Metals

in

Pennsylvania Soils

by

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Contents

INTRODUCTION

The content of metals in soils has been studied for many years. The objective of early studies was to characterize and investigate the genesis of soils. Recent interest in metals in soils revolves around the ability of soils to supply certain elements to plants and the potential toxic effect of these elements on humans and animals (Risser and Baker, 1990). In addition, many of these elements are pollutants that have or could be added to soils in the form of sewage sludge or other materials. Baseline data on the naturally-occurring levels of metals in soils is needed to provide a better understanding of the interactions of these metals in soils. In Pennsylvania, this type of baseline data is not available. Because of this shortcoming, a study was initiated to characterize the metal content of an array of Pennsylvania soils developed from a number of parent materials.

MATERIALS AND METHODS

Two hundred and ten (210) samples representing 67 soil profiles were selected from the Penn State University Soil Characterization Laboratory library of soil samples (Ciolkosz and Thurman, 1993). These samples were collected and analyzed for basic soil characteristics and properties over a number of years as a part of an inventory of Pennsylvania's soil resources. A surface horizon (A) and two or three subsoil horizons (B or C) were selected from each profile (Table 1).

The U.S. EPA Acid Digestion of Sediments, Sludges, and Soils Method 3050 was used to analyze the soils (USEPA, 1986). The Pennsylvania Department of Environment Resources recommends this method for sludge and soil analysis in their Municipal Waste Management program (PADER, 1988). Additional information on sludges is given in NERRP (1985). With this method, the fine earth (< 2 mm) soil sample material is digested in nitric acid, hydrogen peroxide, and hydrochloric acid, and the extract is analyzed by atomic absorption

spectroscopy.

The following elements were analyzed according to Method 3050: Aluminum (Al), Cadmium (Cd), Calcium (Ca), Chromium (Cr), Copper (Cu), Iron (Fe), Lead (Pb), Magnesium (Mg), Manganese (Mn), Nickel (Ni), Potassium (K), Sodium (Na), Zinc (Zn). Total Phosphorous (P) was determined on the sample extracts using the vanadomolybate method of Olsen and Sommers (1982). Additional soil characterization data obtained as a part of the Pennsylvania State University Soil Characterization program (Ciolkosz and Thurman, 1993; Thurman et al., 1992) includes pH (1:1 soil to water); percentages of sand, silt, and clay (pipette method); and percent Fe_2O_3 (Citrate-Bicarbonate-Dithionite, CBD, method). Many of these samples have also been used in a study on the amorphous material in Pennsylvania soils (Ciolkosz et al., 1989). Additional data on metals in Pennsylvania soils are provided in studies by Ciolkosz et al (1993a, 1993b).

RESULTS AND DISCUSSION

The data for Fe, Al, Mn, Ca, Mg, Na, and K are given in Table 1, and the data for Cu, Zn, Ni, Pb, Cd, Cr, and P are given in Table 2. Table 3 summarizes the median, minimum, and maximum values of each element for the surface and subsurface horizons by parent material origin. This study does not provide a representative sampling of all soils in Pennsylvania and does not lend itself to extrapolating baseline data in all cases. For instance, while baseline estimates of elemental extractions for soils forming from limestone residuum may be possible, such estimates may not be reliable for soils forming in other parent materials which have fewer samples.

Most of the values for the extracted elements do not follow a normal distribution (Table 3). The data are predominantly skewed toward the low end of the range, with a few high values. This is especially true in the subsurface horizons. The surface horizons show evidence of additions of many of the elements. Mechanisms for additions probably include application by humans (as in the case of agricultural activities), atmospheric deposition,

biocycling, or a combination of processes. Some general differences in parent materials are evident. Specific trends are noted in the discussion that follows.

An examination of the data shows, with some exceptions, the following trends:

1. Iron (Fe): The nitric acid-hydrogen peroxide-hydrochloric acid method extracts more Fe than the CBD method. The content of extracted Fe is greatest in the subsurface (Bt > Bx > Bw) and least in the surface (A) horizons. The largest quantity of extracted Fe occurs in soils developed from crystalline rock and calcareous shale parent materials. Some limestone-derived soils, particularly those with high clay contents, also had high concentrations. The lowest quantities of extracted Fe occur in soils of glacial till and sandstone parent materials.
2. Aluminum (Al): The extracted Al content is generally high but usually lower than the extracted Fe content. The highest concentrations usually occur in the upper B horizons. The greatest content of extracted Al typically is found in soils derived from crystalline rock and limestone parent materials, and the lowest content usually occurs in sandstone residuum soils.
3. Manganese (Mn): The maximum extracted Mn contents are in the surface (A) horizons; the lowest occur in the the upper B horizons. In some cases, extracted Mn concentrations increase below the B horizon. Poorly drained soils frequently show slightly different trends. The upper B horizons of some limestone and basic crystalline rock soils show high concentrations of Mn. This may be associated with black coatings observed in these soils.
4. Calcium (Ca): The highest contents of extracted Ca occur in soils derived from limestone, red calcareous shale, and basic crystalline parent materials. Soils of acidic parent materials have the lower extracted Ca contents. Surface enrichment of Ca is evident, particularly in the Ap horizons. In soils of calcarous parent materials, the extracted Ca content increases below the B horizon.
5. Magnesium (Mg): The extracted Mg content generally increases with depth in all soils except those forming from crystalline rock parent materials. In these soils, the Mg

content either decreases with depth or reaches a maximum in the upper B horizon. Soils forming in limestone residuum have the greatest extracted Mg content; pre-Wisconsinan till, acid crystalline rock, and sandstone soils have the lowest contents of Mg.

6. Sodium (Na): The greatest concentrations of extracted Na occur in soils derived from basic crystalline rock parent materials. In these soils, the Na content increases with depth. No consistent trend in extracted Na is evident in any of the other soils.
7. Potassium (K): Extracted K content is generally greater in the shale and limestone residuum and colluvial soils and lowest in the crystalline, sandstone, and pre-Wisconsinan till soils. No consistent trend with depth is evident.
8. Phosphorus (P): Total P is typically greatest in the surface (A) horizons and is lowest in the subsurface (generally the Bt horizon).
9. Copper (Cu): The content of extracted Cu generally increases with depth (lowest in the A horizons). Soils forming in basic crystalline rock and red calcareous shale parent materials tend to have the greatest amounts of extracted Cu.
10. Zinc (Zn): Extracted Zn content tends to be greater in soils forming in Wisconsinan till and gray (acid and calcareous) shale parent materials and lower in soils forming in pre-Wisconsinan till, crystalline rock, and sandstone parent materials. No regular trend with depth is evident.
11. Nickel (Ni): The content of extracted Ni generally increases with depth. Soils forming in basic crystalline rock parent materials tend to have the greatest amounts of extracted Ni while soils forming in acid crystalline rock, sandstone, and pre-Wisconsinan till parent materials have the lowest contents.
12. Lead (Pb): The greatest contents of extracted Pb are usually found in the surface horizons (A). Soils forming in limestone and red calcareous shale parent materials generally have greater extracted Pb contents while soils forming in crystalline rock and pre-Wisconsinan till parent materials have lower contents.
13. Cadmium (Cd): The content of extracted Cd tends to be greatest in the surface

horizons (A) and lowest in the B horizons. Soils forming in calcareous parent materials generally have greater extracted Cd contents in the subsurface than soils forming in other parent materials.

14. Chromium (Cr): The B horizons typically have a greater content of extracted Cr than do the A or C horizons. Extracted Cr is generally greater in soils forming in basic crystalline rock parent materials.

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Table 1. Selected soil characterization data and major elements for the soil samples used in this study. Characterization data from Ciolkosz and Thurman (1992).

Soil and Drainage Class	Soil Number	Horizon	Depth in cm	pH	Percent						Parts Per Million					
					Sand	Silt	Clay	Fe_2O_3[1]	Fe_2O_3[2]	Fe	Al	Mn	Ca	Mg	Na	K
							Grayish-Brown Wisconsinan Glacial Till									
Bath	008-011-01	Ap	0-18	5.5	28.2	56.8	15.0	1.5	1.14	0.80	1.55	495	1120	2450	45.7	717
(Well	008-011-03	Bw2	30-43	5.0	36.6	50.3	13.1	1.6	1.86	1.30	1.95	340	257	3275	57.7	1125
drained)	008-011-06	Bx3	69-107	5.0	40.9	45.6	13.5	1.7	2.43	1.70	1.60	585	355	3600	60.8	1700
Bath	008-099-02	A	0-5	4.3	42.3	46.8	10.9	1.2	2.06	1.44	1.04	407	245	1600	44.2	635
(Well	008-099-05	Bw2	36-51	4.4	38.3	47.3	14.4	1.6	2.17	1.52	1.29	337	3	3075	49.2	868
drained)	008-099-09	Bx4	135-180	5.0	22.3	56.4	21.3	2.0	2.93	2.05	1.35	672	667	3925	62.7	1215
	008-099-12	Bx7	285-361	5.2	36.0	48.8	15.2	1.6	3.00	2.10	1.40	697	705	3950	81.7	1600
Volusia	008-014-01	Ap	0-20	6.9	24.4	53.7	21.9	1.6	1.72	1.20	1.60	695	1560	2525	52.0	1200
(Somewhat	008-014-03	E2	28-36	6.7	24.9	53.8	21.3	1.8	2.00	1.40	1.37	225	462	2825	42.0	940
poorly	008-014-06	Bxg3	74-97	5.0	24.5	48.0	27.5	2.1	2.93	2.05	1.68	615	462	3550	63.5	1375
drained)																
Chippewa	008-016-01	Ap	0-15	5.6	11.6	63.4	25.0	2.2	2.60	1.82	1.82	1325	1250	2900	89.7	1100
(Very poorly	008-016-03	Eg	30-43	5.5	14.2	60.7	25.1	2.4	3.69	2.58	2.12	893	660	3325	89.5	1200
drained)	008-016-06	Bxg3	94-130	6.3	20.0	69.2	10.8	1.4	2.57	1.80	1.27	772	1147	3700	67.5	725
							Red Wisconsinan Glacial Till									
Lackawanna	045-080-01	Ap	0-18	5.3	42.3	45.6	12.1	1.4	2.69	1.88	1.24	132	42	1295	35.2	495
(Well	045-080-03	Bw2	36-51	5.7	44.4	43.9	11.7	1.1	3.03	2.12	1.40	322	80	2725	49.7	777
drained)	045-080-05	Bx1	71-109	5.6	51.7	37.6	10.7	1.3	2.53	1.77	0.90	540	70	2400	38.0	520
Morris	058-003-01	Ap	0-18	5.7	34.1	44.9	21.0	1.7	3.15	2.20	2.52	857	1350	3025	92.5	1900
(Somewhat	058-003-03	BA	28-43	6.0	45.9	42.3	11.8	1.2	3.19	2.23	1.60	787	250	3100	60.3	1525
poorly	058-003-07	Bx4	79-117	6.6	41.5	45.2	13.3	1.2	3.55	2.48	1.50	662	840	3600	78.0	2000
drained)																
Norwich	058-021-01	A	0-20	5.0	18.5	36.7	44.8	3.2	4.86	3.40	3.30	2350	2372	2950	76.0	1675
(Poorly	058-021-03	Bwg	25-64	5.2	21.1	47.0	31.9	1.4	3.03	2.12	2.30	280	1623	3075	63.2	1250
drained)	058-021-05	2Bxg2	76-91	5.7	22.5	49.8	27.7	1.7	3.75	2.62	1.24	930	1312	3650	48.2	1212

1 - Fe_2O_3 data from Ciolkosz and Thurman (1992) by the CBD method. 2 - Fe_2O_3 data calculated from the Fe data (Fe x 1.43).

Table 1. Cont. Selected soil characterization data and major elements for the soil samples used in this study. Characterization data from Ciolkosz and Thurman (1992).

