The Impact of Golf Courses on Soil Quality

Annual Report to USGA, November, 1999

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Executive Summary

This project is monitoring soil quality criteria necessary to assess the long-term impact and sustainability of golf courses on the soil environment. Research was initiated in 1997-1998 at a time the future golf course site was in a natural grassland, or pre-construction condition. These field observations and sample collections were made to establish base-line values for a host of critical indicators of soil quality. Mapping of the area identified seven soil series on the golf course site.

During late 1998 and for most of 1999 the course was in the "construction phase". Extensive modification of the original soil occurred in all fairways. Essentially a new and different soil profile was produced. A base layer typically consisting of unweathered or slightly-weathered shale and fractured limestone was put in place to shape each fairway according to architects specifications. In some areas the base layer consisted of subsoil materials quite high in silt and clay content. After topsoil was put in place, and before the fairways were sodded, another set of samples was collected. Sodding finished in late 1999.

During the next several years the same sites will sampled each spring and fall. Our objective is to quantify indicators of soil quality and follow their change during the construction and establishment of a golf course on a natural grassland site. Changes in soil quality indicators will be described, quantified, and used to predict areas where future golf construction and/or management way require special attention.

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Objective: Our objective is to quantify indicators of soil quality and follow their change during the construction and establishment of a golf course on a natural grassland site. First, we will establish baseline values for critical indicators of soil quality prior to construction. Then, these same criteria will be monitored during four critical periods: post-construction/preseeding, grow-in, transition, and maturity. Changes in soil quality indicators will be described, quantified, and used to predict areas where future golf construction and/or management way require special attention.

Research Sampling and Analysis Timeline

I. Pre-construction period (1997 and 1998).

Sampling of the native soils was completed during this time periods and analysis of these samples is nearly completed. That data is attached.

Sample sites were selected using preliminary maps supplied by the golf course architect, Jeff Brauer. All sampling sites were geo-referenced for future identification.

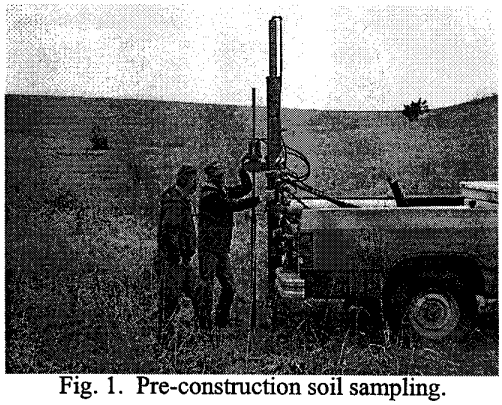

Fig. 1. Pre-construction soil sampling.

II. Post-construction/Pre-seeding (1999).

Fig. 2. Shale and limestone base layer on fairway.

Several changes were necessary in our sampling schedule and technique. Firstly, in several cases changes in the design of the course caused construction to encroach onto sites that the preliminary drawings showed would not be disturbed. This means we will need to re-locate our undisturbed sites and re-sample them to provide baseline information. This re-siting and re-sampling will occur in Fall, 1999 or Spring, 2000. A soil map of the Colbert Hills Golf Course has just been completed.

Extensive modification of the soil occurred in all fairways. Essentially a new and different soil profile was produced. A base layer typically consisting of unweathered or slightly-weathered shale and fractured limestone was put in place to shape each fairway according to architects specifications. In some areas the base layer consisted of subsoil materials quite high in silt and clay content.

Topsoil from on-site was stockpiled and additional topsoil was brought onto the course from several local sources. A 6-12 inch layer of topsoil was placed on the base layer and the fairways and roughs were sodded (a change from seeding indicated in earlier plans). Soil samples were collected from six fairway sites, in August and September, just prior to sodding. The location of these sites corresponded to our pre-construction sampling sites. Analyis of the 1999 samples has just begun.

Fig. 3. Topsoil cap in place on fairway #10.

Fig. 4. Sampling occurred just prior to sodding.

III. Research Schedule for 2000

Two sampling periods will be used in 2000, one in the spring and one in the fall. Sampling will follow earlier standards and techniques. Analysis will continue in the coming year on samples taken in 1999 and 2000.

