Automatic retrieval and analysis of soil characterization data
by Gordon Lee Decker

a thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY in Crop and Soil Science
Montana State University
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Abstract:
Soil site, environmental, morphological and laboratory characterization data for 186 Montana soils (pedons) were encoded using the "Proposed Coding System for the Pedon Data Record for the National Cooperative Soil Survey" and have been stored on magnetic tape at Montana State University. Data for 1466 horizons were stored in the Pedon Data (PD) Record and included observations from the following soil orders; Mollisols, Aridisols, Alfisols, Entisols, and Inceptisols. Mollisols and Aridisols were the dominant orders in the sample.

Encoding soil data on specially prepared mark sense forms required 40 percent less time and was more economical than recording the codes on 80-column data forms and key punching. Cost and preparation of mark sense forms were about the same as the cost of key punching the data with student help, Total required time for processing an 8-horizon pedon with average amounts of characterization data was about three hours.

Computer written pedon descriptions and laboratory tables were produced from encoded data in the PD record for about $0.25 and $0.30, respectively. Multiple copies of the descriptions and tables were copied from labeled files for less than $0.10 each.

Developing new and smaller working files from the Pedon Data (PD) Record with fixed formats and selected characteristics were more economical for statistical analysis than direct retrieval from the lengthy PD record.

The standard deviations of the means calculated from Laboratory data for percent sand, silt, clay, 1/3 bar water retention and 15 bar water retention were higher than expected for some of the field named textural classes.

The mean percent sand, silt, and clay for nearly all the field named textural classes fit within the correct partition of the textural triangle. A majority of the samples were from medium and fine textural classes.

An inventory of available data and correlations between morphological data (includes site and environmental factors) and laboratory characteristics were used as criteria to select variables for statistical analysis. Percent clay (determined in the laboratory) and organic carbon were the best of 58 parameters tested to predict percent soil water at 15 bar tension. The following model was developed using 930 samples: [Percent 15 bar water = 2.1 + 0.29 (percent clay) + O.58 (organic matter)].

Percent water held at 15 bar tension can be predicted using percent clay and moist color value. The following model was developed using 874 samples: [Percent 15 bar water = 7.1 + 0.28 (percent clay) - 0.95 (moist color value)].

The parameters in six models were evaluated and summarized for incorporation into three proposed forms for calculating estimated soil water available to plants.

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ABSTRACT

Soil site, environmental, morphological and laboratory characterization data for 186 Montana soils (pedons) were encoded using the "Proposed Coding System for the Pedon Data Record for the National Cooperative Soil Survey" and have been stored on magnetic tape at Montana State University. Data for 1466 horizons were stored in the Pedon Data (PD) Record and included observations from the following soil orders; Mollisols, Aridisols, Alfisols, Entisols, and Inceptisols. Mollisols and Aridisols were the dominant orders in the sample.

Encoding soil data on specially prepared mark sense forms required 40 percent less time and was more economical than recording the codes on 80-column data forms and key punching. Cost and preparation of mark sense forms were about the same as the cost of key punching the data with student help. Total required time for processing an 8-horizon pedon with average amounts of characterization data was about three hours.

Computer written pedon descriptions and laboratory tables were produced from encoded data in the PD record for about $0.25 and $0.30, respectively. Multiple copies of the descriptions and tables were copied from labeled files for less than $0.10 each.

Developing new and smaller working files from the Pedon Data (PD) Record with fixed formats and selected characteristics were more economical for statistical analysis than direct retrieval from the lengthy PD record.

The standard deviations of the means calculated from laboratory data for percent sand, silt, clay, 1/3 bar water retention and 15 bar water retention were higher than expected for some of the field named textural classes.

The mean percent sand, silt, and clay for nearly all the field named textural classes fit within the correct partition of the textural triangle. A majority of the samples were from medium and fine textural classes.

An inventory of available data and correlations between morphological data (includes site and environmental factors) and laboratory characteristics were used as criteria to select variables for statistical analysis. Percent clay (determined in the laboratory) and organic carbon were the best of 58 parameters tested to predict percent soil water at 15 bar tension. The following model was developed using 930 samples: [Percent 15 bar water = 2.1 + 0.29 (percent clay) + 0.58 (organic matter)].

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The parameters in six models were evaluated and summarized for incorporation into three proposed forms for calculating estimated soil water available to plants.

INTRODUCTION

Soil data are available from different agencies in amounts so great that it is impractical for anyone to manually analyze and digest them for potential users. Automatic Data Processing (ADP) is one method of systematically storing data for quick retrieval and analysis of needed information. ADP allows rapid exchange of information between researchers, educators, planners, and other users.

"The National Cooperative Soil Survey has been collecting, processing, using, and publishing information about soils since its beginning in 1899. Although improvements in handling information have been made, we have been unable, especially in the last decade, to make full use of the data at hand. This deficiency is especially serious in statewide, regional, and nationwide planning and policy making for which soil information summaries are not only needed but must be produced on short notice to be effective" (Orvedal, 1969).

"With the development of the comprehensive soil classification system and the several-fold expansion of soil survey interpretations--where the real payoff comes--not only has the need for data increased, but the opportunities for rewarding use of data have increased even more" (Orvedal, 1969).

Full use of data today means not only handling large volunes of data but handling them rapidly; it means quick response to questions that we need to answer for ourselves, for senators, congressmen, planners, farmers, and others; and it means sophisticated analysis of data and

synthesis of interpretations" (Orvedal, 1969).

"One important key to improved data handling is the proper use of electronic computers and other modern equipment" (Orvedal, 1969).

Information accessible by electronic computer will facilitate statistical analysis and graphical presentation of relationships between data. Relationships between soil morphological, physical, and chemical properties play an important role in many areas of land use planning. Soil relationships need to be studied for practical application in management of crop land, watershed, range, recreation, and wildlife areas; pollution control; roadside seedings; reclamation of salt-affected areas and mine spoils; site location; and regional land use planning. For example, the ability of a soil to absorb, store, and/or render water are some of the most important soil properties which directly or indirectly affect soil behavior in land use planning. Relationships between soil properties can be analyzed, graphically presented and the results rapidly distributed to the user.

The purpose of this study was to test methods of encoding soil site, environmental, morphological, and laboratory determined data; enter the soil characteristics into a data bank using codes developed in the "Proposed Coding System for the Pedon Data Record for the National Cooperative Soil Survey"; test methods of data retrieval; and statistically analyze retrieved soil data to determine relationships between soil properties.

LITERATURE REVIEW

I. Steps in Processing Soil Characterization Data

1. Encoding Soil Data

A search of literature published prior to 1968 did not reveal a standard method of encoding soil pedon data. Swindale (1967) described a method in a report titled "Automatic Data Processing in Soil Characterization" at the National Technical Work-Planning Conference of the National Cooperative Soil Survey in New Orleans, Louisana, January 23-27, 1967. Six 80-column data cards were necessary to encode the data from one horizon of one profile. The cards, their color banding, and the data encoded on them are described in Table 1.

Table 1. Card number, corresponding color band, and soil data encoded by Swindale (1967).

Card No.	Color	Data Type
1	Pink	Horizon Description
2	Orange	Chemical Properties
3	Yellow	Total Analysis
4	Green	Soil Physics
5	Blue	Clay Mineralogy
6	Purple	Soil Environment

Swindale (1967) concluded his remarks about automatic data processing of soils information by saying, "It is to be hoped that a suitable standard card and code system can be devised and published so that many workers in soil survey and characterization can use a uniform system and insure that information and results are readily interchangeable."

National Cooperative Soil Survey Committee 6-Handling Soil Survey

Data - under the chairmanship of A. C. Orvedal was established in 1968. Their first report was given at the National Technical Work-Planning Conference of the Cooperative Soil Survey in Charleston, South Carolina, on January 27-30, 1969. The broad long-range objective of Orvedal et al. (1969) of Committee 6 was to consider, evaluate, and recommend ways and means for achieving more complete and accurate analysis and synthesis of data on soils for the improvement of soil classification and soil predictions by use of electronic equipment. The immediate and limited objectives were to report on developments to date, to evaluate the present status and to recommend action on a proposed national system for coding data about soil pedons (profiles).

Orvedal et al. (1969) of Committee 6 surveyed the scope of soil survey data and considered the kinds of questions they wanted computers to help answer. This led to the concept of a soil data system (SDS). They concluded that this system should be oriented more towards storage and retrieval of information than towards computation, although many computations, including multiple regressions, must be possible. They invisioned the SDS being comprised of the following files:

1. Pedon data (PD) file to be made up of PD records. A record in this file consists of the pedon (profile) description and the laboratory data (chemical, physical and mineralogical) of the pedon.
2. Soil classification (SC) file to show the placement of all soil series in the comprehensive system and to indicate the status

of the soil series.

3. Series description (SD) file to contain all of the current soil series descriptions.

4. Soil interpretations (SI) file to contain information on soil use (or experience) as well as interpretations (predictions) of soil behavior for a variety of uses.

5. Cartographic soil data (CSD) file to contain information about the geographic distribution of soils so as to be retrievable in both tabular and graphic form.

Orvedal et al. (1969) of Committee 6 held a workshop on August 21-23, 1968 for the purpose of developing a coding system for the pedon data (PD) record. This file will contain the records of morphological, physical, chemical, mineralogical, and biological data for individual pedons. It will constitute the basic data of the soil data system. A coding system is most urgently needed for the pedon data (PD) record and the benefits of a nationwide system are likely to be the greatest.

The "Proposed Coding System for the Pedon Data Record for the National Cooperative Soil Survey" was presented as a report by Committee 6 at the National Technical Work-Planning Conference of the Cooperative Soil Survey in Charleston, South Carolina, January 27-30, 1969.

The report consisted of four parts; Part A contained a brief discussion of the concept, purpose, and structure of the pedon data

record; Part B contained a list of items and subitems to be included in the pedon data record along with some information pertinent to coding; Part C contained a listing and discussion of the codes and entries for each item and subitem in the pedon data record; and Part D contained an appendix with illustrations.

Three general types of formats for storing soils information in the pedon data record were discussed in Part A of the proposed coding system. The format types were termed fixed-length, variable-length, and modified fixed-length. A fixed-length record, as the name implies, had a fixed number of characters or spaces in the record. That method resulted in a considerable amount of unused space on the storage media because of the variable nature of information about soil morphological characteristics. However, that record was considered both faster and easier for computer programming and manipulation.

The second type of record format, variable-length varies in length depending upon the requirements of each specific record. That record type makes more efficient use of storage media, but was slower in computer operations.

The third type of record format, modified fixed-length, combines features of both fixed and variable-length formats. In that design each item and subitem had a fixed length and would be entered at least once in every record (using spaces if no data are available). Provisions were made for making more than one entry for many of the items.

The modified fixed-length format reduced the amount of unused storage space with only slight loss of speed in computer operations.

The proposed coding system for the PD record is being reviewed by government agencies and interested universities. Several kinds of soil pedon data have been added to the PD record and minor changes have been made since the original report was presented in 1969.

The final coding system should soon be released for use by anyone interested.

Methods for encoding soil site, environmental and morphological data were not found in reviewing the literature. Swindale (1967) and Pandey (1969) encoded these characteristics but did not outline their procedure in detail.

2. Punching Encoded Data

Laboratory data have been key punched and verified manually from published laboratory data tables[1/]. Tables published with different formats were cut and pasted together to conform with the format being followed by the keypunch operator. This was apparently a very efficient method of encoding the laboratory data[1/].

II. Statistical Analysis of Soil Characterization Data.

Correlations of laboratory data and statistical models predicting soil properties have been investigated and reported in many books and journals. Data for many studies were collected from relatively few soil pedons and were confined to specific geographic boundaries.

1/ Klaus Flach, Head, SCS Soil Survey Laboratory, Riverside, Calif.

such as the Great Plains (Haise et al. 1955), alluvial soils of Louisana (Lund, 1959) and Hawaiian Red Earths (Pandey, 1969). In many cases, the data collected were limited to laboratory determined characteristics.

Relationships of soil morphological data and laboratory determined data have not been extensively reported in the literature. Pandey (1969) determined many relationships between roots, consistance, structure, field textural class, and laboratory data for Hawaiian and Indian Red Earths.

Investigation of complete soil characterization data (site, environmental, morphological, and laboratory properties) has not often been attempted on soils with different classifications and geographic positions.

Many relationships of Montana soil properties were observed in the present study but soil characteristics correlated with soil water retention at 15 bar was considered to merit special emphasis.

1. Predicting Soil Water Retention

Montana researchers have found that available water for plant growth is one of the most important factors that determine success or failure of Montana farmers and ranchers. Brown (1968) has found that it takes 4 inches of water to support the development of wheat to the boot stage at which time the development of grains begins, and with adequate fertility and reasonable growing conditions, each

inch above 4 inches will produce 4 to 7 bushels of wheat per acre.

Simple methods are available to measure the total amount of water, by weight, in the soil. The big problem in dryland agriculture is to determine how much of the total soil water present is unavailable for plant growth. Once this is determined, reasonable predictions of crop yields may be possible.

Gardner (1965) stated that direct or indirect measures of soil water content are needed in practically every type of soil study. For example, in the laboratory, determining and reporting many physical and chemical properties of soil necessitates knowledge of water content.

The capacity of soils to absorb and retain water provides a reservoir from which water may be withdrawn by plants during periods between rainfalls and/or irrigations. The water retention properties of soils and the extraction of water from soils by plants have been intensively studied, and various soil-water constants have been defined and used as an index of the water-holding capacity of soils.

The difference between 1/3 bar water content and 15 atmosphere water content to estimate available water holding capacity has been used by Gardner et al. (1971), Haise et al. (1955), Peterson et al. (1968a), Salter et al. (1965a, 1965b), and Cole et al. (1954). Haise et al. (1955) also studied 1/10 bar water retention for the upper limit and 26 bar water retention for the lower limit to estimate available water holding capacity.

Fifteen bar water retention was found to be highly correlated with texture by Peterson et al. (1968a, 1968b) in Pennsylvania soils, Jamison et al. (1958) in Missouri soils and Lund (1959) in Louisana soils. Salter et al. (1965a, 1966), Gardner et al. (1971) and Nielsen et al. (1958) also found high correlations between 15 bar water retention and soil texture. Organic matter content and water retention were found to be highly correlated by Bouyoncos (1939), Peterson et al. (1968a), and Salter et al. (1966).

METHODS

I. Processing Soil Characterization Data

1. Encoding Soil Data

A copy of the "Proposed Coding System for the Pedon Data Record for the National Cooperative Soil Survey" was obtained in 1969. Part B of the proposed coding system outlined the items and subitems of kinds of information to be stored in the proposed pedon data record. A list of the items and subitems are shown in Appendix I, Tables 16, 17, and 18.

It was decided that Montana soils, with available soil morphological and laboratory data, would be transferred to 80-column data sheets using codes set up in the "Proposed Coding System for the Pedon Data Record for the National Cooperative Soil Survey."

The fixed-length format, previously described appeared to be the most rapid and error free method of encoding morphological and laboratory data.

A key or format was developed identifying the card number and showing the exact placement of soil items and subitems on each 80-column data card. Data card numbers 1 through 5 contained site and environmental characteristics which included climatic, topographic, physiographic and parent material characteristics, vegetal, and other items common to all horizons of a soil pedon. The last 10 columns on data card number 5 contained the number of horizons in the profile and the first part of the horizon designation for horizon number 1. (See Appendix II, Figures 14 and 15.) The first 4 columns of each

of each data card contained an identification number. The first column was an alpha character and was the same for all data cards required to code one soil pedon. The remaining three columns contained a sequential number for each pedon. The numbers ranged from 20 to 185 depending on the number of horizons described for the soil pedon.

Data card numbers 6 through 11 contained items and subitems for morphological characteristics for the first horizon. (See Appendix II, Figures 15 and 16).

Data card numbers 12 through 19 contained items and subitems for laboratory determined characteristics, mineralogy, and engineering test data for the first horizon. (See Appendix II, Figures 16, 17, and 18).

Data card number 20 contained space for additional data and the last 8 columns contained the first part of the horizon designation for the second horizon. (See Appendix II, Figure 18).

The morphological and laboratory data for the second horizon were coded on data card numbers 21 through the first 72 columns of 35 and had the same item and subitem formats as card numbers 6 through the first 72 columns of card 20.

Three methods of encoding soil site, environmental, morphological, and laboratory data were tested. The first two methods required encoding the soils data and recording the proper codes on 80-column data forms. Soil pedon data were encoded in groups of 26 pedons or less with each group having data on a different colored card. This scheme

facilitated sorting cards into groups by color, into the same pedon within a group by the alphabetic character in column 1 and in sequential order using the numeric values in columns 2 through 4.

The first method tested required transferring all codes for items and subitems in sequence for one soil horizon, then transferring all the codes for the next horizon. See Appendix III, Figure 19 for an example of encoded data using this method.

The second method tested required encoding the same items and subitems for several horizons and pedons then returning to the first pedon and encoding the next set of items and subitems. See Appendix III, Figure 20 for an example of encoded data using the second method.

The third method tested made use of IBM 529 mark sense forms. Item and subitem headings were overprinted in the margins of the mark sense form. Codes taken from the proposed code book were also overprinted on the dashed lines under the proper item or subitem heading.

One mark sense form was designed to encode all the site and environmental characteristics for a pedon. See Appendix IV, Figure 21.

Three mark sense forms were designed to encode all possible morphological characteristics for one horizon. One to three of the forms were used depending on the amount and type of data recorded. Examples may be seen in Appendix IV, Figures 22, 23, and 24.

One mark sense form and a continuation form were developed to encode methods used in laboratory determinations for the pedon. For example, see Appendix IV, Figures 25 and 26.

Six mark sense forms were designed to encode all possible laboratory determinations for a horizon. One to six of the forms were used depending on the data recorded. For an example of the form, see Appendix IV, Figures 27 through 32.

The first morphological descriptions encoded were 79 pedons published in Soil Survey Investigations Report No. 7 (U. S. Dept. Agr. Soil Conservation Service in cooperation with Mont. Agr. Exp. Sta., 1966). Tentative unpublished characterization data for years 1950 through 1957 were also encoded and entered into the PD record. A total of 186 soil pedons were processed using Methods 1 and 2.

These data were obtained by Soil Conservation Service laboratory personnel, State and Field Soil Scientists. The laboratory determinations (U. S. Dept. Agr. Soil Conservation Service, 1967), were made by the Soil Conservation Service laboratories in Mandan, North Dakota or Lincoln, Nebraska.

A list of the soil series names, their sample numbers, site numbers and current classifications may be found in Appendix V, Table 19.

