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Water and Waste Department • Service des eaux et des déchets

# Summit Landfill Soil Fabrication Pilot Project

# Year Three Phase One Interim Report

## June 2020

Prepared For:

Manitoba Conservation and Climate
Climate Change and Environmental Protection Division
Environmental Approvals Branch
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Winnipeg, MB R3H 0W4

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## Introduction

On May 7, 2018 the City of Winnipeg received approval from Manitoba Sustainable Development (MSD), now Manitoba Conservation and Climate (MCC) for the three year Summit Soil Fabrication pilot project, 2018-2020, examining the viability of fabricating soil with biosolids to complete the cap system at Summit Landfill. This interim report covers the activities of Year Three Phase One (Y3P1). The main goals for Y3P1 were to test fabricating soil for three months in a row and test operations in spring weather conditions.

The main findings from Y3P1 are:

- Soil fabrication can successfully manage three months' worth of biosolids;
- Spring run off times result in significant increase to daily biosolids volumes, requiring greater operational coordination and flexibility; and
- Incorporation of lime mud has no operational impacts in cold weather conditions.

## Activities since Year Two Phase Two (Y2P2)

Year Two Phase Two concluded on November 29, 2019. Year Three Phase One started on January 20, 2020. This is the shortest inter-phase time period of the pilot project. As this was also during winter and over the holiday season, minimal activities occurred on site.

### Wood and Wood chips

Wood chipping operations continued at Summit Landfill. All wood chips from this operation were directed to the soil fabrication pilot project. City crews and contractors also dumped wood chips at Summit in designated areas. Wood chip volumes on site were reviewed prior to the start of Y3P1 and it was determined there was enough to meet the needs of the first month of operations at approximately 8,000$m^3$. Wood chips continued to be brought to site throughout the operational phase, and chipping operations continued through the operational phase. Pallets from 4R Depot operations were also ground and incorporated into soil fabrication.

### Lime Mud

From January 13$^{th}$ to February 12$^{th}$, 2020, Summit received 25,000 $m^3$ of lime mud. Lime mud was placed in windrows to maximize drainage, and covered with at least 30 cm of wood chips to prevent wind erosion. Wood chips were hauled from Brady Road Resource Management Facility from the Dutch Elm Disease grinding program to cover the windrows.

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## Environmental Monitoring

Wood chip stockpiles and fabricated soil windrow temperatures continue to be taken on an as needed basis. Due to winter weather conditions, most windrows were frozen. No odour was detected from the windrows.

## Operations

The biosolids receiving operation phase started on January 20th, 2020 and was temporarily halted on April 9, 2020. This was one week short of the full three month planned time frame. March and April had average tonnes per day at almost 50% higher than January. The increased volume of biosolids depleted wood chip feedstocks more quickly than average. Additionally, at the end of March and early April the thawing conditions made operating heavy equipment more difficult and time consuming. Biosolids were directed to the biosolids composting, soil fabrication and landfilling operations at BRRMF starting on April 10th, 2020. After a month of drying conditions and refreshed wood chip stockpiles, Summit soil fabrication resumed operations from May 19-22nd, 2020. This completed the three-month Y3P1.

Over the course of this operational phase, 14,403.32 tonnes of biosolids were received at Summit Landfill and mixed into an initial soil blend. All biosolids produced during the operational phase were accepted in the soil fabrication process. Site layout from the operation can be found in Appendix A.

The soil blend of 1(biosolids):2(wood chips):3(sweepings) was continued in this phase. At this ratio, Y3P1 operations produced, in theory 86,419.92 $m^3$ of top soil. However, due to the nature of the material the mixed volume is lower. With mixing, spreading and settlement, it is anticipated that the total volume also reduces over time. Volumes are tracked with drone scans to gain more information on end soil volumes.

An additional soil blend of 1(biosolids): 2(woodchips):2(sweepings):1(lime mud) was also employed during the later half of this phase. This blend is based on the Technical Memorandum: Bench-Scale Soil Fabrication using Lime Mud for Use at Summit Landfill (SYLVIS 2019). This technical memorandum can be found in Appendix B. Approximately 9,000 $m^3$ of lime mud was used in Y3P1. Lime mud did not present any operational changes or challenges compared to street sweepings in cold weather conditions. Soil which includes lime mud will be spread and seeded separately for follow up assessment. The incorporation of lime mud into the soil fabrication process is a beneficial use of an additional waste, and extends the supply of sweepings (the mineral portion of the soil).

