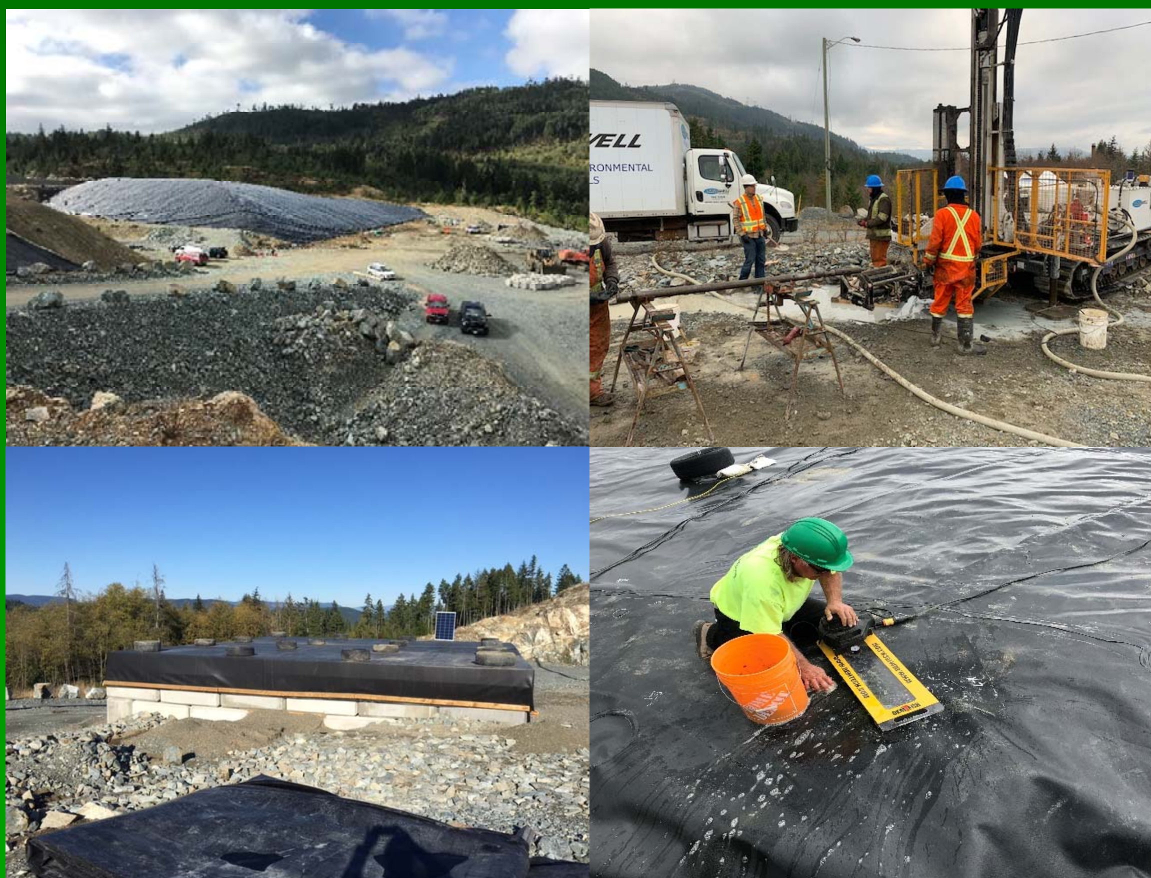
Cobble Hill Landfill
Updated
Environmental Monitoring Plan
2020



PREPARED FOR: Cobble Hill Holdings Ltd.
PREPARED BY: SPERLING HANSEN ASSOCIATES

June 24th, 2020
PRJ18074

SPERLING HANSEN ASSOCIATES

- Landfill Engineering
- Solid Waste Planning
- Environmental Monitoring
- Landfill Fire Control

June 24th, 2020

Mr. Luc Lachance

Office of the Minister
Ministry of Environment and Climate Change Strategy
Parliament Buildings
Victoria, B.C. V8V 1X4

RE: Cobble Hill Landfill Environmental Monitoring Plan

Dear Mr. Lachance,

Please find attached the Environmental Monitoring Plan (EMP) completed by Sperling Hansen Associates (SHA) for the Cobble Hill Landfill.

The EMP for the Cobble Hill Landfill Final Closure Construction project is based on standard landfill monitoring protocols implemented at other landfill sites in B.C. and adjusted to capture the monitoring requirements specified by the Ministry of Environment and Climate Change Strategy (ENV) in their correspondence on this file. The key goals of the program are outlined below, and include:

- Inspection, operation and maintenance of the landfill final cover, including stormwater management works, ditching, topsoil, vegetation and the repair of any damage due to erosion, leachate breakouts, slope failures, settlement and burrowing animals.
- Inspection, operation and maintenance of environmental monitoring and leachate collection and storage works.
- Environmental monitoring program, including leachate monitoring, to verify the escape or spill of leachate into the environment has not occurred.
- Produced volumes of leachate to be tracked at storage facility before transport offsite.
- Focus monitoring on high probability groundwater flow paths in overburden / shallow fractured bedrock.

Sincerely,
SPERLING HANSEN ASSOCIATES

PROFESSIONAL ENGINEER PROVINCE OF BRITISH COLUMBIA A. SPERLING

June 24, 2020

Dr. Tony Sperling, P.Eng.
President

cc. Mr. Marty Block, Cobble Hill Holdings, Mr. Raymond Lam, Allterra Construction

ENVIRONMENTAL MONITORING & POST-CLOSURE REQUIREMENTS

The monitoring plan prepared for the Cobble Hill Landfill (CHL) is based on standard landfill monitoring protocols implemented at other landfill sites in B.C. and adjusted to capture the monitoring requirements specified by the Ministry of Environment and Climate Change Strategy (ENV) in their correspondence on this file. The key goals of the program are outlined below, and include:

- Inspection, operation and maintenance of the landfill final cover, including stormwater management works, ditching, topsoil, vegetation and the repair of any damage due to erosion, leachate breakouts, slope failures, settlement and burrowing animals.
- Inspection, operation and maintenance of environmental monitoring and leachate collection and storage works.
- Environmental monitoring program, including leachate monitoring, to verify the escape or spill of leachate into the environment has not occurred.
- Produced volumes of leachate to be tracked at storage facility before transport offsite.
- Focus monitoring on high probability groundwater flow paths in overburden / shallow fractured bedrock.

1. POST CLOSURE PERIOD

Between February, 2014 and January 2017 the CHL accepted contaminated soils, with contaminant levels below Hazardous Waste Regulations. During the operating life of the landfill, and including the soil currently contained in the Soil Management Area (SMA), approximately 97,595 tonnes of soil will have been landfilled.