Six sectional maps of Montana may be found in Appendix VI, Figures 33 through 38. They show the approximate location of the soil characterization data sites. The number within the circles correspond to the site number, by county, on the list in Appendix V, Table 19.

Soil pedons encoded by Method 3 include site, environmental, and morphological characteristics for Montana benchmark soils; morphological characteristics observed at Montana State University research

fertilization sites; and some complete soil characterization data from North and South Dakota and Wyoming. These data were not used in the statistical analysis of soil property relationships.

2. Punching Encoded Data

Site, environmental, morphological, and laboratory data encoded using Methods 1 and 2 were punched on cards from 80-column data forms by students working at Montana State University. The data encoded using Method 3 were fed into a mark sense reading machine and the cards automatically punched.

3. Checking and Correcting Encoded Data

Computer programs were developed in Fortran IV language to read the site, environmental and morphological codes from cards or magnetic tape and write soil morphological descriptions. The programs were about 2,000 statements in length which included the data statements and required about 15,000 core stored words.

The computer written soil morphological descriptions were compared with the originals as the final method of checking accuracy and compatibility of encoded data.

Computer programs were also developed to read soil laboratory codes from cards or magnetic tape and write new tables containing headings for all possible kinds of data. The programs were about 700 statements long including the data statements and required about 13,000 core stored words.

The computer written tables were checked against the originals as the final method of checking the laboratory encoded data.

The data cards were corrected and again checked by rewriting the morphological descriptions and laboratory data tables.

The corrected data cards for 186 soil morphological descriptions and laboratory tables were transferred to separate magnetic tapes.

The fixed-length format used for encoding the data required 15 cards to store both morphological and laboratory data.

The number of cards needed to store all data for one pedon was high, so the data were divided into two subrecords, one for morphological and one for laboratory. Data cards 1 through 5 for the site and environmental data and 6 through 12 for the horizon data were included in the morphological subrecord. A new card containing the series name, soil survey sample number, number of horizons, horizon designation, and depth limits was prepared for identification information. This new card and cards numbered 13 through 19 for the horizon data were included in the laboratory subrecord.

4. Storage and Retrieval of Encoded Data

Two basic methods of storage and retrieval were tested. In Method 1, the data were stored and retrieved from two files (morphological and laboratory) formatted exactly as outlined in the "Proposed Coding System for the Pedon Data Record for the National Cooperative Soil Survey". Codes were stored alpha/numerically and the desired

code for each subitem "kind" identified by the computer (Appendix I, Table 16, 17, and 18). For example, the item "Cutans" would always be found in the same position on card 10 and 11, but the first subitem "kind" may be clay skins in one horizon, lime coatings in another or organic stains in a third horizon.

In Method 2, the pedon data records were stored as in Method 1. Both records were searched for the "kind" of items to be studied and a new working file stored. The new working file contained data from the morphological and laboratory files. The working file had all numeric codes which were weighted numbers on applicable subitems or dummy numeric codes on subitems that could not be weighted. Each "kind" of item was formatted to a fixed position so retrieval was possible without identifying the codes by computer.

The site, environmental, morphological, and laboratory characteristics for 186 pedons were encoded, transferred to cards, corrected, transferred to tape and were later retrieved for statistical analysis.

II. Statistical Analysis of Soil Characterization Data

1. Inventory of Available Data

Computer programs were developed by the author to search the pedon data (PD) record, calculate the mean (where applicable) and sum the number of observations for selected items and subitems. Items and

subitems were selected on the basis of their expected importance as independent variables in statistical analysis.

All the available characterization data for Montana soils were searched and selected data analyzed. No attempt was made to separate the data by classification, location or other characteristics.

A computer program was written to search the working PD file and calculate the mean, standard deviation, and number of observations for percent total sand, silt and clay, and percent moisture at 1/3 and 15 bar tension for each textural class.

2. Development of Correlation Matrix

A computer program was written by the author to calculate up to 50 correlation coefficients and record the number of observations available for calculating each correlation coefficient. Site, morphological, and laboratory data were selected from the pedon data record and correlation coefficients calculated. Selection of items and subitems depended on number of observations and expected importance in statistical analysis. Only those items and subitems having 100 observations or more were entered in the final correlation matrix.

3. Multiple Regression Analysis

Regressions were generated using a step-wise multiple regression program[2/] revised for the Sigma 7 computer at Montana State University.

A second multiple regression program developed by Dr. R. E. Lund[3/] for the Sigma 7 computer was used for some analysis and as a check.

Multiple regression models for predicting percent water at 15 bar tension were developed using 52 independent variables or combinations of variables. The variables were selected by observing the simple correlation coefficients and expected soil chemical and physical relationships with soil water retained at 15 bar tension.

The working PD file was searched by the computer and each variable, except those coded as binomial, were checked for zero value. All observations that had complete data were stored in a new data file and entered into the multiple regression program. All the variables were tested and those not significantly effecting soil moisture at 15 bar tension were removed from the model. The working file was again searched for complete data. This resulted in a new data file with more observations. The new model was tested and those variables not significant were removed. This process was repeated until an acceptable model was developed with the maximum number of observations available.

2/ "Stepwise Regression" version of May 16, 1968; Revised for Vanderbilt Computing Center, July, 1968; Health Sciences Computing facility, UCLA; Revised for Sigma 7 at Montana State University by Dr. Kenneth Tiahrt, Associate Professor of Statistics, Mathematics Department, Montana State University.

3/ Associate Professor of Statistics, Mathematics Department, Montana State University.

4. Data Plotting

Computer programs were developed by the author to search the working file, select the dependent variable and one to several independent variables, and send the original data, transformed data, or predicted data to plot subroutines developed by Roy Johnson[4/] for the Sigma 7 at Montana State University.

4/ Associate Professor of Electrical Engineering, Montana State University.

RESULTS AND DISCUSSION

I. Time and Costs of Processing Soil Characterization Data

An automated storage and retrieval system is one modern way to handle large volumes of data in a short period of time.

One of the biggest problems in developing a storage and retrieval system is to organize a system that will be useful for many purposes. Fortunately the ground work for this was accomplished by a national committee comprised of members of the National Cooperative Soil Survey. The project reported here was the first to test and use the "Proposed Coding System for the Pedon Data Record for the National Cooperative Soil Survey."

The next big problem in developing a storage and retrieval system is the cost of encoding data and storing the codes in the system.

Once the data are stored, cost of retrieval and data manipulation is minimal.

1. Encoding Soil Data

The first few pedons from Soil Survey Investigations Report No. 7 took about three hours each to encode using Method 1. Considerable time was taken discussing and determining which item and subitem contained certain morphological descriptive phrases. For example, should the phrase "lime pendulents on coarse fragments" be encoded under the item for nodules or cutans? Selecting proper codes for an item also presented problems. Physiography and parent material items and subitems presented the most encoding difficulty. For example,

is a fan terrace recorded as an alluvial or colluvial fan or a stream terrace? Many interpretative decisions had to be made which were difficult for encoders inexperienced in soil morphology. In many cases these decisions were resolved by members on the Montana State Soil Staff of the Soil Conservation Service who were familiar with the pedons. The first 26 pedons were encoded using Method 1. After experience was gained and the major problems were solved, about 2 hours were required to encode an average 8-horizon pedon using this method.

Encoding an average 8-horizon soil morphological description using Method 2 required about one hour, if it was done by an experienced coder who was familiar with soil morphological terms. Most of the soil encoding was done by the author with the help of students majoring in Soil Science at Montana State University.

The laboratory data were encoded by the author, soils students, and students inexperienced in soils. Laboratory data can be encoded by individuals not familiar with soil terminology. Encoding by Method 2 took less time and was more error free than Method 1.

Table 2 summarizes the time and cost of processing morphological and laboratory data for an average 8-horizon pedon using Method 2.

Encoding soils using the mark sense forms (Method 3) required 45 to 50 minutes for an average 8-horizon morphological description

Table 2. Time and cost for processing an average 8-horizon pedon using Method 2.

	(Man Hours)	(Cost/Hour)	Cost
		$	$
Coding			
Morphological Data†	1.00	2.00	2.00
Laboratory Data	1.00	2.00	2.00
Key Punching			
Morphological Data†	.75	2.00	1.50
Laboratory Data	.25	2.00	.50
Checking			
Morphological Data† (.25 hour/pedon x 2 men)	.50	2.00	1.00
Laboratory Data	.25	2.00	.50
Correcting Data Cards			
Morphological Data†	.75	2.00	1.50
Laboratory Data	.50	2.00	1.00
TOTAL	5.00		$10.00

† Includes site, environmental, and morphological characteristics.

Table 3. Time and cost for processing an average 8-horizon pedon using Method 3.*

	Man Hours /Pedon	Cost/Hour	Cost /Pedon**
		$	$
Encoding			
Morphological Data††	.8	2.00	1.60
Laboratory Data	1.0	2.00	2.00
Checking and Correcting			
Morphological††	.7†	2.00	1.40
Laboratory	.5	2.00	1.00
Purchases and Overprinting of Mark Sense Forms (2.2¢/sheet)			
Morphological (19 sheets x .022)			.40
Laboratory (38 sheets x .022)			.85
Processing Forms in IBM 1230			
Morphological (42 pedons/hour)		10.00	.25
Laboratory (21 pedons/hour)		10.00	.50
TOTAL	3.0		$8.00

* Unpublished paper: Dougherty, Brian D. 1972. Time and cost for encoding soil characterization data using mark sense forms. Plant and Soil Science Department, Montana State University.

** Cost/pedon rounded to nearest $0.05

† An additional .1 man hour/pedon was required after additional study was made by the present author.

†† Includes site, environmental, and morphological characteristics.

and about 1 hour for complete laboratory data for an average pedon. The encoder must be experienced and familiar with soil morphological terms.

Time and costs of processing characterization data using Method 3 are summarized in Table 3.

2. Punching Encoded Data

Keypunching cards from data on 80-column forms encoded by Method 2 for an average 8-horizon pedon required about 1 hour for the morphological data and laboratory data. Keypunching cards from encoding Method 1 took more time and resulted in more errors compared with Method 2 because keypunch drums could not be used and frequent use of alpha and numeric shafts were required.

The data punched on the cards were listed by computer and obvious errors corrected by the keypunch operators.

Method 3 required manual keypunching 4 cover cards to identify the series name, sample number, location, and classification. Cards containing remarks were also manually keypunched and placed at the end of the data deck. The encoded data are keypunched automatically by a mark sense reading machine.

3. Checking and Correcting Punched Encoded Data

Comparing the computer listing of the punched data cards with the original data and the code book did not appear to be an efficient way of checking the accuracy of encoded data.

Computer programs were developed by the author to read codes from data cards and write the proper word, value, phrase, and/or headings. The first program coverted the encoded data into a computer written soil morphological description. (Appendix VII, Figure 39.) One major interpretative problem when writing this program was selecting phrases for the computer to write which would be compatable with similar phrases used by different soil scientists. For example, the phrase "masses of lime" was finally selected to represent similar phrases such as: seams of lime, threads of lime, lime nodules, streaks and splotches of lime, lime segretations, lime concentrations, and others.

Initial checking of the morphological descriptions were accomplished by two individuals, the author and one member of the Montana State Soil Survey Staff of the Soil Conservation Service. The computer written description was read and compared with the original description. Incompatible phrases and errors were noted and the respective cards corrected. Students checked the remaining data after most problems had been solved with the State Soil Survey Staff.

The second computer program read encoded information from laboratory data cards, checked the item and subitem codes, and placed the laboratory results and the proper headings in seven tables (Appendix VII, Figure 40 and 41).

The computer written laboratory tables were compared with the originals as the final method of checking the accuracy of encoded data.

4. Storage and Retrieval of Encoded Data

The number of cards required to encode all the site, environmental, morphological, and laboratory data for a pedon became voluminous. Approximately 5 cards were needed to encode the environmental and site data and the laboratory methods. Fifteen cards were required to record the data for each horizon. There were 1466 horizons included in the 186 pedons in the pedon data (PD) record. The number of cards therefore, amounted to [186 (pedons) x 5 (cards for site data) = 930 cards] + [1466 (horizons) x 15 (cards) = 21,990 cards] making a grand total of 22,920 cards in the PD record.

The (PD) record (encoded data for all pedons) was subdivided into a field description (FD) subrecord (encoded field data) and a soil laboratory (SL) subrecord (encoded laboratory data). Dividing the records in approximately half, reduced the amount of computer core storage and reading time required to process encoded data, write soil field descriptions or print out laboratory data tables. Simultaneously processing both subrecords for a pedon with the same program would require more computer storage space than was available during regular job hours.

The number of cards making up the FD subfile (encoded data for field descriptions) and the SL subfile (encoded data for laboratory information) were transferred to separate free magnetic tapes and stored as individual 80-column data card images. This method of storage required about 1200 feet of tape for each record.

Computer written field descriptions were printed using a program that decoded information stored in the FD record. Cost to decode and print a field description depended on complexity, number of pedons processed and location in the FD record and averaged about $.25. The printing cost was reduced to about $.10 per pedon after the field descriptions were stored on labeled tape. Each pedon had its own label and could be independently retrieved.

Computer written laboratory data tables were printed using a program that decoded information stored in the SL subrecord. Cost to decode and print laboratory data tables for one pedon was about $.30. The printing costs were reduced by storing the tables on labeled tape and copying the labeled files.

Labeled files with each morphological description having its own label provided the most economical way of printing multiple copies of field pedon descriptions by computer. The same procedure provided the most economical way of printing multiple copies of laboratory data tables.

Data retrieval for statistical analysis using retrieval Method 1 (directly from PD record) proved to be costly and time consuming. Special subroutines to read the pedon data codes had to be written by the author and incorporated in the statistical programs used at Montana State University. Reading the SL subrecord, checking the "kind" codes, and sending the data to statistical programs cost $16.00 to $20.00 per multiple regression analysis.

The first step in initiating retrieval Method 2 was to create a working file from the PD record. This cost about $25.00. The working file included all the numeric data in fixed format including zero values for missing data. It was created only once. Additional files with fewer observations and complete data cost about $6.00 to create from the working file.

Multiple regression runs from the additional files cost less than $2.00. These files were set up so that several different regressions could be made without creating a new $6.00 file.

II. Statistical Analysis of Soil Characterization Data

1. Inventory of Available Data

An inventory of the pedon data (PD) record was made to determine the volume of data available for statistical analysis. Table 4 lists selected site and environmental data including climatic, topographic, physiographic, parent material, and other items and subitems that are common to all horizons of the pedon. However, the item and subitem characteristics for site and environmental data are included with each horizon observation. The mean and number of observations were calculated on the horizon basis instead of the pedon basis.

Several important facts from the site and environmental data inventory are noted in Table 4. For example, nearly half of the observations recorded in the PD record are made at sites with North

Table 4. Site and environmental item and subitem means (where applicable) and number of observations stored in the pedon data (PD) record. Those characteristics without means were encoded as alpha characters.

SITE CHARACTERISTICS	MEAN	NUMBER OF OBSERVATIONS
Aspect:		
North		131
South		79
East		59
West		83
Northeast		161
Northwest		55
Southeast		81
Southwest		67
Physiography:		
Floodplains		25
Stream Terraces		525
Fans		210
Level Plains		560
Rolling Plains		55
Mountains		77
Parent Material:		
Mode of Accumulation:		
Residual Material		140
Alluvium		785
Eolian		137
Glacial Till		218
Glacial Outwash		23
Lacustrine		120
Solid Rock		49
Unconsilidated Material		40
Partially Weathered		25
Origin of Material		
Unknown		229
Unknown Calcareous		459
Unknown Mixed		476
Fine Igneous		55
Sandstone-unspecified		28
Limestone-unspecified		39
Calcareous Shale		117

Table 4. (Cont.)

SITE CHARACTERISTICS	MEAN	NUMBER OF OBSERVATIONS
Origin of Material (Cont.)		
Sandstone and Shale		63
Shale and Siltstone		19
Coarse Igneous, acid		32
Noncalcareous Sandstone		47
Vegetation:		
Cultivated		264
Grass		947
Forest		175
Permeability Class*	3.12	975
Drainage Class*	4.86	1403
Precipitation (inches)	15.49	771
Percent Slope	6.07	1254
Elevation (feet)	4060.00	746

* Mean calculated from codes in Table 5.

or Northeasterly aspects. The reason for a dominance of sample sites on these aspects is not explained. The 186 pedons in the PD record are mainly sampled under grassland vegetation on stream terraces and level plains with alluvial parent material from an unknown source. An evaluation of the data means show that an average Montana soil is in a 15 1/2 inch precipitation zone with a 6 percent slope, an elevation of 4060 feet, moderately slow permeability and is well drained. The numerical codes shown in Table 5 were used to calculate mean permeability and drainage class. The number of observations for each item did not total the 1466 horizons in the PD record because some pedon descriptions were incomplete. Those site characteristics without means did not have numerical codes assigned to them and were stored in the PD record as alpha characters.

Table 6 lists selected soil morphological characteristics observed in the field. Those morphological characteristics without a mean did not have a numerical rating assigned to them and were stored in the PD record as alpha characters. For example, from data in Table 6, the mean color value (unspecified)[5/] is 5.5 dry and 4 moist. The mean structure is moderate to strong prismatic or blocky. The consistance is hard, friable, sticky and plastic. Textures are mainly loam, silt loam, clay loam, silty clay loam, silty clay or clay. Many horizons have clay skins, masses of lime, and gypsum. The dominant horizon designations are A1, B2, and C with many having t and ca

5/ Munsell Soil Color Chart, Munsell Color Company, Inc.

Table 5. Permeability and drainage class codes stored in the pedon data (PD) record.

CODE	ITEM	CODE	ITEM
	Permeability		Drainage
1	Very slow	1	Very poorly drained
2	Slow	2	Poorly drained
3	Moderately slow	3	Somewhat poorly drained
4	Moderate	4	Moderately well drained
5	Moderately rapid	5	Well drained
6	Rapid	6	Somewhat excessively drained
7	Very rapid	7	Excessively drained
		8	Altered - drained
		9	Altered - wetted

Table 6. Soil morphological item and subitem means (where applicable) and number of observations stored in the pedon data (PD) record. Those characteristics without means were encoded as alpha characters.

