many medium-size	
		mc - many coarse	

A4-4: Water Table in Monitoring Wells

Reference: Field measurements by JPL during 2015 using electrical water level meter.

All depths in centimetres. Stickup is height of top of casing above natural ground level.

NOTE: Some of these wells are tidal, including MW-7, MW-8, and MW-9.

MW	Depth vs. top of casing		**Depth vs. ground level**		Depth of pipe	Length of pipe	Pipe stickup
	2015-04-01	2015-04-13	**2015-04-01**	**2015-04-13**			
1	65		22		80	123	43
2	126		171		215	170	-45
3	73		138		270	205	-65
4	80		25		65	120	55
5	203		123		190	270	80
6-A	> 195		> 150		150	195	45
6-B	198		158		500	540	40
7	127	129	82	84	130	175	45
8	157	166	82	91	120	195	75
9	151		101		110	160	50
10	274		198		387	463	76
11	127		92		125	160	35
12	49		34		100	115	15
13	89		89		160	160	0
14	110		70		110	150	40
15	50		35		95	110	15
16	69		24		145	190	45
17	130		90		500	540	40
18	100		75		490	515	25
19	62		52		110	120	10
20	78		55		100	123	23
21	126		66		120	180	60
22	> 205		> 185		185	205	20
23	80	84	85	89	125	120	-5
24	105	118	55	68	90	140	50
25	127		62		150	215	65
26	75		20		105	160	55
27	124		74		125	175	50
28	72		52		105	125	20
29	86	113	66	93	165	185	20
30	107		52		115	170	55
31	85	99	55	69	100	130	30
32	100	140	100	140	620	620	0

A4-5: Monitoring Well Purging Records

FIRST SAMPLE SET

MW	Date	Well purging: Well volume *Litres*	Well purging: Volume purged *Litres*	Well purging: Total purged *# vols*	Field water quality: Temp *°C*	Field water quality: E.C. *µS/cm*	Field water quality: pH	Sample record: Time	Sample record: Sample appearance	Note
1	1 Apr 2015	1.0	3.6	3.6	9.7	110	5.9	2:59 pm	murky	
2	1 Apr 2015	0.95	3.6	3.8	10.3	49	5.9	2:00 pm	murky	
3	1 Apr 2015	3.1	10.5	3.4	9.7	65	6.0	2:28 pm	murky	
4	1 Apr 2015	0.87	3.0	3.5	9.1	72	5.9	1:09 pm	murky	
5	1 Apr 2015	1.1	3.9	3.5	10.0	73	6.1	5:10 pm	murky	
6A	31 Mar 2015	0.0	0.0	0.0					dry well	
6B	2 Apr 2015	*See*	*footnote*		9.3	110	6.6	10:30 am	clear	(4)
7	1 Apr 2015	0.97	3.3	3.4	9.0	> 4000	7.3	8:02 am	clear brown	(3)
8	1 Apr 2015	0.69	2.25	3.3	9.7	> 4000	7.8	8:22 am	clear	(3)
9	1 Apr 2015	0.1	0.1	1.0	8.7	> 4000	6.5	7:27 am	murky	(2)(3)
10	31 Mar 2015	4.1	20.5	5.1	8.9	1900	6.3	4:47 pm	murky	
11	1 Apr 2015	0.56	2.25	4.0	9.7	86	6.4	10:00 am	murky	
12	1 Apr 2015	1.3	5.5	4.3	9.1	66	5.7	10:33 am	clear	
13	1 Apr 2015	1.4	4.5	3.3	9.5	63	5.8	11:02 am	clear	
14	1 Apr 2015	0.72	3.0	4.2	10.2	110	6.1	5:38 pm	murky	
15	1 Apr 2015	1.1	2.0	1.8	10.4	71	6.1	6:37 pm	murky	(2)
16	1 Apr 2015	2.5	4.0	1.6	9.9	120	6.2	7:35 pm	NN	(2)
17	31 Mar 2015	*See*	*footnote*	*7 mins*	9.3	170	6.1	4:12 pm	clear	(1)
18	31 Mar 2015	*See*	*footnote*	*9 mins*	10.1	200	5.9	3:46 pm	clear	(1)
19	1 Apr 2015	1.1	2.05	1.9	11.3	100	6.1	3:58 pm	murky	(2)
20	1 Apr 2015	0.87	3.0	3.5	10.1	120	5.9	3:24 pm	murky	
21	1 Apr 2015	0.91	3.6	4.0	8.9	48	6.0	1:33 pm	murky	
22	31 Mar 2015	0.0	0.0	0.0					dry well	
23	31 Mar 2015	0.8	3.0	3.8	10.0	57	6.0	12:55 pm	murky	
24	31 Mar 2015	0.61	1.05	1.7	10.7	120	5.9	1:25 pm	murky	(2)
25	31 Mar 2015	1.8	6.0	3.4	9.2	35	5.9	1:55 pm	murky	
26	31 Mar 2015	1.7	5.5	3.2	10.1	240	5.6	2:10 pm	murky	
27	1 Apr 2015	0.98	4.4	4.5	8.6	110	7.5	8:52 am	clear brown	
28	1 Apr 2015	1.1	3.75	3.4	9.1	110	6.4	9:22 am	NN	
29	31 Mar 2015	2.0	8.0	4.1	10.0	21	6.6	6:42 pm	clear	
30	31 Mar 2015	1.3	6.5	5.1	9.3	110	7.0	6:17 pm	clear	
31	31 Mar 2015	0.85	4.8	5.6	9.8	740	5.8	5:30 pm	clear	
32	2 Apr 2015	11	36	3.2	8.7	340	6.7	10:23 am	clear grey	

