FACTOR 4 SOIL REPORT

A Survey of Soils at the Factor 4 Project Area:

British Columbia Institute of Technology, Burnaby, B.C. Campus

16 May 2016

Abstract

A soil survey of the Factor 4 project area at BCIT's Burnaby campus was carried out by the graduating class of the Sustainable Resource Management Technology program. Because of restrictions about excavating soil pits, no soil profile descriptions were carried out. Soils are described based on core samples supplemented by observations of nearby excavations and local knowledge. Soil samples from 16 locations were analyzed for 11 soil physical and chemical properties. The most severe soil quality limitations appear to be high bulk density and low porosity. Levels of nitrogen, phosphorus and potassium are low in some locations. Soils are generally suitable for a range of plant species but tillage along with establishment and some maintenance fertilization will improve soil quality.

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Contents

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ABBREVIATIONS & SYMBOLS USED IN THE REPORT

The following abbreviations are used in the report.

C	clay
Ca	Calcium
CEC	cation exchange capacity
CF	coarse fragments
C/N	carbon to nitrogen ratio
EC	electrical conductivity
K	potassium
L	loam
Mg	magnesium
MRPP	multi response permutation procedure
N	nitrogen
OM	organic matter
PCA	principal component analysis
S	sand
Si	silt
SCL	sandy clay loam
SL	sandy loam
SRMT	Sustainable Resource Management Technology

INTRODUCTION

The Factor 4 project area, situated at the northwest corner of BCIT's Burnaby campus[1], has been identified as a candidate demonstration site for sustainability and, potentially, for ecological restoration. The area is characterized by patches of soil occupied by ornamental trees and lawn. Small patches are present along the north side of Smith Street. Some larger grassy areas and strips are north of English Street. Soils in the area are compacted: either intentionally, during past construction, or from foot traffic, or both. Baseline soil information is needed to support planning and project implementation. A soil survey was carried out by BCIT Sustainable Resource Management students during February 2016 as part of SRMT 2350, "Urban Soils", and SRMT 3150, "Foundations of Urban Forestry and Arboriculture" courses. Objectives of the survey are:

- Assess soil quality and limitations
- Assess available green spaces in the Factor Four area for its soil potential for supporting trees
- Practice design of an urban soil inventory
- Interpret soil survey information, especially soil laboratory data.

Information from the survey will provide a basis for future projects aimed at vegetation and hydrologically-related restoration projects.

METHODS

A reconnaissance survey was first carried out to explore soil variability and facilitate development of a soil sampling plan. Excavation of soil pits and soil profile descriptions were not carried out because excavation of soil pits is too disruptive. Information on soil horizons was derived from sample cores, local knowledge and observations of adjacent excavations. Sampling was carried out using soil augurs at 16 random locations distributed throughout the Factor 4 project area (see Figure 1). Sample depth was 0 to 20 cm. At 3 locations, subsurface samples were taken at depths of 25 to 45 cm.

Soil samples were labelled coded by the initials of each of the crew members. The labels were abbreviated for mapping (see Figure 1) to make the map legible. Another recoding, used in some of the data analysis, was needed to make data compatible with computer software. Table AI in Appendix II summarizes the sample labels.

Soil samples were analyzed at Pacific Soil Analysis, Inc. in Richmond, B.C. Analysis included pH, % organic matter (OM), total % nitrogen (N), carbon to nitrogen ratio (C/N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), electrical conductivity (EC), percentage of coarse fragments (CF), and percentage fines (Fines). Lab methods followed procedures in Carter (1993), Lavkulich (1977), Lavkulich (1978) and McKeague (1987).

[1] See Figure 1 here and Figure A1 in Appendix I.

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Multivariate analysis methods were used to explore sample data for patterns and groups. Principal component analysis (PCA), cluster analysis and multi-response permutation procedure (MRPP) were used to investigate spatial variability in the soil data and to determine if stratification of the project area into different soil types was appropriate. Analyses were carried out with PC-ORD, version 6.20, software (McCune and Mefford 2011). Soil data was standardized for PCA and MRPP so that variables have equal weighting. For cluster analysis, soil data was relativized by maximum.

