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Hydrogeological Assessment of Potential Impact of Proposed Rainbow Ridge Affordable Rental Housing Project, 965 Beasley Road, Cortes Island, B.C.

PREPARED FOR

CORTES ISLAND SENIORS SOCIETY.

MANSON'S LANDING, CORTES ISLAND, B.C.

Project 241 **June 14, 2019**

Executive Summary

Elanco Enterprises Ltd. (Elanco) was retained by the Cortes Island Seniors Society (CISS) to conduct a hydrogeological assessment of the potential impact of developing a residential housing project in the northern part of their 965 Beasley Road Property (the Property) located in Manson's Landing Village area, Cortes Island.

This assessment focused on identifying potential impacts that development of 20 serviced housing units may have on local area surface drainage and water supply wells, as well as Hague Lake water quality.

The work carried out involved a site visit on December 12, 2018, assisting with the collation of information on local area water wells, soils, geology and surface drainage. This information was compiled and the results interpreted to develop an understanding of the active surface and groundwater flow systems in the study area. Based on this information a few small potential impacts were identified and mitigation and monitoring measures were recommended.

A summary of key findings is as follows:

- The sediments underlying the study are comprised primarily of fine to medium sand with intermittent layers of silty sand and sandy silt. This unit extends to a depth of over 120m in places. The water saturated parts of this unit are referred to as aquifers.
- The sand unit is relatively permeable and wells screened in this unit have yields typically in the 14 to 50 litres per minute (3 to 11 gpm) range.
- Most wells are screened in the lower elevations of the sand unit (elevation range about 0 to 16m above sea level), which is the principal aquifer in the area, and is primarily recharged from Hague Lake leakage.
- Some wells are screened at higher elevations, where perched aquifers are located. These wells are typically shallower and potentially have lower long term yields.
- The nearest drilled well to the Rainbow Ridge property is the Health Clinic well. The depth of this well is about 82m and the depth to the static water level on May 10, 2019 was 72.2m below ground.
- The water pumped from several wells in the area typically meets all drinking water criteria except iron and manganese, for which treatment is required in many wells. Some wells have been contaminated by coliform bacteria. However, the most likely source of contamination is from contaminated water being allowed to flow back into the well, rather than from a local source, such as a septic system.
- It is recommended that as drilling proceeds with any new well, the following parameters be monitored in the return water: pH, TDS and Redox, as well as observing the colour of the sediments.
- The new Senior's Village well is 82.3m deep well and is screened in the upper part of the principal aquifer unit. A 4-hour pump test run on this well confirmed that it was capable of sustaining a yield of about 90 L/min (20 gpm) with excellent water quality.
- While a shallower water bearing zone was encountered in some areas, consideration should only be given to installing a well screen in these perched zones if the field information

indicates that the yield and potential water quality in the zone is better than that of the principal aquifer.

- The principal aquifer is very productive, and consistent with this, the interference drawdown between wells (such as the Senior's Village and the Clinic wells) will not have an impact on the yields from neighbouring wells.
- The silty layers overlying the principal aquifer and the thick unsaturated sand will adequately protect the new well from contamination from surface sources, such as septic systems.
- The existing surface water drainage from the western part of the Property is intercepted in a south-north oriented ditch which discharges into the south Beasley Road ditch. A lack of a culvert at the Property entrance is likely resulting in overland flow which contributes to the flooding problem on the Coop property.
- The construction of new housing units and associated paths and driveways will result in an increased rate of rainfall and snowmelt runoff. By installing temporal storage and ground infiltration systems on the Property the impact of this increased precipitation runoff can be mitigated.
- There is a relatively permeable sand and gravel layer underlying most of the property. This unit is thickest in the northwest corner and the thickness gradually diminishes with increasing distance towards the southeast.
- Ground infiltration of surface water runoff into this upper layer will not have an impact on ditch water quality and neighbouring wells, even shallow dug wells. The same likely also applies to the infiltration of treated sewage effluent into the ground. However, as there is a local concern about this issue, selective monitoring of water quality near dispersal fields and in ditches is recommended.
- Of the two proposed first phase development plans, the North-South option has the advantage that most of the area is underlain by a thick permeable upper layer which is better suited to ground dispersal of runoff and sewage effluent.
- There is a possibility that some of the surface runoff can be diverted into the sand unit below a hardpan unit via a series of deep (4-6m) infiltration pits.
- By installing a range of temporal storage and ground infiltration systems it should be feasible to ensure that there is no net increase in peak surface water runoff from the developed portions of the Property.

1.0 Introduction

Elanco Enterprises Ltd. (Elanco) was retained by the Cortes Island Seniors Society (CISS) to conduct a hydrogeological assessment of the potential impact of developing a residential housing project in the northern part of their 965 Beasley Road Property (the Property) on Cortes Island.

This assessment focused on identifying potential impacts that development of 20 serviced housing units on the Property may have on local area surface drainage, nearby water supply wells and Hague Lake water quality.

2.0 The Property

The newly acquired 20.6 hectare (51ac) CISS property is located in the Manson's Landing village area in southern Cortes Island (see attached Figs. 1 to 3). Phase 1 of the property development involves construction of housing units in the northern part of this property (see Fig. 3). This development will include construction of a water supply system which will be sourced from a drilled well. It will also involve construction of a wastewater collection network and a Type 2 treatment system, with ground dispersal.

3.0 Work Carried out

I visited the Property and surrounding areas on December 12th, 2018. This visit provided me with the opportunity to inspect some of the many test holes and drainage ditches on the Property and on adjacent down-slope lands. I also visited the locations of wells located at the Coop, Market, Medical Clinic and Community Hall and also, the Hague Lake shoreline at the end of Belwood Road.

Logs of drilled wells listed on the BC Ministry of Environment website were downloaded and reviewed. With the help of Sandra Wood, logs of five additional drilled wells were obtained, along with locations of dug wells. Relevant information was compiled, with approximate locations of the drilled and dug wells indicated on Figs 2 and 3 and a summary of data for the drilled wells listed on Table I. The lithologic profiles and water levels recorded in the logs were used to construct three hydrogeologic profiles which are presented on Figs 4 to 6.

Information on 31 test pits was reviewed and designated soil zones on the property were indicated on Fig. 2.

4.0 Geological Setting

The sediments underlying the Study Area (outlined on Fig. 2) have been mapped as having Fraser Glaciation drift deposits at surface glaciofluvial sediments below. According to Clague (1977), the drift deposits are mostly glaciomarine in origin and the underlying glaciofluvial deposits are primarily a fine to medium sand. This sand unit has been observed in many areas in the Georgia

Strait area and has been designated as Quadra Sand, based on detailed studies of a cliff face on Quadra Island. The Quadra Sand unit is characterized as having primarily well sorted white sand which is extensively cross-bedded and has no imbedded organic matter. These sediments are typically derived from granitic bedrock. According to Clague (1977) the surface deposits are identified as Vashon till and related glacial deposits and these overlie the Quadra Sand unit. In many areas the contact between these two units is erosional (i.e. sharp), but in some areas (likely in the Study Area) the sand grades upwards through gravelly sands and laminated stony clay and silt into the glacial till.

According to the geological map of British Columbia, underlying the Quadra sand is a Jurassic to Tertiary granodiorite bedrock. This is confirmed by water well drill logs indicating a “granitic” type of bedrock below the overburden sediments.

5.0 Topography and Surface Drainage.

The elevations in the Study Area range from sea level up to about 88 metres above mean sea level (m-asl). The higher elevations are found in the northwest corner of the local drainage basin on Beasley Road (see profile on Fig. 6).

The surface water runoff in the area around the Property is directed towards a small creek that discharges into Hague Lake near Belwood Road. In this report, this creek is henceforth referred to as Belwood Creek and has a drainage area is about 0.75 Km^2, which includes the 0.206 Km^2 Property.

The water surface elevation of Hague Lake is about 22 m-asl, and is controlled by the invert of the outlet creek which discharges westward into Manson Bay. It is understood that occasionally beaver dams on this creek have caused the lake level to rise. A hydrographic survey indicates that the depth of Hague Lake ranges up to about 12m. Gunflint Lake is located north of Hague Lake and this lake discharges into Hague Lake.

Drainage from most of the western part of the Property is intercepted by a south to north oriented ditch that follows along a former forestry road and discharge from which is directed into a ditch on the south side of Beasley Road (see Fig. 2). This roadside ditch on Beasley Road discharges into a ditch along the west side of Sutil Point Road and from there it flows southwards to the Belwood Road junction. It crosses the road in a culvert at this junction and flows east along the south side of Belwood Road until it crosses the road in a another culvert and discharges into a deep gully located on the 1030 Belwood Road property, and from there into Hague Lake.

It is understood that during peak runoff periods the Beasley Road ditch overflows, sheet flow over Sutil Point Road causing flooding on the Coop property. A combination of reducing peak flow from the south-north ditch on the Property and improving roadside ditch channel could help reduce the frequency of this problem.

In the southern and eastern parts of the property the drainage is directed towards a ditch located along the west side of Sutil Point Road. This flow is mostly conducted in a series of natural swales and dug ditches. In the south, there is an extensive boggy area which also drains to the east (see Fig. 2).

6.0 Hydrogeology.

According to the Ministry of Environment website there is an extensive sand and gravel aquifer present below the Study Area. This has been designated as Aquifer 0841 and underlies most of the Sutil Peninsular (see outline on Fig. 1). This 9.5 Km^2 aquifer was rated as having a low vulnerability to contamination from surface sources and the estimated volume of water being abstracted relative to its potential yield volume (the demand) was low.

