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2019 Greenest City Scholars Program

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CITY OF VANCOUVER | GREENEST CITY

## Executive Summary

City of Vancouver's (the City) Zero Waste 2040 Plan has revitalized interest in long term planning for four different waste streams. Disposed soils at the Vancouver Landfill (VLF) are one of the waste streams that are identified for long term planning. Currently, the Vancouver Landfill receives approximately more than 460,000 tonnes per year which is used for landfill cell cover and closures. The Vancouver Landfill is estimated to reach its capacity limits by 2030; seven years earlier than its expected life span. Therefore, identifying, and highlighting beneficial opportunities to repurpose disposed soil after the closure of the Vancouver Landfill were prioritized as a goal for Zero Waste & Resource Recovery (ZWRR), a division of City of Vancouver's Engineering Services. This report focuses on four overarching goals:

- Investigating the amount and composition of incoming soils at the VLF
- Investigating the future expected tonnage of soils received at the VLF
- Identifying promising repurposing options for the existing stockpiled soils at VLF
- Compiling a preliminary viability and favourability analysis of each option-based City of Vancouver staff identified criteria.

The findings indicate that the Vancouver Landfill has received an average of 460,000 tonnes per year from 2010 to 2018. Additionally, the average tonnage of soil received every year has been increasing since the 1980s. It was also found that intermittent activities such as closure of landfill cells occurred 2 to 3 times every 10 years, which require additional soils. These extra soils were provided by other sources.

The composition of the stockpiled soils at the Landfill was mostly found to be similar to Sandy Loam soils composition. It was also found that the current stockpiled soils were better suited for engineering and construction purposes as compared to agricultural purposes which require more nutrients. Table 1 below shows the summary of characterization results from the soil sampling undertaken during this project.

**Table 1: Summary of characterization results of VLF Soil**

| **Sampling Date: May 16, 2019** | | | **No. of Samples: 3** |
|---|---|---|---|
| **Parameters** | **Lowest Detection Limit** | **Units** | **Average Sample results** |
| **Physical Tests (Soil)** | | | |
| Liquid Limit (LL) | 1 | % | 24.5 |
| Moisture at Plastic Limit | 1 | % | 20.0 |
| pH (1:2 soil:water) | 0.10 | pH | 7.5 |
| Plasticity Index (PI) | 1 | % | 4.0 |
| Specific Gravity | 0.010 | kg/L | 1.4 |
| | | | |
| **Particle Size (Soil)** | | | |
| % Gravel (>2mm) | 1.0 | % | 11.4 |
| % Sand (2.0mm - 0.063mm) | 1.0 | % | 54.6 |
| % Silt (0.063mm - 4um) | 1.0 | % | 27.4 |
| % Clay (<4um) | 1.0 | % | 6.6 |
| Texture | | - | Sandy loam |

| | | | |
|---|---|---|---|
| | | | |
| **Organic / Inorganic Carbon (Soil)** | | | |
| Organic Matter | 0.10 | % | 1.9 |
| Total Organic Carbon | 0.050 | % | 1.1 |
| | | | |
| **Plant Available Nutrients (Soil)** | | | |
| Available Nitrate-N | 1.0 | mg/kg | 6.8 |
| Available Phosphate-P | 2.0 | mg/kg | 16.3 |
| Available Potassium | 20 | mg/kg | 101.0 |

Using the historical data compiled in the previous findings, the following Figure 1 illustrates the projection for the amount of soils received at VLF until 2040. By 2040, it is estimated that VLF will receive from 380,000 to 658,000 tonnes a year. If the current trend of increasing excess soils coming from Delta continues, it is estimated that 65% of total incoming excess soils to VLF will be from City of Delta by 2040.

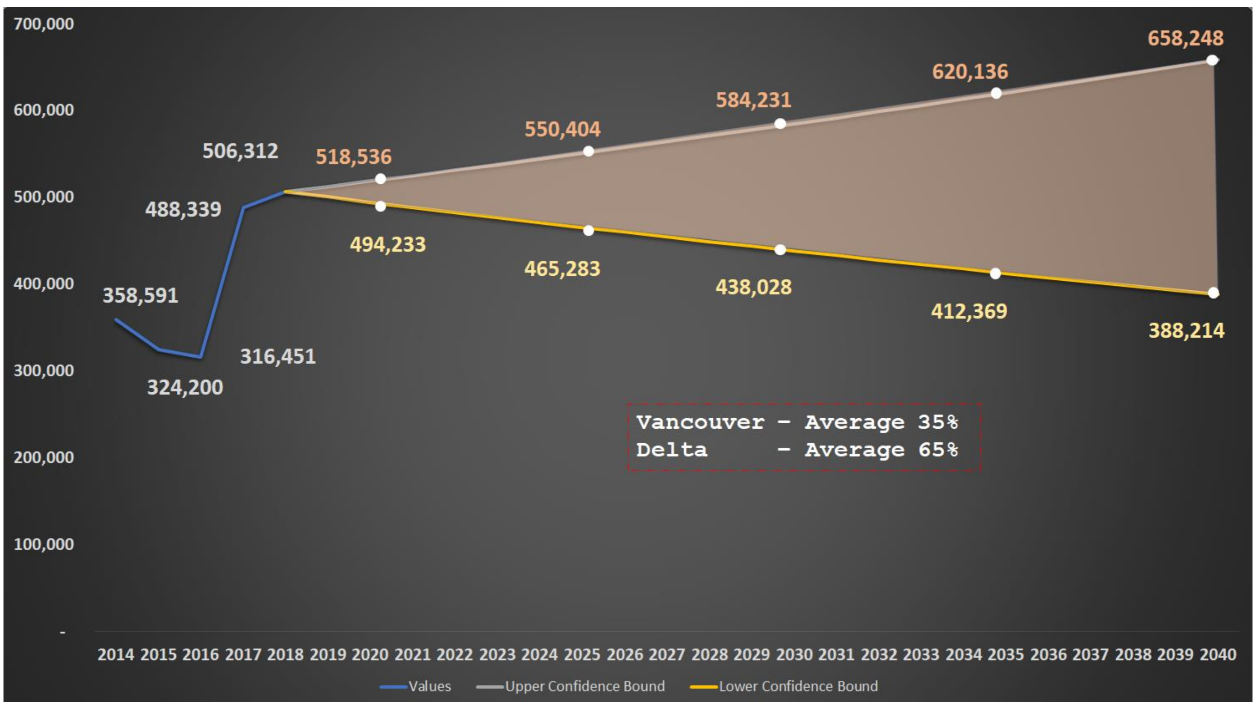


**Figure 1: Future projection of soils tonnage received at VLF**

The evaluation methodology of this report was based on a literature review conducted to examine various methodologies that perform feasibility analyses, identify common evaluation factors used in these feasibility analyses, and select the most effective methodology to conduct a comparative analysis of various disposed soils repurposing solutions. The Pros, Cons and applicability method is found to be the most effective method to evaluate each repurposing option. The options identified using this method was evaluated based on the following criteria:

- **Soil composition compatibility:** Matching the composition between the current soil stockpiled and the option composition requirement
- **Affordability:** The budget required to afford capital cost, operational costs and other relative costs
- **Demand:** An economic principle referring to a consumer's desire to purchase goods and services and willingness to pay a price for a specific good or service produced from repurposing future incoming excavated soils. Holding all other factors constant, an increase in the price of a good or service will decrease the quantity demanded, and vice versa.
- **Environmental friendliness:** Relative potential impacts on the environment (e.g. groundwater contamination, air quality)
- **Job creation:** The number of new jobs provided by the City of Vancouver (CoV)
- **Proven Technology:** Reference facilities, applications and end-product markets that are available
- **Innovation:** The successful exploitation of new ideas which uses soils to make products or provide services to the market
- **Long term viability:** The viability of an option is measured by its long-term applicability and its ability to serve a purpose over a long period of time

A focus group created by CoV employees that were identified as stakeholders was created to evaluate the importance of the identified factors. Their inputs were used to develop weights for these factors. The following Table 2 concludes the feasibility analysis results based on the *Harvey ball* evaluation scoring.

**Table 2: Final Feasibility Analysis Results**

| Description | Soil Quality Compatibility | Affordability | Demand | Environmental Friendly | Jobs Creation | Proven Technology | Innovative | Long term viability | Weighted Score |
|---|---|---|---|---|---|---|---|---|---|
| | 4.2 | 4.4 | 3.8 | 3.6 | 2 | 3.2 | 2 | 4 | |
| Disposal at Sea | ● | ◕ | ● | ◑ | ◔ | ◕ | ◔ | ◑ | 101.2 |
| Building Material Suppliers | ◕ | ◕ | ◕ | ◕ | ◔ | ◑ | ◔ | ◑ | 93.6 |
| Stabilized Mud Blocks | ◑ | ◕ | ◑ | ◕ | ◑ | ◕ | ◑ | ◑ | 92.8 |
| Rammed Earth Walls | ◕ | ◔ | ◔ | ◕ | ◑ | ◕ | ◑ | ◕ | 88.4 |
| Glass Production | ◕ | ◑ | ◑ | ◔ | ◑ | ◕ | ◔ | ◕ | 87.4 |
| Geo-polymer Composite | ◕ | ◑ | ◑ | ◑ | ◑ | ◑ | ◑ | ◑ | 85.8 |
| Soil Blending | ◕ | ◕ | ◔ | ◑ | ◔ | ◕ | ◔ | ◑ | 85.6 |
| Pottery | ◔ | ◕ | ◑ | ◕ | ◔ | ◕ | ◔ | ◔ | 80.6 |
| Burnt Clay Bricks | ◔ | ◕ | ◑ | ◔ | ◑ | ◑ | ◑ | ◑ | 78.2 |
| Hempcrete | ◔ | ◔ | ◔ | ◕ | ◑ | ◔ | ◕ | ◑ | 71.6 |

○ – Lowest Rating   ◔ – Challenging   ◑ - Average   ◕ – Very Good   ● – Top Rating

In conclusion, disposal at sea, providing soil to building material suppliers, and creating products such as Stabilized Mud Blocks (SMBs) should be investigated further in depth through developing business cases using a triple bottom line (Financial, Environmental, Social) approach. The moderate viable options can also be considered for business cases if additional resources are available at the City of Vancouver or if they are deemed a priority at the time.

It is important to note that further discussions are still required between the Transfer and Landfill Operations (TLO), Solid Waste Strategic Services (SWSS) and Kent Construction Supplies and Services (Kent Yard) branches of the Engineering Department to fully map the excavated soils waste stream from source to VLF.

Finally, a soil monitoring program is recommended to provide additional soil composition test results data on a consistent basis to minimize the standard deviation to an acceptable margin of error for potential future business cases.

## Acknowledgements

The scholar program played an important role in my personal and professional life and provided an opportunity to enrich my technical knowledge. In addition to this, the internship provided a valuable experience focussing on zero waste initiatives which gave me the tools and skills to graduate through University and implement the knowledge towards problem solving and innovation for a better world.

I would like to express my deepest gratitude and special thanks to **Mr. Farbod Diba** who, in spite of being extraordinarily busy with his duties, took time out to hear, guide and keep me on the correct path and allowed me to carry out my project at his esteemed organization.

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I regard this opportunity as a big milestone in my career development. I will strive to use the skills and knowledge that I have gained in the best possible way, and I will continue to improve, in order to attain my desired career objectives.

Last but definitely not least, I would like to thank **Ms. Tina Barisky** and **Ms. Karen Taylor** for their continuous support for, not only me, but for all of the scholars to successfully complete their respective projects.

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## Glossary and Acronyms

| Acronyms/Abbreviations | Definition |
| --- | --- |
| BC | British Columbia |
| BP | Brick-Powder |
| BPA | Bisphenol A |
| C&D | Construction & Demolition |
| CEPA 1999 | Canadian Environmental Protection Act, 1999 |
| $CO_2$ | Carbon dioxide |
| CoV | City of Vancouver |
| DO | Drop-off |
| EDCs | Endochirne-Disrupting Compounds |
| FIT | Feed-in-Tariffs |
| IRR | Internal Rate of Return |
| K | Potassium |
| MMCD | Master Municipal Construction Documents |
| MSBs | Mud Stabilized-Blocks |
| MSW | Municipal Solid Waste |
| N | Nitrogen |
| NPV | Net Present Value |
| OM | Organic Matter |
| P | Phosphorus |
| PBDE | Polybrominated Diphenyl Ethers |
| PV | Photo-Voltaic |
| RDF | Refuse Derived Fuel |
| RFP | Request for Proposals |
| SMBs | Stabilized Mud Blocks |
| SOM | Soil Organic Matter |
| SRE | Stabilized Rammed Earth |
| SWOT | Strengths, Weaknesses, Opportunities, and Threats |
| SWSS | Solid Waste Strategic Services |
| TBBPA | Tetrabromobisphenol A |
| TLO | Transfer and Landfill Operations |
| TOC | Total Organic Carbon |
| TRE | Traditional Rammed Earth |
| USA | United States of America |
| VLF | Vancouver Landfill |
| VSTS | Vancouver South Transfer Station |
| ZWRR | Zero Waste & Resource Recovery |

# Terminology

| Terminology | Definition |
|---|---|
| Affordability | Soil as a material is very inexpensive compared to other precious metals and (other) commodities. Therefore, repurposing solutions will need to be measured by how inexpensive the repurposing solution is when the capital investments, operating costs, transportation costs, and other costs are summed up in terms of $/tonnes of soil input. |
| Demand | Demand is an economic principle referring to a consumer's desire to purchase goods and services and willingness to pay a price for a specific good or services produced from repurposing future incoming excavated soils. Holding all other factors constant, an increase in the price of a good or service will decrease the quantity demanded, and vice versa. |
| Environmentally friendly | Environmentally friendly or environment-friendly, (also referred to as eco-friendly, nature-friendly, and green) are in the context of this project |
| Forecasting | Forecasting is a technique that uses historical data as inputs to make informed estimates that are predictive in determining the direction of future trends. |
| Innovation | Innovation is the successful exploitation of new ideas which uses soils to produce products or provide services to market. These new ideas can provide additional benefits in one or more aspects of a technology (convenience, cost, time-saving or lower carbon footprint) compared to traditional methods that utilized soils in a particular application. |
| Jobs creation | This factor is measured by the number new jobs that are created at CoV or in other third-party organizations that can be directly linked to the soil repurposing project initiative. |
| Landfill | A waste disposal facility where waste that cannot be recycled or composted is diverted to and buried under the ground. |
| Long term viability | The viability of an option is measured by its long-term applicability and its ability to serve a purpose over a long period of time. In the context of this project, the long-term viability is measured by CoV's ability to continue utilizing this repurposing solution over long period of time without financial, environmental and technological hindrance. |
| Municipal Organic Waste | The organic fraction of MSW consisting of food waste and yard waste. |
| Municipal Solid Waste | Solid, non-hazardous refuse originating from residential, industrial, commercial, institutional, and consumer drop-off/self-haul sources. |
| Proven technology | In industry, a proven technology has a documented track record for a defined environment. Such documentation shall provide confidence in the technology from practical operations, with respect to the ability of the technology to meet the specified requirements. |
| Rammed Earth Walls | A wall-building method in which an inorganic soil mix is compressed into sufficiently strong and accessible forms. |
| Soil Quality Compatibility | Many repurposing options considered require certain quality of soils in order to beneficially use the soils as feedstocks. These solutions have specific quality control on mineral content, macronutrient content, or the size of the soil particles. This "Soil quality compatibility" factor measure how VLF soils characteristics relate to these specific quality control standards. |
| Stabilizers | A stabilizer is a chemical that is used to prevent degradation. They ensure safe processing and protect products against aging and weathering |

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# 1.0 Introduction

This project is part of the Greenest City Scholar program in conjunction with the University of British Columbia's Sustainability Scholars program, to support the City of Vancouver's Greenest City Goals, City of Vancouver's Zero Waste 2040. In particular, this project supported the zero waste goals to reduce waste entering the landfill. It will also support the Zero Waste 2040 strategy to refocus operations of the Vancouver Landfill to recovery & diversion over disposal. Achieving a goal of zero waste is important for many reasons, one of which is to address limited available disposal capacity at the Vancouver Landfill. The Vancouver Landfill (VLF) is estimated to reach capacity limits by 2030; seven years earlier than forecasted due in part to the significant amount of waste such as excavated soil being disposed at the site. To address this issue, identifying and evaluating beneficial opportunities to repurpose disposed soil were prioritized as a goal for the Zero Waste & Resource Recovery division of City of Vancouver's Engineering Services.

## 1.1 Project Objective

The objective of this project was to identify and rank different repurposing options for incoming excavated soils entering the VLF based with a focus on the current composition and tonnage of excavated soils received at VLF.

## 1.2 Project Scope

This project consisted of the following tasks:

1. Undertake a review of existing tonnage flow of soil to VLF;
2. Undertake a literature review of factors and criteria considered during other feasibility analyses of soil repurposing operation;
3. Conduct interviews with Zero Waste and Resource Recovery Division staff to identify the importance of each factor highlighted in the literature review;
4. Compile and review the composition and characteristics of soils stockpiled at the Landfill;
5. Describe and develop approaches for repurposing the existing stockpile of soils at the landfill; and
6. Compile and develop a comparative analysis based on the evaluation criteria identified in the interviews and literature reviews.

## 1.3 Methods

Part of this project included a literature review of relevant feasibility studies, interviews and discussions with relevant City of Vancouver staff to help identify different approaches and criteria factors for conducting a feasibility analysis of repurposing solutions on VLF's disposed soils. The literature review finds Pros, Cons and applicability method to be the most effective method in conveying the advantages and disadvantages of repurposing solutions. The interviews and discussions with City of Vancouver staff highlighted various important factors to evaluate repurposing options during a feasibility study.

For this project report, the "Harvey ball" method was used for evaluating repurposing options based on the City staff's identified factors. The Harvey ball method is chosen for this feasibility study as it is easily understood by the general public and can be investigated further in the future. The Harvey Ball ratings are shown in Figure 2.