MORPHOLOGICAL CHARACTERISTICS		MEAN	NUMBER OF OBSERVATIONS
Color value			
Dry	(Interior)	5.000	7
Moist	"	4.583	12
Dry	(Exterior)	4.990	192
Moist	"	3.398	211
Dry	(Crushed)	5.545	132
Moist	"	4.067	164
Dry	(Unspecified)	5.587	1185
Moist	"	3.999	1251
Structure*			
Platy	Grade	4.08	238
"	Structure		254
Prismatic	Grade	5.04	394
"	Structure		402
Columnar	Grade	6.29	17
"	Structure		18
Angular Blocky	Grade	5.04	444
"	Structure		463
Subangular Blocky	Grade	4.56	166
"	Structure		179
Granular	Grade	4.65	128
"	Structure		150
Crumb	Grade	4.33	63
"	Structure		71
Massive Structure			277
Single Grain	Grade		
"	Structure		33
Consistance**			
Dry		64.02	1270
Moist		43.15	1325
Plastic		22.62	1176
Sticky		12.56	1176

Table 6. (Cont.)

MORPHOLOGICAL CHARACTERISTICS	MEAN	NUMBER OF OBSERVATIONS
Roots		
Few		279
Few to common		1
Common		275
Common to many		0
Many		359
Texture Classes		
Sand		29
Coarse Sand		1
Fine Sand		4
Very Fine Sand		0
Loamy Coarse Sand		4
Loamy Sand		7
Loamy Fine Sand		10
Loamy Very Fine Sand		0
Coarse Sandy Loam		3
Sandy Loam		23
Fine Sandy Loam		35
Very Fine Sandy Loam		25
Coarse (light) Loam		31
Loam		208
Fine (heavy) Loam		32
Coarse (light) Silt Loam		12
Silt Loam		127
Fine (heavy) Silt Loam		17
Silt		3
Coarse (light) Sandy Clay Loam		8
Sandy Clay Loam		16
Coarse (light) Clay Loam		34
Clay Loam		194
Fine (heavy) Clay Loam		73
Coarse (light) Silty Clay Loam		23
Silty Clay Loam		115
Fine (heavy) Silty Clay Loam		19
Sandy Clay		9
Coarse (light) Clay		22
Clay		220
Fine (heavy) Clay		50
Coarse (light) Silty Clay		11
Silty Clay		109
Fine (heavy) Silty Clay		4

Table 6. (Cont.)

MORPHOLOGICAL CHARACTERISTICS	MEAN	NUMBER OF OBSERVATIONS
Texture Modifiers		
Cobbly		16
Channery		7
Cherty		0
Flaggy		9
Gravelly		83
Very Gravelly		40
Gritty		7
Stony		28
Very Stony		8
Cutans		
Lime Coatings		126
Organic Stains		17
Clay Skins		388
Unstained Sand and/or Silt Grains		138
Stained Sand and/or Silt Grains		32
Nodules		
Gypsum Crystals		124
Insect Casts		1
Masses of Lime		243
Unknown Nodules		4
Salt Crystals		21
Worm Casts		6
Effervescence		
Slight		200
Moderate		479
Violent		49
Noncalcareous		263
Field pH	8.143	161
Horizon Designations		
II		140
III		43
IV		12

Table 6. (Cont.)

MORPHOLOGICAL CHARACTERISTICS	MEAN	NUMBER OF OBSERVATIONS
A1		210
A2		71
A3		4
B1		24
B2		305
B3		126
C or D		597
R		10
Q		31
AB or A & B		32
t		120
ca		239
p		51
cs		89
sa		8
ir		19
b		41
g		20
h		0
si		0

* Means calcualted from codes in Table 8.
**Means calculated from codes in Table 7.

Table 7. Consistance codes stored in the pedon data (PD) record.

CODE	SUBITEM	CODE	SUBITEM
	Wet - Stickiness		Wet - Plasticity
11	Nonsticky	21	Nonplastic
12	Slightly Sticky	22	Slightly Plastic
13	Sticky	23	Plastic
14	Very Sticky	24	Very Plastic
	Moist - Standard		Dry
41	Loose	61	Loose
42	Very Friable	62	Soft
43	Friable	63	Slightly Hard
44	Firm	64	Hard
45	Very Firm	65	Very Hard
46	Extremely Firm	66	Extremely Hard

Table 8. Structural grade codes stored in the pedon data (PD) record.

CODE	SUBITEM	CODE	SUBITEM
	Grade		Grade
1	Very Weak	4	Moderate
2	Weak	5	Moderate to Strong
3	Weak to Moderate	6	Strong

modifiers.

Table 9 lists selected laboratory determined chemical and physical properties. Number of observations represent the number of soil horizons for which a particular laboratory determination was made.

Many important facts were noted from Table 9. For example, some averages for the characterization data in the PD record are 30.5 percent for clay, 11.75 percent for 15 bar water content and 24.75 percent for 1/3 bar water content. Using the means, 15 bar water content can be crudely estimated by multiplying 0.4 times percent clay. One third bar water can be roughly estimated by multiplying 2 times the 15 bar water percent. An average sample has a CEC of 20 meq/100g and a base saturation of nearly 100% with calcium being the dominant cation. Average bulk density is about 1.5 g/cc.

The mean percent clay, silt and sand in Tables 10, 11 and 12 respectively, were calculated from the laboratory data for each field named textural class. The dominant textural classes were loam, silt loam, clay loam, silty clay loam, and clay. The standard deviations of the clay percentages were generally less than for silt and sand. There were very few observations in the coarse textural classes.

The means for percent water held at 1/3 (Table 13) and 15 bar (Table 14) tension were calculated for each field textural class. The standard deviations of the loam texture in both Table 13 and 14 were relatively high. The reason for the high deviation of the water

retention for this texture is not explained.

Figures 1 and 2 summarize data presented in Tables 10, 11 and 12. Figure 1 shows that the mean percent sand, silt and clay for basic field textural classes fit within the correct partition of the textural triangle except silt and sandy clay. The standard deviations of clay and sand in the sandy clay textural class were high with the mean percent clay and sand being over estimated in the field.

Figure 2 shows the location of all the textural classes stored in the pedon data record.

2. Table of Correlation Coefficients

Figures 3, 4, and 5 show the correlation coefficients (x 100) for selected site, environmental, morphological, and laboratory determined characteristics. The 3 or 4 digit value on the diagonal of Figure 3 and 4 is the number of observations available for that item or subitem. For example, there are 192 exterior dry color values stored in the PD record. Correlation coefficients that were not significant or that were calculated using less than 50 observations were not included in Figure 3, 4 or 5.

Some relationships between site, environmental, and morphological characteristics are noted in Figure 3. For example, field pH is significantly correlated to a number of other field characteristics such as color, precipitation and slope. However, there were only 161 field pH observations recorded. More field observations should be

Table 9. Item and subitem means and number of observations determined from laboratory data stored in the pedon data (PD) record.

LABORATORY DETERMINATIONS	MEAN	NUMBER OF OBSERVATIONS
Particle Size Distritution (Percent)		
Total Sand	31.40	1178
Total Silt	38.08	1178
Total Clay	30.54	1182
Very Coarse Sand	3.63	924
Coarse SAnd	3.42	1093
Medium Sand	3.59	1137
Fine Sand	9.88	1167
Very Fine Sand	12.19	1181
Coarse Silt	17.17	433
Fine Silt	22.16	1182
Very Fine Silt	36.61	49
Int II	33.95	1176
Miscellaneous Particle Size (Percent)		
2.0 to .1 mm	23.51	417
<0.074 mm	82.21	214
2 to .2μ	11.29	20
<.2μ	15.00	40
Carbonate Clay (Percent)	9.50	2
Noncarbonate Clay (Percent)	13.00	2
Coarse Fragments (Percent)		
>2 to <5 mm	2.00	17
>2 to <19 mm	10.65	365
≥2 mm (wt.)		
>2 mm (vol.)	20.43	79
>19 mm	0.0	0
>2 to <19 mm (vol.)	3.50	
>5 to <19 mm (wt.)	7.15	20
pH		
Saturated Paste	7.72	545
1:1 Water	7.23	863
1:5 Water	8.19	471
1:10 Water	8.31	649

Table 9. (Cont.)

LABORATORY DETERMINATIONS	MEAN	NUMBER OF OBSERVATIONS
Water Content (Percent)		
1/10 Bar*	15.88	19
1/3 Bar	24.79	275
30 cm*	18.89	9
15 Bar	11.75	1006
Organic Carbon (Percent)	.98	1145
Nitrogen (Percent)	.12	626
Iron as Fe (Percent)	.83	253
Iron as Fe_2O_3 (Percent)	1.50	95
Extractable Acid (Meq/100g)	5.26	398
Cole (Coefficient of Linear Extensibility)	.11	74
Extractable Bases (Meq/100g)		
Ca	10.94	630
Mg	6.90	743
Na	2.22	935
K	.71	1081
Bulk Density (g/cc)		
Field	1.55	79
1/10 Bar*	1.47	27
1/3 Bar	1.41	314
30 cm*	1.54	43
Air Dry	1.56	201
Cation Exchange Capacity (Meq/100g)		
Sum	22.68	221
NH_4OAc	19.55	1086
Base Saturation (Percent)		
Sum	66.14	188
NH_4OAc	94.01	412

Table 9. (Cont.)

LABORATORY DETERMINATIONS	MEAN	NUMBER OF OBSERVATIONS
Calcium Carbonate Equivalent (Percent)		
<2 mm	8.26	759
<2μ	2.84	63
<19 mm	27.25	4
Water Extract (Meq/Liter)		
Ca	20.58	103
Mg	28.29	103
Na	25.82	549
K	.71	462
CO_3	.30	1
HCO_3	5.27	98
Cl	7.01	95
SO_4	91.41	99
Water at Saturation (Percent)*	55.74	564
Gypsum (Percent)*	2.29	66
Gypsum (Meq/100g)*	10.42	72
Exchangeable Sodium (Percent)	11.25	533
Conductivity (Mmhos/cm)	3.40	576

* Values should not be compard with other means because data were incomplete.

Table 10. Mean clay percent, standard deviation, and number of observations for each field textural class.

FIELD TEXTURE	NUMBER OF OBSERVATIONS	MEAN	STANDARD DEVIATION
Sand	23	5.23	4.50
Coarse Sand	1	6.70	--
Fine Sand	2	7.05	6.29
Loamy Coarse Sand	2	6.65	6.44
Loamy Sand	7	5.26	3.26
Loamy Fine Sand	5	10.28	4.76
Coarse Sandy Loam	3	9.30	1.80
Sandy Loam	18	10.27	8.14
Fine Sandy Loam	30	15.43	6.24
Very Fine Sandy Loam	19	13.79	6.02
Coarse (light) Loam	20	9.39	5.18
Loam	165	19.09	8.16
Fine (heavy) Loam	25	22.79	4.96
Coarse (light) Silt Loam	6	19.68	7.28
Silt Loam	103	20.42	7.94
Fine (heavy) Silt Loam	17	22.38	6.51
Silt	2	38.45	34.44
Coarse (light) Sandy Clay Loam	7	15.11	2.70
Sandy Clay Loam	14	20.65	4.18
Coarse (light) Clay Loam	31	26.08	6.64
Clay Loam	162	28.91	7.65
Fine (heavy) Clay Loam	61	30.92	6.12
Coarse (light) Silty Clay Loam	21	31.44	8.71
Silty Clay Loam	105	34.41	10.35
Fine (heavy) Silty Clay Loam	18	35.46	4.40
Sandy Clay	9	22.58	19.17
Coarse (light) Clay	12	36.52	11.13
Clay	189	48.15	15.03
Fine (heavy) Clay	48	55.41	8.50
Coarse (light) Silty Clay	8	38.70	7.04
Silty Clay	97	43.87	9.78
Fine (heavy) Silty Clay	3	58.97	12.58

Table 11. Mean silt percent, standard deviation, and number of observations for each field textural class.

FIELD TEXTURE	NUMBER OF OBSERVATIONS	MEAN	STANDARD DEVIATION
Sand	23	7.87	5.50
Coarse Sand	1	4.70	--
Fine Sand	2	35.55	40.94
Loamy Coarse Sand	2	8.50	8.91
Loamy Sand	7	14.57	8.56
Loamy Fine Sand	5	17.84	9.18
Coarse Sandy Loam	3	16.40	6.50
Sandy Loam	18	25.33	9.12
Fine Sandy Loam	30	34.14	12.25
Very Fine Sandy Loam	19	48.25	16.37
Coarse (light) Loam	20	45.24	11.33
Loam	164	40.03	11.52
Fine (heavy) Loam	25	38.40	8.94
Coarse (light) Silt Loam	6	52.40	14.26
Silt Loam	103	52.35	11.70
Fine (heavy) Silt Loam	17	48.42	14.83
Silt	2	59.95	35.28
Coarse (light) Sandy Clay Loam	7	17.86	6.95
Sandy Clay Loam	14	23.93	6.72
Coarse (light) Clay Loam	30	34.53	8.50
Clay Loam	161	31.82	9.07
Fine (heavy) Clay Loam	61	32.41	5.38
Coarse (light) Silty Clay Loam	21	46.62	9.59
Silty Clay Loam	104	46.68	9.27
Fine (heavy) Silty Clay Loam	18	47.81	10.14
Sandy Clay	9	27.67	4.61
Coarse (light) Clay	12	28.65	6.57
Clay	189	35.93	8.97
Fine (heavy) Clay	48	37.05	5.85
Coarse (light) Silty Clay	8	49.30	9.66
Silty Clay	97	42.51	8.53
Fine (heavy) Silty Clay	3	32.17	13.45

Table 12. Mean sand percent, standard deviation, and number of observations for each field textural class.

FIELD TEXTURE	NUMBER OF OBSERVATIONS	MEAN	STANDARD DEVIATION
Sand	23	86.89	8.69
Coarse Sand	1	88.60	--
Fine Sand	2	77.40	18.95
Loamy Coarse Sand	2	84.84	15.34
Loamy Sand	7	80.17	8.92
Loamy Fine Sand	5	71.88	12.93
Coarse Sandy Loam	3	74.30	4.80
Sandy Loam	18	64.41	10.66
Fine Sandy Loam	30	50.42	14.01
Very Fine Sandy Loam	19	37.96	17.17
Coarse (light) Loam	20	45.36	9.48
Loam	164	40.85	12.14
Fine (heavy) Loam	25	38.81	11.73
Coarse (light) Silt Loam	6	27.92	15.12
Silt Loam	103	27.24	11.90
Fine (heavy) Silt Loam	17	29.19	15.42
Silt	2	1.60	.85
Coarse (light) Sandy Clay Loam	7	67.03	6.78
Sandy Clay Loam	14	55.42	6.55
Coarse (light) Clay Loam	30	39.19	9.77
Clay Loam	161	39.22	11.45
Fine (heavy) Clay Loam	61	36.67	8.56
Coarse (light) Silty Clay Loam	21	21.93	11.31
Silty Clay Loam	104	18.82	11.17
Fine (heavy) Silty Clay Loam	18	16.73	9.60
Sandy Clay	9	49.76	22.27
Coarse (light) Clay	12	34.83	14.81
Clay	189	16.05	14.99
Fine (heavy) Clay	48	7.54	6.25
Coarse (light) Silty Clay	8	12.00	12.83
Silty Clay	97	13.85	10.95
Fine (heavy) Silty Clay	3	8.87	6.37

1. Sand
2. Loamy Sand
3. Sandy Loam
4. Loam
5. Silt Loam
6. Silt
7. Sandy Clay Loam
8. Clay Loam
9. Silty Clay Loam
10. Sandy Clay
11. Clay
12. Silty Clay

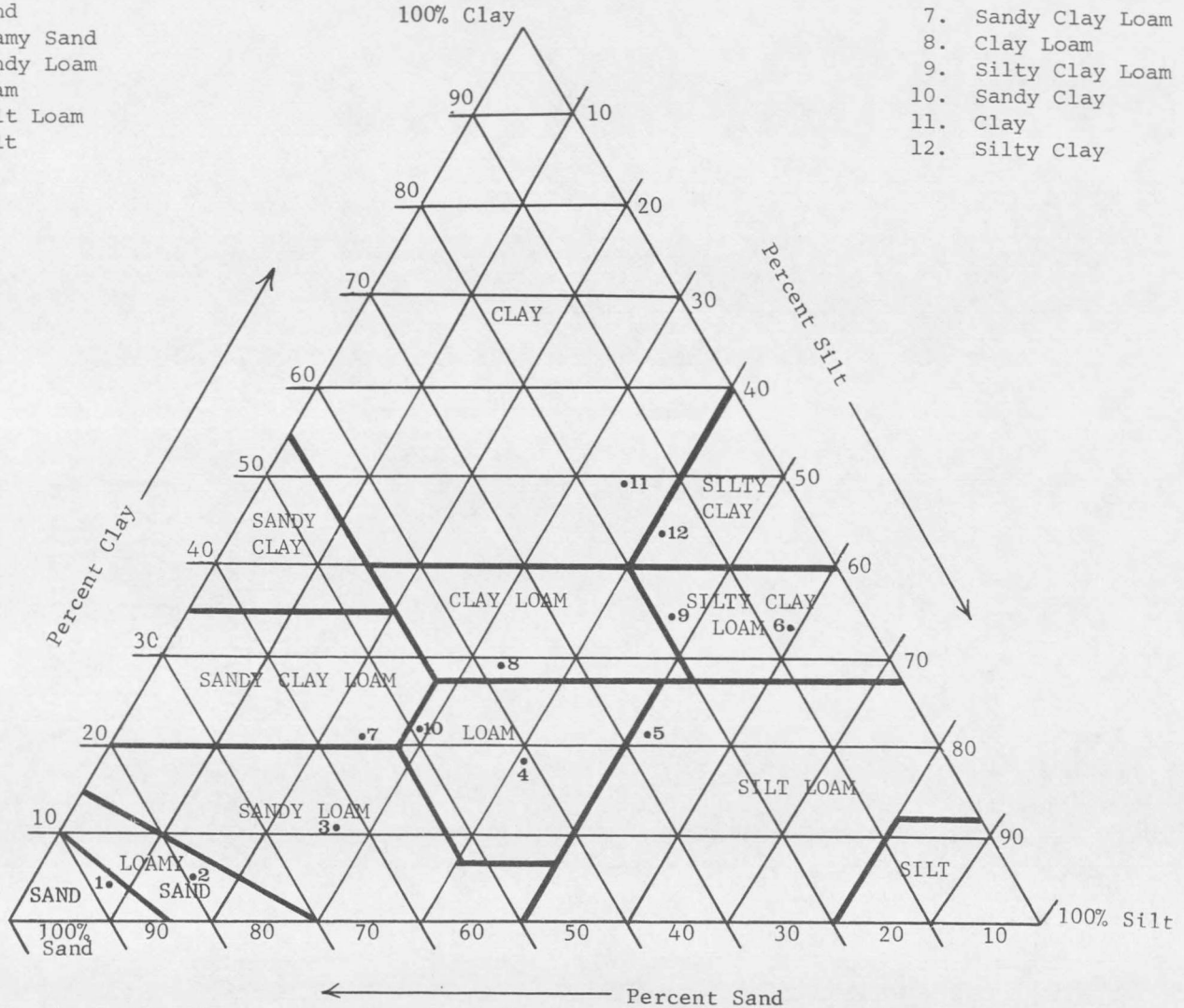


FIGURE 1. Basic textural classes stored in the PD record plotted in the proper partition of the textural triangle using the mean percent sand, silt and clay from Tables 10, 11 and 12.

