CHANGES IN CHEMICAL AND PHYSICAL PROPERTIES OF TWO SOILS IN THE PROCESS OF SURFACE MINING[1/]

R.I. Barnhisel, J.L. Powell, and D.H. Hines[2/]

Abstract.--Two soils were extensively sampled prior to and following reconstruction. Two methods, end-dump truck and scraper pans, were used either by transporting the soil directly or temporarily stockpiling it before reconstruction. It appears changes in organic matter and Bray P may be the most sensitive parameters to determine if mixing of horizons occurred during soil removal and/or reconstruction, whereas changes in pH may be the least reliable measure.

INTRODUCTION

Research on methods, management, and limitations of restoration of prime farmland following surface mining has been the focus of our attention for the past few years. We have initiated several studies and some of these were combined into a general paper, Powell et al., 1985. In addition, earlier articles have been published in which initial or preliminary data were given (Barnhisel et al., 1979; Huntington et al., 1980; and Barnhisel, 1983). From these studies, as well as from research conducted in other states (e.g., Albrecht, 1984), it is apparent that soil compaction may be the most limiting factor in the return of prime farmland to its original productivity. However, conditions typical for most prime land soils in western Kentucky are not like those encountered in Illinois, Iowa, Missouri, and to some extent, Indiana. Prime farmland soils in these states usually have thicker A horizons, higher organic matter contents, more fertile, non-acidic subsoils, and deeper effective rooting depths than those typical of the soils encountered by surface mining in western Kentucky.

The objective of the research reported here was to evaluate soil handling methods as they relate to reconstruction of two contrasting, but typical, prime farmland soils in western Kentucky. This paper should be viewed as a progress report and conclusions are tentative. Unfortunately, it was not possible to complete all the analyses needed to evaluate how some of the chemical and physical properties changed over time.

METHODS

Soil Characterization

Within an area to be surface mined that contained prime farmland, it was determined that two soil series were dominant, namely Belknap and Zanesville. The Belknap soil is an Aeric, Flavaquent, coarse-silty, mixed, acid, mesic, whereas the Zanesville is a Typic, Fragiudalf, fine-silty, mixed, mesic. However, in the early stages of sampling prior to mining, it was determined that the Zanesville soil was mismapped and it really was a Sadler which is a Glossic, Fragiudalf, fine-silty, mixed, mesic; however, this latter soil is also considered to be a prime farmland series. The main differences between the Glossic versus Typic (Fragiudalf) are that the former has few or no clay films above the fragipan and in the case of the Sadler, the argillic horizon is thinner.

The two soils were extensively sampled prior to removal and following reconstruction when the surface mining process had been completed. Ten equally-spaced sites were cored per acre. At each site, two cores were extracted to a depth of about 40 inches with a Giddings® hydraulic probe. One core was subdivided at horizonal boundaries. These horizons were described with respect to physical characteristics, and each sample was analyzed for various chemical and physical properties.

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[2] Richard I. Barnhisel, Professor of Agronomy, University of Ky., Lexington, KY. 40546-0091; James L. Powell, Senior Reclamation Specialist, Peabody Coal Co., P.O. Box 545, Greenville, KY. 42345; and former Graduate Assistant, University of Kentucky, respectively.

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The other core was divided into 6-inch increments, regardless of horizon, and the bulk density was determined on a portion of this 6-inch segment having a length of about 4 inches. The exact length and diameter of each core was measured to the nearest 0.001 inch. The samples were oven dried and the bulk densities calculated.

The samples collected by soil horizon or by depth from both pre-mining soils and following soil reconstruction were characterized with respect to soil structure, color, and drainage models in the moist state. The samples were then air dried and crushed to pass a 2 mm sieve. The texture was determined using the standard pipette method. The pH was measured as a 1:1 weight of soil to volume of deionized water using a pH meter equipped with glass and calomel electrodes. Exchangeable cations were extracted with neutral normal ammonium acetate and determined on an atomic spectrometer. Exchangeable acidity was determined following extraction with 1 M KCl. The Bray-1P test was used to characterize the available phosphorus levels. Organic matter and total nitrogen were determined using a Kjeldahl technique.