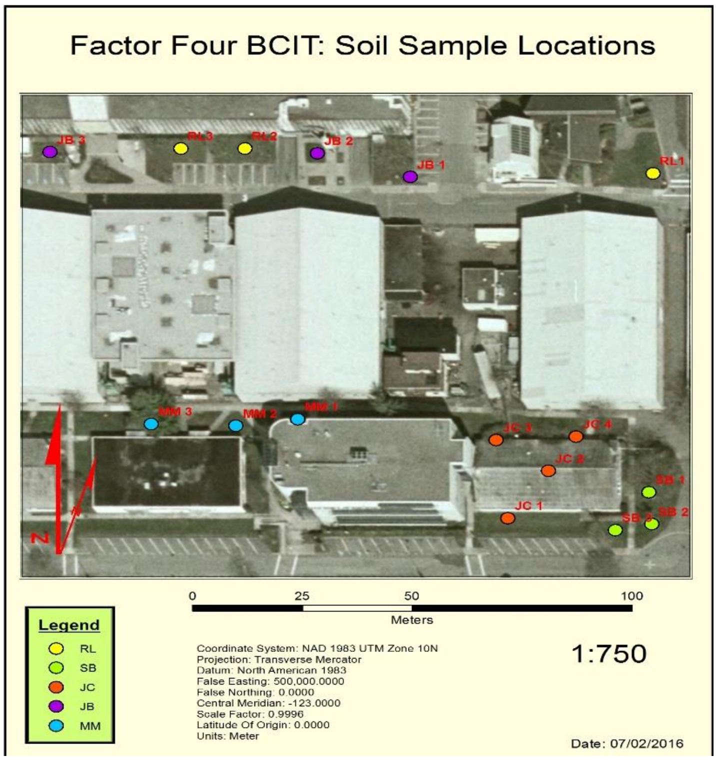

Figure 1. Map of Factor 4 Project Area showing Soil Sample Locations

Principal component analysis was used to see which combinations of soil variables are most influential and to look for patterns in soil sample ranking and grouping. Principal component analysis is a multivariate ordination method aimed at reducing multiple variables to a few (usually 2 or 3) “super variables”, graphically represented as axes, that will account for most of the variation in the samples (Manly 2005). Eleven soil variables were analyzed: pH, OM, total N, C/N, P, K, Ca, Mg, EC,   % coarse fragments, and % fines.

Cluster analysis refers to a variety of procedures for defining groups of samples (see Aldenderfer & Blashfield 1984). The cluster process used here is hierarchical, agglomerative, polythetic clustering. Two-way cluster analysis, which performs analysis on both soil samples and on soil variables, was used. The aim of cluster analysis in this study is to look for grouping patterns that suggest if soils in the project area should be stratified into different types. The cluster analysis was carried out using Ward’s linkage method and Euclidian distances. Soil samples defined by location were overlain on the cluster dendograms to suggest if soils in similar locations were similar in their properties. An example of the 2-way cluster analysis is in Figure A2, Appendix IV.

Multi-response permutation procedure was used to test if soil groups defined by location were significantly different in the 11 soil properties. Multi-response permutation procedure is a nonparametric, multivariate test of differences among predefined groups (see McCune and Grace 2002; Mielke 1991; Mielke and Berry 1976). The critical value for type I error was predetermined at $\alpha = 0.01$.

RESULTS and DISCUSSION

Soil properties from 16 sample sites are summarized in Table 1, below. Complete soil lab data is in Appendix III.

Since soils in Factor 4 are being assessed for their general quality (rather than suitability for particular plant species or species groups), results of soil analysis are interpreted in a general context. There is no one set of best soil guidelines, so results are compared to 3 somewhat different guidelines: USDA, Natural Resources & Conservation Service [Hanks and Lewandowski (2003)] in Table 1, B.C Landscape Society (for nitrogen phosphorus and potassium) in Table 2, and Craul (1999) in Table 3.

SOIL PROPERTY	MEAN	CV %	GUIDELINES[2]
pH	6.1	10	6.0 – 7.5
% Organic matter	7.4	34	≥ 5
% Total Nitrogen	0.23	61	0.2 – 0.6
C/N	13	28	≤ 20:1
Phosphorus ppm	111	67	> 20
Potassium ppm	148	39	> 150
Calcium ppm	1359	44	N/A
Magnesium ppm	109	36	N/A
Electrical Conductivity[3]	0.28 mmhos/cm	24	< 2.5 mmhos/cm
Texture Class	L, SiL, SCL & SL	n/a	L, SiL, SCL, SL or CL
% Coarse Fragments	16	53	< 10

Table 1. Mean values for 11 soil properties of Factor 4 soils.

The mean values for 7 of the 11 soil properties are within range of the standard (right hand column of Table 1). Potassium and % coarse fragments are not within the guidelines. For potassium, the mean value, 148 ppm, is just below the threshold of 150 ppm. For coarse fragments, the mean value of 16% exceeds the threshold of 10%. There are no general guidelines or standards for calcium or magnesium, however, given the values and the absence of soil conditions usually associated with deficiencies[4], both seem to be available in adequate amounts. Soil texture is loamy with fine sandy loam being most common.

[2] SOURCE: Hanks, D. and A. Lewandowski. 2003. "Protecting urban soil quality: Examples for landscape codes and specifications." USDA, Natural Resources Conservation Service. nrcs142_053275.pdf 20 pp.
[3] Guidelines use units of millimhos/cm; the equivalent SI metric unit is dS/m (deci-Siemens per metre).
[4] For example, high pH, very sandy soils, or soils with low (< 1) Ca: Mg ratios.

Variability in soil properties, expressed in Table 1 as CV % (coefficient of variation), is relatively low to moderate. In addressing soil variability, it is useful to compare the range of observed values to guidelines that are expressed as a range of values. Table 2, below, shows B.C. Landscape Society guidelines for nitrogen (N), phosphorus (P) and potassium (K). Nitrogen ranges from 0.03% to 0.5%. With respect to BCLS guidelines that corresponds to very low to high levels; 5 of 16 samples (31%) are very low and 13 of 16 samples (84%) are below adequate levels. Phosphorus ranges from 16 to 282 ppm and is high in 3 of 16 samples (19%), adequate in 7 of 16 (44 %), moderate in 3 (19 %), low in 2 (12 %) and very low in 1 (6%). Potassium ranges from 75 to 315 ppm; 2 of 16 (13 %) of samples are high, 11 of 16 (68 %) are adequate, and 3 of 16 (19% are moderate.

