GEOMORPHOLOGY AND SOIL QUALITY

OF THE

TWIN WATERSHED AREA AND PROJECT

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W. Michalyna
Manitoba Land Resource Unit,
CLBRR, Winnipeg

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GEOMORPHOLOGY AND SOIL QUALITY OF THE TWIN WATERSHED AREA

INTRODUCTION

Water erosion studies have been established on two very small watersheds along the Manitoba Escarpment, in the south western part of the South Tobacco Creek watershed. The installations are designed to receive runoff water and sediment during precipitation events of sufficient intensity for runoff to occur. The watershed is also used to monitor the water quality and nutrients (or other metals and pesticides) in suspension during transport from the two fields.

Soil quality is often considered in terms of suitability for crop production, but more recently has been extended to the reclamation of disturbed lands, and non-agricultural, often point-source pollution of agricultural lands (Acton, 1993).

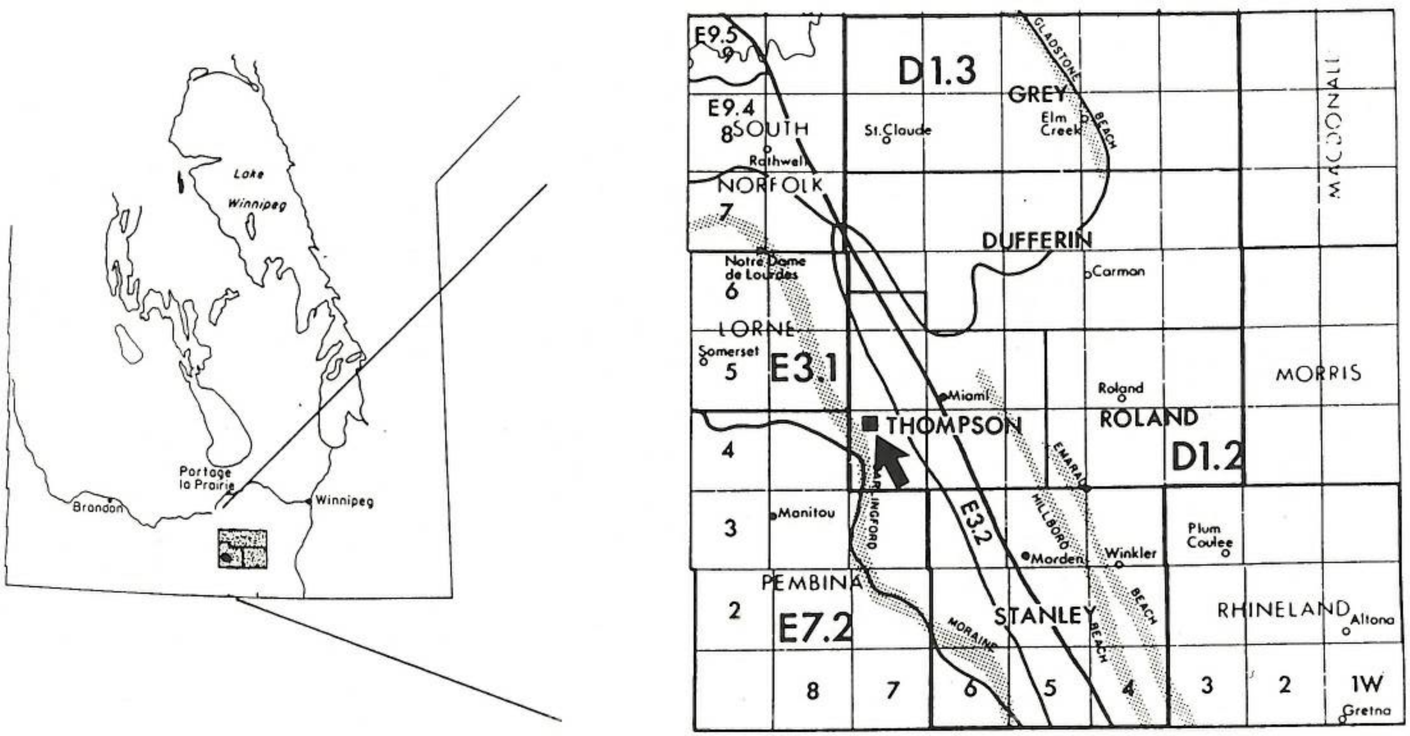
The need to include soil quality in the environmental assessment process is recognized by agencies with mandates for environmental reporting on a national basis (SOER, 1991).

Soil quality should also be considered in the initiation of environmental studies dealing with water quality within a watershed or basin. Baseline soil information is required to interpret nutrient and sediment results from runoff studies, and to provide background information for testing and validation of predictive models within various hydrologic settings or geographic areas. The procedures and data bases could also serve an important role in technology transfer to other hydrologic and geographic areas with similar soil and climate.

This report provides a brief overview of the geomorphology of the area, a summary of the soils, data based on analysis of selected components within the A (Ap) horizon of the two sub-watersheds, and data on common and heavy metal elements at one site within the watershed. Reference to other published data is provided.

AREA DESCRIPTION

A general description of the landscape and soils for this part of south-central Manitoba are provided in the Soils Report D60 (Michalyna et al. 1988). The Twin Watershed occurs within the physiographic region of the Pembina Hills Upland, characterized by undulating to hummocky morainal landscapes with moderate to strong slopes and associated sloughs. These landscapes occur at elevations between 390 to 500 m.a.s.l. The uppermost area is commonly referred to as the Darlingford Moraine, which forms a divide for general



■ SITE LOCATION

DIVISION		SECTION		SUBSECTION	
D	MANITOBA PLAIN	D1.	RED RIVER PLAIN	.2 .3	RED RIVER VALLEY LOWER ASSINIBOINE DELTA
E	SASKATCHEWAN PLAIN	E3.	PEMBINA HILLS UPLAND	.1 .2	PEMBINA HILLS PEMBINA ESCARPMENT
		E7.	PEMBINA RIVER PLAIN	.2	MANITOU PLAIN
		E9.	ASSINIBOINE RIVER PLAIN	.4 .5	BRANDON LAKE PLAIN UPPER ASSINIBOINE DELTA

Canada - Manitoba Soil Survey,
unpublished data

Figure 1. Location of the Twin watershed and Physiography of the Area.

drainage water flow to the east and west of the moraine (Fig.1). The drainageways on the west of the moraine and south of Lizard Lake drain in a south-westerly and southerly direction toward the Pembina River. Lizard Lake drains south-easterly through the moraine and easterly into Shannon Creek. The drainageways on the east part of the Pembina Hills are considerably incised and become steeper and deeper near and through the Manitoba Escarpment.

The Pembina Hills may be considered as a hydrological recharge area. Most of the precipitation either enters into the soil and is either stored, or continues downward as saturated flow; excess moisture that cannot be conducted into the soil is lost as surface runoff to depressional areas or streams. Generally soils developed in recharge areas have relatively low amounts of soluble salts. At the lower elevations of the Pembina Hills and Escarpment areas, the hydrology may vary from a recharge, intermediate, or discharge system depending on the subsoil and bedrock flow pattern. Solonetz soils , developed in shales containing sodium, and saline soils have been mapped along the Escarpment. At the base of the Escarpment, the hydrology may be considered a discharge system; seepage waters from the Escarpment contain appreciable soluble salts. Soils developed under the influence of the seepage waters have a considerable quantity of soluble salts and are considered saline (Michalyna et al. 1988).

The surface deposits consist mainly of glacial till derived from shale (Cretaceous), limestone (Paleozoic) and granitic (Precambrian) origin. They are moderately to very strongly calcareous and have a dominant loam to clay loam texture. The thickness of the till over the bedrock varies from 1 to 10 m, and up to 30 m in localized areas. At lower elevations in the landscape and along broadly defined waterways, thin veneers of lacustrine deposits of clay loam to light clay texture overlay the till.

The bedrock formations underlying the surface deposits are Cretaceous shales. At the higher elevations, bedrock consists of hard siliceous shales of the Riding Mountain Formation; at the lower elevation along the steeply sloping Manitoba Escarpment, shales of the Vermillion River Formation occur near or at the surface.