IV. Data Sets Included

Table 1. Initial soil water content and microbial biomass C and N for the first soil horizon of the seven soils on Colbert Hills golf course.

Table 2. Initial soil water content and microbial biomass C and N for the second soil horizon of the seven soils on Colbert Hills golf course.

Table 3. Initial profile characteristics of the seven representative soils on Colbert Hills golf course.

Table 4. Mineralizeable C (C_o) and N (N_o) and the rate coefficients (K_c, K_n) for the representative soils on Colbert Hills golf course.

Table 5. Colbert Hills Soils Data: Particle size distribution, sand, silt, and clay distribution and textural class designation.

Table 6. Colbert Hills Soils Data: H_2O *p*H, 0.01 M $CaCl_2$ *p*H, total nitrogen (%), total carbon (%), calcium carbonate equivalency (%), exchangeable cations (H, Ca, Mg, K, Na me 100 g^{-1}), base saturation (%), coarse fragment (%), and organic carbon (%).

Table 1

Initial soil water content and microbial biomass C and N for the first soil horizon of the seven soils on the Colbert Hills Golf Course

Location	Depth cm	water content g H_2O g^{-1} Soil	MBM-C µg C g^{-1} soil	MBM-N µg N g^{-1} soil
Pit-31	0-12	0.24	1095	292
Pit-32	0-15	0.27	297	268
Pit-33	0-13	0.29	721	309
Pit-34	0-9	0.24	1045	340
Pit-35	0-10	0.20	728	216
Pit-36	0-11	0.22	1062	359
Pit-49	0-9	0.27	837	339

Table 2

Initial soil water content and microbial biomass C and N for the second soil horizon of the seven soils on the Colbert Hills Golf Course

Location	Depth cm	water content g H_2O g^{-1} Soil	MBM-C µg C g^{-1} soil	MBM-N µg N g^{-1} soil
Pit-31	12-25	0.21	444	125
Pit-32	15-29	0.25	376	103
Pit-33	13.23	0.23	243	99
Pit-34	9-27	0.21	216	111
Pit-35	10-25	0.23	461	123
Pit-36	11-33	0.21	832	237
Pit-49	9-29	0.27	665	171

Table 3

Initial profile characteristics of the seven representative soils on the Colbert Hills Golf Course

Location	Depth cm	Water Content g H_2O g^{-1} Soil	Initial N µg N g^{-1} soil	Total N g N kg^{-1} soil	Total C g C kg^{-1} soil	C:N ratio
pit 31	0-12	0.24	5.52	2.591	27.784	11
	12-25	0.21	1.02	1.771	19.564	11
	25-37	0.34	0.80	1.352	14.961	11
	37-47	0.24	1.04	1.010	10.308	10
	47-59	0.24	0.84	0.791	8.269	10
	59-88	0.23	0.64	0.648	6.090	9
	88-103	0.19	0.86	0.591	4.540	8
	103-124	0.19	0.52	0.525	4.823	9
	124-160	0.19	0.71	0.497	3.462	7
	160-203	0.20	1.20	0.438	2.724	6
pit 32	0-15	0.27	2.13	2.444	29.061	12
	15-29	0.25	0.50	1.492	18.512	12
	29-48	0.22	0.44	1.092	12.642	12
	48-77	0.25	0.15	1.357	15.501	11
	77-107	0.22	0.69	0.778	7.930	10
	107-127	0.21	1.64	0.582	5.532	10
	127-170	0.19	1.10	0.433	3.315	8
	170-196	0.22	1.22	0.385	2.304	6
	196-224	0.24	0.74	1.403	2.221	2