Operations were stopped one week short of a full three-month time frame. This was due to a combination of higher than overage volume of biosolids and increasingly wet surface conditions during spring thaw. Operations were moved to the most accessible areas as surfaces became soft. Additionally, windrows were pushed and roughly spread to create space as close to the road as possible. Accessibility issues were anticipated, and were planned for in coordination with biosolids composting operations at Brady Road Resources Management Facility. No biosolids were landfilled during the Y3P1 period.

Biosolids volumes during Y3P1 were significantly impacted by spring runoff conditions:

- January 20-31 - 2078.59 tonnes (average 208 tonnes/day)
- February 3-28 - 3920.84 tonnes (average 196 tonnes/day)
- March 2-31 - 5788.72 tonnes (average 263 tonnes/day)
- April 1-9 - 1795.03 tonnes (average 256 tonnes/day)

This was higher than the average daily tonnage seen in November 2018 (average 175.5 tonnes/day) and November 2019 (average 150 tonnes/day). This high volume of biosolids resulted in the consumption of both feedstocks and space at a faster rate than an average month of operations in non-spring run off conditions. This volume was managed by extending the hours of the work day.

**Seeding**

Y1 and Y2 soil was spread with a dozer in fall of 2019, covering approximately 13 hectares at 60 cm deep. Approximately 0.68 hectares were seeded with the native grasses and wildflower mix on March 25, 2020. The area of spread Y1P1 soil which was previously seeded with oats was disced the week of May 25th, and seeded with native species. An additional approximate 13.5 hectares was fine graded in spring, and seeded in June, 2020.

**Next Steps**

Soil samples will be taken in spring. Environmental monitoring, including surface water sampling and vegetation monitoring will proceed over the spring and summer months.

## Environmental Results

### Odour

Biosolids odour was detected in the biosolids dumping area while biosolids were being dumped. Odours were observed to be reduced after mixing biosolids with woodchips and street sweepings. No odours were detected offsite during the biosolids receiving operations. No odour complaints were received through 311.

### Soil

Soil samples will be taken from 2020 spread areas after material has thawed in spring and from vegetated areas in summer, 2020. Results will be presented in the Year Three Annual Report.

## Surface Water

The project is located within the boundaries of the Summit Road Landfill leachate and surface water collection and containment system.

Surface water samples were taken in April of 2019 after the spring runoff. Monthly scheduled checks and observations after major rainfall events were done to observe if any surface water was present and none was detected. Sampling results were submitted in the Year Two Annual Report. Surface water will be sampled in spring of 2020, and continuous observation will be done through the year. Results will be presented in the Year Three Annual Report.

## Vectors

No vectors were observed during the operational phase.

## Dust, Noise, Nuisance

There were no dust, noise or nuisance concerns during operations.

## Site Security and Safety

Safe Work Procedures were reviewed every week with staff and followed at Summit. Job Safety Planning Forms were completed daily, where all local hazards were identified and addressed. All personnel onsite were required to wear appropriate PPE, this included safety glasses and High Visibility jackets when appropriate to mitigate any weather hazards. No safety or emergency incidents occurred during Y3P1.

Increased traffic interaction was observed with the newly operational Transport facility on the east side of Summit Road. Observations were reported to City of Winnipeg, Public Works Department.

Provincial, Public Health and City of Winnipeg directives related to the novel coronavirus and COVID-19 were instituted during Y3P1. Operations were reviewed and opportunities to reduce person to person interactions were identified. Public health directives were communicated to staff. Soil fabrication operations are already relatively contactless. Additional measures of not handing out paper tickets, not sharing pens, communicating on site more by phone, and maintaining at least two meters between people were implemented. On-site contractors submitted their COVID-19 safety protocols to the City.

## Year Three Phase Two (Y3P2)

Y3P2 will start approximately October 5th, 2020 and proceed for three months. The actual start date will be determined through coordination with the biosolids land application program.

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## Regulatory Approval

Approval to proceed with the Summit Soil Fabrication Pilot Project under the Exemption Clause (6) of the *Classes of Development Regulation* was received on May 7, 2018. Y3P1 proceeded according to the Summit Soil Fabrication Pilot Year Three Phase One (Y3P1) Project Plan.