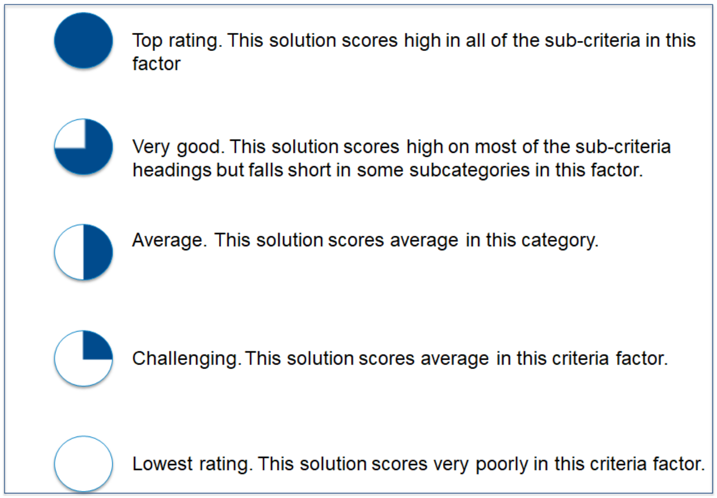


**Figure 2: Harvey Ball evaluation scoring used for evaluation of repurposing solutions**

Several meetings, interviews and project check-in meetings were attended throughout the project. From these meetings, Information was gathered and opportunities for collaboration and synergies were discovered between City of Vancouver and other (public and private) organizations which can be incorporated into future work in finding a suite of optimal repurposing solutions for excavated disposed soils at VLF.

# 2.0 Background

The intent of the background section in this report is to provide an understanding of goals and initiatives set out by the City, the source and origins of excavated soils received at VLF and a brief introduction on soil structure and composition.

## 2.1 Zero Waste 2040 Strategic Plan

Zero Waste 2040 is a long-term strategic vision for Vancouver as a community to achieve the goal of zero waste by 2040. It will help guide future decisions and investments relating to solid waste and identifies areas where the City can play a role in stimulating the community, economic and societal changes needed to achieve the goal of zero waste. [1]

The primary objective of this plan is to eliminate the disposal of solid waste to landfill and incinerator by 2040, an aspirational goal with an outcome dependent on the success of actions taken by the City and those who live, work and visit Vancouver. Zero waste will be achieved through avoiding and reducing waste, keeping materials in circulation as long as possible, and then recycling, composting and producing renewable energy from materials that remain. The plan will be adjusted and updated as experience and knowledge is gained through continuous learning, technology advances and consumer market changes as new policies, plans and regulations are introduced by other levels of government.

Success towards the primary objective will be measured by the annual reduction in tonnes of solid waste from Vancouver disposed to landfill and incinerator, with a 2040 target of zero tonnes disposed.

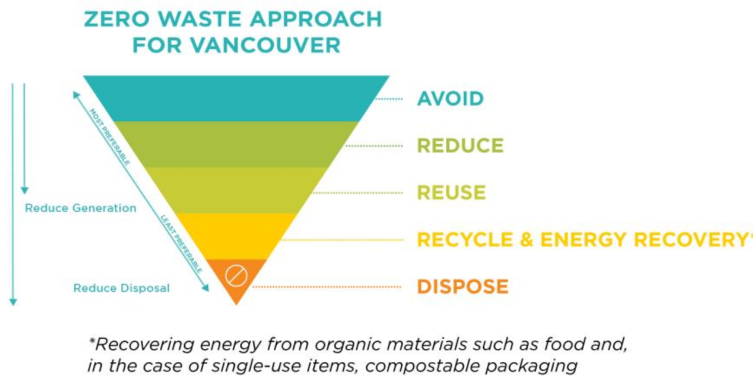


**Figure 3: Zero waste approach for Vancouver[1]**

To achieve zero waste 2040 strategic vision, four transformational projects are considered to transform VLF into a resource recovery centre which includes future work on repurposing excavated soils disposed at VLF. In 2017, 418,339 metric tonnes of soil generated mainly from excavation activities by sewer, water and street construction by the City of Vancouver (60%) and the City of Delta (40%) were disposed at VLF. Landfill operations currently use 59% of the soils as landfill cover and stockpile the rest.

## 2.2 Soil Structure and Composition

To better understand and explore repurposing options for excavated disposed soils, a brief introduction to soils composition and characteristics were provided in this section.

Topsoil is the layer closest to the surface, in which the plants grow. Below the topsoil layer is subsoil and then bedrock. Moreover, the Canadian Soil Classification System classifies these layers more specifically as horizons. Each horizon is unique in its properties and can vary in depth depending on various physical and biological factors. The soil profile in Figure 4 below illustrates the different horizons and how they correspond with common references to the layers, such as topsoil and subsoil. [2] [3]

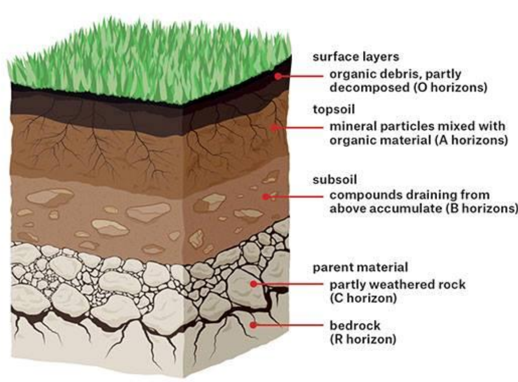


**Figure 4: Soil profile with different horizons[2]**

[1] Source - https://vancouver.ca/green-vancouver/zero-waste-vancouver

Soils also contain organic matter (OM) from biodegraded organics (leaf litter and compost) to produced Compost has an organic content of 40-50% on average. Among the soil particles are pores, which hold air and water. For plant growth purposes, the ideal balance between solid material (minerals and OM) and pore space is half and half.

Topsoil is composed of minerals, OM and living microorganisms. These microorganisms provide the vital service of breaking down OM into humus in the “O” (organic) horizon. Water and species living in soils help to distribute the humus into the “A” horizon, which is where plant roots are located, because the soil nutrients and pore space allows for root growth and water retention. The “B” horizon below commonly referred to as “subsoil”, changes more slowly than the “A” horizon and contains less OM and more mineral content. The “C” horizon, commonly referred to as parent material, is the lowest soil layer above bedrock (the “R” horizon) and contains even less OM and even more mineral content. [2] [3]

The United States Department of Agriculture (USDA) classifies soils by its mineral content using a Soil Triangle (Figure 5). The mineral Content determines the texture and appearance of soils. Sandy soils feel gritty; whereas, when wet, silty soils feel silky and clayey soils feel sticky. The image provided with the Soil Triangle illustrates different soils that are dominant in sand, loam, or clay. A loam soil (the middle pot in Figure 6) is a soil that is well balanced in sand, silt, and clay components. Figure 6 shows a comparison relative soil particle sizes that can be present. [2] [3]

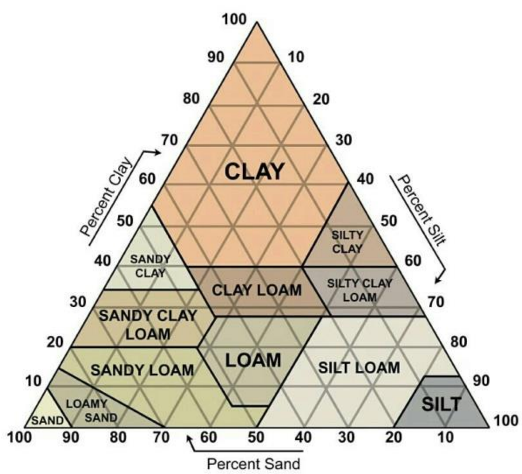



**Figure 5: Soil Classification Triangle (right) and examples of soils with different mineral content (left)[3]**

[2] Source: https://resselaercountyvegetable.blogspot.com/2018/02/topsoil-county-soil-history-backyard

[3] Source: https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_031477

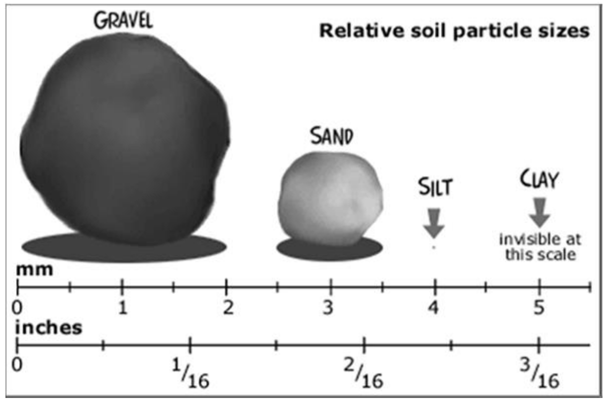


Figure 6: Relative soil particle sizes[4]

## 2.3 Vancouver & Delta Soils

Geomap Vancouver (a geological map of Vancouver metropolitan area) shows the surface distribution of the mineral content and material characteristics of soils that are relevant to engineering and land-use planning in the Metro Vancouver region. Figure 7 below illustrates the mineral content characteristics of Vancouver and Delta soils that may be received currently or in the future at the Vancouver Landfill. It is important to note that this map shows the nature and distribution of different geological materials in the Metro Vancouver region. Based on this Geomap, the incoming excavated soils to VLF are expected to be high in sand content. [4] [5]

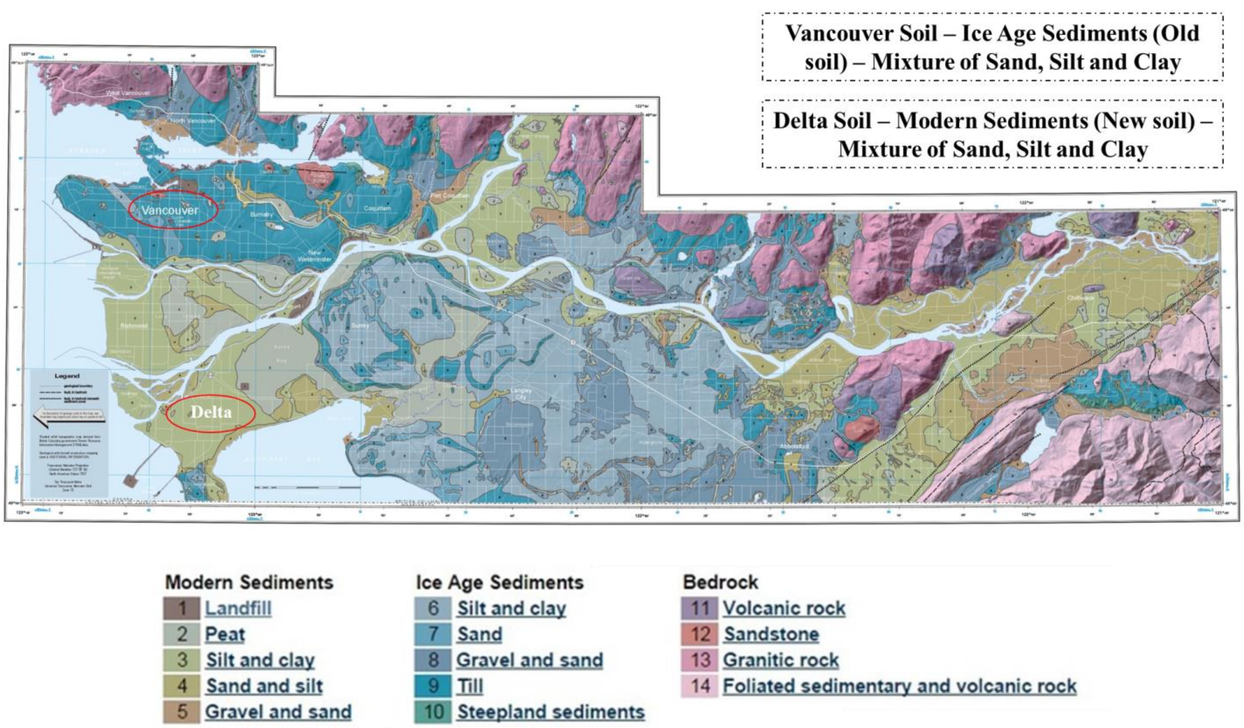


Figure 7: Geo-Map Vancouver[5]

[4] Source: https://www.smore.com/0dc15-soil

## 2.4 Soil Nutrient Content

As mentioned previously, soils contain OM which provides a foundation for plant growth. There are a wide variety of growing medium types, each with its own set of desired specifications. Two sources are used to investigate the best soil specifications for each growing medium. The first growing medium specifications list is found in Sydnie Koch's "Improving Sustainability practices by Repurposing City Construction Waste" research in 2016. Table 3 below illustrates the desired product specifications highlighted in this report. [7]

**Table 3: RFP PS20150950 product specifications**

| Product Specifications | | | | | | |
|---|---|---|---|---|---|---|
| | **Park Shrub Mix** | **Park Turf Blend** | **Special Turf Blend** | **Soil Amendment** | **Street Turf Mix** | **Street Shrub Mix** |
| **Carbon:Nitrogen** | <30:1 | 20:110:1 | 20:1-10:1 | 25:1-10:1 | 20:1-10:1 | 20:1-10:1 |
| **%Organic Matter** | 20%-30% | 10-20% | 5-15% | 40-65% | 3-10% | 10-20% |
| **%Sand** | 50-70% | 70%-85% | 75-90% | 15-35% | 30-60% | 30%-60% |
| **%Silt** | 10-25% | 5-15% | 5-15% | 5-15% | 10-35% | 10-35% |
| **%Clay** | 0-15% | 0-15% | 0-15% | 7-17% | 5-15% | 5-15% |
| **Total Silt &Clay** | 25% max | 20% max | 20% max | 20% max | 15-30% max | 40% max |
| **Acidity(pH)** | 4.5-8.0 | 4.5-8.0 | 4.5-8.0 | 4.5-8.0 | 6.0-7.0 | 4.5-6.5 |
| **Max Particle Size** | 100% passing the 0.5" sieve | 100% passing the 0.5" sieve | 100% passing the 0.375" sieve | 100% passing the 0.5" sieve | 100% passing the 0.5" sieve | 100% passing the 0.5" sieve |

The second growing medium specification is found from three online sources. Table 4 shows agricultural growing medium nutrient specifications for soils that are listed by other sources.

**Table 4: Optimal range of macronutrient specifications for soils**

| Parameter | Optimum Range |
|---|---|
| Nitrogen (N)[6] | 25 to 50 mg/kg |
| Phosphorus (P)[7] | 36 to 50 mg/kg |
| Potassium (K)[7] | 131 to 175 mg/kg |
| pH level[8] | for agricultural use – 5.5 to 7.0<br>for construction use – 6.5 to 7.5 |

[5] Source: http://www.cgenarchive.org/vancouver-geomap
[6] Source - http://www.soilquality.org.au/factsheets/soil-nitrogen-supply
[7] Source - https://www.uaex.edu/publications/PDF/FSA-2118.pdf
[8] Source - https://en.wikipedia.org/wiki/Soil_pH

In order to use the excavated soils for general agricultural and horticultural purposes, the soil matter has to be tested for the previous nutrients with results in the optimum range of these nutrients. It should be noted that other micro-nutrients may become important for certain horticultural or agricultural applications.

## 3.0 Excavated Soils Flow to VLF for Cover and Closure purposes

Understanding the past and present soil tonnage flow to the VLF provides a foundation for identifying the most effective solutions to achieve Vancouver's zero waste goals by 2040 in the context of excess soil. Furthermore, the historical data set gathered by this exercise provides more relevant forecasting of incoming soils from 2019 until 2040.

The VLF property is 320 hectares in size, which contains an operational footprint area (area for Municipal Solid Waste disposal) of 225 hectares. VLF is authorized to accept up to 750,000 tonnes of Municipal Solid Waste (MSW) for disposal each year. Materials used beneficially, such as cover, road building and closure, are not counted towards this limit. Figure 8 below illustrates the Vancouver Landfill with the highlighted soil stockpile area.  The soil stockpile area is more than 34,000 $m^2$ and can hold more than 200,000 tonnes of excess soils.


Figure 8: Vancouver Landfill's stockpile area

The City's Transfer and Landfill Operations (TLO) team has recorded data of soils inflow to VLF from 1980 to 2019. Figure 9 below shows that a non-uniform flow of soil can be seen each year.  This is mainly because every 4 to 5 years there is an intermittent activity such as phase closures. These intermittent activities generally require more soil. On occasion, VLF has used other municipality's excess soils to meet its needs of phase closure soil requirements.