No further landfilling of contaminated soils is planned at CHL, with the exception of soils already contained in the Soil Management Area. Clean fill soil will be accepted to achieve a protective vegetation layer as part of final closure.

Recent correspondence with ENV has made it clear that the CHL is to follow the guidance outlined in the 2016 British Columbia Landfill Criteria for Municipal Solid Waste (LCMSW) in preparing this Closure Plan and the associated monitoring program. As per Section 7.4 of the 2016 LCMSW, the contaminating lifespan of a landfill will not be less than 30 years when determining the requirements for post closure care and financial security. Since CHL stopped receiving waste in 2016 and the site was capped with a geomembrane in 2016, the monitoring program will extend to 2046.

SHA is of the opinion that a 30-year post closure period is indeed appropriate because the nature of wastes received (non-leachable contaminated soils) and the nature of the double encapsulation system adopted at the CHL site surpass normal landfilling practices in British Columbia. Due to the impervious final cover system, the relatively low volumes of leachate released from the PEA, and the significant dilution that will be provided by clean run-off from the final cover system and shallow groundwater flow beneath the cell, SHA is of the opinion that CHL is a protective landfill and that the characteristics of soil disposed at CHL will not pose a risk to human health or the environment beyond the 30-year post closure period and that aquatic life water quality objectives will be achieved at the property boundary after the post closure maintenance period has ended.

SHA notes that the CHL was designed and permitted under the 1993 Landfill Criteria which required only a 25-year post closure period; however, for the purpose of this Closure Plan a 30-year post-closure period is specified at this time to be consistent with the minimum requirements of Section 7.4 of the LCMSW. As such, SHA specifies that the post-closure maintenance and monitoring that is outlined in this EMP be implemented for a total period of 30 years; unless long term monitoring results or QP guidance reveals that a duration of less or more time is required and supported by monitoring data. Considering that the geomembrane liner has been in place on the PEA since 2016 and environmental monitoring has been regularly conducted since that time, SHA specifies the post-closure period finish on January 31, 2046.

As the QP specifying the duration of the monitoring program, SHA recognizes the importance of continued monitoring should the data set indicate that there continues to be a risk of groundwater or surface water impact from the PEA. If water quality down gradient is deteriorating and the origin of the deteriorating water quality is determined to be the PEA, then monitoring of the landfill shall continue as long as there is a concern that water quality is at risk. Also, the duration of the post closure period for the purpose of Section 6 of the SPO shall be subject to further ENV review, approval and/or extension.

2. ENVIRONMENTAL MONITORING PLAN

A detailed Environmental Monitoring Plan (EMP) for leachate, groundwater, surface water, and landfill gas is outlined in the following section and will be implemented during landfill closure and post closure. The EMP has been developed in accordance with the "Guidelines for Environmental Monitoring at Municipal Solid Waste Landfills" for groundwater, surface water, leachate, soils and vegetation. Best management practices for field methods and quality assurance / quality control (QA/QC) will be followed as outlined in the British Columbia Field Sampling Manual complete with QA/QC sampling. Details are provided in Section 2.6 of this EMP. The EMP has been designed with guidance from the Conceptual Model for the site.

The EMP's objectives are to:

- Demonstrate compliance with the performance criteria.
- Demonstrate that monitoring results are consistent with the applicable plans and reports, including the groundwater and surface water impact assessment.
- Address the need for monitoring within 1 km of the landfill footprint.
- Given favorable results over time, the monitoring regime can be reduced upon review by a qualified professional.

Table 1 Summarizes the EMP in table form.

Table 1 – Summary of the Environmental Monitoring Plan

Monitoring Location	Monitoring Frequency	Reporting Frequency
Groundwater: SHA MW19-01, SHA MW19-02 MW-3S	Four times per year with targeted sampling to capture first flush rainfall event and summer low flow events when concentrations likely highest. Recommended sampling to occur at end of August for low flow event, mid November for first flush event. Last two events to occur end of February and end of May.	Reporting Bi-weekly during closure activities. Quarterly for one year following completion of closure activities (post-closure). Semi Annually for years 2 to 5 post closure. Annually thereafter until year 30.
Seepage Blanket SB-1, SB-2, SB-3, SB-4	Same monitoring frequency as above.	Same reporting frequency as above.
Surface water SW-1	Monthly sampling during closure activities and for first 12 months post closure. Quarterly sampling in Year 2 post closure. Semi Annually for years 3 to 5. Annually for years 6 to 30 post closure. Quarterly and Semi annual sampling to capture low flow and first flush events on creek.	Monitoring results to be compiled in biweekly reports during construction and in quarterly reports in Years 1 and 2, Semi Annual Reports in Years 3 to 5 and Annual Reports in Years 6 to 30.
Leachate LE-1	Daily remote monitoring of transducer level data, converted to daily leachate volume, while onsite during closure activities. Leachate quality monitoring prior to pre-treatment and preparation for off-site transportation. Semi-annually if leachate volumes drop such that removal required less frequently than 6 months.	Monitoring results to be compiled in Quarterly reports in Year 1, Semi Annual Reports in Years 2 to 5 and Annual Reports in Years 6 to 30.

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Based on recent monitoring results, CHL's leachate has been found to contain parameters above groundwater benchmarks for conductivity, hardness, chloride, sulfate, calcium, magnesium, and sodium. A summary of the quality is included in Chapter 2 of the Updated Final Closure Plan for the site. In the letter dated September 20, 2018, ENV staff recommended that reporting of the site's water quality include Piper plot analysis. In order to facilitate Piper plot analysis, key parameters will be required to run the analysis, as shown in Table 2. The parameters will include physical parameters, nutrients, and dissolved metals in the seepage blanket, and dissolved metals in surface water and leachate stations.

Table 2 Key Leachate Parameters

Physical Tests
Conductivity (uS/cm)
Hardness (as CaCO3)
pH
Total Dissolved Solids
Turbidity (NTU)
Anions and Nutrients
Alkalinity, Total (as CaCO3)
Chloride (Cl)
Fluoride (F)
Nitrate (as N)
Sulfate (SO4)
Dissolved Metals
Calcium (Ca)
Magnesium (Mg)
Manganese (Mn)
Potassium (K)
Sodium (Na)

2.1 Leachate Monitoring

Leachate that is collected at the toe of the landfill is stored in the Leachate Storage Facility until it reaches a volume such that it is trucked off site to a regulated disposal facility. Since closure the amount of leachate being generated has been steadily dropping, as expected. The amount of leachate has dropped from 5.39 m^3 per 2 weeks on June 20th, 2018 to 1.42 m^3 on June 30th, 2019.