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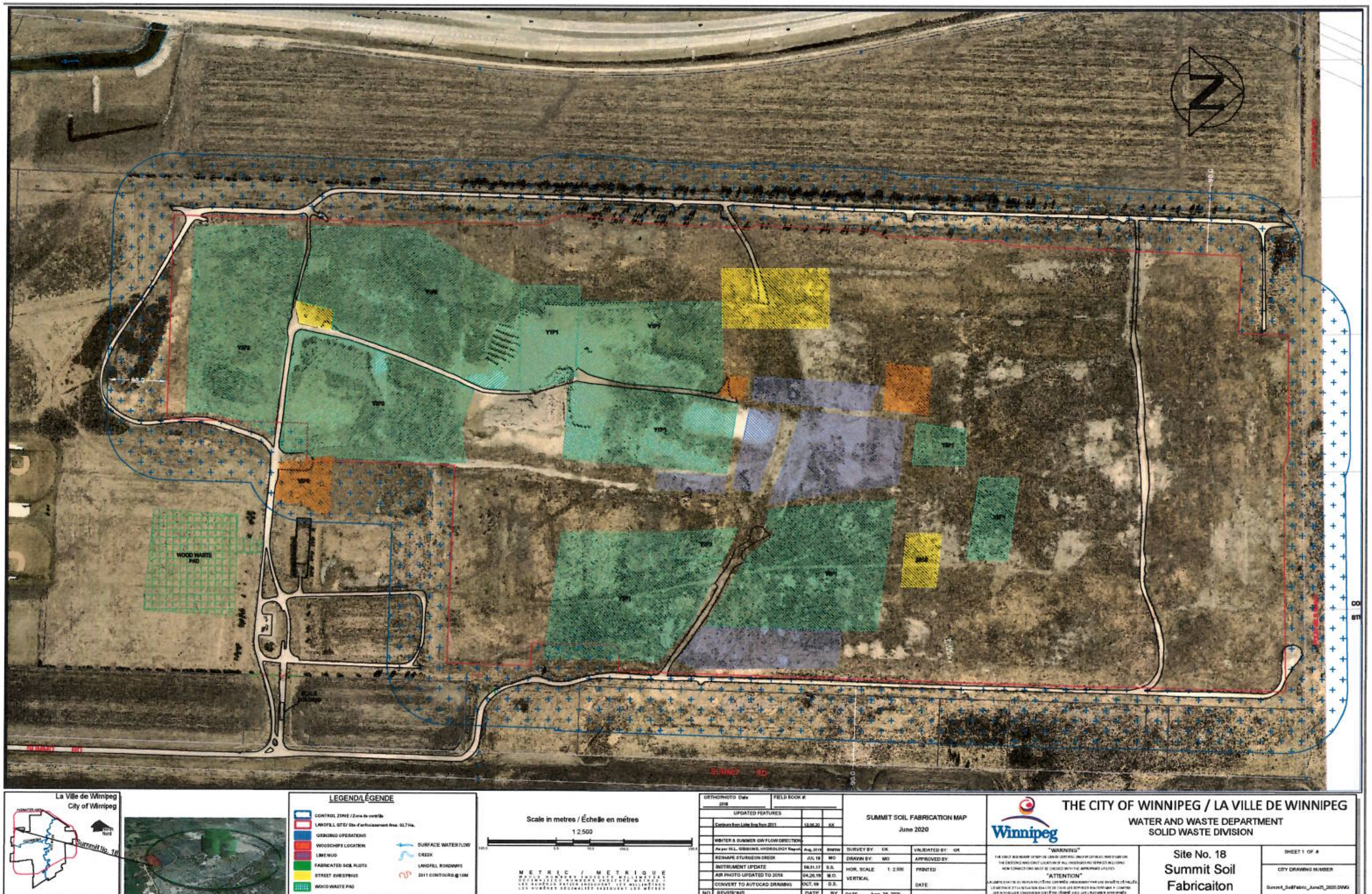

