APPENDIX A - CITY of WINNIPEG BIOSOLIDS LAND APPLICATION PROGRAM ANNUAL SUMMARY REPORT 2024

City of Winnipeg
Biosolids Land Application Program

Annual Summary Report 2024

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Executive Summary

The City of Winnipeg (City) completed the annual Biosolids Land Application Program (Program) under the Environment Act Licence (EAL) #3377. The 2024 Program involves the annual spreading of Class B biosolids onto agricultural land in the Rural Municipality of Rosser. It is well understood that the land application of biosolids is an environmentally sustainable practice that supplies valuable nutrients for crop production and economic return for cooperating farm producers, returns valuable carbon to the soil and provides an opportunity to reuse wastewater biosolids.

The goal of the Program is to conduct biosolids land application in a manner that maximizes beneficial use of biosolids, minimizes the associated environmental and health risks, and complies with applicable regulations. As such, the Program has been designed to be allied with cooperating farm producer fertilization and crop management practices and implements beneficial management practices such as good neighbour practices.

Five agricultural fields were scheduled for the 2024 Program to receive biosolids.

- Field 1(W1/2 24-12-1EPM) a half section of land (130 ha) owned between two cooperating farm producers, located on the east side Mile Road 5E approximately 3.2 Km north of Provincial Trunk Highway (PTH) 6. No biosolids had been previously applied to this field.
- Field 2 (E1/2 29-12-1WPM) a half section of land (116 ha) owned by one cooperating farm producer, located on the west side of Mile Road 4W approximately 1.9 km north of PTH 221. Biosolids were previously applied on this field in 2019.
- Field 3 (S1/2 28-12-1WPM) a half section of land (129 ha) owned by one cooperating farm producer, located on the east side of Mile Road 4W approximately 1.9 km north of PTH 221. Biosolids were previously applied on this field in 2019.
- Field 4 (N1/2 21-12-1WPM) a half section of land (130 ha) owned by one cooperating farm producer, located on the east side of Mile Road 4W approximately 1.0 km north of PTH 221. No biosolids had been previously applied to this field.
- Field 5 (E1/2 20-12-1WPM) a half section of land (120 ha) owned by one cooperating farm producer, located on the west side of Mile Road 4W approximately 0.1 km north of PTH 221. No biosolids were applied to this parcel of land in 2024.

Planning for the 2024 Program targeted an application volume of approximately 20,000 wet tonnes of biosolids with an estimated land requirement of between 400 - 450 ha (990 - 1,110 acres) to meet between 2x to 4x the crop removal rate for phosphorous. The agricultural fields were put forward by three participating farm producers to receive land application of biosolids.

To ensure sufficient volume of biosolids were available for land application and to limit the handling of biosolids, two in-field temporary storage sites were established at the end of May 2024. Good weather only (dry) temporary storage area was established on NW24-11-01EPM (Field 1) meaning that the transport trucks could enter the field site only under dry weather conditions. All-weather receiving temporary storage area was established on S1/2-28-12-01WPM (Field 2), meaning that the site was developed with mud-mats and a deposition bin to permit receiving biosolids under wet weather conditions. A berm was formed around the in-field storage areas consisting of rectangular straw bales. Additional straw bales were supplied to cover over the biosolids each evening after

deliveries to cap the biosolids to ensure odour and vector control. Biosolids were first deposited within the storage area at Field 2 on May 27, 2024, with delivery continuing over approximately 15 weeks with the last load of biosolids received at the Field 2 storage area on September 13, 2024. This temporary storage area supplied biosolids for E1/2 29-12-1WPM and a portion of the biosolids for N1/2 21-12-1WPM.

At the good weather temporary field storage site on NW24-11-01EPM, Rural Municipality (RM) of Rosser Council indicated that there was a historic yard site with a groundwater well. It was unknown how the groundwater well was capped. As a mitigation measure to groundwater protection at this site, WSP identified the historic yard with historic aerial photos and amended the temporary storage yard site away from this historic yard in the field.

The third temporary storage site was established on N1/2 21-12-1WPM during the months of September/October as a direct haul/land application site with stockpiling occurring only for six weeks, with the last load of biosolids received at the storage area on October 18, 2024.

Odour assessments completed over the growing season for the temporary field storage site locations indicated that the odour management approach was successful. Over the course of the five odour monitoring events and between four and 21 odour assessment participants (WSP E&E staff, City of Winnipeg staff, and Manitoba Agriculture representatives), the average odour rank was 1.07, 1.21, 1.25, and 1.55 at assessment distances of 50 m, 25 m, 10 m, and 5 m, respectfully. The control (up wind of the biosolids storage site) average odour rank was 0.0.

Benchmark soil sampling following crop harvest on the four fields was completed on August 22, September 5 and September 16, 2024. Details of this sampling and the applicable prescription rates were submitted to Manitoba Environment and Climate Change following the receipt of the Certificates of Analysis. Biosolids were applied at a target rate between 43 wet tonnes per hectare and 50 wet tonnes per hectare. The City delivered approximately 24,138 wet tonnes of biosolids, achieving 121% of the 20,000 tonne target objective.

Since the start of the City's current Program initiated with the Pilot Project in 2017, over 116,480 wet tonnes (31,991 dry tonnes) of biosolids have been applied to cooperating farm producers' agricultural land in the RMs of Macdonald and Rosser. The reuse of nutrients in the biosolids has equated to over 1,228 dry tonnes of total nitrogen and 608 dry tonnes of total phosphorus made available to crops over the past eight years of the Program. In 2024 approximately 2,226 dry tonnes of carbon were land applied and since 2017 there has been an accumulation of over 9,821 dry tonnes of carbon amended to the soil from the Biosolids Land Application Program.

Annual soil monitoring of nutrient concentrations (nitrogen and phosphorus) in agricultural fields that previously received biosolids is required under the City's EAL for three years post-application. The soil monitoring schedule for agricultural fields in the Program as of 2024 is tracked and details are provided in the body of this report. Each year, as new agricultural fields are added to the Program, post-application monitoring will continue for each field for the required three years.

Based on the findings of the Program (2018 through 2024), the following recommendations are made to further support this Program:

- Best neighbour practices for odour control during land application. Monitor the wind direction and speed in relation to neighbour dwellings within 800 m (half mile) of the field and if necessary complete a risk assessment for the situation. Program managers may need to consider postponement of biosolids application on the field if neighbouring residents that may be directly downwind of the application field are at risk of strong odour.

- Continue the monitoring Program for plant available nutrients, total phosphorous and trace elements on all fields where land application may be occurring on two or more events. This will provide a continual understanding of accumulation of these elements over the years.
- Continued adherence to EAL #3377 and continuation of beneficial management practices including continued communication with Municipal Councils, Advisory Committee and the public.
- Continued monitoring of scientific literature/regulations for emerging contaminants of concern relating to biosolids land application.

Study Limitations

WSP Canada Inc. (“WSP”) prepared this report solely for the use of the intended recipient, City of Winnipeg, in accordance with the professional services agreement between the parties. In the event a contract has not been executed, the parties agree that the WSP General Terms for Consultant shall govern their business relationship which was provided to you prior to the preparation of this report.

The report is intended to be used in its entirety. No excerpts may be taken to be representative of the findings in the assessment.

The conclusions presented in this report are based on work performed by trained, professional and technical staff, in accordance with their reasonable interpretation of current and accepted engineering and scientific practices at the time the work was performed.

The content and opinions contained in the present report are based on the observations and/or information available to WSP at the time of preparation, using investigation techniques and engineering analysis methods consistent with those ordinarily exercised by WSP and other engineering/scientific practitioners working under similar conditions, and subject to the same time, financial and physical constraints applicable to this project.

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Overall conditions can only be extrapolated to an undefined limited area around these testing and sampling locations. The conditions that WSP interprets to exist between testing and sampling points may differ from those that actually exist. The accuracy of any extrapolation and interpretation beyond the sampling locations will depend on natural conditions, the history of site development and changes through construction and other activities. In addition, analysis has been carried out for the identified chemical and physical parameters only, and it should not

be inferred that other chemical species or physical conditions are not present. WSP cannot warrant against undiscovered environmental liabilities or adverse impacts off-site.

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This limitations statement is considered an integral part of this report.

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1 INTRODUCTION

1.1 Background

As part of the City of Winnipeg's (City) Biosolids Master Plan (2014) to reuse biosolids in an environmentally sustainable manner, the City initiated the Biosolids Land Application Program (Program) in 2017 under a Pilot Project. Since the completion of the Pilot Project, the City has continued with a full-scale Program that involves the spreading of Class B biosolids[1] on farmland located primarily to the west of the City's municipal boundary (within approximately 50-60 km of the City) in the Rural Municipalities (RM) of Rosser and Macdonald.

Biosolids are a nutrient-rich, solid by-product of wastewater treatment. Applying biosolids to local farmland supplies valuable nutrients for crop production and provides an opportunity to reuse wastewater biosolids instead of disposing of them in a landfill.

The goal of the Program is to provide a means of reusing a portion of the annual biosolids produced by the City in an environmentally sustainable manner through land application that maximizes beneficial use of biosolids, minimizes the associated environmental and health risks, and that complies with applicable regulations. As such, the Program has been designed to be allied with cooperating farm producers' fertilization and crop management programs while also implementing beneficial management practices that include good neighbour policies.

An Environment Act Proposal (EAP) was submitted in 2017 to the Manitoba Conservation and Climate now Manitoba Environment and Climate Change [MECC]) Environmental Approvals Branch for an *Environment Act* License (EAL) in support of the Program. The EAL #3377 was granted on June 15, 2022 and the 2024 Program was completed in accordance with this EAL.

This year (2024), marked the seventh year of the full-scale Program that included:

- in-field stockpiling and storage of the biosolids materials on agricultural land in the immediate vicinity of where land application is to take place
- land application of the biosolids after harvest onto agricultural fields at agronomic rates that match crop uptake of nutrients and
- fulfilment of monitoring and reporting requirements as outlined in EAL #3377.

1.2 Objectives

The purpose of this report is to provide the City and the Regulator (MECC) with a summary of activities undertaken in 2024 in support of the City's Program including the following:

- temporary field storage and stockpiling of biosolids
- application prescription rates for the land application of the biosolids
- biosolids volumes applied
- field observations collected for the 2024 application season and
- soil monitoring of fields utilized in prior years for the Program as per regulatory requirements

[1] The US Environmental Protection Agency (EPA) guidelines refer to different categories of biosolids: Exceptional Quality, Class A and Class B. The difference between Class A and Class B biosolids is the level of pathogens. Class A biosolids are treated to a greater degree and have less pathogens. There are less restrictions on Class A biosolids reuse (e.g., can be packaged as a soil amendment for public use).

2 SUMMARY OF 2024 ACTIVITIES

2.1 Overview of Land Application Approach

The City's approach for the full-scale Program is to reuse the biosolids materials produced by the City's population/workforce in an environmentally sustainable manner. In consultation with the cooperating farm producers and their agronomic advisors, the Program applies biosolids based on crop nutrient uptake and removal; this means matching agronomic needs with biosolids nutrient content. Therefore, application rates are based on crop uptake and removal of phosphorus for a multi-year application event with the objective of returning to the same agricultural fields on a four-year land rotation. This allows crops to uptake the nutrients released from the biosolids material over four cropping seasons and mitigate the potential for the build-up of nutrients and metals in the soil profile.

Biosolids are only applied to lands where the cropping system includes cereals, oil seeds, field peas, soybeans, lentils, and corn. Biosolids are not applied to cropping systems that include direct edible crops such as potatoes and vegetables or direct grazing by livestock.

The annual cycle of the Biosolids Land Application Program consists of the following steps (refer to Figure 1):

1. Engagement with cooperating farm producers (October to December) to ensure land use and potential future cropping plans align with Program needs and with local Municipal Council(s) to obtain approval and address concerns.
2. In-field storage sites are selected and established on cooperating farm producers' field sites.
3. Biosolids are generated at the North End Water Pollution Control Centre (NEWPCC) and starting early in the growing season (after road restrictions are lifted) biosolids are trucked to the in-field storage site(s) located on cooperating farm producer field(s).
4. Post-harvest soil sampling occurs to confirm residual crop nitrogen, phosphorus, and metal concentrations to determine suitable application rates (prescription rates).

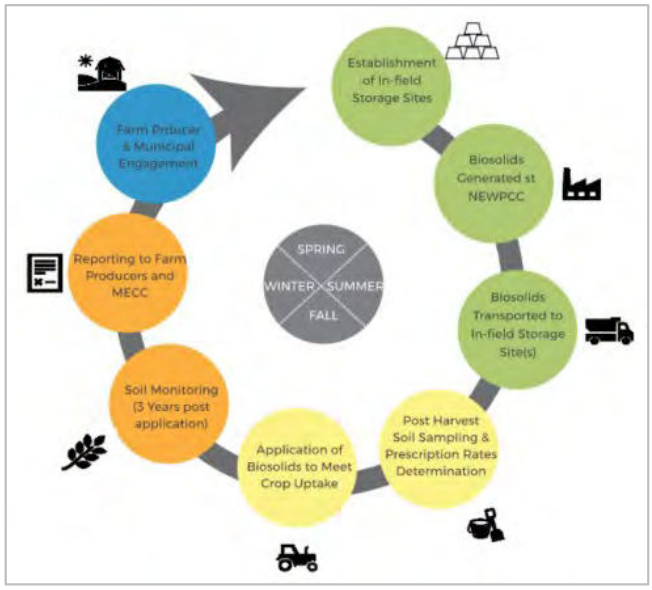

Figure 1: Annual Biosolids Land Application Program Cycle

5. Following the development of prescription rates, fall application of biosolids is completed by a subcontractor with near immediate tillage following spreading completed by farm producer(s).
6. Reporting of application rates and prescription values back to the cooperating farm producer(s) and MECC.
7. For three years following an application event, crop management data and soil sampling for nutrient profiles is completed and reported to MECC.

2.2 Regulatory Requirements

The 2024 Program was managed in accordance with the granted Environment EAL #3377 as of June 15, 2022 as well as in accordance with the Manitoba Acts and Regulations including:

- The *Environment Act* C.C.S.M. c. E125 (1987):
  - *Livestock Manure and Mortalities Management Regulation* 42/98
- The *Water Protection Act* C.C.S.M. c. W65 (2005):
  - *Nutrient Management Regulation* 62/2008
- The published EAP developed for this Program

Additional applicable guidance is provided based on beneficial management practices outlined in:

- guidance documents include the Canadian Council of Ministers of the Environment Guidance Document for the Beneficial Use of Municipal Biosolids, Municipal sludge and Treated Septage document
- applicable academic research
- Winnipeg's Climate Action Plan (2018) and
- OurWinnipeg 2045 Goals and Objectives

2.3 2024 Field Sites

Five agricultural fields were scheduled for the 2024 Program to receive biosolids (refer to Figure 1, Appendix A).

- Field 1(W1/2 24-12-1EPM) a half section of land (130 ha) owned between two cooperating farm producers, located on the east side Mile Road 5E approximately 3.2 Km north of Provincial Trunk Highway (PTH) 6. No biosolids had been previously applied to this field.
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Planning for the 2024 Program targeted an application volume of approximately 20,000 wet tonnes of biosolids with an estimated land requirement of between 400 - 450 ha (990 – 1,110 acres) to meet between 2x and 4x the crop removal rate for phosphorous. The agricultural fields were put forward by three participating farm producers to receive land application of biosolids.

2.4 2024 Program Schedule

A summary of the Program milestone events is outlined in Table 1. Key milestone events were achieved ahead of initial schedule or on the planned schedule.

Table 1: 2024 Program Milestone Overview

Program Activity Overview	Timeline
Selection of land application Fields	November 2023
RM of Rosser Request for Resolution	December 7, 2023
Meeting with RM of Rosser Council	January 20, 2024
RM of Rosser Public Open House	February 22, 2024
RM of Rosser Resolution of Council	March 12, 2024
Landowners use agreements signed by cooperating producers	May 17, 2024
Neighbour Notification	April 29, 2024
EAL #3377 Notice of 2024 Land Application Program MECC Notification	May 21, 2024
Establish temporary field storage sites & baseline soil sampling	May 27, 2024
Biosolids delivery to temporary storage sites	May 27 to October 18, 2024
Odour Assessments	June 11 to August 30, 2024
Benchmark soil sampling, prescription development and submission to MECC	August 28 to September 5, 2024
Biosolids Land Application	August 31 to September 5, 2024 & October 9 to 21, 2024
Residual Soil Nutrient Sampling Program	October 10 - 31, 2024
Temporary Storage Site Clean up	November 8, 2024
Annual Report	April 2024

2.5 Communications and Approvals

2.5.1 Manitoba Environment and Climate

The 2024 Program was managed in accordance with the MECC granted EAL #3377 for the operation of the development being the withdrawal of dewatered biosolids that have undergone digestion from the City's North End Pollution Control Centre (NEWPCC), establishment and operation of temporary field storage facilities for dewatered biosolids, transfer of the dewatered biosolids to the temporary field storage facilities, and application of the dewatered biosolids to agricultural land by the Proponent (City, prepared by WSP) on February 2, 2018.

EAL #3377 addresses several General Terms and Conditions and identifies specific clauses that address operations including: General; Withdrawal, Handling, and Transportation of Biosolids; Temporary Field Storage and Land Application of Biosolids; Monitoring and Reporting; and Review and Revocation.

On May 15, 2024, as per EAL #3377 Clause 15, WSP submitted to the assigned MECC Environment Officer, the required notification for the initiation of the Program to commence on May 27, 2024 with the establishment of temporary storage area. This notification included a listing of perspective agricultural land for the 2024 season, a map of storage site/land applications fields, RM Resolution #23046, Notice of Land Application Program for Neighbours, land use agreements with each cooperating farm producer and status of title for each land use agreement.

On August 30, September 13 and 24 2024, as per EAL #337 Clause 16, WSP submitted to the assigned MECC Environment Officer the additional required notification for commencement of removal, transportation, and land incorporation of biosolids with the submission of field prescription rates with baseline soil nutrient and metal concentrations in the receiving lands as well as application prescription rates.