In the area northeast of this aquifer a fractured granodiorite aquifer has been identified. This is designated as Aquifer 0846 and, as indicated on Fig. 1, along its western side it underlies Aquifer 0841. The 198m deep Well No. 54941 (see location on the east side of Fig. 2) provides an illustration of this interconnection where this well apparently did not find an adequate yield in Aquifer 0841 and after penetrating 155m into Aquifer 0846 it encountered fractures in the bedrock that yielded 14 litres per minute (L/min).

The data on drilled wells in Aquifer 0841 have been grouped them into three areas. As indicated on Fig. 1, these are Areas A (The study area), Area B (Siskin Road subdivision) and Area C (Smelt Bay area). A summary of selected parameters from this analysis is provided in the table on Fig. 1. As might be expected, the median well depths are lowest in Area C near the ocean and highest in the high elevation Area B. Static water levels were mostly below 17 m-asl, and higher water elevations were always present in areas where perched are aquifers likely present. Reported yields ranged from 14 L/min to 1,176 L/min.

Three hydrogeological sections were constructed through the Study Area. The locations of which are indicated as Sections A-A', Section B-B' and Section C-C' on Figs 2 and 3 and the sections are presented on Figs. 4, 5 and 6 respectively. Unfortunately many of the well logs did not have lithologic profiles and, where present, the data made it very difficult to correlate the lithology from well to well.

The static water elevations indicate a gradient leading westward from Hague Lake, which is consistent with seepage from the lake recharging the aquifer and flow towards the ocean. These static water level elevations are based on approximate ground surface elevations (obtained from Google Earth) and on depths to water measured at the time the well was constructed. As such, some degree of deviation from current conditions (+/- 3m) is expected. However, the static water levels trends can generally be grouped into those with wells screened in the main aquifer with elevations less than 20 m-asl and those above, where perched aquifers are likely present. As the well logs rarely indicated the presence of an areally extensive hydraulically restrictive (silty sand or sandy silt) layer upon which a perched aquifer could develop, the sustainability of yields from these relatively shallow wells could be problematic in some areas. For example, a relatively shallow drilled well on the school property (No. 41022) was screened in a perched aquifer and apparently later replaced with a deep well. This may have resulted from the original 23 L/min yield diminishing over time.

The presence of an ephemeral spring on a Belwood Road property confirms that the hydraulically restrictive layer in the sand unit is areally extensive in some areas. (see spring location on Fig. 2 and profile on Fig. 6).

The test pits dug on the Property and the presence of a boggy area and many dug wells in the area confirm that an areally extensive restrictive layer is present throughout most of the study area. This unit is likely soil derived from the Vashon till unit that typically overlies the Quadra Sand Unit, where the aquifers are present. This till unit rarely contains clay in the matrix and hence it is not completely impervious. For this reason it is designated as a restrictive hydraulic unit as it will allow some of the perched water to seep through and recharge the underlying aquifer units (both the main aquifer and local perched aquifers).

The driller's log of the Senior's Village well (Well G) indicated that the hole penetrated a silty sand and gravel layer to a depth of 23m, starting at ground surface (see Profile on Figs. 4 and 6). This is the same unit where many dug wells have their water source, suggesting that there are some horizontally permeable zones within the upper part of this unit.

7.0 Soils and Near Surface Drainage

Ron McMurtrie, of McMurtrie and Associates Consulting Engineers, supervised the digging of test pits on the Property. His analysis of data from 31 test pits show that surface soil layer comprises primarily loose, medium to coarse grained sands, and loamy sands, with significant gravel content in most areas and cobbles in some. The underlying layer is typically a massive dense loamy sand or sandy loam. Groundwater seepage was observed in most of the test pits in April 2018, which confirmed that this unit was acting as a hydraulically restrictive layer.

Based this information, and observations in nearby ditches, it is evident that, at least during the wetter times of the year, there is shallow groundwater flowing eastwards on top of the restrictive layer. Some, if not all, of the flow in the western part of the Property is intercepted in a ditch that runs south to north across the middle of the property (see location on Fig. 2). In the eastern portion, infiltrated precipitation will sustain a discharge towards the Sutil Point Road ditch. In some areas, ditches located on neighbouring properties, have locally diverted this water before discharging into this ditch. In the south east corner of the property there is a relatively extensive "boggy" area from which surface water flow likely occurs much of the year.

The areas with the thickest permeable soil profile above the restrictive layer have been designated as Zone A These range through Zones B and C down to Zone D, which has the thinnest thickness as indicated on Fig. 2. During extreme precipitation events, it is likely that the soils capacity to convey the water in the subsurface in Zone D and possibly Zone C, and overland sheet flow likely occurs in many low-lying areas.

Zones A and B have the potential for constructing relatively simple dispersal fields for waste water dispersal as well as ground infiltration of surface water runoff. Zone C soils could be used for the same purposes but will require detailed engineering and will be more expensive to construct. Zone D soils are not suitable. As can be seen, the Phase 1 area has about a 40% coverage of soil with Zone A characteristics.

8.0 Pre Construction Assessment of Potential for Constructing the Senior's Well.

A review of the profiles indicated in the hydrogeological sections on Figs. 4 and 6, suggested that a 80m deep well drilled on the Senior's Village property (951 Beasley Road) had the potential for adequately penetrating the deep aquifer to provide a yield (40 to 70 L/min) similar to other wells in the area. While a shallow perched aquifer is present in areas west of the Village the drilling results confirmed that it did extend below this property.

The water supply requirement for housing on the Gulf Islands is typically much less than in other parts of Coastal British Columbia. A study of water usage on Gabriola Island indicated that 15m^3/month (0.35 L/min) supply in the winter and a 19.3 m^3/month (0.44 L/min) supply would be adequate for a typical residence with water conservation measures in place. However, the Ministry of Health (MOH) guidelines for on-site waste water systems is typically based on 1,000 L/d (0.69 L/min) for a 2 bedroom unit and 1,300 L/d (0.9 L/min) for a 3 bedroom unit. Using the MOH guideline, 20 two bedroom housing units would require a minimum source supply of 13.9 L/min and 20 three bedroom units would require 18.1 L/min. These supply estimates assume that a storage tank is included in the system to cover short term peak demand periods. If a well yielded 40 L/min this would be represent 2.2 times that of the three bedroom unit option and 2.9 times that of the two bedroom option. However, as indicated above, while the design may follow the MOH guidelines, experience on the Gulf Islands indicates that the actual demand is typically much less (about half), even in the summer when demand is at its peak.

While the yield from wells constructed for private properties are typically in the 14 to 50 litres per minute (3 to 11 gpm) range in the area, experience shows that a well screen designed for higher yields can be achieved in the same aquifer by scientifically selecting the screen slot openings that best fit the aquifer grain size distribution and installing a longer screen.

This pre-construction assessment indicated that the deep aquifer had a high yielding capacity which significantly exceeds the potential yield from the new Senior's Village well.

As indicated in the Elanco Enterprises Ltd. June 4, 2019 post construction report on the 82.3m deep Senior's Village well (Well G) the pump test run on this well confirmed that it was capable of sustaining a yield of about 90 L/min (20 gpm), and that it had no impact on the operational capacity of the nearby Clinic Well (Well C).

9.0 Water Supply Quality Issues.

Information on the water quality for the Senior's Village, Clinic and Coop wells is summarized on Table II. This shows that the water meets the Canadian Drinking Water Guideline objectives for all parameters with the exception of iron and manganese in some of the wells at various times. However, these are aesthetic and not health related objectives. Iron and manganese are naturally occurring elements in the sediments and in some environments they dissolve and migrate with groundwater. These environments are typically not areally extensive within the same aquifer, and hence one well may have this issue while nearby wells may not. If required, treatment for the relatively low concentrations of iron and manganese in the local groundwater is relatively easy and inexpensive. This often involves introducing an oxidant (such as potassium permanganate) followed by removal of the resultant precipitate using an inline filter system.

Elevated concentrations of dissolved iron and manganese are often found in groundwater where, under reducing conditions (lack of oxygen), some of the iron and manganese in the aquifer minerals dissolve into groundwater and migrate into the well screens. This often occurs in localized zones and hence field observations and the use of geochemical test kits when drilling a well can help avoid setting the well screen in these zones, thereby avoiding the need for long term treatment of the well water. This approach was taken when selecting the optimum screen depth in the Senior's Village well, and resulted in the well water having low total and dissolved concentrations for these two metals.

Routine testing has indicated that some of the local area public water supplies have occasionally had unacceptable counts for coliform bacteria when sampled near the well source. As these wells are very deep, the only potential pathways for coliform bacteria getting into the wells is either directly into the well casing or migrating in the annulus outside the steel well casing. As many of the well logs do not indicate that a surface casing seal was installed, there is very small potential for migration down the outside of the casing. However, even with no installed surface seal the fine grained aquifer sediments in these deep wells will most likely have sealed off this pathway. This leaves open the potential for direct ingress into the well casing, possibly via a leaking pitless adapter assembly. Routine disinfection of the well can usually control this problem in an existing well.

By law, the proposed new well must have a surface seal that meets current code, and for this reason coliform contamination should not be an issue.

10.0 Control of Surface Water Runoff

The proposed development will involve construction of buildings and roads with impervious surfaces, which will result in an increased volume and intensity of the surface water runoff. In order to mitigate this it is recommended that a range of measures be considered. These should include installing dry wells and perforated pipes designed to infiltrate water into the ground. While this may only be feasible the area up-slope of the drainage ditch in Zones A and B it may be feasible in down slope areas if construct of deep (5 to 6m) pits could be constructed to penetrate the sand unit below the restrictive layer. In addition the installation of temporal storage facilities such as ponds, wetlands and storage tanks could be installed to reduce peak flows following intense rainfall and fast snow melt events.