SUMMIT RD
WOOD WASTE PAD
La Ville de Winnipeg
City of Winnipeg
Summit No. 18
LEGEND/LÉGENDE
CONTROL ZONE / Zone de contrôle
LANDFILL SITE/ Site d'enfouissement Area: 93.7 Ha.
GRINDING OPERATIONS
WOODCHIPS LOCATION
LIME MUD
FABRICATED SOIL PLOTS
STREET SWEEPINGS
WOOD WASTE PAD
SURFACE WATER FLOW
CREEK
LANDFILL ROADWAYS
2011 CONTOURS @ 1.0M
Scale in metres / Échelle en métres
1:2,500
METRIC / METRIQUE
ORTHOPHOTO Date 2018
FIELD BOOK #
UPDATED FEATURES
WINTER & SUMMER GW FLOW DIRECTION
RESHAPE STURGEON CREEK
INSTRUMENT UPDATE
AIR PHOTO UPDATED TO 2018
CONVERT TO AUTOCAD DRAWING
NO. REVISIONS DATE BY
SUMMIT SOIL FABRICATION MAP
June 2020
SURVEY BY: CK
DRAWN BY: MO
HOR. SCALE 1:2,500
VERTICAL
DATE June. 26, 2020
VALIDATED BY: GR
APPROVED BY:
PRINTED
DATE:
Winnipeg
THE CITY OF WINNIPEG / LA VILLE DE WINNIPEG
WATER AND WASTE DEPARTMENT
SOLID WASTE DIVISION
"WARNING"
"ATTENTION"
Site No. 18
Summit Soil
Fabricaiton
SHEET 1 OF #
CITY DRAWING NUMBER

## *TECHNICAL MEMORANDUM*

# Bench-Scale Soil Fabrication using Lime Mud for Use at Summit Landfill

| | |
|---|---|
| *Presented to:* | City of Winnipeg |
| *Presented by:* | Kasia Caputa, SYLVIS Environmental |
| *Presentation date:* | March 22, 2019 |

### INTRODUCTION

The City of Winnipeg (the City) is undertaking a pilot project at the Summit Landfill to create and place a biosolids fabricated soil as a growing media for final vegetative cover on the closed landfill cap system. The intent of the pilot project is to fabricate a soil using organic and mineral residuals that are generated by the City: municipal biosolids, wood grindings from City tree removal operations, sand and grit mix from winter road maintenance operations (street sweepings), and other potential residuals. The primary goals of this pilot project are to:

- Demonstrate that biosolids fabricated soil is a viable, environmentally sound option for completion of the cap system of Summit Landfill, specifically producing a growing media that can be placed as a topsoil layer to permanently support a prairie ecosystem of native grasses and forbs;
- Demonstrate that soil fabrication is an operationally viable multi-season beneficial reuse option for biosolids and a diversion option for several other residuals, including wood grindings from City tree removal, and mineral material from street sweepings and other sources; and
- Produce sufficient information to complete a business case for an ongoing soil fabrication operations for the City.

SYLVIS Environmental completed a bench-scale assessment in 2018 to determine the following:

- Ideal mixing ratios of the feedstocks to fabricate a soil that meets regulatory and operational requirements;
- The capacity of the test mixes to support germination of native grasses and forbs selected as the desired final vegetation at Summit Landfill; and
- The potential for nutrient leaching from the test mixes into groundwater and surface water sources.

The bench-scale assessment was conducted using three feedstocks: biosolids, street sweepings, and wood grindings. The selected final mix ratio of 1 part biosolids: 2 parts woodchips: 3 parts sweepings is currently being used in the operational scale pilot. The City has identified lime mud as a fourth feedstock to add to the fabricated soil. The use of lime mud is intended to offset the demand for street sweepings, which is currently the most limiting feedstock in terms of quantity, and to create an alternative beneficial use for the lime mud.

As the lime mud has some unique characteristics compared to the other feedstocks, SYLVIS determined that an additional bench-scale test would be required to determine a new mix ratio which incorporates the lime mud with the current feedstocks. This technical memorandum summarizes the findings of this additional bench-scale assessment, provides recommendations on the most suitable mixing ratio for use in the operational scale pilot project, and describes additional operational considerations.

## INVESTIGATION METHODS

### Regulatory Considerations

Current legislation in Manitoba does not include specific regulatory criteria for the production and use of a biosolids fabricated soil. In order to ensure that the biosolids soil mixtures proposed for this demonstration are protective of the environment and human health, and provide a suitable medium for plant establishment and growth, we have aimed to develop blends that meet the quality criteria for biosolids growing medium (BGM) within the *British Columbia (BC) Organic Matter Recycling Regulation* (OMRR; B.C. Reg. 18/2002).

### Feedstock Characterization

Four different feedstocks were used for this bench-scale soil fabrication trial:

- City of Winnipeg dewatered biosolids;
- Street sweepings from City winter road maintenance operations;
- Wood grindings (woodchips) from City tree removal operations; and
- Lime Mud from the Brady Road Resource Management Facility.