2.5.2 RM of Rosser

On December 7, 2023, WSP submitted a request to RM of Rosser Council for a resolution for the 2024 land application Program. Subsequently, the RM of Rosser Council requested from WSP and the City to hold a public open house to provide the residents an opportunity to provide feedback on the proposed Program.

The requested public open house was held on February 22, 2024 between 6 pm and 8 pm at the RM of Rosser office in Rosser, MB. An estimated 40 people attended the event. Based on conversation with various attendees it was interpreted that the attendees were immediate neighbours to the proposed fields; up to residents between 3 km and 8 km distance from the proposed field locations. The Program presented 16 boards of information topics including background information, regulatory framework, benefits, overall land locations, mitigation measures, temporary field storage approach, safe use of biosolids, water protection, odour monitoring, traffic management, 2024 land locations and next steps.

Based on the public feedback a modification was made to the land selection for 2024 and an in-field study of pathogen efficacy was initiated.

On March 11, 2024 WSP resubmitted the RM of Rosser request for resolution with the modification to the receiving land base for 2024 and received Council's Resolution 24 113 and 24 156 on April 3, 2024.

Public Notification

On April 29, 2024, neighbour notifications were delivered to adjacent residences located within a half mile radius of the potential land application fields informing these neighbours about the Program and providing City contact information to address any concerns (refer to Appendix B).

2.6 In-Field Temporary Storage Areas

To ensure sufficient volume of biosolids were available for land application and to limit the handling of biosolids, two in-field temporary storage sites were established at the end of May 2024. A good weather only (dry) temporary storage area was established on NW24-11-01EPM (Field 1) meaning that the transport trucks could enter the field site only under dry weather conditions. An all-weather receiving temporary storage area was established on S1/2-28-12-01WPM (Field 2), meaning that the site was developed with mud-mats and a deposition bin to permit receiving biosolids under wet weather conditions (refer to Figure 2A, Appendix A and to Photos 1, and 3, Appendix C). A berm was formed around the in-field storage areas consisting of rectangular straw bales. Additional straw bales were supplied to cover over the biosolids each evening after deliveries to cap the biosolids to ensure odour and vector control. Biosolids were first deposited within the storage area at Field 2 on May 27, 2024, with delivery continuing over approximately 15 weeks with the last load of biosolids received at the Field 2 storage area on September 13, 2024. This temporary storage area supplied biosolids for E1/2 29-12-1WPM and a portion of the biosolids for N1/2 21-12-1WPM.

At the good-weather temporary field storage site on NW24-11-01EPM, RM of Rosser Council indicated that there was a historic yard site with a groundwater well. It was unknown how the groundwater well was capped. As a mitigation measure to groundwater protection at this site, WSP identified the historic yard with historic aerial photos and amended the temporary storage yard site away from this historic yard in the field.

The third temporary storage site was established on N1/2 21-12-1WPM during the months of September/October as a direct haul/land application site with stockpiling occurring only for six weeks, with the last load of biosolids received at the storage area on October 18, 2024.

As indicated in Table 2 approximately 24,138 wet tonnes were stockpiled at the temporary in-field storage sites delivered through a total of 998 truckloads.

Table 2: Summary of In-field Biosolids Storage Volume

Month	S1/2 28-12-01WPM		NW24-12-01EPM		N1/2 21-12-01WPM	
	Truck Loads	Volume of Biosolids (wet tonnes)	Truck Loads	Volume of Biosolids (wet tonnes)	Truck Loads	Volume of Biosolids (wet tonnes)
May 27 – 31	38	942	-	-	-	-
June 3 – June 28)	189	4,635	-	-	-	-
July 1 – Aug. 2	150	3,547	69	1,637	-	-
August 5 – 30	45	1,160	173	4,165	-	-
September 2 – 27	33	802	56	1,344	113	2,712
September 30 – November 1	-	-	-	-	132	3,194
Total	**455**	**11,086**	**298**	**7146**	**245**	**5,906**

2.6.1 Storage Area Decommissioning

Once the final biosolids from the temporary in-field storage areas were land applied in 2024, the storage area at each field site were decommissioned in early November. This included removal of straw bales used for the berms, removal of the ramp, catch box and mud-mats from the all-weather storage site. In addition, the cooperating farm producer completed a tillage operation of the storage areas to incorporate the remaining biosolids layer.

2.7 Odour Assessments

To evaluate the odour level associated with the in-field temporary storage of biosolids and land application in 2024, odour assessments were completed on five separate dates following the same protocol used since the 2017 for the Program.

2.7.1 Odour Assessment Procedure

Individuals that participated as odour assessors on any given assessment date were asked to rate the degree of odoriferousness following a methodology adapted from the Good Practices Guide for Odour Management in Alberta, 2015, Clean Air Strategic Alliance as outlined below.

Odour Assessment of Storage Area

Five separate odour assessments were completed between the two in-field storage sites (June 11, June 21 July 5, August 2, and August 30, 2024). At each assessment date, an area was selected away from the storage site to provide a location for the collection of a background odour baseline. Odour assessors were asked to wear a carbon filtered mask for vapours (suitable for nuisance level organic vapour relief) for about two minutes to clear their noses (refer to Photo 5 and 6, Appendix C). Assessors then removed their masks, breathed normally, and recorded (on the provided field data recording sheet) a level of annoyance to the odour based on a scale of 0 to 4 as per the scale outlined in Table 3. This same method was then used to record the odour level at each of four

pre-determined distances from the storage site - approximately 50 m, 25 m, 10 m, and 5 m (downwind of storage area based on that day's wind direction). Assessors started at the farthest distance point (i.e., 50 m) and moved forward to each distance point in descending sequence.

Odour Assessment of Field Application

Due to logistics and scheduling no road-side odour assessments were formally completed. Through the land application events at the four field sites no odour concerns were raised by the cooperating farm producers, RM of Rosser and neighbours. Additionally, during the land application process odour was observed by WSP to be negligible but it was not evaluated against the protocol.

Table 3: Odour Scale Used During Odour Assessment of Storage Area

Numerical Value	Annoyance Level	Intensity Level*
0	no odour	No offending odour observed.
1	a little annoying	Faint - The odour is barely detectable: you need to stand still and inhale while facing into the wind to notice it.
2	annoying	Moderate - The odour is easily detected while walking and breathing normally but it is not overpowering.
3	very annoying	Strong - The odour is penetrating; you can't get away from it and it can easily be detected at all times.
4	extremely annoying	Pungent - suffocating, causing a gag reflex.

Notes: *Adapted from: Good Practices Guide for Odour Management in Alberta, 2015, Clean Air Strategic Alliance.

2.7.2 Summary of Odour Assessment Results

A summary of the average odour rank values collected for the 2024 Program during the five odour assessments completed at either of the in-field temporary storage sites from June through August 2024 are provided in Table 4.

Odour assessments were completed on the following:

- June 11, 2024: An odour assessment of the temporary storage area S1/2-28-12-01WPM was conducted by 20 Manitoba Agriculture representatives and one WSP Earth & Environment (E&E) staff. It should be noted that the weather on this day was cloudy, with precipitation in the morning and strong west winds at 39 Km/hr.
- June 21, 2024: An odour assessment of the storage area at S1/2-28-12-01WPM was conducted by four WSP E&E staff and one City staff.
- July 5, 2024: An odour assessment of the temporary storage area S1/2-28-12-01WPM at was conducted by four WSP E&E staff.
- August 2, 2024: An odour assessment of the storage area at W1/2-24-12-01EPM was conducted by four WSP E&E staff.
- August 30, 2024: An odour assessment of the storage area at S1/2-28-12-01WPM was conducted by four WSP E&E staff.

In general, the odour assessment over the growing season for temporary field storage site locations indicated that the odour management approach was successful. Over five odour monitoring events and between four and 21 odour assessment participants (WSP E&E staff, City staff, and MB Agriculture staff), the average odour rank was 1.07, 1.21, 1.25, and 1.55 at assessment distances of 50 m, 25 m, 10 m, and 5 m, respectfully. The control (up wind of the biosolids storage site) average odour rank was 0.0 (Table 4).

Table 4: Average Odour Rank Perceived during Odour Assessment in 2023

Date	Distance from Biosolids Storage Area (metres)					# of Participants
	50	25	10	5	Control	
June 11	2.1	2.5	2.5	2.4	0.2	21*
June 21	0	0	0	0.6	0	5
July 5	1.5	1.8	1.5	1.5	0	4
August 2	0.25	0.25	0.25	1	0	4
August 30	1.5	1.5	2	2.25	0	4
Average	**1.07**	**1.21**	**1.25**	**1.55**	**0**	**-**

Notes: *Extreme wind event with west wind at 39 Km/hr.

2.7.3 Odour Results Year Over Year

A review of the temporary storage sites odour assessment results from 2018 through 2024 is outlined in Table 5. As noted, the methodology has been consistent since 2018 to complete the odour assessment with different participants over the years. In general, the odour assessments completed at the storage sites over the seven assessment years found the following:

- At 50 m downwind from the storage yard sites the assessment varied between 0.4 and 1.5 with an average of 0.8, implying that no odour was detectable.
- At 25 m downwind from the storage yard site the assessment varied between 0.8 to 1.8 with an average of 1.4, implying that an odour was faintly detectable.
- At 10 m downwind from the storage yard site the assessment varied between 1.3 and 2.1 with an average of 1.7, implying that an odour was more than faint and less than moderate being easily detectable.
- At 5 m downwind from the storage yard site the assessment varied between 1.3 and 2.8 with an average of 2.0, implying that an odour was moderately to strongly present and easily detectable.
- At the Check locations, up wind gradient from the storage yard site the assessment varied between 0.0 and 0.3 with an average 0.1, implying that no odour was detected.

To summarize, odour detection was strongly present nearest to the temporary storage site while at only 50 m away from the storage site and downwind, the odour was nearly not detectable. This indicates that the further away a receptor (e.g., person, residence) is from the storage site, odour would not be noticeable and that the straw cover is acting as an effective means in mitigating odour from biosolids stored at the temporary storage sites.

Table 5: Average Annual Odour Assessment Results Year Over Year

Distance from Biosolids Storage Area (metres)	Assessment Years							
	2018	2019	2020	2021	2022	2023	2024	Average
50	0.8	0.7	0.9	0.6	0.4	0.8	1.5	0.8
25	1.8	1.2	1.5	0.8	1.2	1.3	1.8	1.4
10	2.1	1.4	2.1	1.3	1.3	1.6	1.8	1.7
5	2.6	1.7	2.8	1.8	1.3	1.8	1.9	2.0
Check	**0.0**	**0.1**	**0.1**	**0.1**	**0.1**	**0.3**	**0.1**	**0.1**

2.8 Biosolids Land Application

Soil samples were collected after crop harvest on August 22, September 5, and September 16, 2024 from fields that were to receive biosolids to determine biosolids prescription rates (Appendix D). Prescription rates were determined based on soil analytical results received from ALS Laboratory Group and Farmer's Edge as well as biosolids quality information supplied by the City. Included in Appendix E are Table A, the summary of residual nitrogen and phosphorus monitoring. Table B the Trace Element Content for each field where biosolids were land applied in 2024. Table C.1 is a comparison of soil trace elements between 2018, 2023 and 2024 for application fields that received biosolids in both 2018 and 2023. Table C.2 is a comparison of soil trace elements between 2019 and 2024 for application fields that received biosolids in both 2019 and 2024. Copies of the laboratory Certificates of Analysis can be made available upon request. Table 6 summarizes biosolids application information for all application fields in the 2024 Program (refer to Photo 7 and 8, Appendix C).

Table 6: Summary of Biosolids Land Application in 2024

Field #	Legal Location	Benchmark Soil Sample Date	Application Dates (2024)	Approximate Volume of Biosolids (wet tonnes)	Field Area Biosolids Applied To (ha)
1	W1/2 24-12-1EPM	Sept. 5, 2024	Sept. 16 - 19	7,146	129
2	E1/2 29-12-1WPM	Aug. 22, 2024	Aug. 31 – Sept. 2	5,244	114
3	S1/2 28-12-1WPM	Aug. 22, 2024	Sept. 3, 16 & 19	5,842	127
4	N1/2 21-12-1WPM	Sept. 16, 2024	Sept. 25 – Oct. 18	5,906	130
			Total	**24,138**	**500**

Biosolids were applied at a target rate between 43 and 50 wet tonnes per ha (refer to Appendix D for prescription rates). The City delivered approximately 24,138 wet tonnes of biosolids, achieving121% of the 20, 000 tonne target objective.

2.8.1 Summary of Total Biosolids Applied to Date in Program

Since the start of the City's current Program initiated with the Pilot Project in 2017, over 116,480 wet tonnes (31,991 dry tonnes) of biosolids have been applied to cooperating farm producers' agricultural land in the RMs of Macdonald and Rosser (refer to Table 7). The reuse of nutrients in the biosolids has equated to over 1,228 dry tonnes of total nitrogen and 608 dry tonnes of total phosphorus made available to crops over the past eight years of the Program.

In 2024 approximately 2,226 dry tonnes of carbon were land applied and since 2017 there has been an accumulation of over 9,821 dry tonnes of carbon amended to the soil from the Biosolids Land Application Program. According to Northwest Biosolids, for every truck of biosolids that is land applied, an average of 33 tonnes of CO_2 is stored in the soil. One ton of biosolids provides that same amount of carbon storage as 26 tree seedlings grown for ten years (Northwest Biosolids, 2021[2]).

A study looking at carbon and nitrogen storage in biosolids amended soils was completed by Young, Xiao, Cogger, Bary and Pan (2014[3]) from Washington State University in 2014. The study found that based on the U.S. Environmental Protection Agency's lifecycle analysis values for carbon dioxide (CO_2) emissions, trucking one ton of biosolids 400 miles (round trip) emits 262 lbs CO_2equivalents (CO_2e). In comparison Young et al (2014) found that based on biosolids with a carbon content of 33% and a soil retention rate of 77%, 1,863 lbs CO_2e can be stored in soil carbon for each ton of biosolids applied. Young et al. (2014) estimated that the 50,000 tons of biosolids applied to land each year (in the State of Washington) have the potential to sequester tens of thousands of tons of CO_2e as soil carbon.

Table 7: Estimated Total Biosolids, Nitrogen, Phosphorus and Carbon Land Applied in Program to Date

Year	Volume Applied (wT)	Area		Average Total Nitrogen	PAN (Yr1)	Total Phosphorus	Total Available P2O5	Total Carbon
		Hectares	Acres	38.4 kg/tonne	13.2 kg/tonne	19 kg/tonne	10.9 kg/tonne	304 kg/tonne
2017	2,621	55	136	26,650	9,161	13,186	7,565	213,058
2018	10,932	260	642	111,130	38,201	54,986	31,545	888,458
2019	14,178	326	805	144,115	49,540	71,307	40,908	1,152,171
2020	11,175	239	590	113,587	39,046	56,202	32,242	908,106
2021	16,931	331	818	172,109	59,162	85,185	48,854	1,375,974
2022	15,768	251	627	160,090	55,031	79,211	45,442	1,279,883
2023	20,736	450	1,112	222,144	76,362	109,915	63,057	1,775,995
2024	24,138	500	1,235	278,438	95,713	137,769	79,036	2,226,057
Total	**116,480**	**2,421**	**5,981**	**1,228,454**	**422,281**	**607,829**	**348,702**	**9,821,237**

2.9 Soil Monitoring

Annual soil monitoring of nutrient concentrations (nitrogen and phosphorus) in agricultural fields that previously received biosolids is required under the City's EAL for three years post-application. The soil monitoring schedule for agricultural fields in the Program as of 2024 is provided in Table 8. Each year, as new agricultural fields are added to the Program, post-application monitoring will continue for each field for the required three years.

[2] Northwest Biosolids, 2021, You can go carbon neutral with biosolids. Retrieved on November 30, 2021 from: https://nwbiosolids.org/node/16.

[3] Young, L., Xiao, Y., Cogger, C.G., Bary, A.I., and W.L. Pan. 2014 Carbon and Nitrogen Storage in Biosolids Amended Soils. Washington State University. Regional Approaches to Climate Change – Pacific Northwest Agriculture. Retrieved on November 30, 2021 from: https://www.reacchpna.org/posters-and-presentations?page=8.

Table 8: Summary of Soil Monitoring Schedule for Agricultural Fields in the Program

RM Name	Field Location	Year						
		2021	2022	2023	2024	2025	2026	2027
Rosser	36-12-02WPM			X	√	√	√	
Rosser	NW-31-12-01WPM N1/2-SW31-12-01WPM			X	√	√	√	
Rosser	S1/2-28-12-01WPM				X	√	√	√
Rosser	E1/2-29-12-01WPM				X	√	√	√
Rosser	SE-05-10-01EPM	X	√	√	√			
Macdonald	S1/2 of SW & SE 15-09-01-01WPM	X	√	√	√			
Macdonald	14-09-01WPM	X	√	√	√			
Rosser	E1/2-28-11-01EPM, NW-27-11-01EPM, N1/2 of NW-21-11-01EPM, S1/2 of SE-33-11-01EPM		X	√	√	√		
Rosser	SE-35-11-01WPM SW-35-11-01WPM			X	√	√	√	
Rosser	W1/2 24-12-01EPM				X	√	√	√
Rosser	N1/2 21-12-01WPM				X	√	√	√

X – Baseline Sampling; √ Post-Application Monitoring Required

2.9.1 Soil Sample Collection Methods

Composite soil samples were collected from a 20 m diameter area around a centroid georeferenced location established during the benchmark year for each field. Soil samples were collected from depths of 0-15 cm and 15-60 cm and submitted to a laboratory for analysis for available nitrate-nitrogen and available phosphate-phosphorus and soil metals when required.

2.9.2 Benchmark Soil Sampling Results

Biosolids Preapplication Soil Monitoring Results

S1/2 28-12-01WPM

The analytical results are presented in Table A, Appendix E. The 2024 Land Application Program is the second application event on this parcel of land, with the first event in 2019. The post-harvest residual nitrate-nitrogen (0-60 cm) results are acceptable concentrations. The available phosphate – P was below the applicable Nutrient Management Guidelines of 60 parts per million (ppm) for soils sampled for each sample location and are improved from 2019 benchmark sampling event.