Based on current leachate generation rates, the leachate tanks will need to be emptied only once or twice per year. As described in Chapter 7 of the Updated Final Closure Plan, it is expected that the leachate generation rate will continue to diminish since the site has been capped with a geomembrane and overlaying soil layers and the natural consolidation processes that squeeze water out of the fill are completed. A brief uptick in leachate production is expected due to the extra surcharge and resulting consolidation that will occur during soil wedge placement.

The leachate tanks are equipped with a high-level alarm which is triggered when the tanks reach approximately 7,925 gallons (or $30m^3$) per tank (15,850 gallons combined). Once leachate in the tank reaches this trigger level, the tank is emptied via tanker truck. SHA believes this trigger level allows for sufficient time to arrange for removal and transport off-site; at this level, the tanks allow for an additional 4,000 gallons of capacity, which works out to approximately 50 days conservatively assuming leachate is generated at 80 gallons per day (at the 2018 observed leachate generated rate).

To ensure water levels are being monitored accurately, remote readings of water levels shall be taken and recorded daily for a period of one year and the need to continue re-evaluating daily shall be reassessed at that time. If inflows are less than 10 m^3 per month, monitoring can switch to monthly water levels at that time. In addition, staff to log and report transducer levels weekly when staff on site. Monitoring results to be compiled in Quarterly reports in Year 1, Semi Annual Reports in Years 2 to 5 and Annual Reports in Years 6 to 30.

Prior to leachate removal, the leachate is treated to reduce metals concentrations to meet the requirements of the off-site discharge facility. Currently, the leachate is polished onsite utilizing bag filtration and the addition of Potassium Permanganate prior to removal to reduce manganese levels to below 5 ppm, as required by the receiving leachate disposal facility. All leachate samples for leachate characterization testing will be taken prior to treatment.

It is anticipated that the leachate tanks will continue to be emptied by vac truck. During leachate removal, leak detection monitoring for the leachate storage tank will also be conducted. During this time, the leak detection tank will also be monitored and a visual inspection of the condition of the secondary liner will be completed. In the event a leak is observed on the base of the secondary liner system the entire contents of the tank will be removed and the tank will be inspected and repaired or replaced. Interim tanks will be installed to collect all leachate during this time to ensure no spill is made to the environment.

Leachate and leak detection tank volumes will be recorded during each leachate removal and/or leachate tank monitoring event. This will be correlated to precipitation data to assess and confirm cover integrity and demonstrate there is no correlation between rainfall events and leachate production due to cover liner leaks.

In the event potential contact water / leachate is observed in the leak detection storage tank, one-time field testing for conductivity will be completed in the seepage blanket monitoring wells, and samples will be analyzed for leachate parameters as required. Further monitoring and testing of the leak detection system will be undertaken. Remedial measures will then be determined based laboratory analysis outlined above and recommendations by a QP.

As discussed above, SHA specifies leachate monitoring and sampling be conducted from the leachate tank prior to the tank contents being prepared for removal and transportation to the treatment plant (for the parameters outlined below).

Table 3 illustrates the leachate monitoring locations, parameters and frequency. In addition, as discussed above, the Piper plot analysis will be conducted annually and will include calcium, magnesium, sodium, potassium, bicarbonate, sulfate, chloride, dissolved solids, and conductivity.

A number of hydrocarbons including LEPH ($EPH_{w=10-19}$), HEPH ($EPH_{w=19-32)}$) and PAH's have been detected in the leachate collected from the PEA leachate collection system. LEPH and HEPH were detected starting in June, 2018 and have been detected at low levels in the leachate since. PAH's have been non-detect in the leachate for the most part, except for one spike that appeared in the December 17th, 2018 sample and continued to be measured in the following month. Since that time, PAH concentrations have gone back to background levels except for a very slight uptick in naphthalene compounds in April and May, 2019.

Since EPH's and PAH's have appeared in the leachate, SHA recommends that annual testing for those parameters be continued in the leachate sample, all groundwater monitoring wells including the deep wells and the surface water monitoring sites until five continuous years of data show that readings are consistently below 50% of the CSR Drinking Water and Aquatic Life Standards.

Monitoring frequency and range of parameters will be evaluated from time to time by QP's and adjusted as necessary to focus the sampling program on the key parameters of concern.

Table 3 – Leachate Monitoring Summary

Monitoring Location	Physical Tests	Hydrocarbon Testing	Anions and Nutrients	Total Metals Suite Including	Frequency
Leachate Tank (SHA-LE-1)	Conductivity Hardness (as CaCO3) pH Total Dissolved Solids Turbidity (NTU)	EPH_{w10-19} , LEPH PAHs, HEPH EPH_{W19-32}	Alkalinity, Total (as CaCO3) Chloride (Cl) Fluoride (F) Nitrate (as N) Sulfate (SO4)	Calcium (Ca) Magnesium (Mg) Manganese (Mn) Potassium (K) Sodium (Na)	Daily remote monitoring of transducer level data, converted to daily leachate volume, while onsite during closure activities. Leachate quality monitoring prior to pre-treatment and preparation for off-site transportation. Semi-annually if leachate volumes drop such that removal required less frequently than 6 months.
Leak Detection Tank (SHA LD-1)	Conductivity Hardness (as CaCO3) pH Total Dissolved Solids Turbidity (NTU)	EPH_{w10-19} , LEPHw PAHs, HEPH EPH_{W19-32}	Alkalinity, Total (as CaCO3) Chloride (Cl) Fluoride (F) Nitrate (as N) Sulfate (SO4)	Calcium (Ca) Magnesium (Mg) Manganese (Mn) Potassium (K) Sodium (Na)	Sampled at same frequency as LE-1 if Liquid is Present
Leachate Storage Facility	Visual Inspection of Secondary Liner				Following each Leachate Removal

2.2 Surface Water Monitoring

Surface water monitoring is completed at SW-1; which is a tributary to Shawnigan Creek immediately downstream of the settling pond outlet. This tributary creek flows year-round, except in particularly dry summers when it becomes ephemeral. Table 4 illustrates the surface water monitoring locations, parameters and frequency. In addition, as discussed above, the Piper plot analysis will include calcium, magnesium, sodium, potassium, bicarbonate, sulfate, chloride, dissolved solids, and conductivity.

