Appendix A - SCOPE OF SERVICES

Long Term Effect of Land Application of City of Columbus Biosolids on Soil Health and Crop Quality and Performance

Biosolids Experimental Design and Sampling

The experimental design is two biosolids treatments (Com-Til, Class B) and a control with four plots for each treatment (Table 2).

Table 1: Study fields beginning in 2024 and continuing in 2025.

Pre 2024 Field ID	2024 Field ID	Treatment	Field Location Note	Owner Name
1	1	B	N of biosolids facility	City of Columbus (Writsel)
2	2	B	Directly adjacent to biosolids facility	City of Columbus (Writsel)
3	3	B	South of compost facility. Front field N of entry road.	City of Columbus (Writsel)
4	4	B	South of compost facility. Front field S of entry road.	City of Columbus (Writsel)
NA	5	COM	Waverly, OH above retention pond.	Nate Ewing
NA	6	COM	Waverly, OH	Nate Ewing
NA	7	COM	Beaver, OH. North section of large field.	Nate Ewing
NA	8	COM	Beaver OH. South section of large field.	Nate Ewing
NA	CON A	Control	Edge condition of field 3. Adjacent to residential.	City of Columbus (Writsel)
NA	CON B	Control	Edge condition of field 4. Adjacent to residential.	City of Columbus (Writsel)
NA	CON C	Control	Edge condition of field 2. Adjacent to entry road.	City of Columbus (Writsel)
NA	CON D	Control	Edge condition of field 1. Adjacent to main road.	City of Columbus (Writsel)

We will determine the effects (i.e., benefits) of biosolids on soil health and crop quality and performance. Corn and soybean cropping systems will be studied. Soil health will include (i) plant nutrients, (ii) soil physical, chemical and microbial ecology, (iii) soil phosphorus saturation and water quality, and (iv) soil carbon sequestration.

Biosolids Laboratory Measurements

Percent moisture, salinity (electrical conductivity, EC), pH, oxalate extractable Fe, Al, and P (Fe_{ox}, Al_{ox}, and P_{ox}), total P, total C, total organic C, N, S will be determined for biosolids. Phosphorus Saturation Index (PSI) of each byproduct will be calculated from PSI (%) = $[(P_{ox})/(Al_{ox} + Fe_{ox})] \times 100\%$.

Persistent herbicides in Com-Til will be determined.

Crop Yield and Quality Laboratory Measurements

Crop yield will be collected from producers. Crop quality will be assessed by measuring nutrient content (N, P, K, Ca, Mg, S, Cu, Fe, Mn, Zn) of crop grain.

Soil Health Laboratory Measurements

Nitrogen

Slow Release Nitrogen: Potentially Mineralizable N (PMN) and Total Organic N.
PMN is the nitrogen fraction can be made plant available for plant uptake through microbial-assisted mineralization. Total C and N will be determined in soil and analyzed using a dry combustion TCN Analyzer. Plant readily available NH_4^+-N and NO_3^--N will be determined.

Soil Carbon and Sulfur

Total C and S will be determined in soil and analyzed using a dry combustion TCN Analyzer.

Active Carbon

Biologically active soil C will be determined using the method described in the *Comprehensive Assessment of Soil Health Cornell Framework Manual Third Edition*. Potassium permanganate ($KMnO_4$) solution is used to oxidize active C followed by colorimetric analysis.

Total Organic Carbon

Total organic C will be determined by measuring inorganic carbon in samples with pH>7 and subtracting the inorganic carbon from the total carbon.

Macronutrients and Micronutrients

Plant available P, K, and micronutrients will be determined by soil extraction using Mehlich 3 and analyzed by Inductively Coupled Plasma-Atomic Emission Spectrometry (ICP).

Soil Phosphorus and Water Quality Measures

Soil phosphorus measurements important to crop production and water quality will be determined. Soil chemical analytical methods will include Mehlich 3, Olsen P, phosphorus saturation (Psat), and water extractable P (WEP). Phosphorus saturation, Psat, will be determined by measuring Al, Fe, and P extracted by acid ammonium followed by subsequent analysis of P, Fe and Al by Inductively Coupled Plasma Optical Emission Spectroscopy (ICP). Psat will be calculated as follows: % Psat = extracted Pox/ (Alox + Feox) x 100%.

Soil Respiration
Soil respiration measures the soil microbial activities by analyzing CO_2 being released from the soil in a specific period of time. The Solvita gel system will be used to calculate the concentration of CO_2 representing the CO_2 released by the soil microorganisms.