Soil and Drainage Class	Soil Number	Horizon	Depth in cm	pH	Percent						Parts Per Million					
					Sand	Silt	Clay	Fe_2O_3[1]	Fe_2O_3[2]	Fe	Al	Mn	Ca	Mg	Na	K
Pre-Wisconsinan Glacial Till																
Allenwood	013-061-01	Ap	0-18	5.7	26.2	56.7	17.1	2.0	1.12	0.78	1.70	227	517	667	56.5	1025
(Well	013-061-04	Bt2	61-84	5.2	31.2	32.2	36.6	3.9	3.96	2.77	2.58	355	115	340	58.2	1075
drained)	013-061-07	Bt5	155-190	5.2	45.6	37.9	16.5	2.9	2.25	1.57	0.99	627	32	177	34.5	335
Watson	055-002-01	Ap	0-23	6.0	26.5	52.5	21.0	2.5	2.97	2.08	1.16	317	720	582	51.7	860
(Moderately	055-002-03	Bt2	46-56	4.8	28.6	28.9	42.5	3.8	4.68	3.27	1.70	18	140	472	52.2	730
well drained)	055-002-05	Bx2	89-114	4.5	42.3	30.7	27.0	2.2	2.83	1.98	2.05	15	60	760	85.2	1375
Acid Grayish-brown Shale and Sandstone Colluvium and Limestone Colluvium																
Laidig	014-031-03	A	0-8	4.6	34.2	49.7	16.1	1.3	2.43	1.70	1.98	4250	80	1325	44.7	1175
(Well	014-031-06	Bt2	51-58	4.9	42.8	37.4	19.8	2.9	4.62	3.23	2.60	237	120	2425	49.5	2650
drained)	014-031-10	Bx1	102-150	4.9	43.3	36.1	20.6	3.1	5.18	3.62	2.73	955	167	3100	68.8	3200
Murrill	014-088-01	Ap1	0-13	6.1	7.6	69.8	22.6	1.9	3.18	2.23	1.52	1325	1352	1475	48.2	807
(Well	014-088-04	Bt2	40-55	5.5	6.6	60.7	32.7	3.3	5.36	3.75	2.33	410	1415	2425	71.2	1600
drained)	014-088-07	Bt5	110-143	4.8	13.7	62.1	24.2	2.7	5.14	3.60	1.57	1225	510	1500	52.2	1210
	014-088-10	BCt	215-304	5.2	16.6	41.8	41.6	3.5	5.36	3.75	2.00	1090	1952	1115	57.7	1050
Andover	018-013-01	Ap	0-23	6.0	29.6	46.6	23.8	2.3	3.50	2.45	2.08	3975	1385	2100	62.7	1475
(Poorly	018-013-03	Bt	36-46	6.1	33.5	42.4	24.1	3.6	4.72	3.30	2.05	257	295	2275	60.5	2000
drained)	018-013-06	Bxg3	81-97	5.1	41.0	39.5	19.5	3.0	4.58	3.20	2.08	235	42	2300	80.2	2025
Brown Wisconsinan Loess																
Duncannon	009-005-01	Ap	0-25	5.4	8.6	74.0	17.4	1.6	2.43	1.70	1.90	843	542	1875	59.5	101
(Well	009-005-03	Bt1	43-61	6.0	7.9	69.9	22.2	3.0	4.58	3.20	3.05	225	355	3000	111.7	1700
drained)	009-005-05	BC	86-114	6.2	6.6	83.0	10.4	2.5	3.90	2.73	2.05	365	200	3250	90.2	1400
Lawrenceville	009-003-01	Ap	0-28	6.3	11.6	73.0	15.4	1.4	2.25	1.57	1.82	665	745	2000	87.2	113
(Moderately	009-003-03	Bt2	48-64	6.4	8.6	73.4	18.0	2.0	3.50	2.45	2.25	117	495	2575	82.0	1275
well drained)	009-003-05	Bx2	86-102	5.4	12.0	73.4	14.6	2.6	3.82	2.67	1.62	428	295	2550	78.0	1300

1 - Fe_2O_3 data from Ciolkosz and Thurman (1992) by the CBD method. 2 - Fe_2O_3 data calculated from the Fe data (Fe x 1.43).

Table 1. Cont. Selected soil characterization data and major elements for the soil samples used in this study. Characterization data from Ciolkosz and Thurman (1992).

Soil and Drainage Class	Soil Number	Horizon	Depth in cm	pH	Percent						Parts Per Million					
					Sand	Silt	Clay	Fe_2O_3[1]	Fe_2O_3[2]	Fe	Al	Mn	Ca	Mg	Na	K
Doylestown	009-011-01	Ap	0-18	5.5	4.5	73.7	21.8	2.5	3.72	2.60	2.35	428	785	1950	110.5	1162
(Poorly	009-011-02	Btg	18-38	5.5	2.9	61.7	35.4	3.1	4.58	3.20	3.60	72	622	2650	124.5	1525
drained)	009-011-04	Bxtg2	46-69	5.2	7.4	76.0	16.6	2.3	4.05	2.83	2.02	435	407	3550	124.7	1525
					Residual Acid Sandstone											
Clymer	014-083-03	E	0-8	3.8	68.1	30.3	1.6	0.3	0.53	0.37	0.30	10	80	63	17.2	470
(Well	014-083-07	Bw2	43-71	4.6	59.8	29.8	10.4	1.3	1.50	1.05	0.80	100	3	688	44.7	822
drained)	014-083-09	Bt2	94-122	4.6	54.1	23.9	22.0	2.8	4.43	3.10	0.86	455	8	210	36.2	877
	014-083-11	C1	137-168	4.8	69.3	30.3	0.4	1.2	2.04	1.43	0.88	467	92	55	31.3	870
Hazleton	017-012-02	A	0-5	4.8	26.6	52.3	21.1	2.4	2.43	1.70	1.68	1300	582	1825	82.5	1525
(Well	017-012-05	Bt2	33-61	4.8	37.3	43.4	19.3	2.4	4.36	3.05	2.27	810	275	3675	68.5	1675
drained)	017-012-08	Bt5	104-127	5.0	45.1	41.1	13.8	2.2	3.96	2.77	1.65	1032	315	4350	44.7	1107
Cookport	017-015-02	BA	5-15	4.8	31.1	47.4	21.5	3.0	5.92	4.14	1.57	79	100	1157	40.2	690
(Moderately	017-015-04	Bt2	25-38	4.9	35.0	44.8	20.2	2.7	2.25	1.58	1.60	106	95	1600	47.5	805
well	017-015-07	Bx3	84-119	5.2	35.5	43.7	20.8	2.8	4.22	3.25	0.93	712	162	1387	46.0	770
drained)																
Cookport	014-082-01	A	0-8	3.4	48.6	41.9	9.5	0.5	0.96	0.67	0.33	262	247	197	45.2	450
(Somewhat	014-082-04	Bw2	41-61	4.6	42.9	42.2	14.9	1.8	2.62	1.83	1.09	79	30	1145	44.2	882
poorly	014-082-07	Bx3	104-132	4.8	67.2	19.1	13.7	2.3	3.28	2.30	0.67	247	57	267	35.0	800
drained)	014-082-10	Bx6	203-243	4.9	70.0	21.1	8.9	1.5	2.33	1.63	0.51	165	110	460	41.5	805
Nolo	017-019-02	A	0-10	4.2	27.2	63.2	9.6	0.3	0.50	0.35	1.29	10	240	225	52.5	1005
(Poorly	017-019-04	Btg	28-36	4.7	37.5	43.2	19.3	3.1	3.64	2.55	1.11	39	55	990	50.0	818
drained)	017-019-06	Bxg2	79-124	5.3	47.3	37.2	15.5	1.8	2.61	1.33	1.83	217	497	712	56.5	537
					Residual Acid Gray Shales											
Bedington	006-012-02	A	0-5	4.2	36.0	44.5	19.5	2.0	3.00	2.10	1.95	1825	370	1475	48.0	1105
(Well	006-012-05	Bt2	30-58	4.4	44.0	37.9	18.1	2.9	3.46	2.42	2.25	285	3	2775	46.2	1400
drained)	006-012-08	Bt5	119-150	4.6	43.3	21.7	35.0	4.8	5.08	3.55	2.55	790	40	2525	53.2	2350
	006-012-10	Ct	178-208	.	.	.	.	.	5.43	3.80	2.52	1225	22	3675	53.5	1700

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					Sand	Silt	Clay	Fe_2O_3[1]	Fe_2O_3[2]	Fe	Al	Mn	Ca	Mg	Na	K
Gilpin	032-054-01	Ap	0-23	6.6	41.6	52.5	5.9	1.7	3.86	2.70	2.27	1225	1120	2725	69.0	1245
(Well	032-054-03	Bt	36-58	5.3	27.3	50.1	22.6	2.1	4.29	3.00	2.67	325	190	3725	77.7	1575
drained)	032-054-05	C	66-76	5.0	25.9	53.3	20.8	2.4	4.53	3.17	2.30	220	115	3875	75.0	1625
Rayne	056-002-04	Bt3	66-97	4.8	29.9	29.5	40.6	5.5	6.15	4.30	2.27	125	63	1050	71.7	2075
(Well	056-002-07	C1	168-208	4.8	47.4	28.5	24.1	3.5	4.36	3.05	2.23	645	25	1650	59.5	1525
drained)																
Wharton	032-053-01	Ap	0-25	6.2	17.3	69.7	13.0	2.7	1.60	1.12	1.90	1750	1550	1875	58.5	835
(Moderately	032-053-04	Bt2	48-61	4.9	10.3	62.5	27.2	3.8	2.86	2.00	2.52	342	360	3150	74.5	1600
well	032-053-06	C	91-137	4.9	21.7	56.7	21.6	3.1	3.36	2.35	2.10	675	155	3425	58.0	1050
drained)																
Cavode	010-039-01	Ap	0-28	5.3	20.1	52.3	27.6	2.6	3.90	2.73	1.37	957	755	852	54.2	920
(Somewhat	010-039-04	Btg2	53-69	4.9	3.6	40.1	56.3	3.1	4.64	3.25	1.43	20	455	770	83.5	1475
poorly	010-039-07	2Btg5	104-130	4.8	30.9	46.1	23.0	2.3	5.04	3.53	1.62	770	428	1775	75.5	1800
drained)																
Cavode	032-059-01	Ap	0-28	5.2	22.8	61.5	15.7	2.3	2.72	1.90	2.17	2075	530	1270	69.0	1825
(Somewhat	032-059-03	Bt1	41-53	4.9	12.4	48.4	39.2	2.7	4.10	2.87	3.25	160	500	2725	89.2	2750
poorly	032-059-06	Cg	119-145	4.9	28.3	50.6	21.1	1.5	2.83	1.98	1.45	255	105	2700	66.0	2500
drained)																
					Residual Calcareous Red Shales											
Upshur	002-023-01	Ap	0-20	4.8	13.6	66.2	20.2	3.4	5.61	3.93	1.80	1450	927	1925	110.0	2700
(Well	002-023-03	Bt2	41-64	4.5	0.9	32.2	66.9	3.6	5.83	4.08	2.33	35	1517	2575	113.5	2750
drained)	002-023-07	C1	117-142	6.1	2.2	66.4	31.4	5.5	7.93	5.55	1.50	180	6375	3100	147.5	2800
Vandergrift	004-001-01	Ap	0-18	5.0	9.2	60.9	29.9	1.9	1.79	1.25	1.37	1775	900	1192	67.7	1475
(Moderately	004-001-04	Bt3	41-58	5.1	3.3	27.9	68.8	2.7	5.86	4.10	2.00	44	1867	1525	127.5	2600
well	004-001-08	C1	147-180	8.2	3.1	63.9	33.0	1.7	2.72	1.90	1.39	170	4795	2500	115.3	2100
drained)																

1 - Fe_2O_3 data from Ciolkosz and Thurman (1992) by the CBD method. 2 - Fe_2O_3 data calculated from the Fe data (Fe x 1.43).

Table 1. Cont. Selected soil characterization data and major elements for the soil samples used in this study. Characterization data from Ciolkosz and Thurman (1992).