E1/2 29-12-01WPM

The analytical results are presented in Table A, Appendix E. The 2024 Land Application Program is the second application event on this parcel of land, with the first event in 2019. The post-harvest residual nitrate-nitrogen (0-60 cm) results are acceptable concentrations. The available phosphate – P was below the applicable Nutrient Management Guidelines of 60 ppm for soils sampled for each sample location and are improved from 2019 benchmark sampling event.

Trace Elements

Soil total trace elements (Arsenic, Cadmium, Copper, Chromium, Lead, Mercury, Nickel, and Zinc) are within expected parameter ranges for the Red River Valley clays. At the given soil concentrations plus the application rate of biosolids, the cumulative metal concentrations of each of the elements are not limiting to receiving biosolids land application and in most cases are permissible of multiple land application events (Table B, Appendix E).

As SE & SW (S1/2) 28-12-01WPM, SE & NE 29-12-01WPM each previously received one biosolids land application in 2019 a review was conducted of the soil trace elements across each sample benchmark sample point (Table C.2, Appendix E). The trend between 2019 and 2024 can be observed for each soil trace element being monitored at each benchmark sample location in Table C.2, Appendix E. It is observed that there is variation across the sample locations of the trace elements between 2019 to 2024. This determination of difference indicated an accumulation of trace elements for arsenic and nickel primarily and no change in balance of trace elements.

The average soil trace elements across all benchmark soil sample locations (SE & SW (S1/2) 28-12-01WPM, SE & NE 29-12-01WPM) was calculated (Table C.2, Appendix E). This average across all the benchmark sample locations indicates that broadly there is a minimal increase in trace elements such as Arsenic and Nickel, that is likely due to the contribution from biosolids. It is important to note that the increase in trace elements is less than the concentrations of trace elements identified in the biosolids and that the differences may be due to soil sampling error and variation in the soil itself.

Total Phosphorus

Total soil phosphorous is found in two forms, organic and inorganic. While total phosphorous concentrations can be high, large portions of the total phosphorus are immobile and not available for plant uptake, this pool is the organic form of phosphorus. Organic forms of phosphorus include decomposing plant and animal matter, and soil micro-organisms this would additionally include all contributions from biosolids. Inorganic phosphorous forms include plant available (soil solution) phosphorous plus sorbed phosphorous (attached to clay surfaces, iron, aluminium and calcium oxides) and is released slowly over time for plant uptake and mineral phosphorous.

While plant-available phosphorous (Olsen-P) is the required form of soil phosphorous nutrient to monitor in this Program, total phosphorous has been selected as an additional indicator to monitor soil health. Total phosphorous concentrations for SE & SW (S1/2) 28-12-01WPM, SE & NE (E1/2)29-12-01WPM each increased for the respective benchmark locations between 2019 and 2024 after one application of biosolids in 2024 (Table D, Appendix E). The plant-available phosphorous has generally increased, however, this is not consistent with all benchmark locations (Table D, Appendix E).

NW24-12-01EPM

The analytical results are presented in Table A, Appendix E for NW24-12-01EPM. The 2024 Land Application Program is the first application event on this parcel of land. The benchmark post-harvest residual nitrate-nitrogen (0-60 cm) results are low in concentrations. With residual plant available phosphate – P below the applicable Nutrient Management Guidelines of 60 ppm for soils sampled for each sample location.

SW24-12-01EPM

The analytical results are presented in Table A, Appendix E for SW24-12-01EPM. The 2024 land application Program is the first application event on this parcel of land. The benchmark post-harvest residual nitrate-nitrogen (0-60 cm) results are low in concentrations. With residual plant available phosphate – P below the applicable Nutrient Management Guidelines of 60 ppm for soils sampled for each sample location.

NW21-12-01WPM

The analytical results are presented in Table A, Appendix E for NW21-12-01WPM. The 2024 land application Program is the first application event on this parcel of land. The benchmark post-harvest residual nitrate-nitrogen (0-60 cm) results are low in concentrations. With residual plant available phosphate – P below the applicable Nutrient Management Guidelines of 60 ppm for soils sampled for each sample location.

NE21-12-01WPM

The analytical results are presented in Table A, Appendix E for NE21-12-01WPM. The 2024 land application Program is the first application event on this parcel of land. The benchmark post-harvest residual nitrate-nitrogen (0-60 cm) results are low in concentrations. With residual plant available phosphate – P below the applicable Nutrient Management Guidelines of 60 ppm for soils sampled for each sample location.

2.9.3 Post-Application Soil Monitoring Results

Application Year 2021, Third Year Post- Biosolids Application Monitoring Results

(S1/2 SW 15-09-01WPM, S1/2 SE 15-09-01WPM, 14-09-01WPM, SE 05-10-01EPM – RM Macdonald)

The analytical results are presented in Table A., Appendix E. The land application event occurred in the fall of 2021 with 2024 being the third year of post biosolids land application soil residual monitoring. In general, the post-harvest residual nitrate-nitrogen (0-15 cm and 15-60 cm) results demonstrated decreased concentrations in Year 3 of the monitoring Program from the benchmark sampling event in the fall of 2021, and consistent residual nitrate-nitrogen concentration between the fall of 2023 and fall of 2024. The available plant-available phosphate – P is below the applicable Nutrient Management Guidelines of 60 ppm for soils sampled in Year 3 of the Program for each field.

S1/2 SW15-09-01EPM the average soil residual results samples of the one benchmark sample locations are:

- 2021 Olsen-P was 7.8 mg/kg (benchmark)
- 2022 Olsen-P was 8.2 mg/kg was near the benchmark concentration after one year of cropping
- 2023 Olsen-P was 22 mg/kg slightly up from the benchmark concentration
- 2024 Olsen-P was 19 mg/kg less than 2023 residual concentrations

SE15-09-01WPM the soil residual results samples of the two benchmark sample locations are:

- 2021 Olsen-P was 11 mg/kg and 17 mg/kg of the two benchmark waypoints
- 2022 Olsen-P was 3.2 mg/kg and 5.4 mg/kg of the two benchmark waypoints, these were decreased from the benchmark concentration after one year of cropping
- 2023 Olsen-P was 12 mg/kg and 27 mg/kg of the two benchmark waypoint locations, these are slightly up from the previous year

- 2024 Olsen-P was 11 mg/kg and 23 mg/kg of the two benchmark waypoint locations, these are consistent with 2023

14-09-01WPM the average soil residual results of the six benchmark sample locations are:

- 2021 Olsen-P was 11.3 mg/kg (benchmark)
- 2022 Olsen-P was 13.2 mg/kg was increased from the benchmark concentration after one year of cropping:
  - SW14-09-01WPM could not be accessed due to standing crop (corn) at the time of sampling
- 2023 Olsen- P was 17.3 mg/kg slightly elevated but consistent with the previous sampling event
- 2024 Olsen-P was 19.6 mg/kg consistent with the previous sampling event

SE05-10-01EPM the average soil residual results samples of the four benchmark sample locations are:

- 2021 Olsen-P was 13 mg/kg (benchmark)
- 2022 Olsen-P was 32.2 mg/kg was increased from the benchmark concentration after one year of cropping
- 2023 Olsen-P was 13.4 mg/kg was down from the previous year sampling event and consistent with the benchmark sampling event of 2021
- 2024 Olsen-P was 16.0 mg/kg slightly elevated from 2023 but down from 2022

In general, the target application rate (2x crop removal of P) appears nominally influenced by the residual concentration of soil inorganic phosphorus with either no change or only a slight increase of inorganic phosphorus residual concentration over the three-year period. It is likely that production agronomy and climate are contributing factors to the residual concentrations of soil phosphorus due to increase chemical fertilizer application.

Application Year 2022, Second Year Post- Biosolids Application Monitoring Results

(S1/2 SE 33-11-01EPM, E1/2 28-11-01EPM, N1/2 NW 21-11-01EPM, and NW27-11-01EPM – RM of Rosser)

The analytical results are presented in Table A, Appendix E. The land application event occurred in the fall of 2022 with 2024 being the second year of post biosolids land application soil residual monitoring. In general, the post-harvest residual nitrate-nitrogen (0-15 cm and 15-60 cm) results demonstrated a valuable residual nitrate-nitrogen decrease from the previous Year 1 post-application monitoring with one sample location being elevated comparatively (see comments below). The available phosphate – P is below the applicable Nutrient Management Guidelines of 60 ppm for soils sampled in Year 2 of the Program for each benchmark waypoint sample location.

S1/2 SE33-11-01EPM the soil residual sample results for the two benchmark sample locations are:

- 2022 Olsen-P was 14 mg/kg and 7.2 mg/kg (benchmark)
- 2023 Olsen-P was 24 mg/kg and 30 mg/kg
- 2024 Olsen-P was 9 mg/kg and 12 mg/kg

E1/2 28-11-01EPM the soil residual sample results for the five benchmark sample locations are:

- 2022 Olsen-P was 29 mg/kg, 16 mg/kg, 16 mg/kg, 28 mg/kg, and 35 mg/kg (benchmark)
- 2023 Olsen-P was 15 mg/kg, 15 mg/kg, 23 mg/kg, 21 mg/kg and 35 mg/kg

- 2024 Olsen-P was 26 mg/kg, 23 mg/kg, 24 mg/kg, 23 mg/kg, and 20 mg/kg

N1/2 NW 21-11-01EPM the soil residual sample results for the two benchmark sample locations are:

- 2022 Olsen-P was 15 mg/kg and 27 mg/kg (benchmark)
- 2023 Olsen-P was 26 mg/kg and 10 mg/kg
- 2024:
  - At W058 the nitrate-N was 56 mg/kg and 19 mg/kg in 0-15 cm
  - At W058 the Olsen-P was 33 mg/kg:
    - With these both being slightly elevated compared to the balance of the fields this would be an indicator that there may have been a crop failure in around this sample locations.

NW27-11-01EPM the soil residual sample results for the three benchmark sample locations are:

- 2022 Olsen-P was 14, 27 mg/kg and 11 mg/kg (benchmark)
- 2023 Olsen-P was 24 mg/kg, 24 mg/kg and 15 mg/kg
- 2024 Olsen-P was 16 mg/kg, 12 mg/kg and 11 mg/kg

Application Year 2023, First Year Post- Biosolids Application Monitoring Results

NE, NW, SW and SE-36-12-01WPM

The analytical results are presented in Table A, Appendix E. The 2023 land application Program is the second application event on this parcel of land, with the first event in 2018. Thus, particular interest was applied to the review of the soil nutrients and metals profiles for 2024. The 2024 post-harvest residual nitrate-nitrogen (0-60 cm) results are within acceptable concentrations. The available Phosphate – P is below the applicable Nutrient Management Guidelines of 60 ppm for soils sampled for each sample location and are less than the 2023 benchmark sampling event.

NW31-12-01WPM and N1/2 SW31-12-01WPM

The analytical results are presented in Table A, Appendix E. The 2023 land application Program is the second application event on this parcel of land, with the first event in 2019. Thus, particular interest is applied to the review of the soil residual nutrients and trace elements for 2024. In general, the post-harvest residual nitrate-nitrogen (0-15 cm and 15-60 cm) results demonstrated a slight increase in residual concentrations in Year 1 of the monitoring Program from the benchmark sampling event in the fall of 2023. The plant-available Phosphate – P is below the applicable Nutrient Management Guidelines of 60 ppm for soils sampled in Year 1 of the Program for each field.

Trace Elements

Soil total trace elements (arsenic, cadmium, copper, chromium, lead, mercury, nickel, and zinc) are within expected parameter ranges for the Red River Valley clays. At the given soil concentrations plus the application rate of biosolids, the cumulative metal concentrations of each of the elements are not limiting to receiving biosolids land application and in most cases are permissible of numerous land application events (Table B, Appendix E).

As NE, NW, SW, and SE 36-12-01WPM previously received biosolids (2018) and NW31-12-01WPM and N1/2 SW31-12-01WPM (2019), a review was conducted of the soil trace elements across each benchmark sample point (Table C, Appendix E).

To review the trace element concentration across each of the benchmark sample locations the average and standard deviation across each year and benchmark location was calculated. In general, there has been nearly no change to a slight increase of trace elements from the benchmark in 2019 and the subsequent monitoring years of 2023 and 2024 (Table C, Appendix E). This average across all the benchmark sample locations indicates that broadly there is a slight increase in trace elements (i.e. arsenic, copper, chromium, lead, and zinc) that may likely be due to the contribution from biosolids. It is important to note that the increase in trace elements is less than the concentrations of trace elements identified in the biosolids, but the magnitude of increase is consistent with trace elements that are greater in concentration such as copper and zinc. Copper and zinc are both micro-nutrients required by crops; there is a cumulative weight allowed by guidelines.

Total Phosphorus (NW31-12-01WPM and N1/2 SW31-12-01WPM)

While plant-available phosphorous (Olsen-P) is the required form of soil phosphorous nutrient to monitor in this Program, total phosphorous has been selected as an additional indicator to monitor soil health. Total phosphorous concentrations for NW31-12-01WPM and N1/2 SW31-12-01WPM each increased for the respective benchmark locations between 2019 and 2024 after one application of biosolids in 2024 (Table D, Appendix E). The plant-available phosphorous has generally increased, however, this is not consistent with all benchmark locations (Table D, Appendix E).

SE35-11-01WPM and SW35-11-01WPM

The analytical results are presented in Table A, Appendix E. The 2023 Land Application Program is the first application event on this parcel of land. The post-harvest residual nitrate-nitrogen (0-60 cm) results are within acceptable concentrations. The available phosphate – P is below the applicable Nutrient Management Guidelines of 60 ppm for soils sampled for each sample location.

3 CONCLUSIONS

The City's approach for the full-scale Program is to reuse the biosolids materials produced by the City's population/workforce in an environmentally sustainable manner. In consultation with the cooperating farm producers, the Program applies biosolids based on crop nutrient uptake and removal that matches agronomic needs with biosolids nutrient content. Application rates are based on crop uptake and removal of phosphorus for a multi-year application event with the objective of returning to the same agricultural fields on a four-year land rotation. This allows crops to uptake the nutrients released from the biosolids material over several cropping seasons and minimizes the potential for build-up of nutrients and metals in the soil profile.

In 2024, the Program returned to two fields that had previously received biosolids in 2019 (E1/2 29-12-01WPM and S1/2 28-12-01WPM). And fields W1/2 24-12-01EPM and N1/2 21-12-01WPM being included in the Program for the first time in 2024.

To ensure sufficient volume of biosolids were available and to limit the handling of biosolids, a temporary all-weather in-field temporary storage site was established in S1/2 28-12-01WPM and temporary dry weather storage sites were established in W1/2 24-12-01EPM and N1/2 21-12-01WPM. A berm was formed around the in-field temporary storage area consisting of rectangular straw bales. Biosolids were first deposited within the all-weather temporary storage area on May 27, 2024, with delivery continuing over approximately 14 weeks. The dry weather

temporary storage area on W1/2 24-12-01EPM first received biosolids on July 8, 2024 and continued until September 6, 2024. The third temporary storage area received biosolids on September 9 and continued until October 18, the last day of spreading. Straw was applied over the biosolids each evening after deliveries to cap the biosolids to ensure odour and vector control. The biosolids materials stockpiled at the storage area were land applied in the months of August, September and October 2023.

Odour assessments completed over the growing season for the temporary in-field storage area location indicated that the odour management approach was successful. Over the course of the five odour monitoring events and between four and 21 odour assessment participants (WSP E&E staff, City staff, and Manitoba Agriculture), the average odour rank was 1.07, 1.21, 1.25 and 1.55 at assessment distances of 50 m, 25 m, 10 m, and 5 m, respectfully. The control (up wind of the biosolids storage site) average odour rank was 0.0.

A review of the temporary storage sites odour assessment results from 2018 through 2024 was completed. In conclusion odour detection was strongest nearest to the temporary storage sites while at 50 m distant and down wind, the odour was nearly not detectable, indicating that further way from the storage site odour would not be noticeable and that the straw cover was effective to mitigate odour.

Biosolids were applied at a rate between 43 and 50 wet tonnes per ha (refer to Appendix D for prescription rates). The City delivered approximately 24,138 wet tonnes of biosolids, achieving 121% of the target 20,000 tonne target objective. Since the start of the City's current Program initiated with the Pilot Project in 2017, over 116,480 wet tonnes (31,991 dry tonnes) of biosolids have been applied to cooperating farm producer's agricultural land in the RMs of Macdonald and Rosser. The reuse of nutrients in the biosolids has equated to over 1,228 dry tonnes of total nitrogen and 608 dry tonnes of total phosphorus made available to crops over the past seven years of the Program. In addition, over 9,821 dry tonnes of carbon have been amended to the soil from the Biosolids Land Application Program.

The benchmark soil sampling Program observed that in general, the post-harvest residual nitrate-nitrogen (0-15 cm and 15-60 cm) results are as anticipated for the one, two-, and three-years' post-application monitoring. Part of the approach to continued management of residual nitrogen includes the three-year required nutrient monitoring and advisement to the cooperating farm producers of the soil sampling results.

While plant available phosphorous (Olsen-P) is the required form of soil phosphorous nutrient to monitor in this Program, total phosphorous has been selected as an additional indicator to monitor soil health. Total phosphorous in soil is found in two forms, organic and inorganic. While total phosphorous concentrations can be high, large portions of the total phosphorus are immobile and not available for plant uptake, this pool is the organic form of phosphorus. Organic forms of phosphorus include decomposing plant and animal matter, and soil micro-organisms this would additionally include all contributions from biosolids. Inorganic phosphorous forms include plant available (soil solution) phosphorous, sorbed phosphorous (attached to clay surfaces, iron, aluminum and calcium oxides) and is released slowly over time for plant uptake and mineral phosphorous. Twelve (12) benchmark locations have been analysed for total phosphorous in six field in both 2019 and 2024.It has been observed that the total phosphorous has increased in concentration at the 12 benchmark locations but it appears not to have mineralized from the organic pool (biosolids) to the inorganic pool (plant available) as the plant available phosphorous, determined by the Olsen-P analysis, generally is not indicating an increase in this inorganic phosphorous pool.