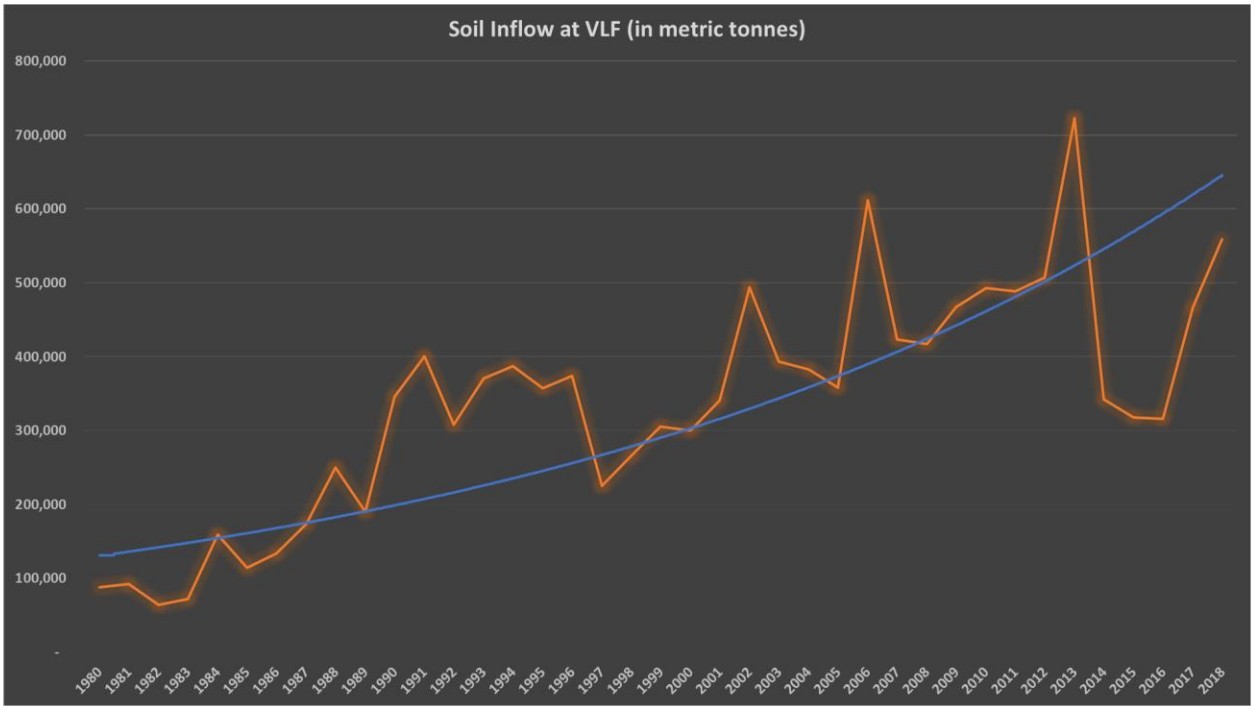


Figure 9: Soil Inflow at VLF-Historical Trends from 1980-2018

Table 5 below illustrates the last 38 years soil inflow data by comparing the data sets for every 10 years. According to this table, circumstantial activities occur 2 to 3 times every 10 years. Furthermore, it was found that soil inflow has increased from an average of 133,600 tonnes in the 1980s to an average of 468,104 tonnes in 2010s. The primary sources of excess soils are generated by sewer, water, and street construction activities within the City of Vancouver and City of Delta.

Table 5: 38 years of soil inflow data segmented every 10 years

| Soil Inflow at VLF from 1980 - 99 | | | |
|---|---|---|---|
| **10 Years** | **Soil Inflow** | **10 Years** | **Soil Inflow** |
| 1980 | 88,000 | 1990 | 346,000 |
| 1981 | 92,000 | 1991 | 400,200 |
| 1982 | 64,000 | 1992 | 308,100 |
| 1983 | 72,000 | 1993 | 370,300 |
| 1984 | 159,000 | 1994 | 387,100 |
| 1985 | 114,000 | 1995 | 357,100 |
| 1986 | 134,000 | 1996 | 374,200 |
| 1987 | 173,000 | 1997 | 225,100 |
| 1988 | 250,000 | 1998 | 265,300 |
| 1989 | 190,000 | 1999 | 305,640 |
| **Average** | **133,600** | **Average** | **333,904** |

| Soil Inflow at VLF from 2000 - 18 | | | |
|---|---|---|---|
| **10 Years** | **Soil Inflow** | **10 Years** | **Soil Inflow** |
| 2000 | 300,369 | 2010 | 492,912 |
| 2001 | 340,374 | 2011 | 488,373 |
| 2002 | 493,392 | 2012 | 507,199 |
| 2003 | 393,586 | 2013 | 722,656 |
| 2004 | 382,756 | 2014 | 342,300 |
| 2005 | 357,931 | 2015 | 317,669 |
| 2006 | 611,436 | 2016 | 316,196 |
| 2007 | 423,340 | 2017 | 466,772 |
| 2008 | 416,721 | 2018* | 558,856 |
| 2009 | 467,073 | | |
| **Average** | **418,698** | **Average** | **468,104** |

*In 2018 - Approx. 467,581 tonnes of soil outsourced from other Municipalities for emergency purposes i.e. Landfill fire and phase closure - Not included

Excess soils received at the Landfill are currently being used for three main purposes:

- Landfill Cover;
- Landfill Cell Closures; and
- Emergencies such as Landfill Fires.

Table 6 below demonstrates the data taken from Vancouver Annual Report from 2011 to 2018 to determine the soil inflow from City of Vancouver and City of Delta. This data is used for forecasting future soil inflow tonnage at VLF.

**Table 6: City of Vancouver & City of Delta Soil Inflow to VLF over the past 8 years**

| Source | Sand and Soil Tonnes | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
| Vancouver Public Works | | | | 268,567 | 235,234 | 233,971 | 250,264 | 229,033 |
| Vancouver Commercial & Residential drop off | 417,747 | 367,391 | 399,641 | | | 1,986 | | 6,056 |
| **Vancouver** | **417,747** | **367,391** | **399,641** | **268,567** | **235,234** | **235,957** | **250,264** | **235,089** |
| Delta Public Works | 33,650 | 42,238 | | 70,280 | 83,162 | 71,919 | 160,711 | 133,776 |
| Delta Commercial and Drop off | | 58 | 6,338 | 1,836 | 5,698 | 8,575 | 7,364 | 82,207 |
| **Delta** | **33,650** | **42,296** | **6,338** | **72,116** | **88,860** | **80,494** | **168,075** | **215,983** |
| Richmond | | 39 | | | | 57 | | 83,143 |
| Surrey | 28,591 | 18,274 | | | | 263 | | 6,092 |
| Other Municipalities* | 8,257 | 16,552 | | 133 | | 97 | | 18,550 |
| **Cover Sand and Soil (1)** | **488,245** | **444,552** | **405,979** | **340,816** | **324,094** | **316,868** | **418,339** | **558,857** |
| Vancouver Public Works | | | | | | | | |
| Vancouver Commercial & Residential drop off | | 43,149 | 272,443 | 17,908 | 19 | | 35,812 | 7,619 |
| **Vancouver** | **-** | **43,149** | **272,443** | **17,908** | **19** | **-** | **35,812** | **7,619** |
| Delta Public Works | | | | | 37 | | | |
| Delta Commercial | | 3 | 43,561 | | 50 | | 34,188 | 47,621 |
| **Delta** | **-** | **3** | **43,561** | **-** | **87** | **-** | **34,188** | **47,621** |
| Richmond | | 30,028 | 24,895 | 192 | 307 | | 78,753 | 315,776 |
| Surrey | | 5,666 | 16,958 | 10,300 | 77 | | | 76,815 |
| Other Municipalities* | | 37,006 | 138,788 | 63 | 51 | 17,401 | 96,049 | 19,751 |
| **Closure Sand and Soil (2)** | **-** | **115,852** | **496,645** | **28,463** | **541** | **17,401** | **244,802** | **467,582** |
| From Vancouver | 417,747 | 410,540 | 672,084 | 286,475 | 235,253 | 235,957 | 286,076 | 242,708 |
| From Delta | 33,650 | 42,299 | 49,899 | 72,116 | 88,947 | 80,494 | 202,263 | 263,604 |
| **Total (From Vancouver & Delta)** | **451,397** | **452,839** | **721,983** | **358,591** | **324,200** | **316,451** | **488,339** | **506,312** |
| **Final Total (1)+(2)** | **488,245** | **560,404** | **902,624** | **369,279** | **324,635** | **334,269** | **663,141** | **1,026,439** |
| **Total % from Vancouver and Delta** | **92%** | **81%** | **80%** | **97%** | **100%** | **95%** | **74%** | **49%** |
| *Other Municipalities - Burnaby, City of Langley, City of North Vancouver, Coquitlam, District of North Vancouver, District of West Vancouver, Langley Township, Maple Ridge, New Westminster, Pitt Meadows, Port Coquitlam, Port Moody. | | | | | | | | |

Figure 10 uses the data from Table 6 to illustrate the soil inflow source from Vancouver and from Delta comparatively over the past seven years. Based on Figure 10, City of Delta has sent more soil to VLF than City of Vancouver in 2018. City of Delta has been increasing its excavated soil outflow tonnage to VLF over the past seven years.

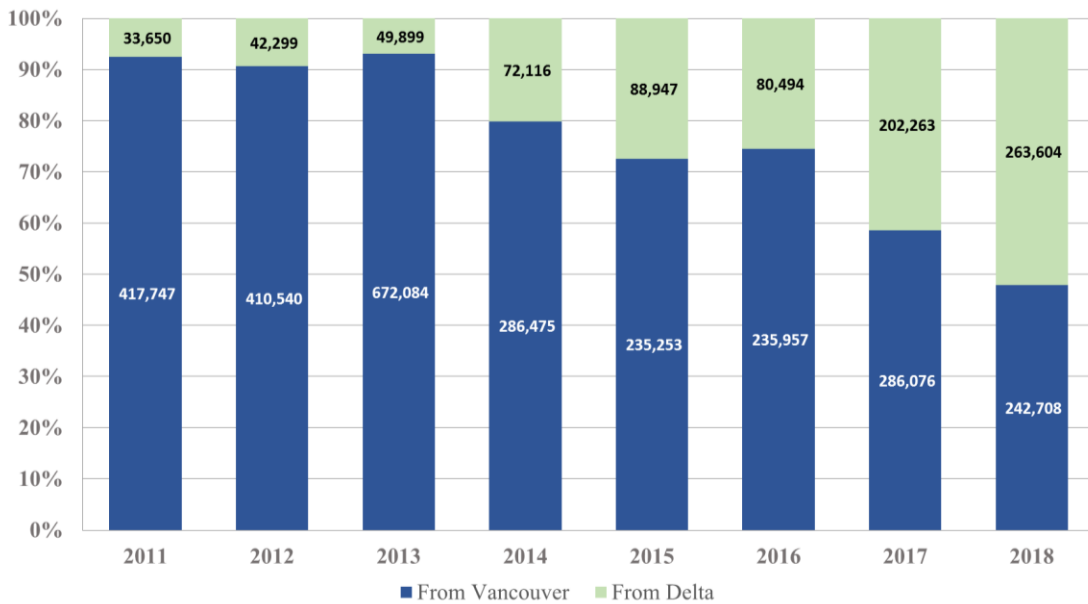


Figure 10: Soil inflow from Vancouver vs. Delta

## 4.0 Forecasting Excavated Soils Inflow to VLF

In order to properly investigate the repurposing solutions for future excavated soils received at the VLF, a forecasting exercise is conducted to find the upper bound and lower bound of expected future excavated soil tonnage. The following is the list of data that have been used during this forecasting exercise:

1. Over 38 years of historical data for incoming excess soils is used to project the incoming flows of the future
2. Metro Vancouver projected population growth projection[9]
3. Metro Vancouver housing demand projection where the population requires more multi-family housing units which would results in more infrastructure (sewer pipes, water pipes, and streets) upgrades[9]

Based on the historical data analysis, it is found that a +/- 12% projection limit is appropriate for forecasting incoming flow of excavated soils to VLF. Figure 11 below illustrates the estimated future tonnages that may be received under standards operating procedure (not including one-offs such as phase closures).

[9] Source: http://www.metrovancouver.org/services/regional-planning/PlanningPublications/OverviewofMetroVancouversMethodsinProjectingRegionalGrowth.pdf

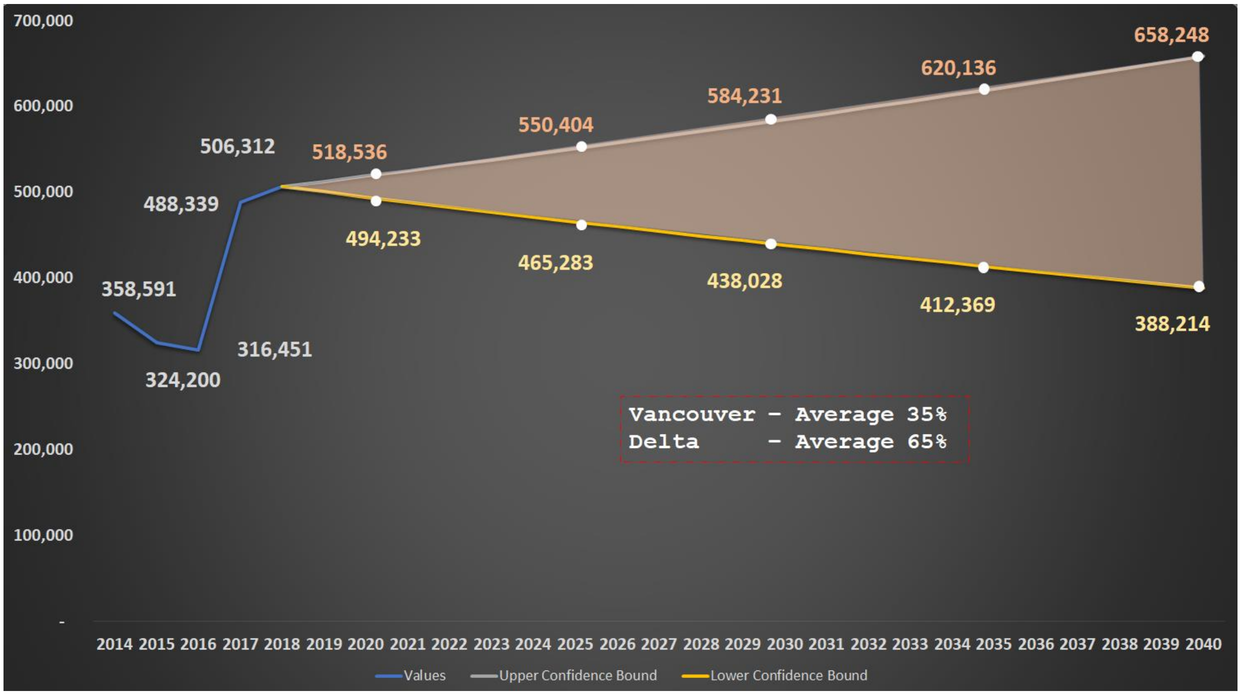


**Figure 11: Estimated projection of incoming soils to VLF**

By 2040, it is estimated that VLF will receive from 380,000 to 658,000 tonnes a year. If the current historical trend of increasing excess soils coming from Delta continues, it is estimated that 65% of incoming excess soils to VLF will be from City of Delta by 2040.

## 5.0 Characterization of Incoming Soils to VLF

The characterization of excavated soils that are stockpiled at VLF provides necessary information needed for the feasibility study of different repurposing options. Currently, soils are stockpiled in a designated area which can be accessed by contractors and TLO team for the closure and covering operations. With the support of TLO and SWSS staff, samples were taken from the soil stockpiles in two buckets. Laboratory samples were taken from these buckets and were sent to ALS Environmental Laboratories in Burnaby for analyses. Figure 12 below illustrates the conditions of samples taken on May 16th, 2019.

Figure 12: Samples taken from soils stockpiles at VLF

To determine VLF soil engineering and agricultural properties, the following geochemical and geotechnical laboratory tests were performed:

- Soil Texture Test: This analysis determines the sand, silt, and clay composition
- Sieve Analysis: This analysis assesses the particle size distribution
- Moisture Content Test: This analysis determines the total moisture content in the soil
- Specific Gravity Test: This analysis determines the specific gravity of the soil which is required in the calculation of soil properties like void ratio, degree of saturation and weight-volume relationship.
- Atterberg Limits Test: This analysis determines the water content at which the soil changes from one state to the other also known as consistency limits or Atterberg limits. Soils have a total of four states – solid, semi-solid, plastic and liquid. There are three limits: liquid limit, plastic limit and shrinkage limit
- pH level test: this analysis measures the acidity and alkalinity in soils. The optimal pH ranges
    - for agricultural use – 5.5 to 7.0
    - for construction use – 6.5 to 7.5
- Soil Fertility Test: This analysis determines – NPK macronutrients content (Nitrogen (N), Phosphorus (P), and Potassium (K)).
- Soil Organic Matter (SOM) Test and Total Organic Carbon (TOC) Test: This analysis determines the organic matter content and total organic carbon content which are important to understand soil characteristics such as colour, nutrient holding capacity, nutrient turnover, and stability.

Table 7 below shows the results of above mentioned tests. As per the test results, VLF stockpiled soil is sandy loam in nature. Sandy loam soils are dominated by sand particles but contain enough clay and sediments to provide some structure and fertility.

Table 7: Soil sample test results for characterization

| Sampling Date: May 16, 2019 | | | No. of Samples: 3 |
|---|---|---|---|
| **Parameters** | **Lowest Detection Limit** | **Units** | **Average Sample results** |
| **Physical Tests (Soil)** | | | |
| Liquid Limit (LL) | 1 | % | 24.5 |
| Moisture at Plastic Limit | 1 | % | 20.0 |
| pH (1:2 soil:water) | 0.10 | pH | 7.5 |
| Plasticity Index (PI) | 1 | % | 4.0 |
| Specific Gravity | 0.010 | kg/L | 1.4 |
| | | | |
| **Particle Size (Soil)** | | | |
| % Gravel (>2mm) | 1.0 | % | 11.4 |
| % Sand (2.0mm - 0.063mm) | 1.0 | % | 54.6 |
| % Silt (0.063mm - 4um) | 1.0 | % | 27.4 |
| % Clay (<4um) | 1.0 | % | 6.6 |
| Texture | | - | Sandy loam |
| | | | |
| **Organic / Inorganic Carbon (Soil)** | | | |
| Organic Matter | 0.10 | % | 1.9 |
| Total Organic Carbon | 0.050 | % | 1.1 |
| | | | |
| **Plant Available Nutrients (Soil)** | | | |
| Available Nitrate-N | 1.0 | mg/kg | 6.8 |
| Available Phosphate-P | 2.0 | mg/kg | 16.3 |
| Available Potassium | 20 | mg/kg | 101.0 |

Sandy loam soils can be further broken down into four sub-categories, including coarse sandy loam, sandy loam, fine sandy loam and very fine sandy loam. The size of the sand particles in millimeters and their concentration in the soil is used to determine which sub-category that particular type of soil falls under. Based on the test results, soils stockpiled at the Vancouver Landfill primarily fall under the regular sandy loam sub-category. Sandy loam soils have visible particles of sand mixed into the soil. When sandy loams soils are compressed, they hold their shape but break apart easily. Sandy loam soils have a high concentration of sand that gives them a gritty feel. Sandy loam soils are capable of quickly draining excess water but cannot hold significant amounts of water or nutrients for your plants. Plants grown in this type of soil will require more frequent irrigation and fertilization than soils with a higher concentration of clay and sediment. Sandy loam soils are often deficient in specific micronutrients and may require additional fertilization to support healthy plant growth. Plants that are grown in a sandy loam soil need frequent irrigation and fertilization to maintain healthy growth. The best way to improve a sandy loam soil for gardening is to mix organic matter into the soil. Incorporating a 2- to 4-inch layer of compost or peat moss over the area can significantly improve the ability of your sandy loam soil to hold nutrients and water.