Composite samples of each of the feedstocks were collected by City staff in January 2019 and shipped to the SYLVIS laboratory in New Westminster, BC. SYLVIS analyzed the feedstocks for bulk density and utilized historic physicochemical data to develop theoretical mix ratios. Data collected for the 2018 bench-scale tests were used for biosolids, woodchips, and sweepings; data from 2016 was used for the lime mud. All feedstock data were based on a single composite samples for each feedstock, and are considered representative of the feedstocks used in the bench-scale mixing (Table 3, Appendix One). The individual feedstocks are depicted in Photograph 1 to Photograph 4, Appendix Two.

### Bench-Scale Soil Fabrication

Three different mix ratios were developed to meet OMRR BGM criteria using a SYLVIS proprietary mixing model and the historic physicochemical data. The test mixes were blended at the SYLVIS laboratory in New Westminster, BC on February 8 and 11, 2019 with a specialized laboratory mixer. The feedstocks were measured out at the appropriate volumetric ratios using 500 mL jars. The feedstocks were added to the mixer in the following order: woodchips, biosolids, lime mud, street sweepings, and mixed together for 75 seconds. The final mix ratios used for this trial are summarized in Table 1, below, and the final mixes are shown in Photograph 4 to Photograph 7, Appendix Two.

**Table 1:** Mix ratios (by volume) for the fabricated soil test mixes. Values in brackets indicate the percent ratio (by volume) of each feedstock within the mix.

| Feedstocks | Mix 1 | Mix 2 | Mix 3 |
|---|---|---|---|
| Biosolids | 1 (17%) | 1 (14%) | 1 (13%) |
| Woodchips | 2 (33%) | 3 (43%) | 4 (50%) |
| Street Sweepings | 2 (33%) | 1.5 (21%) | 1(13%) |
| Lime Mud | 1 (17%) | 1 (21%) | 2 (25%) |

Subsamples from Mix 1, Mix 2, and Mix 3 were submitted to ALS Laboratories in Burnaby, BC for physicochemical analysis on February 13, 2019. A summary of the analytical results is presented in Table 5, Appendix One.

A second run was performed on each test mix to assess how each of the test mixes may perform during a winter mixing event when temperatures are below freezing. Appropriate quantities of the woodchips and street sweepings were placed in a freezer at least two days prior to mixing. The biosolids were refrigerated to ensure that they were well chilled, but not frozen prior to mixing. The feedstocks were blended in the laboratory mixer using the same methods as the original mixing test.

## RESULTS AND DISCUSSION

### Bench-Scale Soil Fabrication

Mix 1 was homogenous, dry to moist, dark in colour, with some clumps of biosolids remaining where the biosolids were coated with the sweepings and lime mud (Photograph 5). Mix 2 was relatively homogenous, dry, with a dark colour, but some of the mineral material did not get fully incorporated (Photograph 6). Mix 3 created the most homogenous blend, moist, with a texture of sandy soil (Photograph 7).

The observations from the different mixing methodology trials suggest that Mix 3 produced the most well blended final mix under both warm weather and cold weather conditions, with slightly higher moisture than Mix 1 and Mix 2. All three mixes were similar in ease of mixing and final appearance. There were no major differences observed between the warm weather mixing and winter mixing trials.

### Fabricated Soil Analysis

Mix 3 had the highest concentrations of available nutrients except for available phosphorous, which was highest in Mix 1 (Table 3, Appendix One). Available nutrients in all three mixes were within the range of predicted values, and are all suitable for vegetation establishment and growth. The pH of the test mixes ranged between 8.26 and 8.37, which is higher than the average pH of the operational mix currently being fabricated. This was expected as the lime mud is high in calcium carbonate and acts as a liming agent. The pH results of the test mixes is still within a suitable range for nutrient availability and plant growth.

Electrical conductivity (EC) in all of the mixes ranged between 5.4 and 5.5 dS/m, which is considered high for most soils, but is lower than the EC of the currently used operational mix. The lime mud has a low EC compared to the other feedstocks, and its addition to the operational blend will provide an additional benefit of lowering the concentration of soluble ions provided by the street sweeping feedstock, which may include road salts.

The C:N ratios of all the test mixes ranged between 16.8 and 22.7, which fall above the OMRR BGM minimum C:N ratio of 15. The total organic carbon in the test mixes was higher than predicted in the model, which led to higher than predicted C:N ratios. This result suggests that the woodchips used in the test mixes had a higher total organic carbon than the historic data used in the model.