3.1 Further Recommendations Based on 2024 Biosolids Land Application Program Findings

Based on the findings of the Program (2018 through 2024), the following recommendations are made to further support this Program:

- Best neighbour practices for odour control during land application. Monitor the wind direction and speed in relation to neighbour dwellings within 800 m (half mile) of the field and if necessary complete a risk assessment for the situation. Program managers may need to consider postponement of biosolids application on the field if neighbouring residents that may be directly downwind of the application field are at risk of strong odour.
- Continue the monitoring Program for plant available nutrients, total phosphorous and trace elements on fields where land application may be occurring on two or more events. This will provide a continual understanding of accumulation of these elements over the years.
- Continued adherence to EAL #3377 and continuation of beneficial management practices including continued communication with Municipal Councils, Advisory Committee and the public.
- Continued monitoring of scientific literature/regulations for emerging contaminates of concern relating to biosolids land application.

Signature Page

If you have any questions or concerns, please contact the undersigned at your convenience at (204) 259-1488 or Darren.keam@wsp.com.

Yours sincerely,

WSP Canada Inc.

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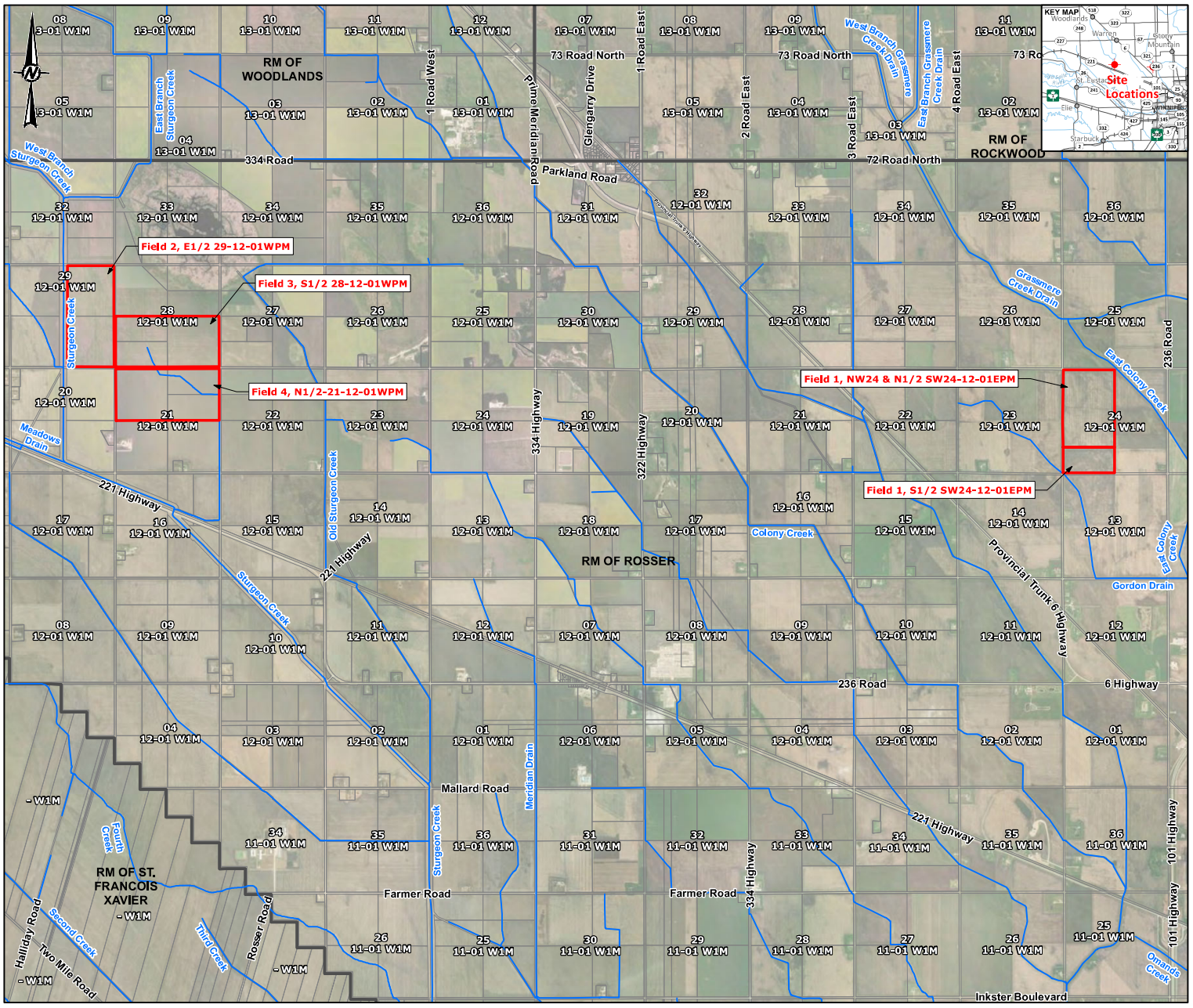
DK/DS/jr

APPENDIX A

Map Figures



LEGEND

- Field Boundary
- Municipal Boundaries
- Parcels
- Drainage Way

0 500 1,000 1,500 2,000 2,500 3,000

1:60,000 Meters

Coordinate System: NAD 1983 UTM Zone 14N

REFERENCE(S)

1. IMAGERY SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS

CLIENT

CITY OF WINNIPEG

PROJECT

CITY OF WINNIPEG
2024 BIOSOLIDS LAND APPLICATION PROGRAM

TITLE

2024 BIOSOLIDS LAND APPLICATION PROGRAM

CONSULTANT

wsp

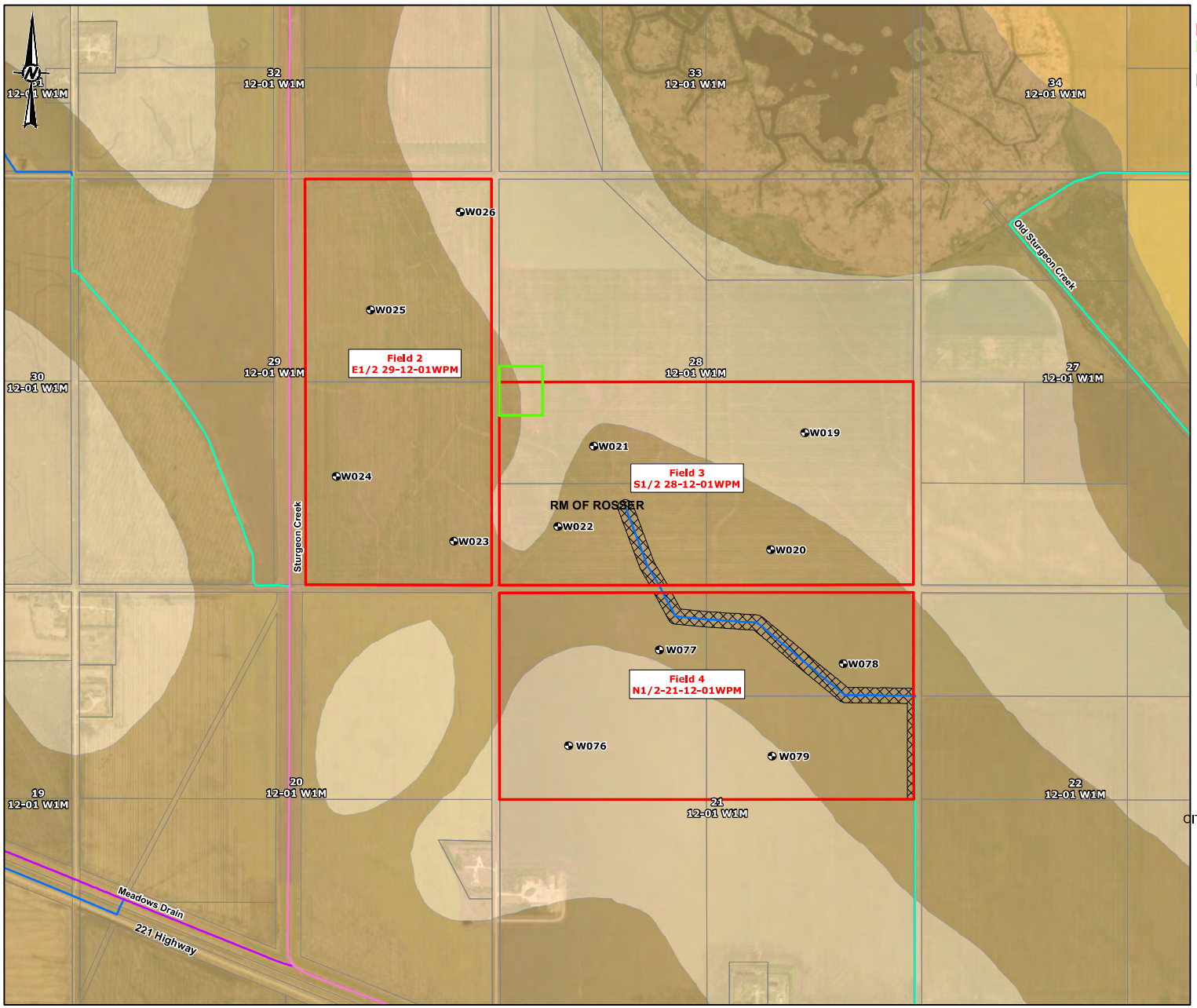
YYYY-MM-DD	2025-03-10
REPORT BY	D.KEAM
DRAWN BY	J.HECK
REVIEWED BY	D.KEAM
OFFICE	WINNIPEG

PROJECT NO.

CA0022187.4729

FIGURE

1



LEGEND

- Field Boundary
- Temporary Storage Yard Site
- Limitations Within Field Boundaries
- Municipal Boundaries
- Parcels
- Soil Sample Location

Drainage Way Order

- 1
- 2
- 3
- 4

Soil Series

- Marquette
- Osborne
- Red River

0 200 400 600 800 1,000

1:15,000 Meters

Coordinate System: NAD 1983 UTM Zone 14N

REFERENCE(S)

1. IMAGERY SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS

CLIENT
CITY OF WINNIPEG

PROJECT
CITY OF WINNIPEG
2024 BIOSOLIDS LAND APPLICATION PROGRAM

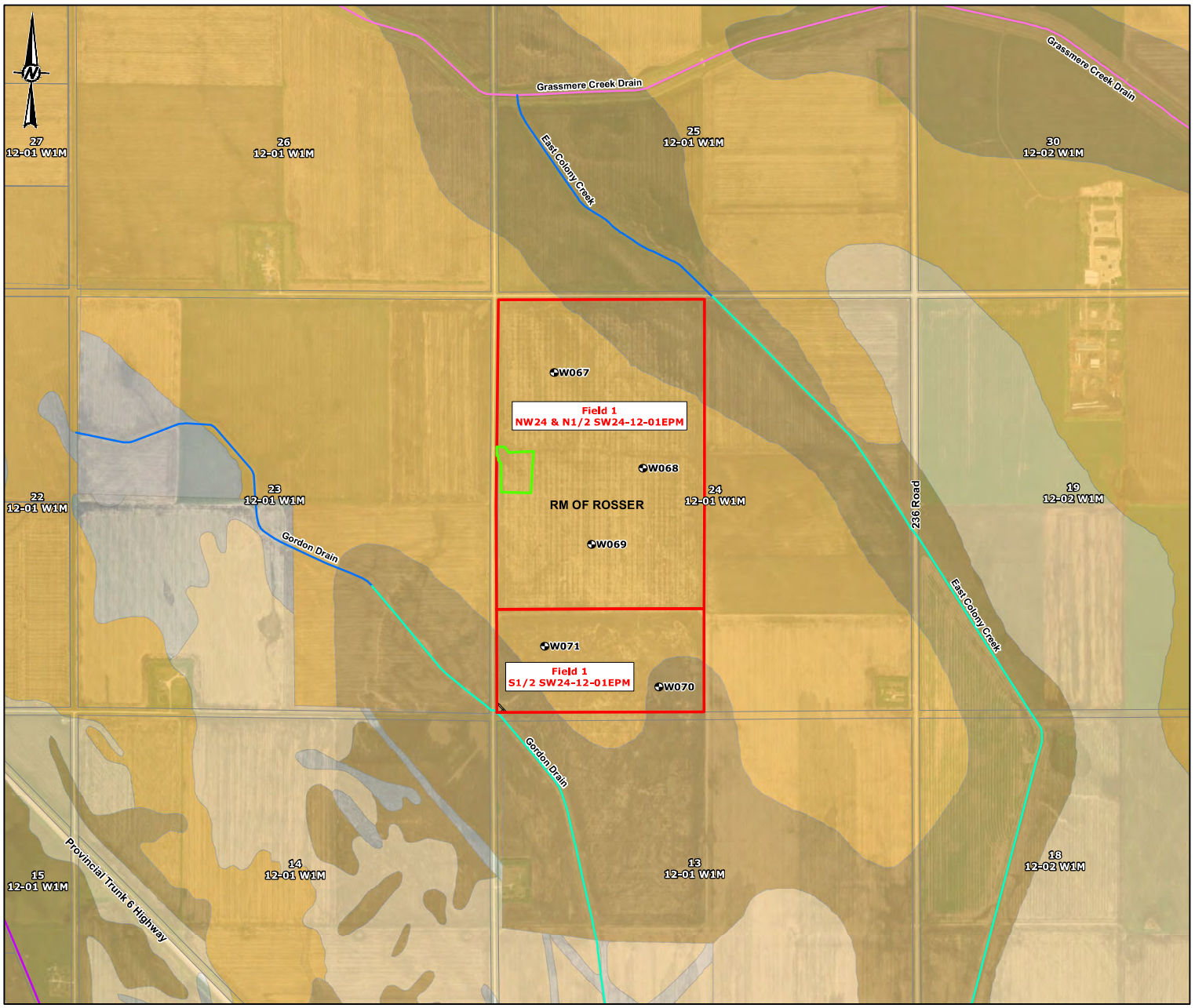
TITLE
2024 BIOSOLIDS LAND APPLICATION PROGRAM
E1/2-29-12-01 W1M, S1/2-28-12-01 W1M AND N1/2-21-12-01 W1M

CONSULTANT

YYYY-MM-DD	2025-03-10
REPORT BY	D.KEAM
DRAWN BY	J.HECK
REVIEWED BY	D.KEAM
OFFICE	WINNIPEG

PROJECT NO. CA0022187.4729

FIGURE 2A



LEGEND

- Field Boundary
- Temporary Storage Yard Site
- Limitations Within Field Boundaries
- Municipal Boundaries
- Parcels
- Soil Sample Location

Drainage Way Order

- 1
- 2
- 3
- 5

Soil Series

- Kline
- Marquette
- Osborne
- Red River

0 200 400 600 800 1,000

1:15,000 Meters

Coordinate System: NAD 1983 UTM Zone 14N

REFERENCE(S)

1. IMAGERY SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS

CLIENT
CITY OF WINNIPEG

PROJECT
CITY OF WINNIPEG
2024 BIOSOLIDS LAND APPLICATION PROGRAM

TITLE
2024 BIOSOLIDS LAND APPLICATION PROGRAM
E1/2-24-12-01 W1M

CONSULTANT

YYYY-MM-DD	2025-03-10
REPORT BY	D.KEAM
DRAWN BY	J.HECK
REVIEWED BY	D.KEAM
OFFICE	WINNIPEG

PROJECT NO.
CA0022187.4729

FIGURE
2B

APPENDIX B

Neighbour Notification

Winnipeg | Water and Waste
Eaux et déchets

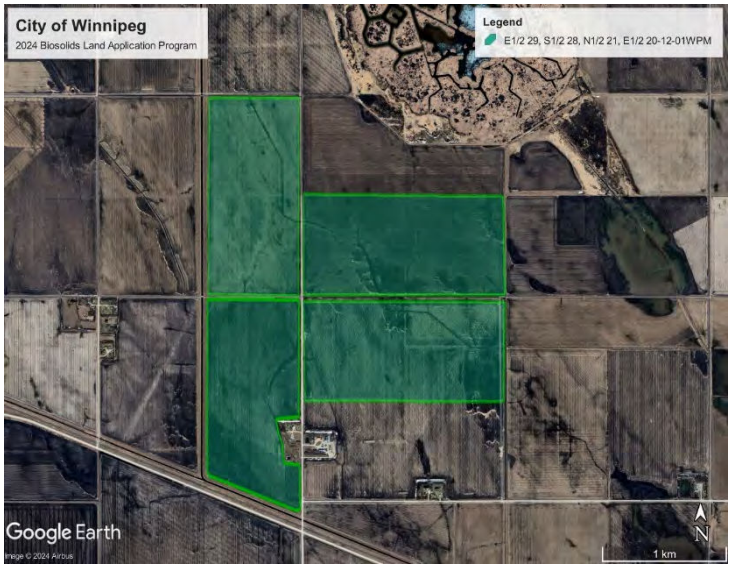
NOTICE TO RESIDENTS
(Français au verso)

City of Winnipeg Biosolids Stockpiling and Land Application Program

The City of Winnipeg is conducting a biosolids land application program this summer on the farmland identified in the map below. Biosolids will be stockpiled and covered with straw daily (Monday through Friday, occationally on a Saturday), from May until the end of October. Biosolids will be applied to the fields after crop harvest and tilled within 48 hours for proper odour and nutrient management.

Biosolids are a nutrient-rich, solid by-product of wastewater treatment. At the City's sewage treatment plants, the solids are separated from the liquid wastewater. These solids are further treated and dewatered. After treatment, the solids are called biosolids.

Biosolids are applied to soil to supply nutrients and improve soil structure. Land application is a widely accepted method to reuse biosolids. The City's program will apply approximately 20,000 tonnes of biosolids to local farmland in 2024. Biosolids land application is regulated by the Province of Manitoba through the Nutrient Management Regulation and a project specific Environment Act Licence #3377 which outline requirements for soil suitability, timing of application, rate of application, setback distances and nutrient management monitoring. Your local municipality is aware of the biosolids land application program being completed by the City.



Application rates will be matched to crop uptake and removal for crop nitrogen and phosphorus. These rates will be developed by a registered Professional Agrologist and follow the principles of 4R Nutrient Stewardship, including the use of the right fertilizer source at the right rate, at the right time and in the right place.