Soil Reconstruction

The Sadler soil was removed and reconstructed in three separate lifts that represented the three significantly different horizons, the Ap, B2t, and Bx horizons, respectively. The Belknap contains two distinctive horizons, Ap and B2, and removal and reconstruction was done in two lifts. Table 1 shows the approximate depths and associated horizons removed and subsequently restored for the two soil series.

Table 1.--Horizon designation and horizon depths of the Sadler and Belknap soils.

Soil Series	Horizon	Depth from surface (in)
Sadler	Ap	0 - 7
Sadler	B2t, A'2	7 - 25
Sadler	Bx	25 - 40
Belknap	Ap	0 - 8
Belknap	B21, B22g, B23g	8 - 36

The experimental treatments have been assigned letters to be used throughout the following text.

BU: Belknap undisturbed
BTD: Belknap, truck with direct respread.
BSD: Belknap, scrapers with direct respread.
BSD: Belknap, truck with stockpiling phase.
BSS: Belknap, scrapers with stockpiling phase.
SU: Sadler undisturbed
STD: Sadler, truck with direct respread.
SSD: Sadler, scrapers with direct respread.
STS: Sadler, truck with stockpiling phase.
SSS: Sadler, scrapers with stockpiling phase.

The general sequence in the reconstruction of the soil was as follows. A suitable area of overburden spoil materials from above the No. 9 coal bed on Peabody's Gibraltar Surface Mine in Muhlenberg Co., Kentucky, was graded to about 3-4 percent slope. For the truck method, dozers pushed the appropriate soil horizons into mini-stockpiles. A 17 cu. yd. endloader was used to place this soil into 50-ton end-dump trucks. The soil was transported either to a storage stockpile (treatments 3 and 7) or directly to the soil reconstruction site (treatments 1 and 5). Later when the stockpiles were to be transported, the same equipment was used. After all the soil of each horizon had been moved to the reconstruction site, dozers were used to level it to a uniform thickness before the next horizon was transplanted. For the Sadler soil, three layers were replaced over the spoil; the Bx on the bottom; the mixture of B2t, A'2 next; and the Ap on the top. For Belknap, soil reconstruction was done in two lifts, the mixture of the various B2 horizons on the bottom lift and the Ap placed on top.

The scraper method was similar to the truck method except 24 cu. yd. twin-engine scraper pans were used. The direct-haul scraper treatments were 2 and 6, with the stockpiled treatments being 4 and 8. Each soil lift was leveled prior to placement of the next. The eight soil reconstruction treatments were placed adjacent to each other, and each was approximately 70 x 320 feet. The soil relocation phase was completed in the spring of 1983.

Three test crops have been used to evaluate this experiment: corn, soybeans, and alfalfa. These crops were established in strips perpendicular to the main treatment blocks of reconstructed soil. Alfalfa was seeded at both ends, and 12-row wide strips of corn and soybeans were alternated across the center area. Four replications of each crop were used.

A severe drought occurred in 1983 and all yields for both corn and soybeans were zero. After collection of the 1984 crop yields, it was decided that the center part of the main treatment blocks of the area planted to corn and soybeans would be split by ripping one-half of each plot lengthwise to a depth of about 24 inches with a Rome* ripper (parabolic subsoiler), creating strips approximately 35 x 240 feet. It was also decided that only corn would be planted, with the rows being parallel to the ripping. Data were collected for corn yields in 1984 and 1985. In 1986, the entire area was planted to corn, including the ends that had been in alfalfa for four years. Data for 1984 and 1985 were reported earlier (Powell et al., 1985). Yields for 1986 will not be given here due to the vast amount of chemical and physical data.

RESULTS AND DISCUSSION

One parameter often studied in prime farmland reconstruction following surface mining is changes in bulk density. Data collected prior to disturbing the Belknap and again approximately two months after reconstruction are given in Table 2. It is obvious that the bulk density below the 6-inch depth increment had increased. Significant increases occurred for all reconstruction methods used (see upper case letters) throughout the 6-36 inch rooting zone. Values for the 0-6 inch level were lower for some of the methods, but this was probably the result of the disking treatment used to prepare a seedbed and to level the area prior to planting corn rather than the reconstruction method used.