Total organic matter, measured using the loss on ignition (LOI) method, was 6.9% in Mix 1, 10.0 % in Mix 2, and 15.7% in Mix 3, which slightly exceeded the OMRR BGM maximum of 15%. Mix 3 had the highest proportion of woodchips, representing 50% of the mix by volume. Mix 3 also had the highest C:N ratio, at 22.7. The ratio of Mix 3 could be adjusted to reduce the proportion of woodchips, which would reduce the organic matter slightly, but still keep the C:N ratio above 15.

Trace element concentrations in all of the test mixes were generally low, and well below the OMRR BGM limits, with the exception of zinc. Zinc concentrations in all three test mixes were above the OMRR limit of 150 mg/kg. The zinc concentration in Mix 3 was 222 mg/kg, which also exceeded the CCME Soil Quality Guideline for agricultural land of 200 mg/kg, but below the industrial land guideline of 360 mg/kg. The zinc concentrations in Mix 1 and Mix 2 were close to the value predicted by the model, but Mix 3 was much higher than predicted, which indicates that zinc concentrations in the feedstocks have high variability.

With the exception of zinc, both Mix 1 and Mix 2 were compliant with OMRR BGM criteria for nutrients and trace elements. With a mix ratio modification to reduce the woodchips by one part, Mix 3 should also meet OMRR BGM criteria for nutrients. It is worthwhile to note that although the OMRR is used in this project to guide soil quality objectives, it is not necessary for the test mixes to meet all of the OMRR BGM requirements to meet the minimum regulatory requirements in this context. All three test mixes will meet the CCME Soil Quality Guidelines for industrial land use.

## CONCLUSION

Based on the results of the bench-scale testing, Mix 3 produced the most thoroughly blended and homogenous soil of the three test mixes. Mix 3 exceeded the OMRR BGM criteria for organic matter content, which could be amended by altering the mix ratio to 1 part biosolids: 3 parts woodchips: 1 part street sweepings: 2 parts lime mud. The modified Mix 3 may be considered the most desirable for the City from an operational perspective, as it uses the highest proportion of lime mud and minimizes the demand for the street sweepings.

Mix 2 is also a suitable blend, using close to equal parts of sweepings and lime mud.

Mix 1 is desirable as it contains the highest proportion of biosolids and therefore maximizes their beneficial use, but it also uses the highest proportion of street sweepings and may be pose challenges in producing a consistent final fabricated soil due to the availability of the sweeping feedstock. The final decision on the selected blend may depend on available volumes of both lime mud and street sweepings so that the use of both of these residuals can be optimized.

## APPENDIX ONE - TABLES

**Table 2**: Physical and chemical characteristics of feedstocks used in the Summit Landfill bench-scale soil mixing assessment.

| Parameter | Units | Wood-chips[(a)] | Biosolids[(a)] | Street Sweepings[(a)] | Lime Mud[(b)] |
|---|---|---|---|---|---|
| **Available Nutrients** | | | | | |
| Ammonia | µg/g | 56.1 | 4,170 | 10.7 | 119 |
| Nitrate-Nitrogen | µg/g | 14 | < 10 | 11 | 13 |
| Potassium | µg/g | 3,800 | 490 | 92 | 480 |
| Sulfur | mg/kg | 120 | 1,800 | 73 | 120 |
| **Salinity and Acidity** | | | | | |
| Electrical Conductivity (Sat Paste) | dS/m | 2.32 | 11.30 | 5.32 | 1.47 |
| pH (1:2 Soil:Water) | pH units | 7.04 | 6.88 | 7.84 | 8.91 |
| **Classification** | | | | | |
| Total Organic Carbon | % | 33.0 | 28.0 | 3.6 | 2.5 |
| Total Kjeldahl Nitrogen | µg/g | 7,300 | 58,000 | 270 | 3,500 |
| C:N Ratio | - | 45 | 5 | 133 | 7.1 |
| Organic Matter (loss on ignition) | % | 79.7 | 58.8 | 4.6 | 4.2 |
| Moisture - wet weight | % | 33 | 74 | 3 | 41 |
| Wet Bulk Density | kg/m3 | 329 | 957 | 1,354 | 764 |

(a) Samples collected on Feb 7th, 2018 by the City of Winnipeg and analyzed by Maxxam Analytics under Report No. R2520741.
(b) Samples collected on Jul 12th, 2016 by the City of Winnipeg and analyzed by Maxxam Analytics under Report No. R2220037.