The climate of the area may be considered continental, with short cool summers and long cold winters; average annual temperatures range from 1.9°C at Pilot Mound to 3.3°C at Morden. In general, the area above the Escarpment is considered slightly cooler than the area along and below the Escarpment. Mean annual precipitation varies from 487 mm recorded at Roland to 620 mm at Deerwood. Mean rainfall for the period May thru August was 278 mm at Pilot Mound and 290 mm at Morden. Additional aerial climate and soil climate data are provided in the Soil Report D-60 (Michalyna et al. 1988).

The soils in the general area vary from Black Chernozems at the lower elevations of the Escarpment area, and are dominantly Dark Gray and Dark Gray Luvisols within the Pembina Hills. Depressional areas are mainly Humic Luvic Gleysols with some localized ares of Rego Humic Gleysols (Michalyna et al. 1988).

DESCRIPTION OF THE TWIN WATERSHED AREA

Location: NE 29-04-07W; Southwest of Miami (Fig. 1, 3 miles south of the Jct. of Hwy. 23 and 240 N, 1 mile west, 1 mile north).

Elevation: Approx. 445 masl (1460 feet).

Landform: Hummocky to undulating glacial moraine.

Slope: Varies from 3 to 10% in the two small watersheds (Fig.2).

Moisture Regime and Drainage: Subhumid, well drained, moderately permeable, moderately rapid runoff.

Soil Parent Material: Varies from moderately to strongly calcareous, slightly stony, loamy glacial till of mixed granitic, limestone and Cretaceous shale origin; there is some variability in the proportion of the shaly and limestone derived materials, which had an effect on the solum development. A thin veneer of lacustrine soil may be present in the lower parts of the landscape (at sites 8 and 10, but have been difficult to differentiate because of the higher shale content encountered).

Soil Classification: Soils are dominantly Orthic Dark Gray (Dezwood series) throughout the area with few localized shallower soils on the crests (either Calcareous Dark Gray or eroded members). Some soils on this study area may have surface colours that are borderline for the Black-Dark Gray subgroup. Dark gray surface colour and the presence of thin clay deposits (cutans) on the ped surfaces within the B horizons are indicative of the Dark Gray soils. At some sites, a Bm horizon rather than a Bt or Btj was observed; classification would be an Black Chernozem.

A profile description of a Dark Gray soil (Dezwood Series) is provided in the Appendix. The classification of the soils by the Canadian System and US Taxonomy are provided in the Appendix, Table 6.

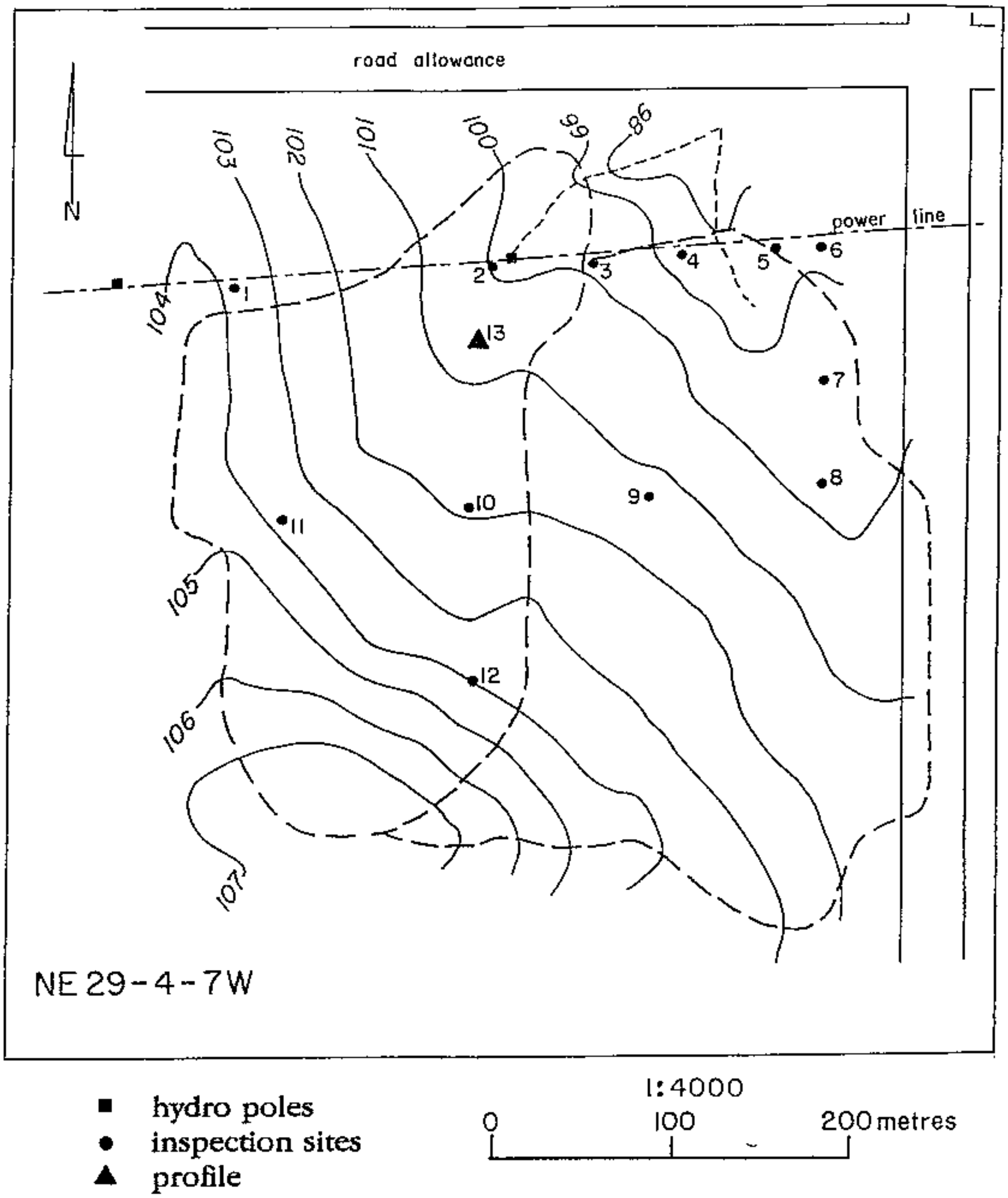


Figure 2. Relative contour map (m) and location of soil characterization sites at the twin Watershed area.

SITE DESCRIPTIONS

The thickness of the Ah horizon is dependent on the slope position and calcium carbonate content (the proportion of the limestone and shale components of the parent material),(Michalyna, 1992). The Ah varies from 8 to 10 cm in the crest positions that have shallower depth to carbonate, and 12 to 40 cm where the shale component is greater and carbonate content lower (Appendix I, Table 5).

The solum (the A and B horizon) thickness is shallower in soils on the crest and upper slopes or in local areas with more calcareous parent material. Where the shale component of the parent material was greater and the limestone component lower, the thickness of solum was greater, depth to carbonates was greater, and the texture of the Bt horizon was clay. The soil texture of the Ah horizon was clay loam at all sites (Michalyna, 1992; Appendix I, Table 5).

Analytical information is presented for: a soil profile (Table 1), a number of surface horizons (as shown in Fig.3) from the east and west Twin Watersheds (Tables 2 and 3), and nitric/ peroxide digestible elements from site W-03 (Table 4).