Table 3 continued

Location	Depth cm	Water Content g H_2O g^{-1} Soil	Initial N µg N g^{-1} soil	Total N g N kg^{-1} soil	Total C g C kg^{-1} soil	C:N ratio
pit 34	0-9	0.24	37.58	3.508	37.273	11
	9-27	0.21	1.26	1.364	14.170	10
	27-43	0.28	1.33	1.602	20.803	13
	43-59	0.27	1.22	1.501	20.616	14
	59-87	0.25	1.10	1.444	19.854	14
	87-109	0.23	0.84	1.058	14.487	14
	109-126	0.24	1.09	0.815	11.600	14
	126-145	0.22	1.51	0.652	6.746	10
	145-163	0.20	0.82	0.626	6.341	10
	163-180	0.17	0.47	0.559	5.486	10
pit 35	0-10	0.20	3.87	2.723	29.420	11
	10-25	0.23	0.74	1.698	19.364	11
pit 36	0-11	0.22	5.54	3.836	44.664	12
	11-33	0.21	1.06	2.941	45.445	15
	33-49	0.21	1.45	1.189	66.074	56
	49-67	0.17	2.81	0.652	47.282	73
	47-87	0.14	1.01	0.393	33.850	86
	87-122	0.19	0.71	0.265	42.807	162
	122-160	0.13	0.63	0.274	14.548	53
pit 49	0-9	0.27	1.12	0.329	4.024	12
	9-29	0.27	1.27	0.315	3.761	12
	29-40	0.29	8.33	0.176	1.799	10
	40-53	0.32	8.42	0.284	1.585	6

Table 4

Mineralizable C (C_0) and N (N_0) and the rate coefficients (K_C, K_N) for the representative soils on the Colbert Hills Golf Course

	K_c	C_0	K_n	N_o
Locations	d^{-1}	$\mu g\ C\ g^{-1}$ soil	d^{-1}	$\mu g\ N\ g^{-1}$ soil
Pit-31	0.00526	3717	0.00262	315
Pit-32	0.00480	4518	0.00394	241
Pit-33	0.00458*	4425*	0.00120!	801!
Pit-34	0.00300	5642	0.00219	705
Pit-35	0.00259	4112	0.00219	228
Pit-36	0.00274	6252	0	0
Pit-49	0.00616	3553	0.00139	568