SYLVIS

**Table 3**: Trace element concentrations of feedstocks used in the 2019 Summit Landfill bench-scale soil mixing assessment.

| Parameter | Units | Wood-chips[(a)] | Biosolids[(a)] | Street Sweepings[(a)] | Lime Mud[(b)] |
|---|---|---|---|---|---|
| **Trace Elements (Total)** | | | | | |
| **Antimony** | µg/g | 0.23 | 2.60 | 0.43 | - |
| **Arsenic** | µg/g | 3.62 | 3.14 | 1.40 | < 0.50 |
| **Barium** | µg/g | 69.9 | 138 | 34.0 | - |
| **Beryllium** | µg/g | < 0.20 | < 0.20 | < 0.20 | - |
| **Cadmium** | µg/g | 0.160 | 3.10 | 0.238 | 0.49 |
| **Chromium** | µg/g | 10.7 | 92.7 | 14.0 | 8.5 |
| **Cobalt** | µg/g | 2.54 | 2.81 | 2.45 | 2.06 |
| **Copper** | µg/g | 29.8 | 469 | 13.4 | 29.0 |
| **Lead** | µg/g | 15.2 | 24.5 | 7.86 | 3.96 |
| **Mercury** | µg/g | < 0.050 | 0.584 | < 0.050 | < 0.050 |
| **Molybdenum** | µg/g | 0.54 | 12.7 | 0.68 | 0.26 |
| **Nickel** | µg/g | 7.61 | 23.2 | 12.3 | 6.34 |
| **Selenium** | µg/g | < 0.50 | 2.78 | < 0.50 | - |
| **Silver** | µg/g | < 0.050 | 5.10 | < 0.050 | - |
| **Thallium** | µg/g | 0.050 | 0.058 | < 0.050 | - |
| **Tin** | µg/g | 1.08 | 19.9 | 0.71 | - |
| **Vanadium** | µg/g | 12.4 | 12.2 | 12.6 | - |
| **Zinc** | µg/g | 143 | 776 | 107 | 34.7 |

(a) Samples collected on Feb 7th, 2018 by the City of Winnipeg and analyzed by Maxxam Analytics under Report No. R2520741.
(b) Samples collected on Jul 12th, 2016 by the City of Winnipeg and analyzed by Maxxam Analytics under Report No. R2220037.

**Table 4**: Physicochemical characteristics of three test mixes used in the Summit Landfill 2019 bench-scale soil mixing assessment [(a)]. Ratios of each test mix are presented in Table 1 of this report. Bold values indicate that one or more regulatory criteria were not met.

| Parameter | Units | Mix 1 | Mix 2 | Mix 3 | OMRR BGM Limits[(b)] |
|---|---|---|---|---|---|
| **Available Nutrients** | | | | | |
| Ammonia | mg/kg | 211 | 223 | 281 | - |
| Nitrate-Nitrogen | mg/kg | 2.9 | 3.5 | 4.0 | - |
| Phosphorus | mg/kg | 167 | 121 | 96 | - |
| Potassium | mg/kg | 416 | 612 | 712 | - |
| Sulfur | mg/kg | 205 | 258 | 341 | - |
| **Salinity and Acidity** | | | | | |
| Electrical Conductivity (Sat Paste) | dS/m | 5.50 | 5.38 | 5.49 | - |
| pH (1:2 Soil:Water) | - | 8.35 | 8.37 | 8.26 | - |
| **Classification** | | | | | |
| Total Organic Carbon | % | 7.35 | 9.09 | 8.55 | - |
| Total Kjeldahl Nitrogen | % | 0.38 | 0.40 | 0.51 | 0.6 |
| C:N Ratio | - | 19.3 | 22.7 | 16.8 | 15 minimum |
| Organic Matter (loss on ignition) | % | 6.9 | 10.0 | **15.7** | 15 |
| Moisture - wet weight | % | 22.7 | 30.5 | 33.9 | - |

(a) Soil fabricated in the SYLVIS lab on Feb 11th, 2019 and analyzed by ALS Environmental under Report No. L2232550.