An example of a deep infiltration pit with temporal storage is presented in Fig 8. These pits can only be installed in areas where a permeable unit (Quadra Sand) can be economically reached by digging a deep (4 to 6m) pit with a backhoe. If feasible, one or more deep pits could be located along the south-north ditch to divert some of the runoff flowing into the Beasley Road ditch.

Flow from roof downspouts and perimeter drains could be directed into small buried tank from where it can either seep through the bottom, or overflow into a perforated pipe leading from the tanks (see illustration on Fig. 9).

A series of small check dams constructed along ditches and or dry basins could be installed to provide temporal storage and provide time for subsurface infiltration to take place. An illustration of a dry basin is provided on Fig. 10.

Another potential solution is to develop a network of ditches and buried pipes to convey the runoff through properties along the eastern boundary, such as CISS's industrial property (785 Sutil Point Road), and discharge into the Sutil Point roadside ditch.

11.0 Contamination of Surface and Near Surface Water

The Type II wastewater treatment system planned for the Project will remove a substantial quantity of the coliforms, and other potential contaminants, prior to discharge into the ground. With the addition of sand to the infiltration bed there will be further removal of contaminants. These systems are engineered to ensure that by the time the infiltrated effluent reaches nearby ditches there no impact on its water quality. This contrasts with the many existing septic tank systems which were constructed using old codes and may not be properly maintained.

Based on experience with conducting assessments in areas with similar hydogeological characteristics, it is concluded that ground infiltration of surface water runoff into this upper layer will not have an impact on ditch water quality and neighbouring wells, including shallow dug wells.

Water quality testing has been conducted in Hague Lake and, while some water quality issues have been indentified in northern parts of the lake, no direct connection between low coliform counts in the southern shoreline of the lake and nearby on-site wastewater systems has been established.

However, to better understand this issue it is recommended that a water quality monitoring program be implemented. This should involve sampling water in the Property ditch just before it reaches Beasley Road and sampling in the Belwood Road ditch. In addition, water samples should be collected from two or more monitoring tubes located near the Clinic's existing Type 2 effluent dispersal field (see plan on Fig. 7). These water samples should initially be analyzed for e-coli and total coliforms, nitrate ammonia and total phosphorous. It is my understanding that planning of this initial sampling is now underway. The parameters and subsequent frequency can be determined after the results of the initial analyses are available.

12.0 Comments on Preliminary Phase 1 Housing Layout.

Of the two proposed first phase development plans, the North-South option has the advantage that most of the area is underlain by a thick permeable upper layer, which is better suited to ground dispersal of runoff and sewage effluent. Also, this option provides more flexibility for locating the proposed dispersal field at least 30m away from the Senior's Village well.

13.0 Recommendations

- When drilling water supply wells in the area, such as the Senior's Village Well, the contractor should monitor TDS/EC, pH, ORP/redox and temperature of the water turned during drilling, as well as note sediment colour. This information, along with indicated formation permeability, should be used to help select a screen elevation that maximizes well yield and minimizes the chance of having to permanently remove iron and/or manganese from the pumped water.

- Consideration should be given to digging a series of deep pits to explore the possibility of constructing deep infiltration pits in selected locations.

- Where feasible a series of temporal detention storage and ground infiltration structures should be installed to reduce peak flow and divert some of the runoff from local ditches and neighbouring properties.

- The proposed sampling and nutrient analysis of groundwater near the existing effluent dispersal field and selected locations in ditches be carried out.

Limitations.

This investigation has been conducted using a standard of care consistent with that expected of scientific and engineering professionals undertaking similar work under similar conditions in B.C. No warranty is expressed or implied.

I trust that this is sufficient for your present purposes.

Yours truly,

Elanco Enterprises Ltd.

R. Allan Dakin, FEC, P. Eng.
Senior Groundwater Engineer

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Tables

TABLE I

MANSONS LANDING AREA - WATER WELL INFORMATION

Public Wells	WTN	Elevation of (m-asl)							Depth to (m)							Yield
		Collar	FWS	RSL top	RSLBase	SWL	Screen bottom	Hole bottom	FWS	RSL top	RSLBase	SWL	Bedrock	Screen bottom	Hole bottom	L/min
	41022	85	67	ni	72	ni	49	48	18	ni	13	ni	na	36	37	23
	52868	42	ni	12	-4	-1	ni	-13	ni	30	46	43	na	ni	55	36
	54941	46	-45	34	28	16	ni	-152	91	12	18	30	43	ni	198	14
	54948	58	ni	34	31	35	ni	20	ni	24	27	23	na	ni	38	23
	85603	69	50	49	45	ni	39	33	19	20	24	ni	na	30	36	18
	88706	35	12	29	26	15	6	5	23	6	9	20	na	29	30	27
Community Hall	93932	68	64	64	44	10	-3	-5	4	4	24	58	na	71	73	68
School	93980	81	ni	ni	ni	14	ni	-23	ni	ni	ni	67	na	ni	104	ni
Market	93981	69	ni	ni	ni	11	ni	3	ni	ni	ni	58	na	ni	66	ni
	97030	44	ni	36	27	ni	na	-90	ni	8	17	ni	17	ni	134	14
	103281	72	ni	63	40	44	36	35	ni	9	32	28	na	36	37	36
	104512	77	13	ni	54	13	2	1	64	ni	23	64	na	75	76	ni
	108252	63	ni	55	46	9	-3	-4	ni	8	17	54	na	66	67	45
	108255	53	25	47	37	15	8	8	28	6	16	38	na	45	45	27
	108339	60	ni	55	38	9	4	3	ni	5	22	51	na	56	57	23
	110054	65	ni	59	42	12	-1	-2	ni	6	23	53	na	66	67	36
	112436	81	75	75	69	15	4	2	6	6	12	66	na	77	79	27
	113800	60	29	58	41	14	-6	-6	31	2	19	46	na	66	66	36
	Well A	35	ni	ni	ni	18	ni	11	ni	ni	ni	17	na	ni	24	68
Coop	Well B	65	ni	47	28	12	1	1	ni	18	37	53	na	64	64	54
Clinic	Well C	76	ni	ni	ni	4	-8	ni	ni	ni	ni	72	ni	ni	ni	
	Well D	87	ni	86	44	44	32	32	ni	1	43	43	na	55	55	82
	Well E	77	ni	ni	36	15	4	4	ni	ni	41	62	na	73	73	91
	Well F	74	ni	71	44	44	39	39	ni	3	30	30	na	35.1	35.4	23
Senior's Village	Well G	74	ni	74	51	3.1	-8	-17	ni	0	23	71	na	82.3	90.8	45
Minimum		35	-45	12	-3.72	-1		-152	4	1	9	20	17		24	14
Median		65	29	52	41	14		2	23	7	20	51			66	27
Average		63	32	50	39	16		-8	32	11	21	47			70	30
Maximum		87	75	86	72	44		48	91	30	46	67	43		198	68

Notes:

1) See locations of wells on Figs 2 and 3.
2) na = not applicable ni = no information available.
   FWS = first reported water strike
   RSL = interpreted uppermost layer that restricts downward movement of water
   SWL = Depth to static water level measured at the time the well was constructed.