Figure 13 below demonstrates the mineral content and texture classification in relation to the Soil Classification Triangle and its primary uses.

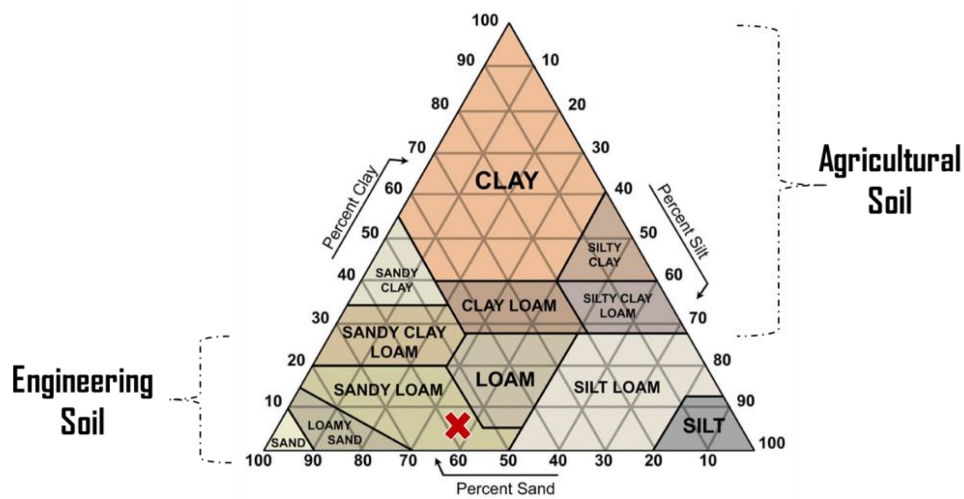


Figure 13: VLF soils mineral content based on Soil Classification Triangle

As per VLF soil results, macronutrients (NPK content) are less than the optimum range. Even organic matter is less than 2 percent. Moreover, VLF soils do require soil blending with 5 to 10 percent of compost before any use for agriculture or horticultural purposes. As shown in Figure 13, VLF soil which is sandy loam in nature is more suitable for engineering applications (construction or other engineering purposes) than agricultural applications. In addition, VLF Soils pH level is around 7.5 which are within the optimum range for engineering applications.

## 6.0 The Literature Review of Relevant Feasibility Studies

The purpose of this section is to provide an overview of the findings from the literature review of relevant feasibility studies performed to identify different approaches and criteria factors for conducting a feasibility analysis of repurposing solutions on VLF's excavated soils.

### Improving Sustainability Practices by Repurposing City Construction Waste (2016) [7]

This section of the report addresses various ways to recycle or repurpose the road and utility construction waste. It identifies various current and future improvement opportunities for recycling construction waste. Kent Yard's processes of evaluating options were used in this project as its facilities are the central hub for construction waste recycling and repurposing.

In this report, the author did the feasibility study of given recommendations based on the following factors:

- Potential issues: One of the key potential issues is that Kent Yard's rubble comes from a variety of locations across the Vancouver area, soil properties can vary from truckload to truckload.
- Potential solutions: Kent yard may need to investigate potential blending facility options to get the consistent physical and chemical soil properties that make it ideal for quality control and assurance.
- Demand: The author insisted that part of a good business plan is to create a product with market demand. Detailed market analysis is needed to determine if Kent yard can be competitive with the private sector.
- Desired Specifications: Two sources were used to investigate the best soil specifications for Vancouver:

    - Master Municipal Construction Documents (MMCD)
    - City's Request for Proposals (RFP) reference number PS20150950

  Both specifications have several common themes. The most important is to note that nearly all the designs require a large portion of sand with little to no gravel and clay. The level of acidity for all the different soil types are quite close as well and fall near 6.0 pH, but the organic content varies significantly depending upon the intended use for the product. This can range anywhere from 3% to 90%.

### Comment

In this feasibility study, the approach is quite basic and straight forward. The author tried to find the potential issues that a facility may face during execution and probable solutions for these issues. The author also discussed other important parameters like product demand using market and competitive analysis and desired specifications as per demand.

### Niche Market Opportunities for Compost Produced at the Vancouver Landfill (2016) [8]

This report explores niche market opportunities for compost produced at the Vancouver Landfill and focused on product quality, sales strategy, product markets, customer service, and opportunities to produce one or more specialty compost products.

A SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis is conducted in this report in the following VL compost program areas:

- Composting process
- Finished product
- Marketing in person
- Marketing by phone
- Marketing online
- Sales & donations process
- Data management

### Comment

Each program area has eight to nine recommendations and for each recommendation, rankings are provided for comparison purpose. The author did not give an overall opinion or decision about each program area. This analysis yielded a great deal of contradicting information which makes the decision process difficult.

### Taking a portfolio approach to financing energy efficiency retrofits in industrial buildings – a feasibility study (2017) [9]

This feasibility study is about testing a fresh approach to engaging small and midsize industrial businesses and property owners involved in energy efficiency retrofit projects through collective financing and project management. It anticipates that the collective approach will yield not only financial savings - through group purchasing, de-risking retrofit investments, and streamlining administration, but also social incentives - through community-building and peer pressure.

Every option is discussed strategically based on three factors

- Pros
- Cons
- Applicability

Other factors considered in this report:

- Cost savings
- Energy savings
- Social and marketing impact

### Comment

This feasibility study is to the point, easy to understand and applicable to issues that have multiple solutions available.

### Solar Energy Feasibility Study at Park Board Buildings and Facilities (2016) [10]

This report examines the feasibility of utilizing solar thermal and solar photovoltaic (PV) systems across the Park Board's properties in order to reach the Greenest City 2020 target as well as to reduce the utility bills.

The Vancouver Park Board has jurisdiction on more than 230 parks. In 2015, the Park Board consumed 33.3 Gigawatt hours of electricity and 164,722 Gigajoules of natural gas across all its facilities. The combined building and transportation emissions totaled just over 10,000 tonnes of carbon dioxide ($CO_2$) into the atmosphere.

Solar thermal and solar photovoltaic (PV) systems are two possible energy solutions for the Park board discussed in this report. To examine the feasibility of these two solutions, the following factors calculated using a high-level design approach through software calculators used for modeling along with a cost-benefit analysis:

- Energy potential
- Monetary savings
- Load Offset
- $CO_2$ Offset

Also, a financial model is developed in order to calculate Simple Payback, Equity Payback, Net Present Value (NPV), and Internal Rate of Return (IRR).

Solar energy technologies in Vancouver face several hurdles that can be categorized as:

- Public Awareness – Research shows that Vancouver does receive less sunlight on average when compared to major cities across the Alberta, Saskatchewan, Manitoba, Ontario, and Quebec. However, Vancouver is sunnier than most major German cities, which led the world in solar rooftop installation per capita.
- Economics – Fuel price plays a critical role in solar energy economics. The higher the fuel rates, the higher the cash flow and the shorter the payback period
- Policy - British Columbia (BC) lacks policy measures. In order to promote solar energy solutions, the BC government needs to provide incentives either through tax credits, rebates, or Feed-in-Tariffs (FIT).

In the end, the author concludes that due to economies of scale, the subsidized nature of the hydroelectric operation in BC, and lack of support policies aiming to drive the solar market, thermal and PV systems will continue to have long payback periods and be seen as unviable solutions.

### Comment

This feasibility report is a relative comparative report of two energy solutions. The author tried to cover all possible parameters. Overall, solar PV is simpler and more cost-effective than solar thermal in the lens of installation, operation and simple payback.

### Recommendation

These reports are relevant to their project topic. For the repurposing soil project, the feasibility study of options based on pros, cons and its applicability can be more informative and conclusive.

The following are the important factors taken from these feasibility reports which could be useful for the feasibility study of this project. These factors are:

- Affordability
- Market analysis/Demand
- Environmentally friendly
- Jobs creation/Maintaining jobs

- Long term viability (10-20 years)

Some significant factors that were not discussed in this report are:

- Soil quality compatibility
- Proven technology
- Innovation

For this project, every option will be checked against the above-mentioned factors. Each factor will be weighted as per its importance and value to the project and COV staff. The ten or more repurposing options will be easier to compare if the study will be based on pros, cons and its applicability.

## 7.0 Factors and Criteria Identified For the Feasibility Analysis

As mentioned earlier, the following are the important factors and criteria taken from the relevant feasibility reports which could be useful for the feasibility study of this project. These factors are:

I. **Soil quality compatibility: [11]**

Many repurposing options considered the required certain quality of soils in order to beneficially use the soils as feedstocks. These solutions have specific quality control on mineral content, macronutrient content, or the size of the soil particles. This "Soil quality compatibility" factor measure how VLF soils characteristics relate to these specific quality control standards.

II. **Affordability: [11]**

Soil as a material is very inexpensive compared to other precious metals and other commodities. Therefore, repurposing solutions will need to be measured by how inexpensive the repurposing solution is when the capital investments, operating costs, transportation costs, and other costs are summed up in terms of $/tonnes of soil input.

III. **Demand:[11]**

Demand is an economic principle referring to a consumer's desire to purchase goods and services and willingness to pay a price for a specific good or service produced from repurposing future incoming excavated soils. Holding all other factors constant, an increase in the price of a good or service will decrease the quantity demanded, and vice versa.

IV. **Environmentally friendly: [11]**

Environmentally friendly or environment-friendliness, (also referred to as eco-friendly or green) in the context of this project contains concepts such as carbon footprint, ecological footprint, energy consumption and toxic substance production.

V. **Jobs creation: [11]**

This factor is measured by the number new jobs that are created at CoV or in other third-party organizations that can be directly linked to the soil repurposing project initiative.

VI. **Proven technology: [11]**

In industry, a proven technology has a documented track record for a defined environment. Such documentation shall provide confidence in the technology from practical operations, with respect to the ability of the technology to meet the specified requirements.

VII. **Innovation: [11]**

Innovation is the successful exploitation of new ideas which uses soils to make products or provide services to market. These new ideas provide additional benefits in one or more aspects of a technology (convenience, cost, time-saving or lower carbon footprint) compared to traditional methods that utilized soils in a particular application.

VIII. **Long term viability: [11]**

The viability of an option is measured by its long-term applicability and its ability to serve a purpose over a long period of time. In the context of this project, the long-term viability is measured by CoV's ability to continue utilizing this repurposing solution over long period of time without financial, environmental and technological hindrance.

## 7.1 Discussions and Survey

On May 28th, 2019 a focus group informational session was conducted to inform TLO and SWSS staff about the project and factors being considered for feasibility analysis and information needed from the group to conduct the analysis. The focus group participants gave their input on these factors based on their experience and knowledge of similar projects conducted. Each factor is rated using the "Harvey bell" rating system. Figure 14 shows the overall survey results[10]

[10] Appendix C – Important Factors for the Feasibility Study – Survey

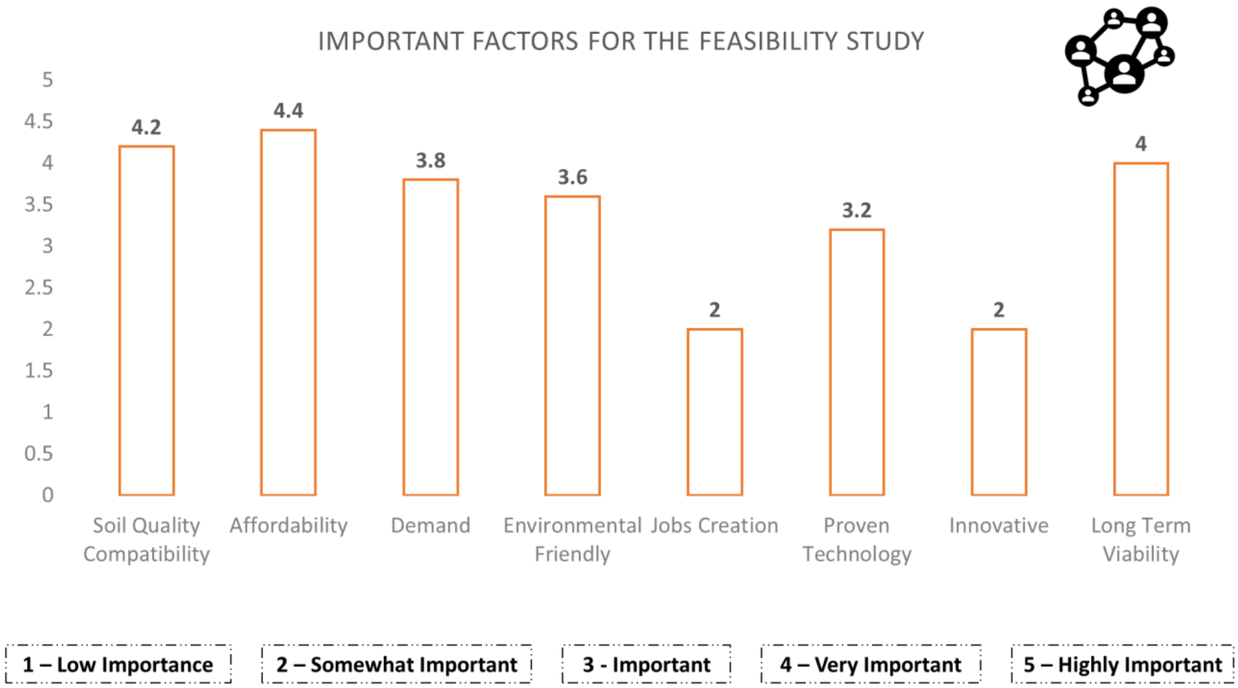


**Figure 14: Weighted Important factors for the feasibility study by Surveying CoV Staff**

## 8.0 The Repurposing Options for Existing Stockpiled Soils at VLF

The following paragraphs summarize the promising repurposing options for existing stockpiled soils at VLF in order of recommended implementation.

### 8.1 Rammed Earth

Rammed earth is a wall-building method in which an inorganic soil mix is compressed into sufficiently strong and accessible forms. There are 3 different grades of rammed earth where the most significant differences between them lie in their strengths:

- Traditional Rammed Earth (TRE) is the original type of rammed earth, as used in the Great Wall of China. It uses clay as a binder and has strength of 1 MPa. It is vulnerable to earthquakes, erosion from rain, and rising damp. [13] [14]

**Figure 15: Great Wall of China – eroded rammed earth wall (Built 2500 years ago)[11]**

**Figure 16: Alhambra, Palace in Granada, Spain (Built 700 years ago)[12]**

[11] Source: https://www.china-mike.com/china-tourist-attractions/great-wall-china/construction-history

[12] Source: https://www.britannica.com/topic/Alhambra-fortress-Granada-Spain

- Stabilized Rammed Earth (SRE) has the same components as TRE, with the addition of 10% cement. It typically has strength of 5 MPa and has reduced vulnerability to earthquakes, water damage, and fluctuating temperatures. [14]

- Structural Insulated Rammed Earth is by far the strongest rammed earth in the world, which makes it ideal for use in challenging climates and more adventurous architectural expression. It has strength of 20 MPa, achieved through careful selection of soil proportions and admixtures. [14]

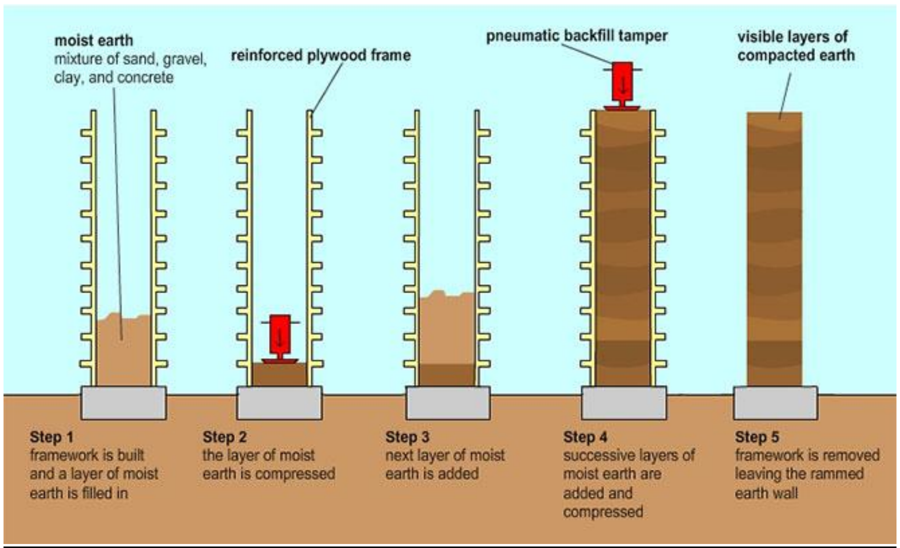


Figure 17: Rammed Earth Wall making process[13]


Figure 18: Van Dusen Botanical Garden, Vancouver[14]