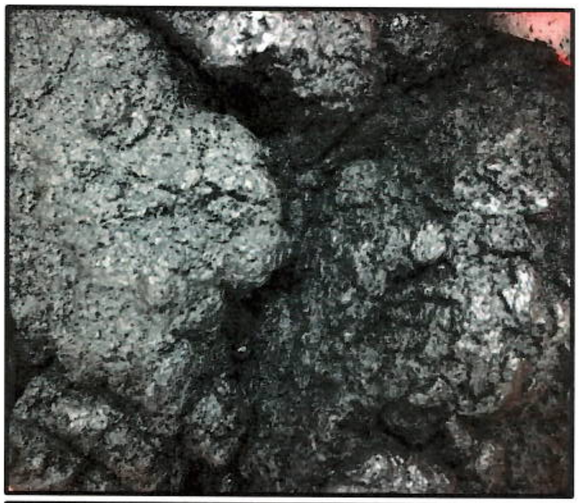
(b) Limits obtained from the *British Columbia Organic Matter Recycling Regulation* (OMRR) for biosolids growing medium (OMMR S4/11).

**Table 5**: Physicochemical characteristics of three test mixes used in the Summit Landfill 2019 bench-scale soil mixing assessment [(a)]. The feedstock ratios of each test mix are presented in Table 1 of this report. Bold values indicate that one or more regulatory criteria were not met.

| Parameter | Units | Mix 1 | Mix 2 | Mix 3 | CCME Industrial Limits[(b)] | OMRR BGM Limits[(c)] |
|---|---|---|---|---|---|---|
| **Trace Elements (Total)** | | | | | | |
| **Antimony** | µg/g | 0.50 | 0.38 | 0.46 | 40 | - |
| **Arsenic** | µg/g | 1.41 | 1.35 | 1.85 | 12 | 13 |
| **Barium** | µg/g | 33.9 | 37.1 | 40.7 | 2,000 | - |
| **Beryllium** | µg/g | 0.10 | 0.11 | 0.12 | 8 | - |
| **Cadmium** | µg/g | 0.290 | 0.326 | 0.433 | 22 | 1.5 |
| **Chromium** | µg/g | 33.1 | 33.5 | 39.4 | 87 | 100 |
| **Cobalt** | µg/g | 1.86 | 1.66 | 1.85 | 300 | 34 |
| **Copper** | µg/g | 48.0 | 49.7 | 64.2 | 91 | 150 |
| **Lead** | µg/g | 8.38 | 7.77 | 8.85 | 600 | 150 |
| **Mercury** | µg/g | 0.062 | 0.046 | 0.054 | 50 | 0.8 |
| **Molybdenum** | µg/g | 1.19 | 1.91 | 1.26 | 40 | 5.0 |
| **Nickel** | µg/g | 10.3 | 8.5 | 11.1 | 89 | 62 |
| **Selenium** | µg/g | < 0.50 | < 0.50 | < 0.50 | 2.9 | 2.0 |
| **Silver** | µg/g | 0.31 | 0.37 | 0.43 | 40 | - |
| **Thallium** | µg/g | < 0.10 | < 0.10 | < 0.10 | 1 | - |
| **Tin** | µg/g | < 5.0 | < 5.0 | < 5.0 | 300 | - |
| **Uranium** | µg/g | 0.86 | 0.96 | 1.17 | 300 | - |
| **Vanadium** | µg/g | 8.64 | 8.90 | 9.84 | 130 | - |
| **Zinc** | µg/g | **162** | **169** | **222** | 410 | 150 |

(a) Samples collected on Mar 3rd, 2017 by SYLVIS and analyzed by Exova Laboratories under Report No. 2173186.
(b) Canadian Council of Ministers of the Environment (CCME) Soil Quality Guidelines for the production of environmental and human health, industrial application.
(c) Limits obtained from the *British Columbia Organic Matter Recycling Regulation* (OMRR) for biosolids growing medium (OMRR S4/11).

**APPENDIX TWO: PHOTOGRAPHS**



**Photograph 1:** City of Winnipeg dewatered biosolids used in the 2019 bench-scale soil fabrication trial (March, 2019).

**Photograph 2:** Woodchips used in the 2019 bench-scale soil fabrication trial (March, 2019).

**Photograph 3:** Street sweepings used in the 2019 bench-scale soil fabrication trial (March, 2019).

**Photograph 4:** Lime Mud used in the 2019 bench-scale soil fabrication trial (March, 2019).

**Photograph 5:** Mix 1, blended at room temperature using the mechanical soil mixer (March, 2019).

**Photograph 6**: Mix 2, blended at room temperature using the mechanical soil mixer (March, 2019).

**Photograph 7**: Mix 3, blended at room temperature using the mechanical soil mixer (March, 2019).