Table II
Manson's Landing Area Well Water Quality

Parameter	Detection Limit	Units	New Senior's Village Well	Cortes Island Health Center (WTN = 93932)		Cortes Natural Food Coop (Well B)	CDWQ Guideline		
Client Sample ID			New Senior's Village Well	Cortes Island Health Center (WTN = 93932)		Cortes Natural Food Coop (Well B)	MAC	AO	IMAC
Date Sampled			14-May-2019	20-Jul-2005	25-Mar-2013	8-Dec-2017			
Time Sampled			7:30 AM			6:45			
Laboratory			ALS Eviro	CanTest	North Is. Lab	Maxxam			
Lab Sample ID			L2273086	507220445	101537	08441366			
Physical Tests (Water)									
UV Absorbance (254 nm)	0.001	Abs/cm	0.004	-	-	-	-	-	-
Colour, True	5	CU	<5.0	<5	-	30	-	15.0	-
Conductivity	2	uS/cm	168	-	-	86.5	-	-	-
Hardness (as CaCO3)	0.5	mg/L	7.44	43	55	21.8	-	-	-
pH	0.1	pH	7.91	7.47	7.30	7.57	-	6.5:10	-
Total Suspended Solids	3	mg/L	3.8	-	-	-	-	-	-
Total Dissolved Solids	20	mg/L	134	98	108	48	-	500	-
Turbidity	0.1	NTU	1.1	5.9	-	6.05	-	-	-
Transmittance, UV (254 nm)	1	%T/cm	99.1	-	-	-	-	-	-
Anions and Nutrients (Water)									
Alkalinity, Total (as CaCO3)		mg/L	72.2	57.7	-	27.3	-	-	-
Bircarbonate alkalinity (as HCO3)		mg/L	-	70	-	33.4	-	-	-
Carbonate alkalinity (as CO3)		mg/L	-	<0.5	-	<1	-	-	-
Hydroxide alkalinity (as OH)		mg/L	-	<0.5	-	<1	-	-	-
Bromide (Br)	0.05	mg/L	<0.05	-	-	-	-	-	-
Chloride (Cl)	0.5	mg/L	8.16	9	11	8.0	-	250	-
Fluoride (F)	0.02	mg/L	<0.02	-	<0.05	<0.02	1.5	-	-
Ammonia, Total (as N)	0.0050	mg/L	<0.0050	-	-	<0.02	-	-	-
Nitrate (as N)	0.0050	mg/L	1.27	-	1.43	0.054	10	-	-
Nitrite (as N)	0.0010	mg/L	<0.0010	-	<0.05	<0.005	1	-	-
Sulfate (SO4)	0.30	mg/L	1.54	1.1	1	3.3	-	500	-
Sulphide as S	0.020	mg/L	<0.018	-	-	0.0146	-	-	-
Organic / Inorganic Carbon (Water)									
Dissolved Organic Carbon	0.50	mg/L	<0.50	-	-	-	-	-	-
Total Organic Carbon	0.50	mg/L	<0.50	-	-	1.29	-	-	-
Bacteriological Tests (Water)									
E. coli		MPN/100mL	<1	-	-	**1**	<1	-	-
Fecal coliform bacteria		MPN/100mL	<1	-	-	-	<1	-	-
Coliform bacteria - Total		MPN/100mL	<1	-	-	**7**	<1	-	-
Non coliform bacteria - Total		MPN/100mL	-	-	-	-	-	-	-
Heterotropic Plate Count		CFU/mi	9	-	-	220	-	-	-
Iron Bacteria		CFU/mi	-	-	-	<25	-	-	-
Sulphate Reducing Bacteria		CFU/mi	-	-	-	**<25**	-	-	-
Total Metals (Water)									
Aluminum (Al)-Total	0.0030	mg/L	0.0399	<0.005	0.010	<0.003	-	-	0.01
Antimony (Sb)-Total	0.0001	mg/L	0.00012	<0.001	<0.0001	<0.0005	0.006	-	-
Arsenic (As)-Total	0.0001	mg/L	0.00024	<0.001	<0.00005	<0.0001	0.01	-	-
Barium (Ba)-Total	0.000050	mg/L	0.00312	0.009	0.0103	0.0017	1	-	-
Beryllium (Be)-Total	0.00010	mg/L	<0.00010	-	<0.00005	<0.0001	-	-	-
Bismuth (Bi)-Total	0.000050	mg/L	<0.000050	-	<0.0001	<0.0001	-	-	-
Boron (B)-Total	0.010	mg/L	0.042	<0.05	0.007	<0.05	5	-	-
Cadmium (Cd)-Total	0.000005	mg/L	0.0000271	<0.0002	<0.00001	0.000011	0.005	-	-
Calcium (Ca)-Total	0.050	mg/L	2.61	11.40	14.6	6.65	-	-	-
Cesium (Cs)-Total	0.00001	mg/L	<0.000010	-	-	-	-	-	-

Table II
Manson's Landing Area Well Water Quality

Parameter	Detection Limit	Units	New Senior's Village Well	Cortes Island Health Center (WTN = 93932)		Cortes Natural Food Coop (Well B)	CDWQ Guideline		
		Client Sample ID	New Senior's Village Well	Cortes Island Health Center (WTN = 93932)		Cortes Natural Food Coop (Well B)	CDWQ Guideline		
		Date Sampled	14-May-2019	20-Jul-2005	25-Mar-2013	8-Dec-2017	MAC	AO	IMAC
		Time Sampled	7:30 AM			6:45			
		Laboratory	ALS Eviro	CanTest	North Is. Lab	Maxxam			
		Lab Sample ID	L2273086	507220445	101537	08441366			
Chromium (Cr)-Total	0.0001	mg/L	0.00762	<0.001	0.0023	<0.001	0.05	-	-
Cobalt (Co)-Total	0.0001	mg/L	0.00053	-	<0.0001	<0.0002	-	-	-
Copper (Cu)-Total	0.0005	mg/L	0.125	0.005	0.0068	0.0423	-	1	-
Iron (Fe)-Total	0.01	mg/L	0.113	**0.44**	0.174	**0.686**	-	0.3	-
Lead (Pb)-Total	0.00005	mg/L	0.00203	<0.001	0.0006	0.00055	0.01	-	-
Lithium (Li)-Total	0.001	mg/L	<0.0010	-	0.0008	-	-	-	-
Magnesium (Mg)-Total	0.005	mg/L	0.223	3.65	4.42	1.26	-	-	-
Manganese (Mn)-Total	0.0001	mg/L	**0.002**	**0.073**	0.0091	0.0372	-	0.05	-
Mercury (Hg)-Total	0.00001	mg/L	<0.0000050	-		0.00001	-	-	-
Molybdenum (Mo)-Total	0.00005	mg/L	0.000355	-	0.00045	<0.001	-	-	-
Nickel (Ni)-Total	0.0005	mg/L	0.185	-	0.0015	<0.001	-	-	-
Phosphorus (P)-Total	0.05	mg/L	<0.050	-	-	-	-	-	-
Potassium (K)-Total	0.05	mg/L	4.4	1.50	1.80	0.621	-	-	-
Rubidium (Rb)-Total	0.0002	mg/L	0.00138	-	-	-	-	-	-
Selenium (Se)-Total	0.00005	mg/L	<0.000050	<0.001	<0.0001	7.76	0.01	-	-
Silicon (Si)-Total	0.05	mg/L	2.34	-	11.8	-	-	-	-
Silver (Ag)-Total	0.00001	mg/L	0.000024	-	<0.00005	<0.00002	-	-	-
Sodium (Na)-Total	0.05	mg/L	2.11	-	11.4	7.1	-	200	-
Strontium (Sr)-Total	0.0002	mg/L	0.00644	-	0.0900	0.0503			
Sulfur (S)-Total	0.5	mg/L	1.65	-	-	-	-	-	-
Tellurium (Te)-Total	0.0002	mg/L	<0.00020	-	-	-	-	-	-
Thallium (Tl)-Total	0.00001	mg/L	<0.000010	-	<0.00001	<0.00001	-	-	-
Thorium (Th)-Total	0.0001	mg/L	<0.00010	-	-	-	-	-	-
Tin (Sn)-Total	0.0001	mg/L	0.00065	-	0.0002	<0.005	-	-	-
Titanium (Ti)-Total	0.0003	mg/L	0.00044	-	<0.0005	<0.005	-	-	-
Tungsten (W)-Total	0.0001	mg/L	<0.00010	-	-	-	-	-	-
Uranium (U)-Total	0.00001	mg/L	0.000028	<0.0005	0.00016	<0.0001	0.02	-	-
Vanadium (V)-Total	0.0005	mg/L	<0.00050		0.0016	<0.005	-	-	-
Zinc (Zn)-Total	0.003	mg/L	0.021	0.008	0.0054	0.0457	5	-	-
Zirconium (Zr)-Total	0.0003	mg/L	<0.000060	-	-	<0.0001	-	-	-
Dissolved Metals (Water)									
Calcium (Ca)-diss		mg/L	-	11.4	-	-	-	-	-
Iron (Fe)- diss		mg/L	0.1	**0.43**	-	-	-	0.3	-
Magnesium (Mg)-diss		mg/L	-	3.6100	-	-		-	
Manganese (Mn)-diss		mg/L	0.0001	0.070	-	-	-	0.05	-
Potassium (K)-diss		mg/L	-	1.5	-	-	-	-	-
Silicon (Si)-diss		mg/L	-	19.2	-	-	-	-	-
Sodium (Na)-diss		mg/L	-	9.4	-	-	-	-	-
Aggregate Organics (Water)									
Tannin & Lignin (as Tannic Acid)	0.10	mg/L	<0.1	-	-	-	-	-	-

Notes:
1) See locations of wells on Fig. 2 and 3.
2) **0.00** = Samples exceeding MAC **0.00** = Samples exceeding AO

Figures

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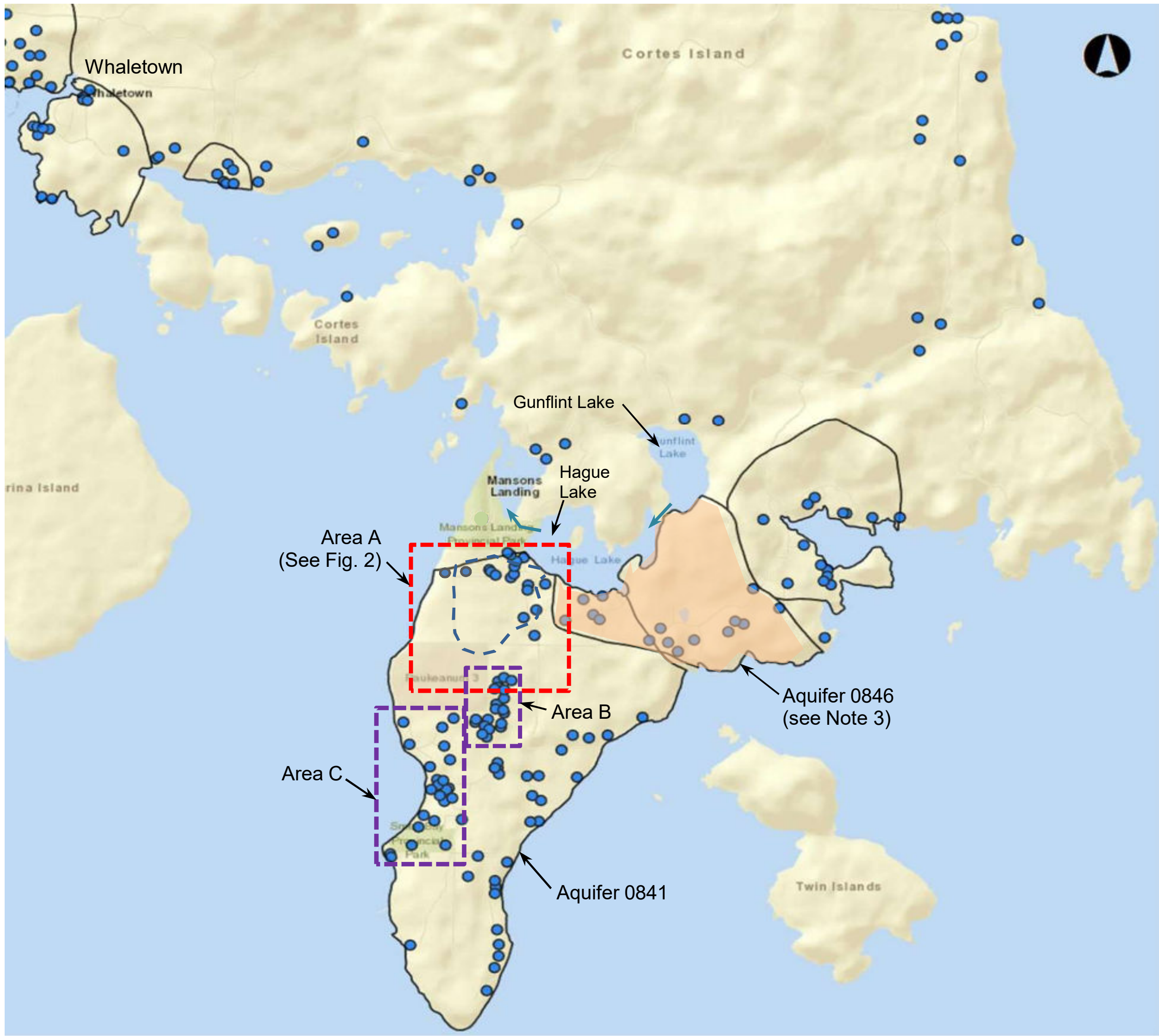