1. Sand
2. Coarse Sand
3. Loamy Sand
4. Loamy Coarse Sand
5. Fine Sand
6. Coarse Sandy Loam
7. Coarse (light) Loam
8. Loamy Fine Sand
9. Sandy Loam
10. Very Fine Sandy Loam
11. Coarse Sandy Clay Loam
12. Fine Sandy Loam
13. Loam
14. Coarse (light) Silt Loam
15. Silt Loam
16. Sandy Clay Loam
17. Fine (heavy Silt Loam
18. Sandy Clay
19. Fine (heavy) Loam
20. Coarse (light) Clay Loam
21. Clay Loam
22. Fine (heavy) Clay Loam
23. Coarse (light) Silty Clay Loam
24. Silty Clay Loam
25. Fine (heavy) Silty Clay Loam
26. Coarse (light) Clay
27. Silt
28. Coarse (light) Silty Clay
29. Silty Clay
30. Clay
31. Fine (heavy) Clay
32. Fine (heavy) Silty Clay

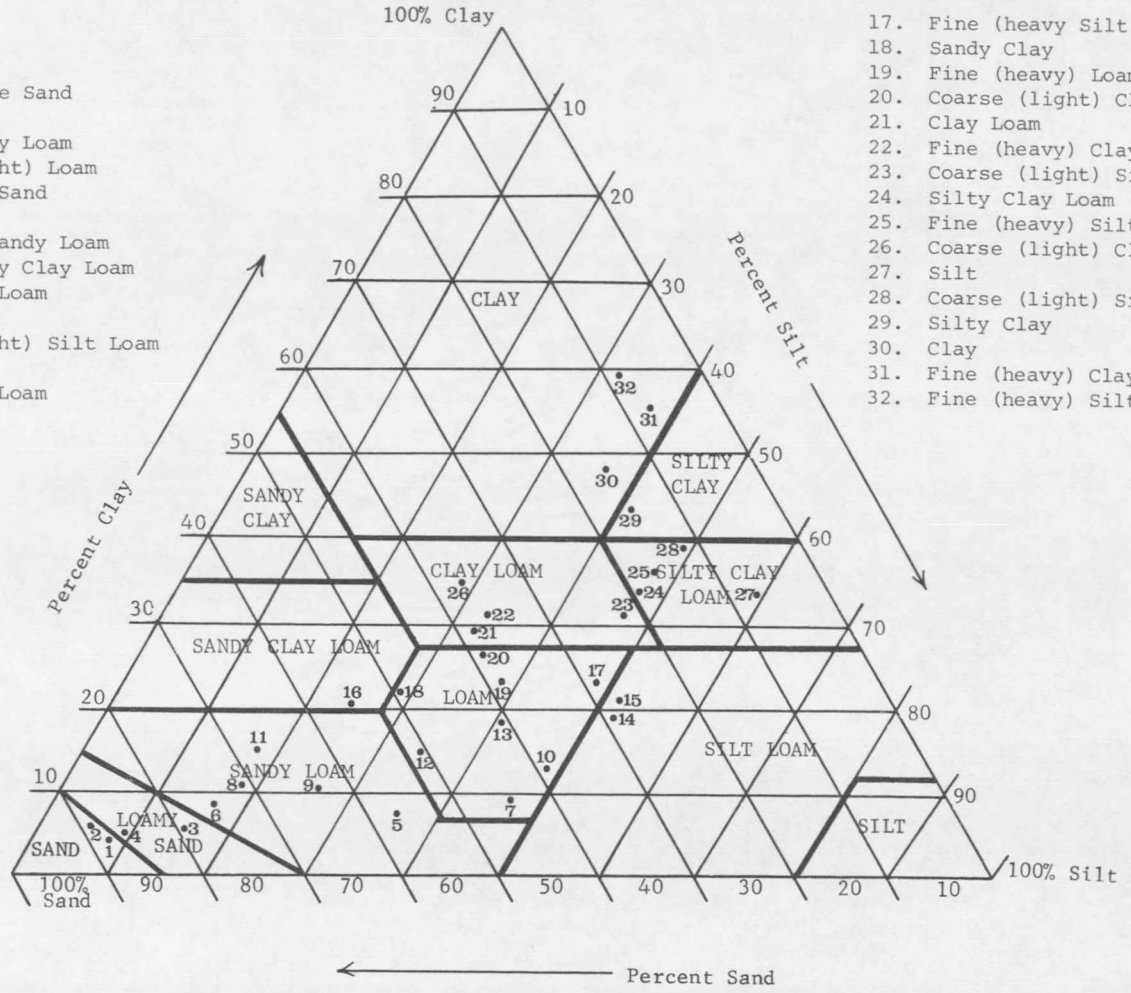


FIGURE 2. Textural classes represented in the PD record plotted on the textural triangle using the mean percent sand, silt, and clay from Tables 10, 11 and 12.

Table 13. Mean water percent (by weight) at 1/3 bar tension, standard deviation, and number of observations for each textural class.

FIELD TEXTURE	NUMBER OF OBSERVATIONS	MEAN	STANDARD DEVIATION
Sand	0	--	--
Coarse Sand	0	--	--
Fine Sand	0	--	--
Loamy Coarse Sand	0	--	--
Loamy Sand	0	--	--
Loamy Fine Sand	0	--	--
Coarse Sandy Loam	0	--	--
Sandy Loam	0	--	--
Fine Sandy Loam	1	17.40	--
Very Fine Sandy Loam	4	20.02	2.63
Coarse (light) Loam	9	25.72	9.12
Loam	28	26.50	8.61
Fine (heavy) Loam	7	17.73	2.92
Coarse (light) Silt Loam	2	23.75	2.61
Silt Loam	18	33.16	10.89
Fine (heavy) Silt Loam	3	22.77	1.52
Silt	0	--	--
Coarse (light) Sandy Clay Loam	0	--	--
Sandy Clay Loam	1	17.00	--
Coarse (light) Clay Loam	6	21.15	2.94
Clay Loam	31	20.80	4.31
Fine (heavy) Clay Loam	18	20.82	2.80
Coarse (light) Silty Clay Loam	5	21.88	2.21
Silty Clay Loam	14	23.36	4.96
Fine (heavy) Silty Clay Loam	2	21.65	6.01
Sandy Clay	2	12.80	1.98
Coarse (light) Clay	3	20.63	3.37
Clay	79	24.94	4.37
Fine (heavy) Clay	11	35.04	13.08
Coarse (light) Silty Clay	4	28.70	4.25
Silty Clay	29	26.26	4.67
Fine (heavy) Silty Clay	4	26.98	2.73

Table 14. Mean percent soil water (by weight) held at 15 bar tension, standard deviation, and number of observations for each textural class.

FIELD TEXTURE	NUMBER OF OBSERVATIONS	MEAN	STANDARD DEVIATION
Sand	8	2.44	1.63
Coarse Sand	0	--	--
Fine Sand	2	2.90	1.27
Loamy Coarse Sand	1	3.40	--
Loamy Sand	7	2.76	1.25
Loamy Fine Sand	5	4.86	1.60
Coarse Sandy Loam	3	7.23	1.88
Sandy Loam	16	4.07	2.87
Fine Sandy Loam	29	6.50	2.24
Very Fine Sandy Loam	17	6.15	2.24
Coarse (light) Loam	23	5.34	2.96
Loam	143	9.47	5.69
Fine (heavy) Loam	24	9.32	2.81
Coarse (light) Silt Loam	5	8.02	1.63
Silt Loam	89	9.20	3.10
Fine (heavy) Silt Loam	16	9.19	3.31
Silt	2	11.35	9.83
Coarse (light) Sandy Clay Loam	3	7.63	1.27
Sandy Clay Loam	11	7.15	2.21
Coarse (light) Clay Loam	22	10.02	2.90
Clay Loam	113	10.92	2.62
Fine (heavy) Clay Loam	58	11.52	2.47
Coarse (light) Silty Clay Loam	21	11.56	2.77
Silty Clay Loam	103	13.12	3.00
Fine (heavy) Silty Clay Loam	18	13.27	2.90
Sandy Clay	9	7.73	6.15
Coarse (light) Clay	11	12.82	3.01
Clay	136	15.67	4.65
Fine (heavy) Clay	48	20.60	3.29
Coarse (light) Silty Clay	10	12.36	2.38
Silty Clay	95	16.07	2.88
Fine (heavy) Silty Clay	4	18.13	3.20

recorded and additional analysis made to explore their potential for predicting related characteristics.

Figure 4 presents some correlations between laboratory data for Montana soils. For example, there were high correlations among different methods of determining CEC, pH, and bulk density. These relationships suggested possibilities of developing conversion formulas to reduce the number of analyses required of the laboratories.

Relationships between field observations and laboratory determined soil data have not been reported extensively in the literature. Therefore, the following relationships from Figure 5 were of great importance: 15 bar water percent vs. consistance and color; organic carbon percent vs. color, consistance, field pH, roots, depth; bulk density vs. consistance, slope, precipitation, roots, horizon depths; CEC vs. color, consistance, and many others. Note that consistancy, at nearly all moisture contents, is highly correlated with many laboratory determinations.

Table 15 summarizes the means, simple correlation coefficients, and number of observations obtained from multiple regression runs. They may differ from those presented in previous tables and figures because of missing data and model size. Correlation between 15 bar water and structure, horizon designation, consistance, color, precipitation, permeability, and transformations using clay, silt and/or organic carbon are shown in Table 15.

	COLOR VALUE-DRY (EXTERIOR)	COLOR VALUE-MOIST (EXTERIOR)	COLOR VALUE-DRY (CRUSHED)	COLOR VALUE-MOIST (CRUSHED)	COLOR VALUE-DRY (UNSPECIFIED)	COLOR VALUE-MOIST (UNSPECIFIED)	CONSISTANCE-DRY	CONSISTANCE-MOIST	CONSISTANCE-PLASTIC	CONSISTANCE-STICKY	FIELD pH	ELEVATION	PERCENT SLOPE	PERMEABILITY CLASS	DRAINAGE CLASS	PRECIPITATION	ROOTS	UPPER LIMITS	LOWER LIMITS
COLOR VALUE-DRY (EXTERIOR)	192																		
COLOR VALUE-MOIST (EXTERIOR)	49	211																	
COLOR VALUE-DRY (CRUSHED)	56	69	132																
COLOR VALUE-MOIST (CRUSHED)	34	57	72	164															
COLOR VALUE-DRY (UNSPECIFIED)	27	33		68	185														
COLOR VALUE-MOIST (UNSPECIFIED)	42	41	53		76	1251													
CONSISTANCE-DRY			21	40		10	1270												
CONSISTANCE-MOIST			20	39			71	1325											
CONSISTANCE-PLASTIC							71	73	1176										
CONSISTANCE-STICKY					-10		69	67	91	1176									
FIELD pH					52	64	53	28	30	19	161								
ELEVATION				-25			-22	-21	-25	-21	-65	746							
PERCENT SLOPE		15		31	14		-18	-12	-25	-26	-63	26	1254						
PERMEABILITY CLASS	-31	-23	-28				-43	-44	-43	-43	-31	29	30	975					
DRAINAGE CLASS		-16	-29				07	-04							1403				
PRECIPITATION					16		-30	-21	-35	-38	-69	59	79	36		711			
ROOTS		-25	-42	-39	-31	-37	-39	-36	-25	-25	-51	13		09		10	914		
UPPER LIMITS	16	40	59	57	28	25	07	15			27						-67	1280	
LOWER LIMITS	16	43	58	59	34	36	21	24	13	08	35						-74	98	1435

FIGURE 3. Correlation coefficients (x 100) for selected site and morphological characteristics. Matrix only includes correlations significant at the 5% level and calculated from 50 or more observations. The 3 or 4 digit numbers on the diagonal are number of observations available for each characteristic.

	TOTAL SAND	TOTAL SILT	TOTAL CLAY	FINE SILT	pH - SAT. PASTE	pH - 1:1 WATER	pH - 1:5 WATER	1/3 BAR WATER	15 BAR WATER	ORGANIC CARBON	1/3 BULK DENSITY	AIR-DRY BULK DENSITY	OVEN-DRY BULK DENSITY	CEC - SUM	BASE SAT. - SUM	CEC - NH_4OAc	BASE SAT. - NH_4OAc	NITROGEN	IRON (Fe)	EXT. ACID	EXT. Ca	EXT. Mg	EXT. Na	EXT. K	EXCH. Na%
TOTAL SAND	1178																								
TOTAL SILT	-61	1178																							
TOTAL CLAY	-76		1182																						
FINE SILT	-75	80	29	1182																					
SAT. PASTE pH				09	545																				
pH - 1:1 WATER		-29	27	-14	94	863																			
pH - 1:5 WATER	-12		15	16	93	99	471																		
1/3 BAR WATER	-42	25	23	34				275																	
15 BAR WATER	-74		87	23		33		50	1006																
ORGANIC CARBON	-12	21		16	-40	-34	-30	43	31	1145															
1/3 BAR BULK DENSITY		-31	26	-19	42	48		-70		-69	314														
AIR-DRY BULK DENSITY		-50	44	-40	58	40		-60		-62	93	201													
OVEN-DRY BULK DENSITY		-30	32	-20		38		-22	33	-72	65		144												
CEC - SUM	-40		37					61	80	63	-51		-32	221											
BASE SAT. - SUM	-24	-34	50	-23		55			26	-29					188										
CEC - NH_4OAc	-62		70	22	-12	12		56	86	37	-28			95	25	1086									
BASE SAT. - NH_4OAc	-20	-35	48	-23	84	76		-36	35	-26	60	59	36	21	93	27	412								
NITROGEN	-08	16		13	-46	-25	-26	43	44	95	-66	-53		61	-31	42	-27	626							
IRON (Fe)	-35	20	20	27		-15		39	24		-39	-51	21	30		22	-26		253						
EXT. ACID	-14	34	-15	37		-38	-54	55	20	70	-79	-79	-57	9	-62	23	-56	59	37	398					
EXT. Ca	-32	-19	47	-12			34	36	63	27	-17			83	41	81	32	27	20		630				
EXT. Mg	-35	-26	56	-13	46	56	53		60	-17	26	44	43	52	55	58	64	-11		-18	28	743			
EXT. Na	-31	13	27	19	36	43	39	36	37	-10		36	25			25	44			-14		40	935		
EXT. K	-43	08	45	21	-21		-10	52	51	33	-38	-20		58		63	10	28	21	18	53	23	25	1081	
EXCH. Na%	-14	23		15	43		47		14	-12	21						-13				-28	28	89	13	533

FIGURE 4. Correlation coefficients (x 100) for selected laboratory determined chemical and physical properties. Matrix only includes correlations significant at the 5% level and calculated from 50 or more observations. The 3 or 4 digit numbers on the diagonal are number of observations available for each characteristic.

	COLOR VALUE-DRY (EXTERIOR)	COLOR VALUE-MOIST (EXTERIOR)	COLOR VALUE-DRY (CRUSHED)	COLOR VALUE-MOIST (CRUSHED)	COLOR VALUE-DRY (UNSPECIFIED)	COLOR VALUE-MOIST (UNSPECIFIED)	CONSISTANCE (DRY)	CONSISTANCE (MOIST)	CONSISTANCE (PLASTIC)	CONSISTANCE (STICKY)	pH - FIELD	ELEVATION	SLOPE (PERCENT)	PERMEABILITY	DRAINAGE	PRECIPITATION	ROOTS	UPPER LIMITS	LOWER LIMITS
TOTAL SAND	-30		-35	-30	15	20	-38	-42	-48	-44	-23	35		48	30	12			09
TOTAL SILT	16	21	25	27		-17	-11	-19	-22	-20	-18		30		-16	33	13		-10
TOTAL CLAY	17				-15	-11	52	61	71	64	40	-36	-31	-59	-26	-40			
FINE SILT	24	22	47	41		-11	10	10				-14	29	-12	-27	28		10	
pH - SAT. PASTE					27	38	10				91	-51	-45		-14	-56	-31	16	29
pH - 1:1 WATER				20	15	23	30	22	28	24		-35	-46	-17	-10	-57	-49	28	35
pH - 1:5 WATER					46	45					91	-44	-21		-23	-44	-59	37	46
1/3 BAR WATER	-21	-40			-18	-33	-13			-19			25			39	14	-26	-27
15 BAR WATER		-23			-36	-31	38	48	58	51	23	-26	-28	-56	-12	-36		-11	-12
ORGANIC CARBON	-32	-44	-58	-67	-43	-50	-34	-32	-29	-27	-61	28	10	11		20	45	-38	-47
1/3 BAR BULK DENSITY	24	45			28	46	62	45	48	50		-34	-60	-26		-58	-46	50	55
AIR-DRY BULK DENSITY						23	81	68	67	65		-26	-55	-35		-55	-44	46	53
OVEN-DRY BULK DENSITY					31	41	62	52	57	51				-38			-31	28	41
CEC - SUM	-53	-47			-64	-59			23	26							15	-41	-37
BASE SAT. - SUM							56	60	66	60		-32	-47	-51		-65	-18	13	14
CEC - NH_4OAc	-45	-45	-51	-50	-50	-40	23	37	45	45		-15	-20	-40	-29	-27		-19	-21
BASE SAT. - NH_4OAc	-22				-19		58	43	53	53		-48	-50	-36		-71	-21		
NITROGEN	-32	-49		-70	-47	-56	-36	-30	-31	-31	-66	37	11	20		24	35	-32	-46
IRON (Fe)						-15							25			33	19	-17	-16
EXT. ACID	-26	-47	-61	-70	-24	-40	-44	-36	-36	-31		25	39	25		50	23	-25	-28
EXT. Ca	-47	-40	-53	-43	-41	-32	11	21	37	38		-25	-24	-26		-26	15	-23	-24
EXT. Mg	-25	-27	-27		-24		51	46	54	50	29	-58	-36	-27		-56	-36	11	17
EXT. Na							23	26	18	18	28	-35	-16	-43	-31	-30	-36	11	16
EXT. K	-23	-36	-45	-55	-34	-34		15	24	24	-29	-21	-16	-32	-31	-27	26	-23	-32
EXCH. Na%												-26		-28	-29	-20	-39		14

FIGURE 5. Significant (5% level) correlation coefficients (x 100) for selected site or morphological characteristics (columns) and laboratory determined chemical and physical properties (rows) with more than 50 observations.