SECOND SAMPLE SET

MW	Date	Well purging Well volume *Litres*	Volume purged *Litres*	Total purged *# vols*	Field water quality Temp *°C*	E.C. *µS/cm*	pH	Sample record Time	Sample appearance	Note
7	13 Apr 2015	0.9	3.0	3.3	10.2	1700	7.7	9:40 am	pale yellow	
8	13 Apr 2015	0.45	1.5	3.3	9.5	740	8.1	10:00 am	clear	
23	13 Apr 2015	7.7	3.0	4.1	9.0	58	6.1	12:15 pm	murky	
24	13 Apr 2015	0.37	1.0	2.7	9.5	120	5.4	1:05 pm	murky	(2)
29	13 Apr 2015	1.4	4.5	3.2	9.2	30	6.7	11:20 am	clear	
31	13 Apr 2015	0.54	2.25	4.2	9.0	760	6.0	11:38 am	clear	
32	13 Apr 2015	10	33	3.2	8.6	260	7.5	10:49 am	clear grey	

Median for All Wells Sampled	Temp	E.C.	pH
First sample set only:	9.7	110	6.1

Abbreviations

E.C. - Electrical conductivity.

vols- Total number of well volumes purged.

NN - Not noted

Footnotes

(1) Privately-owned water supply well; purged at full flow for 7 to 9 minutes before sampling.

(2) This is a low-volume well that was purged dry before sampling.

(3) MW-7, 8, and 9 were installed in beach sand.

(4) There was no practical way to purge this privately-owned well. The sample was collected from the clear mid-level of the well water column.

Appendix 5: Laboratory Summary

Reference: Lab reports from Maxxam.