Area	Number of Wells	Yield (L/min)		Elev. SWL (m-asl)		Well depth (m)
		min	max	min	max	median
A	24	14	68	9	44	66
B	20	27	1176	11	19	79
C	19	18	136	1	20	33

Selected information on wells loceted in Areas A (the Study Area), B and C

Scale (1:75,000)
0 1 2Km

Legend

Approximate extent of Belwood Creek Watershed.

Water well.

NOTES
1) Base map from BC Ministry of Environment web site.
2) See datailed information on wells in Area A on Table I.
3) Aquifer 0846 is in fractured granodiorite and extends under Aquifer 0841 in the NE corner.

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HYDROGEOLOGICAL ASSESSMENT FOR PROPOSED RAINBOW RIDGE PROJECT, 965 BEASLEY ROAD, CORTES ISLAND. B.C.

Map Showing Locations of Water Wells and Study Area

Drawn:

Date
Jun. 2019

Approved:

Fig. **1**

File:2600 \ 241 Figures - final 1 Loc Map 6/15/2019 10:56 PM

JOB NUMBER: 241

Legend

A B C D — Soil zones ranging from A deepest to D shallowest above restrictive layer.

Boggy area (very approximate)

Perennial creek channel or ditch.

Ephemeral creek channel or ditch.

Approximate extent of Belwood Creek Watershed.

B — Hydrogeologic profile B (see Figs 4 to 6)

Drilled 150mm diameter steel cased water well. The number is the Provincially assigned Well Tag number.

Dug well (? indicates assumed type of well)

15 Water table elevations (m-asl) in selected wells.

Developed spring

Potential west to east drain

Interpreted groundwater flow direction

Scale (1:10,000)

0 200 400m

NOTES

1) Base map from BC Ministry of Environment web site (see information on Table I)

2) All well locations are approximate.

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HYDROGEOLOGICAL ASSESSMENT FOR PROPOSED RAINBOW RIDGE PROJECT, 965 BEASLEY ROAD, CORTES ISLAND. B.C.

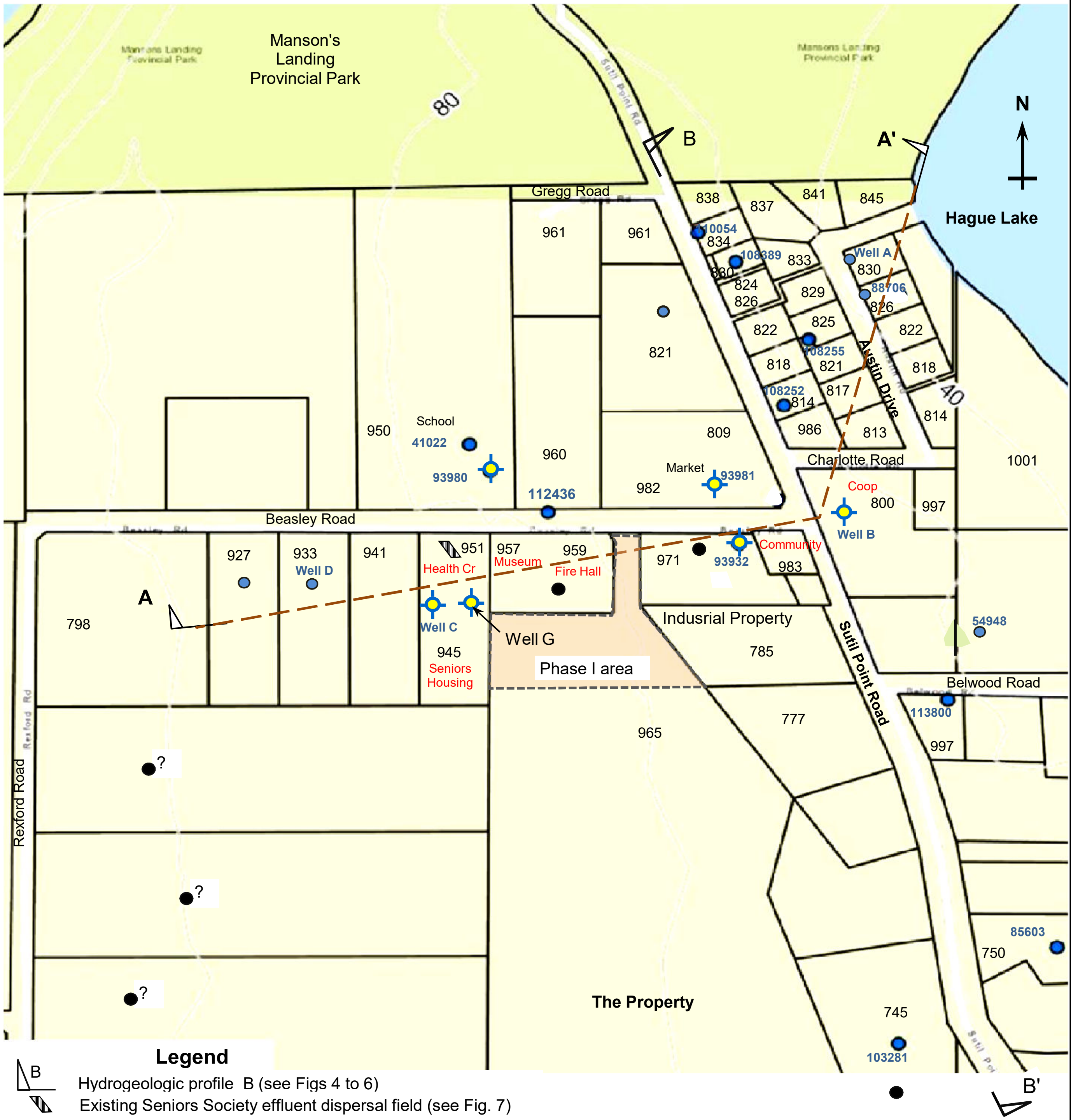
Area Map With Known Water Supply Well Locations

Drawn:

Date: Jun. 2019

Approved:

Fig. **2**



Legend

- B — Hydrogeologic profile B (see Figs 4 to 6)
- Existing Seniors Society effluent dispersal field (see Fig. 7)
- Drilled 150mm diameter steel cased water well. The number is the Provincially assigned Well Tag number.
- Public water supply well
- ? Dug well with known and speculated locations.

NOTES
1) Base map from BC Ministry of Environment web site.