For more information

- Visit: winnipeg.ca/BiosolidsLandApplication
- Contact: Kimsong Bun, C.E.T, Project Coordinator, Water & Wastewater Services, City of Winnipeg, by:
  - email at BiosolidsLandApplication@winnipeg.ca
  - or call 1-888-882-3391

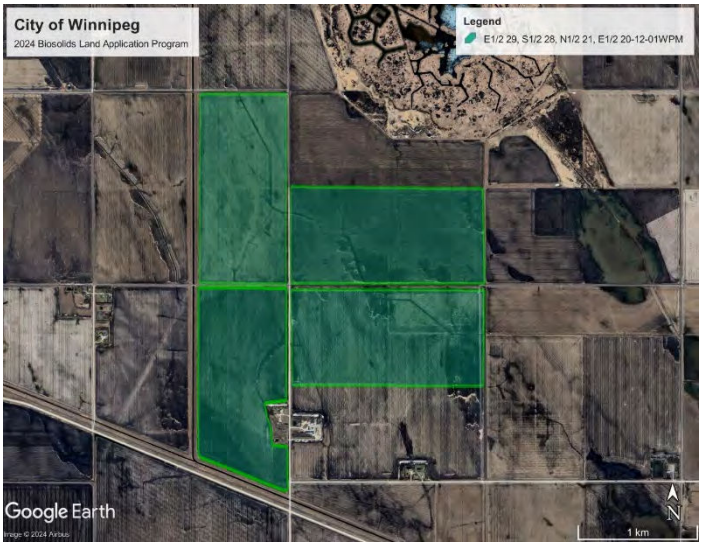
Water and Waste
Eaux et déchets

AVIS AUX RÉSIDENTS
(English on reverse)

Programme d'entreposage et d'épandage des biosolides de la Ville de Winnipeg

Cet été, la Ville de Winnipeg va mettre en œuvre son programme d'épandage des biosolides sur les terres agricoles délimitées sur le plan ci-dessous. Les biosolides seront entreposés et couverts de paille tous les jours (du lundi au vendredi, occasionnellement un samedi), entre le may et la fin du mois de octobre. Les biosolides seront répandus dans les champs après la récolte et labourés dans les 48 heures dans le cadre du contrôle des odeurs et des nutriments.

Les biosolides sont des sous-produits solides, riches en éléments nutritifs, qui proviennent du traitement des eaux usées. Aux stations de traitement des eaux usées de Winnipeg, les matières solides sont extraites des eaux usées liquides. Ces matières sont traitées et déshydratées. Une fois traitées, ces matières sont appelées « biosolides ».



Les biosolides sont répandus sur le sol afin de fournir à celui-ci des éléments nutritifs et d'améliorer sa structure. L'épandage est une méthode de recyclage des biosolides généralement reconnue. Dans le cadre de ce programme municipal, la Ville répandra environ 20 000 tonnes de biosolides sur les terres agricoles du secteur en 2024. L'épandage de biosolides est réglementé par le *Règlement sur la gestion des nutriants* de la Province du Manitoba et par une licence délivrée sous le régime de la *Loi sur l'environnement* pour le projet #3377, qui précise les exigences liées à la compatibilité du sol, à l'horaire et au taux d'épandage, aux distances de retrait et au contrôle de la gestion des nutriments. Votre municipalité est au courant du fait que la Ville va mettre en œuvre son programme d'épandage des biosolides.

Les doses d'épandage seront adaptées en fonction de l'absorption par les cultures de l'azote et du phosphore ainsi que du prélèvement en azote et en phosphore des cultures. Ces taux seront établis par un agronome professionnel inscrit et se conformeront aux principes de la gérance des nutriments 4R, à savoir l'utilisation de la bonne source d'engrais à la bonne dose, au bon moment et au bon endroit.

Renseignements supplémentaires

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Winnipeg | Water and Waste
Eaux et déchets

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Winnipeg | Water and Waste
Eaux et déchets

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APPENDIX C

Photographs

Photo 1: S1/2 29-12-01WPM All-weather temporary storage site entrance

Photo 2: NW24-12-01EPM Dry weather temporary storage site (looking across site)

wsp	Date Taken: May 26, 2024	Client: City of Winnipeg
	Taken by: DKeam	Location: RM of Rosser, Manitoba
	Project No.: CA0022187.4729	

Photo 3: S1/2 29-12-01WPM All-weather temporary storage receiving area

Photo 4: Manitoba Agriculture Site Visit

wsp	Date Taken: June 11, 2024	Client: City of Winnipeg
	Taken by: DKeam	Location: RM of Rosser, Manitoba
	Project No.: CA0022187.4729	

Photo 5: Manitoba Agriculture Site Visit Odour Assessment

Photo 6. Manitoba Agriculture Staff Odour Assessment @ 25M

wsp	Date Taken: June 11, 2024	Client: City of Winnipeg
	Taken by: DKeam	Location: RM of Rosser, Manitoba
	Project No.: CA0022187.4729	

Photo 7: S1/2 29-12-01WPM – Loading Biosolids onto Spreader

Photo 8: S1/2 29-12-01WPM – Land Spreading of Biosolids

wsp	Date Taken: September 2, 2024	Client: City of Winnipeg
	Taken by: DKeam	Location: RM of Rosser, Manitoba
	Project No.: CA0022187.4729	

APPENDIX D

Biosolids Land Application Prescription Rates

Field Prescription Application Rate, City of Winnipeg
Date Modified: 27Aug2024

Field ID:	S1/2 28-12-01WPM	
Land Area Available (ha):	127	
2025 Crop	Canola	
2025 Target Yield (bu/ac, kg/ha):	45	1,017
	lb/ac	kg/ha
Target Nitrogen total less soil residual:	100	112
Fertilizer Phosphate (P2O5) total less soil residual:	10	11
1 x P2O5 Crop Removal @ target Yield:	57	64
2 x P2O5 Crop Removal @ target Yield:	115	128
3 x P2O5 Crop Removal @ target Yield:	171	192
Sulfate-S target:	20	22

Plant Available Nutrients Soil Test Data

	W019		240822_004	W020		240822_005
Sample Depth	0-15 cm	15-60 cm	Total Available	0-15 cm	15-60 cm	Total Available
Units	mg kg^{-1}		kg ha^{-1}	mg kg^{-1}		kg ha^{-1}
Total Nitrogen						
Available Nitrate-N	15.0	7	65	13.0	3	40
Available Phosphate-P	49.0		88	49.0		88
Available Potassium	750		1,350	690.0		1,242
Available Sulfate-S	009	8	66	08.0	12	88
EC (dS/m)	0.77	0.92		00.89	0.91	
Organic Matter (%)	8			7.70		
	W021		**240822_006**	**W022**		**240822_007**
Sample Depth	0-15 cm	15-60 cm	Total Available	0-15 cm	15-60 cm	Total Available
Units	mg kg^{-1}		kg ha-1	mg kg^{-1}		kg ha-1
Total Nitrogen						
Available Nitrate-N	14.0	4	47	20.0	5	63
Available Phosphate-P	41.0		74	43.0		77
Available Potassium	800.0		1,440	670.0		1,206
Available Sulfate-S	11.0	10	82	12.0	19	138
EC (dS/m)	00.79	0.88		00.8		
Organic Matter (%)	8.50			0.90		

City of Winnipeg Biosolids Characteristics and Analysis

Parameter Name	Parameter Description	Unit	Biosolid Analysis Pilot Project
Estimated Biosolid Volume	In-field	m^3	5,842
Specific Gravity	As Received	g cm^{-1}	1.00
Estimated Biosolids		tonnes	5,842
Dry tonnes biosolids available (=wet tonnes x %solids)	Dried Basis	tonnes	1,630
Moisture	As Received	%	73.5
Total Solids	As Received	%	27.9
Organic Matter	Dry Basis	%	49.88
Total Organic Carbon	Dry Basis	%	30.50
C:N Ratio	Dry Basis	x:1	7.7
C:P Ratio	Dry Basis	x:1	16.0
N:P Ratio	Dry Basis	x:1	2.09
pH	Saturated Paste		6.04
Total N	Dried Basis	%	4.0
	Dried Basis	mg kg^{-1}	39,845
	Dried Basis	kg Tonne^{-1}	39.8
Ammonium - N (NH4-N)	Dried Basis	mg kg^{-1}	5,433.10
	Dried Basis	kg Tonne^{-1}	5.43
Available Nitrate-N	Dried Basis	mg kg^{-1}	1.70
Available Nitrate-N		kg Tonne^{-1}	0.002
Total Phosphorous (average)	Dried Basis	mg kg^{-1}	19,071
Amount of Biosolids Nutrient Available to Crop			
Organic N (=TN - Ammonium N)	Dried Basis	mg kg^{-1}	34,412
Organic N	Dried Basis	kg Tonne^{-1}	34.4
Method of Application:			Incorporated 1 day
Anticipated Weather			Warm Dry
Anticipated Volatilization (%)	within 1 day		50
Available Organic N (@ 25%)	Dried Basis	kg Tonne^{-1}	8.6
Ammonium-nitrogen Available	Dried Basis	kg Tonne^{-2}	2.72
Plant Available Nitrogen (PAN) (Year 1)	Dried Basis	kg Tonne^{-1}	11.3
PAN Year 2 (@12% mineralization)	Dried Basis	kg Tonne^{-1}	4.1
PAN Year 3 (@6% mineralization)	Dried Basis	kg Tonne^{-1}	2.1
Phosphorous	Dried Basis	kg Tonne^{-1}	19.1
P_2O_5 equivalent	Dried Basis	kg Tonne^{-1}	43.9
Total Available P_2O_5	Dried Basis	kg Tonne^{-1}	11.0

Application Rate based on Nitrogen				**Land Area Required**
Nitrogen Based Application Rate	Dried Basis	tonnes ha^{-1}	10	**165** Ha
Amount of Available P2O5 applied	Dried Basis	kg ha^{-1}	108	407 Ac
P_2O_5 Application check		%	969	
Application Rate based on Phosphorous (1xCR)				**Land Area Required**
Total Phosphorus Based Application Rate	Dried Basis	tonnes ha^{-1}	6	**280** Ha
	Dried Basis	kg ha^{-1}	66	**692** Ac
Amount of Nitrogen applied		lb ac^{-1}	59	
		kg ha^{-1}	46	
Additional Nitrogen required		lb ac-1	41	
Application Rate based on Phosphorous (2xCR)				**Land Area Required**
Total Phosphorus Based Application Rate	Dried Basis	tonnes ha^{-1}	**12**	**140** Ha
Amount of Nitrogen applied	Dried Basis	kg ha^{-1}	132	**346** Ac
Additional Nitrogen required		kg ha^{-1}	20	
Application Rate based on Phosphorous (3xCR)				**Land Area Required**
Total Phosphorus Based Application Rate	Dried Basis	tonnes ha^{-1}	**17**	**93** Ha
Amount of Nitrogen applied	Dried Basis	kg ha^{-1}	198	**231** Ac
Additional Nitrogen required		kg ha^{-1}	86	

S1/2 SE33-11-01EPM

Selected Application rate based on:		2 x CR P	
Selected Application Rate	Dried Basis	tonnes ha^{-1}	**12**
		tons ac^{-1}	**5**
	Wet Basis	tonnes ha^{-1}	44
		tons ac^{-1}	20
Estimated Biosolids Volume Applied	Wet	Tonnnes	5,624
Estimated Biosolids Volume Remaining	Wet	Tonnes	218

Anticipated Nutrient Application and Removal Rates based on the Selected Application rate				Anticipated Nutrient Removal Yr1 Based on Target yield		Anticipated residual	
Nitrogen Application (kg/ha)			132		**38.68**	93.14	Within Regulation
Total P2O5 Application (kg/ha)			128		**20**	107.32	Within Regulation

Notes:
Available Ammonium N - Volatilization loss associated with different application methods (0% with Injection)
Organic N - TKN - Ammonium N
Available Organic N - Organic N x 0.20 year 1 (Ross and Racz, 2003)
Mineralization of Year 2 = 12%, Year 3 = 6%
Plant Available Nitrogen= (NO3-N)+Volatilization factor (NH4-N)+Organic N Mineralization
Estimated P2O5 Available based on 25% of total Phosphorus as directed by MSD.
Note: the biosolids are FeCl treated and fixes the majority of the total P.
Soil Phosphorous Olsen method.
* See Estimates of Ammonium-N Retained After Biosolids application

C:N exceeds 30:1, N becomes a limiting nutrient for decomposer organisms, and this can reduce the rate of decomposition and results in N immobilization

C:P ratio between 200:1 and 300:1, mineralization and immobilization balance each other to result in no net release of P from the decomposing manure. When C:P is below this range, P is released.

When animal and municipal wastes have N:P ratios ranging from 1:1 to 1:2 are applied based on N rates on soils, over time P will accumulate

Field Crop Nutrient Uptake and Removal in Typical Manitoba Crops
Anticipated Crop Nutrient Removal = (Target Yield (kg/ha) x (N or P2O5 kg/kg]
Corn Nitrogen = 0.0179 kg/kg, P2O5 = 0.0786 kg/kg

Field Prescription Application Rate, City of Winnipeg
Date Modified: 27Aug2024

Field ID:	E1/2 29-12-01WPM	
Land Area Available (ha):	114	
2025 Crop	Canola	
2025 Target Yield (bu/ac, kg/ha):	45	1,017
	lb/ac	kg/ha
Target Nitrogen total less soil residual:	0	0
Fertilizer Phosphate (P2O5) total less soil residual:	50	56
1 x P2O5 Crop Removal @ target Yield:	57	64
2 x P2O5 Crop Removal @ target Yield:	115	128
3 x P2O5 Crop Removal @ target Yield:	171	192
Sulfate-S target:	20	22

Plant Available Nutrients Soil Test Data

	W023		240822_008	W024		240822_009
Sample Depth	0-15 cm	15-60 cm	Total Available	0-15 cm	15-60 cm	Total Available
Units	mg kg^{-1}		kg ha^{-1}	mg kg^{-1}		kg ha^{-1}
Total Nitrogen						
Available Nitrate-N	26.0	23	171	23.0	6	74
Available Phosphate-P	40.0		72	23.0		41
Available Potassium	520		936	590.0		1,062
Available Sulfate-S	033	180	1,146	10.0	38	248
EC (dS/m)	0.95	1.90		00.92	0.97	
Organic Matter (%)	7.1			7.50		
	W025		**240822_010**	**W026**		**240822_011**
Sample Depth	0-15 cm	15-60 cm	Total Available	0-15 cm	15-60 cm	Total Available
Units	mg kg^{-1}		kg ha-1	mg kg^{-1}		kg ha-1
Total Nitrogen						
Available Nitrate-N	35.0	29	220	18.0	12	97
Available Phosphate-P	42.0		76	10.0		18
Available Potassium	670.0		1,206	370.0		666
Available Sulfate-S	19.0	11	104	08.0	31	202
EC (dS/m)	01.11	0.96		00.6	1	
Organic Matter (%)	8.00			7.00		

City of Winnipeg Biosolids Characteristics and Analysis

Parameter Name	Parameter Description	Unit	Biosolid Analysis Pilot Project
Estimated Biosolid Volume	In-field	m^3	5,244
Specific Gravity	As Received	g cm^{-1}	1.00
Estimated Biosolids		tonnes	5,244
Dry tonnes biosolids available (=wet tonnes x %solids)	Dried Basis	tonnes	1,463
Moisture	As Received	%	73.5
Total Solids	As Received	%	27.9
Organic Matter	Dry Basis	%	49.88
Total Organic Carbon	Dry Basis	%	30.50
C:N Ratio	Dry Basis	x:1	7.7
C:P Ratio	Dry Basis	x:1	16.0
N:P Ratio	Dry Basis	x:1	2.09
pH	Saturated Paste		6.04
Total N	Dried Basis	%	4.0
	Dried Basis	mg kg^{-1}	39,845
	Dried Basis	kg Tonne^{-1}	39.8
Ammonium - N (NH4-N)	Dried Basis	mg kg^{-1}	5,433.10
	Dried Basis	kg Tonne^{-1}	5.43
Available Nitrate-N	Dried Basis	mg kg^{-1}	1.70
Available Nitrate-N		kg Tonne^{-1}	0.002
Total Phosphorous (average)	Dried Basis	mg kg^{-1}	19,071

Amount of Biosolids Nutrient Available to Crop

Organic N (=TN - Ammonium N)	Dried Basis	mg kg^{-1}	34,412
Organic N	Dried Basis	kg Tonne^{-1}	34.4
Method of Application:			Incorporated 1 day
Anticipated Weather			Warm/dry
Anticipated Volatilization (%)	within 1 day		50
Available Organic N (@ 25%)	Dried Basis	kg Tonne^{-1}	8.6
Ammonium-nitrogen Available	Dried Basis	kg Tonne^{-2}	2.72
Plant Available Nitrogen (PAN) (Year 1)	Dried Basis	kg Tonne^{-1}	11.3
PAN Year 2 (@12% mineralization)	Dried Basis	kg Tonne^{-1}	4.1
PAN Year 3 (@6% mineralization)	Dried Basis	kg Tonne^{-1}	2.1
Phosphorous	Dried Basis	kg Tonne^{-1}	19.1
P_2O_5 equivalent	Dried Basis	kg Tonne^{-1}	43.9
Total Available P_2O_5	Dried Basis	kg Tonne^{-1}	11.0

Application Rate based on Nitrogen				**Land Area Required**
Nitrogen Based Application Rate	Dried Basis	tonnes ha^{-1}	-	**#DIV/0!** Ha
Amount of Available P2O5 applied	Dried Basis	kg ha^{-1}	-	#DIV/0! Ac
P_2O_5 Application check		%	-	
Application Rate based on Phosphorous (1xCR)				**Land Area Required**
Total Phosphorus Based Application Rate	Dried Basis	tonnes ha^{-1}	6	**251** Ha
	Dried Basis	kg ha^{-1}	66	**621** Ac
Amount of Nitrogen applied		lb ac^{-1}	59	
		kg ha^{-1}	- 66	
Additional Nitrogen required		lb ac-1	- 59	
Application Rate based on Phosphorous (2xCR)				**Land Area Required**
Total Phosphorus Based Application Rate	Dried Basis	tonnes ha^{-1}	**12**	**126** Ha
Amount of Nitrogen applied	Dried Basis	kg ha^{-1}	132	**310** Ac
Additional Nitrogen required		kg ha^{-1}	- 132	
Application Rate based on Phosphorous (3xCR)				**Land Area Required**
Total Phosphorus Based Application Rate	Dried Basis	tonnes ha^{-1}	**17**	**84** Ha
Amount of Nitrogen applied	Dried Basis	kg ha^{-1}	198	**207** Ac
Additional Nitrogen required		kg ha^{-1}	- 198	

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Selected Application rate based on:		**2 x CR P**	
Selected Application Rate	Dried Basis	tonnes ha^{-1}	**12**
		tons ac^{-1}	**5**
	Wet Basis	tonnes ha^{-1}	44
		tons ac^{-1}	20
Estimated Biosolids Volume Applied	Wet	Tonnnes	5,048
Estimated Biosolids Volume Remaining	Wet	Tonnes	196

Anticipated Nutrient Application and Removal Rates based on the Selected Application rate				Anticipated Nutrient Removal Yr1 Based on Target yield		Anticipated residual	
Nitrogen Application (kg/ha)			132		**38.68**	93.14	Within Regulation
Total P2O5 Application (kg/ha)			128		**20**	107.32	Within Regulation

Notes:
Available Ammonium N - Volatilization loss associated with different application methods (0% with Injection)
Organic N - TKN - Ammonium N
Available Organic N - Organic N x 0.20 year 1 (Ross and Racz, 2003)
Mineralization of Year 2 = 12%, Year 3 = 6%
Plant Available Nitrogen= (NO3-N)+Volatilization factor (NH4-N)+Organic N Mineralization
Estimated P2O5 Available based on 25% of total Phosphorus as directed by MSD.
Note: the biosolids are FeCl treated and fixes the majority of the total P.
Soil Phosphorous Olsen method.
* See Estimates of Ammonium-N Retained After Biosolids application

C:N exceeds 30:1, N becomes a limiting nutrient for decomposer organisms, and this can reduce the rate of decomposition and results in N immobilization

C:P ratio between 200:1 and 300:1, mineralization and immobilization balance each other to result in no net release of P from the decomposing manure. When C:P is below this range, P is released.