Table 15. Independent variable items or subitems selected for testing in a percent water at 15 bar tension (dependent variable) multiple regression model.

Item or Subitem	Number of Observations	Dep. Var. Mean	Indep. Var. Mean	Correlation Coefficient
Sand (Percent)	970	11.73	30.41	-.7371††
Silt (Percent)	970	11.73	39.21	.1206††
Clay (Percent)	970	11.73	30.45	.8731††
Fine Silt (Percent)	970	11.73	22.83	.2331††
Est. Clay (Percent)*	900	11.72	30.31	.762 ††
Est. Silt (Percent)*	555	12.08	37.96	.042
Consistance***				
Dry	886	12.00	64.07	.3772††
Moist	953	11.94	43.23	.4841††
Plastic	817	12.04	22.72	.5792††
Sticky	816	12.00	12.64	.5088††
Dry Color Value	845	11.83	5.59	-.3561††
Moist Color Value	902	11.78	3.90	-.3054††
Organic Carbon (Percent)	933	11.80	.93	.3052††
(Organic Carbon)^2 "	555	12.08	3.81	.225 ††
Precipitation (Inches)	366	11.47	15.92	-.357 ††
Permeability**	352	11.35	3.28	-.570 ††
Organic Carbon x Clay (Percent)	352	11.35	24.75	.398 ††
Silt x Clay (Percent)	352	11.35	1159.85	.788 ††
Silt + Clay (Percent)	352	11.35	68.68	-.747 ††
Structure Grade†††				
Platy	72	---	---	-.029
Prismatic	131	---	---	.194 †
Columnar	3	---	---	.054
Angular Blocky	123	---	---	.311 ††
Subangular Blocky	59	---	---	-.107
Granular	56	---	---	.080
Crumb	14	---	---	-.086
Structure Type†††				
Platy	72	---	---	-.030
Prismatic	131	---	---	.214 †
Columnar	3	---	---	.054
Angular Blocky	123	---	---	.309 ††
Subangular Blocky	59	---	---	-.202
Granular	56	---	---	.082
Crumb	14	---	---	-.092
Single Grain	60	---	---	-.256 †
Parallel Piped	3	---	---	-.098
Massive	2	---	---	.194

Table 15. (Cont.)

Item or Subitem	Number of Observations	Dep. Var. Mean	Indep. Var. Mean	Correlation Coefficient
Horizon Designation				
Capital - Arabic†††				
A1	128	---	---	.134
A2	48	---	---	-.245
A3	2	---	---	-.024
B1	15	---	---	-.038
B2	198	---	---	.165†
B3	83	---	---	-.003
C	373	---	---	-.037
R	2	---	---	-.056
Ø	0	---	---	---
Lower Case†††				
t	68	---	---	.184
ca	140	---	---	-.050
p	40	---	---	-.005
cs	61	---	---	.135
sa	6	---	---	.085
ir	19	---	---	-.145
b	31	---	---	-.062
g	5	---	---	.032

* Field textural class names were assigned clay percent from Table 10.
** Calculated from numerical codes. See Table 5.
***Calculated from numerical codes. See Table 7.
† r values significant at the 5% level.
†† r values significant at the 1% level.
†††Means were not calculated for this subitem.

3. Multiple Regression Models for Predicting Soil Water

Several models were developed for predicting soil water precent at 15 bar tension. Model 1a is used when percent clay is known from laboratory analysis.

(Model 1a) $\hat{Y} = A + B_1X_1$

Where:

$\hat{Y}$ = Percent soil water at 15 bar tension

A = 3.19 (Intercept)

B_1 = .28

X_1 = Percent Clay

R^2 = .76

F = 2952.66

n = 930

$s_{y:x}$ = 2.50

Model 1b may also be used to predict percent soil moisture held at 15 bar tension when percent clay is estimated from field texture in Table 10.

(Model 1b) $\hat{Y} = A + B_1X_1$

Where:

$\hat{Y}$ = Percent soil water held at 15 bar tension

A = 2.44

B_1 = .31

X_1 = Estimated percent clay from Table 10

R^2 = .58

F = 1244.56

n = 900

$s_{y.x}$ = 3.31

The intercept and regression coefficient were very similar in Models 1a and 1b. However, the confidence interval of the prediction increased from 5 percent to 6 percent respectively at the 95 percent level.

Model 2 is used when percent clay and organic carbon or organic matter is known from laboratory analysis.

(Model 2) $Y = A + B_1X_1 + B_2X_2$

Where:

Y = Percent soil water at 15 bar tension

A = 2.1

B_1 = .29

X_1 = Percent Clay

B_2 = 1.0 (organic carbon) or .58 (organic carbon)

X_2 = Percent organic carbon or organic carbon

R^2 = .84

F = 2462.79

n = 930

sy.x = 2.04

Model 3 is used when clay percent is known from laboratory determinations or is estimated from field texturing, moist color value determinations and horizon designations. The simple correlation coefficient for the A1 horizon designation from Table 15 was not significant; however, the partial correlation with fixed percent clay and moist color value was significant and becomes important in Models 3 and 4.

(Model 3) $\hat{Y} = A + B_1X_1 + B_2X_2 + B_3X_3 + B_4X_4$

Where:

$\hat{Y}$ = Percent soil water held at 15 bar tension

A = 6.09

B_1 = .28

X_1 = Percent Clay

B_2 = -.75

X_2 = Moist color value

B_3 = 1.88

X_3 = 1 (horizon an A1 or Ap)
0 (horizon not an A1 or Ap)

B_4 = -1.91

X_4 = 1 (horizon an Ap)
0 (horizon not an Ap)

R^2 = .80

F = 877.39

n = 874

sy.x = 2.29

Model 4 is used when clay percent is estimated from field texture in Table 10 and moist color values and horizon designations are known from field observations.

(Model 4) $\hat{Y} = A + B_1X_1 + B_2X_2 + B_3X_3 + B_4X_4$

Where:

$\hat{Y}$ = Percent soil water held at 15 bar tension

A = 5.14

B_1 = .30

X_1 = Estimated percent clay from Table 10

B_2 = -.71

X_2 = Moist color value

B_3 = 2.57

X_3 = 1 (horizon an A1 or Ap)
0 (horizon not an A1 or Ap)

B_4 = -2.87

X_4 = 1 (horizon an Ap)
0 (horizon not an Ap)

R^2 = .64

F = 393.06

n = 900

sy.x = 3.08

Model 5 was developed using mean percent clay from Table 10 and mean percent soil water held at 15 bar tension from Table 14 for each field textural class.

(Model 5) $\hat{Y} = A + B_1X_1$

Where:

$\hat{Y}$ = Percent soil water held at 15 bar tension

A = 2.00

B_1 = .30

X_1 = Mean percent clay determined from textural class

R^2 = .94

F = 495.14

n = 31

$sy.x$ = 1.09

x = 24.6

The parameters in Model 5 are similar to those in Model 1 and Model 2. Two basic assumptions must be made before this model can be used. First, the individual determining the field textural class is assumed to be average in his ability to estimate soil texture. Second, the individual must texture several samples before determining the average textural class.

Figure 6 shows the distribution of mean percent soil water held at 15 bar tension from Table 14 on the vertical axis (Y) plotted against mean percent clay (field textural class from Table 10). Each

1. Fine (heavy) silty clay
2. Fine (heavy) clay
3. Clay
4. Silty clay
5. Coarse (light) silty clay
6. Silt
7. Coarse (light) clay
8. Fine (heavy) silty clay loam
9. Silty clay loam
10. Coarse (light) silty clay loam
11. Fine (heavy) clay loam
12. Clay loam
13. Coarse (light) clay loam
14. Fine (heavy) loam
15. Sandy clay
16. Fine (heavy) silt loam
17. Sandy clay loam
18. Silt loam
19. Coarse (light) silt loam
20. Loam
21. Fine sandy loam
22. Coarse sandy clay loam
23. Very fine sandy loam
24. Sandy loam
25. Loamy fine sand
26. Coarse (light) loam
27. Coarse sandy loam
28. Fine sand
29. Loamy coarse sand
30. Loamy sand
31. Sand

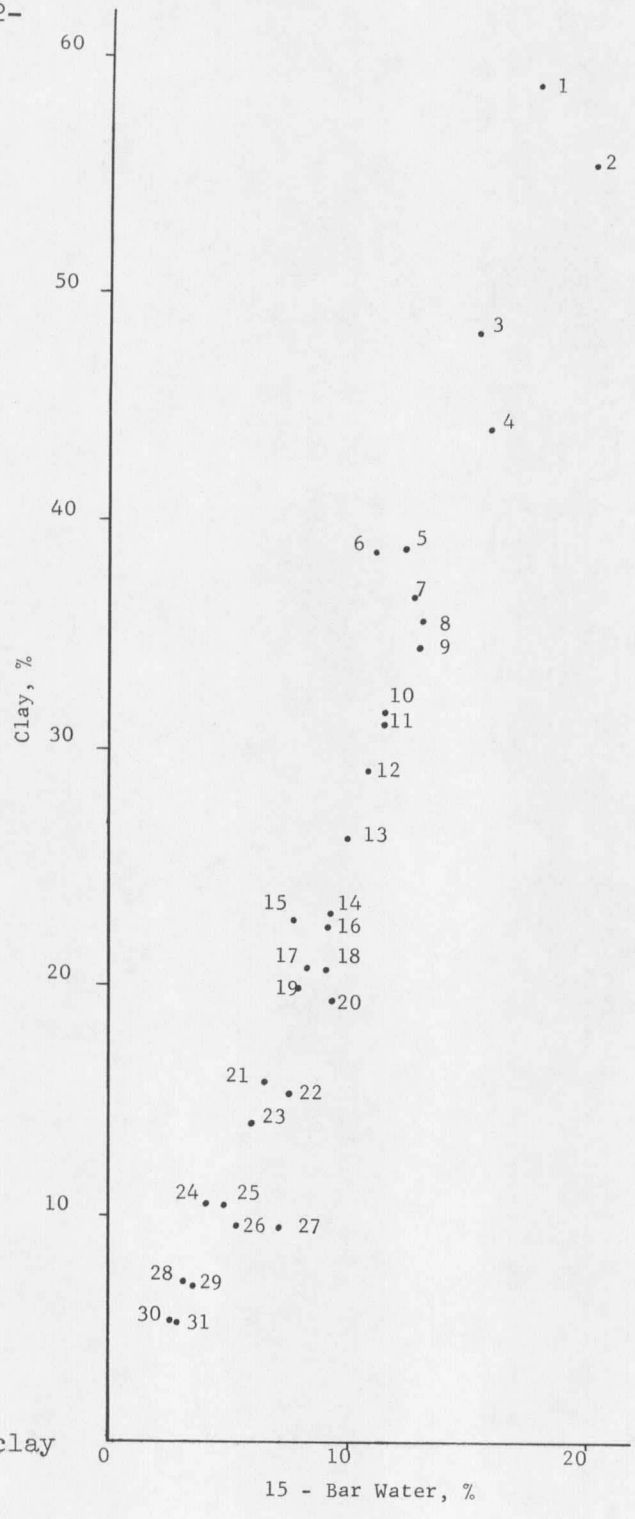


Figure 6. Soil water plotted against mean percent clay for textural classes represented in the PD record.

point on the graph represents a field textural class.

Model 6 is a reduction of Models 3 and 4 using actual percent clay or estimated percent clay from the textural class (Table 10) and moist color value. However, 15 bar water retention can be predicted more accurately using actual percent clay (Model 3) vs. estimated percent clay (Model 4.) The parameters in the first two steps of developing Models 3 and 4 round off to those in Model 6.

(Model 6) $\hat{Y} = B_1X_1 + B_2X_2$

Where:

$\hat{Y}$ = Percent soil water held at 15 bar tension

A = 7.0

B_1 = 0.3

X_1 = Actual or mean percent clay

B_2 = 1.0

X_2 = Moist color value

(Actual Percent Clay)	(Estimated Percent Clay)
R^2 = .79	R^2 = .62
F = 1646.54	F = 723.42
n = 874	n = 900
sy.x = 2.35	sy.x = 3.16

Preliminary investigations were made in relationships between characteristics observed in the field and laboratory determined

characteristics such as bulk density and organic carbon content. Several preliminary models have been developed for predicting bulk density and organic carbon but it is believed that more investigations are needed before a final model is developed.

4. Plots of Residuals Using the Statistical Models

Figures 7, 8, 9 and 10 are computer drawn graphs of actual percent soil water held at 15 bar tension plotted against predicted values. Models 1a, 2, 3, and 4 respectively were used to predict the percent soil water. Each point on the graphs represents the predicted value on the vertical (Y) axis and the laboratory determined value on the horizonal (X) axis. The solid line at a 45° angle extending from coordinates (0,0) represents the location of all points if percent soil water retained at 15 bar tension could be predicted without error.

The dashed lines enclose the area ± 5 percent water from a perfect prediction. The 5 percent value was selected on the basis that most people would be satisfied predicting percent soil water held at 15 bar tension within 5 percent, 95 percent of the time. The points outside the dashed line represent the number of soil samples out of 930, 930, 874, and 900 samples respectively that were not predicted within 5 percent water. This is within ± 1 percent of 2 standard deviations calculated in the models.

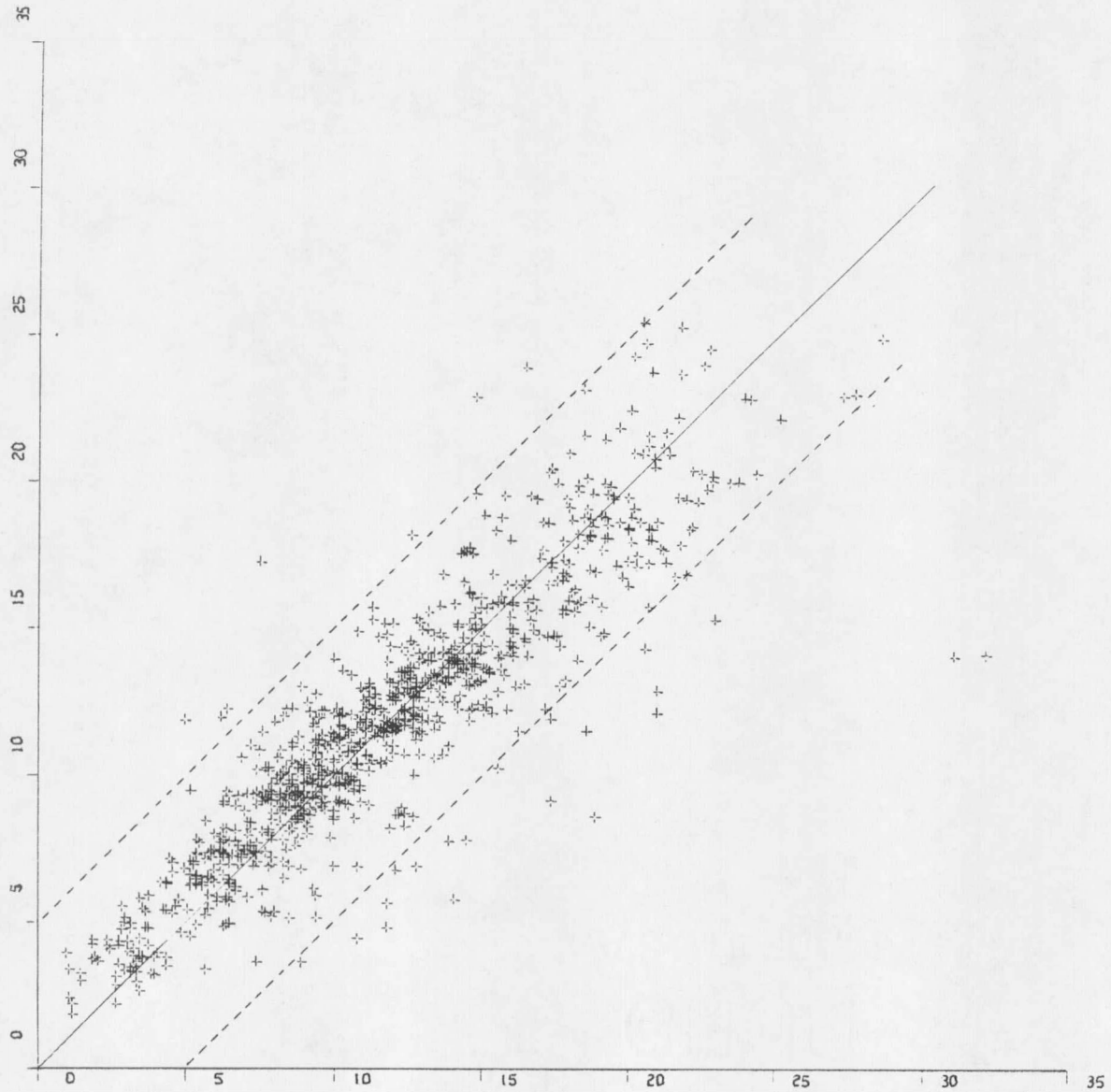


FIGURE 7. Distribution of the predicted values (Y axis) using Model 1a [$\hat{Y}$ = 3.19 + 0.28 (percent clay)] plotted against the actual value (X axis) for percent soil water held at 15 bar tension. Vertical distance of points from the solid diagonal line represents over or under prediction of percent soil water.