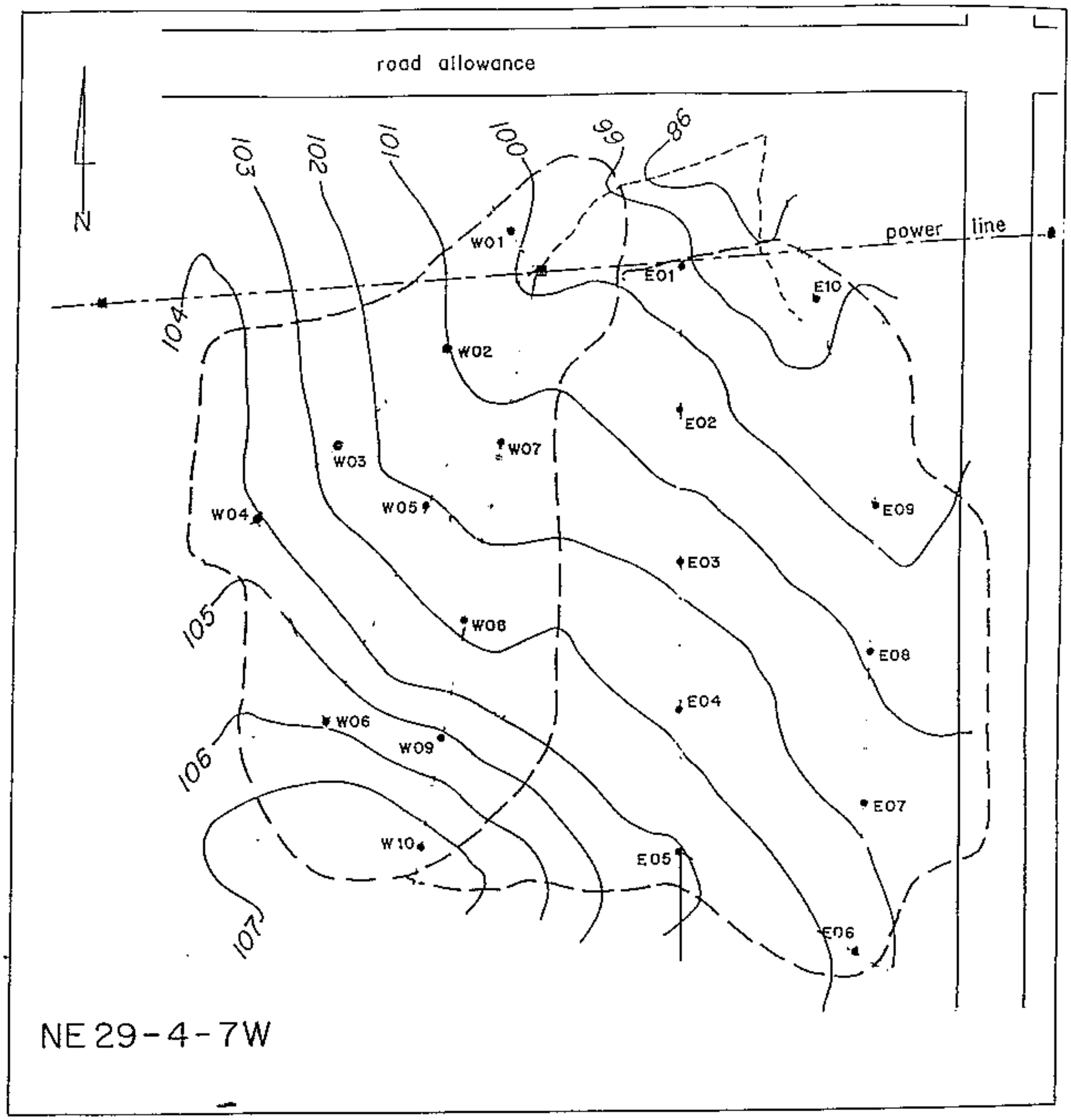


Figure 3. Location of soil nutrient sampling sites at the west and east Twin Watershed areas.

Table 1. Profile analysis of a Dezwood series from the Twin Watershed study area.

Horizon	Depth	Sand %	Silt %	Clay %	Cond. dS/m	pH	Org.C %	CaCO3 %
Ap	0-12	28	36	36	0.66	6.13	2.65	-
Btj	12-40	26	34	40	0.25	6.88	0.65	-
BC	40-50	30	34	36	0.19	7.01	0.53	tr
Ck	50-80	28	37	35	0.19	7.69	0.55	17.5

Table 2. Analysis of the surface A (Ap) horizon at selected sites within the west and east portion of the Twin Watershed study area.

Site	Particle Size %S	%Si	%C	Text.	O.M. %	N %	NO_3-N ug/g	PO_4-P ug/g	K ug/g	pH	Cond. dS/m	Sat. %	SAR
W-01							39.0	7	274	7.7	0.61	51	<0.1
W-02	25.8	40.6	33.6	CL	4.6	0.27	29.0	7	267	7.9	0.48		
W-03							47.0	15	380	7.4	0.84	53	<0.1
W-04							16.0	17	374	8.0	0.25		
W-05	25.8	39.6	34.6	CL	4.4	0.26	29.0	11	311	7.9	0.30		
W-06							29.0	17	504	8.0	0.43		
W-07					4.4	0.25	19.0	15	256	7.7	0.31		
W-08					5.5	0.28	29.0	15	273	7.6	0.46		
W-09	28.8	35.6	35.6	CL	3.0	0.18	10.0	17	331	8.0	0.22		
W-10							29.0	16	336	8.3	0.64	46	<0.1
E-01							17.0	16	256	8.2	0.38		
E-02							18.0	18	274	8.0	0.24		
E-03	24.8	40.6	34.6	CL	4.7	0.28	37.0	21	498	7.9	0.53	51	0.1
E-04					4.5	0.27	44.0	21	453	8.0	0.60	53	<0.1
E-05							16.0	19	336	8.1	0.27		
E-06						0.29	10.0	22	377	8.0	0.22		
E-07	26.8	39.6	33.6	CL	4.9	0.29	21.0	30	407	8.0	0.25		
E-08							35.0	26	567	8.1	0.34		
E-09	22.8	43.6	33.6	CL	5.6	0.32	31.0	14	421	8.1	0.37		
E-10					3.9	0.22	47.0	15	380	8.2	0.70	53	<0.1

Table 3. Soluble ion analysis of the surface A (Ap) horizons from selected sites within the Twin Watershed study area.

Ions	EXTR	Unit	Sites W-03	Sites E-04
Ca	1	me/l	6.38	4.93
Mg	1	me/l	2.07	1.32
K	1	me/l	0.29	0.56
Na	1	me/l	0.11	0.07
SO_4-S	1	me/l	0.64	0.57
Cl	1	me/l	0.12	0.11
HCO_3	1	me/l	4.35	2.5
F	1	ug/g	0.20	
B	2	ug/g	0.15	

1. Saturated soil paste -MSS 3.21
2. Hot water extraction/ICP -MSS 4.6

Table 4. Element analysis (ug/g) from the Twin Watershed study in comparison with published soil and shale bedrock element analysis of the general area.

Element	W-03	DGF	Odanah	Millwood	Pembina
Al	9430	67940	45500	74300	68370
Ba	175				
Be	0.4				
Ca	5750	20590	4260	8660	6250
Cd	1.5				
Co	9				
Cr	19.4				
Cu	15.5				
Fe	15800	25060	16630	31430	38000
K	2240	14030	12280	18920	27800
Mg	2970	10500	5760	18120	15420
Mn	1840	2460		6620	
Mo	<2				
Na	96	6060	2150	10060	8730
Ni	28				
P	471	1070	45		
Pb	14				
S				2400	1240
Th	<10				
V	50.3				
Zn	75.4				

Methods used for above analysis

	W-03	ICP Metals, EPA 3050 (Nitric acid/Peroxide Digestion)
Reference	DGF	Darlingford soil (Ah). Ehrlich et al. 1955.
	Odanah	Bannatyne, 1970.
	Millwood	Bannatyne, 1970.
	Pembina	Bannatyne, 1970.

The ICP Metals, EPA 3050 was used for analysis of 23 elements. They were digested with nitric acid/hydrogen peroxide. Analysis was performed by the inductively coupled argon plasma spectrometry on a JY 50 ICP simultaneous spectrometer, following the U.S. E.P.A. Method 6010. This method is used by the US Environmental Agency and is a suitable procedure for preparing a digest of some soil and sediment samples for the ICP scan. It is common for environmental considerations and provides analytical results which are somewhat lower than the conventional perchloric acid digestion, Xray fluorescence and neutron diffraction which are recognized methods for total recoveries.

DATA REQUIREMENTS AND PROCEDURES FOR EVALUATING SOIL AND WATER QUALITY

The characterization baseline data about a site or geographic area and setting is important for several reasons:

1. -to gain knowledge on the characteristics of the landscape, chemical and physical properties of the soil, and the nutrient status of the soil at some initial reference period.
2. -to measure and interpret the changes that may result from the impact of climatic events or land management practises.
3. -to facilitate the development of algorithms or predictive models for environmental quality assessments, and
4. -to facilitate the comparison or technological transfer of data to other geographic settings and environments.

Interpretation on risk of surface runoff, sediment loss and nutrient transfer during climatic events is provided by the application of the Universal Soil Loss Equation (USLE).