LEVEL	NITROGEN (N) %	Phosphorus (P) %	Potassium (K) %
Very Low	< 0.20	< 20	< 50
Low	0.20 – 0.25	20 – 30	50 – 70
Moderate	0.25 – 0.35	30 – 60	70 – 100
Adequate	> 0.35	60 - 200	100 – 200
High	n/a	> 200	> 200

Table 2. B.C. Landscape Society (BCLS) Soil Fertility Guidelines for N, P & K

No measurements of bulk density, porosity, available water storage capacity, or hydraulic conductivity were carried out. However, based on soil texture and depth along with field observations on soil density, it is estimated that[5]:

- Subsoil bulk densities are moderately high to high (roughly 1.4 to 1.8 Mg/m^3)
- Porosity values corresponding to the above bulk density estimates are .47 to .32
- Surface soils (upper 20 cm) are estimated to have bulk densities of about 1.2 to 1.5; corresponding porosities are .55 to .43
- Available water storage capacity is roughly estimated to be within the 15-25% range
- Saturated hydraulic conductivity is estimated to be in the moderately high (1-10 µm/s), for more porous surface soils, to moderately low classes (0.1 – 1 µm/s), for subsurface soils
- Soil drainage is limited in some locations, notably at the southeast part of the project area, in the vicinity of samples JC3, JC4, SB1, SB2 and SB3.

Cation exchange capacity (CEC) was not measured. However, based on soil texture and on rule-of-thumb relationships between CEC, % silicate clay and % organic matter:

- 0.5 cmol/kg for each % of silicate clay
- 2.0 cmol/kg for each % well unified organic matter

CEC is estimated to have an average value of about 15 cmol/kg. The range in estimated CEC is about 0.5 cmol/kg in some subsoils to 30 cmol/kg in more clayey and organic matter-rich surface soils. Cation exchange capacity seems to be generally adequate.

[5] Available water storage capacity and saturated hydraulic conductivity were estimated based on rule-of-thumb relationships in Soil Survey Staff (1993).

Table 3, below, compares Factor 4 soils to generally desired soil characteristics for urban soils. Soil texture, organic matter, pH, and soluble salts are all in favorable ranges. Nitrogen, P and K are marginally low at some locations. Calcium and Mg, as mentioned above, appear to be at least adequate. Percentage of coarse fragments is 6% over the guideline shown in Table 1. However, coarse fragment particle size observed in Factor 4 soils are small (roughly 2-5 mm). Given the small percentage and small particle size, coarse fragments do not present a serious limitation on soil quality. In fact, given the drainage limitations in some locations, higher coarse fragment content might improve soil quality.

Soil Properties or Characteristics	Desired Criteria	Factor 4 Soil
Texture	SL to SCL	L, SiL, SCL & SL
Structure	Granular, crumb, or fine SAB. Single grained or massive have limitations.	Meets criteria for upper 10-20 cm. Uncertain below 20 – 30 cm
Bulk Density & Porosity	1.1 – 1.4 Mg/m^3 desirable. Not > 1.6 $Mg/^3$. Macroporosity > 15% by volume	Appears satisfactory, at least in upper 20-30 cm.
AWSC	15 – 25% by volume	Estimated to meet criterion
Soil Drainage	No mottling within 50 cm of surface	Some locales with density high density subsoils or in microtopographic depressions do not meet criteria
Organic Matter	1 to 5 % by weight	Mostly (79% of samples) meet or exceed criterion
Soil Organisms	There should be ample evidence of soil organism activity	None overserved (but probably are active in upper soil).
pH	5.0 to 7.5 Extremes to be avoided	Average = 6.1, range = 5.4 – 7.5
CEC	5 to 25 cmol/kg	Estimated average = 15 cml/kg, range 0.5 – 25 cmol/kg
Nutrients	Normal content of N, P & K, etc.	N, P & K may be marginal in some soils
Soluble Salts	< 200 ppm with caution @ 600 ppm	Assessed by Electrical Conductivity: 0-2 dS/m (not significant to plants)
Contaminants	Should not have anthropeic materials known to contain toxins.	Not analyzed but no evidence.

Table 3. Factor 4 Soils Compared to Generally Desired Soil Characteristics for Urban Soils[6].

Field work was carried out during a cold, wet weather in February 2016. No soil organisms or direct signs of them were observed. If necessary, they should be assessed in a separate survey when organisms are more active and field conditions are favorable for observations.

[6] SOURCE: Craul 1999.

Soils were not analyzed for contaminants (*e.g.*, heavy metals, pesticides, fuels, solvents). Their presence can sometimes be indirectly indicated by unusual values for conventional soil variables like pH and EC or by symptoms of nutrient imbalances in vegetation. No signs of contaminants were observed.

Soil Variability with Depth

Soils at 3 locations were sampled at 2 depths: surface soils at 0 to 20 cm depth and subsurface soils at 25 to 45 cm depth. The small number of samples is not sufficient to draw statistically valid conclusions but does suggest trends. The results are in Table 4, below. Figure 2 summarizes the differences in 5 selected soil properties for surface and subsurface soils. Lower subsoil values for OM, N, P and K are a typical pattern observed in many natural soils. Why % coarse fragments are greater in subsurface soils is uncertain. It could reflect a pattern related to past landscaping practices or could be a random occurrence.