Table 4 – Surface Water Monitoring Summary

Monitoring Location	Physical Tests	Anions and Nutrients	Hydrocarbons	Total Metals Suite Including	Frequency
Shawnigan Creek Tributary (SHA-SW-1)	Conductivity Hardness (as CaCO3) pH Total Dissolved Solids Turbidity (NTU)	Alkalinity, Total (as CaCO3) Chloride (Cl) Fluoride (F) Nitrate (as N) Sulfate (SO4)	, LEPHw PAHs, HEPH EPH_{w10-19} EPH_{W19-32}	Calcium (Ca) Magnesium (Mg) Manganese (Mn) Potassium (K) Sodium (Na)	Monthly sampling during closure activities and for 12 months post closure. Quarterly sampling in Year 2 post closure. Semi Annually for Years 2 to 5 post closure and annually for Years 6 to 30 post closure. Semi annual sampling to occur during low flow and first flush.

Monitoring frequency and range of parameters can be adjusted over time dependent on construction activities and water quality results.

2.3 Seepage Blanket Monitoring

Three seepage blanket monitoring wells were installed in 2017 and an additional seepage blanket monitoring well was installed in 2019. Following closure construction, these wells were surveyed to allow for geodetic water level monitoring, including depth, ground elevation and stick-up. Since these wells were installed downgradient of the PEA it is anticipated that they will serve as a good detection system for any leachate escaping from the PEA. Recent drilling has confirmed that flow through the seepage blanket is considered the primary pathway for leachate should a failure of the double liner system ever occur.

The primary means of impact detection will be (#1) a Piper plot, augmented by trend line graphs for key leachate indicator parameters, with a focus on Sodium and Chloride as these parameters are particularly elevated in the soils placed in the PEA.

Conductivity readings from the wells will be collected during the scheduled inspections. During closure activities and following the completion of closure activities, detailed water quality analysis of the seepage wells will also be completed at the same time as groundwater sampling. A QP will review the findings of the analysis to determine if the seepage layer monitoring program is sufficient and based on the results determine if additional monitoring locations are required.

Since the seepage blanket interflow is controlled by precipitation which can dilute the water chemistry, the seepage blanket monitoring wells will be sampled during the August low flow period and also shortly after first flush precipitation events. Table 5 illustrates the seepage blanket monitoring locations, parameters and frequency. In addition, as discussed above, the Piper plot analysis will include calcium, magnesium, sodium, potassium, bicarbonate, sulfate, chloride, dissolved solids, and conductivity.

During each sampling event, the total well depth, depth to water, and geodetic water level will be recorded. Because the landfill closure design involves extending the seepage blanket wells to facilitate the placement of final cover; once closure is completed, all wells will be surveyed and the elevations will be updated.

Table 5 – Seepage Blanket Monitoring Summary

Monitoring Location	Physical Tests	Anions and Nutrients	Hydrocarbons	Dissolved Metals Suite Including	Frequency
Seepage Blanket (SHA-SB-1, SHA-SB-2, SHA-SB-3, SHA-SB-4)	Water Level Total Depth Conductivity	Alkalinity, Total (as CaCO3)	EPH_{w10-19}	Calcium (Ca)	Four times per year with targeted sampling to capture first flush rainfall event and summer low flow events when concentrations likely highest. Recommended sampling to occur at end of August for low flow event, mid November for first flush event. Last two events to occur end of February and end of May.
	Hardness (as CaCO3)	Chloride (Cl)	, LEPHw	Magnesium (Mg)	
	pH	Fluoride (F)	PAHs,	Manganese (Mn)	
	Total Dissolved Solids	Nitrate (as N)	HEPH	Potassium (K)	
	Turbidity (NTU)	Sulfate (SO4)	EPH_{W19-32}	Sodium (Na)	

Monitoring frequency and range of parameters can be adjusted over time dependent on construction activities and water quality results.

2.4 Groundwater Monitoring

The original waste discharge permit stated that a minimum of seven groundwater wells would be installed and maintained. A detailed review of the conceptual hydrogeologic model has revealed that the primary pathways for leachate migration occur through overburden / fill in the seepage blanket and underlying shallow fractured bedrock. Because there is an upward hydraulic gradient and competent bedrock with very few fractures, the chance of detecting any impact in the deep groundwater wells is extremely remote and therefore, sampling of those wells for routine leachate indicator parameters (major ions, metals, nutrients) is not recommended in our professional opinion. Continued precautionary monitoring of the deep wells for DNAPL hydrocarbons is recommended once per year.

Instead, two new shallow bedrock wells MW19-01 and MW19-02, downgradient of the PEA, were installed in 2019. These shallow bedrock wells will further develop the dataset for the site, they will provide two additional sentinel wells in the highest risk pathway in the event of a leak, and they will assist in detecting any contamination leaching from the landfill.

The 2019 shallow groundwater monitoring well installation indicated that there are limited water bearing fractures at depth, and as such, most of the water is clearly moving through shallow bedrock on top of the low permeability competent bedrock below. Therefore, SHA specifies (#1) to stop monitoring the deep wells until such a time that a breach of the liner system is suspected. Instead, the monitoring will (#1) focus on the two new shallow bedrock wells and the seepage blanket wells.

If (#1) significant changes are (#1) observed in the groundwater, additional wells existing on the site can be reactivated as part of the monitoring program, under QP guidance.

During environmental monitoring, the wells will (#1) be inspected and any maintenance undertaken on the well caps and standpipes as necessary. Groundwater level will (#1) also be recorded while environmental sampling is occurring. Any new wells will (#1) be surveyed, including depth of well, ground elevation and stick-up, to allow for geodetic water level monitoring.

Table 6 illustrates the groundwater monitoring locations, parameters and frequency. In addition, as discussed above, the Piper plot analysis would include calcium, magnesium, sodium, potassium, bicarbonate, sulfate, chloride, dissolved solids, and conductivity.

Table 6 – Groundwater Monitoring Summary

Monitoring Location	Parameters	Frequency
SHA MW19-01 (New Shallow) SHA MW-19-02 (New Shallow) MW-3S (#7)	Dissolved Metals Anions and Nutrients Physical Tests Temperature pH Conductivity Hydrocarbons EPH_{w10-19} EPH_{W19-32} HEPH LEPHw PAHs Groundwater level Total Depth	Four times per year with targeted sampling to capture first flush rainfall event and summer low flow events when concentrations likely highest. Thus, expected monitoring events to occur mid August and early October each year. Additional events to occur late December and late March during closure activities. Hydrocarbon testing only in August and November.
MW-01S/D, MW-02, MW-3S/D, MW-5S/D, MW-06	Groundwater level Total Depth Hydrocarbons EPH_{w10-19} EPH_{W19-32} HEPH LEPHw PAHs	Sampling frequency same as above for water level and depth. Hydrocarbon sampling to occur 1 time per year during the low flow sampling event in mid-August.

Monitoring frequency and range of parameters can (#1) be adjusted over time dependent on construction activities and water quality results.

Locations for monitoring wells, water wells, surface water stations and air sampling stations are presented on Figure 1.