Cation Exchange Capacity/Exchangeable Bases
The method to find soil cation exchange capacity (CEC) is described by Sumner & Miller (1996). Soil will be extracted with 0.1 M $BaCl_2$ with subsequent analysis of exchangeable cations (Ca, Mg, Na, K, Al, and Mn) by ICP.

Soil pH and Salinity
Soil pH will be determined in 1:1 soil:water solution using a glass electrode (Thomas, 1996). Soil salinity will be determined by measuring electrical conductivity (EC) (Rhodes et al., 1996).

Elemental Analysis
Inorganic metal contaminants will be analyzed in soil using X-ray fluorescence with an XRF Niton XL2 analyzer as described in USEPA Method 6200 (EPA, 2007).

Available Water Capacity
The amount of water that a soil can hold that is available for plant uptake is referred to as available water capacity (AWC). It is calculated by

$$AWC = FC - PWP$$

Field capacity (FC) is the upper end of soil wetness after water has drained from gravity, and permanent wilting point (PWP) is the lower end when only hygroscopic water, or water unavailable to plants, is left. The container capacity (CC) method will be used for this study to substitute for FC. PWP will be found using a pressure plate extractor. PWP results will then be subtracted from CC results to give AWC expressed as g of water per g of soil.

Bulk Density
The core method will be used to find bulk density as descried by. One core will be taken for each sampling point. Mean bulk density will be determined for each plot.

Aggregate Stability
Wet aggregate stability will be determined using a Cornell Sprinkle Infiltrometer that releases raindrops of 4mm diameter and delivers a simulated rain event to the soil of 15 drops per second, equivalent to a heavy thunderstorm. The method is described in the *Comprehensive Assessment of Soil Health Cornell Framework Manual Third Edition*.

Microbial Community Analysis
Linked Fatty Acid Methyl Ester (EL FAME) method will be used to determine the makeup of microbial communities and population shifts from agricultural practices.

Soil Microbial Ecology

Microbial biomass plays an important role in nutrient cycling and organic matter transformations. Soil enzymes are involved in nutrient cycling, organic matter decomposition, and conversion of organic to inorganic substances, as well as in energy transformation. All microbial ecology studies will be performed in the Soil Microbial Lab under Dr. Richard Dick of Ohio State University. The following soil enzyme assays will be performed.

Biological function	**Soil enzyme assay**	**Ecosystem service**
Glucose availability	B-glucosidase	Microbial energy source
Sulfate metabolism	Arylsulfatase	Indirect indicator of fungi; potential degradation of microconstituents

Data Evaluation and Report Preparation

The contractor shall prepare and submit reports that summarize sampling, analysis, and evaluation of data collected.

Project Management

The contractor shall provide the necessary project management to schedule, coordinate, and manage the personnel to perform the services required. Management services shall include, but are not limited to, scheduling, invoicing, and participating in progress meetings with the City. The following annual timeline is proposed

Soil sampling: autumn (Sept-Dec)
Biosolid Collection: (Sept-Dec)
Com-Till Collection (Sept-Dec)
Grain sampling: autumn (Sept-Nov)
Soil and grain analysis: winter (Dec-April)
Data analysis and reporting (May-June)
Annual meeting with City of Columbus and producers (July-Aug)

Project Budget

	Cost per Sample	Count	Cost
Soil Collection	$1,000	12	$12,000
Lab Analyses			$27,750
Soil			
Soil Plant Nitrogen	$25.00	48	$1,200
Total Carbon, Nitrogen and Sulfur	$17.50	48	$840
Active Carbon	$12.50	48	$600
Total Organic Carbon	$31.25	48	$1,500
Macro and Micronutrients	$12.50	48	$600
Soil pH and Salinity	$3.75	48	$180
Bulk Density	$50.00	48	$2,400
Aggregate Stablity	$50.00	48	$2,400
Particle Size Analysis	$43.75	48	$2,100
Water Extractable Phosphorus	$12.50	48	$600
Phosphorus Saturation (Oxalate)	$17.50	48	$840
Olsen P	$12.50	48	$600
EL-FAME	$25.00	48	$1,200
Enzyme Analysis	$35.00	48	$1,680
Soil Processing Fee	$3.75	48	$180
Available Water Capacity	$45	48	$2,160
XRF for As, Cd, Pb, Zn	$31.25	48	$1,500
Cation Exchange Capacity/Exchangable bases	$15	48	$720
Soil Respiration	$12.50	48	$600
Mineralizable N	$20	48	$960
Biosolids			
Soil pH and Salinity	$3.75	2	$8
Total Carbon, Nitrogen and Sulfur	$17.50	2	$35
Phosphorus Saturation (Oxalate)	$17.50	2	$35
Total P 3051a	$31.25	2	$63
Persistent herbicide in com-til	$500.00	2	$1,000
Grain			
Macro and Micronutrients	$31.25	120	$3,750
Data Analysis and Reporting	$75.00	180	$13,500
Annual Meeting	$1,000.00	1	$1,000
Total			$54,250