* only two reps. fit the model
! only one rep. fit the model

Table 5. Colbert Hills Soils Data, Sept. 10, 1999

				Particle Size Distribution (% < 2 mm)														
				Sand: (mm)						Silt: (µm)				Clay: (µm)			
Sample				VCS	CS	MS	FS	VFS	TS	CSI	MSI	FSI	TSI	CC	FC	TC	Textural
#	Soil Series	Horizon	Depth,cm	2.00-1.00	1.00-0.50	0.50-0.25	0.25-0.10	0.10-0.05	2.00-0.05	50.0-20.0	20.0-5.0	5.0-2.0	50.0-2.0	2.0-0.2	<0.2	<2.0	Class
489	Tully	A1	0-12	3.9	1.4	0.5	0.6	4.8	11.2	38.5	16.8	5.4	60.7			28.2	sicl
490	97KS999-031	A2	12-25	0.2	0.3	0.2	0.3	6.3	7.3	38.6	18.4	3.6	60.6			32.2	sicl
491		BA	25-37	0.4	0.3	0.3	0.3	5.5	6.8	35.8	17.5	6.8	60.1			32.9	sicl
492		Bt1	37-47	0.2	0.2	0.3	0.4	4.0	5.1	30.1	17.2	5.5	52.8			42.1	sic
493		Bt2	47-59	0.0	0.1	0.2	0.4	3.3	4.0	27.0	18.1	5.3	50.4			45.6	sic
494		Bt3	59-88	0.0	0.1	0.1	0.3	2.9	3.4	28.9	18.5	5.5	52.9			43.7	sic
495		Bt4	88-103	0.0	0.0	0.1	0.2	2.9	3.2	30.2	21.1	5.3	56.6			40.4	sic
496		2Btk	103-124	0.1	0.2	0.1	0.3	4.2	4.9	32.4	21.4	5.9	59.7			35.4	sicl
497		2Bt1-up	124-128	0.1	0.1	0.1	0.4	6.0	6.7	31.8	19.5	5.9	57.2			36.2	sicl
498		2Bt1-low	128-160	0.1	0.1	0.1	0.5	6.4	7.2	33.6	18.7	5.1	57.4			35.5	sicl
499		2Bt1-up	160-177	0.1	0.1	0.1	0.5	5.3	6.1	34.1	19.4	4.8	58.3			35.7	sicl
500		2Bt1-low	177-203+	0.0	0.1	0.2	0.6	5.3	6.2	5.7	19.7	4.8	60.2			33.6	sicl
501	Tully	A1	0-15	0.6	0.5	0.6	0.8	6.7	9.2	39.8	19.3	4.8	63.9			27.0	sil/sicl
502	97KS999-032	A2	15-29	0.7	1.0	0.6	0.7	6.0	9.0	7.4	18.9	6.4	82.7			28.5	sicl
503		AB	29-48	0.1	1.3	1.2	1.1	6.5	10.2	34.5	18.0	5.4	57.9			32.0	sicl
504		2Bw	48-77	0.3	0.4	0.3	0.4	5.2	6.6	35.2	19.4	6.7	61.0			32.2	sicl
505		2Bt1	77-107	0.3	0.2	0.2	0.2	4.4	5.5	37.9	19.5	5.0	61.9			33.5	sicl
506		2Bt2	107-127	0.2	0.3	0.2	0.2	3.6	4.5	36.9	21.7	3.9	62.5			33.1	sicl
507		2Bt3	127-170	0.0	0.2	0.2	0.3	2.8	3.5	32.6	25.0	5.2	62.8			33.7	sicl
508		2Bt4	170-196	0.0	0.2	0.3	0.4	4.4	5.3	33.4	22.5	5.2	61.1			33.3	sicl
509		2Bt5	196-224	0.0	0.1	0.2	0.3	4.1	4.7	33.7	23.5	5.3	62.5			33.0	sicl