2.4.1 Procedure for Hydrocarbon Investigation

Periodic hits of various hydrocarbon species have been detected in various wells from time to time. The source of these hydrocarbon hits is unknown. The rock quarry has a history of using Ammonium Nitrate Fuel Oil as an explosive agent which introduced liquid hydrocarbons into the rock mass. Also, some spills from equipment leaks and fuel handling likely occurred. The PEA did receive some hydrocarbon contaminated soil, but most of the contamination levels were below CSR Industrial levels. The majority of the soil that was received was soil impacted by NaCl above BC CSR Industrial Land Use Standards. According to site records, the vast majority of soil placed in the PEA did not contain hydrocarbon contamination above BC CSR Industrial Land Use Standards. Reportedly, only 1.26% of soil received in Q3 of 2016 (totalling 223 tonnes) contained hydrocarbons, reported as LEPH/HEPH contamination only. This information suggests that the PEA is a low risk source for hydrocarbon contamination.

Nevertheless, because there is concern about the origin of the random hydrocarbon hits that have been detected in the groundwater monitoring wells from time to time, Cobble Hill Holdings will retain a QP with a CSAP designation to undertake a one time forensic review of the complete environmental monitoring data set collected to date to determine if possible, the likely source of the observed hydrocarbon hits. The selection of the appropriate QP will be undertaken with approval of ENV and the study shall be completed within six months, by December 31st, 2020. The scope of the review shall include:

i. Characterize the product;
ii. Determine the source(s) through review of historic soil data and consideration of onsite construction equipment, history of using ANFO based explosives and local land use.
iii. Evaluate the product age and degredation, if any; and
iv. Describe mitigations to eliminate the sources(s) if the pollutants are expected to exceed water quality criteria beyond the property boundary.

If hydrocarbons are detected above CSR Drinking Water or Aquatic Life Standards during future groundwater analysis, the first step will be to repeat the sampling as soon as possible, and within 5 business days.

If the CSR trigger level exceedance is confirmed then CHL will follow QP recommendations for further investigation, and will not rely solely on the contents of this plan. In general, a blank sample and a duplicate will also be completed, along with any other QP specified QAQC measures.

If hydrocarbons are detected above CSR Drinking Water or Aquatic Life Standards, and are not detected in the blank samples, the water sample will be further analyzed and investigated to determine the type of contaminant present. Additional parameters for analysis will be determined by a QP as necessary and will include analysis of petroleum hydrocarbons, gasoline components and biomarkers. Mitigation measures will be recommended by a QP, as needed.

2.5 Field Program

Common groundwater sampling methods that involve purging three to five well volumes from a monitoring wells can cause high levels of turbidity in collected samples (Puls and Barcelona 1996) and will be very time consuming in a low recharge environment. High levels of turbidity can result "in the inclusion of otherwise immobile artifactual particles which produce an overestimation of certain analytes of interest (e.g. metals or hydrophobic organic compounds)." The target turbidity level is less than 10 NTU. Samples must contain turbidity levels below 50 NTU.

To ensure the collected water samples do not have high levels of turbidity, low stress (low flow) sampling procedures will be used at the site, targeting stabilization of physical parameters including temperature, pH and conductivity. For low-flow purging and sampling, stability is indicated when three successive readings within 5 minutes of each other fall within the following target ranges: pH ± 0.2 pH units, conductivity ± 3% of reading, temperature ± 0.2°C

2.6 Quality Assurance / Quality Control Program

The Quality Assurance / Quality Control measures applicable to this report includes:

- Use of a CALA (Canadian Association for Laboratory Accreditation Inc.) accredited laboratory;
- Use of electronically transferred data into tables to minimize manual entry;
- Use of unique sample identification for each sample;
- Recording of the date and time of sample collection;
- Recording the source of sample (including name, location, and sample type);
- Use of preservative as required;
- Accurate completion of chain of custody forms;
- Submission of samples within recommended holding times; and
- Analysis of duplicate sample results and laboratory internal QA/QC.
- Collection of blind field duplicates to supplement internal laboratory evaluation of precision

2.6.1 Field QA/QC

Recommendations for Field Quality Assurance / Quality Control measures applicable to this report are as follows:

- Field equipment should be cleaned, calibrated and maintained in good working condition. Regularly used equipment used in the field should be cleaned in between each sampling location.
- New nitrile gloves should be used for each sample collected.
- All sample containers should be provided by the laboratory pre-cleaned and pre-sterilized.
- Sample containers should be labelled with their respective sampling location and date.
- Samples should be kept cool by storing and transporting them in a cooler with ice. When required, preservatives should be added to the sample containers for certain parameters to

maintain sample integrity.

- A chain of custody should be prepared to detail the sample number, sample description and chemical parameters being analyzed.
- The completed chain of custody should be sent with the samples to an independent Canadian Association of Laboratory Accreditation Inc. (CALA)-accredited laboratory.
- Chain-of-custody procedures (i.e. sign off between parties when the samples changed custody) should be followed when transporting the samples.
- Duplicate samples analysis may occur at a minimum of one (1) for every ten (10) samples analyzed, per analysis batch.
- Matching duplicate samples should be analyzed for the purpose of calculating Relative Percent Difference (RPD). The RPD procedure is summarized below:

2.6.2 Relative Percent Difference

Relative Percent Difference (RPD) can be calculated to compare the differences between a sample and its duplicate. RPD quantifies the reproducibility or precision of the data. RPD is calculated by taking the absolute value of the difference between the sample and the duplicate, dividing it by the average of the sample and duplicate, and then multiplied by 100 to obtain a percentage.

$$RPD = \frac{|\text{Sample Concentration} - \text{Duplicate Concentration}|}{\left(\frac{\text{Sample Concentration} + \text{Duplicate Concentration}}{2}\right)} * 100\%$$

BC Environmental Laboratory Manual (2015) (BCELM) recommends that further review is conducted for RPD values greater than listed in the table below. However, if the concentration of the analyte is less than five (5) times the method detection limit, or if the analyte is a metal in soil, then an RPD greater than 35% may be reasonable. If the RPD is greater than 50% in soil or groundwater, it is generally necessary to determine the cause and how it affects the findings of the investigation. For soil vapour, though a recommendation is not provided in the BCELM, further review is conducted where RPD values exceed 100%.