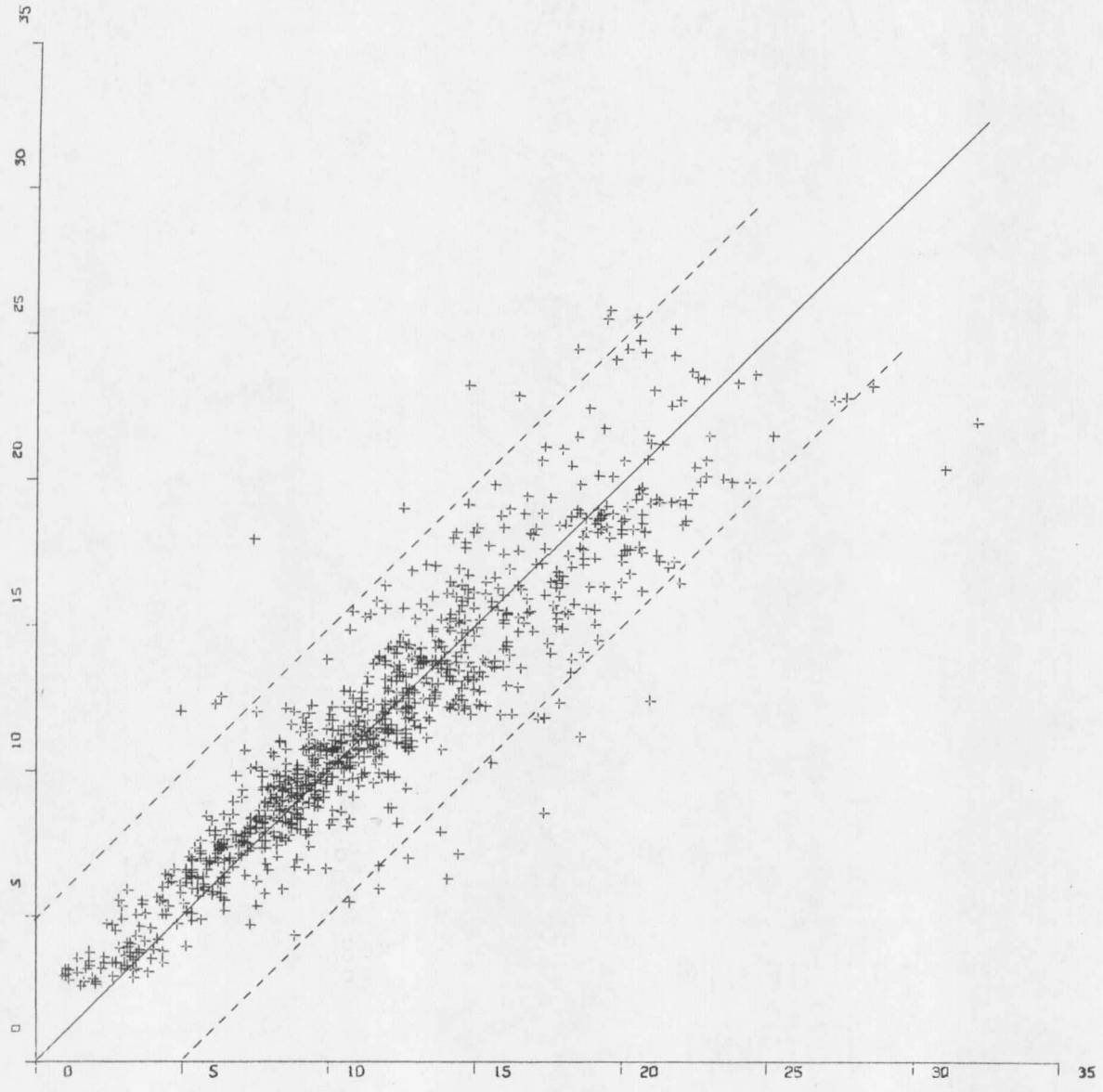


FIGURE 8. Distribution of the predicted values (Y axis) using Model 2 [$\hat{Y}$ = 2.1 + 0.29 (percent clay) + 1.0 (organic carbon)] plotted against the actual value (x axis) for percent soil water held at 15 bar tension. Vertical distance of points from the solid diagonal line represents over or under prediction of percent soil water.

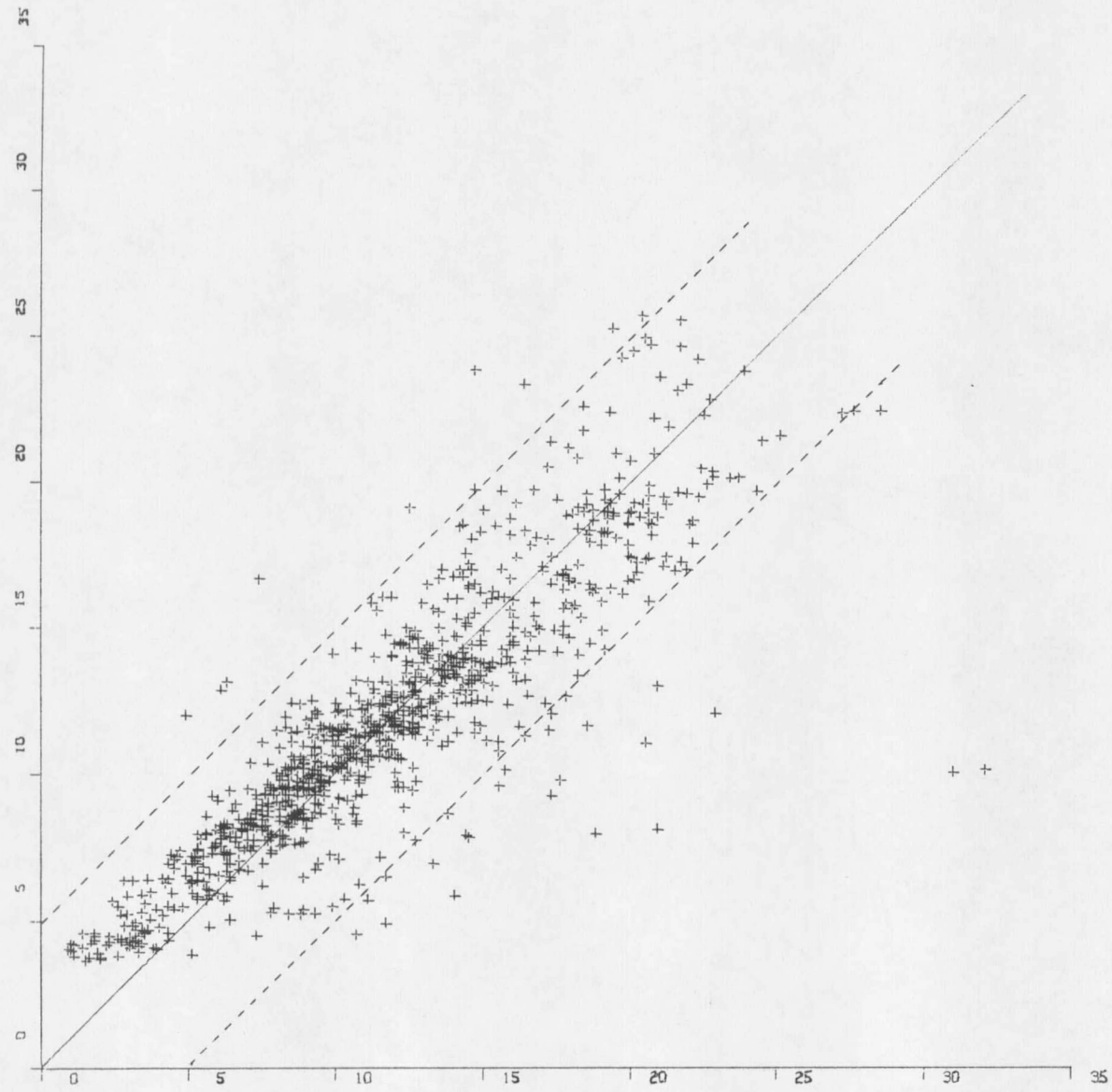


FIGURE 9. Distribution of the predicted values (Y axis) using Model 3 [$\hat{Y}$ = 6.1 + .28 (percent clay) - 0.75 (moist color value) + 1.9 (A1 horizon) - 1.9 (Ap horizon)] plotted against the actual value (X axis) for percent soil water held at 15 bar tension. Vertical distance of points from the solid diagonal line represents over or under prediction of percent soil water.

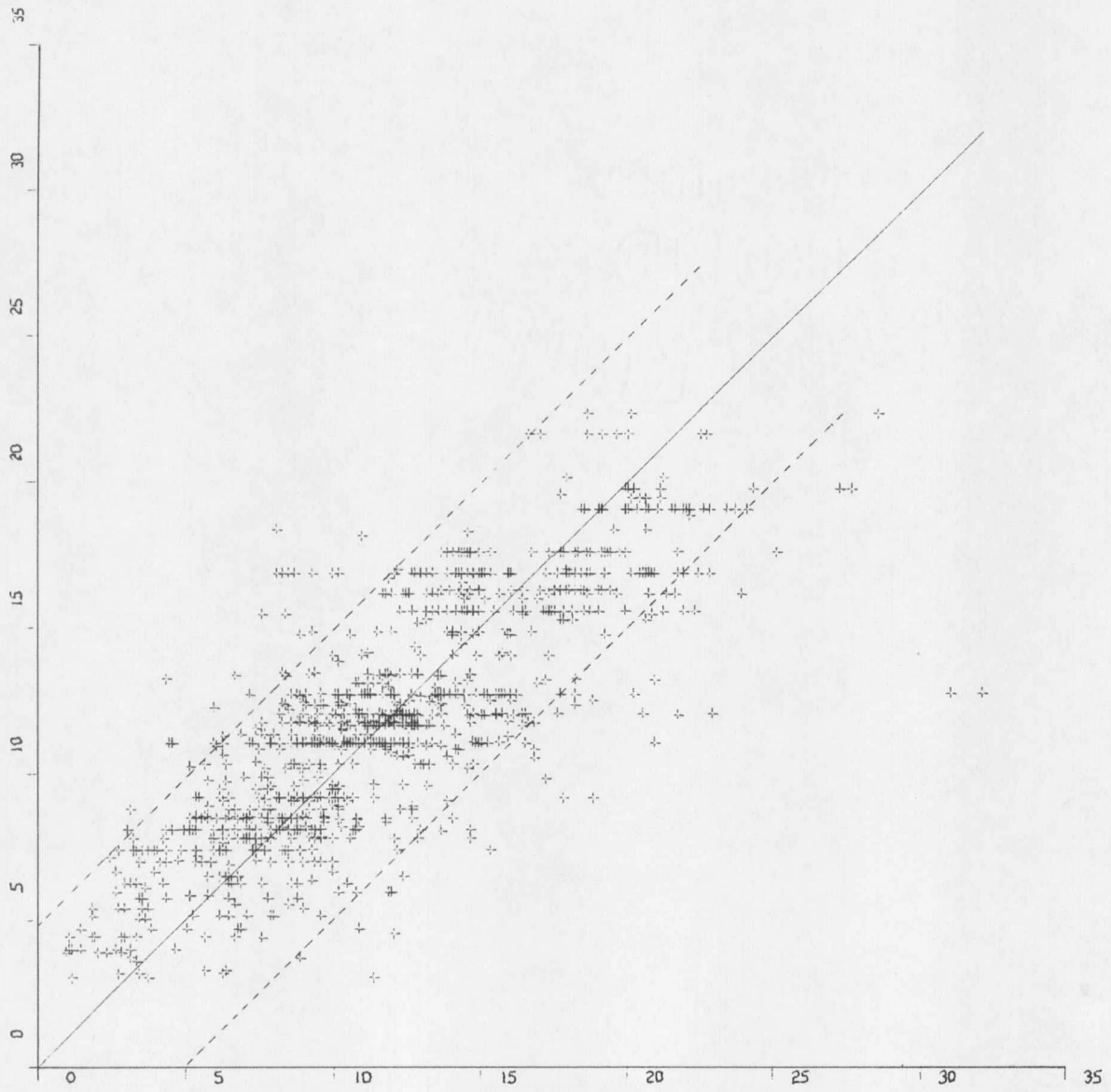


FIGURE 10. Distribution of the predicted values (Y axis) using Model 4 [$\hat{Y}$ = 5.1 + 0.30 (est. clay) - 0.71 (moist color value) + 2.6 (A1 horizon) - 2.9 (Ap horizon)] plotted against the actual value (X axis) for percent soil water held at 15 bar tension. Vertical distance of points from the solid diagonal line represents over or under prediction of percent soil water.

III. Practical Application of Statistical Models

Three operational forms for estimating soil water available to plants have been developed. The form used depends on the kind of information available for predicting the amount of soil water that is not available to the plant. The form requires measurement of the total amount of water stored in the soil by weight. The unavailable water is calculated by the formula provided in the form and subtracted from the total amount stored. The difference is converted to water by volume, all the layers in the root zone being totaled to obtain the estimated soil water available to plants.

The form illustrated by Figure 11 was developed using statistical Model 1a where the actual clay in the soil was known. This form was also used when only the textural class was known and the mean clay percent for that texture from Table 10 substituted in the formula.

The form illustrated by Figure 12 was developed using statistical Model 2 where actual percent clay and organic matter were known from laboratory analysis. This is the most reliable model for estimating total soil water available to plants.

The form illustrated in Figure 13 was developed using statistical Model 6 which was a reduction and combination of Models 3 and 4. Known or estimated percent clay and moist color value are needed when using Model 6.

Percent clay determined in the laboratory is a better predictor of percent soil water held at 15 bar than the mean percent clay assigned from the textural class. This is true in all models.

1 Sample Depth Limits Upper	2 Lower	3 Sample Weights Wet	4 Dry	5 Water by Weight	6	7	8	9 15 Bar Water by Weight	10 Available Water by Weight	11 Bulk Density	12 Available Water by Volume	13 Sample Thickness	14 Available Water
inches	inches	g	g	%	Constant	Constant	Clay* %	%	%	g/cc	%	inches	inches
____ to	____	____ -	____ =	____	3.0 + (.3	x ____) =		____	____ x	____ =	____ x	____ =	____
____ to	____	____ -	____ =	____	3.0 + (.3	x ____) =		____	____ x	____ =	____ x	____ =	____
____ to	____	____ -	____ =	____	3.0 + (.3	x ____) =		____	____ x	____ =	____ x	____ =	____
____ to	____	____ -	____ =	____	3.0 + (.3	x ____) =		____	____ x	____ =	____ x	____ =	____
____ to	____	____ -	____ =	____	3.0 + (.3	x ____) =		____	____ x	____ =	____ x	____ =	____

Total Estimated Soil Water Available to Plants _____

* If actual percent clay is unavailable, use the mean clay percent for the field textural class.

Columns 1 and 2.	Upper and lower boundary of the soil layer sampled. (Example: 0 to 12 inches).
Columns 3 and 4.	Weight of soil sample before and after drying.
Column 5.	(Column 3 - Column 4)/(Column 4).
Columns 6 and 7.	Predetermined constants found by analyzing laboratory data.
Column 8.	Laboratory determined percent clay.
Column 9.	(Column 6) + (Column 7 x Column 8).
Column 10.	(Column 5) - (Column 9).
Column 11.	Actual bulk density (if known) or estimated bulk density.
Column 12.	(Column 10) x (Column 11).
Column 13.	Thickness, in inches, of the soil layer the sample represents. (Column 2) - (Column 1)
Column 14.	(Column 12) x (Column 13).

FIGURE 11. Method 1 of calculating total estimated soil water available to plants using Model 1 [$\hat{Y}$ = 3.0 + 0.3 (percent clay)] when percent clay is known. Values in column 16 are actually divided by 100 to give estimates of available water in inches.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Depth Limits		Sample Weights		Water by	Constants		Clay	Constant	Organic* Matter	15 Bars Water by	Available Water by	Bulk	Available Water by	Sample	Available
Upper	Lower	Wet	Dry	Weight						Weight	Weight	Density	Volume	Thickness	Water
inches	inches			%			%		%	%	%	g/cc	%	inches	inches
___	to ___	___	- ___	= ___	2.0 +	(.3 x ___)	+ (.6 x	___)	=	___	___	x ___	= ___	x ___	= ___
___	to ___	___	- ___	= ___	2.0 +	(.3 x ___)	+ (.6 x	___)	=	___	___	x ___	= ___	x ___	= ___
___	to ___	___	- ___	= ___	2.0 +	(.3 x ___)	+ (.6 x	___)	=	___	___	x ___	= ___	x ___	= ___
___	to ___	___	- ___	= ___	2.0 +	(.3 x ___)	+ (.6 x	___)	=	___	___	x ___	= ___	x ___	= ___
___	to ___	___	- ___	= ___	2.0 +	(.3 x ___)	+ (.6 x	___)	=	___	___	x ___	= ___	x ___	= ___

Total Estimated Soil Water Available to Plants _____

* Organic Matter = 1.72 x Organic Carbon

Columns 1 and 2. Upper and lower boundary of the soil layer sampled.
Columns 3 and 4. Weight of soil sample before and after drying.
Column 5. (Column 3 - Column 4) / (Column 4).
Columns 6,7 and 9. Predetermined constants found by analyzing laboratory data.
Columns 8 and 10. Laboratory determined percent clay and organic carbon or organic matter.
Column 11. (Column 6) + (Column 7 x Column 8) + (Column 9 x Column 10).
Column 12. (Column 5) - (Column 11).
Column 13. Actual bulk density (if known) or estimated bulk density.
Column 14. (Column 12) x (Column 13).
Column 15. Thickness, in inches, of the soil layer the sample represents.
Column 16. (Column 14) x (Column 15).

Total estimated soil water available for plants = the sum of Column 16.

FIGURE 12. Method 2 of calculating total estimated soil water available to plants using Model 2 [$\hat{Y} = 2.0 + 0.3$ (percent clay) + .6 (organic matter)] when percent clay and organic carbon or organic matter is known. Values in column 16 are actually divided by 100 to give estimates of available water in inches.

1 Sample Depth Limits Upper	2 Lower	3 Sample Weights Wet	4 Dry	5 Water by Weight	6 Constant	7 Constant	8 Clay*	9 Constant	10 Moist Color Value	11 15 bar Water by Weight	12 Available Water by Weight	13 Bulk Density	14 Available Water by Volume	15 Sample Thickness	16 Available Water
inches	inches	g	g	%			%			%	%	g/cc	%	inches	inches
____ to	____	____ -	____ =	____	7.0 + (.3	x ____) - (	1.0	x ____) =		____	____ x	____ =	____ x	____ =	____
____ to	____	____ -	____ =	____	7.0 + (.3	x ____) - (	1.0	x ____) =		____	____ x	____ =	____ x	____ =	____
____ to	____	____ -	____ =	____	7.0 + (.3	x ____) - (	1.0	x ____) =		____	____ x	____ =	____ x	____ =	____
____ to	____	____ -	____ =	____	7.0 + (.3	x ____) - (	1.0	x ____) =		____	____ x	____ =	____ x	____ =	____
____ to	____	____ -	____ =	____	7.0 + (.3	x ____) - (	1.0	x ____) =		____	____ x	____ =	____ x	____ =	____

Total Estimated Soil Water Available to Plants _____

* If actual percent clay is unavailable, use the mean clay percent for the field textural class.

Columns 1 and 2. Upper and lower boundary of the soil layer sampled. (Example: 0 to 12 inches)
Columns 3 and 4. Weight of soil sample before and after drying.
Column 5. (Column 3 - Column 4)/(Column 4).
Columns 6, 7, & 9. Predetermined constants found by analyzing laboratory data.
Columns 8 and 10. Laboratory determined percent clay and organic crabon or organic matter.
Column 11. (Column 6) + (Column 7 x Column 8) + (Column 9 x Column 10).
Column 12. (Column 5) - (Column 11)
Column 13. Actual bulk density (if known) or estimated bulk density.
Column 14. (Column 12) x (Column 13).
Column 15. Thickness, in inches, of the soil layer the sample represents (Column 2 - Column 1).
Column 16. (Column 14) x (Column 15)

Total estimated soil water available to plants = the sum of Column 16.