The increase in bulk density of various depths below 6 inches ranged from 0.09 to 0.25 g/cc. In general, the upper range of this difference occurred for the subsoil samples. Due to our sampling by horizon for pre-mined sites, direct comparison cannot be made for the 12-18 or 24-30 inch depth increments; however, had we used the same sampling frequency for the pre-mined sites, we believe similar statistical differences would have occurred for these depth increments. On an average, the level of increase ranged from 0.14 to 0.17 as a result of soil reconstruction. The average bulk density of the 6-36 inch depth increased 0.08 to 0.12 g/cc. The bulk density of the Belknap was increased upon stockpiling by 0.03 or 0.04 g/cc for truck and scraper pan, respectively.

Similar changes in bulk densities following reconstruction were observed for the Sadler soil, Table 3. All mining methods significantly increased the bulk density for all sampling depths. There was a significant increase between the 0-6 and 6-12 inch sampling depth for all treatments, ranging from 0.11 to 0.15 g/cc. This difference in density was the result of two factors; tillage required for seedbed preparation and leveling that reduced the bulk density of the surface layer, as well as the difference due to texture of the two soil materials. The 0-6 inch depth was restored with the Ap material, whereas the 6-12 inch deptb was restored with B2t materials. The overall average increase in bulk density for the 6-36 inch portion ranged from 0.14 to 0.18, depending upon the reconstruction method used. The stockpiling phase, which requires double handling, increased the bulk density 0.04 g/cc for both scraper pan and the truck method.

There were differences between construction methods as related to bulk density, but there were no consistent differences. In other words, at one depth the truck method gave a lower bulk density, whereas at some other depth, densities from the scraper pan method were lower. For Belknap soil (Table 2), excluding the 0-6 inch depth since this layer had been disked prior to sampling, in six cases the truck method gave lower bulk densities, in two cases the scraper pan method was lower, and in two cases they were equal. However, in only one case for each comparison of two reconstruction methods was the difference significant. In addition, when data from the 6-36 inch depth are averaged, only the direct haul scraper pan value was higher than the truck value by 0.01 g/cc.

Comparison of densities for the same method but for direct haul versus stockpiling produced four cases in which the direct haul approach had significantly lower bulk densities, and in no case were there significantly lower bulk densities for stockpiled soil versus the direct haul. Averaging over the 6-36 inch depth, stockpiling increased the bulk density for both methods.

Similar inconsistent results, as just presented for Belknap, also occurred for Sadler (Table 3) when comparisons were made between truck versus scraper pans as to which method produced the higher bulk densities. In three cases the truck method had a significantly higher bulk density than the scraper pan method, but in one case the scraper pan produced a higher bulk density. Numerically, the bulk density values for the truck method exceeded the scraper pan method six times, whereas, four times the reverse was true. Where the bulk densities for the 6-36 inch depth were averaged, the values were identical for scraper pan and truck, however, as pointed out earlier, stockpiling increased the bulk density by 0.04 g/cc.

The effect of ripping on bulk density for the Belknap is given in Table 4 for samples collected in 1985 and 1986. These data were averaged for all four soil reconstruction methods. Few significant decreases in bulk density occurred as the result of ripping either year, although numerically, ripping decreased the bulk density. Recall, ripping was done only once prior to sampling in 1985. The changes that occurred were found in the top three sampling depths. One would not expect changes much below 18 inches, as this was the approximate operating depth of the ripper.

Comparisons of bulk densities following three years of alfalfa can be made for 1986. There was a significant decrease for the top two sampling depths between the alfalfa plots and the non-ripped treatment. However, significant differences between these plots (previously having been in alfalfa) and the ripped treatment did not occur.