Table 1: BC Environmental Laboratory Manual Recommended Relative Percent Differences

Parameter Category	Recommended RPD for Concentrations Exceeding five (5) times the Mean Detection Limit (MDL)
Organics in Solids - PAHs - Volatile Organics (including VPH) - EPH	 50% 40% 40%
Organics in Water	30%
Metals in Solids	30%
Metals in Water	20%
General Inorganics Solids	30%
General Inorganics in Water	20%

2.6.3 Groundwater Monitoring & Sampling

General methods for water quality sampling applicable to the CHL are listed below:

Samples are collected following well development if required. Wells are developed to reduce sediment content as much as possible and to set the sand pack surrounding the screen. Typical products used include well dedicated Waterra™ inertia pumps and purge blocks for well development and subsequent removal of at least five to seven well volumes throughout the development process. After development, wells are left to geochemically and physically stabilize, usually not less than 24 hours.

The sampling procedure is as follows:

- The depth to water is measured with a well tape utilizing the north side of the top of pipe as the measuring point.
- The well is then purged using low flow removal methods by collecting the water from the middle of the saturated portion of the screen until measured parameters of pH, conductivity and have stabilized. If products such as hydrasleeves are utilized, the water level post hydrasleeve insertion should be observed to reach equilibrium prior to sampling. Note that purging is not required when hydrasleeves are utilized.
- When the measured field parameters are stabilized, the water samples are obtained with the low flow peristaltic pump, bailer, WaterraTM inertial foot valve, or hydrasleeve.
- During sample collection, monitoring of the water level within the well is evaluated to ensure the well is not drawn-down during the sampling process. In the case of hydrasleeves, the sample should be extracted to ensure that the groundwater screened level is isolated.
- Samples are placed directly from these apparatus into the sample container except for metals samples, which are field filtered.
- The first collected samples are VOCs due to the volatility if required.

- The remainder of the samples are then collected ensuring that the collection point is the middle of the saturated port.

2.7 Landfill Gas Monitoring and Ambient Air Monitoring

As the landfill is not a Municipal Waste Landfill and the gas generation rate for the types of waste being landfilled is extremely slow if at all, Landfill Gas is not deemed to be of great concern at the site. Therefore, landfill gas monitoring is not required.

The current soil cell (PEA) has been capped with 40 mil LLDPE liner since the Fall of 2016. Other than ballasting that was completed in 2017, the landfill cell is not currently being held down with significant weight. Since installation, no uplifting of the liner due to landfill gas has been observed. SHA does not foresee volatile gases being an issue at this site after closure.

A review of leachate testing has indicated that VOC's are generally non-detect in the leachate. Therefore; release of volatile organic compounds through the barrier layer is no longer a concern. This will be verified with a one-time monitoring run of VOC's emissions on completion of closure from the landfill surface. A VOC instrument will be used to sample from a minimum of 10 locations (1 sample per 200 m^2) on top of the PEA.

Even though the risk is deemed to be low, no permanent structures should be built on top of the landfill unless they are constructed with properly ventilated foundations. Also, standard confined space entry procedures must be followed when entering any manholes or other structures on or near the landfill site as landfill gas can accumulate in such structures over time.

Additionally, ambient air monitoring was required due to potential dust concerns from soil mixing, blasting, mining and landfilling activities. Given there is no activity currently in operation at the site, SHA does not foresee the need for continued monitoring for air quality post closure.

2.8 Geotechnical Inspection

A cover stability inspection will be conducted monthly by a field technician who will examine the entire landfill closure area for cracks and signs of erosion. Any such signs will be documented with photographs and forwarded promptly to a geotechnical engineer for evaluation and investigation, as necessary. The geotechnical engineer will then assess whether further action/investigation is required. As well, a comprehensive geotechnical inspection will be undertaken by a QP on an annual basis to inspect the landfill footprint. This inspection will also include checking the cover for potential problems arising from slumping, cracking or erosion, and determining the state of other infrastructure that does not receive regular inspection.

If significant issues with infrastructure are identified, a Qualified Professional should be retained to resolve them.

As indicated in the November 28th 2019 Cobble Hill Landfill Slope Stability Report, monitoring of potential damage to the leachate infrastructure will be completed following major earthquakes. The geotechnical inspection is to be documented in the Annual Monitoring Report submission. Surface water structures will be inspected during monitoring events at the site. Ditches and downchutes will be maintained to ensure proper drainage at the site, and to minimize the potential of erosion of surrounding structures.

2.9 Post Closure Inspection

An annual inspection of all infrastructure will be completed by a QP prior to compilation of the annual report. This inspection will include the following:

- Final Cover System
- Ditching
- Topsoil / Vegetation
- Erosion
- Potential Leachate Breakouts – not expected with geosynthetic basal and final cover geomembrane system
- Leachate Collection, Conveyance and Storage Facility
- Environmental Monitoring Infrastructure.

As part of the on-going leachate collection and on-site treatment program, the system will be evaluated for operational effectiveness. The double lined leachate storage facility does allow for leak detection monitoring, as outlined previously. Maintenance will be completed as required.

Any observed deficiencies will be recorded and remedied as required.

2.10 Report

Reporting will continue to comply with requirements of the ENV SPO. During closure implementation biweekly reports will be submitted documenting construction activities and including a compilation of weekly reports.

During the first year post closure, Quarterly Monitoring Reports will be prepared. In Years 2 to 5, the frequency of reporting will be reduced to semi-annual commensurate with the frequency of sampling. In years 5 to 30, Annual Monitoring Reports will be prepared.

In each Monitoring Report a Qualified Professional will collect the required monitoring data and compile the Quarterly / Semi-Annual / Annual Report outlining the closure performance of the landfill.

In the Annual Report a Qualified Professional will assess the groundwater and surface water quality for potential impacts and evaluate the leachate generation rate and quality. Piper diagrams will be used to augment the hydrogeological interpretation and to characterize the leachate and water samples.

All infrastructure maintenance and improvements identified in the post closure inspection will be outlined in the Annual Report. In addition, the report will indicate if any accumulation of liquid was observed in the secondary containment of the leachate storage facility. In each report the Qualified Professional will make recommendations on the existing monitoring program and identify any changes that would improve the post closure monitoring.

Leachate, seepage blanket and groundwater quality data will be compared to Contaminated Sites Regulation Drinking Water (DW) and Aquatic Life (AW) standards, and surface water quality data to BC Approved and Working Water Quality Guidelines for drinking water and freshwater aquatic life, and the limits will be integrated in the reporting tables that are presented in these reports. The annual evaluation will include benchmarking of results against the water quality limits, baseline and background data, interpretations of time trend analysis for key indicator parameters and Piper diagrams.

Following completion of all closure activities, quarterly implementation reports will be submitted in accordance with the SPO Section 6: "Implementation reports must include records of inspections, operations and maintenance of the Facility, records of the volumes of Leachate collected, stored and transported, including the name and location of the authorized facility(ies) receiving the Leachate, and environmental monitoring program records interpreted and certified by a Qualified Professional." for one year following completion of closure activities (post-closure).

