LHC Lowen Hydrogeology
Consulting Ltd.

September 23, 2012
LHC Project File: 1218

Shawnigan Residents Association
PO Box 443
Shawnigan Lake, BC
V0R 2W0

Attention : Gary Horwood, President

Dear Sir:

Re: Proposed SIA Contaminated Soils Landfill, Stebbings Road, Malahat Land District, BC

As discussed in our July meeting we have reviewed the South Island Aggregates (SIA) proposal for a Contaminated Soils Landfill at the above noted site. Information regarding the landfill development has been obtained from the SIA website. A preliminary assessment of the proposed landfill site and its suitability for the intended purpose has been carried out utilizing existing information. Several environmental and human health risks regarding the landfill have been identified. Our investigations are focused on the site hydrogeology and potential for negative impacts on the local groundwater flow system and those dependant on this system for their drinking water.

Writer's Qualifications

Dennis Lowen, P. Eng., P. Geo. is a geological engineer with 40 years of experience in hydrogeology. He specializes in hydrogeology studies, environmental impacts studies plus groundwater supply projects. Mr. Lowen has worked in hydrogeology in Western Canada and in 10 overseas nations with extensive experience in BC since 1978. He has completed several landfill siting, design and closure projects and numerous landfill leachate studies. Mr. Lowen has provided hydrogeological expert witness testimony before the BC Environmental Review Board and the Supreme Court of BC. Mr. Lowen's company (LHC) has completed at least 6 projects in the south Shawnigan Lake region over the last 10 years. LHC also has extensive experience in aquifer mapping having mapped more than 400 aquifers for the BC Ministry of Environment.

Our comments are provided in the following sections:

→ *In italic:* *SIA information*
→ In blue: LHC comments

SIA Website Presentation

Under the "Groundwater" section it is noted that the BC Ministry of Environment (MOE) has mapped two bedrock aquifers in the region, but none below the landfill site.

MOE aquifer mapping is preliminary only and depends on concentrations of existing well information. The reason why there is no aquifer mapped beneath the landfill site is because at the time of the mapping there were too few drilled wells in the site area. There are a sufficient number of wells in the region now to confirm that there is an aquifer beneath the proposed site. This aquifer is used as a drinking water source for local residents, some located less than 300 m. from the site, and the aquifer must be protected.

Also in the Groundwater Section SIA notes that there are two aquifers in the region; one to the north and one east of the site. These two Aquifers # 203 & 208 are described with respect to demand and productivity.

Demand and productivity are only two of the three main descriptors used in the BC Aquifer Classification System used in mapping aquifers in BC. The omitted descriptor is the Aquifer Vulnerability which rates the aquifers' susceptibility to contamination from surface sources. Both aquifers 203 & 208 are rated as highly vulnerable to contamination.

The same or very similar hydrogeologic settings are present in aquifers 203, 208 and the aquifer beneath the landfill site. Hence the aquifer beneath the landfill site is highly vulnerable to contamination from surface sources.

Further more from our work on this site and our experience in aquifer mapping it is apparent that aquifer #203 extends beneath the proposed landfill site. The landfill would pose a risk to aquifer #203 and it is a developed drinking water source. Any contaminated surface water run-off or landfill leachate that escapes the site may reach the aquifer readily and this would constitute a health hazard.

Aquifers #203 and #208 are referred to by name in the SIA presentation namely the Shawnigan Lake/Cobble Hill Bedrock Aquifer and the Spectacle Lake/Malahat Bedrock Aquifer respectively.

*The SIA Groundwater section also describes the bedrock beneath the site as having extremely low permeability (more commonly called hydraulic Conductivity or "K") and estimates **K** at 7.6×10^{-10} m/s or nearly impermeable. This impermeable rock is quoted to provide "a very high level of protection to the underlying aquifer".*

The rock under the site is identified as Wark Gneiss by the Geological Survey of Canada, Map 1553A. This is a fractured metamorphic rock with hydraulic conductivity in the range of 8×10^{-9} to 3×10^{-4} m/sec. (Domenico & Schwartz, 1990) Also wells completed in this rock formation have reported yields up to 6.3 Liters/second or 100 USgallons/minute which indicates a relatively high hydraulic conductivity for a fractured rock aquifer. A more reasonable estimate of **K** for the rock under the SIA site is 5×10^{-7} m/sec. This is 1000 times higher than the K reported by SIA. The Wark Gneiss rock unit also has inclusions of limestone (or Marble). The on-site well record (well # 86152, Appendix A) indicates fractured limestone beneath the subject site. These fractured rocks provide little protection for the underlying aquifer.