Scale (1:5,000)
0 80 160m

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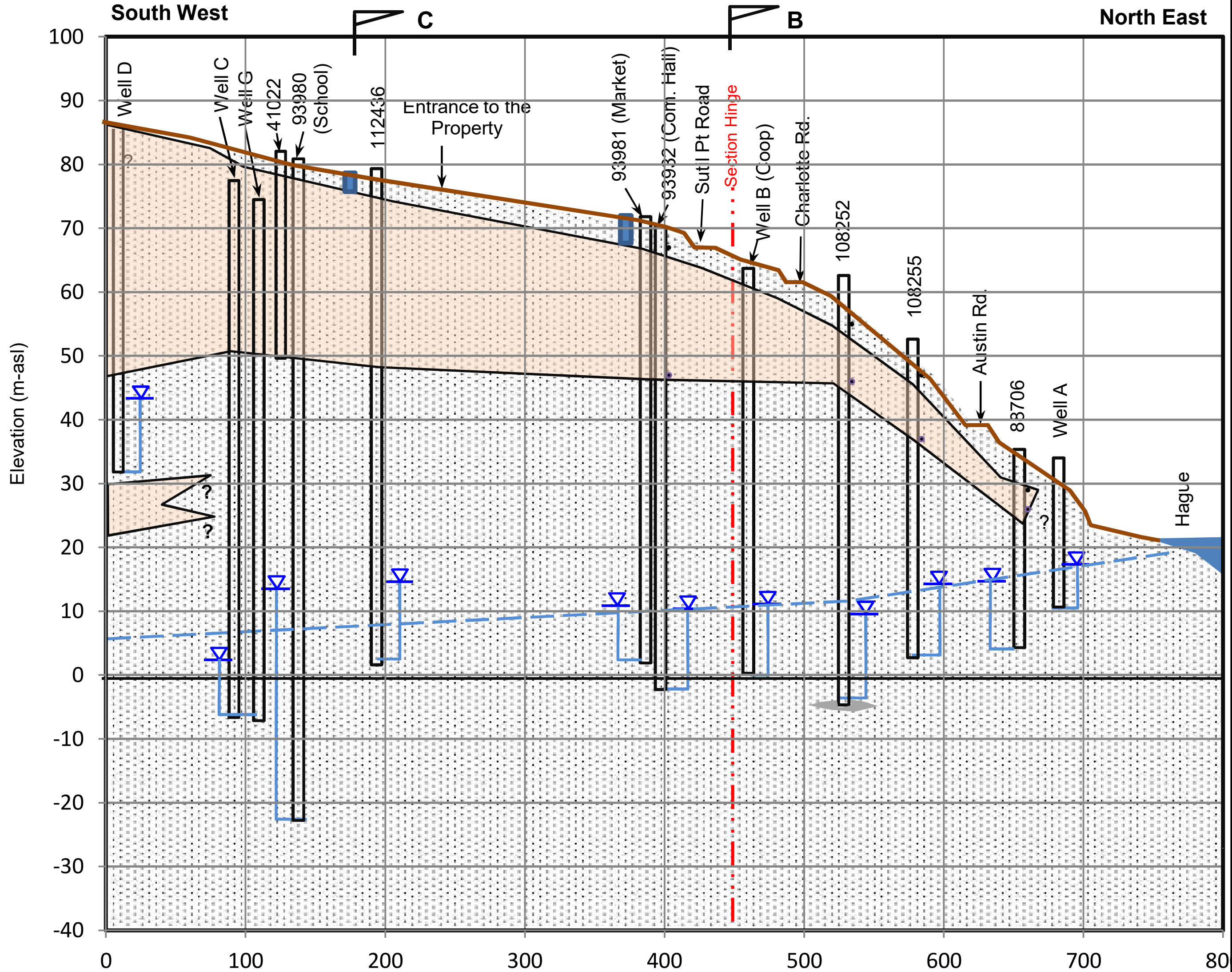
Water Wells in Village Core

Drawn:	Date Jun. 2019
Approved:	Fig. 3

JOB NUMBER: 241



Distance (m)

Legend

Clay layer

Dug well (See Note 3)

Developed spring

Fine sand, with some gravel and occasional silt lenses.

Interpreted hydraulically restrictive layer (See Note 2)

Drilled 150mm diameter steel cased water well. The number is the Provincially assigned Well Tag number.

Elevation of static water level at time of well construction.

Well screen location.

Vertical exaggeration = 10x

NOTES
1) See location of section on Figs. 2 and 3
3) The restrictive layer is a zone with higher apparent silt content in the sand and is generally grey in colour. It is not well defined in many areas.
3) Dug wells are typically 5 to 7m deep and are often used for a potable water supply .

Horizontal Scale (1:5,000)
0 80 160m

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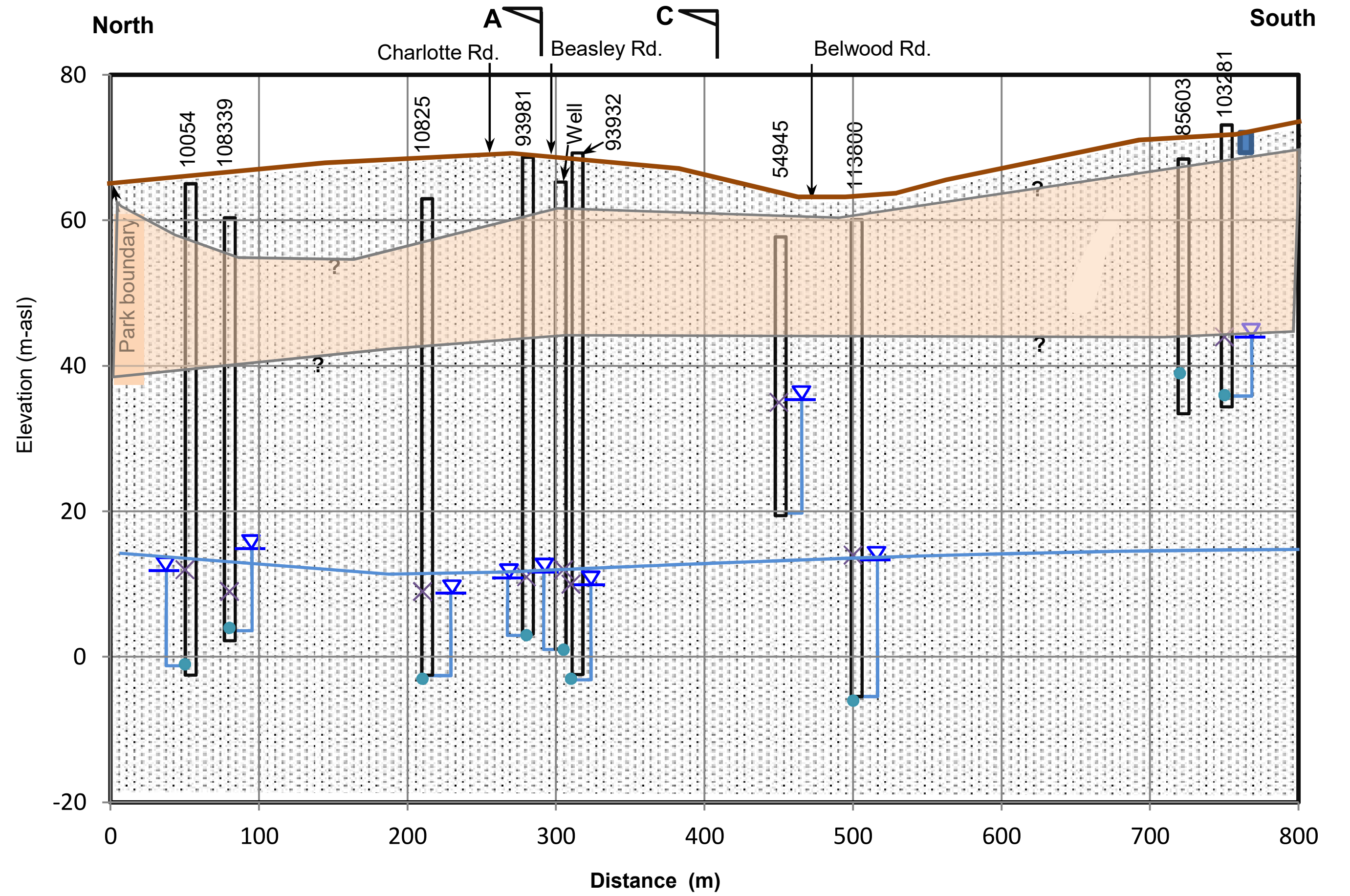
HYDROGEOLOGICAL SECTION A - A'

Drawn:

Date: Jun. 2019

Approved:

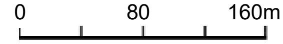
Fig. **4**



See legend on Fig. 4

Vertical exaggeration = 10x

NOTES
1) See location of section on Fig. 2.
3) The restrictive layer is a zone with higher apparent silt content in the sand and is generally grey in colour. It is not well defined in many areas.
3) Dug wells are typically 5 to 7m deep and are rarely used for a potable water supply in the area..



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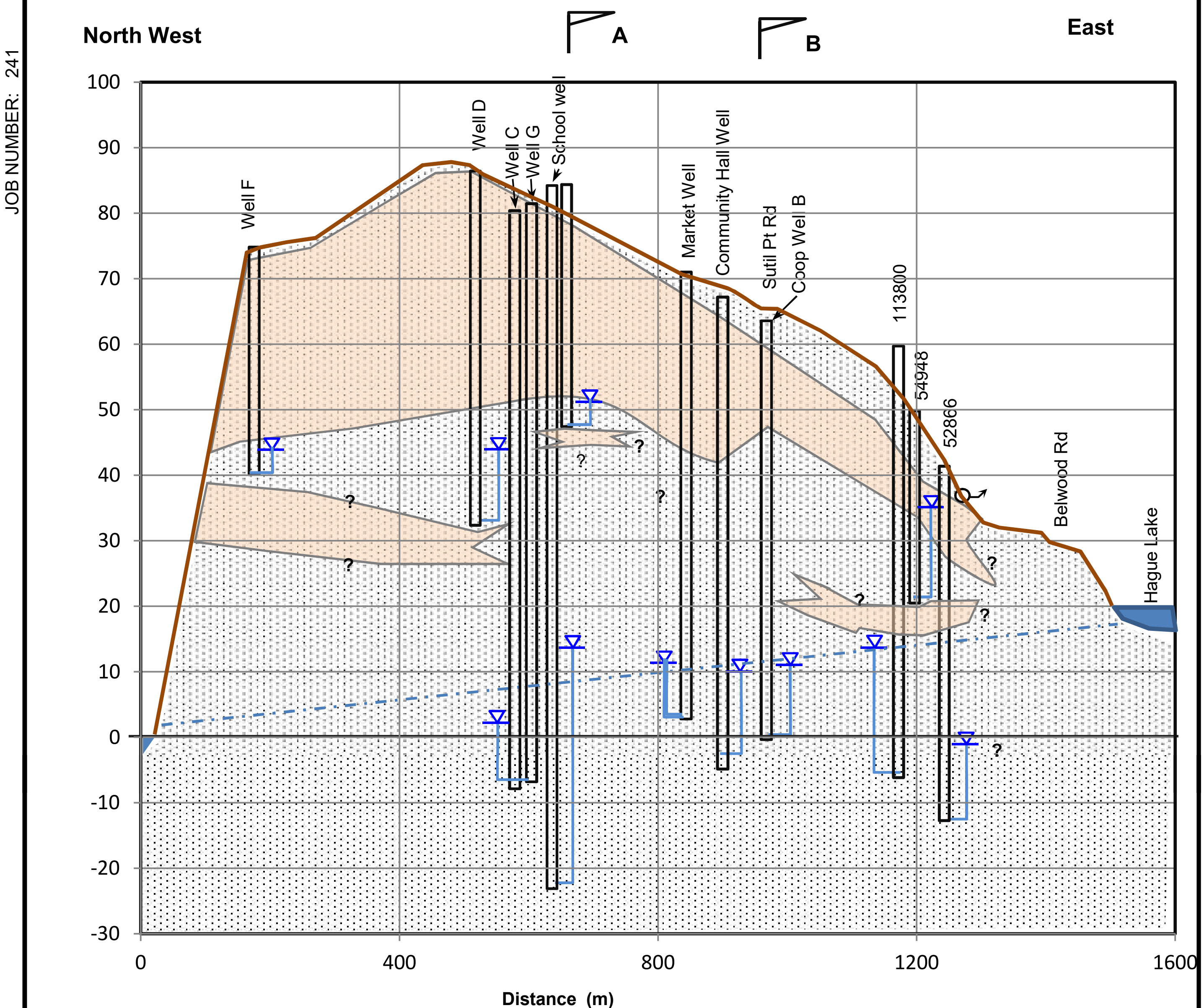
HYDROGEOLOGICAL ASSESSMENT FOR PROPOSED RAINBOW RIDGE PROJECT, 965 BEASLEY ROAD, CORTES ISLAND. B.C.	**HYDROGEOLOGICAL SECTION B - B'**	Drawn:	Date Jun. 2019
		Approved:	Fig. **5**