Soil and Drainage Class	Soil Number	Horizon	Depth in cm	pH	Percent						Parts Per Million					
					Sand	Silt	Clay	Fe_2O_3[1]	Fe_2O_3[2]	Fe	Al	Mn	Ca	Mg	Na	K
Residual Calcareous Gray Shales																
Westmoreland	063-043-01	Ap	0-25	7.1	12.8	71.6	15.6	2.4	3.25	2.27	1.57	2400	1873	2350	55.7	1070
(Well	063-043-04	Bt2	53-74	4.6	21.0	48.6	30.4	3.4	5.93	4.15	2.05	1275	367	2925	53.7	2025
drained)	063-043-07	C	127-147	4.7	41.5	46.5	12.0	2.5	4.98	3.48	1.73	675	577	4425	80.2	2350
Dormont	002-007-02	Ap	0-18	4.7	9.7	68.6	21.7	3.1	4.32	3.02	1.43	2125	252	1377	56.3	1325
(Moderately	002-007-05	Bt2	38-48	5.3	11.5	59.2	29.3	4.5	5.08	3.55	1.50	557	855	2075	60.8	1400
well drained)	002-007-08	Bw1	79-102	4.8	29.5	51.1	19.4	3.3	3.96	2.77	1.27	620	420	3075	51.5	1375
Library	063-045-01	Ap	0-25	5.7	9.1	68.8	22.1	2.6	4.18	2.92	1.31	1295	1637	1775	64.2	1475
(Somewhat	063-045-04	Btg1	48-61	6.0	9.0	58.3	32.7	3.7	4.48	3.13	1.85	850	1570	2075	84.7	1625
poorly	063-045-08	C1	124-132	6.8	5.0	39.5	55.5	2.1	2.76	1.93	1.35	1295	2805	1925	109.5	1900
drained)																
Residual Limestones																
Duffield	014-074-01	A	0-18	5.3	6.8	75.9	17.3	1.2	2.22	1.55	1.31	2575	1567	1532	36.2	1475
(Well	014-074-05	Bt2	71-94	4.9	3.5	57.2	39.3	3.3	4.29	3.00	2.89	547	470	6275	46.7	2950
drained)	014-074-11	3C1	193-211	5.3	8.7	51.8	39.5	3.6	4.86	3.40	2.75	627	267	7125	57.0	3625
Duffield	036-017-01	Ap	0-18	5.8	11.7	69.9	18.4	2.0	2.29	1.60	1.11	1370	925	1600	35.7	660
(Well	036-017-03	Bt1	30-56	6.4	10.9	54.7	34.4	4.7	4.82	3.37	1.35	395	620	1022	31.7	610
drained)	036-017-06	C	102-132	6.6	31.1	40.1	28.8	1.6	4.36	3.05	2.23	237	852	4450	41.0	1600
Hagerstown	014-005-01	Ap	0-23	5.7	6.0	70.0	24.0	3.2	3.43	2.40	1.11	1137	900	1807	32.2	1342
(Well	014-005-04	Bt3	66-79	4.9	1.7	32.5	65.8	5.1	5.29	3.70	1.95	642	1392	3075	45.0	2375
drained)	014-005-07	C	135-173	7.5	8.7	53.1	38.2	3.7	3.96	2.77	1.74	567	34450	11425	80.0	2650
Hagerstown	014-007-01	Ap	0-25	6.1	16.5	72.2	11.3	3.0	2.53	1.77	1.17	1625	1915	1277	38.7	940
(Well	014-007-05	Bt2	79-109	4.8	2.2	36.0	61.8	4.7	4.40	3.08	2.21	415	722	1510	46.2	2375
drained)	014-007-07	BC1	142-183	5.2	1.9	29.5	68.6	3.4	4.68	3.27	2.44	435	767	1785	49.7	1950
Hagerstown	014-014-01	Ap	0-30	6.7	1.5	87.2	11.3	1.8	2.22	1.55	1.19	1500	1495	1252	48.0	772
(Well	014-014-04	Bt1	51-76	6.9	0.8	46.2	53.0	4.3	5.22	3.65	2.21	740	4875	1347	56.7	1342
drained)	014-014-05	Bt2	76-102	7.5	1.0	41.6	57.4	3.9	4.86	3.40	2.47	640	9225	1640	73.0	1250

1 - Fe_2O_3 data from Ciolkosz and Thurman (1992) by the CBD method. 2 - Fe_2O_3 data calculated from the Fe data (Fe x 1.43).

Table 1. Cont. Selected soil characterization data and major elements for the soil samples used in this study. Characterization data from Ciolkosz and Thurman (1992).

Soil and Drainage Class	Soil Number	Horizon	Depth in cm	pH	Percent						Parts Per Million					
					Sand	Silt	Clay	Fe_2O_3[1]	Fe_2O_3[2]	Fe	Al	Mn	Ca	Mg	Na	K
Hagerstown	014-066-01	A	0-8	5.5	4.7	77.2	18.1	1.5	4.48	3.13	0.78	430	220	441	38.0	1007
(Well	014-066-05	Bt2	53-76	4.8	5.4	44.4	50.2	4.4	4.58	3.20	2.38	620	2950	1842	39.5	1325
drained)	014-066-08	3C	112-178	7.5	3.3	65.2	31.5	3.6	5.25	3.67	2.94	672	30525	18475	82.0	2200
Hagerstown	014-067-01	A	0-10	5.4	3.4	79.1	17.5	1.5	2.54	1.78	1.10	1825	3675	2300	43.0	1045
(Well	014-067-05	Bt2	53-76	4.8	2.9	40.7	56.4	4.5	6.40	4.48	3.68	275	1277	8175	61.5	5225
drained)	014-067-08	3C2	137-155	7.9	9.0	56.0	35.0	1.6	2.61	1.83	0.95	177	132775	78600	195.0	1200
Hagerstown	014-068-01	A	0-8	5.8	8.1	75.3	16.6	1.2	1.64	1.15	0.85	2350	5350	6025	44.5	1110
(Well	014-068-05	Bt2	61-84	5.8	20.2	45.9	33.9	2.3	2.69	1.88	3.20	242	870	28050	63.2	8450
drained)	014-068-08	3Cr1	140-160	6.6	19.2	51.4	29.4	2.2	2.47	1.73	3.01	192	2267	33500	89.2	7675
Hagerstown	014-069-01	A	0-10	5.8	4.5	75.2	20.3	1.5	1.57	1.10	1.24	2475	3600	1962	45.7	1200
(Well	014-069-05	Bt2	53-69	5.1	3.5	38.6	57.9	4.4	5.76	4.03	3.49	325	1002	6100	64.2	4000
drained)	014-069-08	3C	99-147	8.0	5.4	57.2	37.4	2.0	2.97	2.08	1.32	225	117525	62225	150.0	1775
Hagerstown	014-070-01	A	0-8	5.3	10.8	73.9	15.3	1.0	2.65	1.85	1.25	3075	7125	2825	97.0	693
(Well	014-070-06	3Bt3	66-89	5.3	7.4	51.0	41.6	3.2	4.68	3.27	2.97	335	695	3425	49.7	2025
drained)	014-070-09	3Bt6	160-183	5.7	1.7	43.9	54.4	3.8	5.08	3.55	4.18	367	977	9800	63.0	4125
Hagerstown	014-071-01	A	0-8	5.0	9.2	73.4	17.4	1.4	2.47	1.73	1.22	2650	625	1110	51.2	772
(Well	014-071-05	Bt2	61-86	5.3	2.7	41.0	56.3	4.4	5.89	4.12	3.15	305	537	3375	40.2	232
drained)	014-071-07	3C	112-142	6.9	3.2	50.1	46.7	4.4	5.36	3.75	2.73	387	3700	6575	68.0	2650
Hagerstown	014-072-01	A	0-8	5.4	9.4	74.6	16.0	1.2	2.29	1.60	1.26	3125	1748	1302	39.2	655
(Well	014-072-05	Bt2	46-79	5.1	2.9	54.2	42.9	3.1	3.65	2.55	2.44	300	503	3750	38.0	1825
drained)	014-072-09	3BC	145-157	6.9	2.5	77.0	20.5	3.6	4.18	2.92	3.56	327	2467	13725	107.5	5125
Hagerstown	014-073-01	A	0-8	5.4	9.8	73.8	16.4	1.2	2.12	1.48	1.37	2900	1180	21700	78.5	877
(Well	014-073-05	Bt2	61-86	5.6	10.4	48.3	41.3	2.9	3.43	2.40	2.62	295	397	13275	42.7	3200
drained)	014-073-08	3C1	140-165	6.6	18.3	45.1	36.6	3.8	4.36	3.05	2.19	385	1692	5975	56.7	1750
Hagerstown	014-075-01	A	0-10	6.6	10.3	73.2	16.5	1.2	3.07	2.15	1.25	3475	2700	1365	33.7	970
(Well	014-075-05	3Bt2	61-86	5.4	3.8	38.4	57.8	4.1	4.76	3.33	3.37	340	820	6500	40.0	3100
drained)	014-075-08	3Bt5	150-160	7.5	4.3	42.6	53.1	3.8	4.26	2.98	3.15	247	3000	10725	43.8	2925

1 - Fe_2O_3 data from Ciolkosz and Thurman (1992) by the CBD method. 2 - Fe_2O_3 data calculated from the Fe data (Fe x 1.43).

Table 1. Cont. Selected soil characterization data and major elements for the soil samples used in this study. Characterization data from Ciolkosz and Thurman (1992).

Soil and Drainage Class	Soil Number	Horizon	Depth in cm	pH	Percent						Parts Per Million					
					Sand	Silt	Clay	Fe_2O_3[1]	Fe_2O_3[2]	Fe	Al	Mn	Ca	Mg	Na	K
Hagerstown	014-080-01	A	0-8	4.9	19.2	73.4	7.4	1.5	2.72	1.90	1.32	5150	2023	1177	32.7	672
(Well	014-080-05	Bt2	61-89	4.6	9.1	26.3	64.6	5.5	5.58	3.90	2.66	470	630	1165	36.2	1475
drained)	014-080-09	BC	183-254	4.9	4.1	45.5	50.4	4.2	3.86	2.70	1.53	295	370	1045	34.5	5100
Hagerstown	018-009-01	Ap	0-18	6.2	15.8	62.5	21.7	3.1	3.25	2.27	1.15	932	1095	1102	39.7	732
(Well	018-009-04	Bt3	38-53	6.0	4.9	19.2	75.9	8.4	7.82	5.47	4.01	197	1510	2102	56.7	1925
drained)	018-009-06	BC	71-81	6.2	9.1	29.3	61.6	6.3	7.94	5.55	3.30	457	1767	2215	52.0	1750
Hagerstown	018-010-01	Ap	0-15	6.0	19.3	64.1	16.6	2.1	2.60	1.82	1.34	1037	692	732	28.0	667
(Well	018-010-05	Bt2	53-71	5.3	11.8	56.0	32.2	2.7	3.60	2.52	1.39	365	428	827	32.2	652
drained)	018-010-08	BC2	112-137	5.2	6.6	40.8	52.6	4.8	4.86	3.40	1.61	135	410	685	30.7	755
Hagerstown	022-006-01	Ap	0-23	6.5	21.6	62.2	16.2	3.2	3.55	2.48	1.82	1800	1890	1892	55.5	1085
(Well	022-006-05	Bt3	74-89	7.0	9.5	14.3	76.2	4.2	7.65	5.35	3.13	790	1750	1482	67.7	1075
drained)	022-006-08	BC	147-152	6.7	2.8	19.2	78.0	5.0	7.55	5.28	3.61	855	2335	5475	74.5	1975
Hagerstown	022-007-01	Ap	0-18	6.6	15.3	65.3	19.4	2.6	3.60	2.52	1.89	1277	1810	1975	42.7	840
(Well	022-007-05	Bt3	64-71	6.8	26.9	42.3	30.8	4.8	5.69	3.98	2.36	1575	1022	1375	41.7	1025
drained)	022-007-09	BC	142-163	6.2	6.9	33.3	59.8	5.5	6.86	4.80	3.77	557	1067	4875	62.0	2350
Hagerstown	036-014-01	Ap	0-20	7.0	14.2	63.2	22.6	2.5	3.29	2.30	1.91	1187	1882	1540	41.7	955
(Well	036-014-04	Bt2	56-84	5.5	6.7	35.3	58.0	.	5.15	3.60	2.22	240	1662	895	43.2	690
drained)	036-014-08	Bt6	163-190	4.9	8.3	59.4	32.3	.	3.46	2.42	2.16	637	330	962	32.0	705
Hagerstown	036-015-01	Ap	0-18	6.0	12.9	68.5	18.6	2.0	3.04	2.13	1.73	1222	962	1425	38.5	697
(Well	036-015-04	Bt2	58-84	6.8	9.7	31.2	59.1	4.5	7.07	4.95	3.41	217	1827	1112	52.7	972
drained)	036-015-07	BCt2	157-203	5.1	18.0	32.1	49.9	4.2	7.00	4.90	2.59	220	807	970	37.7	960
Hagerstown	036-019-01	Ap	0-25	6.0	11.2	64.3	24.5	3.2	5.48	3.83	1.69	1082	745	1252	34.7	922
(Well	036-019-04	Bt3	71-86	5.3	7.6	43.6	48.8	4.7	7.58	5.30	2.64	395	627	1257	34.7	797
drained)	036-019-07	C1	142-168	5.1	9.0	47.7	43.3		6.79	4.75	2.06	340	210	1217	30.2	655
Clarksburg	014-081-01	A	0-8	5.0	12.2	69.8	18.0	1.7	2.47	1.73	1.24	3925	1087	1475	49.7	835
(Moderately	014-081-04	Bt	36-69	4.6	9.1	64.6	26.3	3.1	4.71	3.30	1.65	447	492	2825	63.2	1375
well	014-081-06	Bx2	104-140	5.0	23.5	57.5	19.0	2.7	4.97	3.48	1.45	685	665	2525	60.5	1775
drained)	014-081-10	2C3	223-259	4.7	20.8	44.0	35.2	2.8	4.29	3.00	1.75	877	467	1750	60.0	2375

1 - Fe_2O_3 data from Ciolkosz and Thurman (1992) by the CBD method. 2 - Fe_2O_3 data calculated from the Fe data (Fe x 1.43).