When animal and municipal wastes have N:P ratios ranging from 1:1 to 1:2 are applied based on N rates on soils, over time P will accumulate

Field Crop Nutrient Uptake and Removal in Typical Manitoba Crops
Anticipated Crop Nutrient Removal = (Target Yield (kg/ha) x (N or P2O5 kg/kg]
Corn Nitrogen = 0.0179 kg/kg, P2O5 = 0.0786 kg/kg

Field Prescription Application Rate, City of Winnipeg
Date Modified: 9Sept2024

Field ID:	NW 24-12-01EPM	
Land Area Available (ha):	65	
2025 Crop	Wheat	
2025 Target Yield (bu/ac, kg/ha):	120	1,017
	lb/ac	kg/ha
Target Nitrogen total less soil residual:	120	134
Fertilizer Phosphate (P2O5) total less soil residual:	55	62
1 x P2O5 Crop Removal @ target Yield:	55	62
2 x P2O5 Crop Removal @ target Yield:	110	123
3 x P2O5 Crop Removal @ target Yield:	165	185
Sulfate-S target:	20	22

Plant Available Nutrients Soil Test Data

	W067		240905_056	W068		240905_057
Sample Depth	0-15 cm	15-60 cm	Total Available	0-15 cm	15-60 cm	Total Available
Units	mg kg^{-1}		kg ha^{-1}	mg kg^{-1}		kg ha^{-1}
Total Nitrogen						
Available Nitrate-N	03.0	1	11	04.0	3	23
Available Phosphate-P	18.0		32	28.0		50
Available Potassium	440		792	550.0		990
Available Sulfate-S	005	4	34	07.0	7	56
EC (dS/m)	0.56	0.62		00.58	0.56	
Organic Matter (%)	6.1			5.50		

City of Winnipeg Biosolids Characteristics and Analysis

Parameter Name	Parameter Description	Unit	Biosolid Analysis Pilot Project
Estimated Biosolid Volume	In-field	m^3	2,990
Specific Gravity	As Received	g cm^{-1}	1.00
Estimated Biosolids		tonnes	2,990
Dry tonnes biosolids available (=wet tonnes x %solids)	Dried Basis	tonnes	834
Moisture	As Received	%	73.5
Total Solids	As Received	%	27.9
Organic Matter	Dry Basis	%	49.88
Total Organic Carbon	Dry Basis	%	30.50
C:N Ratio	Dry Basis	x:1	7.7
C:P Ratio	Dry Basis	x:1	16.0
N:P Ratio	Dry Basis	x:1	2.09
pH	Saturated Paste		6.04
Total N	Dried Basis	%	4.0
	Dried Basis	mg kg^{-1}	39,845
	Dried Basis	kg Tonne^{-1}	39.8
Ammonium - N (NH4-N)	Dried Basis	mg kg^{-1}	5,433.10
	Dried Basis	kg Tonne^{-1}	5.43
Available Nitrate-N	Dried Basis	mg kg^{-1}	1.70
Available Nitrate-N		kg Tonne^{-1}	0.002
Total Phosphorous (average)	Dried Basis	mg kg^{-1}	19,071

Amount of Biosolids Nutrient Available to Crop

Organic N (=TN - Ammonium N)	Dried Basis	mg kg^{-1}	34,412
Organic N	Dried Basis	kg Tonne^{-1}	34.4
Method of Application:			Incorporated 1 day
Anticipated Weather			Warm/dry
Anticipated Volatilization (%)	within 1 day		50
Available Organic N (@ 25%)	Dried Basis	kg Tonne^{-1}	8.6
Ammonium-nitrogen Available	Dried Basis	kg Tonne^{-2}	2.72
Plant Available Nitrogen (PAN) (Year 1)	Dried Basis	kg Tonne^{-1}	11.3
PAN Year 2 (@12% mineralization)	Dried Basis	kg Tonne^{-1}	4.1
PAN Year 3 (@6% mineralization)	Dried Basis	kg Tonne^{-1}	2.1
Phosphorous	Dried Basis	kg Tonne^{-1}	19.1
P_2O_5 equivavent	Dried Basis	kg Tonne^{-1}	43.9
Total Available P_2O_5	Dried Basis	kg Tonne^{-1}	11.0

Application Rate based on Nitrogen				**Land Area Required**
Nitrogen Based Application Rate	Dried Basis	tonnes ha^{-1}	12	**70** Ha
Amount of Available P2O5 applied	Dried Basis	kg ha^{-1}	130	174 Ac
P_2O_5 Application check		%	211	
Application Rate based on Phosphorous (1xCR)				**Land Area Required**
Total Phosphorus Based Application Rate	Dried Basis	tonnes ha^{-1}	6	**149** Ha
	Dried Basis	kg ha^{-1}	64	**367** Ac
Amount of Nitrogen applied		lb ac^{-1}	57	
		kg ha^{-1}	71	
Additional Nitrogen required		lb ac-1	63	
Application Rate based on Phosphorous (2xCR)				**Land Area Required**
Total Phosphorus Based Application Rate	Dried Basis	tonnes ha^{-1}	**11**	**74** Ha
Amount of Nitrogen applied	Dried Basis	kg ha^{-1}	127	**183** Ac
Additional Nitrogen required		kg ha^{-1}	7	
Application Rate based on Phosphorous (3xCR)				**Land Area Required**
Total Phosphorus Based Application Rate	Dried Basis	tonnes ha^{-1}	**17**	**50** Ha
Amount of Nitrogen applied	Dried Basis	kg ha^{-1}	191	**122** Ac
Additional Nitrogen required		kg ha^{-1}	- 56	

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Selected Application rate based on:		2 x CR P	
Selected Application Rate	Dried Basis	tonnes ha^{-1}	**11**
		tons ac^{-1}	**5**
	Wet Basis	tonnes ha^{-1}	43
		tons ac^{-1}	19
Estimated Biosolids Volume Applied	Wet	Tonnnes	2,780
Estimated Biosolids Volume Remaining	Wet	Tonnes	210

Anticipated Nutrient Application and Removal Rates based on the Selected Application rate				Anticipated Nutrient Removal Yr1 Based on Target yield		Anticipated residual	
Nitrogen Application (kg/ha)			127		**38.68**	88.52	Within Regulation
Total P2O5 Application (kg/ha)			123		**20**	102.84	Within Regulation

Notes:
Available Ammonium N - Volatilization loss associated with different application methods (0% with Injection)
Organic N - TKN - Ammonium N
Available Organic N - Organic N x 0.20 year 1 (Ross and Racz, 2003)
Mineralization of Year 2 = 12%, Year 3 = 6%
Plant Available Nitrogen= (NO3-N)+Volatilization factor (NH4-N)+Organic N Mineralization
Estimated P2O5 Available based on 25% of total Phosphorus as directed by MSD.
Note: the biosolids are FeCl treated and fixes the majority of the total P.
Soil Phosphorous Olsen method.
* See Estimates of Ammonium-N Retained After Biosolids application

C:N exceeds 30:1, N becomes a limiting nutrient for decomposer organisms, and this can reduce the rate of decomposition and results in N immobilization

C:P ratio between 200:1 and 300:1, mineralization and immobilization balance each other to result in no net release of P from the decomposing manure. When C:P is below this range, P is released.

When animal and municipal wastes have N:P ratios ranging from 1:1 to 1:2 are applied based on N rates on soils, over time P will accumulate

Field Crop Nutrient Uptake and Removal in Typical Manitoba Crops
Anticipated Crop Nutrient Removal = (Target Yield (kg/ha) x (N or P2O5 kg/kg)
Corn Nitrogen = 0.0179 kg/kg, P2O5 = 0.0786 kg/kg

Field Prescription Application Rate, City of Winnipeg
Date Modified: 9Sept2024

Field ID:	N1/2 SW24-12-01EPM	
Land Area Available (ha):	32	
2025 Crop	Wheat	
2025 Target Yield (bu/ac, kg/ha):	45	1,017
	lb/ac	kg/ha
Target Nitrogen total less soil residual:	90	101
Fertilizer Phosphate (P2O5) total less soil residual:	60	67
1 x P2O5 Crop Removal @ target Yield:	55	62
2 x P2O5 Crop Removal @ target Yield:	110	123
3 x P2O5 Crop Removal @ target Yield:	165	185
Sulfate-S target:	20	22

Plant Available Nutrients Soil Test Data

	W069		240905_058			
Sample Depth	0-15 cm	15-60 cm	Total Available	0-15 cm	15-60 cm	Total Available
Units	mg kg^{-1}		kg ha^{-1}	mg kg^{-1}		kg ha^{-1}
Total Nitrogen						
Available Nitrate-N	13.0	5	50			-
Available Phosphate-P	11.0		20			-
Available Potassium	500		900			-
Available Sulfate-S	008	5	46			-
EC (dS/m)	0.65	0.60				
Organic Matter (%)	6.6					

City of Winnipeg Biosolids Characteristics and Analysis

Parameter Name	Parameter Description	Unit	Biosolid Analysis Pilot Project
Estimated Biosolid Volume	In-field	m^3	1,472
Specific Gravity	As Received	g cm^{-1}	1.00
Estimated Biosolids		tonnes	1,472
Dry tonnes biosolids available (=wet tonnes x %solids)	Dried Basis	tonnes	411
Moisture	As Received	%	73.5
Total Solids	As Received	%	27.9
Organic Matter	Dry Basis	%	49.88
Total Organic Carbon	Dry Basis	%	30.50
C:N Ratio	Dry Basis	x:1	7.7
C:P Ratio	Dry Basis	x:1	16.0
N:P Ratio	Dry Basis	x:1	2.09
pH	Saturated Paste		6.04
Total N	Dried Basis	%	4.0
	Dried Basis	mg kg^{-1}	39,845
	Dried Basis	kg Tonne^{-1}	39.8
Ammonium - N (NH4-N)	Dried Basis	mg kg^{-1}	5,433.10
	Dried Basis	kg Tonne^{-1}	5.43
Available Nitrate-N	Dried Basis	mg kg^{-1}	1.70
Available Nitrate-N		kg Tonne^{-1}	0.002
Total Phosphorous (average)	Dried Basis	mg kg^{-1}	19,071

Amount of Biosolids Nutrient Available to Crop

Organic N (=TN - Ammonium N)	Dried Basis	mg kg^{-1}	34,412
Organic N	Dried Basis	kg Tonne^{-1}	34.4
Method of Application:			Incorporated 1 day
Anticipated Weather			Warm/dry
Anticipated Volatilization (%)	within 1 day		50
Available Organic N (@ 25%)	Dried Basis	kg Tonne^{-1}	8.6
Ammonium-nitrogen Available	Dried Basis	kg Tonne^{-2}	2.72
Plant Available Nitrogen (PAN) (Year 1)	Dried Basis	kg Tonne^{-1}	11.3
PAN Year 2 (@12% mineralization)	Dried Basis	kg Tonne^{-1}	4.1
PAN Year 3 (@6% mineralization)	Dried Basis	kg Tonne^{-1}	2.1
Phosphorous	Dried Basis	kg Tonne^{-1}	19.1
P_2O_5 equivavent	Dried Basis	kg Tonne^{-1}	43.9
Total Available P_2O_5	Dried Basis	kg Tonne^{-1}	11.0

Application Rate based on Nitrogen				**Land Area Required**
Nitrogen Based Application Rate	Dried Basis	tonnes ha^{-1}	9	**46** Ha
Amount of Available P2O5 applied	Dried Basis	kg ha^{-1}	98	114 Ac
P_2O_5 Application check		%	145	
Application Rate based on Phosphorous (1xCR)				**Land Area Required**
Total Phosphorus Based Application Rate	Dried Basis	tonnes ha^{-1}	6	**73** Ha
	Dried Basis	kg ha^{-1}	64	**181** Ac
Amount of Nitrogen applied		lb ac^{-1}	57	
		kg ha^{-1}	37	
Additional Nitrogen required		lb ac-1	33	
Application Rate based on Phosphorous (2xCR)				**Land Area Required**
Total Phosphorus Based Application Rate	Dried Basis	tonnes ha^{-1}	**11**	**37** Ha
Amount of Nitrogen applied	Dried Basis	kg ha^{-1}	127	**90** Ac
Additional Nitrogen required		kg ha^{-1}	- 26	
Application Rate based on Phosphorous (3xCR)				**Land Area Required**
Total Phosphorus Based Application Rate	Dried Basis	tonnes ha^{-1}	**17**	**24** Ha
Amount of Nitrogen applied	Dried Basis	kg ha^{-1}	191	**60** Ac
Additional Nitrogen required		kg ha^{-1}	- 90	

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Selected Application rate based on:		**2 x CR P**
Selected Application Rate	Dried Basis	tonnes ha^{-1} **11**
		tons ac^{-1} 5
	Wet Basis	tonnes ha^{-1} 43
		tons ac^{-1} 19
Estimated Biosolids Volume Applied	Wet	Tonnnes 1,368
Estimated Biosolids Volume Remaining	Wet	Tonnes 104

Anticipated Nutrient Application and Removal Rates based on the Selected Application rate				Anticipated Nutrient Removal Yr1 Based on Target yield		Anticipated residual	
Nitrogen Application (kg/ha)			127		**38.68**	88.52	Within Regulation
Total P2O5 Application (kg/ha)			123		**20**	102.84	Within Regulation

Notes:
Available Ammonium N - Volatilization loss associated with different application methods (0% with Injection)
Organic N - TKN - Ammonium N
Available Organic N - Organic N x 0.20 year 1 (Ross and Racz, 2003)
Mineralization of Year 2 = 12%, Year 3 = 6%
Plant Available Nitrogen= (NO3-N)+Volatilization factor (NH4-N)+Organic N Mineralization
Estimated P2O5 Available based on 25% of total Phosphorus as directed by MSD.
Note: the biosolids are FeCl treated and fixes the majority of the total P.
Soil Phosphorous Olsen method.
* See Estimates of Ammonium-N Retained After Biosolids application

C:N exceeds 30:1, N becomes a limiting nutrient for decomposer organisms, and this can reduce the rate of decomposition and results in N immobilization

C:P ratio between 200:1 and 300:1, mineralization and immobilization balance each other to result in no net release of P from the decomposing manure. When C:P is below this range, P is released.