Data for the Sadler soil showing the effect of ripping are given in Table 5. Ripping significantly decreased the bulk density in the top two layers in 1985 and in the top three layers, or upper 18 inches, in 1986. The reason for significance for the 12-18 inch depth in 1986, which was not significant in 1985, is the result of a lower coefficient of variation in 1986. As discussed for Belknap, one should not expect a ripping effect below 18 inches, the approximate operating depth of the ripper. Also note that where alfalfa had been grown for the previous three years, bulk densities for the upper 18 inches were as low as for the area which had been ripped, and significantly lower than for the non-ripped area.

A trend was observed for the general increase in bulk density with time for the 6-36 inch zone. For example, in 1983 the average bulk density value for Belknap was 1.68, it decreased to 1.67 in 1985, but increased to 1.72 in 1986. The latter two values were computed from the non-ripped treatment. The zone below where the ripper penetrated increased a similar amount between 1983 and 1986.

Changes in some of the chemical properties for the Belknap as a result of soil reconstruction methods are given in Tables 6 through 10. In general, the pH was rather uniform for all horizons, and few significant differences occurred between sampling depths within a soil reconstruction method or between methods at any given sampling depth (Table 6). Since there were few differences in pH among the original horizons (treatment BU), changes in pH as a function of reconstruction method would not be expected to provide evidence of mixing of horizons, by any of these methods for the Belknap soil.

Data for exchangeable calcium for the Belknap soil are given in Table 7. The undistrubed soil exhibited significant differences between the surface samples and the lower two depths. However, upon inspection of the data, the truck-direct treatment had no significant differences between samples with depth. The scraper pan-direct treatment had the highest exchangeable calcium level for the 30-36 inch depth, although this value did not differ significantly from the 0-6 or 6-12 inch sampling depths. For the truck-stockpiled treatment, the values for the 0-6 and 6-12 inch depths were significantly greater than for the lower 4 depths. The exchangeable Ca for samples from the scraper pan-stockpiled method gave a similar pattern, in that the values of samples from the 0-6 and 6-12 inch depths were significantly greater than for the samples from lower depths.

It is not known why, but there seemed to be a generally greater amount of exchangeable Ca in the reconstructed soil than the original values. The greatest discrepency was within the 6-12 inch samples where the reconstructed soils were 3-6 cmol(+)/kg higher. Lime or other fertilizers had not been added prior to collection of these samples. Although regression analyses were not performed between exchangeable Ca and pH, one would not expect too high of a correlation since the range of both data sets is not great. The sample with the highest pH did not have the highest exchangeable Ca level.

Data for total exchangeable acidity are given in Table 8. There were significant differences between sampling depths for the undisturbed soil. As one would expect, the exchangeable acidity increased with depth. This change is the result of a small increased clay content for the lower horizons (data not shown) and perhaps differences in mineralogy. This latter statement is speculation based on data from other sites but not a part of this study.

When one inspects the total exchangeable acidity data for the reconstructed soils, for only the two methods in which the soil was stockpiled did significant differences occur with depth, the general trend of the pre-mined soil. For the stockpiled soil, samples from 0-6 and 6-12 inch depths had significantly lower total exchangeable acidity than the two deepest samples.

In general, all total exchangeable acidity values were lower for the reconstructed soil than those determined from pre-mined samples. There also seemed to be a good (negative) relationship between exchangeable Ca and total exchangeable acidity, but regression analyses were not conducted. As pointed out above, lime had not been applied as a part of soil reconstruction and even though significant changes occurred, we offer no reason to explain them, although they are consistent with the exchangeable Ca data.

Data for Bray P are given in Table 9 for the Belknap soils. In comparisons of the P levels for the undisturbed soil, significant differences for various sampling depths were observed; hence, like exchangeable Ca and total exchangeable acidity, these data may be useful in determining if mixing occurred between soil depths as a result of reconstruction methods. Even though there were small numerical differences between the 0-6 and 6-12 inch sampling depths, these differences were maintained to a lesser degree for the reconstructed soils. There were numerical and significant differences between reconstruction methods and the original samples as well as between the methods themselves. The phosphorus levels from the stockpiled soils, especially for the 18-36 inch zone, were lower than those from the direct-haul treatment as well as from the undisturbed site. It is not known if these changes were a function of stockpiling, better segregation between the Ap and B horizons, or some other yet unknown reason. In any case, the Bray P levels were very low and unless fertilizers were applied, crop yields would also have been expected to be reduced.