		March 31 - April 2, 2015			April 13, 2015			Log-mean or median (4)				
MW	Foot Note	E. coli *MPN*	Nitrate *mg/L*	Nitrite *mg/L*	E. coli *MPN*	Nitrate *mg/L*	Nitrite *mg/L*	E. coli *MPN*	Nitrate *mg/L*	Nitrite *mg/L*	Pass	Fail
1		< 1	< 0.020	0.010				< 1	< 0.020	0.010	1	
2		< 1	0.64	< 0.005				< 1	0.64	< 0.005	1	
3		1	0.97	< 0.005				1	0.97	< 0.005	1	
4		< 1	< 0.020	0.013				< 1	< 0.020	0.013	1	
5		< 1	< 0.020	< 0.005				< 1	< 0.020	< 0.005	1	
6-A	(1)											
6-B	(2)	< 1	0.46	< 0.005				< 1	0.46	< 0.005	1	
7		< 1	3.45	< 0.050	< 1	4.36	< 0.050	< 1	3.91	< 0.050		1
8		2	16.50	< 0.005	< 1	4.59	0.006	0.4	10.55	0.004		1
9	(3)	3	4.40	0.009				3	4.40	0.009		1
10	(2)	< 1	0.04	0.018				< 1	0.04	0.018	1	
11		< 1	0.46	< 0.005				< 1	0.46	< 0.005	1	
12		< 1	0.81	0.011				< 1	0.81	0.011	1	
13		< 1	0.95	0.037				< 1	0.95	0.037	1	
14		< 1	0.60	0.012				< 1	0.60	0.012	1	
15		< 1	2.38	0.050				< 1	2.38	0.050	1	
16		< 1	1.33	0.058				< 1	1.33	0.058	1	
17	(2)	< 1	0.29	< 0.005				< 1	0.29	< 0.005	1	
18	(2)	< 1	0.58	< 0.005				< 1	0.58	< 0.005	1	
19		< 1	0.12	0.015				< 1	0.12	0.015	1	
20		< 1	0.25	< 0.050				< 1	0.25	< 0.050	1	
21		< 1	< 0.020	< 0.005				< 1	< 0.020	< 0.005	1	
22	(1)										1	
23		165	1.65	0.011	3.1	1.37	0.011	23	1.51	0.011		1
24		< 1	3.69	0.043	< 1	3.51	0.009	< 1	3.60	0.026		1
25		< 1	0.26	< 0.005				< 1	0.26	< 0.005	1	
26		1	< 0.20	< 0.050				1	< 0.20	< 0.050	1	
27		< 1	< 0.20	< 0.050				< 1	< 0.20	< 0.050	1	
28		< 1	< 0.020	< 0.005				< 1	< 0.020	< 0.005	1	
29		34	0.25	0.014	5.3	< 0.020	0.019	13	0.13	0.017	1	
30		1	0.64	0.012				1	0.64	0.012	1	
31		> 200	1.16	< 0.050	165.2	1.34	0.011	257	1.25	0.018		1
32	(2)	13.7	0.29	0.006	7.5	0.114	0.013	10	0.20	0.010	1	

STATISTICS:

	March 31 - April 2, 2015			April 13, 2015			Log-mean or median (4)				
	E. coli *MPN*	Nitrate *mg/L*	Nitrite *mg/L*	E. coli *MPN*	Nitrate *mg/L*	Nitrite *mg/L*	E. coli *MPN*	Nitrate *mg/L*	Nitrite *mg/L*	Pass	Fail
Total #:	31	31	31	7	7	7	31	31	31	26	6
Minimum:	< 1	0.01	0.003	0	0.01	0.006	0	0.01	0.003		
Median:	< 1	0.46	0.010	3	1.37	0.011	0	0.46	0.010		
Maximum:	> 200	16.5	0.058	165	4.59	0.025	257	10.55	0.058		

Objectives	E. coli	Nitrate	Nitrite
Objective:	< 14	< 3.0	< 0.10
Resample if:	> 2	> 3.0	> 0.10

Overall failure rate = 6 out of 32 = 19%

Footnotes

(1) Dry well; could not be sampled. MW-22 is rated as a "pass" because of the relatively deep water table.

(2) Privately-owned drinking water well, irrigation well, or monitoring well; used with owner's permission.

(3) MW-9 was removed between April 2 and April 13, so could not be resampled on April 13.

(4) In columns 9 through 11 of the table, the E. coli is a log-mean value and the nitrate and nitrate concentrations are median values. The log-mean is commonly used to express typical values for the density of microorganisms in water.

Appendix 6: Water Quality Objectives

British Columbia Water Quality Guidelines				
Water Use	E. coli *MPN/100mL*	Fecal coliforms *MPN/100mL*	Nitrate *mg/L as N*	Nitrite *mg/L as N*
Raw drinking water – partial treatment – *Oyster River and private drinking water wells*	< 100 *(1)*	< 100 *(1)*	< 10 *(1)*	< 1.0 *(1)*
Marine aquatic life – shellfish harvesting – *Saratoga and Miracle Beach areas*	< 14 *(2)*	< 14 *(2)*	< 3.7 *(2)*	NA *(4)*
Freshwater aquatic life – *Oyster River*	< 14 *(2)*	< 14 *(2)*	< 3.0 *(2)*	< 0.02 *(2)*
Irrigation – crops eaten raw – *private irrigation wells*	< 77 *(3)*	< 200 *(3)*	NA *(4)*	NA *(4)*
Recreation – primary contact - *swimming*	< 77 *(3)*	< 200 *(3)*	NA *(4)*	NA *(4)*
Selected Project-Specific Water Quality Objectives				
For this project:	E. coli *MPN/100mL*	Fecal coliforms *MPN/100mL*	Nitrate *mg/L as N*	Nitrite *mg/L as N*
Selected project-specific objective *(2)*	< 14	< 14	< 3.0	< 0.10 *(5)*
Selected re-sampling threshold	> 2	> 2	> 3.0	> 0.10