We have assessed several well pumping tests in the local bedrock aquifer. The pumping test data is used to calculate aquifer hydraulic conductivity. One of our pumping tests in the local bedrock aquifer indicates a hydraulic conductivity (K) of 6.9×10^{-7} m/sec. This analysis corroborates our estimated **K** = 5×10^{-7} m/sec. noted above. There is a well located on the SIA Landfill site with well tag #86152 and reported yield of 20 USgallons per minute. This well should be tested by pumping to obtain site specific data.

SIA further states that measurements indicate that it will take surface water 100,000 years to migrate downwards to the aquifer.

This statement runs contrary to the extensive body of data available from observation wells on Vancouver Island and the Gulf Islands. These observation wells show a relatively quick response in bedrock wells to rainfall events. That is to say water levels rise quickly in bedrock wells following a rainfall event indicating rapid infiltration from surface down to the aquifers. The time lag is usually less than a few days. This phenomenon is due to the fact that the bedrock is fractured throughout from surface to the aquifer. The main water flow from surface to the aquifer occurs in fractures in the rock which are essentially open channels which facilitate flow.

SIA also states that in addition to the 100,000 years travel time for water to reach the aquifer from surface that additional layers of protection will be included to make the disposal site safer.

We assume this refers to a landfill liner system where low permeability soil, plastic sheets or a composite liner are used to contain liquids in the landfill. Many studies have shown that landfill liners eventually leak. In fact they generally leak soon after filling has begun. An engineered liner is no guarantee that contaminated landfill liquids will not escape the proposed landfill. The contaminated flow from the landfill will readily reach the underlying drinking water aquifer and could present a health risk.

Site Hydrogeology

The proposed landfill site is located overlying a fractured bedrock aquifer that extends from the site down to Shawnigan Lake. In our opinion the aquifer appears to have moderate productivity, moderate demand and highly vulnerability to contamination from surface sources. See a listing of the local well records used for this analysis in Appendix A, attached.

The on-site well record indicates fractured limestone rock beneath the proposed landfill. This rock is fractured and permeable plus limestone is a soluble rock which will be susceptible to solution weathering from acidic landfill leachate. This process will make the rock more permeable.

Rainfall that infiltrates the ground at the subject site will flow downward to the aquifer and then flow toward the northwest (toward Shawnigan Lake). See Figure 1 for a graphic representation of the groundwater flow system.

Local rainfall is high = 1,138 mm/year and annual recharge has been estimated at 20% of total precipitation or 228 mm/year. This is a significant rate of recharge = 2,280 m^3/Ha./year. There is a large volume of water that can be impacted by the proposed landfill operation.

The water table slope from the proposed landfill site to the lake is 0.05. This slope provides a good driving head to propel groundwater from the site to the lake. The groundwater velocity from the landfill site to the lake is estimated at 5 – 10 m/d. Therefore the 5 Km distance would be traversed within 1.4 to 2.7 years. Any contamination carried by the groundwater flow would reach the lake with little attenuation. There would be little adsorption or filtration in open bedrock fractures and only dilution would reduce contaminant concentrations. Dilution alone may not be enough to prevent contamination of lake water.

Not only Shawnigan Lake water is put at risk with the proposed landfill there are also many drinking water wells nearby and downstream from the site. There are 5 wells within 250 m. of the proposed landfill site. These drinking water wells could draw water from beneath the proposed landfill site. There are up to 10 more wells downstream from the landfill site. All these wells may have water quality impacted by the landfill.