SAMPLE # (MAP)	SAMPLE # (DATA)	DEPTH[7]	pH	% N	P ppm	K ppm	% OM	% FINES	% CF
SB 1	31	2	5.6	0.22	137	195	6.8	44	13.2
SB 1	34	1	5.7	0.25	79	175	7.4	48	2.1
JB 4	44	2	5.8	0.31	185	150	7.8	43	10.4
JB 1	41	1	5.8	0.34	144	315	8.9	47	5.1
MM 4	54	2	6.6	0.11	144	95	2.6	53	19.6
MM 5	53	1	6.2	0.40	282	175	10.4	47	11.4

Table 4. Variation in Soil properties with Depth at 3 Factor 4 Sample Locations.

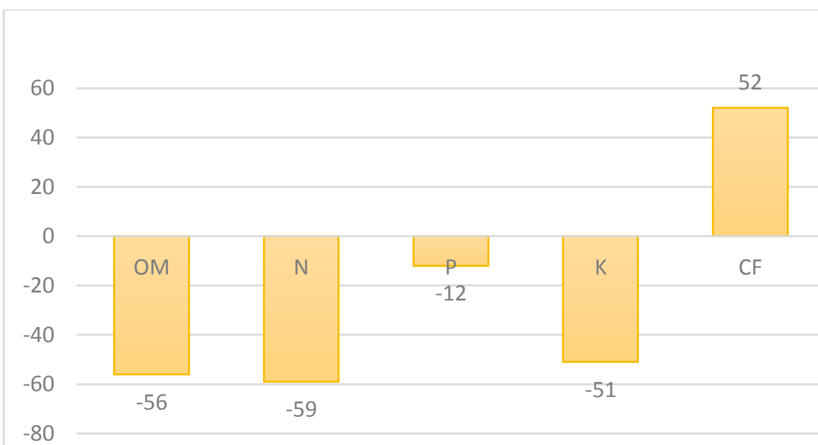

Figure 2. Differences Between Surface and Subsurface for 5 Selected Soil Properties. (Difference calculated as: subsurface value-surface value, expressed as a % of overall mean. Negative numbers show that values are lower for subsurface soils.)

[7] 2 = subsurface, 25-45 cm: 1 = surface, 0-20 cm

<u>Soil Spatial Variability: Multivariate Analysis</u>

Results of PCA with 4 location groups overlain are shown in Figure 3, below[8]. The 2 axes account for about 65% of variance. Axis 1 has a p-value of 0.001 and accounts for 44% of variance; axis 2 has a p-value of 0.22 and accounts for 20% of variance. The PCA results as shown in Figure 3 are useful for showing some relationships and trends among soil variables and location but they should not be over-interpreted. While PCA is an appropriate method for the data, the sample size (n = 16) is marginal relative to the number of soil variables (11). For example, Tabachnik and Fidell (1989) suggest the general rule that there should be at least 5 sample units for each observed variable. In this case, that would mean there should be 11 x 5 = 55 samples. However, they later said: "If there are strong and reliable correlations and a few distinct factors, a smaller sample size is adequate." (Tabachnik and Fidell 1996)[9]. Here, PCA is used as an exploratory tool to get a quick picture of the sample data.