(1) Based on 90th percentile or 9 out of 10 consecutive samples.
(2) Median or average
(3) Geometric mean
(4) Not applicable – Ministry of Environment has not published an objective in this category.
(5) For nitrite in shallow groundwater, this is based on an estimate chloride concentration of 10 to 20 mg/L (Based on Katz et al, 2011). For nitrite in river water, this is based on a chloride concentration of 1 to 2 mg/L (based on Comox Valley RD, 2012-2013), and a river water to groundwater dilution ratio of at least 5:1.

Sources:

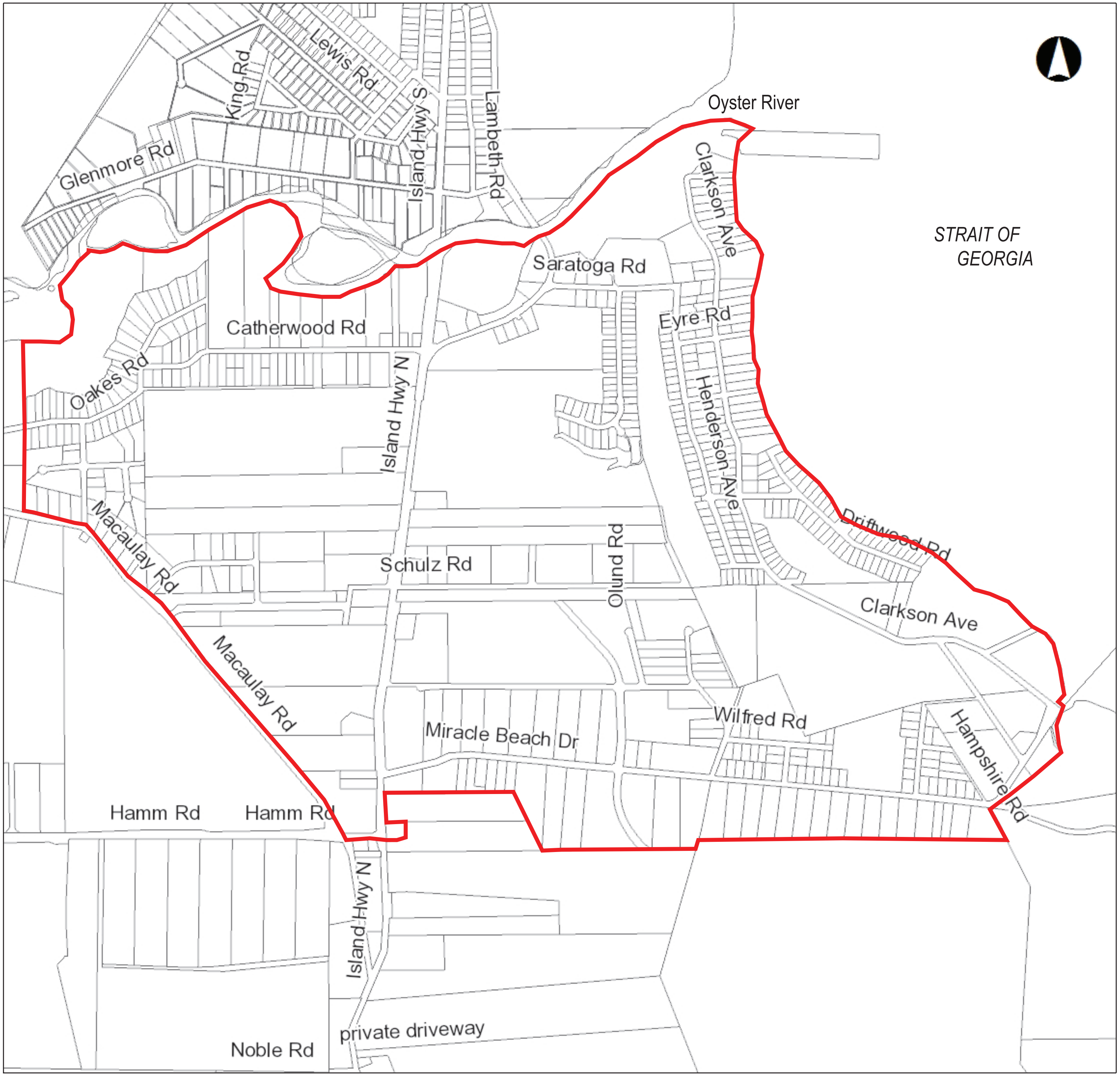
BC Ministry of Environment, 2001 - 2009. *Approved Water Quality Objectives*.