Appendix B - SCOPE OF SERVICES

Biosolids Mine Reclamation Impact on Soil Health and Water Quality

Experimental Design and Sampling

Cake biosolids (total solids ~20%) have been used for mine reclamation at two Deep Row Hybrid Poplar Tree Farms in New Lexington and Cadiz, Ohio since 2012 and 2023 respectively.

The New Lexington Deep Row Hybrid Poplar Tree Farm, owned and operated by Ohio Mulch Supply Inc, is located in Perry County, Ohio and consists of 314.0 permitted acres across 24 fields. These fields range in slope, soil type, and biosolids application history. Soil samples will be collected from 11 total fields

The Cadiz Regional Tree Farm, owned and operated by Quasar Energy, is located in Harrison County, Ohio and consists of 210.3 permitted acres across 3 fields. These fields range in slope, soil type, and biosolids application history. Soil and soil water samples will be collected from 7 total fields.

The Soil Water Environment Lab (SWEL) at Ohio State University will determine the effects of biosolids cake application for mine reclamation on soil health and water quality. A summary of sites and treatments (application history) are presented in Table 1. SWEL will work with the City to select i) soil sampling points which best represent site variation and ii) water sampling locations which best represent surface waters entering the site, exiting the site, and contained within the site.

Table 1. Study site locations, application history and the number of fields to be sampled.

Site	Application History	Fields
New Lexington	Established Stand, 7+ years	4
New Lexington	New Stand, 1-3 years	4
New Lexington	Control, no biosolids application	1
Cadiz Regional	New Stand, 1-3 years	4
Cadiz Regional	Control, no biosolids application	3

<u>Soil Samples</u>

Soil samples (4 per field) will be collected in the fall and analyzed for soil health metrics in accordance with USDA's Soil Management and Assessment (SMAF) soil health framework.

<u>Soil Health Laboratory Measurements</u>

Nitrogen

Slow-Release Nitrogen: Potentially Mineralizable N (PMN) and Total Organic N.
PMN is the nitrogen fraction can be made plant available for plant uptake through microbial-assisted mineralization. Total C and N will be determined in soil and analyzed using a dry combustion TCN Analyzer. Plant readily available NH4+-N and NO3 - -N will be determined.

Soil Carbon
Total C will be determined in soil and analyzed using a dry combustion TCN Analyzer.

Active Carbon
Biologically active soil C will be determined using the method described in the Comprehensive Assessment of Soil Health Cornell Framework Manual Third Edition. Potassium permanganate (KMnO4) solution is used to oxidize active C followed by colorimetric analysis.

Total Organic Carbon
Total organic C will be determined by measuring inorganic carbon in samples with pH>7 and subtracting the inorganic carbon from the total carbon.

Macronutrients and Micronutrients
Plant available P, K, and micronutrients will be determined by soil extraction using Mehlich 3 and analyzed by Inductively Coupled Plasma-Atomic Emission Spectrometry (ICP).

Soil Phosphorus and Water Quality Measures
Soil phosphorus measurements important to crop production and water quality will be determined. Soil chemical analytical methods will include Mehlich 3, Olsen P, phosphorus saturation (Psat), and water extractable P (WEP). Phosphorus saturation, Psat, will be determined by measuring Al, Fe, and P extracted by acid ammonium followed by subsequent analysis of P, Fe and Al by Inductively Coupled Plasma Optical Emission Spectroscopy (ICP). Psat will be calculated as follows: % Psat = extracted Pox/ (Alox + Feox) x 100%.

Cation Exchange Capacity/Exchangeable Bases
The method to find soil cation exchange capacity (CEC) is described by Sumner & Miller (1996). Soil will be extracted with 0.1 M BaCl2 with subsequent analysis of exchangeable cations (Ca, Mg, Na, K, Al, and Mn) by ICP.

Soil pH and Salinity
Soil pH will be determined in 1:1 soil:water solution using a glass electrode (Thomas, 1996). Soil salinity will be determined by measuring electrical conductivity (EC) (Rhodes et al., 1996).

Elemental Analysis
Inorganic metal contaminants will be analyzed in soil using X-ray fluorescence with an XRF Niton XL2 analyzer as described in USEPA Method 6200 (EPA, 2007).