Table 1. Cont. Selected soil characterization data and major elements for the soil samples used in this study. Characterization data from Ciolkosz and Thurman (1992).

Soil and Drainage Class	Soil Number	Horizon	Depth in cm	pH	Percent						Parts Per Million					
					Sand	Silt	Clay	Fe_2O_3[1]	Fe_2O_3[2]	Fe	Al	Mn	Ca	Mg	Na	K
	Residual Acid Crystalline Rocks															
Chester	036-049-01	A	0-8	4.1	41.0	41.6	17.4	2.8	3.07	2.15	1.10	55	372	542	49.7	647
(Well	036-049-04	Bw1	36-56	4.5	47.2	33.7	19.1	4.0	5.48	3.83	2.15	61	117	905	31.3	712
drained)	036-049-08	3C2	135-152	5.4	79.2	18.4	2.4	3.9	5.53	3.87	0.63	128	110	28	18.2	330
	036-049-12	3C3	244-386	5.4	75.3	22.3	2.4	3.6	4.72	3.30	0.40	94	112	25	23.2	480
Chester	036-052-01	A	0-8	4.5	26.2	54.5	19.3	2.9	3.57	2.50	2.35	745	38	680	68.0	680
(Well	036-052-04	Bt1	33-48	5.0	27.7	41.4	30.9	6.1	6.48	4.53	3.40	84	20	975	63.2	1050
drained)	036-052-07	2Bt4	97-119	5.8	52.6	21.1	26.3	6.5	8.62	6.03	4.67	31	13	262	45.5	445
	036-052-08	2Bt5	119-160	5.8	49.9	23.8	26.3	6.0	8.18	5.72	4.78	40	742	487	58.7	475
Chester	067-008-01	Ap	0-20	5.1	31.6	46.0	22.4	4.0	5.15	3.60	2.52	1202	1052	1040	57.0	777
(Well	067-008-04	Bt2	53-66	6.9	37.6	30.8	31.6	5.7	7.55	5.28	3.90	440	1207	927	69.0	890
drained)	067-008-06	C	171-86	6.1	53.8	16.5	29.7	6.2	8.29	5.80	3.87	802	592	557	50.7	570
Chester	036-050-01	A	0-5	4.8	32.7	50.8	16.5	2.4	3.25	2.27	1.82	725	390	955	41.0	607
(Well	036-050-04	Bt	30-66	5.2	38.1	40.1	21.8	3.9	5.51	3.85	2.48	188	125	1290	40.0	977
drained)	036-050-08	3Bt	157-203	5.7	41.4	29.1	29.5	4.8	6.26	4.38	3.50	95	22	672	43.0	797
	036-050-14	9C	328-338	5.6	43.6	22.2	34.2	5.9	7.91	5.53	3.77	205	5	720	63.2	1002
Glenelg	006-011-02	A	0-12	4.3	45.3	35.5	19.2	2.3	3.54	2.48	2.40	1142	335	852	49.7	375
(Well	006-011-05	Bt2	46-66	4.4	48.4	31.0	20.6	2.8	5.90	4.13	4.20	130	208	1230	55.2	780
drained)	006-011-08	C1	124-160	4.6	69.1	19.6	11.3	1.9	4.26	2.98	3.35	242	82	445	43.2	592
	006-011-11	C4	246-322	4.3	60.2	31.8	8.0	3.2	5.83	4.08	2.45	352	5	1340	56.0	1070
Glenelg	036-027-01	Ap	0-25	7.3	51.6	34.2	14.2	2.3	3.03	2.12	1.01	685	737	882	32.0	685
(Well	036-027-02	Bt1	25-48	7.3	35.1	41.0	23.9	3.9	4.26	2.98	1.77	277	1265	1192	39.7	922
drained)	036-027-05	C1	84-107	7.1	61.0	35.3	3.7		4.76	3.33	0.50	397	20	630	24.0	185
Manor	036-028-01	Ap	10-13	6.9	38.1	45.4	16.5	2.9	4.15	2.90	1.88	805	1255	2625	53.0	930
(Well	036-028-03	Bw	25-51	6.5	46.5	41.4	12.1	2.5	4.29	3.00	1.35	547	297	2375	27.0	405
drained)	036-028-06	C1	84-94	7.2	59.7	36.0	4.3	2.0	2.97	2.08	0.67	1032	52	1875	23.5	117

1 - Fe_2O_3 data from Ciolkosz and Thurman (1992) by the CBD method. 2 - Fe_2O_3 data calculated from the Fe data (Fe x 1.43).

Table 1. Cont. Selected soil characterization data and major elements for the soil samples used in this study. Characterization data from Ciolkosz and Thurman (1992).

Soil and Drainage Class	Soil Number	Horizon	Depth in cm	pH	Percent						Parts Per Million					
					Sand	Silt	Clay	Fe_2O_3[1]	Fe_2O_3[2]	Fe	Al	Mn	Ca	Mg	Na	K
Residual Basic Crystalline Rocks																
Neshaminy	009-051-01	Ap	0-18	6.6	20.2	57.4	22.4	5.3	6.84	4.78	4.22	1357	1462	2175	101.0	557
(Well	009-051-03	Bt2	33-58	6.6	29.0	37.2	33.8	7.7	11.40	7.97	6.62	1220	1492	1900	120.0	552
drained)	009-051-05	C	91-163	6.6	50.6	21.4	28.0	6.0	6.58	4.60	6.95	902	2100	2275	145.0	357
Neshaminy	046-013-01	Ap	0-15	5.9	25.4	57.2	17.4	6.1	8.79	6.15	4.80	1450	1410	2750	110.7	525
(Well	046-013-05	Bt2	41-51	6.6	38.2	34.0	27.8	5.3	8.69	6.08	3.55	1092	1192	5375	122.7	322
drained)	046-013-08	C1	84-99	7.0	60.4	25.2	14.4	3.1	5.76	4.03	5.30	680	2075	4050	445.0	720
Mount Lucas	001-016-01	Ap	0-20	6.5	19.7	68.1	12.2	2.1	1.79	1.25	1.50	1235	1652	2100	100.5	337
(Moderately	001-016-04	Bt2	46-61	6.6	43.8	31.5	24.7	1.9	3.75	2.62	3.40	597	4688	7325	575.0	405
well drained)	001-016-06	C	71-99	6.9	79.7	14.1	6.2	0.6	1.39	0.97	3.00	285	10782	6075	2050.0	335
Watchung	009-012-01	Ap	0-20	6.4	9.2	76.6	14.2	1.7	2.06	1.44	1.17	375	1047	1112	61.8	202
(Poorly	009-012-04	Btg3	53-71	7.0	14.8	55.3	29.9	2.6	4.15	2.90	2.33	150	2580	2875	65.0	382
drained)	009-012-06	Bx2	99-135	6.9	26.9	64.4	8.7	4.6	6.03	4.22	3.73	732	3508	2550	220.0	395
Watchung	009-013-01	Ap	0-18	6.3	5.6	70.0	24.4	2.3	1.89	1.32	2.30	460	1777	1650	90.0	492
(Poorly	009-013-04	Btg2	53-71	6.8	19.7	57.6	22.7	5.5	5.72	4.00	3.37	820	1625	2275	110.0	455
drained)	009-013-06	Bxg2	104-127	5.5	32.7	43.4	23.9	6.8	8.98	6.28	5.72	1145	1492	1725	165.0	478
Gray Acid Floodplain																
Pope	014-084-01	A	0-10	4.3	34.7	46.8	18.5	2.0	3.33	2.33	1.16	585	557	1475	56.5	1325
(Well	014-084-05	Bw3	61-86	4.1	30.2	47.6	22.2	2.4	4.14	2.90	1.24	485	217	1825	53.5	932
drained)	014-084-08	2C1	114-142	4.9	51.9	31.3	16.8	3.1	5.69	3.98	1.30	522	547	1875	57.5	1150

1 - Fe_2O_3 data from Ciolkosz and Thurman (1992) by the CBD method. 2 - Fe_2O_3 data calculated from the Fe data (Fe x 1.43).

Table 2. Selected soil characterization data and minor elements for the soil samples used in this study. Characterization data from Ciolkosz and Thurman (1992).

Soil and Drainage Class	Soil Number	Horizon	Depth in cm	pH	Percent			Parts Per Million						
					Sand	Silt	Clay	Cu	Zn	Ni	Pb	Cd	Cr	P
					Grayish-Brown Wisconsinan Glacial Till										
Bath	008-011-01	Ap	0-18	5.5	28.2	56.8	15.0	11.7	54.7	13.5	18.2	0.175	14.2	572.5
(Well	008-011-03	Bw2	30-43	5.0	36.6	50.3	13.1	15.5	51.2	17.2	15.5	0.100	18.0	527.5
drained)	008-011-06	Bx3	69-107	5.0	40.9	45.6	13.5	22.0	54.2	19.7	16.5	0.150	16.2	427.5
Bath	008-099-02	A	0-5	4.3	42.3	46.8	10.9	9.5	50.0	15.5	44.0	0.300	12.5	457.5
(Well	008-099-05	Bw2	36-51	4.4	38.3	47.3	14.4	24.5	55.0	18.0	12.0	0.100	14.7	350.0
drained)	008-099-09	Bx4	135-180	5.0	22.3	56.4	21.3	25.5	75.0	26.0	15.7	0.125	20.0	475.0
	008-099-12	Bx7	285-361	5.2	36.0	48.8	15.2	25.7	72.5	25.2	17.2	0.175	18.5	532.5
Volusia	008-014-01	Ap	0-20	6.9	24.4	53.7	21.9	12.7	58.0	14.5	22.5	0.100	14.5	645.0
(Somewhat	008-014-03	E2	28-36	6.7	24.9	53.8	21.3	14.2	50.0	17.0	16.0	0.075	14.7	237.5
poorly	008-014-06	Bxg3	74-97	5.0	24.5	48.0	27.5	22.5	65.0	22.5	18.8	0.100	15.7	442.5
drained)														
Chippewa	008-016-01	Ap	0-15	5.6	11.6	63.4	25.0	12.2	90.0	16.0	24.5	0.275	18.5	572.5
(Very	008-016-03	Eg	30-43	5.5	14.2	60.7	25.1	9.5	90.0	17.0	18.0	0.050	23.0	392.5
poorly	008-016-06	Bxg3	94-130	6.3	20.0	69.2	10.8	24.5	60.0	22.7	14.0	0.150	14.5	467.5
drained)														
					Red Wisconsinan Glacial Till									
Lackawanna	045-080-01	Ap	0-18	5.3	42.3	45.6	12.1	8.5	44.5	8.2	9.5	0.325	12.5	137.5
(Well	045-080-03	Bw2	36-51	5.7	44.4	43.9	11.7	18.0	42.7	14.7	4.5	0.200	15.0	82.5
drained)	045-080-05	Bx1	71-109	5.6	51.7	37.6	10.7	16.5	39.5	13.8	2.7	0.175	10.2	56.3
Morris	058-003-01	Ap	0-18	5.7	34.1	44.9	21.0	11.5	98.2	12.5	15.7	0.500	22.2	592.5
(Somewhat	058-003-03	BA	28-43	6.0	45.9	42.3	11.8	8.2	55.2	13.0	8.0	0.200	16.5	122.5
poorly	058-003-07	Bx4	79-117	6.6	41.5	45.2	13.3	15.0	59.5	17.0	12.2	0.300	16.7	375.0
drained)														
Norwich	058-021-01	A	0-20	5.0	18.5	36.7	44.8	16.2	162.7	15.0	47.5	0.700	27.3	658.7
(Poorly	058-021-03	Bwg	25-64	5.2	21.1	47.0	31.9	17.5	54.7	14.0	18.5	0.175	22.5	281.3
drained)	058-021-05	2Bxg2	76-91	5.7	22.5	49.8	27.7	22.2	78.5	22.5	42.2	0.175	15.7	272.5

Table 2. Cont. Selected soil characterization data and minor elements for the soil samples used in this study. Characterization data from Ciolkosz and Thurman (1992).