[13] Source: https://www.innovativeearth.ca/rammed-earth

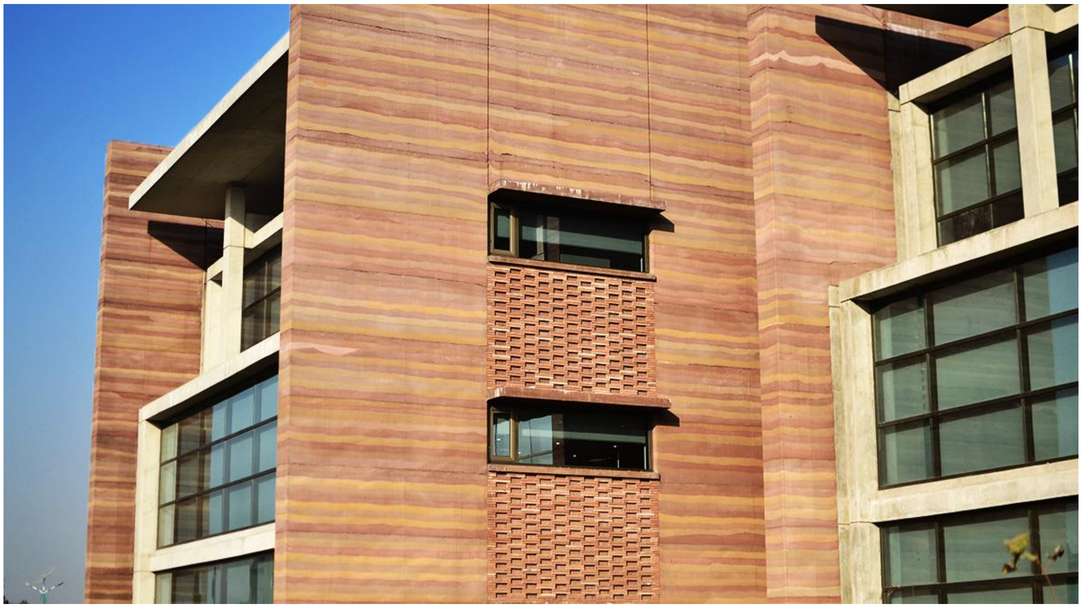

Figure 19: Telenor Head office, Islamabad[15]

Rammed Earth Walls are very challenging to implement in the Lower Mainland. Proper insulation and proper design mix are needed in order for these type of non- structural walls (walls that do not have load bearing purposes in the structural integrity of a building) to have a long life span. [14][15]

Figure 20: Efflorescence at cold joints in rammed earth wall, Van Dusen Botanical Garden[16]

14 Source: https://sirewall.com/project/van-dusen-botanical-garden
15 Source: https://sirewall.com/project/telenor-headoffice-islamabad
16 Source: Facilities Development Department of the City of Vancouver

### Soil type requirements & VLF soil compatibility [13] [14]

Soil requirements for rammed earth wall construction are:

- Clay, sand and gravel up to size of 3cm. Sand and gravel provide the structural strength where clay is the glue which holds the mixture together.
- Cement replaced the function of the clay as the glue in modern age. Almost every soil is suitable for rammed earth. The aim is to use local soil for the mixture. There is no existing fixed formula for the mixture since soil differs from one place to another. Every type of soil has to be analyzed, and sand and gravel added according to its clay content. One of the repurposing options for the excess waste soil can be rammed earth wall construction. The characteristics and composition of waste soil (Sandy loam and negligible organic matter) are quite suited with requirements of rammed earth wall construction.

### Pros: [14]

- **Long-term viability –** Rammed Earth Walls consist of 80-90 percent of soil. Large amount of soils is used to implement these types of walls.
- **Environmentally friendly** – It is more sustainable and environment-friendly option compared to cement construction based on the carbon footprint[17] of each product.
- **Soil quality compatibility** – VLF soil is compatible with soil quality requirements for rammed earth walls.

### Cons: [15]

- **Affordability –** More expensive than presently able construction methods (1.25 to 1.5 times approximately) mainly because of lack of expertise and high labour demand.
- **Proven technology** – Rammed earth is easy to do but difficult to do well. To achieve the desired structural properties, careful mix-design is required.

### Applicability

To implement this option, CoV should hire rammed earth wall specialists. During the first year of operation, wall construction costs might be higher than conventional construction methods due mainly to learning curves during implementation. It can be long term solution for the VLF's excess soil problem.

[17] The amount of carbon dioxide and other carbon compounds emitted due to the consumption of fossil fuels during the process.

## 8.2 Stabilized Mud Blocks (SMBs)

Stabilized Mud Blocks (SMBs) are manufactured by compacting wetted mixture of soil, sand, and stabilizer (Lime, Cement etc.) in a machine into a high-density block. Such blocks are used for the construction of load-bearing masonry. Key highlights are:

- High Compressive Strength
- Reduction of carbon footprint as compared to concrete construction
- Common Stabilizers – Lime and Cement

To improve the quality of bricks, proper clay selection and mix design are essential. Careful selection is required of raw materials including clay, lime, gypsum, and cement, which can assist in the production of strong, high-quality bricks/blocks. [16] [17]

### Technology

The introduction of manual and semi-mechanized machines to produce mud stabilized bricks and blocks have improved the overall properties of the final products. Using semi-automatic hydraulic machines has also resulted in increased production capacity. Different sized blocks can be produced by changing the molds on a single machine. [16] [17]

**Figure 21: Stabilized Mud Blocks production technology**[18]

### Selection of Materials

Topsoil and organic soils (eventually lead to growth of mould) must not be used. But, with some knowledge and experience, it is possible to choose from many different types of soil to produce mud stabilized blocks. Identifying the correct type of soil with compatible properties of soil is essential in producing good-quality products. Furthermore, the selection of a stabilizer will depend on the quality of the soil and the project's requirements. Cement is preferable for sandy soils and to achieve greater strength quickly. Lime is better for high clay content soil but takes longer to harden and to produce strong blocks. [16] [17]

[18] Source: Google Images

### Stacking and Curing of the Blocks

When first produced, stabilized blocks are very low in strength. To attain a suitable strength, as well as other physical properties (tensile strength, flexural strength etc.), blocks need curing for three weeks. Cement-based stabilized-blocks reach their cured strength in approximately three weeks, but the lime and gypsum may continue to gain strength over time, even after blocks have been incorporated into the construction. Whenever cement is used, it must be covered and cured properly. Cement needs water to gain strength (hydration) and it requires 28 days to achieve full strength. It achieves 65% of its cured strength in the first seven days, reaching about 85%-strength by 14 days. The remainder of the cured strength is obtained during the third week of formation and curing. [16] [17]

### Sustainability and Environmental Friendliness

Stabilized mud blocks always qualify as green building materials. The soil is a traditional construction material and is widely available throughout the world, and the production of mud blocks using machine-based stabilization processes consumes less energy than producing an equivalent quantity of burnt clay or cement bricks. The use of an interlocking design with SMBs can also result in material savings when joining and plastering sections of the wall. [16] [17]

### Soil type requirements & VLF soil compatibility

Stabilized Mud Blocks (SMBs) can be another repurposing option for excess waste soil to use in construction. It is a very good alternative for burnt clay bricks and also has better structural properties than conventional bricks. Obtaining high-quality SMBs depends on access to good and locally available soil, selecting a stabilizer that will complement the soil type, and following good practice during the production of the blocks and their use in construction. [16] [17]

### Pros: [16] [17] [18] [45]

- **Affordability** – SMBs technology offers affordable construction implementation. The bricks are weatherproof, meaning there is no requirement for a plaster finish on the building exterior. In addition, because of its interlocking design, little cement is needed between block joints, allowing walls to be constructed rapidly, with associated savings in labour. Moreover, SMB machinery is easy to transport and use on construction sites.
- **Proven Technology** – SMBs constructions have been proved to be strong and durable compared with traditional construction methods. They are suitable for the construction of multi-storey buildings and have good compressive strength.
- **Proven Technology (SMBs machine)** – The SMBs machine is easy-to-use and to maintain. After long periods of use, repairs are easy to carry out locally, using scrap material and welding. The interlocking design of the blocks, walls are easy and quick to construct.
- **Environmentally Friendly –** SMBs technology provides an alternative to the widely seen fired brick which is currently causing serious environmental degradation.
- **Job Creation –** Typically a block production operation would require 11- 13 personnel

- **Demand –** SMBs technology is growing in popularity as a result of its aesthetic appeal and has been successfully embraced by many communities that have developed the knowhow to make use of it. Another benefit of SMB is its compatibility with traditional methods of construction that local contractors are familiar with.
    - Sanitation - Stabilized Mud Blocks (SMBs) are ideal for water and sanitation applications. SMBs can be used to construct water tanks, linings for pit latrines, and septic tanks.

**Cons:**

- CoV does not have the subject matter expertise for Stabilized Mud Blocks production

**Applicability**

To understand the mix-design and stabilizer selection process, a specialist is needed. SMBs machine is easy to transport and can be used on big construction site which eliminate the transportation cost of bricks.

## 8.3 Soil-Brick Powder based Geo-polymer Composite

Geo-polymer products can be made using materials that are rich in silica and alumina with alkalis as a polymerisation agent. The chemical reaction, also known as poly-condensation, takes place with the assistance of thermal and/or mechanical activation. The production of this moderate-strength geo-polymer composite uses two raw materials:

- Soil
- Brick-Powder (BP)

By varying the proportion of soil and brick-powder, cubes with moderate strength (3.5–10.0 MPa) can be produced. The strength gain has been further enhanced by thermal activation at ambient temperature and mechanical activation by inter-grinding of Cement, Brick-Powder (BP), and soil. [19][20]

**Material Requirements [19]**

- High-Clay Content Soil
- Brick Powder
- Lime-pozzolana Cement
- Sodium hydroxide and Sodium silicate solution

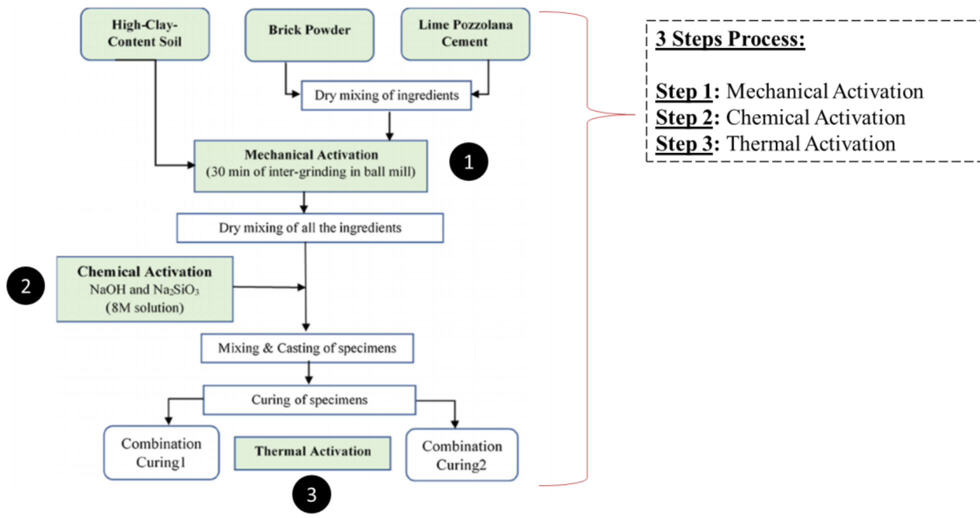


Figure 22: Flow chart for the making of Geo-polymer composite[19]

### Soil type requirements & VLF soil compatibility [19] [20]

This option provides the ability to use two types of wastes such as Soil (from the transformational project – Excess Soil) and Brick Powder (from the transformational project – Construction & Demolition waste). Soil-Brick Powder based Geo-polymer composite can be useful for making electric power poles, waste containment, bus stop seating etc.

### Pros: [19] [20]

- **Long Term Viability -** It can be a common solution for two transformational projects.
- **Environmentally Friendly –** Because of less use of cement, it is more environmentally friendly compare to conventional concrete.
- **Affordability –** Cost effective and easy process.

### Cons: [19]

- COV does not have the expertise in this field
- **Soil Quality Compatibility** – High Clay Content Soil required. Available VLF soil is sandy in nature.

### Applicability

COV may need to hire a specialist to understand and proper execution of the process. Sandy soil can be used but special additives (i.e. Lime or cement) should be added to maintain the same strength.

[19] Source: Jyothi, T.K., P.T. Jitha, S.K. Pattaje, and J. Kaup (2018) Studies on the Strength Development of Lime–Pozzolana Cement–Soil–Brick Powder Based Geo-polymer Composites, Journal of The Institution of Engineers (India): Series A

## 8.4 Glass Production

Sand alone is enough to make glass, however, the temperature required to melt it will be much higher. For this reason, Sodium Carbonate is added as a modifier. Limestone (Calcium Oxide) is added to make the glass more durable.

The Manufacturing process begins with the raw materials being automatically mixed (Sand, Silica, Limestone, Soda Ash and chemicals for coloring) fed into a furnace where they are super-heated and fused. This molten glass is then poured into different machines for further shaping and designing. [21]

### Packaging

Many sources and subject matter experts agree that when it comes to packaging, storing, microwaving, consuming, boiling, freezing or baking, glass is the best material to use. Here is a look at why other packaging is bad, and finally why glass is so good. [21]

- **Plastic Packing [21]**

  The foods that we consume are always touching plastic, from raw material transport to production lines, shipping and storing. The biggest factor with plastic packaging is that the container leaks little particles of chemicals to the food that is supposedly not good for human consumption. So, if any, what are the actual hazards of having plastic so closely interconnected with the food that we consume?

  There are a lot of different kinds of plastic, and manufacturers add different chemicals depending on how exactly they want their plastic. It could be for durability, storage, minimum production costs, flexibility, etc.

  Usually, these components consist of Bisphenol A (BPA), Polybrominated Diphenyl Ethers (PBDE) and Tetrabromobisphenol A (TBBPA). And studies have shown that these chemicals alter hormonal expression in animals and humans. These chemicals are grouped under Endochirne-Disrupting Compounds (EDCs) and the hormone distributions that they effect include oestrogen activity, anti-androgens, thyroid hormone homeostasis interference, and prostate gland development in foetuses, infants and children. Some of the plastic additives are chemicals called Monomers which research has shown to have cancer-causing compounds along with mutation inducing elements.

- **Canned Food [21]**

  As with plastic, the chemical responsible for the most worry in canned food is also Bisphenol A (BPA). The chemical compound is used in the plastic as a lining for the aluminium container.

- **Glass Packaging [21]**

  Glass packaging does not leak chemicals into the food and keeps airtight food fresh for a long time, not interfering with the taste and odour of the food inside. It is an excellent barrier to the outside world as it is nonporous and impermeable. It also has a zero rate of chemical interactions maintaining the food inside correctly. Because glass is viscous when heated, packaging can take any form or shape, and certain high-end products are packaged with unique handmade glass containers.

  Glass containers and packaging comes in the form of bottles, jars, cups, jugs, mugs, glasses for various beverages, plates, pans to cook, trays to bake and microwave, baby products, etc. Nearly all of these containers and packs are safer in terms of human health than their alternatives.

### Materials Required for Glass Production and VLF Soil Compatibility [21]

- Sand or Silica – 75 to 85 percent
- Sodium Carbonate – 5 to 10 percent
- Lime or Calcium Oxide – 5 to 10 percent
- Additives – Lead/Boron/Lanthanum Oxide/Iron – 1 to 2 percent
- Colour Additives – 1 to 2 percent

VLF Soil can be used for glass production. It's anticipated that to achieve zero waste 2040 strategic vision, single-use item should be banned, and glass products can be the substitute products that serve beverage and food containment need.

### Pros: [21]

- **Proven Technology –** Glass has been proven to be the best packaging for food in terms of health, taste and the environment.
- **Demand –** Glass containers and packaging comes in the form of bottles, jars, cups, jugs, mugs, glasses for various beverages, plates, pans to cook, trays to bake and microwave, baby products etc.
- **Soil Quality Compatibility –** Sand alone is enough to make glass. VLF soil is compatible for glass production because of its sandy nature.
- **Environmentally Friendly –** It is 100% recyclable making it good for the environment we live in. It also had a zero rate of chemical interactions maintaining the food inside correctly.
- **Affordability –** Glass making process is easy and inexpensive.

### Cons: [21]

- CoV does not have the expertise in this field.

### Applicability [21]

This option can be used in two ways:

- Excess soil can be given to an already existing glass manufacturer; or
- After single use item banned for use, CoV can do demand and opportunity analysis and go for in-house glass production.

## 8.5 Soil Blending

### For use in agriculture or horticulture

Soil blending for use in agriculture or horticulture means to mix soil or other material that is suitable for agriculture or any other land to obtain a uniform material of a desired quality, harmonizing the individual components. [22]

#### VLF soil compatibility

As per lab tests and VLF site review, certain excess soil at VLF requires soil blending (probably with 5 to 10 percent of compost) before it is appropriate for any use for agriculture or horticulture.

#### Pros:

- **Demand –** After a certain amount of time, agriculture lands do require blended soil to replenish its nutrient holding capacity. Blended soil from VLF will be helpful for farmers and local residents.
- **Soil Quality Compatibility –** Blended soil with compost will result in nutrient rich soil. It can also be used for maintenance of CoV's parks and farmlands.
- **Affordability –** Inexpensive and easy process.

#### Cons:

- **Demand –** Variable and insignificant demand
- Easy and reasonable price of compost by VL Compost Facility. Farmers may prefer compost over the blended soil.

#### Applicability

The VLF already has soil blenders which are being used for blending soil for landfill covering and closing process. The same blenders can be used for this option.

### For use in Landfill closure / Mine reclamation

#### Landfill covering and closure: [22]

The cover on an operational landfill site is the layer of compressed soil which is laid on top of the deposition of waste. The cover helps prevent the interaction between the waste and the air, reducing odours and enabling a firm based upon which vehicles may operate. The excavated soils that are stockpiled at VLF are currently being used for this purpose.

#### Mine reclamation: [22]

Mine reclamation is the process of restoring land that has been mined to a natural or economically usable state. Although the process of mine reclamation occurs once mining is completed, the planning of mine reclamation activities occurs prior to a mine being permitted or started. These reclamation activities would require soils that have not been contaminated with toxic or mine substances. Therefore, the excavated soils received at Vancouver Landfill can be repurposed as soils used for mine reclamations.

### VLF soil compatibility

For the past four decades, excavated waste soils were used at VLF for landfill covering and closing processes. After each of VLF's cells closure projects has been completed, the excavated soils can be used for other landfill closures or mine reclamation projects in other regions.