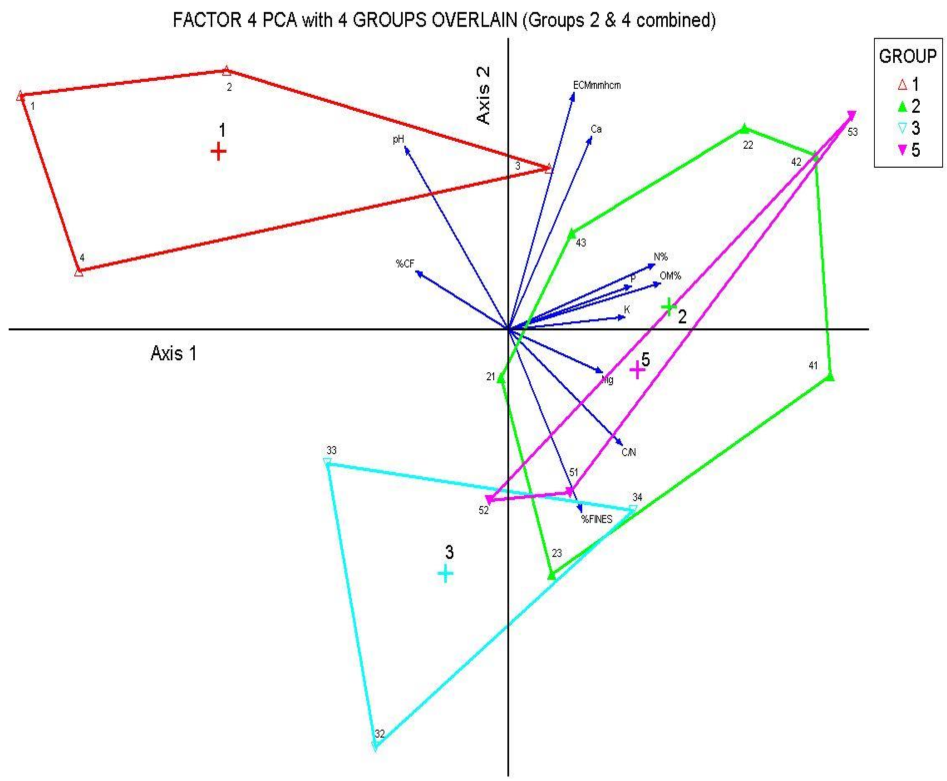

Figure 3. PCA Ordination of Factor 4 Soils with 4 Groups. Crosses with numbers 1 (JC), 2 (RL & JB), 3 (SB) & 5 (MM) represent the centroids for each group. Smaller font numbers represent samples. Lines connect samples of the same group. Arrows radiating from the centre show the contribution of soil variables to axes. The longer they are, the greater their contribution. The more parallel they are to an axis, the more is their contribution to the axis. Values are increasing in the direction of the arrow. Example: K contributes mostly to axis 1 and is increasing to the right-hand side; % Fines is contributing mostly to axis 2 and is decreasing upwards.

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[8] The groups are labelled 1, 2, 3 & 5: GROUP 1: JC1, JC2 & JC3; GROUP 2: RL1, RL2, RL3, JB1, JB2 & JB3; GROUP 3: SB1, SB2 & SB3; GROUP 5; MM1, MM2 & MM3. [Note that there were initially 5 groups but groups 2 and 4 were so similar that they were subsequently lumped together.]

[9] Tabachnik, B.G. and LS. Fidell. 1996. *Using multivariate statistics*. 3rd ed. Harper-collins. NY. 880 pp.

The p-value for axis 2 is too large to be considered statistically significant. So interpretation focuses on axis 1. Axis 1 can be regarded as a super variable influenced mainly by increasing OM, N, C/N, P, K, Ca, Mg and decreasing % coarse fragments and pH. Increasing OM, N, P & K are relatively strong influences. That is not a surprising result; soil fertility accounts for significant variability in soils. Organic matter is the source of many nutrients, especially N. Nitrogen is the nutrient required by plants in greatest amounts and it is often at low levels in mineral soils. Furthermore, N is sometimes low, so small increases may, in some cases, have a disproportionately large effect on soil fertility. Also of interest: there is a trend moving from left to right of increasing fertility from Group 1 to Group 3, to Groups 2 and 5. It suggests that there might be enough separation among some of the groups to make stratification of Factor 4 soils into 2 or more soil types.

Two-way cluster analysis was used to further investigate the appropriateness of stratification into soil types. The result showed no pattern of association between soil sample location (groups) and groups identified by the cluster analysis. An example of results from cluster analysis is in Appendix IV.

Results of MRPP to test for differences among the 4 soil sample groups defined by location are shown in Table 5, below. The overall test results are: T = -3.97883, A = 0.16599, p = 0.001235, indicating some potentially significant differences among groups.

Group Comparison	T	A	p
1 *vs*. 2 (JC vs. RL)	-3.5427	0.16827	0.006714**
1 *vs*. 3 (JC vs. SB)	-2.1953	0.13998	0.030797**
1 *vs*. 5 (JC vs. MM)	-2.1685	0.17032	0.037189**
2 *vs*. 3 (RL vs. SB)	-2.1511	0.09186	0.036676**
2 *vs*. 5 (RL vs. MM)	-0.9368	0.04394	0.158410
3 *vs*. 5 (SB vs. MM)	-1.6600	0.09527	0.048457**

Table 5. Results of MRPP for Testing Differences Among 4 Soil Groups

The T statistic can be interpreted here as being somewhat analogous to the Student's –t in univariate statistics. For T, however, the smaller the value (the more negative), the more significant it is. A is a measure of effect size[10]: values between about 0.1 and 0.3 may be significant for ecological data. However, effect sizes (A in Table 5) are mainly low - moderate at best. The p-values in Table 5 have not been adjusted for multiple comparisons. The statistical differences are in line with the trends in PCA and shown in Figure 3. The p-values for all the group comparisons, except 1 *vs*. 2[11], are not significant (α =- 0.05) when adjusted for multiple comparisons using the Bonferroni correction[12]. Therefore, it is not recommended that the project area be stratified into different soil types. Still, it could become important to recognize differences among areas when planning or carrying out planting or restoration.

[10] A = 1 when all observations in a group are the same; A = 0 when heterogeneity within groups equals that expected by chance; A < 1 means that heterogeneity within groups is greater than expected by chance.
[11] As shown in Figure 1: JC vs. RL & JB.
[12] Coppick, A. 2015; Greenacre & Primicerio 2013.

SUMMARY & CONCLUSIONS

Surface soil core samples from 16 locations throughout the Factor 4 project area were analyzed for pH, % OM, % total N, P, K, Ca, Mg, EC, % fines (silt + clay) and % coarse fragments. Subsoil samples were taken at 3 of the 16 locations. Surface soil quality is favorable for vegetation establishment with respect to Ca, Mg, EC, % fines (soil texture) and % coarse fragments. Percentage OM, N, P and K are, on average, low to adequate, with some local exceptions.