510	Kahola	A1	0-13	0.0	0.2	0.2	0.5	8.7	9.6	39.2	18.8	4.9	62.9			27.7	sicl
511	97KS999-033	A2	13-23	0.1	0.2	0.4	1.0	8.3	10.0	34.2	20.8	5.1	60.1			30.0	sicl
512		AC	23-36	0.0	0.1	0.2	1.1	9.5	10.9	43.0	15.5	5.0	63.5			25.7	sil
513		C1-up	36-56	0.0	0.1	0.2	1.0	9.8	11.1	42.9	16.6	4.7	64.2			24.8	sil
514		C1-low	56-77	0.0	0.3	0.7	1.3	9.1	11.4	40.7	15.8	5.3	61.8			26.9	sil/sicl
515		C2-up	77-91	0.4	1.2	1.4	1.6	10.4	15.0	38.6	15.8	5.9	60.3			24.8	sil
516		C2-low	91-124	0.0	0.1	0.2	0.7	10.9	11.9	46.4	14.0	4.6	65.0			23.2	sil
517		Ab1	124-140	0.0	0.2	0.4	0.9	8.9	10.4	42.1	16.9	6.2	65.2			24.5	sil
518		Ab2	140-170	0.1	0.3	1.0	1.0	6.3	8.5	35.8	21.6	7.6	64.9			26.7	sil
519	Kahola	A1	0-9	0.5	1.2	0.8	0.8	6.6	9.9	35.2	17.4	4.7	57.3			32.9	sicl
520	97KS999-034	A2	9-27	0.6	1.6	1.0	1.0	8.3	12.5	38.6	16.8	5.2	60.6			26.9	sil/sicl
521		Ab1	27-43	0.1	0.4	0.4	0.5	5.4	6.8	36.7	18.6	4.8	60.1			33.2	sicl
522		Ab2	43-59	0.3	0.6	0.5	0.6	4.4	6.4	64.1	22.6	8.9	65.6			28.0	sicl
523		ABkb	59-87	0.4	0.6	0.5	0.7	5.4	7.6	35.7	21.4	8.0	65.1			27.5	sicl
524		Bkb	87-109	0.2	0.4	0.5	0.7	6.1	7.9	34.6	24.5	6.3	65.4			26.7	sil
525		2Bwb1	109-126	0.4	0.7	0.5	0.5	5.4	7.5	36.6	16.3	6.1	58.9			33.6	sicl
526		2Bwb2	126-145	0.8	0.8	0.4	0.4	4.8	7.2	34.3	21.0	5.8	61.0			31.9	sicl
527		2Bwb3	145-163	0.3	0.5	0.4	0.4	4.9	6.5	35.5	19.6	6.4	61.5			32.0	sicl
528		2Bwb4	163-180	0.6	0.7	0.5	0.5	4.3	6.6	33.3	20.2	6.6	60.1			33.3	sicl
529	Konza	A1	0-10	0.0	0.1	0.2	0.3	3.2	3.8	41.1	26.3	7.6	75.0			21.2	sil
530	97KS-999-035	A2	10-17	0.0	0.1	0.2	0.3	3.7	4.3	37.3	23.5	6.4	67.2			28.5	sicl
531		Bt1	27-25	0.0	0.1	0.2	0.3	3.3	3.9	27.4	21.2	6.1	54.7			41.4	sic
532		Bt2	25-43	0.0	0.2	0.2	0.3	3.8	4.5	26.4	22.1	6.6	55.1			40.4	sic
533		2Bt3	43-56	0.0	0.4	0.5	0.6	5.9	7.4	36.0	23.1	5.3	64.4			28.2	sicl
534		2Bt4	56-68	0.1	0.6	0.7	0.7	7.0	8.4	36.3	21.8	5.6	63.7			27.9	sicl
535		2Bt5	68-87	0.4	0.6	0.4	0.5	7.6	9.5	34.1	19.1	4.8	58.0			32.5	sicl
536		3Bt6	87-101	0.5	0.7	0.5	0.4	6.6	8.7	33.3	14.8	3.6	51.7			39.6	sicl