### Pros:

- **Affordability –** Soil Blending is an easy and inexpensive process.
- **Demand –** Due to Vancouver's location near to USA border, there may be some opportunity from the State of Washington for their landfill closure projects.
- **Demand –** Mine reclamation soil demand is variable but significant.

### Cons:

- Unpredictable demand.
- Soil transporting to the USA can be a tricky process. It may require a lot of paperwork and permits.

### Applicability

Proper communication to other municipalities and major mining companies about the quantity and quality of available soil is essential.

## 8.6 Pottery

Pottery, one of the oldest and most widespread of the decorative arts, consists of objects made of clay and hardened with heat. The objects that are produced from this process include plates or bowls that can be decorative and functional.[23] However, high clay content soils are needed for pottery produced objects. Sandy loam soils can contain as much as 20% clay. Though most soil has some clay content, the yield will obviously be higher for high clay soils. There are two traditional methods for harvesting clay: [24]

- Dry clay harvest method
- Wet Clay harvest method

### VLF soil compatibility

After single-use items ban, pottery and ceramic products can be a good alternative, in addition to glass products. However, VLF soil waste is mostly sandy loam (having clay content 5-10 percent) in nature and which is not very good raw material for making pottery.

**Pros: [24]**

- **Affordability –** Inexpensive and easy process.
- **Demand –** Vancouver itself has more than 20 pottery houses. Waste soil can be given away to these pottery houses. Major pottery houses in Vancouver:
  - Britannia Community Services Centre, 1661 Napier St, Vancouver, BC V5L 4X4
  - Douglas Park Community Centre — located at 801 West 22nd Avenue
  - The False Creek Community Centre is located at 1318 Cartwright St, Vancouver, BC. 604-257-8195
  - Kensington Community Centre, 5851 W Boulevard, Vancouver, BC. 604-257-8100

**Cons:**

- **Demand –** Insignificant tonnage, one pottery house may require maximum of 10 tonnes of soil in a year.
- **Environmentally Friendly –** The whole process requires mainly only clay so 80-90 percent of sand will be the wasted from the process. It may not serve the ultimate intent of the Zero waste 2040 plan

**Applicability:**

Not recommended. But it should be discussed further with local pottery house managers.

## 8.7 Bricks

In the history of professional construction practices, brick is one of the oldest of all building materials. It is also arguably the most durable, since there are brick walls, foundations, pillars, and road surfaces constructed thousands of years ago that are still intact. Today, bricks are most often used for wall construction, especially as an ornamental outer wall surface. [25] [27]

Bricks are produced in numerous classes, types, materials, and sizes which vary with region and time period, and are produced in bulk quantities. Two basic categories of bricks are fired and non-fired bricks. [26] [27]

- Fired bricks are one of the longest-lasting and strongest building materials, sometimes referred to as artificial stone, and have been used since circa 4000 BC.
- Air-dried bricks, also known as mudbricks, have a history older than fired bricks, and have an additional ingredient of a mechanical binder such as straw.

Starting in the 20th century, the use of brickwork declined in some areas due to concerns with earthquakes. Earthquakes revealed the weaknesses of unreinforced brick masonry in earthquake-prone areas. During seismic events, the mortar cracks and crumbles, and the bricks are no longer held together. Brick masonry with steel reinforcement helped hold the structure together during earthquakes, and was used to replace many of the unreinforced masonry buildings. Retrofitting older unreinforced masonry structures has been mandated in many jurisdictions. [28]

Figure 23: Old State House Boston[20]

### Brick Making Process [29]

Manufacturing of bricks consists of the following 4 operations or steps.

1. Preparation of brick clay or brick earth
2. Moulding of bricks
3. Air drying of bricks
4. Burning of bricks

[20] Source: brickarchitecture.com/about-brick/why-brick/the-history-of-bricks-brickmaking

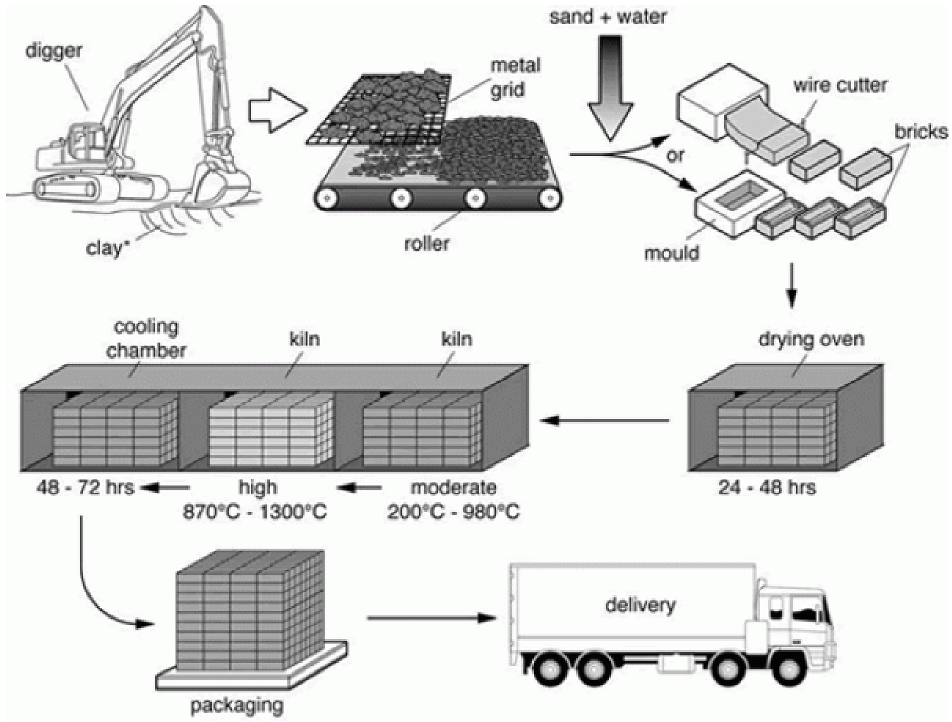


Figure 24: Brick making process[21]

### Burnt Clay Bricks contain: [30]

- Silica (sand) – 50% to 60% by weight
- Alumina (clay) – 20% to 30% by weight
- Lime – 2 to 5% by weight
- Iron oxide – ≤ 7% by weight
- Magnesia – less than 1% by weight

### VLF Soil compatibility

Burnt Clay Bricks can be one of the options to reuse the VLF waste soil. Although VLF waste soil only has clay content of 5% to 10%, that soil can be used after adding special modifiers like cement or lime.

[21] Source: civilblog.org/2014/02/25/4-primary-steps-involves-in-brick-manufacturing/

### Pros [28] [29] [30]

- **Affordability –** Cost effective and easy process.
- **Proven Technology –** Brick making is a 2,000 years old process and it doesn't require any special expertise.
- **Demand –** these days, bricks are most often used for wall construction, especially as an ornamental outer wall surface.
  - Aesthetics: Bricks offer natural and a variety of colors, including various textures.
  - Strength: Bricks offer excellent high compressive strength.
  - Porosity: The ability to release and absorb moisture is one of the most important and useful properties of bricks, regulating temperatures and humidity inside structures.
  - Fire protection: When prepared properly, a brick structure can give a fire protection maximum rating of 6 hours.
  - Sound attenuation: The brick sound insulation is normally 45 decibels for a 4.5 inches brick thickness and 50 decibels for a 9-inch thick brick.
  - Insulation: Bricks can exhibit above normal thermal insulation when compared to other building materials. Bricks can help regulate and maintain constant interior temperatures of a structure due to their ability to absorb and slowly release heat. In this way, bricks can produce significant energy savings—more than 30 percent when compared to wood construction.
  - Wear-resistance: A brick is so strong such that its composition provides excellent wear resistance when compared to wood.

### Cons: [27] [28] [29] [30]

- **Environmental Impact** – Fired brick making process has a significant carbon footprint.
- **Demand**
  - Very low tensile strength
  - Rough surfaces of bricks may cause mold growth if not properly cleaned
  - Cleaning brick surfaces is a hard job
  - Colour of low-quality brick changes when exposed to sun for a long period of time
  - Time consuming construction
  - Cannot be used in high seismic zones
  - Since bricks absorb water easily, it causes efflorescence when not exposed to air

### Applicability

The City of Vancouver can have discussion with major brick producers in BC to take soil from the VLF which can be used as a raw material for brick making. Cost of transporting soil from VLF to their plant should be discussed beforehand. Major brick producers in BC include:

- BC Brick Supplies Ltd., 3100 No. 5 Road, Richmond, B.C. Canada V6X 2T5
- I-XL Surrey, #105 – 19033 54 Ave., Surrey, BC V3S 4R1, Phone: (604) 574-2288

## 8.8 Hempcrete

Hemp can be used to make building and insulation material by combining the shiv -the woody inner core of the hemp plant- with lime, Clayey soil and water, to make a bio-composite with the consistency of porridge. To date, this hemp-lime mixture has been used as a type of concrete; poured into removable wooden formwork[22], lightly tamped down and dried to produce a 450mm wall cast around a timber frame. This process provides structural stability as well as insulating benefits and was named 'Hempcrete'. [31] [32]

This natural concrete is highly insulating, lightweight, and resistant to pests and mould, and has good acoustics. In this form, although fairly strong, is not suitable for structural, load-bearing walls. This makes the material perfect for the renovation and retrofitting of old buildings to new energy efficiency standards. [34]

The additional benefit of this bio composite is that it acts as a carbon sink. The hemp plant absorbs CO2 in the growth phase, which is then locked into the material. The material then continues to absorb CO2 throughout its lifetime, pulling more CO2 from the atmosphere, but also increasing the strength of the material. It is claimed that hemp and lime mixtures of this nature can lock up approximately 110 kg of CO2 per $m^3$ of wall. [33] [34]

Figure 25: Main entrance of the Maui hemp house[23]

### Material Required [34][35]

- Hemp Hurds (fibres) – 25 to 35 percent
- Paper pulp – 5 to 10 percent
- Lime – 10 to 15 percent
- Clayey Soil – 35 to 50 percent
- Additives – 1 to 2 percent

[22] Formwork is temporary or permanent molds into which concrete or similar materials are poured.
[23] Source: American Lime Technology (Builder: George Rixey, Rixey Co.; Photographer: Travis Rowan, Living Maui Media)

### VLF soil compatibility

Most VLF soil is sandy in nature. It cannot be used directly for hempcrete production. It does require adding some modifiers to achieve desired properties. The main objective to include hempcrete as an option is to introduce this new product to the industry and convey that a lot of research is going on. In future, sandy soil could be directly used for the production of hempcrete.

### Pros [35]

- **Environmentally friendly** – Potential for carbon neutral construction
- Energy efficient– Thermal mass assists temperature control in both low and high temperatures
- **Demand:**
    - Earthquake resistance-rebar reinforced monolithic integral wall system
    - Inherent fire resistance and noise cancelling
    - Natural moisture regulation within the home


Figure 26: Advantages of Hempcrete[24]

[24] Source: criticalconcrete.com

### Cons [35]

- **Innovation**: Not enough research has taken place on hemp concrete to date. Lack of complete understanding of material science. Not commercially viable at present.
- **Proven Technology**: At present, hemp concrete is used as a non-load bearing building component/ in-fill material
- **Proven Technology:** Only one method of construction - timber frame structure has been scientifically validated.
- **Affordability:** Manufacturing processes are not standardised. Safe only for non-structural purposes and difficult to estimate total cost.
  - Lime based construction is tricky and requires a certain amount of training to be imparted to personnel.
  - Mechanical properties are not in the desired range - low compressive strength, flexural strength, etc.

### Applicability

Presently, VLF excess soil is efficiently being used at the landfill for covering and closing purposes. In the future, when VLF starts implementing other repurposing options to manage its waste soil, hempcrete making processes should be revisited.

## 8.9 Disposal at Sea

Disposal at sea is the deliberate disposal of approved material from a ship, an aircraft, platforms or other structures at sea. It is permitted by Canadian law under Part 7, Division 3 of the Canadian Environmental Protection Act, 1999 (CEPA 1999). The permit system allows Canada to meet its international obligation to prevent marine pollution by regulating the disposal of wastes and other matter in accordance with the London Protocol. [36] [37]

### Approved Materials in British Columbia for Disposal at sea

In British Columbia, approved material for which no beneficial use or practical land-based disposal options can be identified may be disposed of at designated disposal sites. This material includes: [36] [37]

- Dredged material
- Inert, inorganic geological matter
- Uncontaminated organic matter
- Inert, bulky items such as concrete, steel
- Ships, aircraft, platforms, or other structures

CEPA 1999 prohibits the disposal at sea of material which may be harmful to human health and the marine environment. The disposal of hazardous wastes in Canadian marine waters is prohibited.

### Permit Process and Regulation [38] [39]

Environment Canada regulates disposal at sea by means of a permitting process in accordance with the requirements and regulations of CEPA 1999. All proposed disposal at sea projects are also reviewed and assessed in accordance with the Canadian Environmental Assessment Act and are registered in an on-line public registry. This registry is available at www.ceaa-acee.gc.ca.

- Permit applications to load and dispose of material are reviewed and assessed by Environment Canada. Permit applications must include proof of publication of a Notice of Intent in a newspaper local to the proposed project area.
- The public is invited to comment on the proposed loading and disposal activities during the application process.
- Only material that has been rigorously tested and meets CEPA 1999 regulations may be considered for disposal at sea. Guidance for sampling and testing is updated to keep pace with new methods and technology.
- All disposals at sea permits and permit amendments are published in the Canada Gazette before issuance and are subject to a 30-day public comment period.
- Once the permit is issued, Environment Canada Enforcement Officers may conduct surveillance monitoring and inspections at both loading and disposal sites to ensure compliance with disposal at sea permit conditions.

### Disposal at sea: service standards and fees: [40]

Table 8: Disposal at Sea: service standards and fee

| | Until March 31, 2019 | April 1, 2019 |
|---|---|---|
| **Application fee (non-refundable)** | $2,500 | $2,555 |
| **Permit fee (in cubic meter)** | $470 per 1000 $m^3$ | $480.34 per 1000 $m^3$ |
| **Permit fee (in tonnage) *** | $470 per 1500 metric tonnes | $480.34 per 1500 metric tonnes |

*One cubic metre of moderately damp soil (as freshly dug) soil weighs 1.3- 1.7 tonnes when dug, depending on how tightly packed it is.[25]

### Why is Disposal at Sea Necessary? [36] [37]

In British Columbia, coastal topography and the availability of suitable landfill sites are key constraints to waste management alternatives. Disposal at sea is one of these waste management alternatives that can be considered when all practical land-based and beneficial-use methods are exhausted.

### Disposal Sites in British Columbia [36] [37]

In British Columbia, there are 14 designated sites. Disposal sites are designated according to selection criteria established by CEPA 1999. The disposal site selection criteria include:

- Proximity to fishery resources and habitat

[25] Source - https://www.topsoilshop.co.uk/topsoil-calculator

- Interference with marine use in the area
- Evaluation of mixing and transport characteristics at the site
- Feasibility of monitoring the disposal site
- First Nations concerns

Disposal Sites

1. Brown Passage
2. Johnstone strait - Hanson Island
3. Johnstone strait - Hickey Point
4. Cape Mudge
5. Malaspina strait
6. Cape Lazo
7. Five Finger Island
8. Watts point
9. Thornbrough Chancer
10. Point Grey
11. Sand Heads
12. Victoria
13. Porfler pass
14. Gabriola

### Disposal Site Monitoring [36] [37]

Disposal site monitoring is an integral part of the disposal at sea program. Monitoring helps ensure that the permit conditions are met by the permit holder, and that assumptions made during the permit review and site selection process are accurate and sufficient to protect human health and the environment. Monitoring activities provide important feedback to resource managers about the permit and assessment whereby terms and conditions may be modified as necessary to ensure adequate environmental protection.

Disposal sites in British Columbia have been routinely monitored over the past thirty years. Sediment from the disposal sites is collected and analyzed for chemical, biological and physical parameters. The results indicate that the marine environment at disposal sites has not been significantly affected by disposal at sea activities.

### VLF soil compatibility [36] [37]

VLF soil can be disposed of at sea. It can receive approval under the material category “inert, inorganic geological matter”.

### Pros:

- It can be a backup plan for VLF soil waste management.
- **Affordability** – Economical solution to get rid of a large amount of waste soil.
- **Proven Technology** – The City of Vancouver can give subcontracts to private excavators to avoid permit applications and handling processes.

### Cons:

- **Environmental Impact** – It is not a 100 percent sustainable option and may have some environmental impact.

### Applicability

As of the writing of this report, there is significant construction underway in Metro Vancouver. Excavated soil is the most common waste product of all construction activities. Major private contractors in Vancouver are subcontracting to private excavators for excavation and handling their excavated waste soil. VLF can hire one of these private excavators for handling its waste soil.

## 8.10 Local Building Material Suppliers[26]

There are a number of companies in Vancouver region using significant amounts of soil for various purposes such as backfilling after oil tank removals, beach sand for volleyball ground preparation etc. These companies mostly rely on local building material suppliers for soil.

### VLF soil compatibility

As per the discussions with one of these companies' regional managers, VLF soil can be processed as per their standard and then sent for further distribution. They sold approximately 1.5 million metric tonnes of soil last year in the Vancouver region. [43] [44]

### Pros: [44]

- **Long Term Viability** – It can be long term solution for VLF soil waste.
- **Demand –** With the help of these companies, VLF excess soil will get a new and bigger platform.
- **Affordability** – Inexpensive and a less risky and option than others.

### Cons: [44]

- **Soil quality compatibility** – VLF may need to start a soil quality monitoring program to support soil standardization.

[26] Appendix E- Lafarge Product Guide – Sand Selection

### Applicability

Further discussion with key personnel of these companies is required. As per understanding, they would need to do a site visit and perform a detailed soil analysis before consideration of VLF soil.