FIGURE 13. Method 3 of calculating total estimated soil water available to plants using Model 6 [$\hat{Y}$ = 7.0 + 0.3 (percent clay) + 1.0 (moist color value)] when percent clay and moist color value are known. Values in column 16 are actually divided by 100 to give estimates of available water in inches.

SUMMARY

Soil characterization data for 186 Montana soil pedons were obtained from the Soil Conservation Service. The data were encoded using the "Proposed Coding System for the Pedon Data Record for the National Cooperative Soil Survey." The codes were keypunched on cards and stored on magnetic tape at Montana State University's Computer Center.

Three methods of encoding site, environmental, morphological, and laboratory characteristics were tested. Twenty-six pedons were encoded using Method 1; however, a good cost analysis is not available to compare with the other two methods. It is estimated that Method 1 would require about double the man hours needed to process one pedon by Method 2. One hundred sixty pedons were encoded using Method 2. Encoded data using Methods 1 and 2 were manually keypunched on cards. About 200 morphological descriptions and 50 laboratory characterizations were encoded using Method 3. Keypunching in Method 3 was done automatically which eliminated the errors in that process.

Verification of encoded data was accomplished by comparing computer written pedon descriptions and laboratory data tables with the original data. Computer programs were developed to identify data codes and write the correct word or phrase for pedon descriptions and data and headings for laboratory tables. Cost of materials and printing mark sense forms nearly equaled the cost of student help for keypunching. This did not include keypunch verification.

Tests indicated that Method 3 was the most efficient way of processing soils data. The man hours and costs using Method 3 were reduced 40 percent and 20 percent respectively, from Method 2.

All soil data were stored on magnetic tape because of the volume of data involved and limited disc space available. Magnetic tapes (2400 feet) rent for $1.00 per month. This includes cleaning and storage of the tapes by the computing center. Private disc paks are now available for rent but this method of storage has not been tested.

Two methods of data retrieval were tested and it was found that working files containing numerically selected data from the PD record were the most economical method of retrieval. This method reduced the length of the file to be read and eliminated the need for identifying each "kind" of data.

Computer programs were developed to search the working file, determine the kind of data available and calculate the mean and total number of observations for each "kind" of data.

Programs were also developed to calculate correlation coefficients between soil characteristics observed in the field and soil properties determined in the laboratory.

Fifty-eight site, environmental, morphological, and laboratory characteristics were selected to investigate their relationships with percent soil water held at 15 bar tension. The variables selected were dependent on the number of observations determined from the

inventory and the correlation coefficients. These variables were tested and 6 models containing 1 to 4 independent variables were developed using combinations of laboratory and/or field characteristics. Laboratory determined percent clay and organic carbon were the two best parameters of the 58 tested to predict percent soil water held at 15 bar tension. Characteristics observed in the field that reflect the above properties, such as textural class, moist color value and horizon designation were also reliable predictors of soil water. Predicted values plotted against the actual values graphically showed the reliability or confidence of predicted percent soil water held at 15 bar tension.

Three practical models were developed from Models 1, 2 and 6. They were incorporated into 3 forms to determine total estimated soil water available to plants. The form requires measurement of total water (by weight) in a soil layer, subtracting the "unavailable" (15 bar) water, converting the value to volume, and summing the soil layers to obtain the total inches of "available" water.

Soil characterization data stored in the PD record are available to assist in establishing relationships between soil properties and data from many other desciplines to achieve a high degree of reliance in predicting soil behavior. For example, one can more confidently classify soils for engineering uses after determining relationships of soil properties with Atterberg limits. This basic

information contributes greatly toward the accurate determination of soil limitations or hazards for a variety of uses such as local streets and roads, dwellings, road fill material, embankments, highway locations and sanitary landfills.

Relationships between soil properties and yields of dryland crops or native range can be estimated and yield prediction equations developed. The equations can be used to predict crop yields or potential range production on other soils with similar soil characteristics.

APPENDIX I

Appendix Table 16. Site and environmental items and subitems stored in the pedon data (PD) record.

ITEM NO.	ITEM	FREQ.*	NO. OF CHAR.**	NO. OF DEC.†	A/N††
1	SOIL SERIES NAME	1	20	0	A/N
2	SOIL SURVEY SAMPLE NO.	1	-	-	-
	a) Kind	1	1	0	A
	b) Year (sampled or described)	1	2	0	N
	c) State	1	6	0	A
	d) County	1	3	0	N
	e) Pedon Number	1	3	0	N
3	STATE PLANT COORDINATES	1	-	-	-
	a) Zone	1	1	0	A/N
	b) East-west (X)	1	7	0	N
	c) North-south (Y)	1	7	0	N
4	ELEVATION	1	5	0	N
5	SLOPE	1	-	-	-
	a) Percent	1	2	0	N
	b) Class	1	1	0	A
	c) Kind	1	1	0	A
	d) Microrelief	1	1	0	A
	e) Aspect	1	2	0	A
6	LABORATORY IDENTIFICATION	1	-	-	-
	a) Lab.	1	1	0	A
	b) State	1	6	0	A
7	MONTH SAMPLED AND DESCRIBED	1	2	0	N
8	YEAR ANALYZED	1	2	0	N
9	PHYSIOGRAPHY	1	2	0	A
10	NUMBER OF KINDS OF PARENT MATERIAL	1	1	0	N

Appendix Table 16 (Cont.)

ITEM NO.	ITEM	FREQ.*	NO. OF CHAR.**	NO. OF DEC.†	A/N††
11	PARENT MATERIAL OR UNDERLYING MATERIAL	1-4	-	-	-
	a) Mode of accumulation or deposition	1	1	0	A
	b) Origin or source	2	2	0	A/N
	c) Bedding inclination	1	1	0	A
12	AVERAGE AIR TEMPERATURE	3	2	0	N
13	VEGETATION	1	1	0	A
14	STONINESS CLASS	1	1	0	N
15	PREMEABILITY CLASS	1	1	0	N
16	SOIL DRAINAGE CLASS	1	1	0	N
17	WATER TABLE	1	-	-	-
	a) Depth in inches	1	3	0	N
	b) Months observed	1	2	0	N
18	AVERAGE ANNUAL PRECIP.	1	4	1	N
19	LABORATORY METHODS	250	1	0	N
20	TOTAL NUMBER OF HORIZONS	1	2	0	N

* Number of times the item or subitem may be reported for the pedon.
** Number of alphabetic and/or numeric characters specified for each item or subitem.
† Number of decimal places specified.
†† Character codes are alphabetic (A), numeric (N) or alpha-numeric (A/N).

APPENDIX TABLE 17. Soil morphological items and subitems stored in the pedon data (PD) record.

ITEM NO.	ITEM	FREQ.*	NO. OF CHAR.**	NO. OF DEC.†	A/N††
21	HORIZON NUMBER	1	2	0	N
22	HORIZON DESIGNATION	1	-	-	-
	a) Roman numeral(s)	1	3	0	A
	b) Capital letter(s)	1	2	0	A/N
	c) Arabic number(s)	1	2	0	N
	d) Lower case letter(s)	5	2	0	A
23	HORIZON LIMITS (DEPTH)	2	4	1	N
24	NUMBER OF SOIL COLORS	1	1	0	N
25	SOIL COLORS	1-8	-	-	-
	a) Location & moisture	1	1	0	N
	b) Percent of matrix	1	3	0	N
	c) Hue (or color)	1	4	1	A/N
	d) Value	1	2	1	N
	e) Chroma	1	2	1	N
26	NUMBER OF KINDS OF MOTTLES	1	1	0	N
27	MOTTLES	1-4	-	-	-
	a) Abundance (or % of soil)	1	2	0	A/N
	b) Location & moisture	1	1	0	N
	c) Size	1	2	0	A
	d) Contrast	1	1	0	A
	e) Hue (or color)	1	4	1	A/N
	f) Value	1	2	1	N
	g) Chroma	1	2	1	N
28	NUMBER OF HORIZON TEXTURES	1	1	0	N
29	HORIZON TEXTURE	1-2	5	0	A
30	NUMBER OF HORIZON TEXTURE MODIFIERS	1	1	0	N
31	HOR. TEXTURE MODIFIERS	1-2	3	0	A
32	NUMBER OF KINDS OF LAMELLAE, ETC.	1	1	0	N

APPENDIX TABLE 17 (Cont.)

ITEM NO.	ITEM	FREQ.*	NO. OF CHAR.**	NO. OF DEC.†	A/N††
33	LAMELLAE, BANDS OR POCKETS	1-4	-	-	-
	a) Kind	1	1	0	A
	b) Texture	1	5	0	A
	c) Texture modifier	2	3	0	A
	d) Consistence, etc.	1	2	0	N
	e) Abundance (or No./Hor.)	1	2	0	A/N
	f) Note	1	1	0	A
	g) Average thickness	1	2	1	N
	h) Total thickness/horizon	1	3	1	N
	i) Hue (or color)	1	4	1	A/N
	j) Value	1	2	1	N
	k) Chroma	1	2	1	N
34	NUMBER OF KINDS OF STRUCTURES	1	1	0	N
35	STRUCTURE	1-4	-	-	-
	a) Grade	1	1	0	N
	b) Size	1	2	0	A
	c) Type	1	3	0	A
	d) Moisture condition	1	1	0	A
36	NUMBER OF KINDS OF CONSISTENCE	1	1	0	N
37	CONSISTENCE, ETC.	1-5	2	0	N
38	CEMENTING AGENT	1	1	0	A
39	ROOTS	1	-	-	-
	a) Abundance	1	2	0	A
	b) Size	1	2	0	A
	c) Location	1	1	0	A
40	NUMBER OF KINDS OF PORES	1	1	0	N
41	SOIL PORES	1-3	-	-	-
	a) Kind	1	2	0	A
	b) Abundance or percent	1	2	0	A/N
	c) Size	1	2	0	A

APPENDIX TABLE 17 (Cont.)

ITEM NO.	ITEM	FREQ.*	NO. OF CHAR.**	NO. OF DEC.†	A/N††
42	NUMBER OF KINDS OF CUTANS	1	1	0	N
43	CUTANS	1-3	-	-	-
	a) Kind	1	1	0	A
	b) Abundance	1	2	0	A
	c) Distinctness	1	1	0	A
	d) Location	1	1	0	A
	e) Hue (or color)	1	4	1	A/N
	f) Value	1	2	1	N
	g) Chroma	1	2	1	N
44	NUMBER OF KINDS OF NODULES	1	1	0	N
45	NODULES (CONCRETIONS OR ACCRETIONS)	1-2	-	-	-
	a) Kind	1	2	0	A
	b) Abundance or percent by volume	1	2	0	A/N
	c) Hardness	1	1	0	A
	d) Size	1	2	0	A
46	NUMBER OF KINDS OF COARSE FRAGMENTS	1	1	0	N
47	COARSE FRAGMENTS	1-3	-	-	-
	a) Kind	1	1	0	A
	b) Abundance or percent	1	2	0	A/N
	c) Size	1	1	0	N
48	pH (FIELD DETERMINED)	1	-	-	-
	a) Method	1	1	0	A
	b) pH or reaction class	1	3	1	A/N
49	EFFERVESCENCE	1	-	-	-
	a) Class	1	1	0	A
	b) Agent	1	1	0	A

APPENDIX TABLE 17 (Cont.)

ITEM NO.	ITEM	FREQ.*	NO. OF CHAR.**	NO. OF DEC.†	A/N††
50	LOWER BOUNDARY	1	-	-	-
	a) Distinctness	1	1	0	A
	b) Topography	1	1	0	A
51	HORIZON THICKNESS	1	-	-	-
	a) Average	1	3	1	N
	b) Lower limit of range	1	3	1	N
	c) Upper limit of range	1	3	1	N

* Number of times the item or subitem may be reported for the horizon.
**Number of alphabetic and/or numeric characters specifiec for each item or subitem.
† Number of decimal places specified.
††Character codes are alphabetic (A), numeric (N), or alpha-numeric (A/N).

APPENDIX TABLE 18. Soil laboratory items and subitems stored in the pedon data (PD) record.

ITEM NO.	ITEM	FREQ.*	NO. OF CHAR.**	NO. OF DEC.†	A/N††
52	SAMPLE IDENTIFICATION	1	-	-	-
	a) Laboratory number	1	7	0	A/N
	b) Data base	1	1	0	N
53	PARTICLE SIZE	12	-	-	-
	a) Note	1	1	0	A
	b) Percent	1	3	1	N
54	NUMBER OF MISCELLANEOUS PARTICLE SIZES	1	1	0	N
55	MISCELLANEOUS PARTICLE SIZES	1-5	-	-	-
	a) Kind	1	1	0	A
	b) Note	1	1	0	A
	c) Percent	1	3	1	N
56	NUMBER OF KINDS OF LAB. DET. COARSE FRAGMENTS	1	1	0	N
57	LAB. DET. COARSE FRAGMENTS	1-4	-	-	-
	a) Kind	1	1	0	A
	b) Note	1	1	0	A
	c) Percent	1	2	0	N
58	ORGANIC MATTER	1	-	-	-
	a) Note	1	1	0	A
	b) Percent	1	3	1	N
59	ORGANIC CARBON	1	-	-	-
	a) Note	1	1	0	A
	b) Percent	1	4	2	N
60	NITROGEN	1	-	-	-
	a) Note	1	1	0	A
	b) Percent	1	4	3	N

APPENDIX TABLE 18 (Cont.)

ITEM NO.	ITEM	FREQ.*	NO. OF CHAR.**	NO. OF DEC.†	A/N††
61	EXT. IRON AS Fe	1	-	-	-
	a) Note	1	1	0	A
	b) Percent	1	3	1	N
62	EXT. IRON AS Fe_2O_3	1	-	-	-
	a) Note	1	1	0	A
	b) Percent	1	3	1	N
63	NUMBER OF "KINDS" OF CARBONATES AS $CaCO_3$	1	1	0	N
64	CARBONATE AS $CaCO_3$	1-2	-	-	-
	a) Kind	1	1	0	N
	b) Note	1	1	0	A
	c) Percent	1	2	0	N
65	NUMBER OF BULK DENSITIES	1	1	0	N
66	BULK DENSITY	1-4	-	-	-
	a) Moisture	1	1	0	N
	b) Result (g/cc)	1	3	2	N
67	Cm	1	2	2	N
68	COLE	1	3	3	N
69	NUMBER OF KINDS OF WATER CONTENT DETERMINATIONS	1	1	0	N
70	WATER CONTENT	1-5	-	-	-
	a) Kind	1	1	0	N
	b) Notes	1	1	0	A
	c) Percent	1	4	1	N
71	NUMBER OF LAB. DET. pH's	1	1	0	N
72	pH (LAB. DET.)	1-5	-	-	-
	a) Method	1	1	0	N
	b) Result (pH)	1	3	1	N

APPENDIX TABLE 18 (Cont.)

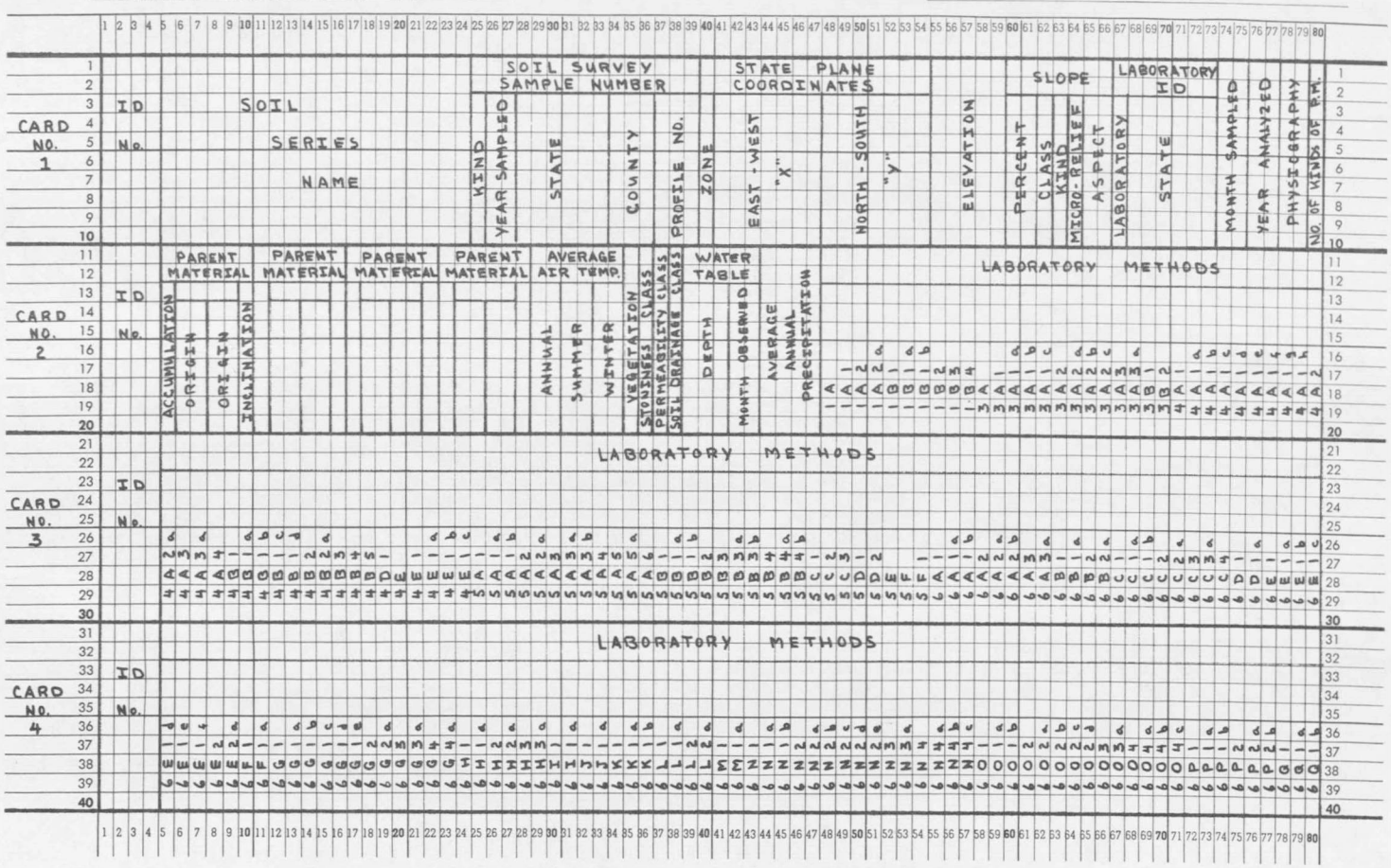
ITEM NO.	ITEM	FREQ.*	NO. OF CHAR.**	NO. OF DEC.†	A/N††
73	EXTRACTABLE BASES	5	-	-	-
	a) Notes	1	1	0	A
	b) Results (MEQ)	1	3	1	N
74	EXTRACTABLE ACIDITY	1	-	-	-
	a) Note	1	1	0	A
	b) Result (MEQ)	1	3	1	N
75	KCL EXT. Al	1	-	-	-
	a) Notes	1	1	0	A
	b) Result (MEQ)	1	3	1	N
76	NH_4OAc EXT. SO_4	1	-	-	-
	a) Notes	1	1	0	A
	b) Result (MEQ)	1	3	1	N
77	NUMBER OF CEC AND BASE SAT. DETERMINATIONS	1	1	0	N
78	CEC AND BASE SAT.	1-4	-	-	-
	a) Notes	1	1	0	A
	b) Method	1	1	0	N
	c) CEC (MEQ)	1	4	1	N
	d) Base Sat. (%)	1	3	0	N
79	NUMBER OF KINDS OF WATER EXTRACT DETERMINATIONS	1	1	0	N
80	WATER EXTRACT	1-10	-	-	-
	a) Notes	1	1	0	A
	b) Kind	1	1	0	N
	c) Results	1	4	1	N
81	NUMBER OF KINDS OF MISCELLANEOUS RESULTS	1	1	0	N

APPENDIX TABLE 18 (Cont.)