Sediment Loss

Since 1930, research studies under controlled conditions in the United States, on experimental plots and small watersheds, have supplied valuable information on the relation of the climatic, soil, landscape, and management factors that affect the loss of soil and water from land surfaces during rainfall events. Analyses of the data has resulted in improved soil loss predictions commonly referred as the USLE; it is described as follows:

$$A = RKLSCP$$

where:

- A = soil loss in tons per acre (tonnes per hectare)
- R = rainfall factor, a rainfall erosion index units in a normal year's rain, based on the sum of individual storm erosivity values for qualifying storms, expressed as hundreds of foot-tonf*•inch per acre•hour•year (megajoule•millimetre per hectare hour•year)
- K = soil erodibility factor, a relative soil loss rate determined experimentally based on standard plots, expressed as ton•acre•hour per hundreds of acre foot-tonf*• inch (tonne• hectare• hour per hectare megajoule•millimetre)
- LS = slope-length (L) and steepness (S) factor, a dimensionless ratio of soil loss from a given slope to that from a unit plot with all factors equal.
- C = cropping management factor, a ratio of the soil loss from an area with specified cover and management to that from an identical area in tilled continuous fallow.
- P = erosion control practise factor, a ratio of soil

loss with contouring, strip cropping or terracing to that with straight row farming up-and-down the slope.

* tonf represents a ton force; ton represents a ton mass

Application of the USLE to the conditions in the Twin Watershed study requires data about a number of climatic, soil and management conditions. These are derived from published references or adapted from the data in the report.

R = 50 - annual erosivity, this number is generally considered as 50 for this geographic area. A specific value may be computed for specific storm events; these are commonly referred to as Energy Intensity (EI) levels. (The total energy for a storm, and the storm's maximum 30-minute rainfall intensity). (for metric, multiply by 17.02)

K = 0.18 -the soil erodibility factor can be derived using a nomograph based on the following information from the Darlingford soils: VFS 10%; SI 36%; C 36%; S 18% (size 0.10 to 2.0 mm); OM 4.6% (maximum for the chart is 4); structure is fine to medium granular -numeric 3; permeability is moderate -numeric 3. An alternate method is to use the formula (Wischmeier and Smith, 1978) which is:

$$100\ K_{US} = 2.1M^{1.14}(10^{-4})(12-a) + 3.25(b-2) + 2.5(c-3)$$

where M is (VFS+SI) X (100-C)

a is percent OM (to a max. of 4.0%)

b is structure value

c is permeability value

(for metric, multiply K_{US} by 0.1317)

LS =0.80 -for the west watershed, a slope length of 600 feet and a slope of 4% were estimated; using the LS chart, the value of 0.80 was obtained.

C =1.0 -commonly used for management using bare fallow

=0.19 -crop management was considered as continuous spring grain, fall chisel and spring tillage; value obtained from the chart.

P = 1.0 -no special erosion control practices were used, however, only a portion of the study area could be considered cultivated in an up-and-down slope pattern; this factor could range from 0.6 to 1.0 depending on the special practices adopted to decrease rain impact and runoff.

Based on the values above, the amount of annual erosion was estimated at : A = 50 X 0.18 X 0.80 X 1.0 X 1.0

= 7.2 ton/ac/yr (16.1 t/ha/yr)

or using the alternate farm practice, the amount of annual erosion is estimated at

A = 50 X 0.18 X 0.80 X 0.19

= 1.37 ton/ac/yr (3.06 t/ha/yr)

If data are available on the duration and intensity of rain events, the R factor may be computed for a particular occurrence. Research data has been collected on Wischmeier USLE type plots at a number of sites in Manitoba (Shaykewich et al.1991), and the methodology described.

The east watershed with slightly less sloping land would have a lower estimated annual loss than the west watershed area.

Nutrient Loss

Characterization of the nutrient status of the Twin Watershed area provides a dated reference of the fertility or nutrients in the surface soil layer. This background data could be used to develop predictive models for estimating nutrient losses from various types of landscapes due to rainstorms of differing intensities and duration. Following soil erosional events, researchers would be able to determine the amount of nutrients in soluble form and in sediment; then using the background information, calculate the relative fraction of nutrient losses. The background data also provide a check on the analyzed data in solution and sediment; it should not exceed background levels.

Nutrients in soil may occur in various forms; these may be considered as water soluble, exchangeable, relatively insoluble and part of the soil particulate. The electrical conductance of the soil solution serves as a guide for the amount of soluble constituents; generally in well drained soil this value is very low (<0.5 dS/m). Nitrate-N is one of the most soluble nutrients that could move with soil solution and become part of the runoff water. Other nutrients that could be part of the soluble constituents are sulphate-S, chloride, and some phosphate-P (from fertilizer).

The P extracted as the sodium-bicarbonate method is commonly used as an index of soil-available P (to plants). Sodium bicarbonate acts through a pH and ion effect to remove solution P plus some labile solid phase P compounds such as phosphate adsorbed to free carbonates, slightly soluble calcium phosphate precipitates, and P loosely sorbed to Al and Fe oxide surfaces.

Some potassium may be readily lost to runoff water from decomposing plant material on the soil surface, but most K is part of the soil colloid as an exchangeable cation. Most of the K moves with the sediment, not in solution. Similarly, most other "available" cations are present as part of the exchange complex (colloids of clay or organic matter), and move in suspended sediment during runoff. (Available K reported was determined as the exchangeable and soluble ion).

A very slight amount of organic material may be soluble in runoff water, but most of it is incorporated as coatings or bridging between the soil particles; it is mainly lost as part of the sediment in runoff. Most of the other elements reported are part of the organic matter or soil particulate.

Comparative studies on nutrient losses have been conducted in Minnesota and Manitoba. Burwell et al.1975 (Minnesota), have reported on nutrient transport (N,P and K) in surface water runoff and sediment (from a Barnes loam, similar in properties to the Darlingford-Dezwood soils in Manitoba); most of the annual losses of N,P and K in surface runoff were associated with sediment losses which occurred during the critical erosion period (the 2 month period following seeding of a crop). Soil erosion from events during the 1966-1971 period exceeded the desired upper limit (11.2 t/ha) for the fallow and continuous corn treatments. Losses of soluble N,P and K were much less than the losses of these nutrients transported in the sediment; total N and total P losses in the dissolved fraction are relatively insignificant (4%) as compared to the sediment fraction. Average annual losses of N transported in runoff by water and sediment ranged from 4.1 kg/ha for the hay treatments to 150 kg/ha for the fallow treatment. Average loss of total P ranged from 0.68 kg/ha for the hay treatment to 33 kg/ha for the fallow treatment. Average annual K losses in runoff ranged from 1.90 kg/ha for rotation corn to 8.4 kg/ha for the fallow treatment.

In Manitoba, Hargrave and Shaykewich (1991) reported on nitrogen and phosphorus losses in runoff sediment from standard Wischmeier plots for the period 1988 to 1990. The nutrient loss was related to the energy-intensity levels (EI) of the storms. Total N and P losses in 1988 and 1989 were considered low due to low (EI<100) and moderately erosive (EI= 100 to 400) storms combined with relatively dry soil condition which absorbed a considerable amount of the initial rainfall. However, in 1990, storms were more frequent and more intense. A few examples of nutrient loss in relation to storm intensity are provided for the Gretna clay (located south of Miami), for May 31, 1990, on which EI was 950. Total N losses were 42, 160 and 245 kg/ha on the wheat, fallow and corn treatments, respectively. Total P losses were 19, 54 and 98 kg/ha on the wheat, fallow and corn treatments, respectively. Total N annual loss for 1990 reported were 2.4, 245, 448 and 471 kg/ha for the alfalfa, wheat, corn and fallow treatments, respectively. Total P annual loss for 1990 reported were 0.8, 87, 184,and 187 kg/ha for the alfalfa, wheat, fallow and corn treatments, respectively.

Nutrient losses are mainly associated with major storm events. During the three year period 1988 to 1990, total N losses on the Gretna clay were much lower in 1988 and 1989 than in 1990; two events on June 1 (EI=950) and June 11 (EI=280) accounted for 68 to 75% of the total N losses from the entire three years.

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Table 5. Soil Properties at Twin Watershed Sites.