Soil and Drainage Class	Soil Number	Horizon	Depth in cm	pH	Percent			Parts Per Million						
					Sand	Silt	Clay	Cu	Zn	Ni	Pb	Cd	Cr	P
					Pre-Wisconsinan Glacial Till										
Allenwood	013-061-01	Ap	0-18	5.7	26.2	56.7	17.1	12.2	95.0	6.5	18.5	0.525	16.0	412.5
(Well	013-061-04	Bt2	61-84	5.2	31.2	32.2	36.6	31.3	39.2	14.0	15.5	0.025	25.7	355.0
drained)	013-061-07	Bt5	155-190	5.2	45.6	37.9	16.5	16.5	18.5	4.7	13.0	0.025	18.0	247.5
Watson	055-002-01	Ap	0-23	6.0	26.5	52.5	21.0	12.0	28.0	5.7	11.7	0.200	15.2	250.0
(Moderately	055-002-03	Bt2	46-56	4.8	28.6	28.9	42.5	10.5	17.7	5.5	5.2	0.125	15.7	32.5
well	055-002-05	Bx2	89-114	4.5	42.3	30.7	27.0	10.2	19.5	8.8	6.3	0.125	17.5	72.5
drained)														
					Acid Grayish-brown Shale and Sandstone Colluvium and Limestone Colluvium									
Laidig	014-031-03	A	0-8	4.6	34.2	49.7	16.1	8.5	48.7	9.7	8.0	0.175	15.2	322.5
(Well	014-031-06	Bt2	51-58	4.9	42.8	37.4	19.8	35.5	66.2	23.0	7.7	0.075	27.3	180.0
drained)	014-031-10	Bx1	102-150	4.9	43.3	36.1	20.6	42.5	63.5	27.8	9.5	0.150	28.7	440.0
Murrill	014-088-01	Ap1	0-13	6.1	7.6	69.8	22.6	14.7	48.7	13.8	20.5	0.150	19.2	620.0
(Well	014-088-04	Bt2	40-55	5.5	6.6	60.7	32.7	27.8	140.0	18.8	17.7	0.075	31.3	345.0
drained)	014-088-07	Bt5	110-143	4.8	13.7	62.1	24.2	19.5	49.5	17.2	21.7	0.100	33.2	302.5
	014-088-10	BCt	215-304	5.2	16.6	41.8	41.6	22.2	40.2	16.0	23.5	0.175	35.2	177.5
Andover	018-013-01	Ap	0-23	6.0	29.6	46.6	23.8	15.0	64.5	20.0	20.0	0.275	17.5	327.5
(Poorly	018-013-03	Bt	36-46	6.1	33.5	42.4	24.1	21.5	39.2	14.5	7.0	0.200	25.7	87.5
drained)	018-013-06	Bxg3	81-97	5.1	41.0	39.5	19.5	28.7	48.7	20.5	12.2	0.200	25.7	232.5
					Brown Wisconsinan Loess									
Duncannon	009-005-01	Ap	0-25	5.4	8.6	74.0	17.4	12.5	55.5	11.2	21.2	0.200	21.7	395.0
(Well	009-005-03	Bt1	43-61	6.0	7.9	69.9	22.2	21.2	44.2	15.2	18.2	0.050	41.0	213.8
drained)	009-005-05	BC	86-114	6.2	6.6	83.0	10.4	13.8	37.5	12.5	8.5	0.050	29.7	255.0
Lawrenceville	009-003-01	Ap	0-28	6.3	11.6	73.0	15.4	11.7	47.0	10.5	16.0	0.175	22.0	377.5
(Moderately	009-003-03	Bt2	48-64	6.4	8.6	73.4	18.0	25.2	38.5	10.7	11.0	0.075	33.5	225.0
well	009-003-05	Bx2	86-102	5.4	12.0	73.4	14.6	18.0	39.5	13.0	9.5	0.100	26.5	362.5
drained)														

Table 2. Cont. Selected soil characterization data and minor elements for the soil samples used in this study. Characterization data from Ciolkosz and Thurman (1992).

Soil and Drainage Class	Soil Number	Horizon	Depth in cm	pH	Percent			Parts Per Million						
					Sand	Silt	Clay	Cu	Zn	Ni	Pb	Cd	Cr	P
Doylestown	009-011-01	Ap	0-18	5.5	4.5	73.7	21.8	11.0	52.2	10.5	23.0	0.175	34.0	267.5
(Poorly	009-011-02	Btg	18-38	5.5	2.9	61.7	35.4	16.2	41.2	12.0	13.5	0.125	53.5	83.7
drained)	009-011-04	Bxtg2	46-69	5.2	7.4	76.0	16.6	20.0	60.0	15.5	12.2	0.125	39.5	352.5
					Residual Acid Sandstone									
Clymer	014-083-03	E	0-8	3.8	68.1	30.3	1.6	3.8	7.2	0.5	2.2	0.025	1.3	67.5
(Well	014-083-07	Bw2	43-71	4.6	59.8	29.8	10.4	23.0	24.0	5.2	10.7	0.025	8.0	110.0
drained)	014-083-09	Bt2	94-122	4.6	54.1	23.9	22.0	23.2	33.5	5.7	20.5	0.025	15.7	155.0
	014-083-11	C1	137-168	4.8	69.3	30.3	0.4	6.5	11.5	1.3	9.2	0.025	2.7	92.5
Hazleton	017-012-02	A	0-5	4.8	26.6	52.3	21.1	18.0	87.5	12.7	26.5	0.325	22.2	795.0
(Well	017-012-05	Bt2	33-61	4.8	37.3	43.4	19.3	26.5	90.0	29.2	18.0	0.025	33.2	357.5
drained)	017-012-08	Bt5	104-127	5.0	45.1	41.1	13.8	30.5	92.5	31.0	19.0	0.025	29.5	377.5
Cookport	017-015-02	BA	5-15	4.8	31.1	47.4	21.5	9.0	35.0	6.5	8.8	0.075	17.5	250.0
(Moderately	017-015-04	Bt2	25-38	4.9	35.0	44.8	20.2	10.2	53.2	9.2	9.5	0.125	13.0	360.0
well	017-015-07	Bx3	84-119	5.2	35.5	43.7	20.8	20.5	53.5	16.0	13.0	0.125	14.2	382.5
drained)														
Cookport	014-082-01	A	0-8	3.4	48.6	41.9	9.5	29.7	37.7	4.2	83.2	0.400	7.5	450.0
(Somewhat	014-082-04	Bw2	41-61	4.6	42.9	42.2	14.9	22.5	38.0	7.2	13.5	0.025	15.7	130.0
poorly	014-082-07	Bx3	104-132	4.8	67.2	19.1	13.7	13.2	40.5	7.5	18.2	0.025	9.5	147.5
drained)	014-082-10	Bx6	203-243	4.9	70.0	21.1	8.9	25.2	43.2	6.8	10.2	0.025	7.0	160.0
Nolo	017-019-02	A	0-10	4.2	27.2	63.2	9.6	4.7	12.0	0.8	6.0	0.200	2.2	255.0
(Poorly	017-019-04	Btg	28-36	4.7	37.5	43.2	19.3	7.5	18.8	4.5	10.7	0.025	10.7	117.5
drained)	017-019-06	Bxg2	79-124	5.3	47.3	37.2	15.5	13.8	25.7	7.2	13.0	0.125	11.5	147.5
					Residual Acid Gray Shales									
Bedington	006-012-02	A	0-5	4.2	36.0	44.5	19.5	17.2	112.5	14.0	85.2	0.525	19.5	627.5
(Well	006-012-05	Bt2	30-58	4.4	44.0	37.9	18.1	25.0	95.0	25.2	17.2	0.025	28.7	392.5
drained)	006-012-08	Bt5	119-150	4.6	43.3	21.7	35.0	35.2	92.5	24.0	28.2	0.025	32.5	497.5
	006-012-10	Ct	178-208	.	.	.	.	38.5	117.5	39.0	39.5	0.050	32.0	540.0

Table 2. Cont. Selected soil characterization data and minor elements for the soil samples used in this study. Characterization data from Ciolkosz and Thurman (1992).

Soil and Drainage Class	Soil Number	Horizon	Depth in cm	pH	Percent			Parts Per Million						
					Sand	Silt	Clay	Cu	Zn	Ni	Pb	Cd	Cr	P
Gilpin	032-054-01	Ap	0-23	6.6	41.6	52.5	5.9	16.7	86.5	21.2	17.0	0.325	30.0	612.5
(Well	032-054-03	Bt	36-58	5.3	27.3	50.1	22.6	19.5	75.7	24.5	10.7	0.175	36.5	155.0
drained)	032-054-05	C	66-76	5.0	25.9	53.3	20.8	24.7	67.5	26.0	13.5	0.150	37.0	295.0
Rayne	056-002-04	Bt3	66-97	4.8	29.9	29.5	40.6	19.7	43.8	10.7	14.0	0.200	32.0	195.0
(Well	056-002-07	C1	168-208	4.8	47.4	28.5	24.1	16.5	58.7	18.0	16.2	0.175	25.2	372.5
drained)														
Wharton	032-053-01	Ap	0-25	6.2	17.3	69.7	13.0	12.2	77.5	17.5	19.7	0.300	21.2	422.5
(Moderately	032-053-04	Bt2	48-61	4.9	10.3	62.5	27.2	24.2	67.5	23.2	14.5	0.050	37.7	267.5
well	032-053-06	C	91-137	4.9	21.7	56.7	21.6	28.7	82.5	30.5	16.5	0.050	31.5	470.0
drained)														
Cavode	010-039-01	Ap	0-28	5.3	20.1	52.3	27.6	25.7	82.5	12.7	24.7	0.375	16.7	432.5
(Somewhat	010-039-04	Btg2	53-69	4.9	3.6	40.1	56.3	25.0	37.2	8.8	15.2	0.025	25.7	110.0
poorly	010-039-07	2Btg5	104-130	4.8	30.9	46.1	23.0	20.0	102.5	26.2	19.0	0.100	21.0	110.0
drained)														
Cavode	032-059-01	Ap	0-28	5.2	22.8	61.5	15.7	11.5	84.7	15.0	18.5	0.400	22.0	320.0
(Somewhat	032-059-03	Bt1	41-53	4.9	12.4	48.4	39.2	91.0	252.5	16.7	12.2	0.250	40.0	136.2
poorly	032-059-06	Cg	119-145	4.9	28.3	50.6	21.1	27.8	88.5	20.5	13.0	0.325	23.7	100.0
drained)														
					Residual Calcareous Red Shales									
Upshur	002-023-01	Ap	0-20	4.8	13.6	66.2	20.2	16.5	58.0	18.0	35.0	0.275	38.2	252.5
(Well	002-023-03	Bt2	41-64	4.5	0.9	32.2	66.9	22.5	35.5	17.7	23.2	0.125	49.0	37.5
drained)	002-023-07	C1	117-142	6.1	2.2	66.4	31.4	66.7	57.7	47.7	21.2	0.200	40.7	1697.5
Vandergrift	004-001-01	Ap	0-18	5.0	9.2	60.9	29.9	24.0	77.5	16.0	33.5	0.525	23.2	322.5
(Moderately	004-001-04	Bt3	41-58	5.1	3.3	27.9	68.8	66.5	38.5	21.5	38.5	0.075	51.5	162.5
well	004-001-08	C1	147-180	8.2	3.1	63.9	33.0	68.0	68.2	43.2	21.5	0.200	29.0	126.2
drained)														

Table 2. Cont. Selected soil characterization data and minor elements for the soil samples used in this study. Characterization data from Ciolkosz and Thurman (1992).