Comox Valley RD, 2012. *Water Quality Monitoring for the Black Creek Oyster Bay Water System.*

Katz, B.G., S.M. Eberts, and L.J. Kauffman, 2011. Using Cl / Br ratios and other indicators to assess potential impacts on groundwater quality from septic systems: A review and examples from principle aquifers in the United States. In *Journal of Hydrology. Vol. 397, pp. 151-166.*

Appendix 7: Figures

List of figures:



BRITISH COLUMBIA

Map of the Study Area

Legend

Digital Road Atlas - Labels

Integrated Cadastral Fabric

Outline of the Study Area

0 0.41 0.81 km

1: 20,000

Notes

1. To accompany PEG report to CVRD dated October 2015.

2. Base plan from iMapBC.

3. Study Area provided by Comox Valley Regional District.

Figure 1

Map of the Study Area

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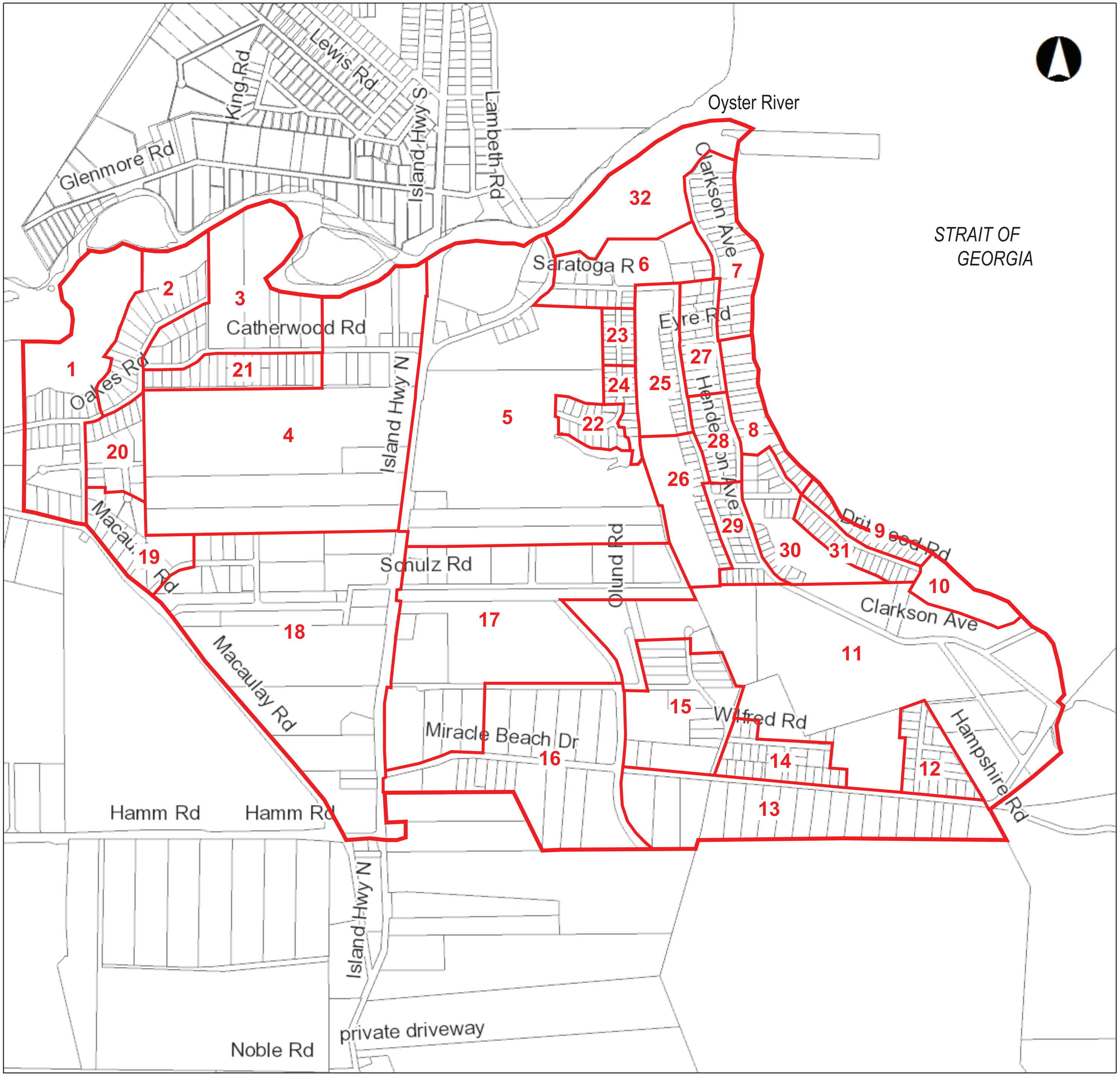