Similar to the phosphorus data, the significant differences in organic matter, shown in Table 10, should be a useful criterion to evaluate reconstruction methods. The upper two sample depths of the four reconstructed treatments were significantly higher. There was approximately a 0.5% drop between the 0-6 and 12-18 inch sampling zone for all methods. In general, there were higher organic matter contents for reconstructed soils than the for pre-mined sites at most sampling depths. The higher levels for the reconstructed soil may be explained in mixing of the existing vegetation with the 0-6 inch soil, as only the mineral soil portion was collected for the pre-mined samples. In summary of data from the Belknap soil, it is apparent that some of the 0-6 and 6-12 inch material was mixed together in the original soil removal process, because this soil was wet and it was very difficult for the equipment operator to keep dozer blades and scraper pans at the desired depths. It is apparent that there was a better separation of the Ap from the B horizons for the stockpiled soils than for the direct-haul method, this may be partially the result of development in the skills of the operator of the equipment as soil removal progressed. The first soil to be removed was for the direct-haul treatments for Belknap, followed by the Belknap stockpiled treatments, then the Sadler direct, and the last treatment to be completed was the stockpiled treatments. This was a new experience for us as well as for the equipment operators. In addition, it was easier for them to see the contrast between horizons for the Sadler soil than for the wetter, darker colored Belknap soil.

Changes in sample depth and reconstruction methods are given in Table 11. The 0-6 inch, or Ap horizon, had a generally higher pH value than lower depths, with the exception being the scraper pan-direct treatment. In general, pH's for direct-haul reconstructed methods were lower than for the stockpiled treatment. Although many of the differences between reconstruction methods were significant, numerically, the differences were small, as in some cases, differences as small as 0.04 pH unit were reported as being significant.

As one would expect, similar trends as observed for pH were also seen for exchangeable Ca (Table 12) and the reciprocal observed for total exchangeable acidity (Table 13). For this series of data, the scraper pan-direct samples seem to be consistently out of place. The pH's and exchangeable Ca were generally lower, and total exchangeable acidity values were higher. Perhaps this site was slightly more eroded as the organic matter was also lower. We cannot statistically analyze the undisturbed sites to verify this possible explanation, since the identity as to which undisturbed site was used as the scraper pan-direct method is unknown.

The total exchangeable acidity data (Table 13) for the reconstructed treatments followed the general trend observed for the undisturbed samples. The level was lowest for the 0-6 inch or Ap samples, highest for the 24-36 inch or Bx samples, and intermediate for the 6-24 inch or B2t samples. As pointed out above, the data for the 0-6 inch samples for the scraper pan-direct treatments seem to be high and out of place. Fewer significant differences occurred between the truck-reconstructed soil treatment and the pre-mined samples than for similar comparisons between scraper pan methods and the original total exchangeable acidity values.

There was a sharp boundary between the 0-6 and 6-12 inch samples for the undisturbed sites for Bray P (Table 14). The magnitude of this difference decreased upon soil reconstruction. However, based on other data, this drop in Bray P doesn't seem to be a function of soil mixing in the process of soil handling, but is more likely related to soil disturbance as such.

Similar to the phosphorus data, there were sharp contrasts and significant differences between sampling depths for the organic matter content, as shown in Table 15. For the undisturbed soil, these differences were significant and similar significant differences were also found for the reconstructed treatments. Also similar to P data, the reconstructed soil had lower levels of organic matter in the 0-6 inch sampling depth, but at lower depths the levels increased slightly. The fact that the organic matter levels were lower in the reconstructed soil, unlike that for Belknap (Table 10), may be related to the vegetation prior to reconstruction. The Belknap sites were in sod (grass and weeds), whereas the Sadler sites had been cropped (corn) for at least the past two years.