Mainly because of restrictions on sampling practices, full soil profile descriptions were not done and no measurements of bulk density, porosity or saturated hydraulic conductivity were taken. However estimates of the latter variables were made based on soil texture and field observations of soil density and depth. Subsurface soils appear to be compacted with low porosity and low hydraulic conductivity. Surface soils in some lawn-covered areas appear to have bulk density, porosity and saturated hydraulic conductivity favorable to plant growth. Those properties in surface soils in areas of heavy foot traffic are more like subsurface soils: compacted with high bulk density, low porosity and low hydraulic conductivity.

Subsurface soils were not intensely investigated. As would be expected, they appear to be lower in nutrients and organic matter, higher bulk density, poorer in structure and of lower permeability.

The major limitations of Factor 4 soils appear to be physical properties, such as bulk density. In some places (such as depressional sites in the lawn near the southeast corner of the project area) soil drainage and aeration are limiting. Soil tillage, either broadcast or in areas of planting holes or beds, should be carried out prior to planting. Broad-scale tillage can be done with tractor-drawn plowing implements; locally it can be done with power, hand-held equipment or hand tools. Although, Factor 4 soils often have adequate amounts of organic matter, addition of some organic matter can help to promote development of stable soil structure, especially in sites where organic matter content is low. It may also enhance fertility and soil water storage. Compost produced at BCIT may be a suitable source of organic matter.

Average fertility levels are adequate for most nutrients but vary from very low to high, depending on the nutrient element, location, soil depth and the species that are to be planted. It is likely that some fertilization with low analysis N, P and K fertilizers will be appropriate at establishment with some follow-up, maintenance fertilization in the seasons following establishment.

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APPENDIX I: Map of the FACTOR 4 Project Area

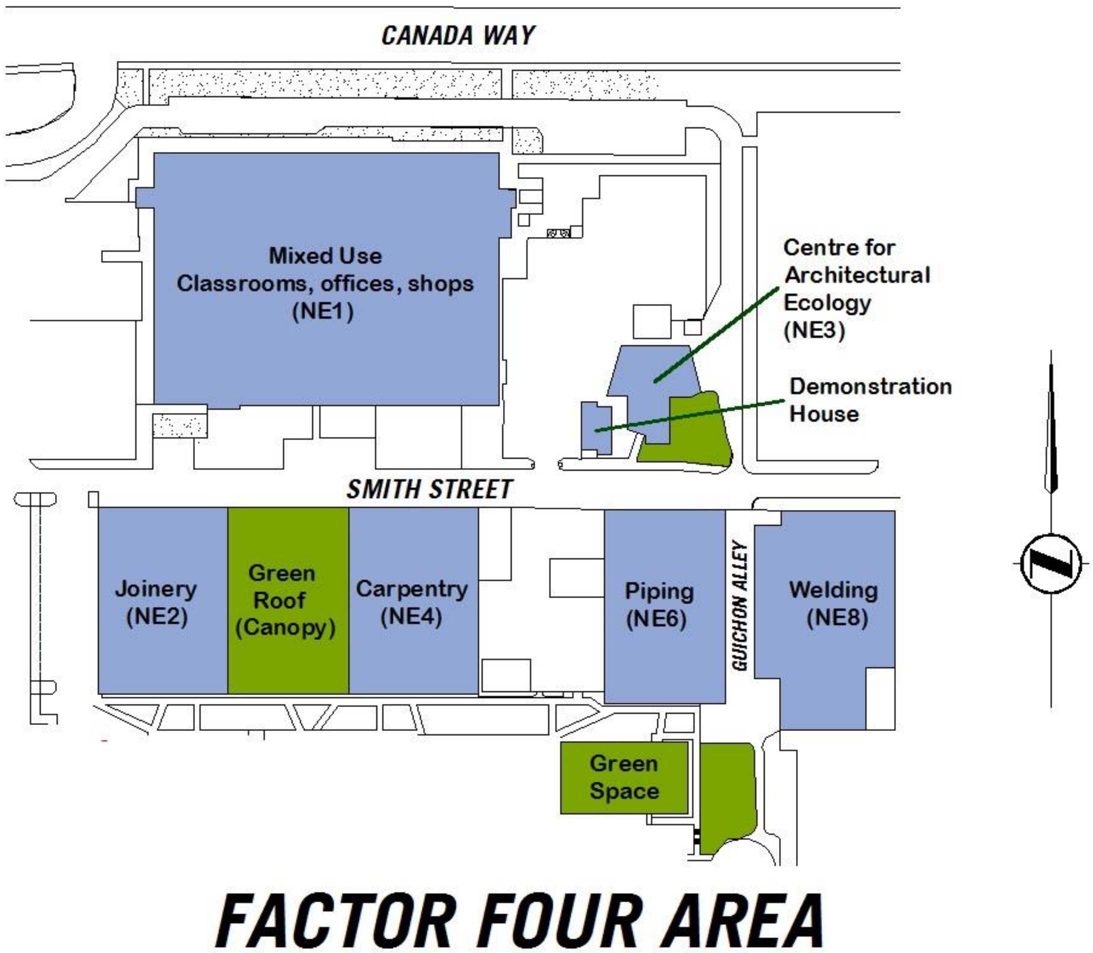

Figure A1. Factor 4 Project Area: British Columbia Institute of Technology, Burnaby Campus.