When animal and municipal wastes have N:P ratios ranging from 1:1 to 1:2 are applied based on N rates on soils, over time P will accumulate

Field Crop Nutrient Uptake and Removal in Typical Manitoba Crops
Anticipated Crop Nutrient Removal = (Target Yield (kg/ha) x (N or P2O5 kg/kg)
Corn Nitrogen = 0.0179 kg/kg, P2O5 = 0.0786 kg/kg

Field Prescription Application Rate, City of Winnipeg
Date Modified: 9Sept2024

Field ID:	S1/2 SW24-12-01EPM	
Land Area Available (ha):	32	
2025 Crop	Canola	
2025 Target Yield (bu/ac, kg/ha):	45	1,017
	lb/ac	kg/ha
Target Nitrogen total less soil residual:	60	67
Fertilizer Phosphate (P2O5) total less soil residual:	55	62
1 x P2O5 Crop Removal @ target Yield:	55	62
2 x P2O5 Crop Removal @ target Yield:	110	123
3 x P2O5 Crop Removal @ target Yield:	165	185
Sulfate-S target:	20	22

Plant Available Nutrients Soil Test Data

	W070		240905_059	W071		240905_060
Sample Depth	0-15 cm	15-60 cm	Total Available	0-15 cm	15-60 cm	Total Available
Units	mg kg^{-1}		kg ha^{-1}	mg kg^{-1}		kg ha^{-1}
Total Nitrogen						
Available Nitrate-N	05.0	10	63	09.0	14	92
Available Phosphate-P	03.2		6	09.8		18
Available Potassium	460		828	500.0		900
Available Sulfate-S	004	2	20	04.0	4	32
EC (dS/m)	0.50	0.66		00.72	0.77	
Organic Matter (%)	6.1			6.30		

City of Winnipeg Biosolids Characteristics and Analysis

Parameter Name	Parameter Description	Unit	Biosolid Analysis Pilot Project
Estimated Biosolid Volume	In-field	m^3	1,472
Specific Gravity	As Received	g cm^{-1}	1.00
Estimated Biosolids		tonnes	1,472
Dry tonnes biosolids available (=wet tonnes x %solids)	Dried Basis	tonnes	411
Moisture	As Received	%	73.5
Total Solids	As Received	%	27.9
Organic Matter	Dry Basis	%	49.88
Total Organic Carbon	Dry Basis	%	30.50
C:N Ratio	Dry Basis	x:1	7.7
C:P Ratio	Dry Basis	x:1	16.0
N:P Ratio	Dry Basis	x:1	2.09
pH	Saturated Paste		6.04
Total N	Dried Basis	%	4.0
	Dried Basis	mg kg^{-1}	39,845
	Dried Basis	kg Tonne^{-1}	39.8
Ammonium - N (NH4-N)	Dried Basis	mg kg^{-1}	5,433.10
	Dried Basis	kg Tonne^{-1}	5.43
Available Nitrate-N	Dried Basis	mg kg^{-1}	1.70
Available Nitrate-N		kg Tonne^{-1}	0.002
Total Phosphorous (average)	Dried Basis	mg kg^{-1}	19,071

Amount of Biosolids Nutrient Available to Crop

Organic N (=TN - Ammonium N)	Dried Basis	mg kg^{-1}	34,412
Organic N	Dried Basis	kg Tonne^{-1}	34.4
Method of Application:			Incorporated 1 day
Anticipated Weather			Warm/dry
Anticipated Volatilization (%)	within 1 day		50
Available Organic N (@ 25%)	Dried Basis	kg Tonne^{-1}	8.6
Ammonium-nitrogen Available	Dried Basis	kg Tonne^{-2}	2.72
Plant Available Nitrogen (PAN) (Year 1)	Dried Basis	kg Tonne^{-1}	11.3
PAN Year 2 (@12% mineralization)	Dried Basis	kg Tonne^{-1}	4.1
PAN Year 3 (@6% mineralization)	Dried Basis	kg Tonne^{-1}	2.1
Phosphorous	Dried Basis	kg Tonne^{-1}	19.1
$P_2O_{5\ equivalent}$	Dried Basis	kg Tonne^{-1}	43.9
Total Available P_2O_5	Dried Basis	kg Tonne^{-1}	11.0

Application Rate based on Nitrogen				**Land Area Required**
Nitrogen Based Application Rate	Dried Basis	tonnes ha^{-1}	6	**69** Ha
Amount of Available P2O5 applied	Dried Basis	kg ha^{-1}	65	171 Ac
P_2O_5 Application check		%	106	
Application Rate based on Phosphorous (1xCR)				**Land Area Required**
Total Phosphorus Based Application Rate	Dried Basis	tonnes ha^{-1}	6	**73** Ha
	Dried Basis	kg ha^{-1}	64	**181** Ac
Amount of Nitrogen applied		lb ac^{-1}	57	
		kg ha^{-1}	4	
Additional Nitrogen required		lb ac-1	3	
Application Rate based on Phosphorous (2xCR)				**Land Area Required**
Total Phosphorus Based Application Rate	Dried Basis	tonnes ha^{-1}	**11**	**37** Ha
Amount of Nitrogen applied	Dried Basis	kg ha^{-1}	127	**90** Ac
Additional Nitrogen required		kg ha^{-1}	- 60	
Application Rate based on Phosphorous (3xCR)				**Land Area Required**
Total Phosphorus Based Application Rate	Dried Basis	tonnes ha^{-1}	**17**	**24** Ha
Amount of Nitrogen applied	Dried Basis	kg ha^{-1}	191	**60** Ac
Additional Nitrogen required		kg ha^{-1}	- 124	

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Selected Application rate based on:		**2 x CR P**	
Selected Application Rate	Dried Basis	tonnes ha^{-1}	**11**
		tons ac^{-1}	**5**
	Wet Basis	tonnes ha^{-1}	43
		tons ac^{-1}	19
Estimated Biosolids Volume Applied	Wet	Tonnnes	1,368
Estimated Biosolids Volume Remaining	Wet	Tonnes	104

Anticipated Nutrient Application and Removal Rates based on the Selected Application rate				Anticipated Nutrient Removal Yr1 Based on Target yield		Anticipated residual	
Nitrogen Application (kg/ha)			127		**38.68**	88.52	Within Regulation
Total P2O5 Application (kg/ha)			123		**20**	102.84	Within Regulation

Notes:
Available Ammonium N - Volatilization loss associated with different application methods (0% with Injection)
Organic N - TKN - Ammonium N
Available Organic N - Organic N x 0.20 year 1 (Ross and Racz, 2003)
Mineralization of Year 2 = 12%, Year 3 = 6%
Plant Available Nitrogen= (NO3-N)+Volatilization factor (NH4-N)+Organic N Mineralization
Estimated P2O5 Available based on 25% of total Phosphorus as directed by MSD.
Note: the biosolids are FeCl treated and fixes the majority of the total P.
Soil Phosphorous Olsen method.
* See Estimates of Ammonium-N Retained After Biosolids application

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Field Crop Nutrient Uptake and Removal in Typical Manitoba Crops
Anticipated Crop Nutrient Removal = (Target Yield (kg/ha) x (N or P2O5 kg/kg)
Corn Nitrogen = 0.0179 kg/kg, P2O5 = 0.0786 kg/kg

Field Prescription Application Rate, City of Winnipeg
Date Modified: 242024

Field ID:	N1/2 21-12-01WPM	
Land Area Available (ha):	130	
2025 Crop	Canola	
2025 Target Yield (bu/ac, kg/ha):	45	1,017
	lb/ac	kg/ha
Target Nitrogen total less soil residual:	100	112
Fertilizer Phosphate (P2O5) total less soil residual:	10	11
1 x P2O5 Crop Removal @ target Yield:	65	73
2 x P2O5 Crop Removal @ target Yield:	130	146
3 x P2O5 Crop Removal @ target Yield:	195	218
Sulfate-S target:	20	22

Plant Available Nutrients Soil Test Data

	W076		240916_001	W077		240916_002
Sample Depth	0-15 cm	15-60 cm	Total Available	0-15 cm	15-60 cm	Total Available
Units	mg kg^{-1}		kg ha^{-1}	mg kg^{-1}		kg ha^{-1}
Total Nitrogen						
Available Nitrate-N	45.0	10	135	08.0	3	31
Available Phosphate-P	15.0		27	05.8		10
Available Potassium	530		954	370.0		666
Available Sulfate-S	009	7	60	04.0	44	272
EC (dS/m)	0.72	0.77		00.74	1.13	
Organic Matter (%)	8			6.60		
	W078		240916_003	W079		240916_004
Sample Depth	0-15 cm	15-60 cm	Total Available	0-15 cm	15-60 cm	Total Available
Units	mg kg^{-1}		kg ha-1	mg kg^{-1}		kg ha-1
Total Nitrogen						
Available Nitrate-N	22.0	4	61	05.0	6	41
Available Phosphate-P	18.0		32	02.7		5
Available Potassium	610.0		1,098	410.0		738
Available Sulfate-S	05.0	22	142	03.0	3	24
EC (dS/m)	00.78	0.76		00.7	0.78	
Organic Matter (%)	6.90			5.70		

City of Winnipeg Biosolids Characteristics and Analysis

Parameter Name	Parameter Description	Unit	Biosolid Analysis Pilot Project
Estimated Biosolid Volume	In-field	m^3	5,980
Specific Gravity	As Received	g cm^{-3}	1.00
Estimated Biosolids		tonnes	5,980
Dry tonnes biosolids available (=wet tonnes x %solids)	Dried Basis	tonnes	1,668
Moisture	As Received	%	73.5
Total Solids	As Received	%	27.9
Organic Matter	Dry Basis	%	49.88
Total Organic Carbon	Dry Basis	%	30.50
C:N Ratio	Dry Basis	x:1	7.7
C:P Ratio	Dry Basis	x:1	16.0
N:P Ratio	Dry Basis	x:1	2.09
pH	Saturated Paste		6.04
Total N	Dried Basis	%	4.0
	Dried Basis	mg kg^{-1}	39,845
	Dried Basis	kg Tonne^{-1}	39.8
Ammonium - N (NH4-N)	Dried Basis	mg kg^{-1}	5,433.10
	Dried Basis	kg Tonne^{-1}	5.43
Available Nitrate-N	Dried Basis	mg kg^{-1}	1.70
Available Nitrate-N		kg Tonne^{-1}	0.002
Total Phosphorous (average)	Dried Basis	mg kg^{-1}	19,071
Amount of Biosolids Nutrient Available to Crop			
Organic N (=TN - Ammonium N)	Dried Basis	mg kg^{-1}	34,412
Organic N	Dried Basis	kg Tonne^{-1}	34.4
Method of Application:			Incorporated 1 day
Anticipated Weather			Warm Dry
Anticipated Volatilization (%)	within 1 day		50
Available Organic N (@ 25%)	Dried Basis	kg Tonne^{-1}	8.6
Ammonium-nitrogen Available	Dried Basis	kg Tonne^{-2}	2.72
Plant Available Nitrogen (PAN) (Year 1)	Dried Basis	kg Tonne^{-1}	11.3
PAN Year 2 (@12% mineralization)	Dried Basis	kg Tonne^{-1}	4.1
PAN Year 3 (@6% mineralization)	Dried Basis	kg Tonne^{-1}	2.1
Phosphorous	Dried Basis	kg Tonne^{-1}	19.1
P_2O_5 equivalent	Dried Basis	kg Tonne^{-1}	43.9
Total Available P_2O_5	Dried Basis	kg Tonne^{-1}	11.0

Application Rate based on Nitrogen				Land Area Required
Nitrogen Based Application Rate	Dried Basis	tonnes ha^{-1}	10	**169** Ha
Amount of Available P2O5 applied	Dried Basis	kg ha^{-1}	108	**417** Ac
P_2O_5 Application check		%	969	
Application Rate based on Phosphorous (1xCR)				**Land Area Required**
Total Phosphorus Based Application Rate	Dried Basis	tonnes ha^{-1}	7	**251** Ha
	Dried Basis	kg ha^{-1}	75	**621** Ac
Amount of Nitrogen applied		lb ac^{-1}	67	
		kg ha^{-1}	37	
Additional Nitrogen required		lb ac-1	33	
Application Rate based on Phosphorous (2xCR)				**Land Area Required**
Total Phosphorus Based Application Rate	Dried Basis	tonnes ha^{-1}	**13**	**126** Ha
Amount of Nitrogen applied	Dried Basis	kg ha^{-1}	150	**310** Ac
Additional Nitrogen required		kg ha^{-1}	- 38	
Application Rate based on Phosphorous (3xCR)				**Land Area Required**
Total Phosphorus Based Application Rate	Dried Basis	tonnes ha^{-1}	**20**	**84** Ha
Amount of Nitrogen applied	Dried Basis	kg ha^{-1}	225	**207** Ac
Additional Nitrogen required		kg ha^{-1}	- 113	

S1/2 SE33-11-01EPM

Selected Application rate based on:		2 x CR P	
Selected Application Rate	Dried Basis	tonnes ha^{-1}	**13**
		tons ac^{-1}	**6**
	Wet Basis	tonnes ha^{-1}	50
		tons ac^{-1}	23
Estimated Biosolids Volume Applied	Wet	Tonnnes	6,547
Estimated Biosolids Volume Remaining	Wet	Tonnes	- 567

Anticipated Nutrient Application and Removal Rates based on the Selected Application rate				Anticipated Nutrient Removal Yr1 Based on Target yield		Anticipated residual	
Nitrogen Application (kg/ha)			150		**38.68**	111.64	Within Regulation
Total P2O5 Application (kg/ha)			146		**20**	125.24	Within Regulation

Notes:
Available Ammonium N - Volatilization loss associated with different application methods (0% with Injection)
Organic N - TKN - Ammonium N
Available Organic N - Organic N x 0.20 year 1 (Ross and Racz, 2003)
Mineralization of Year 2 = 12%, Year 3 = 6%
Plant Available Nitrogen= (NO3-N)+Volatilization factor (NH4-N)+Organic N Mineralization
Estimated P2O5 Available based on 25% of total Phosphorus as directed by MSD.
Note: the biosolids are FeCl treated and fixes the majority of the total P.
Soil Phosphorous Olsen method.
* See Estimates of Ammonium-N Retained After Biosolids application

C:N exceeds 30:1, N becomes a limiting nutrient for decomposer organisms, and this can reduce the rate of decomposition and results in N immobilization
C:P ratio between 200:1 and 300:1, mineralization and immobilization balance each other to result in no net release of P from the decomposing manure. When C:P is below this range, P is released.
When animal and municipal wastes have N:P ratios ranging from 1:1 to 1:2 are applied based on N rates on soils, over time P will accumulate
Field Crop Nutrient Uptake and Removal in Typical Manitoba Crops
Anticipated Crop Nutrient Removal = (Target Yield (kg/ha) x (N or P2O5 kg/kg)
Corn Nitrogen = 0.0179 kg/kg, P2O5 = 0.0786 kg/kg

City of Winnipeg Biosolids and Application Field Trace Element Content

Analyte	Biosolids Trace Elements				S1/2 28-12-01WPM										Application Rate (12 T/ha, dry)	Cumulative Metal Concentration	Cumulative Weight Allowed by Guideline[2]		Applications Events Permitted before meeting applied Criteria based on Average Metal Concentrations
	Minimum	Maximum	Mean	Mean	(W019, 0-15cm)		(W020, 0-15cm)		(WO21, 0-15cm)		(WO22, 0-15cm)		Mean						
	Total Concentrations (mg/kg - Dry)			(kg/T)	(mg/kg)	(kg/ha)	(mg/kg)	(kg/ha)	(mg/kg)	(kg/ha)	(mg/kg)	(kg/ha)	(mg/kg)	(kg/ha)	(kg/ha)	(kg/ha)	(mg/kg)	(kg/ha)	Count
Arsenic	0.1	6.3	4.0	0.004	5.89	10.60	6.59	11.86	6.69	12.04	8.00	14.40	6.79	12.23	0.05	12.273	12	21.6	202
Cadmium	10.7	2.5	5.0	0.005	0.414	0.75	0.445	0.80	0.45	0.80	0.40	0.73	0.43	0.77	0.06	0.827	1.4	2.5	30
Copper	143.0	954.0	560.4	0.560	35.4	63.72	36.3	65.34	36.30	65.34	38.10	68.58	36.53	65.75	6.52	72.270	63	113.4	7
Chromium	33.1	112.9	112.9	0.113	54	97.20	49.5	89.10	52.60	94.68	52.80	95.04	52.23	94.01	1.31	95.320	64	115.2	16
Lead	3.5	325.0	55.4	0.055	22.4	40.32	22.7	40.86	20.80	37.44	19.50	35.10	21.35	38.43	0.65	39.075	70	126	136
Mercury*	0.1	1.8	0.8	0.001	0.0356	0.06	0.0616	0.11	0.0372	0.07	0.0414	0.07	0.04	0.08	0.01	0.089	6.6	11.9	1254
Nickle	7.1	121.0	42.5	0.042	38.80	69.84	39.10	70.38	39.90	71.82	40.20	72.36	39.50	71.10	0.49	71.595	50	90	38
Zinc	626.0	5080.0	1319.2	1.319	92.80	167.04	99.80	179.64	103.00	185.40	106.00	190.80	100.40	180.72	15.36	196.080	200	360	12

Analyte	Biosolids Trace Elements				E1/2 29-12-01WPM										Application Rate (T/ha, dry)	Cumulative Metal Concentration	Cumulative Weight Allowed by Guideline[2]		Applications Events Permitted before meeting applied Criteria based on Average Metal Concentrations
	Minimum	Maximum	Mean	Mean	(W023, 0-15cm)		(W024, 0-15cm)		(WO25, 0-15cm)		(WO26, 0-15cm)		Mean						
	Total Concentrations (mg/kg - Dry)			(kg/T)	(mg/kg)	(kg/ha)	(mg/kg)	(kg/ha)	(mg/kg)	(kg/ha)	(mg/kg)	(kg/ha)	(mg/kg)	(kg/ha)	(kg/ha)	(kg/ha)	(mg/kg)	(kg/ha)	Count
Arsenic	0.1	6.3	4.0	0.004	5.57	10.03	6.71	12.08	9.35	16.83	6.44	11.59	7.02	12.63	0.05	12.678	12	21.6	194
Cadmium	10.7	2.5	5.0	0.005	0.474	0.85	0.473	0.27	0.27	0.48	0.49	0.87	0.42	0.62	0.06	0.676	1.4	2.5	30
Copper	143.0	954.0	560.4	0.560	35.8	64.44	35.5	63.90	32.70	58.86	36.80	66.24	35.20	63.36	6.52	69.885	63	113.4	8
Chromium	33.1	112.9	112.9	0.113	45.1	81.18	51.4	92.52	55.10	99.18	53.50	96.30	51.28	92.30	1.31	93.610	64	115.2	17
Lead	3.5	325.0	55.4	0.055	13.9	25.02	15	27.00	14.60	26.28	16.00	28.80	14.88	26.78	0.65	27.420	70	126	154
Mercury*	0.1	1.8	0.8	0.001	0.0369	0.07	0.0335	0.06	0.0324	0.06	0.0376	0.07	0.04	0.06	0.01	0.073	6.6	11.9	1255
Nickle	7.1	121.0	42.5	0.042	36.40	65.52	40.30	72.54	43.60	78.48	40.20	72.36	40.13	72.23	0.49	72.720	50	90	36
Zinc	626.0	5080.0	1319.2	1.319	105.00	189.00	110.00	198.00	94.40	169.92	116.00	208.80	106.35	191.43	15.36	206.790	200	360	11