It is also possible that in the soil removal process for the scraper pan-direct treatment, more of the B2t horizon was mixed with the Ap than occurred for the other three treatments, thus lowering the pH, exchangeable Ca, and organic matter content and increasing the total exchangeable acidity. In any case, it would appear that the dozer method (or equipment operator) was more successful in keeping the horizons separated.

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Table 2.--Changes in bulk density of the Belknap soil as a result of soil reconstruction methods.

Depth	BU	BTD	BSD	BTS	BSS
	g/cc				
0- 6	1.51 a A*	1.44 c B	1.53 b A	1.43 c B	1.47 d AB
6-12	1.50 a C	1.61 b B	1.63 a B	1.72 ab A	1.61 c B
12-18	-----	1.66 ab A	1.66 a A	1.65 b A	1.66 bc A
18-24	1.44 b B	1.68 a A	1.69 a A	1.69 ab A	1.71 ab A
24-30	-----	1.61 b B	1.69 a A	1.68 ab A	1.70 ab A
30-36	1.47 c C	1.66 ab B	1.66 a B	1.74 a A	1.73 a A

* Means with the same letters are not significantly different at LSD (10). Lower case letters are for comparisons of values with depth and within a treatment, whereas upper case letters are for comparisons of values at a given depth but between treatments.

Table 3.--Changes in bulk density of the Sadler soil as a result of soil reconstruction methods.

Depth	SU	STD	SSD	STS	SSS
	g/cc				
0- 6	1.35 a B*	1.49 e A	1.57 b A	1.51 c A	1.53 c A
6-12	1.43 b C	1.60 d B	1.68 a A	1.65 b A	1.68 b A
12-18	-----	1.61 cd B	1.64 a AB	1.67 ab A	1.65 b AB
18-24	1.46 b D	1.65 bc B	1.61 ab C	1.71 ab A	1.66 b B
24-30	-----	1.68 ab BC	1.65 a C	1.72 a A	1.69 ab AB
30-36	1.63 a C	1.72 a A	1.67 a BC	1.71 ab AB	1.75 a A

* See footnote for Table 2.

Table 4.--Effect of ripping on changes in bulk density of the Belknap Soil.

Depth	Non-Ripped	Ripped	Following Alfalfa
		g/cc	
		1985	
0- 6	1.48 c A*	1.46 d A	----
6-12	1.61 b A	1.56 c B	----
12-18	1.64 b A	1.63 b A	----
18-24	1.70 a A	1.71 a A	----
24-30	1.68 a A	1.69 a A	----
30-36	1.70 a A	1.70 a A	----
		1986	
0- 6	1.46 d A	1.45 c AB	1.39 c B
6-12	1.64 c A	1.58 b B	1.59 b B
12-18	1.74 ab A	1.72 a A	1.74 a A
18-24	1.72 b B	1.74 a AB	1.76 a A
24-30	1.74 ab B	1.76 a AB	1.77 a A
30-36	1.77 a A	1.75 a A	1.54 bc B

* See footnote for Table 2.

Table 5.--Effect of ripping on changes in bulk density of the Sadler soil.

Depth	Non-Ripped	Ripped	Following Alfalfa
		g/cc	
		1985	
0- 6	1.50 e A*	1.46 d B	----
6-12	1.63 d A	1.54 c B	----
12-18	1.68 c A	1.64 b A	----
18-24	1.70 bc A	1.69 a A	----
24-30	1.71 ab A	1.69 a A	----
30-36	1.74 a A	1.71 a B	----
		1986	
0-6	1.53 b A	1.47 c B	1.48 d B
6-12	1.71 a A	1.63 b B	1.61 c B
12-18	1.75 a A	1.71 a B	1.71 b B
18-24	1.75 a A	1.73 a A	1.74 ab A
24-30	1.74 a AB	1.73 a B	1.75 ab A
30-36	1.73 a B	1.74 a AB	1.77 a A

* See footnote for Table 2.

Table 6.--Changes in pH of the Belknap soil as a result of soil reconstruction methods.