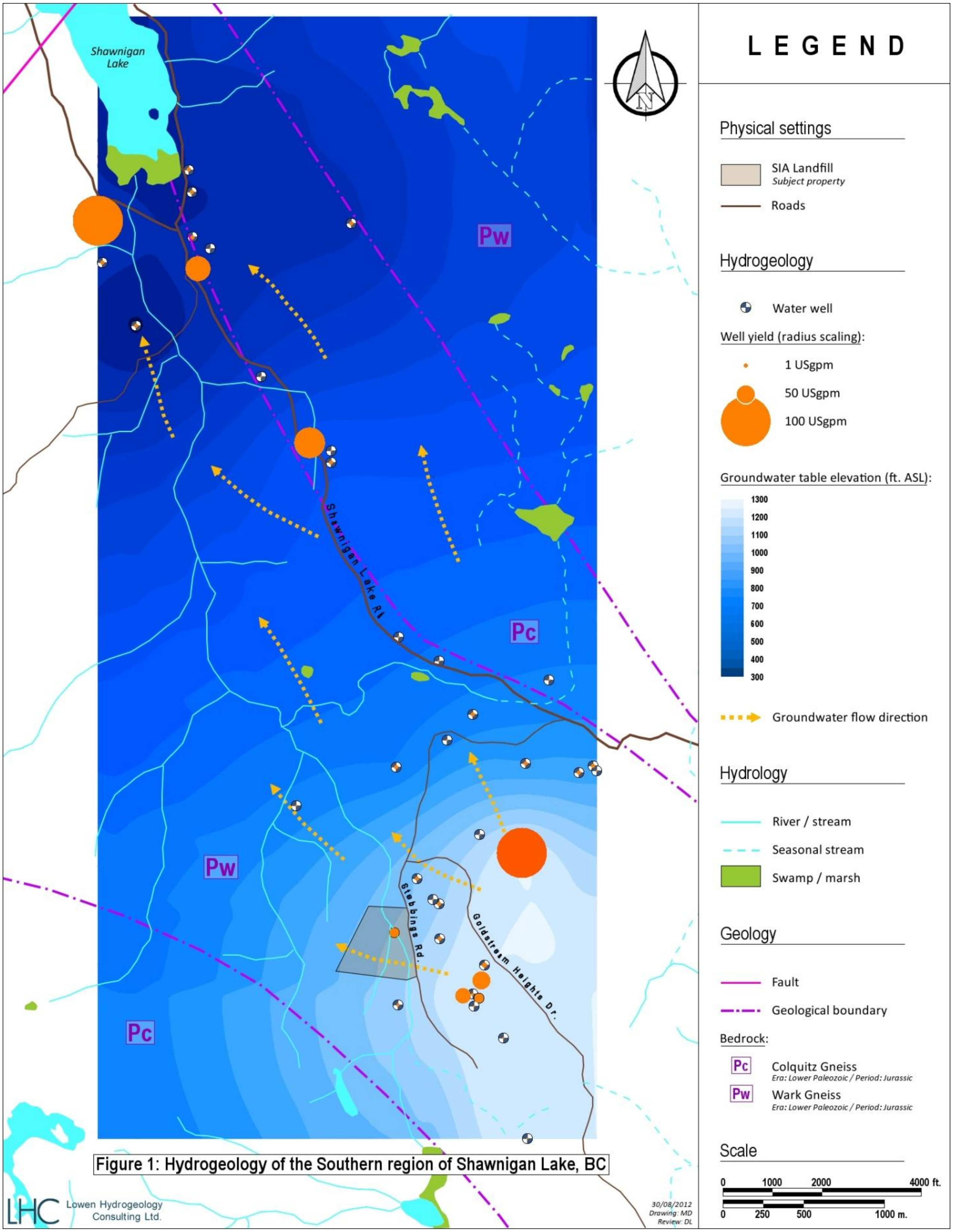

Figure 1: Hydrogeology of the Southern region of Shawnigan Lake, BC

An alternate method for evaluating aquifer vulnerability at a specific site has been used for our analysis. The Aquifer Vulnerability Index Calculation (Van Stempvoort, 1992) has been employed using well record information from the site Well Tag #86152. The calculation indicates a high degree of Vulnerability for the aquifer. The calculation is attached at Appendix B.

Further regarding aquifer vulnerability the Vancouver Island University in Nanaimo has completed Intrinsic Vulnerability Mapping, 2010 (Aquifer Vulnerability) for all of Vancouver Island. This study found the proposed landfill site area to have Moderate Vulnerability however the scale of the study was very large and the previous two analyses outlined in this letter are more specific (ie. more valid).