APPENDIX II: Labelling & Coding of soil Samples

Code on Map	Code in Data Analysis & Sample #'s	Code for Soil Sample Lab Data Sheets	# of Sample Locat-ions	Description of Location
JC	Single digit #'s: 1, 2, 3 & 4	JC1, JC 2, JC3 & JC4	4	Next most southeasterly samples; JC1, JC2, JC3 & JC4; just south of NE 6
RL	2-digit #'s beginning with "2": 21, 22 & 23	RL1, RL2 & RL3	3	From Guichon Way-Smith St. intersection west along Smith
SB	2-digit #'s beginning with "3"; 31, 32, 33 & 34	SBMBMC Pit1, Site1, Site 2 & Site 3	3	Most southeasterly samples. Lawn south of NE 6 & NE 8.
JB	2-digit #'s beginning with "4": 41, 42, 43 & 44	JBLSBJELCZ 1, 2 & 3 and JB 1-2	3	Along Smith St., south of NE 1; interspersed with RL samples.
MM	2-digit # beginning with "5": 51, 52, 53 & 54	DDDCERDS 1, 2, 3 & 3A	3	Most southwesterly samples: south side of NE 2 & NE 4

Table A1. Cross Reference for Soil Sample Labels & Codes: Map, Computer Codes & Soil Data Sheet

APPENDIX III: Soil laboratory Data

Sample	NEW	pH	E.C.	O.M.	N	C/N	P	K	Ca	Mg				
	SAMPLE #	pH	mmhos	%	%		ppm	ppm	ppm	ppm	%CF	%S	%Fines	TEXTURE
JC1	1	7.5	0.28	0.2	0.03	3.2	16	110	1050	70	33.7	78	22	SL
JC2	2	7.3	0.4	1.2	0.07	10.2	28	115	1600	85	32.1	63	37	SCL
JC3	3	6.4	0.36	7.2	0.28	14.9	108	85	2000	115	16.2	65	35	SCL
JC4	4	6.6	0.24	0.4	0.04	6	28	75	650	23	12.1	86	14	LS
RL1	21	5.6	0.28	6.9	0.31	12.9	82	105	950	75	7.6	71	29	SL
RL2	22	6.1	0.4	9.8	0.5	11.3	96	185	2100	135	11.4	55	45	SCL
RL3	23	5.5	0.22	7.4	0.34	12.7	55	140	500	165	19	52	48	L
SBMBMC Pit 1	31	5.6	0.24	6.8	0.22	18	137	195	850	85	13.2	56	44	SL
SBMSMC Site 1	32	5.7	0.18	0.9	0.04	13.5	46	145	600	105	16.1	30	70	SiL
SBMBMC Site 3	33	6.9	0.2	0.6	0.03	11.3	31	105	1475	183	10.9	51	49	L
JBLSBJELCZ 1	41	5.8	0.32	8.9	0.4	12.9	144	315	1150	185	5.1	53	47	L
JBLSBJELCZ 2	42	5.9	0.42	9.3	0.39	13.8	219	225	1750	140	8.6	61	39	SCL
JBLSBJELCZ 3	43	6.4	0.28	8.1	0.3	15.6	82	190	1950	100	20.7	66	34	SL
JBLSBJELCZ 1_2	44	5.8	0.22	7.8	0.31	14.5	185	150	1250	125	10.4	57	43	SL
DDDCERDS 1	51	5.4	0.24	5.7	0.2	16.7	236	150	1100	75	25.5	53	47	SL
DDDCERDS 2	52	5.7	0.24	6.4	0.21	17.7	113	80	1100	95	24.7	54	46	SCL
DDDCERDS 3	53	6.2	0.34	10.4	0.4	15	282	175	3000	125	11.4	53	47	SCL
DDDCERDS 3A	54	6.6	0.26	2.6	0.11	13.5	144	95	1550	95	19.6	47	53	SCL
SBMBMC Site 2	34	5.7	0.26	7.4	0.25	17.2	79	175	1200	95	2.1	52	48	L
MEAN		**6.14**	**0.28**	**5.68**	**0.23**	**13.21**	**111.11**	**148.16**	**1359.21**	**109.26**	**15.81**	**58.12**	**41.88**	
SDs		**0.60**	**0.07**	**3.41**	**0.14**	**3.66**	**74.12**	**57.88**	**598.97**	**39.50**	**8.40**	**11.70**	**11.70**	
CV%		**9.70**	**24.39**	**59.96**	**60.85**	**27.70**	**66.71**	**39.07**	**44.07**	**36.15**	**53.15**	**20.14**	**27.94**	
AVDEV		**0.50**	**0.06**	**2.97**	**0.12**	**2.65**	**60.12**	**44.90**	**479.09**	**31.46**	**6.87**	**8.73**	**8.73**	
MAX		**7.5**	**0.42**	**10.4**	**0.50**	**18.00**	**282**	**315**	**3000**	**185**	**33.7**	**85.84**	**69.73**	
MIN		**5.4**	**0.18**	**0.20**	**0.03**	**3.20**	**16**	**75**	**500**	**23**	**2.1**	**30.27**	**14.16**	
MEDIAN		**5.9**	**0.26**	**6.90**	**0.25**	**13.50**	**96**	**145**	**1200**	**100**	**13.2**	**55.32**	**44.68**	
MODE		**5.7**	**0.24**	**7.40**	**0.03**	**12.90**	**28**	**105**	**1100**	**95**	**11.4**			
COUNT		**19**	**19**	**19**	**19**	**19**	**19**	**19**	**19**	**19**	**19**	**19**	**19**	

Table A2. Soil Laboratory Data for Factor 4 Soils

Note: "DDCERDS…" samples are labeled as "MM" on map (Figure 1).