Soil and Drainage Class	Soil Number	Horizon	Depth in cm	pH	Percent			Parts Per Million						
					Sand	Silt	Clay	Cu	Zn	Ni	Pb	Cd	Cr	P
					Residual Calcareous Gray Shales									
Westmoreland	063-043-01	Ap	0-25	7.1	12.8	71.6	15.6	17.7	65.5	15.7	19.7	0.450	19.2	215.0
(Well	063-043-04	Bt2	53-74	4.6	21.0	48.6	30.4	22.5	67.0	20.0	14.5	0.200	28.2	130.0
drained)	063-043-07	C	127-147	4.7	41.5	46.5	12.0	21.5	85.2	26.2	14.5	0.200	32.7	257.5
Dormont	002-007-02	Ap	0-18	4.7	9.7	68.6	21.7	16.5	85.7	17.0	28.2	0.650	22.7	512.5
(Moderately	002-007-05	Bt2	38-48	5.3	11.5	59.2	29.3	29.5	66.2	19.5	17.2	0.350	22.5	272.5
well	002-007-08	Bw1	79-102	4.8	29.5	51.1	19.4	45.0	90.0	23.0	13.0	0.325	21.2	241.2
drained)														
Library	063-045-01	Ap	0-25	5.7	9.1	68.8	22.1	19.0	86.5	16.0	24.5	0.400	22.0	322.5
(Somewhat	063-045-04	Btg1	48-61	6.0	9.0	58.3	32.7	24.5	52.2	21.7	17.0	0.100	23.2	123.7
poorly	063-045-08	C1	124-132	6.8	5.0	39.5	55.5	45.5	62.7	34.2	18.2	0.250	19.2	105.0
drained)														
					Residual Limestones									
Duffield	014-074-01	A	0-18	5.3	6.8	75.9	17.3	14.0	85.0	13.0	34.5	0.325	25.0	601.2
(Well	014-074-05	Bt2	71-94	4.9	3.5	57.2	39.3	20.7	36.7	24.5	14.7	0.050	54.2	175.0
drained)	014-074-11	3C1	193-211	5.3	8.7	51.8	39.5	20.7	28.7	29.7	14.2	0.325	62.5	108.0
Duffield	036-017-01	Ap	0-18	5.8	11.7	69.9	18.4	14.2	48.0	12.0	20.7	0.225	26.0	402.5
(Well	036-017-03	Bt1	30-56	6.4	10.9	54.7	34.4	22.7	54.7	17.5	14.5	0.050	17.7	252.5
drained)	036-017-06	C	102-132	6.6	31.1	40.1	28.8	23.7	49.7	22.7	14.5	0.075	20.5	477.5
Hagerstown	014-005-01	Ap	0-23	5.7	6.0	70.0	24.0	13.8	40.5	15.5	17.5	0.125	20.7	450.0
(Well	014-005-04	Bt3	66-79	4.9	1.7	32.5	65.8	27.3	51.0	35.7	18.8	0.125	25.5	233.7
drained)	014-005-07	C	135-173	7.5	8.7	53.1	38.2	23.0	47.5	27.5	17.2	0.150	26.2	335.0
Hagerstown	014-007-01	Ap	0-25	6.1	16.5	72.2	11.3	18.5	48.0	13.5	24.0	0.250	22.5	477.5
(Well	014-007-05	Bt2	79-109	4.8	2.2	36.0	61.8	32.5	75.0	27.0	22.5	0.150	29.2	152.5
drained)	014-007-07	BC1	142-183	5.2	1.9	29.5	68.6	34.0	82.5	32.2	23.7	0.150	34.5	168.7
Hagerstown	014-014-01	Ap	0-30	6.7	1.5	87.2	11.3	11.5	40.7	12.0	19.0	0.225	19.7	495.0
(Well	014-014-04	Bt1	51-76	6.9	0.8	46.2	53.0	20.2	43.2	20.2	23.0	0.225	38.2	260.0
drained)	014-014-05	Bt2	76-102	7.5	1.0	41.6	57.4	20.5	43.8	20.5	21.0	0.225	34.7	240.0

Table 2. Cont. Selected soil characterization data and minor elements for the soil samples used in this study. Characterization data from Ciolkosz and Thurman (1992).

Soil and Drainage Class	Soil Number	Horizon	Depth in cm	pH	Percent			Parts Per Million						
					Sand	Silt	Clay	Cu	Zn	Ni	Pb	Cd	Cr	P
Hagerstown	014-066-01	A	0-8	5.5	4.7	77.2	18.1	18.2	34.0	10.0	16.7	0.050	13.0	351.2
(Well	014-066-05	Bt2	53-76	4.8	5.4	44.4	50.2	21.0	39.0	24.0	20.2	0.025	45.7	217.5
drained)	014-066-08	3C	112-178	7.5	3.3	65.2	31.5	26.7	67.5	39.0	18.5	0.075	53.0	227.5
Hagerstown	014-067-01	A	0-10	5.4	3.4	79.1	17.5	15.2	65.0	14.2	21.5	0.225	23.0	601.2
(Well	014-067-05	Bt2	53-76	4.8	2.9	40.7	56.4	24.5	40.2	43.2	14.7	0.050	74.0	257.5
drained)	014-067-08	3C2	137-155	7.9	9.0	56.0	35.0	12.0	15.5	23.0	12.7	0.025	28.5	201.3
Hagerstown	014-068-01	A	0-8	5.8	8.1	75.3	16.6	19.2	125.0	11.2	43.8	0.600	35.7	485.0
(Well	014-068-05	Bt2	61-84	5.8	20.2	45.9	33.9	20.2	32.0	37.2	9.7	0.075	73.7	231.2
drained)	014-068-08	3Cr1	140-160	6.6	19.2	51.4	29.4	26.2	36.0	36.7	12.0	0.025	82.7	342.5
Hagerstown	014-069-01	A	0-10	5.8	4.5	75.2	20.3	19.2	100.0	16.2	32.0	0.450	29.7	585.0
(Well	014-069-05	Bt2	53-69	5.1	3.5	38.6	57.9	27.0	49.7	44.5	16.2	0.150	71.5	248.7
drained)	014-069-08	3C	99-147	8.0	5.4	57.2	37.4	19.7	24.5	31.5	14.5	0.050	35.5	260.0
Hagerstown	014-070-01	A	0-8	5.3	10.8	73.9	15.3	18.8	117.5	12.2	39.7	0.550	35.0	633.7
(Well	014-070-06	3Bt3	66-89	5.3	7.4	51.0	41.6	19.2	29.0	20.7	19.0	0.050	61.5	151.2
drained)	014-070-09	3Bt6	160-183	5.7	1.7	43.9	54.4	23.2	42.0	33.7	14.2	0.050	70.5	175.0
Hagerstown	014-071-01	A	0-8	5.0	9.2	73.4	17.4	23.2	80.0	12.5	40.2	0.425	26.0	495.0
(Well	014-071-05	Bt2	61-86	5.3	2.7	41.0	56.3	26.2	36.2	32.5	21.5	0.025	68.2	112.5
drained)	014-071-07	3C	112-142	6.9	3.2	50.1	46.7	22.5	40.2	38.5	15.5	0.050	66.7	196.2
Hagerstown	014-072-01	A	0-8	5.4	9.4	74.6	16.0	19.7	125.0	12.0	42.5	0.550	27.5	523.7
(Well	014-072-05	Bt2	46-79	5.1	2.9	54.2	42.9	20.7	45.5	19.5	15.2	0.100	45.0	103.8
drained)	014-072-09	3BC	145-157	6.9	2.5	77.0	20.5	24.5	47.5	31.0	15.2	0.125	55.2	157.5
Hagerstown	014-073-01	A	0-8	5.4	9.8	73.8	16.4	14.0	77.5	12.7	24.5	0.225	21.5	433.8
(Well	014-073-05	Bt2	61-86	5.6	10.4	48.3	41.3	17.7	23.5	23.7	9.7	0.050	56.0	151.2
drained)	014-073-08	3C1	140-165	6.6	18.3	45.1	36.6	21.0	25.7	29.2	15.0	0.000	58.0	220.0
Hagerstown	014-075-01	A	0-10	6.6	10.3	73.2	16.5	18.5	127.5	11.0	46.5	0.675	37.2	544.0
(Well	014-075-05	3Bt2	61-86	5.4	3.8	38.4	57.8	22.7	37.0	25.5	17.5	0.850	55.0	93.8
drained)	014-075-08	3Bt5	150-160	7.5	4.3	42.6	53.1	20.7	32.2	26.0	14.7	0.200	54.7	105.0

Table 2. Cont. Selected soil characterization data and minor elements for the soil samples used in this study. Characterization data from Ciolkosz and Thurman (1992).

Soil and Drainage Class	Soil Number	Horizon	Depth in cm	pH	Percent			Parts Per Million						
					Sand	Silt	Clay	Cu	Zn	Ni	Pb	Cd	Cr	P
Hagerstown	014-080-01	A	0-8	4.9	19.2	73.4	7.4	16.7	75.0	12.5	77.5	0.600	19.5	486.2
(Well	014-080-05	Bt2	61-89	4.6	9.1	26.3	64.6	55.2	87.5	28.0	45.5	0.050	26.5	183.7
drained)	014-080-09	BC	183-254	4.9	4.1	45.5	50.4	36.0	46.7	19.5	24.5	0.000	21.2	167.5
Hagerstown	018-009-01	Ap	0-18	6.2	15.8	62.5	21.7	12.2	33.0	14.5	16.7	0.125	24.7	425.0
(Well	018-009-04	Bt3	38-53	6.0	4.9	19.2	75.9	33.0	46.2	39.7	19.0	0.150	71.7	308.7
drained)	018-009-06	BC	71-81	6.2	9.1	29.3	61.6	32.7	42.5	43.0	20.2	0.100	64.0	438.7
Hagerstown	018-010-01	Ap	0-15	6.0	19.3	64.1	16.6	10.7	33.0	11.5	32.7	0.125	19.5	210.0
(Well	018-010-05	Bt2	53-71	5.3	11.8	56.0	32.2	12.2	34.7	13.2	17.5	0.025	23.5	113.7
drained)	018-010-08	BC2	112-137	5.2	6.6	40.8	52.6	18.2	28.0	20.5	19.5	0.125	27.5	185.0
Hagerstown	022-006-01	Ap	0-23	6.5	1.6	62.2	16.2	19.2	75.0	14.5	52.5	0.300	26.0	643.7
(Well	022-006-05	Bt3	74-89	7.0	9.5	14.3	76.2	38.2	160.0	24.0	66.2	0.100	43.2	352.5
drained)	022-006-08	BC	147-152	6.7	2.8	19.2	78.0	38.5	170.0	34.7	46.7	0.250	43.0	561.2
Hagerstown	022-007-01	Ap	0-18	6.6	15.3	65.3	19.4	13.2	53.7	13.2	26.7	0.175	35.5	490.0
(Well	022-007-05	Bt3	64-71	6.8	26.9	42.3	30.8	23.0	50.7	19.7	31.7	0.100	43.0	290.0
drained)	022-007-09	BC	142-163	6.2	6.9	33.3	59.8	35.5	87.5	39.5	30.5	0.125	32.5	360.0
Hagerstown	036-014-01	Ap	0-20	7.0	14.2	63.2	22.6	15.7	40.7	11.7	20.0	0.100	43.0	665.0
(Well	036-014-04	Bt2	56-84	5.5	6.7	35.3	58.0	16.0	35.2	12.2	19.7	0.025	32.5	333.7
drained)	036-014-08	Bt6	163-190	4.9	8.3	59.4	32.3	10.2	29.0	7.7	19.0	0.000	30.5	262.5
Hagerstown	036-015-01	Ap	0-18	6.0	12.9	68.5	18.6	22.0	37.0	9.7	20.0	0.125	24.2	667.5
(Well	036-015-04	Bt2	58-84	6.8	9.7	31.2	59.1	20.7	50.2	18.5	21.5	0.175	34.5	527.5
drained)	036-015-07	BCt2	157-203	5.1	18.0	32.1	49.9	17.0	39.7	13.5	18.0	0.075	49.7	475.0
Hagerstown	036-019-01	Ap	0-25	6.0	11.2	64.3	24.5	12.5	38.0	12.0	23.7	0.150	33.5	442.5
(Well	036-019-04	Bt3	71-86	5.3	7.6	43.6	48.8	25.5	75.0	26.5	27.3	0.075	27.5	602.5
drained)	036-019-07	C1	142-168	5.1	9.0	47.7	43.3	24.2	95.0	26.0	23.5	0.100	28.2	378.7
Clarksburg	014-081-01	A	0-8	5.0	12.2	69.8	18.0	12.5	82.5	16.7	55.5	0.700	14.5	882.5
(Moderately	014-081-04	Bt	36-69	4.6	9.1	64.6	26.3	27.8	87.5	19.0	15.7	0.225	22.2	347.5
well	014-081-06	Bx2	104-140	5.0	23.5	57.5	19.0	35.7	45.7	19.0	15.2	0.150	27.0	342.5
drained)	014-081-10	2C3	223-259	4.7	20.8	44.0	35.2	18.5	34.5	18.0	17.7	0.225	33.7	330.0

Table 2. Cont. Selected soil characterization data and minor elements for the soil samples used in this study. Characterization data from Ciolkosz and Thurman (1992).