Whenever the QP review of monitoring data identifies any exceedances or concerning trends, SHA or specialized subject matter experts will submit separate proposed recommendations for additional monitoring, investigations, mitigation, remediation and actions to the Ministry for review and feedback. The first such review will be based on elevated readings observed in MW 19-02 in December, 2019. This report will be submitted to ENV no later than July 15th, 2020. Subsequent investigations will be undertaken as required on review of the periodic reporting submitted to ENV on review between our QP and ENV staff.

2.11 Adjustments to Monitoring Programs Over Time

For many years SHA has recognized there is a strong correlation between electrical conductivity and leachate impacts in groundwater at landfill sites in B.C. It is recommended that at the CHL landfill electrical conductivity be recorded during each sample run and that the environmental monitoring samples be correlated to conductivity based on the historical data set and for the first 2 years of sampling. Provided that a good level of correlation exists, SHA recommends that conductivity measurements be taken quarterly and that laboratory sampling of groundwater and leachate be scaled back from quarterly to semi-annual after two years of sampling, and from semi annual to annual after 5 years of sampling provided that trend lines continue to show steady state or improving water quality conditions. If water quality is determined to be deteriorating over time, then the frequency of sampling shall remain quarterly.

Named Parties may, with supporting rationale certified by a Qualified Professional (QP), request revisions to the EMP, and, in response to the Named Parties' request, or for other reasons, ministry staff may specify revisions to the EMP and/or a revised EMP.

This EMP proposes planned future revisions/reductions in sampling, monitoring and reporting frequencies and parameters after the first year after the completion of closure activities (Year 1 post-closure), including for groundwater, seepage blanket, surface water, leachate quality, leachate volume, post-closure and geotechnical inspections, and reports. These planned future revisions/reductions are not currently approved by ENV. However, after Year 1 post-closure, the Named Parties may, with supporting rationale certified by a Qualified Professional (QP) request these planned revisions/reductions. The requested planned frequency and parameter revisions/reductions in sampling, monitoring and reporting, would be reviewed by ENV and implemented only if approved by ENV.

2.12 Contingency Actions for EMP – Trigger Response Plan

This contingency plan outlines planned responses that will be undertaken in the event that problems are identified, or natural events transpire that potentially compromise the integrity of the PEA. In responding to any incident, a systematic five step approach will be adopted that will include the following:

- Routine Monitoring
- Confirmatory Monitoring
- Additional Investigation to establish magnitude of problem
- Mitigation Strategy to fix problem
- Follow up monitoring to confirm mitigation strategy was successful

1. **Routine Monitoring:** Routine monitoring will be conducted at the locations, frequencies and sampling parameters stipulated in this EMP following the specified sampling, testing and reporting protocols documented herein.

2. **Confirmatory Monitoring:** If elevated water quality is detected in the monitoring network, then the sample will be retested to validate the exceedance or negative trend in water quality detected. If validation confirms elevated levels, then the confirmatory sampling will be expanded to adjacent wells as well and additional investigation will be initiated. Sampling of deep wells will also be initiated.

CHL will use CSR Drinking Water (DW) and Aquatic Life (AL) Standards to evaluate groundwater quality and BC Approved and Working Water Quality Guidelines for drinking water and freshwater aquatic life to evaluate surface water quality. If new or unusual exceedances to the Water Quality Criteria are observed, Step 3will be initiated. Step 3 will also be initiated if there is a sustained negative trend in water quality detected that is evident over three consecutive sampling events.

3. **Additional Investigation:** In the event results from Steps 1 and 2 above indicate that there is a negative trend in water quality detected, or there are other events that could cause a breach of the containment system like an earthquake, a massive erosion event or slope failure, CHL will engage with a QP to develop appropriate investigation plan and remedial actions as required.

Additional investigation will depend on the problem encountered, but will likely involve development of new sampling points downgradient, including additional seepage blanket wells, new surface water sampling sites, and frequent monitoring of leachate being captured by the leachate collection and leak detection systems. The integrity of the PEA would also be inspected by a QP for any signs of visible damage.

A Risk Assessment may be warranted if the water quality data suggests the landfill is impacting the water quality beneath the landfill and/or off-site. The assessment should look at the specific parameters of concern and determine if there is a risk to the receiving environment and drinking water supplies; and if remedial measures are required.

In addition, separate proposed QP recommendations will be submitted for additional monitoring, investigations, mitigation, remediation and actions, that arise from Section 2.10, to the Ministry for review and feedback.

4. **Mitigation Strategy:** The mitigation strategy will depend on the nature of the problem. An early line of defense will include installation of a leachate / leak detection contingency trench to capture all shallow groundwater moving through the seepage blanket. Details on this trench are presented in Section 7.3 of SHA's 2019 Updated Final Closure Plan for the site. Examples of additional measures involve excavation, exposure and repair of the liner in visibly distressed areas, development of an on-

site treatment process to remediate impacted groundwater, lining of the up-slope diversion ditch to further limit infiltration of water below the PEA. Other mitigation measures will be identified, depending on the characterization of the problem in Additional Investigation task.

5. **Follow Up Monitoring:** will involve resampling the impacted sites to verify that the water quality at the impacted sites is improving, that the trend is one of reduced concentrations. Follow up monitoring will continue at an increased frequency (e.g. monthly) until there is a very high degree of confidence that the remedial measures were effective.

2.12.1 Leachate Management Contingency Plan

Contemplated circumstances that contribute to possible failure of the leachate works include exhaustion of leachate storage capacity, leachate leaking through the liner and a breach of the final cover geomembrane.

The leachate storage tanks are equipped with a high-level alarm system which sends a notification when the leachate has reached a certain level in the tanks. The high-level alarm is set at a level which provides at least one month of additional capacity once the alarm has been triggered. This alarm will continue to remain operational at the site.

As outlined in the 2019 Updated Final Closure Plan, SHA has designed a conceptual leachate cut-off trench which will be implemented in the event that the basal liner is confirmed to be failing. This trench is envisioned to be excavated into the competent bedrock downgradient of the PEA. Lining of the trench with shotcrete will be required to prevent loss of any captured water. Leachate flowing through the subsurface would be captured in this trench, diverted to the leachate collection and storage tank, and removed for off-site treatment.

In the event that leachate storage capacity is exceeded, leachate will start to collect on the secondary containment liner. In that event vac trucks will be organized on an emergency response basis to transport the leachate to an approved treatment facility. If pre-treatment was required, leachate will be temporarily transferred to the leak detection tank, and if additional capacity was required, additional storage tanks will be mobilized to the site.