537		3Bt7	101-120	0.5	0.7	0.5	0.4	6.6	8.7	28.6	11.7	3.2	43.5			47.8	sic
538		3Bt8	120-144	0.7	1.3	1.0	0.7	9.7	13.4	33.4	8.6	2.3	44.3			42.3	sic
539		3Bt9	144-161	0.6	0.5	1.3	1.1	12.6	16.1	31.5	13.5	3.3	48.3			35.6	sicl
540		4Bt10	161-181	0.3	1.6	1.0	1.4	4.7	9.0	16.2	16.1	8.8	43.1			47.9	sic
541		5R	181-186	R material													
542	Clime	A1	0-11	1.1	0.7	0.4	0.4	4.0	6.6	27.8	18.6	6.2	52.6			40.9	sic
543	97KS-999-036	A2	11-33	4.9	2.1	0.7	0.6	2.4	10.7	16.6	18.0	10.0	44.6			44.8	sic
544		Bw1	33-49	9.3	4.0	1.1	1.0	1.8	17.2	10.8	24.4	16.9	52.0			30.9	sicl
545		Bw2	49-67	0.4	1.2	1.2	1.5	1.7	6.0	8.9	30.3	22.6	61.8			32.2	sicl
546		2Bck1	67-87	0.1	0.2	0.4	0.7	1.0	2.4	6.7	25.8	27.7	60.1			37.5	sicl
547		2Bck2	87-122	0.1	0.2	0.5	1.0	0.8	2.5	8.5	25.5	22.4	56.3			41.2	sic
548		2Cr	122-160	0.3	0.4	0.3	0.4	1.1	2.5	20.3	30.5	14.9	65.7			31.8	sicl
549	Tuttle	A1	0-15	1.5	2.0	1.2	1.0	3.4	9.1	24.3	17.8	9.8	51.9			39.1	sicl
550	97KS161-047	A2	15-43	2.8	3.2	2.2	2.7	3.8	14.7	15.2	19.1	13.7	48.0			37.4	sicl
551		2Bw1	43-58	1.0	7.3	3.4	4.4	3.0	19.1	18.2	24.4	17.5	60.1			21.0	sil
552		2Bw2	58-110	1.7	3.7	3.3	4.7	3.0	16.4	8.3	28.3	19.4	56.0			27.7	sicl
553		2Cr	58-110	5.6	6.1	5.0	7.7	4.7	29.1	7.5	27.0	19.0	53.5			17.5	sil
554		3BC	110-120	0.7	2.0	1.7	2.0	1.6	8.0	9.0	33.8	24.0	66.8			25.3	sil
555		3Cr	120-160	0.2	1.5	2.2	2.5	2.1	6.0	11.1	31.0	25.6	67.7			26.6	sil
556	Florence	A1	0-10	2.0	1.1	0.5	0.6	5.6	9.8	37.3	18.9	4.2	60.4			29.9	sicl
557	97KS161-048	A2	10-28	0.1	0.2	0.3	0.5	6.4	7.5	32.9	20.6	6.3	59.8			32.8	sicl
558		Bt	28-53	2.1	1.6	0.8	0.6	1.3	6.4	14.5	10.3	9.3	34.1			59.5	c
559	Benfield	A1	0-9	0.7	0.4	0.3	0.4	2.4	4.2	29.3	17.4	9.0	55.7			40.2	sic
560	97KS161-049	A2	9-29	2.2	0.9	0.5	0.6	1.7	5.9	19.0	12.7	8.7	40.4			53.7	sic
561		2Bt1	29-40	1.4	1.2	0.7	1.1	1.4	5.8	14.1	10.8	9.8	34.7			59.7	c
562		2Bt2	40-53	1.6	1.2	0.7	1.1	1.3	5.9	12.9	11.4	10.2	34.4			59.8	c
563		2Bt3	53-78	1.7	2.3	2.4	4.2	9.8	20.4	23.7	11.0	6.1	40.8			38.8	cl
		3Cr	78-100														