APPENDIX IV: 2-Way Cluster Analysis of Soil Samples and Soil Properties

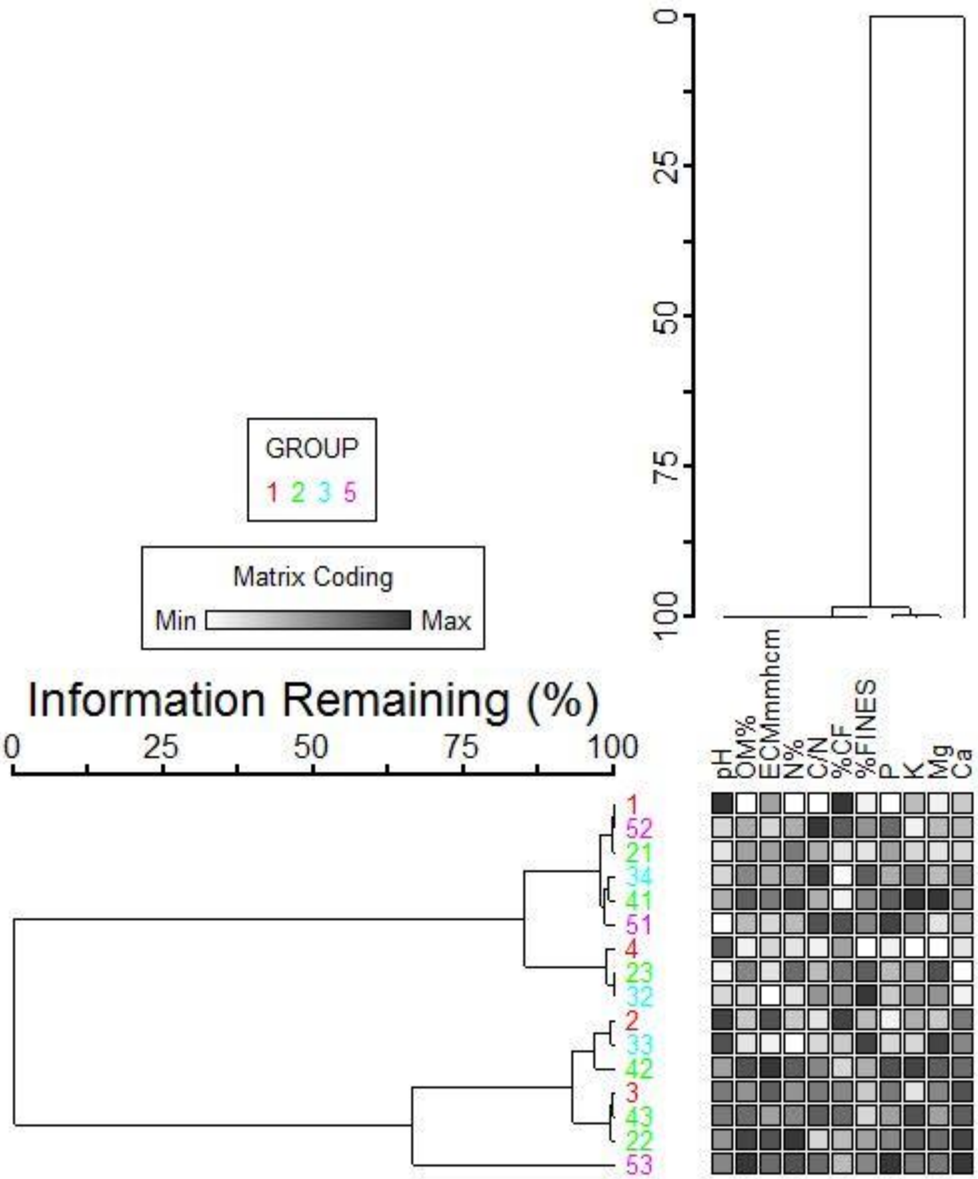

Figure A2. 2-Way cluster diagram for 4 groups (group #'s 1, 2, 3 & 5, defined by their location). The above matrix is the cluster dendogram for soil properties and, to the left, for groups. The magnitude of soil variables is proportional to the darkness of the gray-tone in the cells. Clustering of soil properties is not very informative but it does show the relative abundance and variability of calcium (Ca) compared to other properties. Clustering of groups shows 2 clusters: Cluster 1 with samples 1, 52, 21, 34, 41, 51, 4, 23 & 32: Cluster 2 with samples 2, 33, 42, 3, 43, 22 & 53. That is, each cluster contains samples from each location group. So there is no pattern of clustering of groups defined by location. The above cluster analysis was carried out using Ward's linkage method and soil data was relativized by maximum. Other cluster analysis was carried out using flexible beta (β = -

.25) linkage, with group averaging linkage, with standardized soil data, and with 5 location groups. Results are all generally similar.