	Treatment				
Depth	BU	BTD	BSD	BTS	BSS
0- 6	5.29 a A*	5.07 ab B	5.15 b AB	5.35 a A	5.31 a A
6-12	5.27 a A	4.99 b B	5.20 b AB	5.35 a A	5.29 a A
12-18	----	5.12 ab BC	5.32 b A	5.19 ab B	5.08 b C
18-24	5.25 a A	5.09 ab C	5.18 b B	5.10 bc C	5.00 b D
24-30	----	5.11 ab AB	5.19 b A	4.95 c B	5.00 b B
30-36	5.32 a B	5.17 a BC	6.07 a A	4.99 bc C	5.10 b C

* See footnote for Table 2.

Table 7.--Changes in exchangeable calcium of Belknap soil as a result of soil reconstruction methods.

Depth	BU	BTD	BSD	BTS	BSS
	Treatment				
	cmol(+)kg^{-1}				
0- 6	12.8 a BC*	11.2 a C	13.7 abc B	14.6 a B	18.1 a A
6-12	9.6 b C	13.0 a B	14.7 ab AB	13.8 a AB	15.7 b A
12-18	----	12.7 a AB	13.0 bc A	11.6 b B	9.9 c C
18-24	8.3 c C	12.2 a A	11.6 c AB	10.2 b B	9.8 c BC
24-30	----	11.6 a A	12.0 bc A	10.6 b B	10.3 c B
30-36	7.8 c D	12.1 a B	15.8 a A	11.2 b BC	10.3 c C

* See footnote for Table 2.

Table 8.--Changes in total exchangeable acidity of the Belknap soil as a result of soil reconstruction methods.

Depth	BU	BTD	BSD	BTS	BSS
	Treatment				
	cmol(+)kg^{-1}				
0- 6	0.34 c AB*	0.45 a A	0.29 a B	0.22 b BC	0.13 b C
6-12	0.58 b A	0.45 a A	0.23 a B	0.23 b B	0.22 b B
12-18	----	0.28 ab C	0.23 a C	0.41 ab B	0.53 a A
18-24	0.71 a A	0.31 ab C	0.26 a C	0.46 ab B	0.49 a B
24-30	----	0.32 ab C	0.31 a C	0.68 a A	0.49 a B
30-36	0.69 a A	0.25 b C	0.35 a BC	0.59 a AB	0.42 a B

* See footnote for Table 2.

Table 9.--Changes of Bray P of the Belknap soil as a result of soil reconstruction methods.

Depth	BU	BTD	BSD	BTS	BSS
	Treatment				
	lbs/A				
0- 6	6.8 a B*	6.9 a B	8.8 a AB	9.9 a AB	10.9 a A
6-12	3.9 c C	6.3 ab B	7.4 a AB	8.5 b A	7.4 b AB
12-18	----	5.8 b B	6.6 ab A	5.6 c B	4.8 bc C
18-24	4.8 bc A	4.6 c A	4.6 b A	2.9 d B	3.3 c B
24-30	----	4.4 c A	4.5 b A	2.9 d B	3.1 c B
30-36	6.0 ab A	4.7 c B	4.8 b B	3.0 d C	3.4 c C

* See footnote for Table 2.

Table 10.--Changes in organic matter of the Belknap soils as a result of soil reconstruction methods.

Depth	BU	BTD	BSD	BTS	BSS
	Treatment				
	%				
0- 6	1.35 a B*	1.34 a B	1.48 a AB	1.42 a B	1.60 a A
6-12	0.88 b B	1.28 a A	1.40 a A	1.32 a A	1.26 b A
12-18	----	1.13 b A	0.99 b AB	0.96 b B	0.85 c C
18-24	0.73 c C	1.00 c A	0.88 b AB	0.84 c B	0.83 c B
24-30	----	0.91 c A	0.92 b A	0.89 bc A	0.76 c B
30-36	0.69 c C	0.89 c B	1.31 a A	0.92 bc B	0.88 c B

* See footnote for Table 2.