General Comments

Upon reviewing the SIA proposed contaminated soil landfill project one question appears quite obvious. Why was this site selected for disposal? Generally when a landfill site is required the initial effort is spent selecting a suitable site. Landfill siting is a difficult, complex, tedious, sometimes emotional and protracted process requiring evaluation of many different criteria. Geographical Information System (GIS) tools are used in conjunction with environment, biophysical, ecological and socioeconomic variables which lead to an analysis and decision-making process. For example one area underlain by a thick layer of impermeable clay which offers natural protection for the underlying aquifer would be preferred over a gravel pit with a water table close to the pit floor. Similarly a site in a rock quarry over a fractured rock aquifer would score very low on the suitability scale. Was there a siting study completed prior to selection of this landfill site ?

For comparison when a large scale in-ground wastewater disposal site is approved by the Provincial Government there is a requirement for at least four observation wells, one upstream from the development and three downstream. These wells are installed and monitored before approval and are used for the site analysis. This proposed site should meet or exceed this standard.

We understand some soils are being dumped at the site now. If this is the case what type of soil is it? It seems that the liner and drainage works have not been done as yet so the site is not ready to receive contaminated soil.

Our studies have been focused on underground water flow but the surface hydrology is also an issue. The site borders Shawnigan Creek and any contaminated run-off from the site would quickly flow to the creek and to Shawnigan Lake. Since the lake is a drinking water source this appears to be a significant risk. Containment works are planned but can they eliminate all the risks? How will the containment works be maintained over the long term and after the site is closed?

Recommendations

1. A comprehensive Environmental Impact Study must be completed before this site could be approved for disposal. These kinds of studies are mandatory for wastewater disposal which is a smaller risk than contaminated soil.
2. Construction of monitoring wells, aquifer testing, water quality sampling and contaminant flow modeling should be undertaken to assess the suitability of this site.
3. The site should have a leak detection system and a contamination containment plan. Commonly contaminated groundwater is pumped out of the aquifer and piped to a treatment plant. Naturally all these necessary risk reduction measures are very costly therefore long-term financing plans would also be needed.
4. A cost-benefit analysis should be carried out to ensure that this proposal is sustainable.

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

Yours very truly,

LOWEN HYDROGEOLOGY CONSULTING LTD.

Dennis A. Lowen, P. Eng. P. Geo.
DAL/ MD /hmr

APPENDIX A

Well Records

WATER WELLS OF THE SOUTHERN REGION OF SHAWNIGAN LAKE, BC

WELL TAG NO.	UTM Coordinates EASTING	UTM Coordinates NORTHING	ELEVATION	YIELD	STATIC WATER LEVEL	DEPTH TO BEDROCK
			ft.	USgpm	ft.	ft.
#86152*	455434	5377844	1115	20	10	0
#83527	455458	5377397	1148	3	-	20
#95485	455713	5377804	1214	4	45	8
#93401	455858	5377454	1247	30	-0.25	0
#85099	455925	5377389	1279	2.5	-	2
#86036	456108	5377190	1279	1.25	-	42
#83531	455955	5377439	1279	20	-	55
#85100	455917	5377464	1279	4	-	4
#86037	455971	5377547	1312	35	102	3
#89253	455990	5377644	1312	10	60	9
#83528	456257	5376570	1411	0.5	-	1
#85309	455706	5378020	1214	4	67	6
#96080	455672	5378049	1214	3	95	5
#95480	455573	5378178	1148	6	45	14
#105940	456222	5378338	1247	100	-12	13
#96095	455442	5378868	1000	5	145	118
#97026	456245	5378893	1050	7	100	81
#96127	455919	5379195	919	5	45	70
#96123	456574	5378836	1017	4	45	68
#81952	456665	5378875	1017	3	-	33
#81951	456687	5378858	1017	10	-	35
#52475	455708	5379521	853	1.5	-	7
#106005	455458	5379672	853	3	-	25
#53806	455039	5380753	787	7	-	10
#53807	455042	5380823	787	25	-	15
#80059	454912	5380876	738	60	50	2
#80056	454894	5380916	738	5	70	-
#99931	454610	5381287	607	2.5	80	42
#104661	453836	5381601	443	6	44	3
#84468	454219	5381956	459	50	35	1
#84469	454294	5382078	525	3	-	10
#69093	454184	5382149	459	6	-	9
#84470	455168	5382236	459	5	25	18
#84471	454180	5382427	410	6	20	15
#84472	454162	5382569	410	8	-4	15
#104658	453628	5381993	459	8	42	1
#105772	453600	5382252	426	14	-15	14