In the event that an earthquake or catastrophic weather event causes a failure of the cover system, steps will be taken to implement a temporary cover to prevent further ingress of precipitation into the PEA. A plan will then be developed to identify a cause and remediate the failed liner.

All of the above contingency actions are considered highly unlikely, but have been developed as a worst-case scenario response.

2.12.2 Surface Water Management Contingency Plan

Contemplated circumstances that contribute to possible failure and/or non-compliance of the surface water works include: extreme weather events, increased snowmelt, clogging or blockage of infrastructure, erosion and water quality issues during first flush run-off.

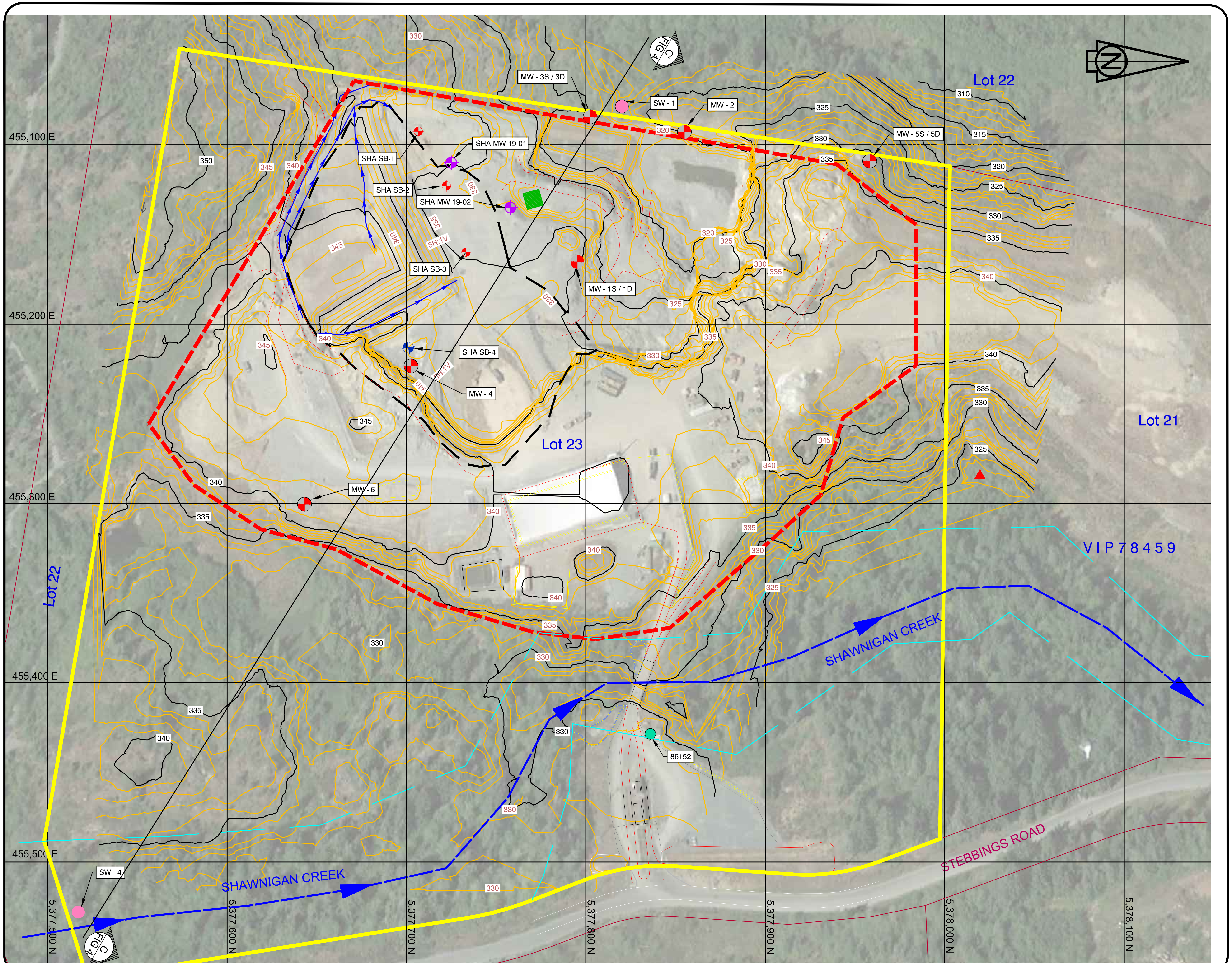
As a precaution, SHA has designed surface water management works (ditches and downchutes) with flow capacity and ditch geometry that is able to handle flows in excess of a 1 in 200 year storm event. Post-closure monitoring will include inspection of the surface water management works and any required maintenance of the infrastructure will be completed in a timely matter.

In the event that a rain event causes a wash out to the stormwater ditches then the washout will be assessed quickly and temporary erosion control measures implemented to prevent continued erosion and sediment transport. The washout will then be repaired as quickly as possible.

In the event that run-off from the capped area exceeds some water quality parameters, run-off shall be stored in the settling pond until water quality is acceptable for discharge. Additional filtration and erosion control measures will be added, including straw bales in ditches, additional loose straw on slopes, additional straw wattles at toe of slope and possible geotextile filtration.

In the event that run-off from the PEA does not meet discharge objectives or background levels (whichever are higher), then additional on-site treatment of water in the settling pond will be introduced. This treatment process will be developed by a QP.

In the event that environmental monitoring indicates the surface water downstream of the landfill is being impacted, the CHL will retain a QP to determine the appropriate remedial or mitigative measures required.



SPERLING HANSEN ASSOCIATES

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LEGEND:

- 5m EXISTING CONTOUR
- 1m EXISTING CONTOUR
- ROAD
- SURFACE WATER DITCH
- PROPERTY LINES
- PROPOSED CLOSURE AREA
- PROPERTY BOUNDARY
- QUARRY BOUNDARY
- EXISTING WATER SUPPLY
- SEEPAGE BLANKET MONITORING WELL
- LEACHATE AND LEAK DETECTION STORAGE FACILITY
- EXISTING CLOSURE MONITORING WELL
- SEEPAGE BLANKET MONITORING WELL
- EXISTING MONITORING WELL
- SURFACE WATER MONITORING LOCATION

CLIENT:

COBBLE HILL HOLDINGS LTD.

PROJECT:

COBBLE HILL LANDFILL
UPDATED FINAL CLOSURE PLAN
2019

TITLE:

MONITORING PLAN

SCALE:	DATE:	PROJECT NO:
1:2,000	2019/12/19 (yyyy/mm/dd)	PRJ 18074

DESIGNED	SG	DRAWING NO:
DRAWN	SR	FIGURE 1
CHECKED	TS	