SITE No.	SOIL_CODE	THICKNESS Ah	THICKNESS Solum	DEPTH_TO $CaCO_3$	SOIL_TEXTURE Ah	SOIL_TEXTURE (Bm)Bt	THICKNESS (Bm)Bt	THICKNESS BC
1	DZW/xcxx	12	65	65	CL	C	38	15
2	DZW/xcxx	25	75	65	CL	C	35	15
3	DZW/xcxx	12	35	30	CL	C	16	7
4	DZW/xcxx	8	60	55	CL	C	42	10
5	DZW/1cxx	8	23	18	CL	C	10	5
6	DZW/1cxx	10	13	10	CL	(CL)	(3)	-
7	DZW/xcxx	12	40	35	CL	SiC	23	5
8	DZW/xcxx	30	60	60	CL	(CL)	30	5
9	DZW/xcxx	15	65	60	CL	C	35	15
10	DZW/xcxx	40	75	70	CL	C	20	15
11	DZW/xcxx	10	35	30	CL	SiC	15	15
12	DZW/xdxx	12	60	60	CL	C	33	15
13	DZW/xcxx	12	50	50	CL	C	28	10

SOIL DESCRIPTION -Dezwood Series (DZW)

The Dezwood series is the well to moderately well drained Orthic Dark Gray soil developed on moderately to strongly calcareous, deep loamy (L,CL,SiCL), mixed deposits of shale, limestone and granitic origin. These soils occur on extensive areas above the Manitoba Escarpment (Pembina Hills) on mid to upper slopes of undulating, hummocky and inclined morainal landscapes. The soils have moderate permeability and moderate surface runoff. They are generally slightly stony, and may be slightly eroded in the crest and upper slope positions. Native vegetation often includes tall prairie grasses interspersed with aspen-poplar groves. The majority of these soils are currently used for grain production.

The solum is approximately 40 cm thick. It has a dark grayish brown A (Ap or Ah) horizon, 15 to 20 cm thick; occasionally a thin light gray Ae horizon, 2 to 4 cm thick; a pale brown Bt (or Btj) horizon 20 to 40 cm thick. A light gray Cca horizon 20 to 40 cm thick may be present. The parent material is typically a light gray mixed till with few coarse fragments. In cultivated areas, part of the B may have been incorporated into the Ap plow layer.

At the Twin Watershed area, the soils are dominantly the Dezwood series with local areas of slightly eroded conditions on some crest positions. The solum depth varied from 25 to 75 cm, with an Ap horizon of 8 to 15 cm, an Ah of 0 to 25 cm thick, a Bt (clay) 10 to 42 cm thick, and a BC of 5 to 15 cm thick. At two sites (Fig 2, no.5 and 6), the solum depth was less than 25 cm; the parent material contained an appreciable amount of carbonates and coarse fragments.

Detailed soil description

Ap 0 to 12 cm; dark gray (10YR 4.0/1.0 d; 10YR 2.0/1.0 m); clay loam; moderate, fine to medium, granular; sticky when wet, friable when moist, slightly hard when dry, slightly plastic; moderately porous; neutral; abrupt, smooth boundary

Bt 12 to 40 cm; brown to dark brown (10YR 4.0/3.0 inped moist) clay; common, thin, very dark grayish brown clay films on peds (10YR 3.0/2.0m); moderate, fine to medium subangular blocky; sticky when wet, friable when moist, slightly hard when dry, plastic; neutral; clear, smooth boundary

BC 40 to 50 cm; dark grayish brown (10YR 4.0/2.0 m); clay loam; weak to moderate, fine to medium subangular blocky; sticky when wet, friable when moist, slightly hard when dry, slightly plastic; moderately porous; mildly alkaline; non to weak effervescence; clear, smooth boundary

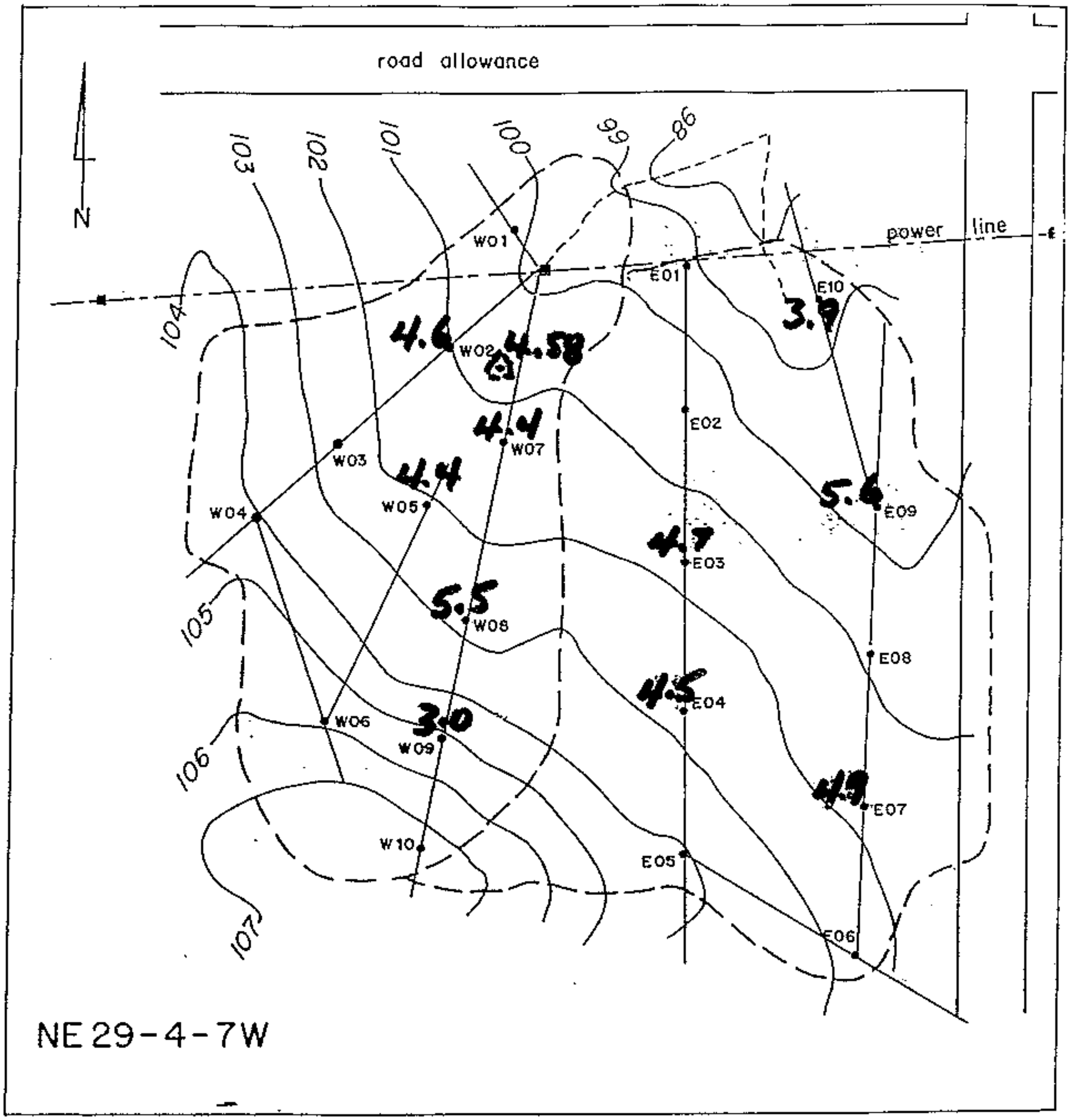
Ck 50 to 80 cm; light yellowish brown to pale brown (10YR 6.0/3.5 m); clay loam; weak, fine subangular blocky; sticky when wet, friable when moist, slightly hard when dry, slightly plastic; moderately porous; moderately alkaline; strongly calcareous

Table 6. A comparison of the soil of the Twin Creeks Watershed by the Canadian System and the US Soil Taxonomy.