Table 6. Colbert Hills Soils Data, Sept. 10, 1999

Sample #	soil series	Horizon	Depth,cm	pH: H_2O (1:1)	pH: 0.01M $CaCl_2$ (2:1)	Total Nitrogen (%)	Total Carbon: (%)	Carbonates: CCE (%)	Extractable Cations (meq/100g soil) H	Ca	Mg	K	Na	Sum Bases	Sum Cations	Base Sat. %	Coarse Frag. (%) (by wt.)	Organic Carbon % Calculated
489	Tully	A1	0-12	6.2	5.6	0.2710	3.380	1.5	6.1	12.6	2.61	2.48	0.15	17.9	23.9	74.67	~	3.2
490	97KS999-031	A2	12-25	6.3	5.5	0.1550	2.040	1.3	4.9	11.8	3.69	1.08	0.04	16.6	21.5	77.02	~	1.884
491		BA	25-37	6.4	5.6	0.1280	1.650	1.5	6.5	10.7	2.37	0.83	0.09	14.0	20.5	68.36	0.8	1.47
492		Bt1	37-47	6.4	5.5	0.1050	1.290	2.2	5.6	14.0	5.59	0.79	0.02	20.4	26.0	78.45	2.5	1.026
493		Bt2	47-59	6.5	5.5	0.0823	0.891	1.8	6.3	16.9	6.85	0.73	0.15	24.6	30.9	79.55	~	0.675
494		Bt3	59-88	6.8	5.8	0.0676	0.696	1.3	4.1	18.1	6.89	0.69	0.2	25.9	29.9	86.45	~	0.54
495		Bt4	88-103	7.3	6.4	0.0645	0.573	2.9	2.4	19.4	5.8	0.6	0.2	26.0	28.4	91.44	~	0.225
496		2Btk	103-124	7.9	7.2	0.0555	0.454	2.5		18.1	4.33	0.52	0.21	23.1	23.1	100	3.9	0.154
497		2Bt1-up	124-128	7.9	7.2	0.0634	0.564	2.0		16.3	4.5	0.24	0.14	21.2	21.2	100	0.1	0.324
498		2Bt1-low	128-160	7.9	7.0	0.0536	0.404	2.3		15.6	4.6	0.49	0.14	20.8	20.8	100	~	0.128
499		2Bt1-up	160-177	7.9	7.0	0.0499	0.406	1.5		14.9	4.61	0.56	0.28	20.3	20.3	100	~	0.226
500		2Bt1-low	177-203+	7.9	7.0	0.0466	0.383	2.3		14.2	4.56	0.49	0.13	19.4	19.4	100	~	0.107
501	Tully	A1	0-15	6.4	5.6	0.2050	2.760	1.5	3.7	13.3	3.42	0.87	0.06	17.6	21.3	82.76	2.2	2.58
502	97KS999-032	A2	15-29	6.3	5.4	0.1410	1.900	2.5	4.9	14.1	4.06	0.53	0.05	18.7	23.6	79.36	2.5	1.6
503		AB	29-48	6.8	5.5	0.0993	1.260	1.5	4.3	14.1	3.4	0.59	0.1	18.2	22.5	80.81	10.0	1.08
504		2Bw	48-77	6.5	5.5	0.1190	1.500	2.3	5.8	11.4	0.67	3.47	0.13	15.7	21.5	72.89	1.4	1.224
505		2Bt1	77-107	6.5	5.6	0.0767	0.900	2.0	3.9	11.5	3.77	0.65	0.13	16.0	19.9	80.45	~	0.66
506		2Bt2	107-127	6.6	5.5	0.0600	0.626	2.0	3.9	13.3	4.56	0.59	0.14	18.6	22.5	82.69	~	0.386
507		2Bt3	127-170	6.7	5.7	0.0440	0.368	1.5	1.9	13.2	4.6	0.56	0.14	18.5	20.5	90.49	~	0.188
508		2Bt4	170-196	6.8	5.8	0.0390	0.347	1.5	1.1	13.4	4.61	0.57	0.15	18.8	19.8	94.54	~	0.167
509		2Bt5	196-224	6.8	5.8	0.0389	0.334	1.8	1.7	21.1	2.6	1.38	0.12	25.2	26.9	93.58	~	0.118
510	Kahola	A1	0-13	7.3	6.7	0.2360	2.860	1.5	1.3	19.1	2.34	0.83	0.04	22.3	23.6	94.51	~	2.68
511	97KS999-033	A2	13-23	7.7	7.0	0.1190	1.250	2.0	3.2								~	1.01
512		AC	23-36	8.2	7.5	0.7590	0.926	11.8									~	-0.49
513		C1-up	36-56	8.3	7.5	0.0812	1.020	3.7									~	0.576
514		C1-low	56-77	8.3	7.5	0.0837	1.190	5.2									~	0.566
515		C2-up	77-91	8.3	7.5	0.0939	1.390	4.9									~	0.802
516		C2-low	91-124	8.3	7.4	0.0806	1.240	3.9									~	0.772
517		Ab1	124-140	8.1	7.3	0.1050	1.660	2.3									~	1.384
518		Ab2	140-170	8.0	7.4	0.1300	2.310	5.4	0.3								~	1.662
519	Kahola	A1	0-9	8.1	6.9	0.2410	2.890	3.4	1.1	20.9	2.68	1.17	0.03	24.8	25.9	95.83	~	2.482
520	97KS999-034	A2	9-27	7.8	7.4	0.1150	1.470	4.4	0.4								0.1	0.942
521		Ab1	27-43	8.0	7.2	0.1470	2.160	2.5									~	1.86
522		Ab2	43-59	8.1	7.3	0.1360	2.020	3.0									~	1.66