Analyte	Biosolids Trace Elements				NW24 & S1/2 SW 24-12-01EPM								Application Rate (T/ha, dry)	Cumulative Metal Concentration	Cumulative Weight Allowed by Guideline[2]		Applications Events Permitted before meeting applied Criteria based on Average Metal
	Minimum	Maximum	Mean	Mean	(W067, 0-15cm)		(W068, 0-15cm)		(WO69, 0-15cm)		Mean						
	Total Concentrations (mg/kg - Dry)			(kg/T)	(mg/kg)	(kg/ha)	(mg/kg)	(kg/ha)	(mg/kg)	(kg/ha)	(mg/kg)	(kg/ha)	(kg/ha)	(kg/ha)	(mg/kg)	(kg/ha)	Count
Arsenic	0.1	6.3	4.0	0.004	8.82	15.88	7.73	13.91	7.32	13.18	7.96	14.32	0.04	14.367	12	21.6	157
Cadmium	10.7	2.5	5.0	0.005	0.344	0.62	0.286	0.27	0.34	0.61	0.32	0.50	0.06	0.555	1.4	2.5	33
Copper	143.0	954.0	560.4	0.560	34.8	62.64	29.3	52.74	28.90	52.02	31.00	55.80	6.30	62.096	63	113.4	9
Chromium	33.1	112.9	112.9	0.113	59.7	107.46	51	91.80	50.60	91.08	53.77	96.78	1.27	98.048	64	115.2	14
Lead	3.5	325.0	55.4	0.055	15.8	28.44	13.9	25.02	14.60	26.28	14.77	26.58	0.62	27.203	70	126	154
Mercury*	0.1	1.8	0.8	0.001	0.0269	0.05	0.0303	0.05	0.0262	0.05	0.03	0.05	0.01	0.059	6.6	11.9	1257
Nickle	7.1	121.0	42.5	0.042	42.70	76.86	39.40	70.92	36.60	65.88	39.57	71.22	0.48	71.697	50	90	38
Zinc	626.0	5080.0	1319.2	1.319	97.90	176.22	80.50	144.90	94.40	169.92	90.93	163.68	14.82	178.501	200	360	13

Analyte	Biosolids Trace Elements				S1/2 SW24-12-01EPM						Application Rate (T/ha, dry)	Cumulative Metal Concentration	Cumulative Weight Allowed by Guideline[2]		Applications Events Permitted before meeting applied Criteria based on Average Metal Concentrations
	Minimum	Maximum	Mean	Mean	(W070, 0-15cm)		(W071, 0-15cm)		Mean						
	Total Concentrations (mg/kg - Dry)			(kg/T)	(mg/kg)	(kg/ha)	(mg/kg)	(kg/ha)	(mg/kg)	(kg/ha)	(kg/ha)	(kg/ha)	(mg/kg)	(kg/ha)	Count
Arsenic	0.1	6.3	4.0	0.004	9.22	16.60	5.78	10.40	7.50	13.50	0.04	13.545	12	21.6	175
Cadmium	10.7	2.5	5.0	0.005	0.339	0.61	0.388	0.70	0.36	0.65	0.06	0.711	1.4	2.5	32
Copper	143.0	954.0	560.4	0.560	34.4	61.92	27.6	49.68	31.00	55.80	6.30	62.096	63	113.4	9
Chromium	33.1	112.9	112.9	0.113	56.9	102.42	45.4	81.72	51.15	92.07	1.27	93.338	64	115.2	18
Lead	3.5	325.0	55.4	0.055	16.5	29.70	13.3	23.94	14.90	26.82	0.62	27.443	70	126	154
Mercury*	0.1	1.8	0.8	0.001	0.0358	0.06	0.0268	0.05	0.03	0.06	0.01	0.065	6.6	11.9	1256
Nickle	7.1	121.0	42.5	0.042	41.00	32.30		0.00	41.00	16.15	0.48	16.627	50	90	33
Zinc	626.0	5080.0	1319.2	1.319	100.00	180.00	92.20	165.96	96.10	172.98	14.82	187.801	200	360	12

Analyte	Biosolids Trace Elements				N1/2 21-12-01WPM										Application Rate (T/ha, dry)	Cumulative Metal Concentration	Cumulative Weight Allowed by Guideline[2]		Applications Events Permitted before meeting applied Criteria based on Average Metal Concentrations
	Minimum	Maximum	Mean	Mean	(W076, 0-15cm)		(W077, 0-15cm)		(WO78, 0-15cm)		(WO79, 0-15cm)		Mean						
	Total Concentrations (mg/kg - Dry)			(kg/T)	(mg/kg)	(kg/ha)	(mg/kg)	(kg/ha)	(mg/kg)	(kg/ha)	(mg/kg)	(kg/ha)	(mg/kg)	(kg/ha)	(kg/ha)	(kg/ha)	(mg/kg)	(kg/ha)	Count
Arsenic	0.1	6.3	4.0	0.004	7.49	13.48	7.14	12.85	5.73	10.31	8.66	15.59	7.26	13.06	0.05	13.105	12	21.6	184
Cadmium	10.7	2.5	5.0	0.005	0.432	0.78	0.358	0.64	0.35	0.63	0.24	0.43	0.34	0.62	0.06	0.679	1.4	2.5	32
Copper	143.0	954.0	560.4	0.560	29.1	52.38	30.3	54.54	29.80	53.64	36.20	65.16	31.35	56.43	6.52	62.955	63	113.4	9
Chromium	33.1	112.9	112.9	0.113	50.2	90.36	49.7	89.46	46.90	84.42	53.40	96.12	50.05	90.09	1.31	91.405	64	115.2	19
Lead	3.5	325.0	55.4	0.055	14.5	26.10	13.3	23.94	14.40	25.92	12.60	22.68	13.70	24.66	0.65	25.305	70	126	157
Mercury*	0.1	1.8	0.8	0.001	0.0218	0.04	0.0261	0.05	0.0257	0.05	0.0259	0.05	0.02	0.04	0.01	0.054	6.6	11.9	1257
Nickle	7.1	121.0	42.5	0.042	36.40	65.52	36.70	66.06	35.00	63.00	48.20	86.76	39.08	70.34	0.49	70.830	50	90	40
Zinc	626.0	5080.0	1319.2	1.319	99.40	178.92	91.40	164.52	79.40	142.92	93.50	168.30	90.93	163.67	15.36	179.025	200	360	13

Notes:

[2] = Cumulative Weight Allowed by Guideline includes the metals in soils.

Inputs/Assumptions

Soil Bulk Density	1,200	kg/m3	
Sample Depth	0.15	m	
Hectare	10,000	m2/ha	
Soil Mass	1,000,000	mg/kg	
Anticipated Application Rate	12	T/ha - dry	S1/2 28-12-01WPM
Anticipated Application Rate	12	T/ha - dry	E1/2 29-12-01WPM
Anticipated Application Rate	11	T/ha - dry	NW24-12-01EPM
Anticipated Application Rate	11	T/ha - dry	S1/2 24-12-01EPM
Anticipated Application Rate	13	T/ha - dry	N1/2 21-12-01WPM

APPENDIX E

Data Tables Soil Monitoring Results

Table A: Summary of Residual Nitrogen and Phosphorus Post-Biosolids Application Monitoring

Benchmark Sampling Analysis: (Olsen-P, Nitrate-N, metals: 0-15cm), (Nitrate-N: 15-60cm

Legal Land Location							Soil Monitoring								Crop Monitoring (Crop/Yield bu/ac) OR (N/P/K/S)						Application Year									Post Application Event Monitoring								
																					Soil Benchmark			Application Rate				1st Year			2nd Year			3rd Year		
Quarter	Section	Twp	Range	Field Area (ha)	Sample Site ID	Application Year(s)	2021	2022	2023	2024	2025	2026	2027	2028	2021	2022	2023	2024	2025	2026	Nitrate-N (mg/kg)		Olsen P (mg/kg)	wet T/ha	Plant Available N (kg/ha)	Target P205 (kg/ha)	Nitrate-N (mg/kg)		Olsen P (mg/kg)	Nitrate-N (mg/kg)		Olsen P (mg/kg)	Nitrate-N (mg/kg)		Olsen P (mg/kg)			
																					(0-15 cm)	(15-60 cm)	(0-15 cm)				(0-15 cm)	(15-60 cm)	(0-15 cm)	(0-15 cm)	(15-60 cm)	(0-15 cm)	(0-15 cm)	(15-60 cm)	(0-15 cm)
					W005				Benchmark	1st Year	2nd Year	3rd Year	Done					Soybeans	Canola/43 (0 lbN, 10 lbP/ac)			23	19	42				13	37	24						
NE	36	12	02W	60	W006				Benchmark	1st Year	2nd Year	3rd Year	Done					Soybeans	Canola/43 (0 lbN, 10 lbP/ac)			17	11	50				5	7	33						
					W007				Benchmark	1st Year	2nd Year	3rd Year	Done					Soybeans	Canola/43 (0 lbN, 10 lbP/ac)			39	29	39				39	60	34						
NW	36	12	02W	63	W008				Benchmark	1st Year	2nd Year	3rd Year	Done					Soybeans	Canola/43 (0 lbN, 10 lbP/ac)			10	24	32				33	15	21						
					W009				Benchmark	1st Year	2nd Year	3rd Year	Done					Soybeans	Wheat/68 (0 lbN, 10 lbP/ac			12	8	34				-	-	-						
					W010				Benchmark	1st Year	2nd Year	3rd Year	Done					Soybeans	Wheat/68 (0 lbN, 10 lbP/ac			9	2	27				-	-	-						
					W013				Benchmark	1st Year	2nd Year	3rd Year	Done					Soybeans	Wheat/68 (0 lbN, 10 lbP/ac			20	22	45				25	10	8						
SW	36	12	02W	61	W014				Benchmark	1st Year	2nd Year	3rd Year	Done					Soybeans	Wheat/68 (0 lbN, 10 lbP/ac			8	4	34				36	11	17						
SE	36	12	02W	58	W011	2018			Benchmark	1st Year	2nd Year	3rd Year	Done					Soybeans	Wheat/68 (0 lbN, 10 lbP/ac			9	13	18				46	26	17						
SE	36	12	02W	58	W012	2023			Benchmark	1st Year	2nd Year	3rd Year	Done					Soybeans	Wheat/68 (0 lbN, 10 lbP/ac			13	7	22	46	154	128	38	13	16						
					W015				Benchmark	1st Year	2nd Year	3rd Year	Done						Canola/44 (120 lbN/ac)			10	5	25				26	9	12						
NW	31	12	01W	90	W016				Benchmark	1st Year	2nd Year	3rd Year	Done						Canola/44 (120 lbN/ac)			14	13	23				26	12	13						
					W017	2019			Benchmark	1st Year	2nd Year	3rd Year	Done						Canola/44 (120 lbN/ac)			13	16	13				43	14	22						
N1/2 SW	31	12	01W	90	W018	2023			Benchmark	1st Year	2nd Year	3rd Year	Done						Canola/44 (120 lbN/ac)			12	14	17	46	154	128	11	13	8.6						
					W019					Benchmark	1st Year	2nd Year	3rd Year	Done	Canola (19bu/ac)						15	7	49												
					W020					Benchmark	1st Year	2nd Year	3rd Year	Done	Canola (19bu/ac)						13	3	49												
					W021	2019				Benchmark	1st Year	2nd Year	3rd Year	Done	Canola (19bu/ac)						14	4	41												
S1/2	28	12	01W	127	W022	2024				Benchmark	1st Year	2nd Year	3rd Year	Done	Canola (19bu/ac)						20	5	43	44	132	128									
					W023					Benchmark	1st Year	2nd Year	3rd Year	Done	Canola (12bu/ac)						26	23	40												
					W024					Benchmark	1st Year	2nd Year	3rd Year	Done	Canola (12bu/ac)						23	6	23												
					W025	2019				Benchmark	1st Year	2nd Year	3rd Year	Done	Canola (12bu/ac)						35	29	42												
E1/2	29	12	01W	114	W026	2024				Benchmark	1st Year	2nd Year	3rd Year	Done	Canola (12bu/ac)						18	12	10	44	132	128									
					W034		Benchmark	1st Year	2nd Year	3rd Year	Done					Canola (52bu/ac)					32	30	13				40	24	29	61	27	22	22	8	20
					W035		Benchmark	1st Year	2nd Year	3rd Year	Done					Canola (52bu/ac)					67	56	13				41	13	61	-	-	-	5	2	15
					W035b		Benchmark	1st Year	2nd Year	3rd Year	Done					Canola (52bu/ac)											37	16	11	30	16	7.4	13	4	13
SE	5	10	01E	62	W036		Benchmark	1st Year	2nd Year	3rd Year	Done					Canola (52bu/ac)					67	56	13				21	4	28	30	29	11	-	-	-
N1/2 of N	14	9	01W	32	W037		Benchmark	1st Year	2nd Year	3rd Year	Done					Canola 48bu/ac)					74	25	23				21	27	32	12	7	33	7	3	27
S1/2 of N	14	9	01W	32	W038		Benchmark	1st Year	2nd Year	3rd Year	Done					Grain corn (140bu/ac)					30	9	16				14	4	53	13	6	29	10	4	26
					W039		Benchmark	1st Year	2nd Year	3rd Year	Done					Grain corn (140bu/ac)					27	13	6				-	-	-	12	6	13	6	4	7
SW	14	9	01W	63.2	W040		Benchmark	1st Year	2nd Year	3rd Year	Done					Grain corn (140bu/ac)					72	32	19				-	-	-	8	6	26	27	13	27
					W041		Benchmark	1st Year	2nd Year	3rd Year	Done					Spring wheat (72bu/ac)					15	6	19				8	15	13	6	3	24	5	2	23
NE	14	9	01W	64	W042		Benchmark	1st Year	2nd Year	3rd Year	Done					Spring wheat (72bu/ac)					35	23	9.8				6	10	4.8	29	22	16	6	5	20
					W043		Benchmark	1st Year	2nd Year	3rd Year	Done					Canola (48bu/ac)					48	31	8.4				28	14	16	21	13	19	5	2	15
SE	14	9	01W	62.8	W044		Benchmark	1st Year	2nd Year	3rd Year	Done					Canola (48bu/ac)					32	18	5.6	44	148	123	25	18	19	24	13	6	7	2	12
					W045		Benchmark	1st Year	2nd Year	3rd Year	Done					Wheat (65bu/ac)					44	27	11				13	5	3.2	8	3	12	13	7	11
SE	15	9	01W	64	W046		Benchmark	1st Year	2nd Year	3rd Year	Done					Wheat (65bu/ac)					72	30	17				14	4	5.4	8	4	27	8	2	23
					W047		Benchmark	1st Year	2nd Year	3rd Year	Done					Wheat (65bu/ac)					53	26	8.4				13	5	3.4	8	4	5.2	10	5	4
NE	15	9	01W	59	W048		Benchmark	1st Year	2nd Year	3rd Year	Done					Wheat (65bu/ac)					38	13	6.4	46	154	128	9	3	<2	8	3	4.8	9	4	4.2
S1/2 of S	15	9	01W	31	W049	2021	Benchmark	1st Year	2nd Year	3rd Year	Done					Wheat (65bu/ac)					28	14	7.8	44	148	123	8	11	8.2	12	3	22	8	3	19
					W050			Benchmark	1st Year	2nd Year	3rd Year	Done							Canola/45 (100-40-0-15)		2	9	14				68	37	24	11	5	9			
S1/2 SE	33	11	1EPM	26	W051			Benchmark	1st Year	2nd Year	3rd Year	Done									14	6	7.2				32	15	30	7	3	12			
					W052			Benchmark	1st Year	2nd Year	3rd Year	Done									34	10	29				110	56	15	10	18	26			
					W053			Benchmark	1st Year	2nd Year	3rd Year	Done									24	12	16				31	16	15	5	4	23			
					W054			Benchmark	1st Year	2nd Year	3rd Year	Done							Canola/45 (100-40-0-15)		25	13	16				66	38	23	5	2	24			
					W055			Benchmark	1st Year	2nd Year	3rd Year	Done									36	27	28				59	33	21	7	3	13			
E1/2	28	11	1EPM	125	W056			Benchmark	1st Year	2nd Year	3rd Year	Done									26	12	35				63	28	35	5	2	20			
					W057			Benchmark	1st Year	2nd Year	3rd Year	Done									6	2	15				38	17	26	4	2	9.4			
N1/2 NW	21	11	1EPM	32	W058			Benchmark	1st Year	2nd Year	3rd Year	Done							Canola/45 (100-40-0-15)		16	6	27				36	21	10	56	19	33			
					W059			Benchmark	1st Year	2nd Year	3rd Year	Done									14	6	14				17	9	24	12	48	16			
					W060			Benchmark	1st Year	2nd Year	3rd Year	Done							Corn/135 (100-40-10)		22	14	27				23	18	24	5	3	12			
NW	27	11	1EPM	65	W061	2022		Benchmark	1st Year	2nd Year	3rd Year	Done									22	8	11	63	225	224	38	28	15	9	3	11			
					W062				Benchmark	1st Year	2nd Year	3rd Year	Done								4	5	6.2				20	5	27						
SE	35	11	1WPM	58	W063				Benchmark	1st Year	2nd Year	3rd Year	Done								8	5	22				19	4	12						
					W064				Benchmark	1st Year	2nd Year	3rd Year	Done						Wheat/78 (0 lbN, 10 lbP/ac)		10	6	41				12	3	12						
					W065				Benchmark	1st Year	2nd Year	3rd Year	Done								10	6	16				25	7	8.3						
SW	35	11	1WPM	58	W066	2023			Benchmark	1st Year	2nd Year	3rd Year	Done								8	5	13	44	154	128	23	7	12						
					W067					Benchmark	1st Year	2nd Year	3rd Year	Done					Canola		3	1	18												
NW	24	12	1EPM		W068					Benchmark	1st Year	2nd Year	3rd Year	Done					Canola		4	3	28												
N1/2 SW	24	12	1EPM	97	W069					Benchmark	1st Year	2nd Year	3rd Year	Done					Canola		13	5	11												
					W070					Benchmark	1st Year	2nd Year	3rd Year	Done					Barley		5	10	3.2												
S1/2 SW	24	12	1EPM	32	W071	2024				Benchmark	1st Year	2nd Year	3rd Year	Done					Barley		9	14	9.8	43	127	123									
					W076					Benchmark	1st Year	2nd Year	3rd Year	Done					Wheat		45	10	15												
NW	21	12	01WPM	65	W077					Benchmark	1st Year	2nd Year	3rd Year	Done					Wheat		8	3	5.8												
N1/2 NE	21	12	01WPM	32	W078					Benchmark	1st Year	2nd Year	3rd Year	Done					Wheat		22	4	18												
S1/2 NE	21	12	01WPM	33	W079	2024				Benchmark	1st Year	2nd Year	3rd Year	Done					Wheat		5	6	2.7	50	150	146									

wsp