## 9.0 Conclusions & Recommendations

CoV staff stakeholders were selected for a focus group to evaluate the importance of the previously identified feasibility factors. Their inputs were used to develop weighting for these factors. The following Table 8 summarizes the feasibility analysis results based on the *Harvey ball* Evaluation scoring.

**Table 9: Final Evaluation Matrix**

| Description | Soil Quality Compatibility | Affordability | Demand | Environmental Friendly | Jobs Creation | Proven Technology | Innovative | Long term viability | Weighted Score |
|---|---|---|---|---|---|---|---|---|---|
| | 4.2 | 4.4 | 3.8 | 3.6 | 2 | 3.2 | 2 | 4 | |
| Disposal at Sea | ● | ◕ | ● | ◑ | ◔ | ◕ | ◔ | ◑ | 101.2 |
| Building Material Suppliers | ◕ | ◕ | ◕ | ◕ | ◔ | ◑ | ◔ | ◑ | 93.6 |
| Stabilized Mud Blocks | ◑ | ◕ | ◑ | ◕ | ◑ | ◕ | ◑ | ◑ | 92.8 |
| Rammed Earth Walls | ◕ | ◔ | ◔ | ◕ | ◑ | ◕ | ◑ | ◕ | 88.4 |
| Glass Production | ◕ | ◑ | ◑ | ◔ | ◑ | ◕ | ◔ | ◕ | 87.4 |
| Geo-polymer Composite | ◕ | ◑ | ◑ | ◑ | ◑ | ◑ | ◑ | ◑ | 85.8 |
| Soil Blending | ◕ | ◕ | ◔ | ◑ | ◔ | ◕ | ◔ | ◑ | 85.6 |
| Pottery | ◔ | ◕ | ◑ | ◕ | ◔ | ◕ | ◔ | ◔ | 80.6 |
| Burnt Clay Bricks | ◔ | ◕ | ◑ | ◔ | ◑ | ◑ | ◑ | ◑ | 78.2 |
| Hempcrete | ◔ | ◔ | ◔ | ◕ | ◑ | ◔ | ◕ | ◑ | 71.6 |

○ – Lowest Rating ◔ – Challenging ◑ - Average ◕ – Very Good ● – Top Rating

Disposal at sea, building material suppliers, and Stabilized Mud Blocks (SMBs) repurposing solutions should be investigated further in depth using a triple bottom line business case approach. The moderate viable options can undergo business case evaluations if additional resources are available at the City of Vancouver.

It is important to note that further discussions are needed between the Transfer and Landfill Operations (TLO), Solid Waste Strategic Services (SWSS) and Kent Construction Supplies and Services (Kent Yard) branches of the Engineering Department to fully map the excavated soils waste stream from source to VLF.

Finally, a soil monitoring program is required in order to provide additional soil composition test results data on a consistent basis to minimize the standard deviation to an acceptable margin of error for potential future business cases.

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# Appendix A: VLF Soil Inflow – Forecasting

VLF Soil Inflow - Forecasting - Based on Historical Trends

| | Max | Min | Max | Min | Max | Min | | |
|---|---|---|---|---|---|---|---|---|
| **Year** | **From Vancouver** | **From Vancouver** | **From Delta** | **From Delta** | **Total (From Vancouver & Delta)** | **Total (From Vancouver & Delta)** | **From Vancouver %** | **From Delta %** |
| **2014** | 286,475 | 286,475 | 72,116 | 72,116 | 358,591 | 358,591 | 80% | 20% |
| **2015** | 235,253 | 235,253 | 88,947 | 88,947 | 324,200 | 324,200 | 73% | 27% |
| **2016** | 235,957 | 235,957 | 80,494 | 80,494 | 316,451 | 316,451 | 75% | 25% |
| **2017** | 286,076 | 286,076 | 202,263 | 202,263 | 488,339 | 488,339 | 59% | 41% |
| **2018** | 242,708 | 242,708 | 263,604 | 263,604 | 506,312 | 506,312 | 48% | 52% |
| **2019** | 240,497 | 234,793 | 271,891 | 265,443 | 512,388 | 500,236 | 47% | 53% |
| **2020** | 238,197 | 227,033 | 280,339 | 267,200 | 518,536 | 494,233 | 46% | 54% |
| **2021** | 235,808 | 219,426 | 288,951 | 268,877 | 524,759 | 488,303 | 45% | 55% |
| **2022** | 233,327 | 211,968 | 297,729 | 270,475 | 531,056 | 482,443 | 44% | 56% |
| **2023** | 230,753 | 204,658 | 306,676 | 271,996 | 537,429 | 476,654 | 43% | 57% |
| **2024** | 228,083 | 197,493 | 315,795 | 273,441 | 543,878 | 470,934 | 42% | 58% |
| **2025** | 225,316 | 190,470 | 325,088 | 274,812 | 550,404 | 465,283 | 41% | 59% |
| **2026** | 222,450 | 183,588 | 334,559 | 276,112 | 557,009 | 459,699 | 40% | 60% |
| **2027** | 219,482 | 176,843 | 344,211 | 277,340 | 563,693 | 454,183 | 39% | 61% |
| **2028** | 216,411 | 170,233 | 354,046 | 278,499 | 570,458 | 448,733 | 38% | 62% |
| **2029** | 213,235 | 163,757 | 364,068 | 279,591 | 577,303 | 443,348 | 37% | 63% |
| **2030** | 209,952 | 157,412 | 374,279 | 280,616 | 584,231 | 438,028 | 36% | 64% |
| **2031** | 206,559 | 151,195 | 384,683 | 281,576 | 591,241 | 432,771 | 35% | 65% |
| **2032** | 203,054 | 145,105 | 395,282 | 282,473 | 598,336 | 427,578 | 34% | 66% |
| **2033** | 199,436 | 139,139 | 406,081 | 283,308 | 605,516 | 422,447 | 33% | 67% |
| **2034** | 195,701 | 133,296 | 417,082 | 284,082 | 612,783 | 417,378 | 32% | 68% |
| **2035** | 191,848 | 127,572 | 428,288 | 284,797 | 620,136 | 412,369 | 31% | 69% |
| **2036** | 187,874 | 121,967 | 439,703 | 285,453 | 627,578 | 407,421 | 30% | 70% |
| **2037** | 183,778 | 116,478 | 451,331 | 286,053 | 635,109 | 402,532 | 29% | 71% |
| **2038** | 179,556 | 111,104 | 463,174 | 286,598 | 642,730 | 397,701 | 28% | 72% |
| **2039** | 175,206 | 105,841 | 475,236 | 287,088 | 650,443 | 392,929 | 27% | 73% |
| **2040** | 170,726 | 100,689 | 487,522 | 287,525 | 658,248 | 388,214 | 26% | 74% |

## Appendix B: Vancouver Landfill – Transformational Projects

# Vancouver Landfill: Transformational Projects

**MSW**

- Reducing the amount of MSW going to Landfill by removing recyclables, organics and soil.
- Converting residual into an Refuse Derived Fuel (RDF)

**C&D**

- Reducing amount of C&D going to Landfill by processing the wood Alternative Fuel (AF) for cement kilns.
- Removing products from landfill including metals and concrete.

**ORGANICS**

- Adding food waste processing capacity within Metro Vancouver
- De-risking the City's exposure to relying on one processor

**SOIL**

(Future Project)

- Reducing amount of soil going to Landfill by creating topsoil or other soil amendments.

## Appendix C: Important factors for the feasibility study – Survey

**Important Factors for the Feasibility Study – Survey**

**Name:** Nicole **Date:** May 28, 2019

Please rate the following information on a scale of 1 to 5, with 5 being "strongly agree" and 1 being "strongly disagree"

| | | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| a. | Soil Quality Compatibility | | | | | ✓ |
| b. | Cost | | | | ✓ | |
| c. | Market Analysis /Demand | | | | ✓ | |
| d. | Environmental Impact | | | | ✓ | |
| e. | Jobs Creation / Maintaining Jobs | | ✓ | | | |
| f. | Tested-proved-implemented | | | ✓ | | |
| g. | Innovation | | | ✓ | | |
| h. | Long term solution (10-20 years) | | | | ✓ | |
| i. | Short term relief | ✓ | | | | |

## Important Factors for the Feasibility Study – Survey

**Name:** JERRY SOBEJKO **Date:** 28 MAY 2019

Please rate the following information on a scale of 1 to 5, with 5 being "strongly agree" and 1 being "strongly disagree"

| | | | | | | |
|---|---|---|---|---|---|---|
| a. | Soil Quality Compatibility | 1 | 2 | 3 | 4 | 5 |
| b. | Cost | 1 | 2 | 3 | 4 | 5 |
| c. | Market Analysis /Demand | 1 | 2 | 3 | 4 | 5 |
| d. | Environmental Impact | 1 | 2 | 3 | 4 | 5 |
| e. | Jobs Creation / Maintaining Jobs | 1 | 2 | 3 | 4 | 5 |
| f. | Tested-proved-implemented | 1 | 2 | 3 | 4 | 5 |
| g. | Innovation | 1 | 2 | 3 | 4 | 5 |
| h. | Long term solution (10-20 years) | 1 | 2 | 3 | 4 | 5 |
| i. | Short term relief | 1 | 2 | 3 | 4 | 5 |

## Important Factors for the Feasibility Study – Survey

**Name:** Faisal Mirza **Date:** May 28, 2019

Please rate the following information on a scale of 1 to 5, with 5 being "strongly agree" and 1 being "strongly disagree"

| | | | | | | |
|---|---|---|---|---|---|---|
| a. | Soil Quality Compatibility | 1 | 2 | 3 | **4** | 5 |
| b. | Cost | 1 | 2 | 3 | 4 | **5** |
| c. | Market Analysis /Demand | 1 | 2 | 3 | **4** | 5 |
| d. | Environmental Impact | 1 | 2 | **3** | 4 | 5 |
| e. | Jobs Creation / Maintaining Jobs | 1 | 2 | **3** | 4 | 5 |
| f. | Tested-proved-implemented | 1 | 2 | 3 | **4** | 5 |
| g. | Innovation | 1 | **2** | 3 | 4 | 5 |
| h. | Long term solution (10-20 years) | 1 | 2 | 3 | 4 | **5** |
| i. | Short term relief | 1 | **2** | 3 | 4 | 5 |

## Important Factors for the Feasibility Study – Survey

**Name:** Farbod Diba **Date:** May 28, 2019

Please rate the following information on a scale of 1 to 5, with 5 being "strongly agree" and 1 being "strongly disagree"

| | | | | | | |
|---|---|---|---|---|---|---|
| a. | Soil Quality Compatibility | 1 | 2 | 3 | 4 | 5 |
| b. | Cost | 1 | 2 | 3 | 4 | 5 |
| c. | Market Analysis /Demand | 1 | 2 | 3 | 4 | 5 |
| d. | Environmental Impact | 1 | 2 | 3 | 4 | 5 |
| e. | Jobs Creation / Maintaining Jobs | 1 | 2 | 3 | 4 | 5 |
| f. | Tested-proved-implemented | 1 | 2 | 3 | 4 | 5 |
| g. | Innovation | 1 | 2 | 3 | 4 | 5 |
| h. | Long term solution (10-20 years) | 1 | 2 | 3 | 4 | 5 |
| i. | Short term relief | 1 | 2 | 3 | 4 | 5 |

## Important Factors for the Feasibility Study – Survey

**Name:** Bhushan Goyal **Date:** May 28, 2019

Please rate the following information on a scale of 1 to 5, with 5 being "strongly agree" and 1 being "strongly disagree"

| | | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| a. | Soil Quality Compatibility | 1 | 2 | 3 | 4 ✓ | 5 |
| b. | Cost | 1 | 2 | 3 | 4 ✓ | 5 |
| c. | Market Analysis /Demand | 1 | 2 | 3 | 4 ✓ | 5 |
| d. | Environmental Impact | 1 | 2 | 3 | 4 ✓ | 5 |
| e. | Jobs Creation / Maintaining Jobs | 1 | 2 | 3 ✓ | 4 | 5 |
| f. | Tested-proved-implemented | 1 | 2 | 3 ✓ | 4 | 5 |
| g. | Innovation | 1 | 2 | 3 ✓ | 4 | 5 |
| h. | Long term solution (10-20 years) | 1 | 2 | 3 | 4 ✓ | 5 |
| i. | Short term relief | 1 | 2 | 3 ✓ | 4 | 5 |

## Appendix D: Soil Analysis - Report

CITY OF VANCOUVER - ENGINEERING
ATTN: Farbod Diba
1200-459 SW Marine Driver
Vancouver bc V5X DC3

Date Received: 29-MAY-19
Report Date: 17-JUN-19 14:59 (MT)
Version: FINAL REV. 2

Client Phone: 604-829-9507

# Certificate of Analysis

Lab Work Order #: L2281717
Project P.O. #: NOT SUBMITTED
Job Reference:
C of C Numbers:
Legal Site Desc:

Comments: ADDITIONAL 11-JUN-19 12:49

Edward Ngai
Account Manager



ADDRESS: 8081 Lougheed Hwy, Suite 100, Burnaby, BC V5A 1W9 Canada | Phone: +1 604 253 4188 | Fax: +1 604 253 6700
ALS CANADA LTD Part of the ALS Group An ALS Limited Company

# ALS ENVIRONMENTAL ANALYTICAL REPORT

| | Sample ID | L2281717-1 | L2281717-2 | L2281717-3 | | |
|---|---|---|---|---|---|---|
| | Description | soil | soil | soil | | |
| | Sampled Date | 16-MAY-19 | 16-MAY-19 | 16-MAY-19 | | |
| | Sampled Time | 12:00 | 12:00 | 12:00 | | |
| | Client ID | SAMPLE 1 VAN LANDFILL MAY 16,2019 | SAMPLE 2 VAN LANDFILL MAY 16,2019 | SAMPLE 3 VAN LANDFILL MAY 16,2019 | | |
| **Grouping** | **Analyte** | | | | | |
| **SOIL** | | | | | | |
| **Physical Tests** | Liquid Limit (LL) (%) | N/A ICC | 20 | 29 | | |
| | Moisture at Plastic Limit (%) | N/A ICC | 17 | 23 | | |
| | pH (1:2 soil:water) (pH) | 7.52 | 7.47 | 7.51 | | |
| | Plasticity Index (PI) (%) | N/A ICC | 3 | 5 | | |
| | Specific Gravity (kg/L) | 1.49 | 1.40 | 1.33 | | |
| **Particle Size** | % Gravel (>2mm) (%) | 13.9 | 13.6 | 6.6 | | |
| | % Sand (2.0mm - 0.063mm) (%) | 57.6 | 56.0 | 50.3 | | |
| | % Silt (0.063mm - 4um) (%) | 23.1 | 24.9 | 34.3 | | |
| | % Clay (<4um) (%) | 5.4 | 5.5 | 8.8 | | |
| | Texture | Sandy loam | Sandy loam | Sandy loam | | |
| **Organic / Inorganic Carbon** | Organic Matter (%) | 1.82 | 1.56 | 2.19 | | |
| | Total Organic Carbon (%) | 1.06 | 0.906 | 1.27 | | |
| **Plant Available Nutrients** | Available Nitrate-N (mg/kg) | 8.0 | 5.5 | 7.0 | | |
| | Available Phosphate-P (mg/kg) | 20.4 | 17.0 | 11.5 | | |
| | Available Potassium (mg/kg) | 85 | 88 | 130 | | |

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

# Reference Information

**QC Samples with Qualifiers & Comments:**

| QC Type Description | Parameter | Qualifier | Applies to Sample Number(s) |
|---|---|---|---|

**Qualifiers for Individual Parameters Listed:**

| Qualifier | Description |
|---|---|
| ICC | Insufficient Clay Content for determination of Plastic Limit or Plasticity Index. Soil is non-plastic. |

**Test Method References:**

| ALS Test Code | Matrix | Test Description | Method Reference** |
|---|---|---|---|
| **ATTERBERG-SK** | Soil | Atterberg limits | CARTER CSSS 58 |

The liquid limit (or upper plastic limit) is the point at which the soil becomes semifluid, like softened butter. In operational terms, the liquid limit is defined as the water content at which a trapezoidal groove cut in moist soil is closed after 25 taps on a hard rubber plate (ASTM D-18, 1958).

The plastic limit (or lower plastic limit) is defined as the water content at which soil begins to crumble on being rolled into a thread 1/8 inch (or 3 mm) in diameter. It represents the lowest water content at which soil can be deformed readily without cracking.

The plastic index (which is the difference between the liquid and plastic limits) gives an indication of the "clayeyness" or plasticity of a clay and is employed in engineering classification systems for soils.

This method is equivalent to ASTM D4318-10.

| | | | |
|---|---|---|---|
| **C-TIC-PCT-SK** | Soil | Total Inorganic Carbon in Soil | CSSS (2008) P216-217 |

A known quantity of acetic acid is consumed by reaction with carbonates in the soil. The pH of the resulting solution is measured and compared against a standard curve relating pH to weight of carbonate.

| | | | |
|---|---|---|---|
| **C-TOC-CALC-SK** | Soil | Total Organic Carbon Calculation | CSSS (2008) 21.2 |

Total Organic Carbon (TOC) is calculated by the difference between total carbon (TC) and total inorganic carbon. (TIC)

| | | | |
|---|---|---|---|
| **C-TOT-LECO-SK** | Soil | Total Carbon by combustion method | CSSS (2008) 21.2 |

The sample is ignited in a combustion analyzer where carbon in the reduced $CO_2$ gas is determined using a thermal conductivity detector.

| | | | |
|---|---|---|---|
| **IC-CACO3-CALC-SK** | Soil | Inorganic Carbon as $CaCO_3$ Equivalent | Calculation |
| **NO3-AVAIL-SK** | Soil | Available Nitrate-N | Alberta Ag (1988) |

Available Nitrate and Nitrite are extracted from the soil using a dilute calcium chloride solution. Nitrate is quantitatively reduced to nitrite by passage of the sample through a copperized cadmium column. The nitrite (reduced nitrate plus original nitrite) is then determined by diazotizing with sulfanilamide followed by coupling with N-(1-naphthyl) ethylenediamine dihydrochloride. The resulting water soluble dye has a magenta color which is measured at colorimetrically at 520nm.

| | | | |
|---|---|---|---|
| **OM-CALC-SK** | Soil | Organic Matter Calculation | SPAC |

Soil organic matter is calculated by using the Van Bemmelen Factor to convert from Total Organic Carbon (TOC)

For use with C-TC,TOC,TIC-SK

| | | | |
|---|---|---|---|
| **PH-1:2-SK** | Soil | pH (1:2 Soil:Water Extraction) | AB Ag (1988) p.7 |

1 part dry soil and 2 parts de-ionized water (by volume) is mixed. The slurry is allowed to stand with occasional stirring for 30 - 60 minutes. After equilibration, pH of the slurry is measured using a pH meter.

| | | | |
|---|---|---|---|
| **PO4/K-AVAIL-SK** | Soil | Plant Available Phosphorus and Potassium | Comm. Soil Sci. Plant Anal, 25 (5&6) |

Plant available phosphorus and potassium are extracted from the soil usng Modified Kelowna solution. Phosphorous in the soil extract is determined colorimetrically at 880 nm, while potassiumis determined by flame emission at 770 nm.

| | | | |
|---|---|---|---|
| **PSA-PIPET+GRAVEL-SK** | Soil | Particle size - Sieve and Pipette | SSIR-51 METHOD 3.2.1 |

Particle size distribution is determined by a combination of techniques. Dry sieving is performed for coarse particles, wet sieving for sand particles and the pipette sedimentation method for clay particles.