Soil and Drainage Class	Soil Number	Horizon	Depth in cm	pH	Percent			Parts Per Million						
					Sand	Silt	Clay	Cu	Zn	Ni	Pb	Cd	Cr	P
					Residual Acid Crystalline Rocks									
Chester	036-049-01	A	0-8	4.1	41.0	41.6	17.4	12.0	26.5	4.2	29.0	0.225	12.7	368.7
(Well	036-049-04	Bw1	36-56	4.5	47.2	33.7	19.1	23.2	25.0	7.5	9.2	0.050	21.0	362.5
drained)	036-049-08	3C2	135-152	5.4	79.2	18.4	2.4	22.2	8.5	3.5	6.5	0.075	17.5	376.2
	036-049-12	3C3	244-386	5.4	75.3	22.3	2.4	16.2	14.2	4.5	10.0	0.050	5.0	360.0
Chester	036-052-01	A	0-8	4.5	26.2	54.5	19.3	10.0	35.5	8.0	31.5	0.275	23.0	296.2
(Well	036-052-04	Bt1	33-48	5.0	27.7	41.4	30.9	17.2	29.5	9.5	14.0	0.150	41.7	241.2
drained)	036-052-07	2Bt4	97-119	5.8	52.6	21.1	26.3	18.8	12.5	5.7	14.7	0.225	37.0	257.5
	036-052-08	2Bt5	119-160	5.8	49.9	23.8	26.3	20.5	19.2	7.0	20.0	0.150	34.2	225.0
Chester	067-008-01	Ap	0-20	5.1	31.6	46.0	22.4	28.7	37.0	11.2	18.5	0.100	32.7	730.0
(Well	067-008-04	Bt2	53-66	6.9	37.6	30.8	31.6	45.7	27.5	10.7	16.5	0.050	38.0	452.5
drained)	067-008-06	C1	71-86	6.1	53.8	16.5	29.7	62.3	23.7	9.2	15.7	0.075	32.2	535.0
Chester	036-050-01	A	0-5	4.8	32.7	50.8	16.5	20.7	32.2	7.5	21.7	0.150	24.5	218.8
(Well	036-050-04	Bt	30-66	5.2	38.1	40.1	21.8	18.5	31.0	9.7	16.2	0.200	38.5	237.5
drained)	036-050-08	3Bt	157-203	5.7	41.4	29.1	29.5	21.2	26.7	8.0	16.2	0.150	38.0	262.5
	036-050-14	9C	328-338	5.6	43.6	22.2	34.2	28.2	41.2	13.0	28.7	0.250	33.0	197.5
Glenelg	006-011-02	A	0-12	4.3	45.3	35.5	19.2	9.5	72.5	7.0	39.5	0.225	10.2	610.0
(Well	006-011-05	Bt2	46-66	4.4	48.4	31.0	20.6	7.7	45.0	7.7	9.0	0.025	14.2	300.0
drained)	006-011-08	C1	124-160	4.6	69.1	19.6	11.3	10.7	36.5	1.8	4.7	0.075	1.0	220.0
	006-011-11	C4	246-322	4.3	60.2	31.8	8.0	9.0	49.2	2.7	4.5	0.050	5.7	285.0
Glenelg	036-027-01	Ap	0-25	7.3	51.6	34.2	14.2	13.0	29.5	8.8	13.5	0.200	14.7	156.3
(Well	036-027-02	Bt1	25-48	7.3	35.1	41.0	23.9	21.2	33.5	11.2	10.2	0.125	26.5	251.3
drained)	036-027-05	C1	84-107	7.1	61.0	35.3	3.7	35.0	33.7	11.7	8.8	0.175	14.7	201.3
Manor	036-028-01	Ap1	0-13	6.9	38.1	45.4	16.5	28.7	91.2	21.7	17.2	0.250	24.0	637.5
(Well	036-028-03	Bw	25-51	6.5	46.5	41.4	12.1	33.2	79.0	20.2	11.0	0.150	19.0	322.5
drained)	036-028-06	C1	84-94	7.2	59.7	36.0	4.3	12.0	68.0	16.7	9.7	0.150	10.7	86.2

Table 2. Cont. Selected soil characterization data and minor elements for the soil samples used in this study. Characterization data from Ciolkosz and Thurman (1992).

Soil and Drainage Class	Soil Number	Horizon	Depth in cm	pH	Percent			Parts Per Million						
					Sand	Silt	Clay	Cu	Zn	Ni	Pb	Cd	Cr	P
					Residual Basic Crystalline Rocks									
Neshaminy	009-051-01	Ap	0-18	6.6	20.2	57.4	22.4	71.5	85.0	45.7	21.5	0.175	141.0	647.5
(Well	009-051-03	Bt2	33-58	6.6	29.0	37.2	33.8	119.7	49.7	76.7	10.7	0.075	172.5	487.5
drained)	009-051-05	C	91-163	6.6	50.6	21.4	28.0	98.7	44.2	64.0	7.2	0.125	139.2	442.5
Neshaminy	046-013-01	Ap	0-15	5.9	25.4	57.2	17.4	68.5	71.2	57.5	15.2	0.200	112.0	558.7
(Well	046-013-05	Bt2	41-51	6.6	38.2	34.0	27.8	75.2	44.5	47.5	5.0	0.175	108.0	100.0
drained)	046-013-08	C1	84-99	7.0	60.4	25.2	14.4	87.0	36.5	43.2	4.2	0.225	62.7	190.0
Mount Lucas	001-016-01	Ap	0-20	6.5	19.7	68.1	12.2	16.5	34.0	19.2	13.0	0.100	134.5	265.0
(Moderately	001-016-04	Bt2	46-61	6.6	43.8	31.5	24.7	50.0	33.2	47.2	8.0	0.050	280.0	85.0
well	001-016-06	C	71-99	6.9	79.7	14.1	6.2	62.7	22.5	35.2	4.7	0.050	129.7	352.5
drained)														
Watchung	009-012-01	Ap	0-20	6.4	9.2	76.6	14.2	12.7	47.0	9.5	18.0	0.175	32.5	227.5
(Poorly	009-012-04	Btg3	53-71	7.0	14.8	55.3	29.9	36.2	38.0	25.7	11.2	0.025	104.2	52.5
drained)	009-012-06	Bx2	99-135	6.9	26.9	64.4	8.7	67.7	39.5	41.2	9.5	0.075	127.5	337.5
Watchung	009-013-01	Ap	0-18	6.3	5.6	70.0	24.4	17.2	70.0	20.7	24.5	0.250	94.2	430.0
(Poorly	009-013-04	Btg2	53-71	6.8	19.7	57.6	22.7	28.7	33.7	40.7	12.7	0.050	170.0	142.5
drained)	009-013-06	Bxg2	104-127	5.5	32.7	43.4	23.9	45.0	39.2	65.5	14.5	0.050	360.0	245.0
					Gray Acid Floodplain									
Pope	014-084-01	A	0-10	4.3	34.7	46.8	18.5	11.7	65.0	15.2	19.5	0.125	16.0	390.0
(Well	014-084-05	Bw3	61-86	4.1	30.2	47.6	22.2	13.2	82.5	17.5	11.0	0.075	18.8	285.0
drained)	014-084-08	2C1	114-142	4.9	51.9	31.3	16.8	19.5	77.5	23.7	18.2	0.250	19.5	455.0

Table 3. Median, minimum, and maximum values for extracted elements of surface (A) and subsurface (B or C) horizons by parent material origin.

Element	Parent Material	Surface Horizon				Subsurface Horizon			
		No.	Median	Minimum	Maximum	No.	Median	Minimum	Maximum
Fe, %	Glacial Till								
	brown Wisconsinan	4	1.32	0.80	1.82	9	1.80	1.30	2.58
	red Wisconsinan	3	2.20	1.88	3.40	6	2.18	1.77	2.62
	pre-Wisconsinan	2	--	0.78	2.08	4	2.38	1.57	3.27
	Colluvium	3	2.23	1.70	2.45	7	3.60	3.20	3.75
	Loess	3	1.70	1.57	2.60	6	2.78	2.45	3.20
	Residuum								
	sandstone	5	0.67	0.35	4.14	12	2.06	1.05	3.25
	gray acid shale	5	2.10	1.12	2.73	13	3.05	1.98	4.30
	red calcareous shale	2	--	1.25	3.93	4	4.09	1.90	5.55
	gray calcareous shale	3	2.92	2.27	3.02	6	3.30	1.93	4.15
	limestone	23	1.82	1.10	3.83	47	3.40	1.73	5.55
	acid crystalline	7	2.48	2.12	3.60	18	3.98	2.08	6.03
	basic crystalline	5	1.44	1.25	6.15	10	4.12	0.97	7.97
	Alluvium, acid floodplain	1	2.33	--	--	2	--	2.90	3.98
Al, %	Glacial Till								
	brown Wisconsinan	4	1.58	1.04	1.82	9	1.40	1.27	2.12
	red Wisconsinan	3	2.52	1.24	3.30	6	1.45	0.90	2.30
	pre-Wisconsinan	2	--	1.16	1.70	4	1.88	0.99	2.58
	Colluvium	3	1.98	1.52	2.08	7	2.08	1.57	2.73
	Loess	3	1.90	1.82	2.35	6	2.15	1.62	3.60
	Residuum								
	sandstone	5	1.29	0.33	1.68	12	1.01	0.51	2.27
	gray acid shale	5	1.95	1.37	2.27	13	2.27	1.43	3.25
	red calcareous shale	2	--	1.37	1.80	4	1.75	1.39	2.33
	gray calcareous shale	3	1.43	1.31	1.57	6	1.62	1.27	2.05
	limestone	23	1.25	0.78	1.91	47	2.59	0.95	4.18
	acid crystalline	7	1.88	1.01	2.52	18	2.92	0.40	4.78
	basic crystalline	5	2.30	1.17	4.80	10	3.64	2.33	6.95
	Alluvium, acid floodplain	1	1.16	--	--	2	--	1.24	1.30

Table 3. Cont. Median, minimum, and maximum values for extracted elements of surface (A) and subsurface (B or C) horizons by parent material origin.

Element	Parent Material	Surface Horizon				Subsurface Horizon			
		No.	Median	Minimum	Maximum	No.	Median	Minimum	Maximum
Mn, ppm	Glacial Till								
	brown Wisconsinan	4	595	407	1325	9	615	225	893
	red Wisconsinan	3	857	132	2350	6	601	280	930
	pre-Wisconsinan	2	--	227	317	4	186	15	627
	Colluvium	3	3975	1325	4250	7	410	235	1225
	Loess	3	665	428	843	6	295	72	435
	Residuum								
	sandstone	5	79	10	1300	12	232	39	1032
	gray acid shale	5	1750	957	2075	13	325	20	1225
	red calcareous shale	2	--	1450	1775	4	107	35	180
	gray calcareous shale	3	2125	1295	2400	6	762	557	1295
	limestone	23	1800	430	5150	47	385	135	1575
	acid crystalline	7	745	55	1202	18	196	31	1032
	basic crystalline	5	1235	375	1450	10	776	150	1220
	Alluvium, acid floodplain	1	585	--	--	2	--	485	522
Ca, ppm	Glacial Till								
	brown Wisconsinan	4	1185	245	1560	9	462	3	1147
	red Wisconsinan	3	1350	42	2372	6	545	70	1623
	pre-Wisconsinan	2	--	517	720	4	88	32	140
	Colluvium	3	1352	80	1385	7	295	42	1952
	Loess	3	745	542	785	6	381	200	622
	Residuum								
	sandstone	5	240	80	582	12	94	3	497
	gray acid shale	5	755	370	1550	13	115	3	500
	red calcareous shale	2	--	900	927	4	3331	1517	6375
	gray calcareous shale	3	1637	252	1873	6	716	367	2805
	limestone	23	1567	220	7125	47	977	210	132775
	acid crystalline	7	390	38	1255	18	111	5	1265
	basic crystalline	5	1462	1047	1777	10	2088	1192	10782
	Alluvium, acid floodplain	1	557	--	--	2	--	217	547

Table 3. Cont. Median, minimum, and maximum values for extracted elements of surface (A) and subsurface (B or C) horizons by parent material origin.