BRITISH COLUMBIA

Legend

Digital Road Atlas - Labels

Integrated Cadastral Fabric

Outline of Sub-Areas

15 Sub-Area Number

0 0.41 0.81 km

1: 20,000

Notes

1. To accompany PEG report to Comox Valley RD dated October 2015.

2. Base plan from iMapBC.

3. Sub-area numbers correspond to monitoring well numbers (e.g. MW-15).

Figure 2
Sub-Areas for Monitoring

Payne Engineering Geology

File WLC-1 Report 1

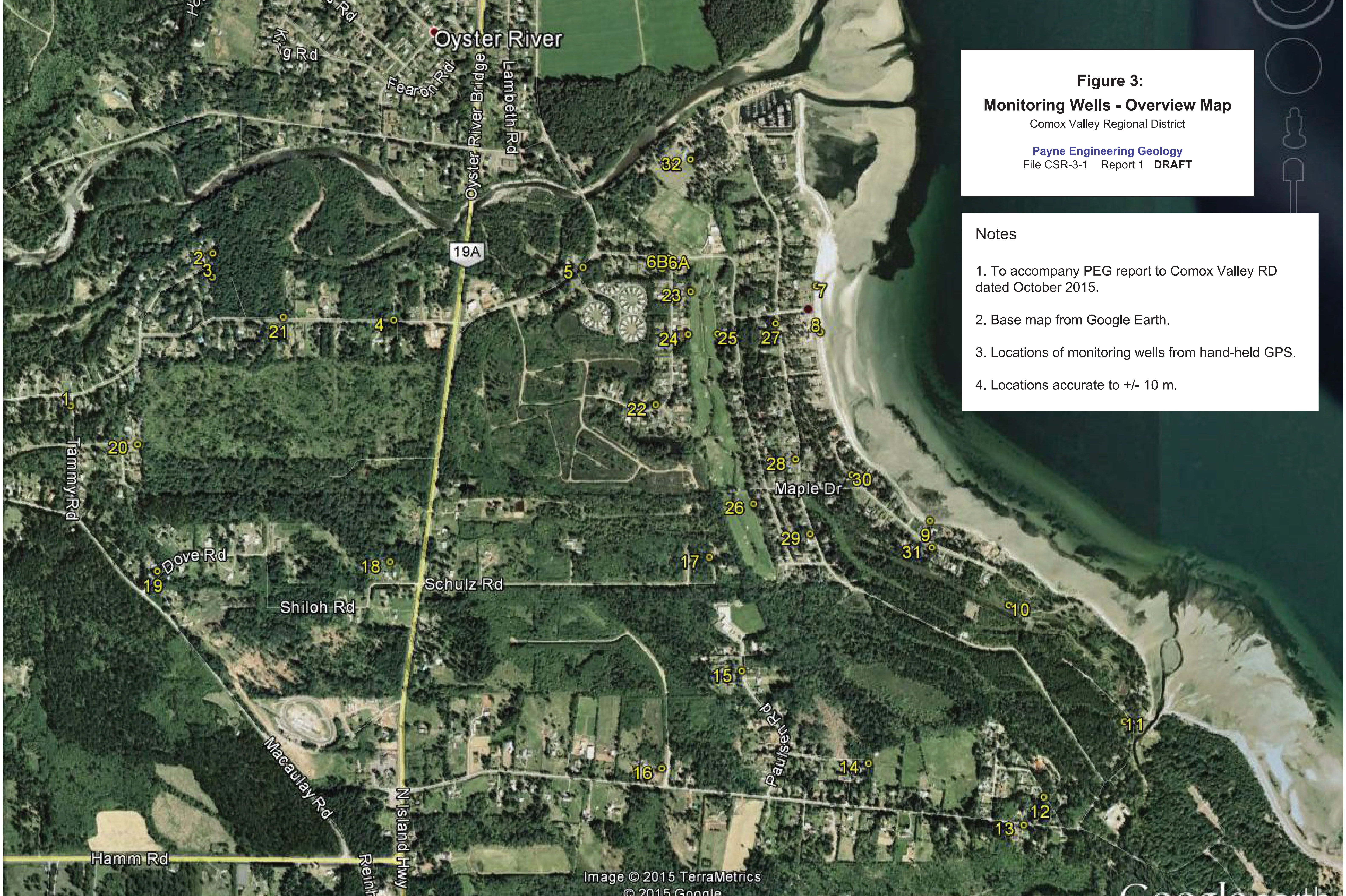

Figure 3:

Monitoring Wells - Overview Map

Comox Valley Regional District

Payne Engineering Geology

File CSR-3-1 Report 1 **DRAFT**

Notes

1. To accompany PEG report to Comox Valley RD dated October 2015.
2. Base map from Google Earth.
3. Locations of monitoring wells from hand-held GPS.
4. Locations accurate to +/- 10 m.


Notes
1. To accompany PEG report to Comox Valley RD dated October 2015.
2. Base map from Google Earth.
3. Locations of monitoring wells from hand-held GPS.
4. Locations accurate to +/- 10 m.