Reference:

Burt, R. (2009). Soil Survey Field and Laboratory Methods Manual. Soil Survey Investigations Report No. 5. Method 3.2.1.2.2. United States Department of Agriculture Natural Resources Conservation Service.

| | | | |
|---|---|---|---|
| **SPECGRAV-CL** | Soil | Specific Gravity | ASTM D 5057 - 90 |

A portion of sample is weighed in a container that is calibrated for volume. Specific Gravity is reported as the mass of sample per mass of an equal volume of pure water, where the density of pure water is taken to be 1.00 g/mL.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

*The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:*

# Reference Information

| Laboratory Definition Code | Laboratory Location |
| --- | --- |
| SK | ALS ENVIRONMENTAL - SASKATOON, SASKATCHEWAN, CANADA |
| CL | ALS ENVIRONMENTAL - CALGARY, ALBERTA, CANADA |

**Chain of Custody Numbers:**

**GLOSSARY OF REPORT TERMS**

*Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.*
*mg/kg - milligrams per kilogram based on dry weight of sample.*
*mg/kg wwt - milligrams per kilogram based on wet weight of sample.*
*mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.*
*mg/L - milligrams per litre.*
*< - Less than.*
*D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).*
*N/A - Result not available. Refer to qualifier code and definition for explanation.*

*Test results reported relate only to the samples as received by the laboratory.*
*UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.*
*Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.*

## Quality Control Report

Workorder: L2281717 Report Date: 17-JUN-19 

Client: CITY OF VANCOUVER - ENGINEERING
1200-459 SW Marine Driver
Vancouver bc V5X DC3
Contact: Farbod Diba

| Test | Matrix | Reference | Result | Qualifier | Units | RPD | Limit | Analyzed |
|---|---|---|---|---|---|---|---|---|
| ATTERBERG-SK | Soil | | | | | | | |
| **Batch R4660406** | | | | | | | | |
| **WG3069339-1 DUP** | | **L2281717-3** | | | | | | |
| Liquid Limit (LL) | | 29 | 29 | | % | 0.3 | 20 | 06-JUN-19 |
| Moisture at Plastic Limit | | 23 | 23 | | % | 0.7 | 20 | 06-JUN-19 |
| Plasticity Index (PI) | | 5 | 5 | | % | 1.5 | 20 | 06-JUN-19 |
| **WG3069339-2 IRM** | | **ATB-1_SOIL** | | | | | | |
| Liquid Limit (LL) | | | 104.2 | | % | | 80-120 | 06-JUN-19 |
| Moisture at Plastic Limit | | | 94.0 | | % | | 80-120 | 06-JUN-19 |
| Plasticity Index (PI) | | | 118.5 | | % | | 80-120 | 06-JUN-19 |
| C-TIC-PCT-SK | Soil | | | | | | | |
| **Batch R4660515** | | | | | | | | |
| **WG3066208-1 DUP** | | **L2281717-3** | | | | | | |
| Inorganic Carbon | | 0.139 | 0.146 | | % | 5.1 | 20 | 06-JUN-19 |
| **WG3066208-4 IRM** | | **08-109_SOIL** | | | | | | |
| Inorganic Carbon | | | 106.2 | | % | | 80-120 | 06-JUN-19 |
| **WG3066208-2 LCS** | | **0.5** | | | | | | |
| Inorganic Carbon | | | 99.1 | | % | | 80-120 | 06-JUN-19 |
| **WG3066208-3 MB** | | | | | | | | |
| Inorganic Carbon | | | <0.050 | | % | | 0.05 | 06-JUN-19 |
| C-TOT-LECO-SK | Soil | | | | | | | |
| **Batch R4659944** | | | | | | | | |
| **WG3066886-2 IRM** | | **08-109_SOIL** | | | | | | |
| Total Carbon by Combustion | | | 104.8 | | % | | 80-120 | 05-JUN-19 |
| **WG3066886-4 LCS** | | **SULFADIAZINE** | | | | | | |
| Total Carbon by Combustion | | | 101.1 | | % | | 90-110 | 05-JUN-19 |
| **WG3066886-3 MB** | | | | | | | | |
| Total Carbon by Combustion | | | <0.05 | | % | | 0.05 | 05-JUN-19 |
| NO3-AVAIL-SK | Soil | | | | | | | |
| **Batch R4659576** | | | | | | | | |
| **WG3067955-3 IRM** | | **SAL814** | | | | | | |
| Available Nitrate-N | | | 92.7 | | % | | 70-130 | 05-JUN-19 |
| **WG3067955-2 MB** | | | | | | | | |
| Available Nitrate-N | | | <1.0 | | mg/kg | | 1 | 05-JUN-19 |
| PH-1:2-SK | Soil | | | | | | | |
| **Batch R4670769** | | | | | | | | |
| **WG3077549-1 DUP** | | **L2281717-2** | | | | | | |
| pH (1:2 soil:water) | | 7.47 | 7.55 | J | pH | 0.08 | 0.3 | 14-JUN-19 |
| **WG3077549-2 IRM** | | **SAL814** | | | | | | |

ALS Environmental

# Quality Control Report

Workorder: L2281717 Report Date: 17-JUN-19 

| Test | Matrix | Reference | Result | Qualifier | Units | RPD | Limit | Analyzed |
|---|---|---|---|---|---|---|---|---|
| PH-1:2-SK | Soil | | | | | | | |
| **Batch R4670769** | | | | | | | | |
| **WG3077549-2 IRM** | | **SAL814** | | | | | | |
| pH (1:2 soil:water) | | | 8.03 | | pH | | 7.65-8.25 | 14-JUN-19 |
| **WG3077549-3 LCS** | | | | | | | | |
| pH (1:2 soil:water) | | | 6.95 | | pH | | 6.66-7.06 | 14-JUN-19 |
| PO4/K-AVAIL-SK | Soil | | | | | | | |
| **Batch R4660439** | | | | | | | | |
| **WG3069235-3 IRM** | | **FARM2005** | | | | | | |
| Available Phosphate-P | | | 98.3 | | % | | 80-120 | 06-JUN-19 |
| Available Potassium | | | 97.1 | | % | | 70-130 | 06-JUN-19 |
| **WG3069235-2 MB** | | | | | | | | |
| Available Phosphate-P | | | <2.0 | | mg/kg | | 2 | 06-JUN-19 |
| Available Potassium | | | <20 | | mg/kg | | 20 | 06-JUN-19 |
| PSA-PIPET+GRAVEL-SK | Soil | | | | | | | |
| **Batch R4660554** | | | | | | | | |
| **WG3065804-2 IRM** | | **2017-PSA** | | | | | | |
| % Sand (2.0mm - 0.063mm) | | | 44.3 | | % | | 39.1-49.1 | 06-JUN-19 |
| % Silt (0.063mm - 4um) | | | 37.9 | | % | | 32.5-42.5 | 06-JUN-19 |
| % Clay (<4um) | | | 17.9 | | % | | 13.4-23.4 | 06-JUN-19 |
| SPECGRAV-CL | Soil | | | | | | | |
| **Batch R4661023** | | | | | | | | |
| **WG3070757-2 DUP** | | **L2281717-1** | | | | | | |
| Specific Gravity | | 1.49 | 1.47 | | kg/L | 1.4 | 20 | 07-JUN-19 |
| **WG3070757-1 IRM** | | **DI H2O** | | | | | | |
| Specific Gravity | | | 100.0 | | % | | 90-110 | 07-JUN-19 |

**Legend:**

| | |
|---|---|
| Limit | ALS Control Limit (Data Quality Objectives) |
| DUP | Duplicate |
| RPD | Relative Percent Difference |
| N/A | Not Available |
| LCS | Laboratory Control Sample |
| SRM | Standard Reference Material |
| MS | Matrix Spike |
| MSD | Matrix Spike Duplicate |
| ADE | Average Desorption Efficiency |
| MB | Method Blank |
| IRM | Internal Reference Material |
| CRM | Certified Reference Material |
| CCV | Continuing Calibration Verification |
| CVS | Calibration Verification Standard |
| LCSD | Laboratory Control Sample Duplicate |

**Sample Parameter Qualifier Definitions:**

| Qualifier | Description |
|---|---|
| J | Duplicate results and limits are expressed in terms of absolute difference. |

**Hold Time Exceedances:**

| ALS Product Description | Sample ID | Sampling Date | Date Processed | Rec. HT | Actual HT | Units | Qualifier |
|---|---|---|---|---|---|---|---|
| **Plant Available Nutrients** | | | | | | | |
| Available Nitrate-N | | | | | | | |
| | 1 | 16-MAY-19 12:00 | 04-JUN-19 16:00 | 3 | 19 | days | EHTR |
| | 2 | 16-MAY-19 12:00 | 04-JUN-19 16:00 | 3 | 19 | days | EHTR |
| | 3 | 16-MAY-19 12:00 | 04-JUN-19 16:00 | 3 | 19 | days | EHTR |

**Legend & Qualifier Definitions:**

| | |
|---|---|
| EHTR-FM: | Exceeded ALS recommended hold time prior to sample receipt. Field Measurement recommended. |
| EHTR: | Exceeded ALS recommended hold time prior to sample receipt. |
| EHTL: | Exceeded ALS recommended hold time prior to analysis. Sample was received less than 24 hours prior to expiry. |
| EHT: | Exceeded ALS recommended hold time prior to analysis. |
| Rec. HT: | ALS recommended hold time (see units). |

Notes*:
Where actual sampling date is not provided to ALS, the date (& time) of receipt is used for calculation purposes.
Where actual sampling time is not provided to ALS, the earlier of 12 noon on the sampling date or the time (& date) of receipt is used for calculation purposes. Samples for L2281717 were received on 29-MAY-19 15:15.

ALS recommended hold times may vary by province. They are assigned to meet known provincial and/or federal government requirements. In the absence of regulatory hold times, ALS establishes recommendations based on guidelines published by the US EPA, APHA Standard Methods, or Environment Canada (where available). For more information, please contact ALS.

The ALS Quality Control Report is provided to ALS clients upon request. ALS includes comprehensive QC checks with every analysis to ensure our high standards of quality are met. Each QC result has a known or expected target value, which is compared against pre-determined data quality objectives to provide confidence in the accuracy of associated test results.

Please note that this report may contain QC results from anonymous Sample Duplicates and Matrix Spikes that do not originate from this Work Order.

**ALS Environmental**
www.alsglobal.com

## Chain of Custody (COC) / Analytical Request Form

Canada Toll Free: 1 800 668 9878

L2281717-COFC

COC Number: 14 -

Page ____ of ____

| Report To | |
|---|---|
| Company: | City of Vancouver |
| Contact: | Farbod Diba |
| Address: | 1200-450 SW Marine Drive, Vancouver, BC, V5X 0C3 |
| Phone: | 604-829-9507 |

| Report Format / Distribution | |
|---|---|
| Select Report Format: | ☑ PDF ☑ EXCEL ☐ EDD (DIGITAL) |
| Quality Control (QC) Report with Report | ☑ Yes ☐ No |
| ☑ Criteria on Report - provide details below if box checked | |
| Select Distribution: | ☑ EMAIL ☐ MAIL ☐ FAX |
| Email 1 or Fax | farbod.diba@vancouver.ca |
| Email 2 | bhushan.goyal@vancouver.ca |

Select Service Level Below (Rush Turnaround Time (TAT) is not available for all tests)

- R ☑ Regular (Standard TAT if received by 3 pm - business days)
- P ☐ Priority (2-4 bus. days if received by 3pm) 50% surcharge - contact ALS to confirm TAT
- E ☐ Emergency (1-2 bus. days if received by 3pm) 100% surcharge - contact ALS to confirm TAT
- E2 ☐ Same day or weekend emergency - contact ALS to confirm TAT and surcharge

Specify Date Required for E2,E or P:

| Invoice To | |
|---|---|
| Same as Report To | ☑ Yes ☐ No |
| Copy of Invoice with Report | ☑ Yes ☐ No |
| Company: | City of Vancouver - Solid Waste Strategic Services |
| Contact: | Farbod Diba |

| Invoice Distribution | |
|---|---|
| Select Invoice Distribution: | ☑ EMAIL ☐ MAIL ☐ FAX |
| Email 1 or Fax | farbod.diba@vancouver.ca |
| Email 2 | |

| Project Information | |
|---|---|
| ALS Quote #: | 74238 |
| Job #: | |
| PO / AFE: | |
| LSD: | |
| ALS Lab Work Order # (lab use only) | |

| Oil and Gas Required Fields (client use) | |
|---|---|
| Approver ID: | Cost Center: |
| GL Account: | Routing Code: |
| Activity Code: | |
| Location: | |
| ALS Contact: | Sampler: |

Analysis Request — Indicate Filtered (F), Preserved (P) or Filtered and Preserved (F/P) below

| ALS Sample # (lab use only) | Sample Identification and/or Coordinates (This description will appear on the report) | Date (dd-mmm-yy) | Time (hh:mm) | Sample Type | Atterberg limits | Total Organic Carbon Combustion | Available N,P,K | Organic Matter Calculation | Dry & Grind | Particle Size - Sieve & Pipette | Specific Gravity | Number of Containers |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sample 1 Van Landfill May 16, 2019 | 16-005-19 | 12:00pm | Soil | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| | Sample 2 Van Landfill 〃 | 〃 | 〃 | Soil | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| | Sample 3 Van Landfill 〃 | 〃 | 〃 | Soil | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |

**Drinking Water (DW) Samples[1] (client use)**

Are samples taken from a Regulated DW System? ☐ Yes ☐ No

Are samples for human drinking water use? ☐ Yes ☐ No

**Special Instructions / Specify Criteria to add on report (client Use)**

**SAMPLE CONDITION AS RECEIVED (lab use only)**

| | | | |
|---|---|---|---|
| Frozen ☐ | | SIF Observations | Yes ☐ No ☐ |
| Ice packs Yes ☐ | No ☐ | Custody seal intact | Yes ☐ No ☐ |
| Cooling Initiated ☐ | | | |
| INITIAL COOLER TEMPERATURES °C | | FINAL COOLER TEMPERATURES °C | 24 |

| SHIPMENT RELEASE (client use) | | | INITIAL SHIPMENT RECEPTION (lab use only) | | | FINAL SHIPMENT RECEPTION (lab use only) | | |
|---|---|---|---|---|---|---|---|---|
| Released by: Farbod Diba | Date: May 29, 2019 | Time: 12:00pm | Received by: | Date: | Time: | Received by: HA | Date: 5/29 | Time: 3:15 pm |

REFER TO BACK PAGE FOR ALS LOCATIONS AND SAMPLING INFORMATION — WHITE - LABORATORY COPY — YELLOW - CLIENT COPY

Failure to complete all portions of this form may delay analysis. Please fill in this form LEGIBLY. By the use of this form the user acknowledges and agrees with the Terms and Conditions as specified on the back page of the white - report copy.

1. If any water samples are taken from a Regulated Drinking Water (DW) System, please submit using an Authorized DW COC form.

# Appendix E: Building supplier Sand Selection Guide Example

## Sand Selection

greater vancouver
**aggregates division**

Sand Selection Guide

| | |
|---|---|
| Bank Sand-No Spec | Naturally graded, unscreened sand from the pit bank; some rock. |
| Beach Sand | Well graded grayish in colour, averages 5mm in size. |
| Block Sand | Coarsely graded sand primarily used in the production of Brick & Block. |
| Concrete Sand | Lafarge's premier washed well graded specification used primarily in the production of ready-mix concrete. |
| Construction Sand | A washed, semi-permeable sand with excellent compaction properties. |
| Cove Sand | City of Vancouver Engineering Dept. approved washed sand used as backfill, trenchfill and as a pipe bedding. |
| Gyro Sand | A sharp 4mm manufactured sand with good compaction properties; used in all-weather sportsfield applications. |
| Jointing Sand | A 2mm free flowing filler sand primarily used in interlocking paver applications. |
| Masonry Sand | A finely graded washed sand used in the production of parging, mortar & concrete blends |
| Paving Sand | A very coarse sand used in the production of asphalt mixes. |
| Play Sand | Uniformly graded fine washed sand, but the Schools prefer Birdseye. |
| Screened Sand | Screened sand from the bank, some small rocks used for backfill and pipe bedding. |
| Septic Sand | Gradations meeting ASTM C-33 and the Modified Specification as recommended by Fraser Health for use in Septic Mounds. |
| Stucco Sand | Produced to meet the gradation of the British Columbia Building Code. |
| Winter Sand | Two gradations, meeting Municipal and BC-MoTI Highway Specification. |

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