See legend on Fig. 4

Developed spring

Vertical exaggeration = 10x

NOTES
1) See location of section on Fig. 2.
3) The restrictive layer is a zone with higher apparent silt content in the sand and is generally grey in colour. It is not well defined in many areas.
3) Dug wells are typically 5 to 7m deep and are often used for a potable water supply .

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HYDROGEOLOGICAL ASSESSMENT FOR PROPOSED RAINBOW RIDGE PROJECT, 965 BEASLEY ROAD, CORTES ISLAND. B.C.	**Hydrogeological Section C-C'**	Drawn:	Date Jun. 2019
		Approved:	Fig. **6**

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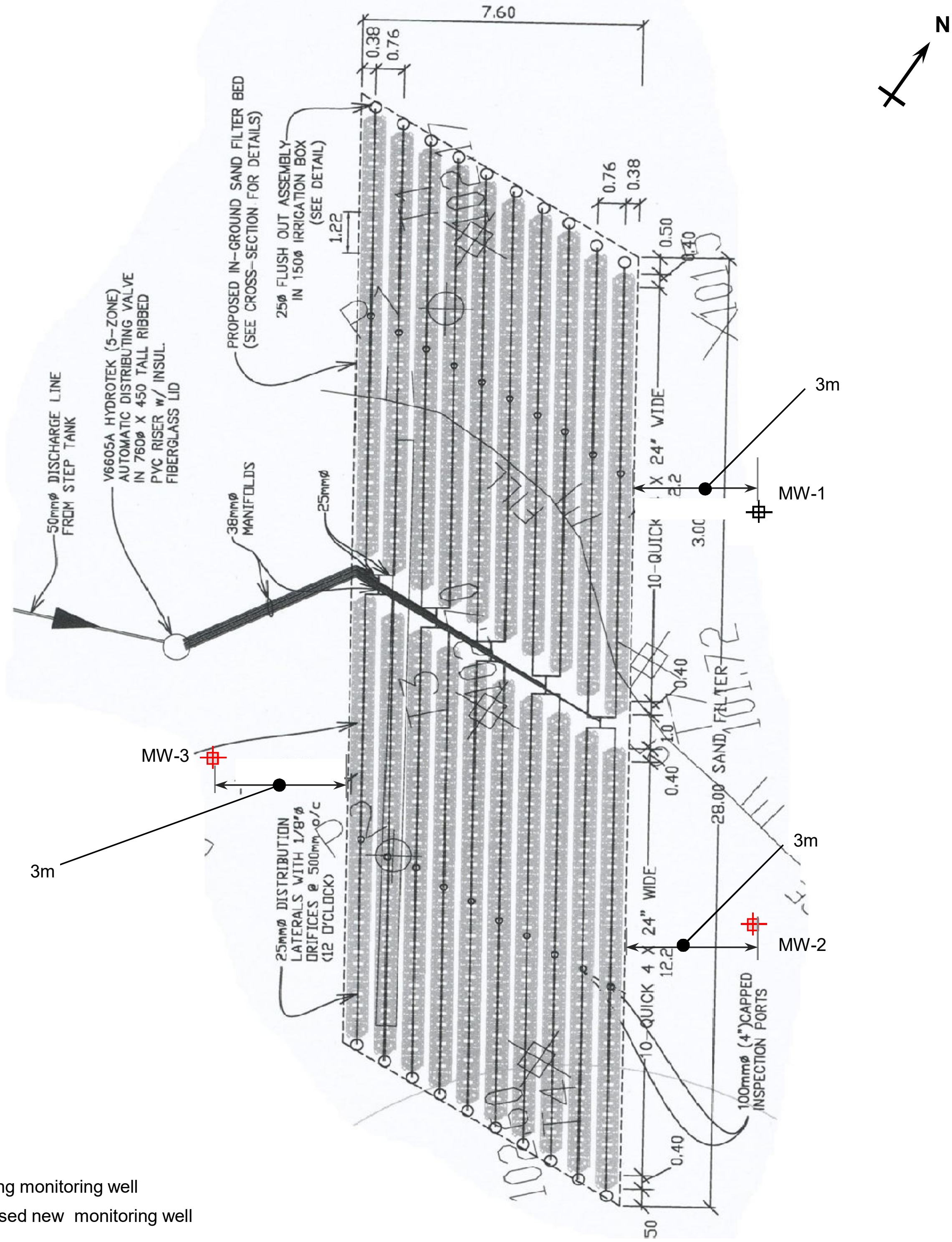

Legend

- Existing monitoring well
- Proposed new monitoring well

NOTES
1) Base prepared by Ron McMurtrie & Associates Consulting Engineers..
2) See location of field on Fig. 3

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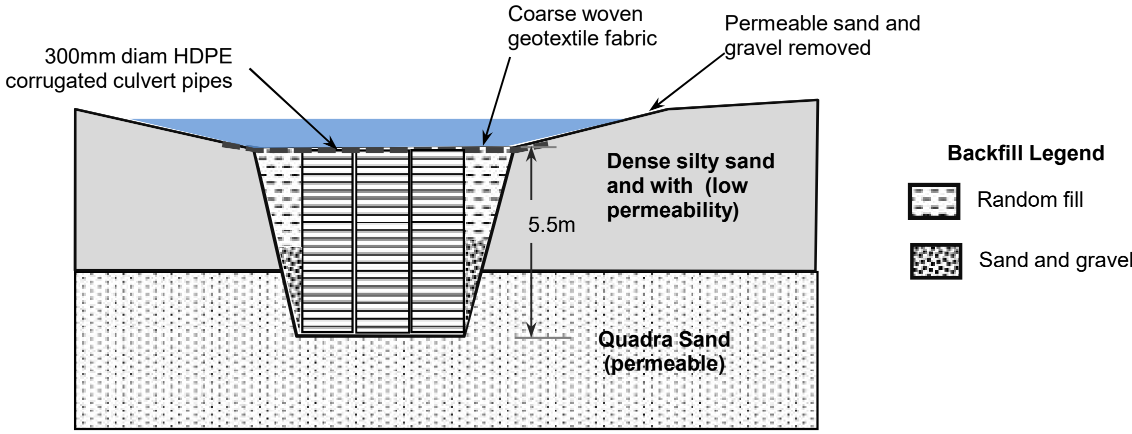
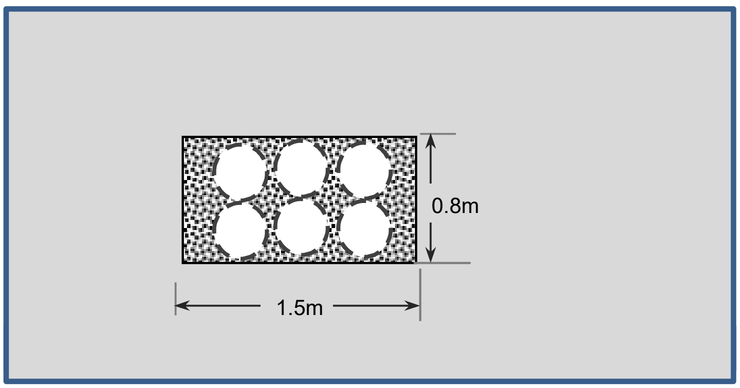
HYDROGEOLOGICAL ASSESSMENT FOR PROPOSED RAINBOW RIDGE PROJECT, 965 BEASLEY ROAD, CORTES ISLAND. B.C.	**PLAN OF SENIORS SOCIETY EFFLUENT DISPERSAL FIELD SHOWING RECOMMENDED MONITORING WELLS**	Drawn:	Date Mar. 2019
		Approved:	Fig. **7**

JOB NUMBER: 241



Profile



Plan

Test Pit in Quadra Sand at Qualicum Beach

NOTES
1) Dimensions are for illustrative purposes only . Actual dimensions will vary.
2) Water storage capacity for this example is about 2.6 m^3.
3) Potential infiltration capacity could range up to 13m^3/day in Quadra Sand unit.
4) These deep pits can only be effective in areas where Quadra Sand can easily be accessed at a depth reached with a backhoe.
5) Locations near the north-south ditch could be very beneficial in diverting a portion of the flow.