Figure 4: Monitoring Wells
Detailed Maps - Sheet 1 of 3
Comox Valley Regional District
Payne Engineering Geology
File CSR-3-1 Report 1 DRAFT
N
2
3
Penner Rd
21
4
Catherwood Rd
Regent Rd
Oakes Rd
1
Emmerson Rd
20
Tammy Rd
Macaulay Rd
N Island Hwy
18
Dove Rd
19
Finlay Rd
Schulz Rd
Shiloh Rd
© 2015 Google
Image © 2015 MTCAN
Google earth
2005
Imagery Date: 7/16/2005 10 U 346239.81 m E 5525500.12 m N elev 40 m eye alt 1.56 km

Notes
1. To accompany PEG report to Comox Valley RD dated october 2015.
2. Base map from Google Earth.
3. Locations of monitoring wells from hand-held GPS.
4. Locations accurate to +/- 10 m.

Figure 4: Monitoring Wells
Detailed Maps - Sheet 1 of 3
Comox Valley Regional District

Payne Engineering Geology
File CSR-3-1 Report 1 **DRAFT**

Notes
1. To accompany PEG report to Comox Valley RD dated October 2015.
2. Base map from Google Earth.
3. Locations of monitoring wells from hand-held GPS.
4. Locations accurate to +/- 10 m.