	SOIL CLASSIFICATION		
	CANADIAN TAXA	SOIL TAXONOMY	(N.DAKOTA equivalent)
ORDER	CHERNOZEMIC	MOLLISOLS	
SUBORDER		BOROLLS	BOROLLS
GREAT GROUP	DARK GRAY (BLACK)	CRYOBOROLLS	ARGIBOROLLS HAPLOBOROLLS
SUBGROUP	ORTHIC DARK GRAY	ARGI CRYOBOROLLS	UDIC ARGIBOROLLS
	(ORTHIC BLACK)	TYPIC CRYOBOROLLS	UDIC PACHIC HAPLOBOROLLS
FAMILY	MOD.CALC;F-LOAMY; MIXED MINERALOGY	F-LOAMY, MIXED	
SERIES	DEZWOOD (DARLINGFORD)		BOTTINEAU (SVEA)
PAR.MATERIAL	TILL (Lm,Gr,Sh)		TILL
SOIL TEMP.	MOD.COOL BOREAL	CRYIC	FRIGID
MAST	5.4- 6.1 °C	< 8°C	< 8°C
MSST	11.0-13.2 °C	<15°C	>15°C

APPENDIX II

SAMPLE LOCATIONS AND ANALYTICAL DATA FOR THE WATERSHED



△ profile site

Figure 4. Organic matter(%) of Ap horizon.

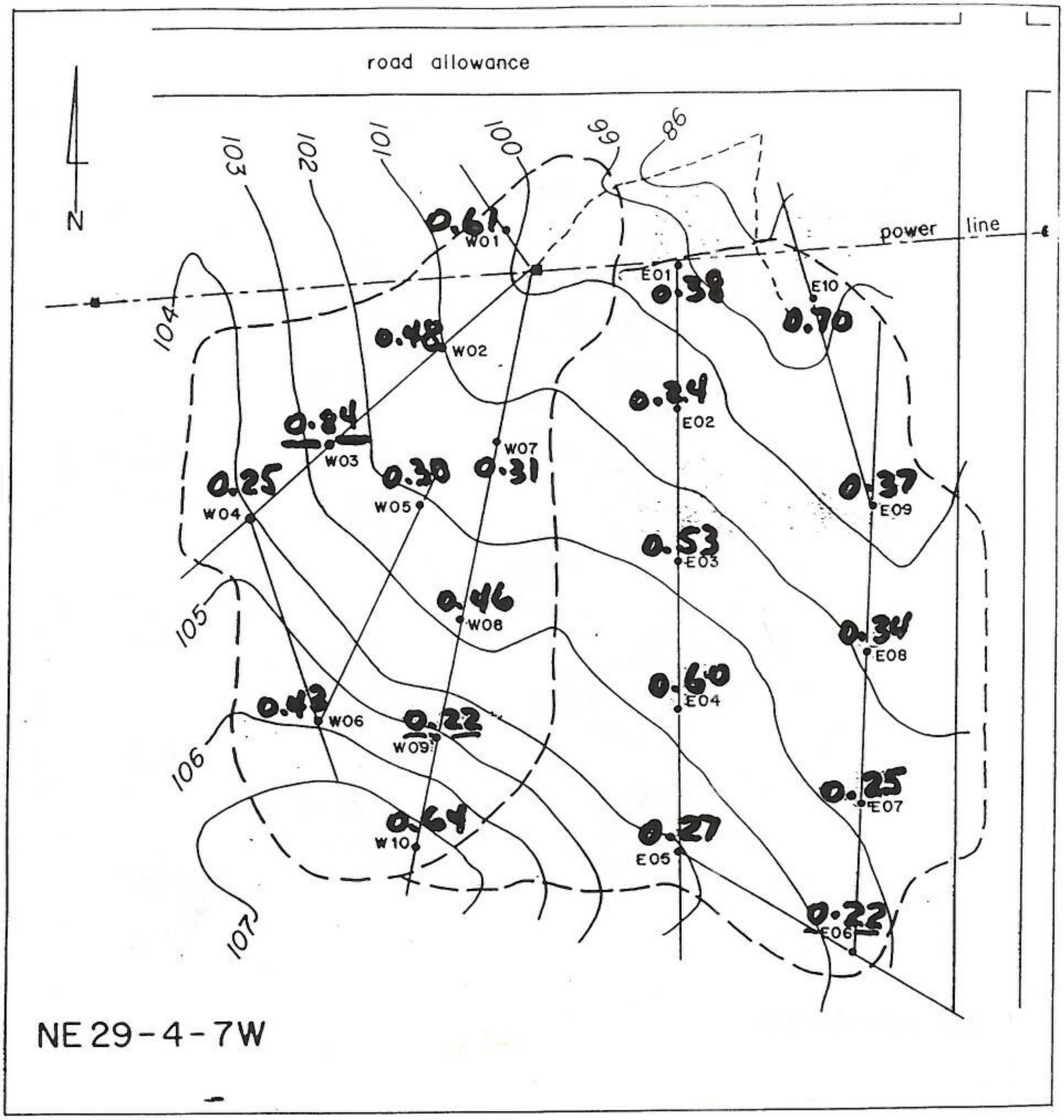
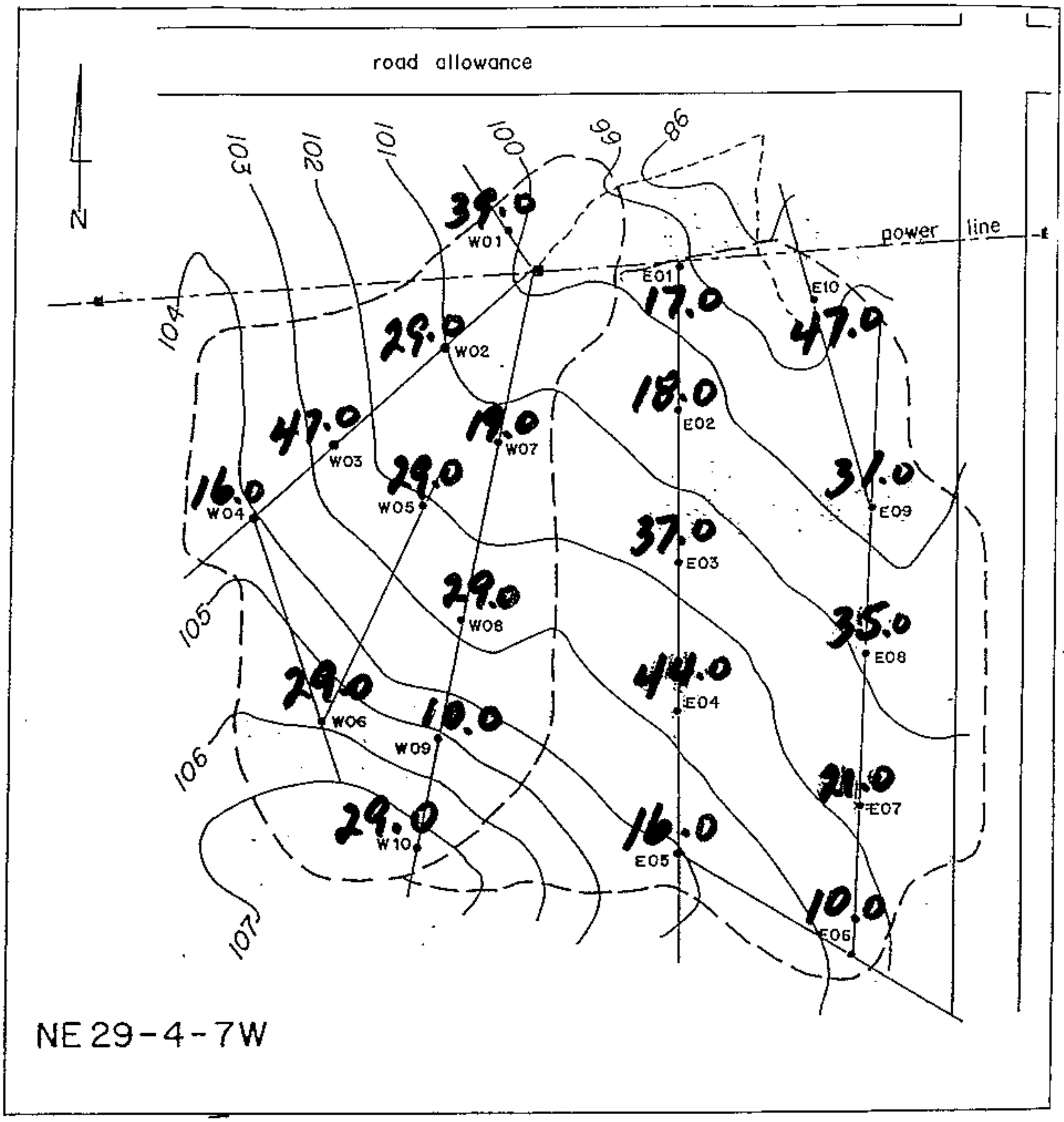
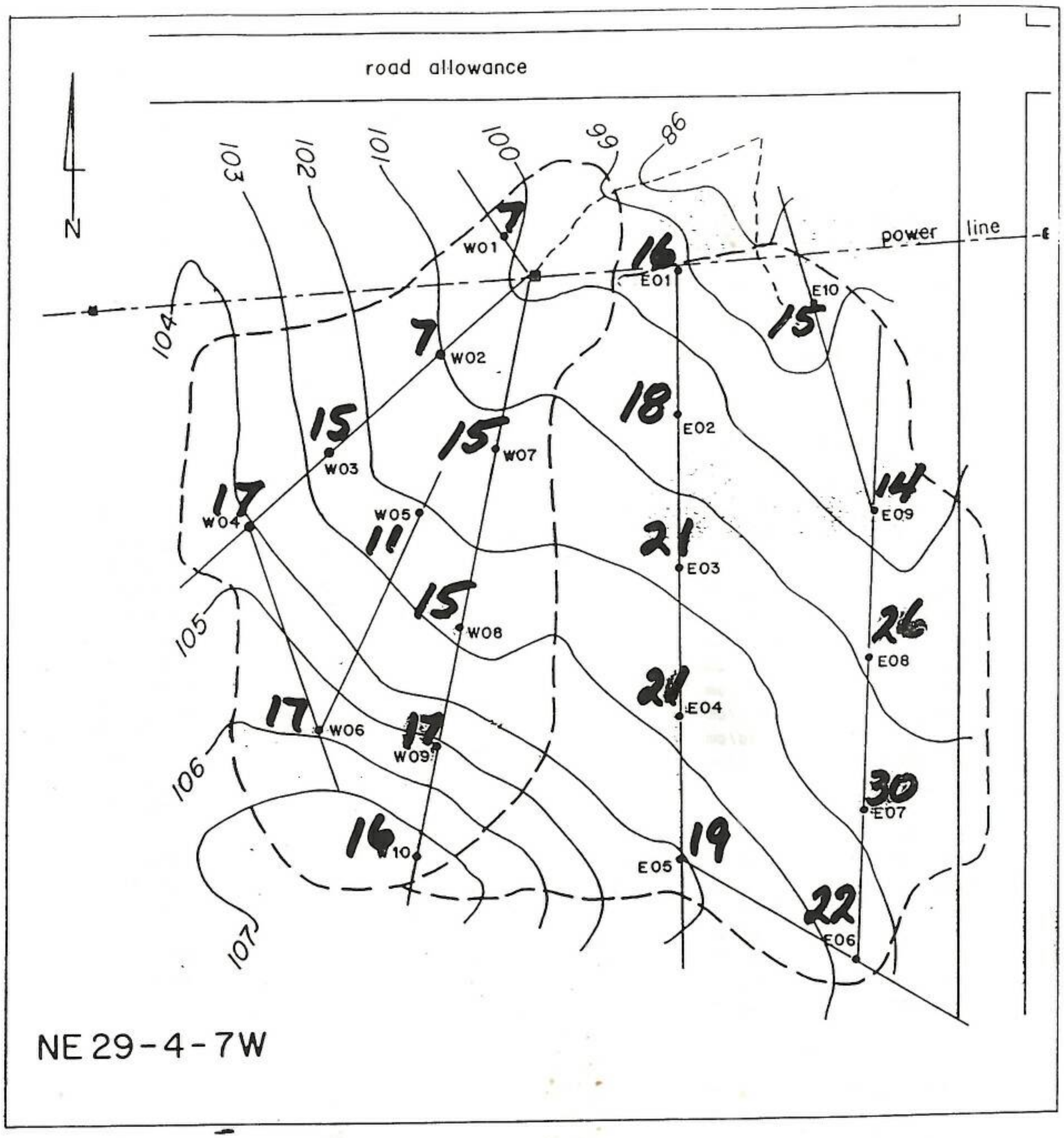