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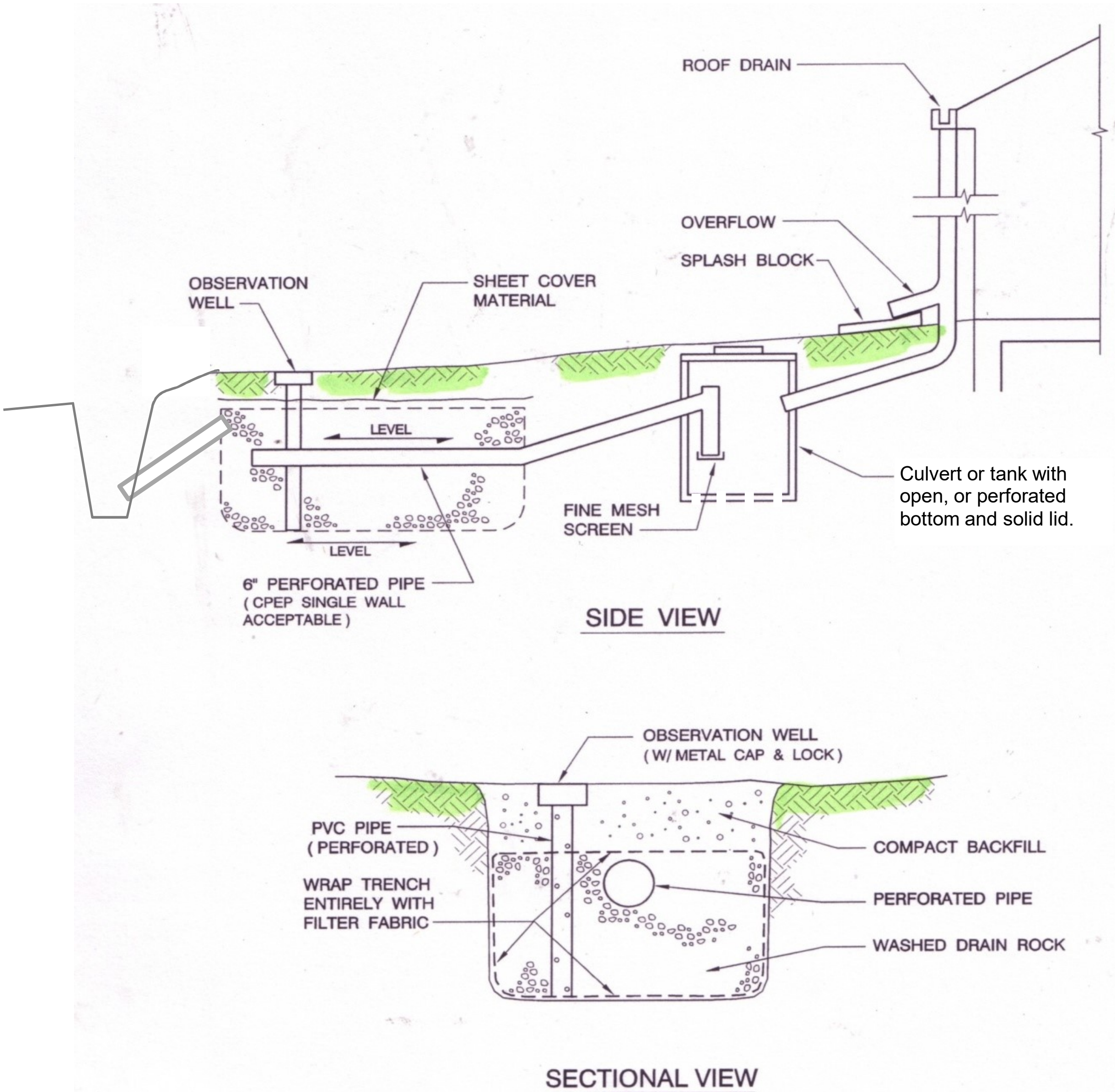
HYDROGEOLOGICAL ASSESSMENT FOR PROPOSED RAINBOW RIDGE PROJECT, 965 BEASLEY ROAD, CORTES ISLAND. B.C.

Concept for Deep Infiltration Pit

Drawn:
Date Mar. 2019
Approved:
Fig. **8**

JOB NUMBER: 241



TYPICAL ROOF DOWNSPOUT SYSTEM

NOTES
1) A modified version of this system could be constructed at each new housing unit.

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HYDROGEOLOGICAL ASSESSMENT FOR PROPOSED RAINBOW RIDGE PROJECT, 965 BEASLEY ROAD, CORTES ISLAND. B.C.	**Roof Downspout System**	Drawn:	Date Mar. 2019
		Approved:	Fig. **9**

File:2600 \ 241 Figures - final Fig.9 Downspout systems 6/15/2019 10:59 PM

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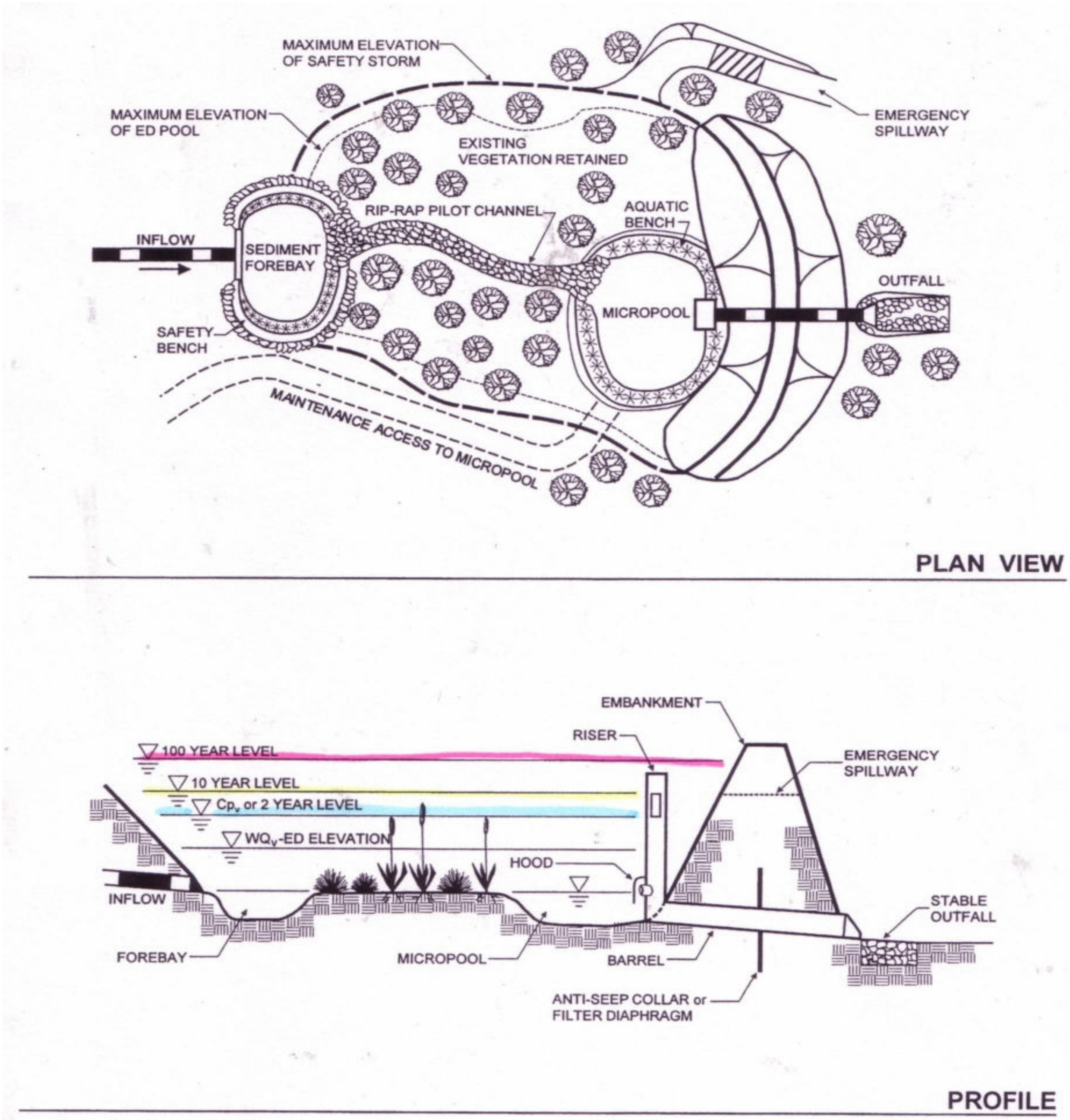

EXAMPLE OF MICRO POOL EXTENDED DETENTION DRY BASIN

NOTES

1) A simplified version of this basin could be constructed along side the north-south ditch.
2) A deep seepage infiltration pit (see Fig. 8) could be used to help drain the pond following an intense runoff event.

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HYDROGEOLOGICAL ASSESSMENT FOR PROPOSED RAINBOW RIDGE PROJECT, 965 BEASLEY ROAD, CORTES ISLAND. B.C.	**Detention Dry Basin For Surface Water Runoff**	Drawn: RQ	Date Mar. 2019
		Approved:	Fig. **10**