* *SIA well. See following page for well record details.*

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 86152

Owner: SOUTH ISLAND AGGREGATES

Address: STEBBINGS ROAD

Area: MALAHAT

WELL LOCATION:
MALAHAT Land District
District Lot: Plan: DD 1896741 Lot: 23
Township: Section: Range:
Indian Reserve: Meridian: Block:
Quarter:
Island: VANCOUVER ISLAND
BCGS Number (NAD 27): 092B052422 Well: 1

Class of Well: Water supply
Subclass of Well: Domestic
Orientation of Well: Vertical
Status of Well: New
Well Use: Private Domestic
Observation Well Number:
Observation Well Status:
Construction Method:
Diameter: 6 inches
Casing drive shoe: N Y
Well Depth: 325 feet
Elevation: 1100 feet (ASL)
Final Casing Stick Up: 24 inches
Well Cap Type: WELDED
Bedrock Depth: feet
Lithology Info Flag: Y
File Info Flag: N
Sieve Info Flag: N
Screen Info Flag: N

Site Info Details:
Other Info Flag:
Other Info Details:

Construction Date: 2006-10-10 00:00:00.0

Driller: Drillwell Enterprises
Well Identification Plate Number: 16588
Plate Attached By: RANDY CREAMER
Where Plate Attached: CASING

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 20 (Driller's Estimate) U.S. Gallons per Minute
Development Method: Air lifting
Pump Test Info Flag: N
Artesian Flow:
Artesian Pressure (ft):
Static Level: 10 feet

WATER QUALITY:
Character: Clear, Fresh
Colour:
Odour:
Well Disinfected: Y
EMS ID:
Water Chemistry Info Flag: N
Field Chemistry Info Flag:
Site Info (SEAM): N

Water Utility: N
Water Supply System Name:
Water Supply System Well Name:

SURFACE SEAL:
Flag: Y
Material: Bentonite clay
Method: Poured
Depth (ft): 16 feet
Thickness (in): 2 inches
Liner from To: feet

WELL CLOSURE INFORMATION:
Reason For Closure:
Method of Closure:
Closure Sealant Material:
Closure Backfill Material:
Details of Closure:

Screen from	to feet	Type	Slot Size

Casing from	to feet	Diameter	Material	Drive Shoe
0	16	6	null	N
16	325	null	Open hole	Y

GENERAL REMARKS:

LITHOLOGY INFORMATION:
From 0 to 260 Ft. Medium 12 Gallons per Minute (U.S./Imperial) FRACTURE 258-260 green limestone
From 260 to 297 Ft. Medium 3 Gallons per Minute (U.S./Imperial) FRACTURE 296-297 black granite
From 297 to 325 Ft. Medium 5 Gallons per Minute (U.S./Imperial) FRACTURE 307-308 green limestone

APPENDIX B

Aquifer Vulnerability Calculation

AQUIFER VULNERABILITY INDEX CALCULATIONS*

PROJECT:	SIA Contaminated Soils
PROJECT No.:	1218
DATE:	19/08/2012
WELL ID. PLATE No.:	16588
WELL TAG No.:	86152
LOCATION:	460 Stebbings Road, Malahat Land District, BC

Well Tag No. 86152

Layer	Thickness (m)	K value (m/d)	c** (years)
Limestone	79.2	0.01	21.70
Igneous bedrock	11.3	1	3.10E-02
Limestone	8.5	0.01	2.33
		TOTAL	**24.06** years

High Vulnerability

***** Van Stempvoort, D.,Ph.D., Ewart,L., and L.Wassener, 1992. AVI: A Method for Groundwater Protection Mapping in the Prairie Provinces of Canada, Prairie Provinces Water Board, Regina, Sask.

****** Hydraulic Resistance "c"
Hydraulic Resistance, $c = \Sigma di / Ki$, for layers 1 to i
The lower the hydraulic resistance (c) the higher the vulnerability:
c = Less than 10 years - extremely high vulnerability
c = 10 - 100 years - high vulnerability
c = 100 - 1000 years - moderate vulnerability
c = 100 - 10,000 - low vulnerability
c = greater than 10,000 - extremely low vulnerability