Figure 5. Electrical conductivity (dS/m) of Ap horizon.



Sampled: Apr.20/93
Figure 6. Nitrate-N (ug/g) of Ap horizon.



Sampled: Apr.20/93

Figure 7. Phosphate-P (ug/g) of Ap horizon.

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Wallie Michalyna
Twin Watershed
20-04-93

Preliminary

SAMPLE		65 W1	66 W2	67 W3	68 W4
2 PT HYDROMETER					
SAND	%		25.8		
SILT	%		40.6		
CLAY	%		33.6		
PARTICLE SIZE AN			C.LOAM		
ORGANIC MATTER					
ORGANIC MATTER	%		4.6		
NITROGEN	%		0.27		
ICP METALS,3050					
ALUMINUM	ug/gm			ws301480	
BARIUM	ug/gm			ws301480	
BERYLLIUM	ug/gm			ws301480	
CADMIUM	ug/gm			ws301480	
CALCIUM	ug/gm			ws301480	
CHROMIUM	ug/gm			ws301480	
COPPER	ug/gm			ws301480	
IRON	ug/gm			ws301480	
LEAD	ug/gm			ws301480	
MAGNESIUM	ug/gm			ws301480	
MANGANESE	ug/gm			ws301480	
MOLYBDENUM	ug/gm			ws301480	
NICKEL	ug/gm			ws301480	
PHOSPHORUS	ug/gm			ws301480	
POTASSIUM	ug/gm			ws301480	
SODIUM	ug/gm			ws301480	
VANADIUM	ug/gm			ws301480	
ZINC	ug/gm			ws301480	
COBALT	ug/gm			ws301480	
THALLIUM	ug/gm			ws301480	
PG FERTILITY MJR					
NITRATE -N	ug/gm	39.0	29.0	47.0	16.0
PHOSPHATE -P	ug/gm	7	7	15	17
POTASSIUM	ug/gm	274	267	380	374

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SAMPLE		65 W1	66 W2	67 W3	68 W4
MINOR NUTRIENTS					
BORON	ug/gm			0.15	
PG SOIL SALINITY					
pH		7.7	7.9	7.4	8.0
ELECTRICAL COND	dS/m	0.61	0.48	0.84	0.25
SATURATION %	%	51		53	
SOD. ADS. RATIO		<0.1		<0.1	
SOLUBLE SALTS					
CALCIUM	meq/L	5.11		6.38	
CALCIUM	mg/kg	52.4		68.2	
MAGNESIUM	meq/L	1.63		2.07	
MAGNESIUM	mg/kg	10.1		13.4	
SODIUM	meq/L	0.11		0.11	
SODIUM	mg/kg	1.3		1.4	
POTASSIUM	meq/L	0.29		0.72	
POTASSIUM	mg/kg	5.82		15.0	
SULPHATE-S	meq/L	0.41		0.64	
SULPHATE-S	mg/kg	3.3		5.5	
CHLORIDE	meq/L	0.11		0.12	
CHLORIDE	mg/kg	2.1		2.2	
BICARBONATE	meq/L	4.50		4.35	
FLUORIDE	ug/gm			0.20	

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SAMPLE		1 W3-GEN 67
ICP METALS,3050		
ALUMINUM	ug/gm	9430
BARIUM	ug/gm	175
BERYLLIUM	ug/gm	0.4
CADMIUM	ug/gm	1.5
CALCIUM	ug/gm	5750
CHROMIUM	ug/gm	19.4
COPPER	ug/gm	15.5
IRON	ug/gm	15800
LEAD	ug/gm	14
MAGNESIUM	ug/gm	2970
MANGANESE	ug/gm	1840
MOLYBDENUM	ug/gm	<2
NICKEL	ug/gm	28
PHOSPHORUS	ug/gm	471
POTASSIUM	ug/gm	2240
SODIUM	ug/gm	96
VANADIUM	ug/gm	50.3
ZINC	ug/gm	75.4
COBALT	ug/gm	9
THALLIUM	ug/gm	<10