Table 11.--Changes in pH of the Sadler soil as a result of soil reconstruction methods.

Depth	SU	STD	SSD	STS	SSS
	Treatment				
0- 6	5.46 a A*	5.29 a B	4.96 a C	5.50 a A	5.08 a C
6-12	4.90 b B	5.07 b AB	4.88 a B	5.23 b A	5.00 ab B
12-18	--	5.02 b A	4.90 a AB	4.96 c A	4.88 c B
18-24	4.78 c C	4.98 bc A	4.91 a B	4.91 c B	4.89 bc B
24-30	--	4.82 c BC	4.76 b C	4.99 c A	4.87 c B
30-36	4.74 c C	4.59 d D	4.94 a B	4.98 c A	4.93 bc B

* See footnote for Table 2.

Table 12.--Changes in exchangeable calcium of the Sadler soil as a result of soil reconstruction methods.

Depth	SU	STD	SSD	STS	SSS
	Treatment				
	$cmol(+)kg^{-1}$				
0-6	19.8 a BC*	22.8 a A	11.2 a D	22.1 a AB	19.2 a C
6-12	15.9 b A	19.1 b A	10.8 ab B	18.1 b A	16.5 ab A
12-18	---	15.2 c A	9.2 bc B	14.1 c A	14.9 bc A
18-24	8.4 c C	10.0 d B	10.1 ab B	12.9 c AB	13.8 bcd A
24-30	---	7.8 de D	8.7 cd C	10.8 d B	12.6 cd A
30-36	5.9 d E	6.6 e D	7.3 d C	8.8 e B	10.8 d A

* See footnote for Table 2.

Table 13.--Changes in total exchangeable acidity of the Sadler soil as a result of soil reconstruction methods.

Depth	SU	STD	SSD	STS	SSS
	Treatment				
	$cmol(+)kg^{-1}$				
0- 6	0.28 d C*	0.19 d C	1.17 d A	0.26 e C	0.62 c B
6-12	1.33 c A	1.02 c A	1.54 cd A	1.01 d A	1.22 b A
12-18	----	1.57 c B	2.16 bc A	2.19 c A	1.51 b B
18-24	2.95 b B	3.19 b A	1.91 c D	2.71 b B	2.16 a C
24-30	----	3.79 a A	2.71 b B	3.13 b AB	2.17 a C
30-36	4.26 a A	3.94 a AB	3.39 a C	3.72 a B	2.74 a B

* See footnote for Table 2.

Table 14.--Changes in Bray P of the Sadler soil as a result of soil reconstruction methods.

Depth	SU	STD	SSD	STS	SSS
	Treatment				
	lbs/A				
0- 6	15.3 a A*	6.8 a B	5.6 a B	5.3 a B	5.7 a B
6-12	2.5 b C	4.3 b B	4.5 ab B	3.6 b BC	5.7 a A
12-18	----	3.5 bc B	3.8 b A	1.8 c C	3.7 b B
18-24	2.2 b D	2.8 cd C	3.4 b B	1.8 c D	4.4 b A
24-30	----	2.4 d C	3.6 b B	1.5 c D	4.3 b A
30-36	2.3 b C	2.0 d C	3.3 b B	1.3 c D	3.7 b A

* See footnote for Table 2.

Table 15.--Changes in organic matter of the Sadler soil as a result of soil reconstruction methods.

Depth	SU	STD	SSD	STS	SSS
	Treatment				
	%				
0- 6	1.81 a A*	1.28 a B	0.82 a C	1.29 a B	1.13 a B
6-12	0.49 b C	0.94 b A	0.61 b BC	0.84 b A	0.81 b A
12-18	----	0.68 c A	0.38 c C	0.60 c B	0.68 bc A
18-24	0.30 c C	0.40 d B	0.42 c B	0.48 d AB	0.55 c A
24-30	----	0.26 d C	0.43 c B	0.40 de B	0.49 c A
30-36	0.21 d C	0.24 d C	0.37 c B	0.34 e B	0.51 c A

* See footnote for Table 2.