Element	Parent Material	Surface Horizon				Subsurface Horizon			
		No.	Median	Minimum	Maximum	No.	Median	Minimum	Maximum
Mg, ppm	Glacial Till								
	brown Wisconsinan	4	2487	1600	2900	9	3550	2825	3950
	red Wisconsinan	3	2950	1295	3025	6	3088	2400	3650
	pre-Wisconsinan	2	--	582	667	4	406	177	760
	Colluvium	3	1475	1325	2100	7	2300	1115	3100
	Loess	3	1950	1875	2000	6	2825	2550	3550
	Residuum								
	sandstone	5	225	63	1825	12	851	55	4350
	gray acid shale	5	1475	852	2725	13	2725	770	3875
	red calcareous shale	2	--	1192	1925	4	2538	1525	3100
	gray calcareous shale	3	1775	1377	2350	6	2500	1925	4425
	limestone	23	1475	441	21700	47	3075	685	78600
	acid crystalline	7	882	542	2625	18	812	25	2375
	basic crystalline	5	2100	1112	2750	10	2713	1725	7325
	Alluvium, acid floodplain	1	1475	--	--	2	--	1825	1875
Na, ppm	Glacial Till								
	brown Wisconsinan	4	48.8	44.2	89.7	9	62.7	42.0	89.5
	red Wisconsinan	3	76.0	35.2	92.5	6	55.0	38.0	78.0
	pre-Wisconsinan	2	--	51.7	56.5	4	55.2	34.5	85.2
	Colluvium	3	48.2	44.7	62.7	7	60.5	49.5	80.2
	Loess	3	87.2	59.5	110.5	6	101.0	78.0	124.7
	Residuum								
	sandstone	5	45.2	17.2	82.5	12	44.7	31.3	68.5
	gray acid shale	5	58.5	48.0	69.0	13	71.7	46.2	89.2
	red calcareous shale	2	--	67.7	110.0	4	121.4	113.5	147.5
	gray calcareous shale	3	56.3	55.7	64.2	6	70.5	51.5	109.5
	limestone	23	39.7	28.0	97.0	47	52.0	30.2	195.0
	acid crystalline	7	49.7	32.0	68.0	18	43.1	18.2	69.0
	basic crystalline	5	100.5	61.8	110.7	10	155.0	65.0	2050.0
	Alluvium, acid floodplain	1	56.5	--	--	2	--	53.5	57.5

Table 3. Cont. Median, minimum, and maximum values for extracted elements of surface (A) and subsurface (B or C) horizons by parent material origin.

Element	Parent Material	Surface Horizon				Subsurface Horizon			
		No.	Median	Minimum	Maximum	No.	Median	Minimum	Maximum
K, ppm	Glacial Till								
	brown Wisconsinan	4	908	635	1200	9	1200	725	1700
	red Wisconsinan	3	1675	495	1900	6	1231	520	2000
	pre-Wisconsinan	2	--	860	1025	4	902	335	1375
	Colluvium	3	1175	807	1475	7	2000	1050	3200
	Loess	3	113	101	1162	6	1462	1275	1700
	Residuum								
	sandstone	5	690	450	1525	12	820	537	1675
	gray acid shale	5	1105	835	1825	13	1625	1050	2750
	red calcareous shale	2	--	1475	2700	4	2675	2100	2800
	gray calcareous shale	3	1325	1070	1475	6	1763	1375	2350
	limestone	23	877	655	1475	47	1825	232	8450
	acid crystalline	7	680	375	930	18	652	117	1070
	basic crystalline	5	492	202	557	10	400	322	720
	Alluvium, acid floodplain	1	1325	--	--	2	--	932	1150
P, ppm	Glacial Till								
	brown Wisconsinan	4	572.5	457.5	645.0	9	442.5	237.5	532.5
	red Wisconsinan	3	592.0	138.0	659.0	6	197.5	56.3	375.0
	pre-Wisconsinan	2	--	250.0	412.5	4	160.0	32.5	355.0
	Colluvium	3	327.5	322.5	620.0	7	232.5	87.5	440.0
	Loess	3	377.5	267.5	395.0	6	240.0	83.7	362.5
	Residuum								
	sandstone	5	255.0	67.5	795.0	12	151.3	92.5	382.5
	gray acid shale	5	432.5	320.0	627.5	13	267.5	100.0	540.0
	red calcareous shale	2	--	252.5	322.5	4	144.0	93.8	1697.0
	gray calcareous shale	3	322.5	215.0	512.5	6	185.6	105.0	272.5
	limestone	23	495.0	210.0	882.5	47	255.0	36.2	602.5
	acid crystalline	7	368.7	156.3	730.0	18	260.0	86.2	535.0
	basic crystalline	5	430.0	227.5	647.5	10	217.5	52.5	487.5
	Alluvium, acid floodplain	1	390.0	--	--	2	--	285.0	455.0

Table 3. Cont. Median, minimum, and maximum values for extracted elements of surface (A) and subsurface (B or C) horizons by parent material origin.

Element	Parent Material	Surface Horizon				Subsurface Horizon			
		No.	Median	Minimum	Maximum	No.	Median	Minimum	Maximum
Cu, ppm	Glacial Till								
	brown Wisconsinan	4	12.0	9.5	12.7	9	22.5	9.5	25.7
	red Wisconsinan	3	11.5	8.5	16.2	6	17.0	8.2	22.2
	pre-Wisconsinan	2	--	12.0	12.2	4	13.5	10.2	31.3
	Colluvium	3	14.7	8.5	15.0	7	27.8	19.5	42.5
	Loess	3	11.7	11.0	12.5	6	19.0	13.8	25.2
	Residuum								
	sandstone	5	9.0	3.8	29.7	12	21.5	6.5	30.5
	gray acid shale	5	16.7	11.5	25.7	13	25.0	16.5	91.0
	red calcareous shale	2	--	16.5	24.0	4	66.6	22.5	68.0
	gray calcareous shale	3	17.7	16.5	19.0	6	27.0	21.5	45.5
	limestone	23	15.7	10.7	23.2	47	23.4	10.2	55.2
	acid crystalline	7	13.0	9.5	28.7	18	20.8	7.7	62.3
	basic crystalline	5	17.2	12.7	71.5	10	65.2	28.7	119.7
	Alluvium, acid floodp lain	1	11.7	--	--	2	--	13.2	19.5
Zn, ppm	Glacial Till								
	brown Wisconsinan	4	56.4	50.0	90.0	9	60.0	50.0	90.0
	red Wisconsinan	3	98.2	44.5	162.7	6	55.0	39.5	78.5
	pre-Wisconsinan	2	--	28.0	95.0	4	19.0	17.7	39.2
	Colluvium	3	48.7	48.7	64.5	7	49.5	39.2	140.0
	Loess	3	52.2	47.0	55.5	6	40.4	37.5	60.0
	Residuum								
	sandstone	5	35.0	7.2	87.5	12	39.2	11.5	92.5
	gray acid shale	5	84.7	77.5	112.5	13	82.5	37.2	252.5
	red calcareous shale	2	--	58.0	77.5	4	48.1	35.5	68.2
	gray calcareous shale	3	85.7	65.5	86.5	6	66.6	52.2	90.0
	limestone	23	65.0	33.0	127.5	47	45.6	15.5	170.0
	acid crystalline	7	35.5	26.5	91.2	18	30.2	8.5	79.0
	basic crystalline	5	70.0	34.0	85.0	10	38.6	22.5	49.7
	Alluvium, acid floodplain	1	65.0	--	--	2	--	77.5	82.5

Table 3. Cont. Median, minimum, and maximum values for extracted elements of surface (A) and subsurface (B or C) horizons by parent material origin.

Element	Parent Material	Surface Horizon				Subsurface Horizon			
		No.	Median	Minimum	Maximum	No.	Median	Minimum	Maximum
Ni, ppm	Glacial Till								
	brown Wisconsinan	4	15.0	13.5	16.0	9	19.7	17.0	26.0
	red Wisconsinan	3	12.5	8.2	15.0	6	14.4	13.0	22.5
	pre-Wisconsinan	2	--	5.7	6.5	4	7.2	4.7	14.0
	Colluvium	3	13.8	9.7	20.0	7	18.8	14.5	27.8
	Loess	3	10.5	10.5	11.2	6	12.8	10.7	15.5
	Residuum								
	sandstone	5	4.2	0.5	12.7	12	7.2	1.3	31.0
	gray acid shale	5	15.0	12.7	21.2	13	24.0	8.8	39.0
	red calcareous shale	2	--	16.0	18.0	4	32.4	17.7	47.7
	gray calcareous shale	3	16.0	15.7	17.0	6	22.4	19.5	34.2
	limestone	23	12.5	9.7	16.7	47	26.2	7.7	44.5
	acid crystalline	7	8.0	4.2	21.7	18	8.6	1.8	20.2
	basic crystalline	5	20.7	9.5	57.5	10	45.2	25.7	76.7
	Alluvium, acid floodplain	1	15.2	--	--	2	--	17.5	23.7
Pb, ppm	Glacial Till								
	brown Wisconsinan	4	23.5	18.2	44.0	9	16.0	12.0	18.8
	red Wisconsinan	3	15.7	9.5	47.5	6	10.1	2.7	42.2
	pre-Wisconsinan	2	--	11.7	18.5	4	9.6	5.2	15.5
	Colluvium	3	20.0	8.0	20.5	7	12.2	7.0	23.5
	Loess	3	21.2	16.0	23.0	6	11.6	8.5	18.2
	Residuum								
	sandstone	5	8.8	2.2	83.2	12	13.0	9.2	20.5
	gray acid shale	5	19.7	17.0	85.2	13	15.2	10.7	39.5
	red calcareous shale	2	--	33.5	35.0	4	22.4	21.2	38.5
	gray calcareous shale	3	24.5	19.7	28.2	6	15.8	13.0	18.2
	limestone	23	26.7	16.7	77.5	47	18.9	9.7	66.2
	acid crystalline	7	21.7	13.5	39.5	18	10.6	4.5	28.7
	basic crystalline	5	18.0	13.0	24.5	10	8.8	4.2	14.5
	Alluvium, acid floodplain	1	19.5	--	--	2	--	11.0	18.2

Table 3. Cont. Median, minimum, and maximum values for extracted elements of surface (A) and subsurface (B or C) horizons by parent material origin.

Element	Parent Material	Surface Horizon				Subsurface Horizon			
		No.	Median	Minimum	Maximum	No.	Median	Minimum	Maximum
Cd, ppm	Glacial Till								
	brown Wisconsinan	4	0.225	0.100	0.300	9	0.100	0.050	0.175
	red Wisconsinan	3	0.500	0.325	0.700	6	0.188	0.175	0.300
	pre-Wisconsinan	2	--	0.200	0.525	4	0.075	0.025	0.125
	Colluvium	3	0.175	0.150	0.275	7	0.150	0.075	0.200
	Loess	3	0.175	0.175	0.200	6	0.088	0.050	0.125
	Residuum								
	sandstone	5	0.200	0.025	0.400	12	0.025	0.025	0.125
	gray acid shale	5	0.375	0.300	0.525	13	0.100	0.025	0.325
	red calcareous shale	2	--	0.275	0.525	4	0.162	0.075	0.200
	gray calcareous shale	3	0.450	0.400	0.650	6	0.225	0.100	0.350
	limestone	23	0.225	0.050	0.700	47	0.100	0.000	0.850
	acid crystalline	7	0.225	0.100	0.275	18	0.138	0.025	0.250
	basic crystalline	5	0.175	0.100	0.250	10	0.062	0.025	0.225
	Alluvium, acid floodplain	1	0.125	--	--	2	--	0.075	0.250
Cr, ppm	Glacial Till								
	brown Wisconsinan	4	14.4	12.5	18.5	9	16.2	14.5	23.0
	red Wisconsinan	3	22.2	12.5	27.3	6	16.1	10.2	22.5
	pre-Wisconsinan	2	--	15.2	16.0	4	17.8	15.7	25.7
	Colluvium	3	17.5	15.2	19.2	7	28.7	25.7	35.2
	Loess	3	22.0	21.7	34.0	6	36.5	26.5	53.5
	Residuum								
	sandstone	5	7.5	1.3	22.2	12	12.2	2.7	33.2
	gray acid shale	5	21.2	16.7	30.0	13	32.0	21.0	40.0
	red calcareous shale	2	--	23.2	38.2	4	44.8	29.0	51.5
	gray calcareous shale	3	22.0	19.2	22.7	6	22.8	19.2	32.7
	limestone	23	25.0	13.0	43.0	47	36.4	17.7	82.7
	acid crystalline	7	23.0	10.2	32.7	18	23.8	1.0	41.7
	basic crystalline	5	112.0	32.5	141.0	10	134.4	62.7	360.0
	Alluvium, acid floodplain	1	16.0	--	--	2	--	18.8	19.5