Available Water Capacity
The amount of water that a soil can hold that is available for plant uptake is referred to as available water capacity (AWC). It is calculated by

$$AWC = FC - PWP$$

Field capacity (FC) is the upper end of soil wetness after water has drained from gravity, and permanent wilting point (PWP) is the lower end when only hygroscopic water, or water unavailable to plants, is left. The container capacity (CC) method will be used for this study to substitute for FC. PWP will be found using a pressure plate extractor. PWP results will then be subtracted from CC results to give AWC expressed as g of water per g of soil.

Bulk Density

The core method will be used to find bulk density as descried by. One core will be taken for each sampling point. Mean bulk density will be determined for each plot.

Aggregate Stability

Wet aggregate stability will be determined using a Cornell Sprinkle Infiltrometer that releases raindrops of 4mm diameter and delivers a simulated rain event to the soil of 15 drops per second, equivalent to a heavy thunderstorm. The method is described in the Comprehensive Assessment of Soil Health Cornell Framework Manual Third Edition.

Biosolid Samples

Biosolid and Com-Till samples, 2 per year will be collected and analyzed under the land application scope of work (Appendix A) for:

Percent moisture, salinity (electrical conductivity, EC), pH, oxalate extractable Fe, Al, and P (Feox, Alox, and Pox), total P, total C, total organic C, N, S will be determined for biosolids.

Phosphorus Saturation Index (PSI) of each byproduct will be calculated from PSI (%) = [(Pox)/(Alox + Feox)] x 100%.

Com-Till will also be analyzed for persistent herbicides.

Surface water Samples

One surface water samples will be collected for each treatment at both the New Lexington and Cadiz Sites (5 samples) in the Spring and Fall. The samples will be analyzed for The surface water samples shall be analyzed for pH, nitrogen, nitrate, nitrite, ammonia, fecal coliform bacteria, sulfate, iron, and heavy metal concentration

Data Evaluation and Report Preparation

The contractor shall prepare and submit reports that summarize sampling, analysis, and evaluation of data collected.

Project Management

The contractor shall provide the necessary project management to schedule, coordinate, and manage the personnel to perform the services required. Management services shall include, but are not limited to scheduling, invoicing, and participating in progress meetings with the City. The following annual timeline is proposed:

Sampling event 1 (soil + water): Autumn 2025 (Sept -Dec)
Sampling event 2 (water): Spring 2026 (Apr-May)
Sample analysis event 1: winter (Dec-April)
Data analysis and reporting: spring to summer (May-June)
Annual meeting with City of Columbus and tree farms: summer (July-Aug)

Project Budget

	Cost per Sample	Count	Cost
Collection			**$14,000**
Soils Collection	$1,000	12	$12,000
Water Collection	$200	10	$2,000
Lab Analyses			**$24,988**
Soil			
Total Carbon, Nitrogen and Sulfur	$17.50	72	$1,260
Active Carbon	$12.50	72	$900
Total Organic Carbon	$31.25	72	$2,250
Macro and Micronutrients	$12.50	72	$900
Soil pH and Salinity	$3.75	72	$270
Olsen P	$12.50	72	$900
Bulk Density	$50.00	72	$3,600
Water Extractable Phosphorus	$12.50	72	$900
Phosphorus Saturation (Oxalate)	$17.50	72	$1,260
Soil Processing Fee	$3.75	72	$270
Available Water Capacity	$45	72	$3,240
XRF (suggest switching to 3051a for As, Cd, Pb, Zn)	$31.25	72	$2,250
Cation Exchange Capacity/Exchangable bases	$15	72	$1,080
Minralizable N + plant available N	$20	72	$1,440
Aggregate Stablity	$50.00	72	$3,600
Water			
pH	$3.75	10	$38
Total Nitrogen	$14	10	$140
Dissolved Nitrate	$8	10	$80
Dissolved Nitrite	$8	10	$80
Dissolved Ammonia	$8	10	$80
Dissolved Sulfur, Iron, Arsenic, Cadmium, Lead, and Zinc	$10	10	$100
fecal coliform	$35	10	$350
Biosolids			
Soil pH and Salinity	$3.75	0	$0
Total Carbon, Nitrogen and Sulfur	$17.50	0	$0
Phosphorus Saturation (Oxalate)	$17.50	0	$0
Total P 3051a	$31.25	0	$0
Persistent herbicide in com-til	$500.00	0	$0
Data Analysis and Reporting	$75.00	180	**$13,500**
Total			**$52,488**