Figure 4: Monitoring Wells
Detailed Maps - Sheet 1 of 3
Comox Valley Regional District

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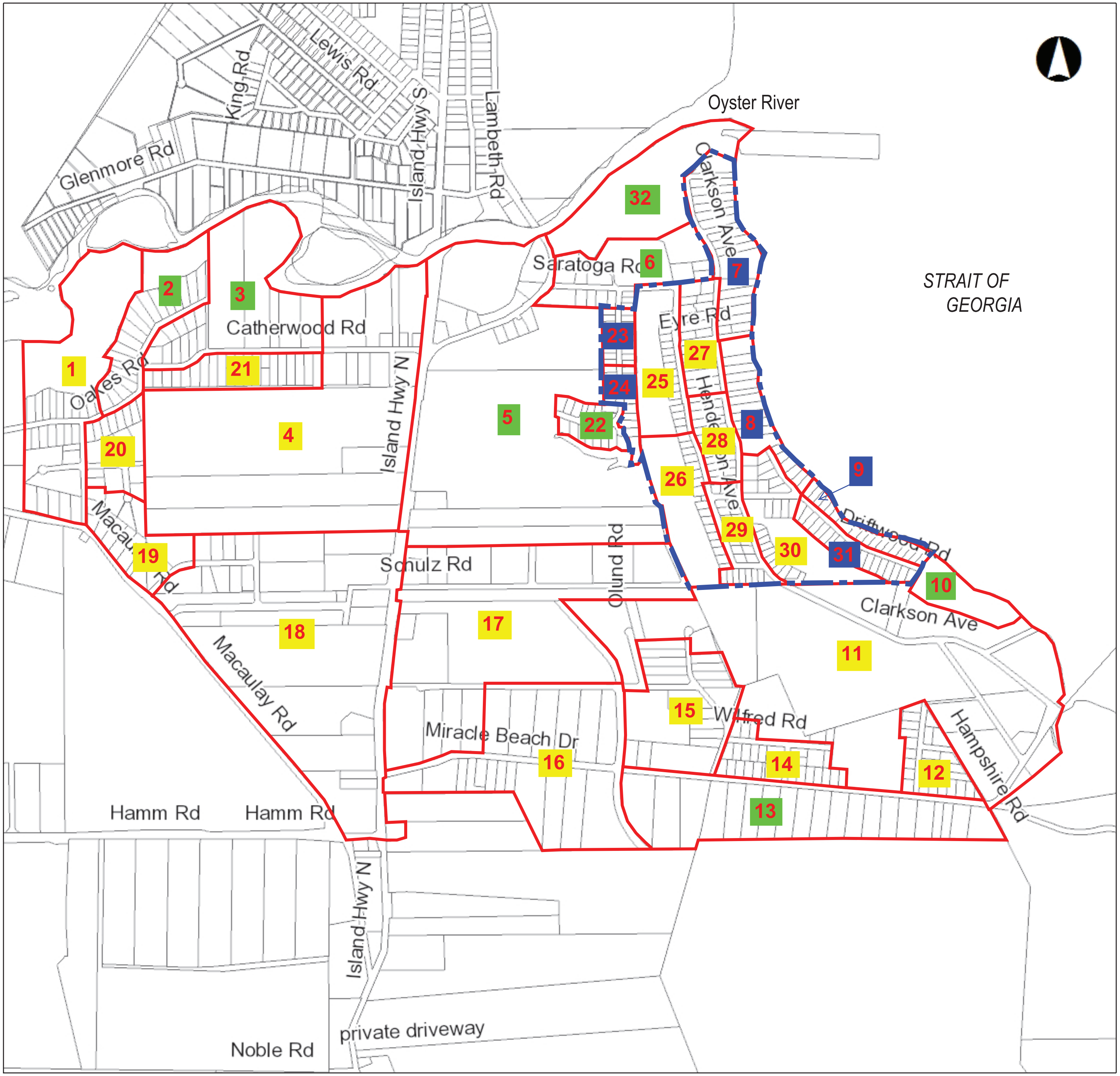
File CSR-3-1 Report 1 **DRAFT**



BRITISH COLUMBIA

Legend

Digital Road Atlas - Labels

Integrated Cadastral Fabric

Outline of Sub-Areas

15 Sub-Area Number

Failed wells

Water table shallower than 100 cm

Water table deeper than 100 cm

Designated Area - Note (3)

0 0.41 0.81 km

1: 20,000

Notes

(1) To accompany PEG report to CVRD dated October 2015.

(2) Base plan from iMapBC.

(3) The Designated Area has the least favourable conditions for on-site sewage systems, based on the 2015 groundwater monitoring and PEG data interpretation.

Figure 5
Land Suitability for Onsite Systems

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File WLC-1 Report 1