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SAMPLE		69 W5	70 W6	71 W7	72 W8
2 PT HYDROMETER					
SAND	%	25.8			
SILT	%	39.6			
CLAY	%	34.6			
PARTICLE SIZE AN		C.LOAM			
ORGANIC MATTER					
ORGANIC MATTER	%	4.4		4.4	5.5
NITROGEN	%	0.26		0.25	0.28
PG FERTILITY MJR					
NITRATE -N	ug/gm	29.0	29.0	19.0	29.0
PHOSPHATE-P	ug/gm	11	17	15	15
POTASSIUM	ug/gm	311	504	256	273
PG SOIL SALINITY					
pH		7.9	8.0	7.7	7.6
ELECTRICAL COND	dS/m	0.30	0.43	0.31	0.46

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SAMPLE		73 W9	74 W10	75 E1	76 E2
2 PT HYDROMETER					
SAND	%	28.8			
SILT	%	35.6			
CLAY	%	35.6			
PARTICLE SIZE AN		C.LOAM			
ORGANIC MATTER					
ORGANIC MATTER	%	3.0			
NITROGEN	%	0.18			
PG FERTILITY MJR					
NITRATE -N	ug/gm	10.0	29.0	17.0	18.0
PHOSPHATE-P	ug/gm	17	16	16	18
POTASSIUM	ug/gm	331	336	256	274
PG SOIL SALINITY					
pH		8.0	8.3	8.2	8.0
ELECTRICAL COND	dS/m	0.22	0.64	0.38	0.24
SATURATION %	%		46		
SOD. ADS. RATIO			<0.1		
SOLUBLE SALTS					
CALCIUM	meq/L -sat. ext.		5.72		
CALCIUM	mg/kg-soil		52.9		
MAGNESIUM	meq/L		1.63		
MAGNESIUM	mg/kg		9.1		
SODIUM	meq/L		0.07		
SODIUM	mg/kg		0.7		
POTASSIUM	meq/L		0.44		
POTASSIUM	mg/kg		7.85		
SULPHATE-S	meq/L		0.47		
SULPHATE-S	mg/kg		3.5		
CHLORIDE	meq/L		0.14		
CHLORIDE	mg/kg		2.4		
BICARBONATE	meq/L		4.50		

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SAMPLE		77 E3	78 E4	79 E5	80 E6
2 PT HYDROMETER					
SAND	%	24.8			
SILT	%	40.6			
CLAY	%	34.6			
PARTICLE SIZE AN		C.LOAM			
ORGANIC MATTER					
ORGANIC MATTER	%	4.7	4.5		
NITROGEN	%	0.28	0.27		
PG FERTILITY MJR					
NITRATE-N	ug/gm	37.0	44.0	16.0	10.0
PHOSPHATE-P	ug/gm	21	21	19	22
POTASSIUM	ug/gm	498	453	336	377
PG SOIL SALINITY					
pH		7.9	8.0	8.1	8.0
ELECTRICAL COND	dS/m	0.53	0.60	0.27	0.22
SATURATION %	%	51	53		
SOD. ADS. RATIO		0.1	<0.1		
SOLUBLE SALTS					
CALCIUM	meq/L SAT. EXT	4.01	4.93		
CALCIUM	mg/kg SOIL	40.8	52.7		
MAGNESIUM	meq/L	1.19	1.32		
MAGNESIUM	mg/kg	7.3	8.5		
SODIUM	meq/L	0.21	0.07		
SODIUM	mg/kg	2.5	0.8		
POTASSIUM	meq/L	0.63	0.56		
POTASSIUM	mg/kg	12.4	11.8		
SULPHATE-S	meq/L	0.40	0.57		
SULPHATE-S	mg/kg	3.3	4.9		
CHLORIDE	meq/L	0.11	0.11		
CHLORIDE	mg/kg	2.0	2.1		
BICARBONATE	meq/L	2.00	2.50		

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SAMPLE		81 E7	82 E8	83 E9	84 E10
2 PT HYDROMETER					
SAND	%	26.8		22.8	
SILT	%	39.6		43.6	
CLAY	%	33.6		33.6	
PARTICLE SIZE AN		C.LOAM		C.LOAM	
ORGANIC MATTER					
ORGANIC MATTER	%	4.9		5.6	3.9
NITROGEN	%	0.29		0.32	0.22
PG FERTILITY MJR					
NITRATE -N	ug/gm	21.0	35.0	31.0	47.0
PHOSPHATE -P	ug/gm	30	26	14	15
POTASSIUM	ug/gm	407	567	421	380
PG SOIL SALINITY					
pH		8.0	8.1	8.1	8.2
ELECTRICAL COND	dS/m	0.25	0.34	0.37	0.70
SATURATION %	%				53
SOD. ADS. RATIO					<0.1
SOLUBLE SALTS					
CALCIUM	meq/L sat. ext				5.70
CALCIUM	mg/kg soil				60.7
MAGNESIUM	meq/L				2.15
MAGNESIUM	mg/kg				13.8
SODIUM	meq/L				0.20
SODIUM	mg/kg				2.4
POTASSIUM	meq/L				0.50
POTASSIUM	mg/kg				10.5
SULPHATE-S	meq/L				0.78
SULPHATE-S	mg/kg				6.6
CHLORIDE	meq/L				0.29
CHLORIDE	mg/kg				5.5
BICARBONATE	meq/L				4.50

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The following published METHODS OF ANALYSIS were used:

EPA6010 ALUMINUM
ICP Spectroscopy. Ref. EPA 6010 (SW-846)
EPA6010 BARIUM
ICP Spectroscopy. Ref. EPA 6010 (SW-846)
EPA6010 BERYLLIUM
ICP Spectroscopy. Ref. EPA 6010 (SW-846)
EPA6010 CADMIUM
ICP Spectroscopy. Ref. EPA 6010 (SW-846)
EPA6010 CALCIUM
ICP Spectroscopy. Ref. EPA 6010 (SW-846)
EPA6010 CHROMIUM
ICP Spectroscopy. Ref. EPA 6010 (SW-846)
EPA6010 COPPER
ICP Spectroscopy. Ref. EPA 6010 (SW-846)
EPA6010 IRON
ICP Spectroscopy. Ref. EPA 6010 (SW-846)
EPA6010 LEAD
ICP Spectroscopy. Ref. EPA 6010 (SW-846)
EPA6010 MAGNESIUM
ICP Spectroscopy. Ref. EPA 6010 (SW-846)
EPA6010 MANGANESE
ICP Spectroscopy. Ref. EPA 6010 (SW-846)
EPA6010 MOLYBDENUM
ICP Spectroscopy. Ref. EPA 6010 (SW-846)
EPA6010 NICKEL
ICP Spectroscopy. Ref. EPA 6010 (SW-846)
EPA6010 PHOSPHORUS
ICP Spectroscopy. Ref. EPA 6010 (SW-846)
EPA6010 POTASSIUM
ICP Spectroscopy. Ref. EPA 6010 (SW-846)
EPA6010 SODIUM
ICP Spectroscopy. Ref. EPA 6010 (SW-846)
EPA6010 VANADIUM
ICP Spectroscopy. Ref. EPA 6010 (SW-846)
EPA6010 ZINC
ICP Spectroscopy. Ref. EPA 6010 (SW-846)
EPA6010 COBALT
ICP Spectroscopy. Ref. EPA 6010 (SW-846)
EPA6010 THALLIUM
ICP Spectroscopy. Ref. EPA 6010 (SW-846)
EPA 3050 EPA DIGEST 3050
Acid digestion of sediments, soils,and sludges using nitric acid/hydrogen peroxide. Reported on dry weight(mg/kg). Ref. EPA 3050 (SW-846)
MSS4.311 NITRATE
MSS 4.6 BORON
MSS 3.21 SATURATED PASTE
MSS 3.14 pH
MSS 3.26 SOD. ADS. RATIO
MSS 3.26 CALCIUM
MSS 3.26 MAGNESIUM
MSS 3.26 SODIUM

Method References:

1. APHA Standard Methods for the Examination of Water and Wastewater, American Public Health Assoc., 17th ed.
2. EPA a. Test Methods for Evaluating Solid Waste, Physical/Chemical Methods SW-846, 3rd ed., US EPA, 1986
   b. Methods for Chemical Analysis of Water and Wastewater, US EPA, 1983
3. MSS Manual on Soil Sampling and Methods of Analysis, Cdn. Soc. of Soil Science, J. A. McKeague, 2nd ed. /1978

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