523		ABkb	59-87	8.1	7.4	0.1200	1.920	3.7									~	1.476
524		Bkb	87-109	8.2	7.5	0.0836	1.290	3.0									~	0.93
525		2Bwb1	109-126	8.2	7.5	0.0651	0.787	3.2									~	0.403
526		2Bwb2	126-145	7.9	7.5	0.5700	0.636	2.7	2.4								3.4	0.312
527		2Bwb3	145-163	7.9	7.4	0.0603	0.654	1.8	1.9								1.2	0.438
528		2Bwb4	163-180	7.9	6.6	0.0578	0.589	2.3	2.9	22	2.71	1.17	0.02	25.9	28.8	89.85	1.2	0.313
529	Konza	A1	0-10	6.1	5.2	0.2570	3.280	1.8	7.1	11.1	4.38	0.93	0.25	16.6	23.8	69.99	~	3.064
530	97KS-999-035	A2	10-17	6.0	4.8	0.1610	2.090	2.8	7.8	9.23	4.97	0.3	0.49	15.0	22.8	65.84	~	1.754
531		Bt1	27-25	6.2	5.0	0.1330	1.560	5.6	8.1	12.8	7.97	0.54	0.81	22.2	30.3	73.17	~	0.888
532		Bt2	25-43	7.0	5.7	0.1100	1.190	2.3	9.4	13.7	8.68	0.5	1.09	23.9	33.3	71.77	~	0.914
533		2Bt3	43-56	7.3	7.3	0.0653	0.640	1.5	3.5	9.66	5.88	0.32	0.95	16.8	20.3	82.92	~	0.46
534		2Bt4	56-68	7.9	7.5	0.0395	0.391	2.0									~	0.151
535		2Bt5	68-87	8.2	7.7	0.0312	0.241	1.5									~	0.061
536		3Bt6	87-101	8.4	7.8	0.0325	0.274	2.3									2.9	-0.002
537		3Bt7	101-120	8.2	7.8	0.0303	0.178	2.3									4.1	-0.098
538		3Bt8	120-144	8.1	7.8	0.0249	0.166	2.3									1.9	-0.11
539		3Bt9	144-161	8.0	7.8	0.0202	0.086	15.1									1.3	-1.7261
540		4Bt10	161-181	7.9	7.8	0.0253	0.100	2.0									3.2	-0.14
541		5R	181-186	R material													~	0
542	Clime	A1	0-11	7.8	7.5	0.3390	4.620	2.5									29.2	4.32
543	97KS-999-036	A2	11-33	8.0	7.5	0.2430	5.070	15.8									*48.8	3.174
544		Bw1	33-49	8.0	7.6	0.1060	5.870	36.1									21.6	1.538
545		Bw2	49-67	8.3	7. 8	0.0677	4.790	36.1									~	0.458
546		2Bck1	67-87	8.4	7.7	0.0344	3.930	29.4									+	0.402
547		2Bck2	87-122	8.2	7.7	0.0294	3.610	31.7									+	-0.194
548		2Cr	122-160	8.3	7.7	0.0303	1.160	13.7									~	-0.484
549	Tuttle	A1	0-15	8.1	7.6	0.3930	6.040	18.3									25.8	3.844
550	97KS161-047	A2	15-43	8.1	7.7	0.2520	6.860	32.7									28.5	2.936
551		2Bw1	43-58	7.9	7.5	0.1190	8.460	58.7									13.0	1.416
552		2Bw2	58-110	8.0	7.6	0.0868	6.510	49.3									*13.0	0.594
553		2Cr	58-110	7.9	7.6	0.0368	8.650	71.7									~	0.046
554		3BC	110-120	8.2	7.7	0.0369	5.040	41.4									~	0.072
555		3Cr	120-160	8.1	7.7	0.0270	4.430	37.9									~	-0.118
556	Florence	A1	0-10	6.0	5.5	0.4040	4.960	1.5	14.6	13.2	3.01	1.69	0	17.9	32.5	55.1	27.6	4.78
557	97KS161-048	A2	10-28	5.5	5.3	0.2690	3.110	7.2	13.6	15.5	3.43	1.56	0.02	20.5	34.1	60.05	*42.9	2.246
558		Bt	28-53	5.6	5.8	0.2340	2.620	0.8	12.3	25	7.14	1.58	0.02	33.7	46.1	73.2	+	2.524
559	Benfield	A1	0-9	5.8	5.8	0.2810	3.620	0.0	12.0	23.3	4.01	1.06	0.08	28.5	40.5	70.33	7.8	3.62
560	97KS161-049	A2	9-29	6.0	5.8	0.2160	2.590	0.8	9.4	28.6	4.02	0.81	0.12	33.6	43.0	78.13	30.5	2.494
561		2Bt1	29-40	6.5	6.1	0.1800	2.070	3.0	9.4	33.9	3.34	0.85	0.13	38.2	47.6	80.27	5.8	1.71
562		2Bt2	40-53	6.6	6.3	0.1610	1.840	2.8	8.4	35.7	2.7	0.84	0.9	39.29	47.7	82.34	~	1.504
563		2Bt3	53-78	7.9	7.5	0.1110	6.080	42.2									53.4	1.016

~no analysis done-little to no coarse fragment material was sampled
* Does not reflect field values-large size fragments were not sampled
+ Unable to complete Coarse fragment analysis despite large amounts