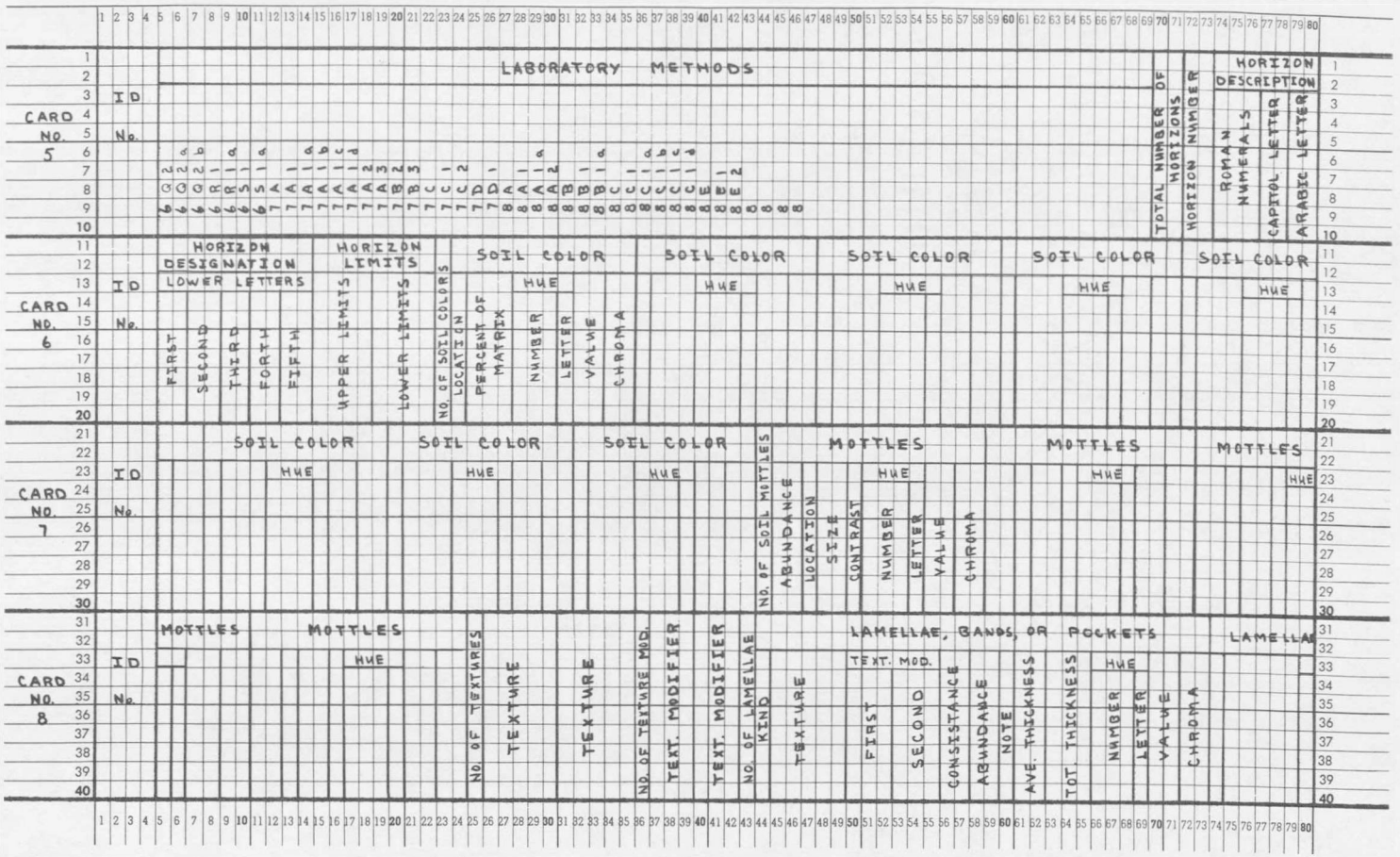
ITEM No.	ITEM	FREQ.*	NO. OF CHAR.**	NO. OF DEC.†	A/N††
82	MISCELLANEOUS RESULTS	1-7	-	-	-
	a) Notes	1	1	0	A
	b) Kind	1	1	0	A
	c) Result	1	3	1	N
83	NUMBER OF KINDS OF ENGINEERING DATA	1	1	0	N
84	ENGINEERING DATA	1-4	-	-	-
	a) Kind	1	1	0	N
	b) Notes	1	1	0	A
	c) Result	1	3	0	N
85	NUMBER OF MINERALOGIC DATA	1	2	0	N
86	MINERALOGY	1-25	-	-	-
	a) Fraction	1	1	0	A
	b) Method	1	1	0	A
	c) Percent or abundance	1	2	0	A/N
	d) Kind of mineral	1	4	0	A/N

* Number of times the item or subitem may be reported for the horizon.
**Number of alphabetic and/or numeric characters specified for each item or subitem.
† Number of decimal places specified.
††Character codes are alphabetic (A), numeric (N), or alpha-numeric (A/N).

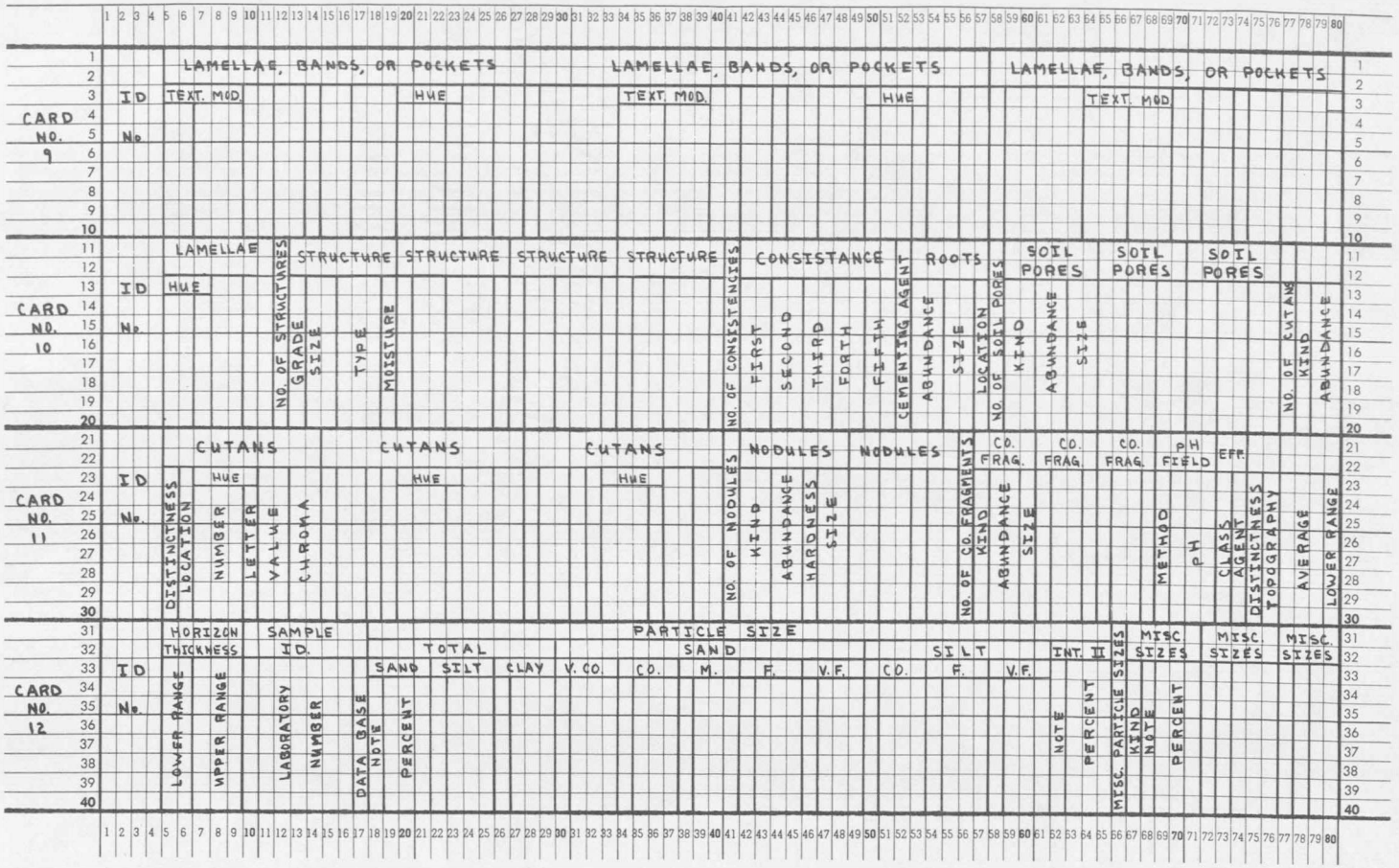
APPENDIX II



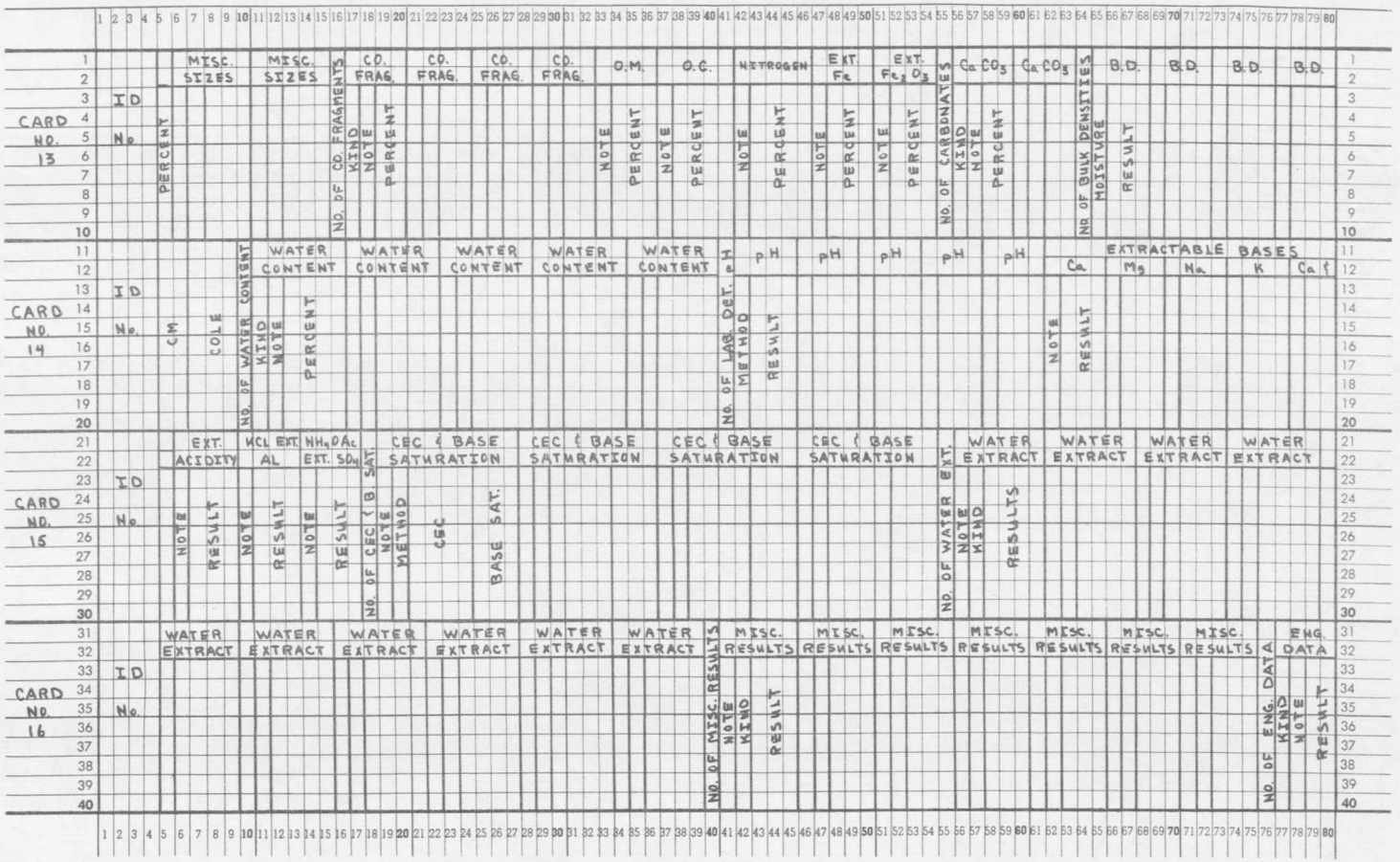
APPENDIX FIGURE 14. Formats used for encoding site and environmental characteristics and the first 185 laboratory methods.



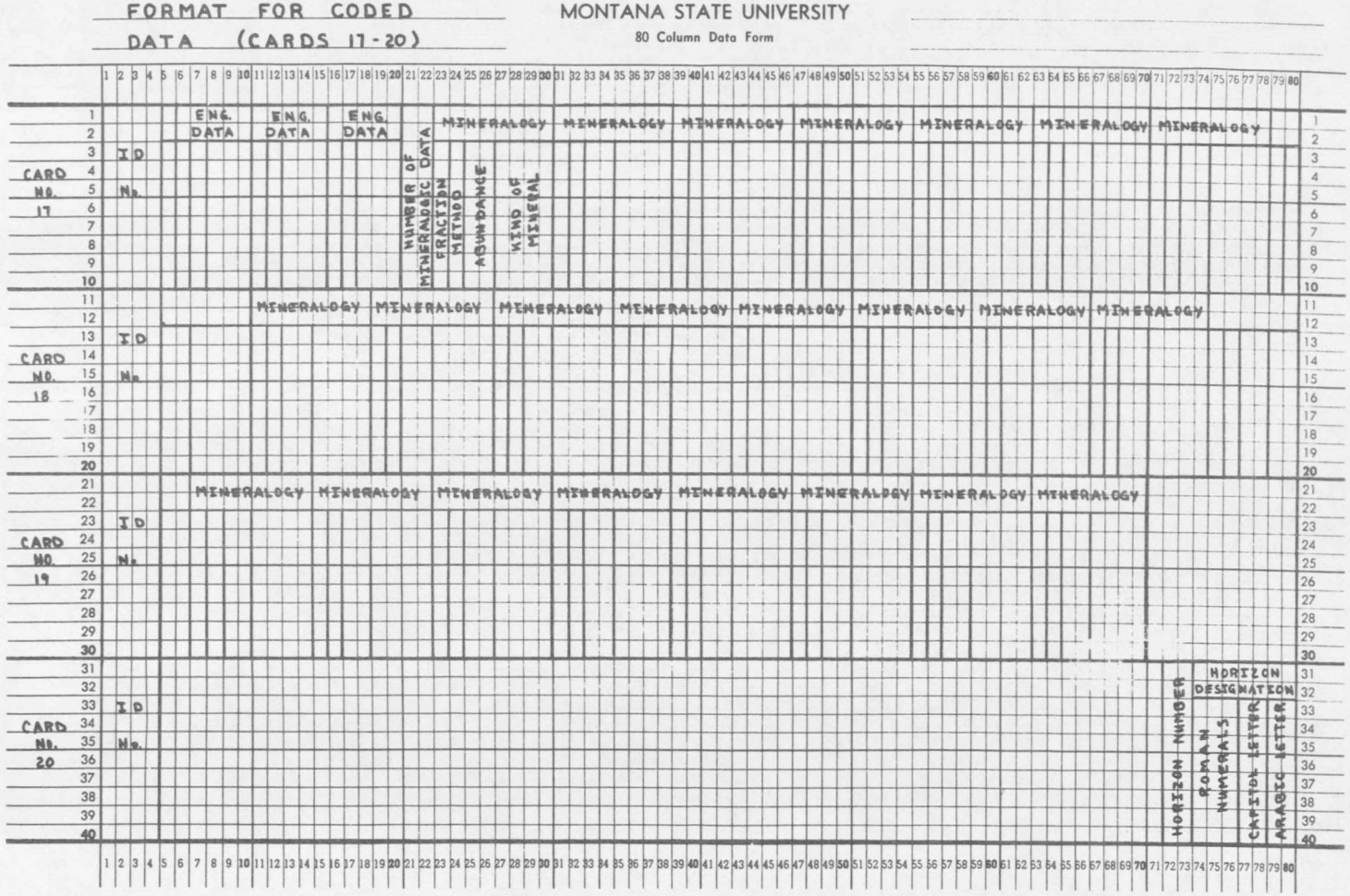
APPENDIX FIGURE 15. Formats used for encoding the remaining laboratory methods and part of the morphological data. Card 5 is completed once for a pedon while cards 6 through 8 are completed for each horizon.



APPENDIX FIGURE 16. Formats used for encoding the remaining morphological data, particle size distribution and the first 3 miscellaneous particle sizes from the laboratory characterization data.



APPENDIX FIGURE 17. Formats used for encoding laboratory characterization data. The last 5 columns of card 16 are used to encode the first engineering test data, if available.



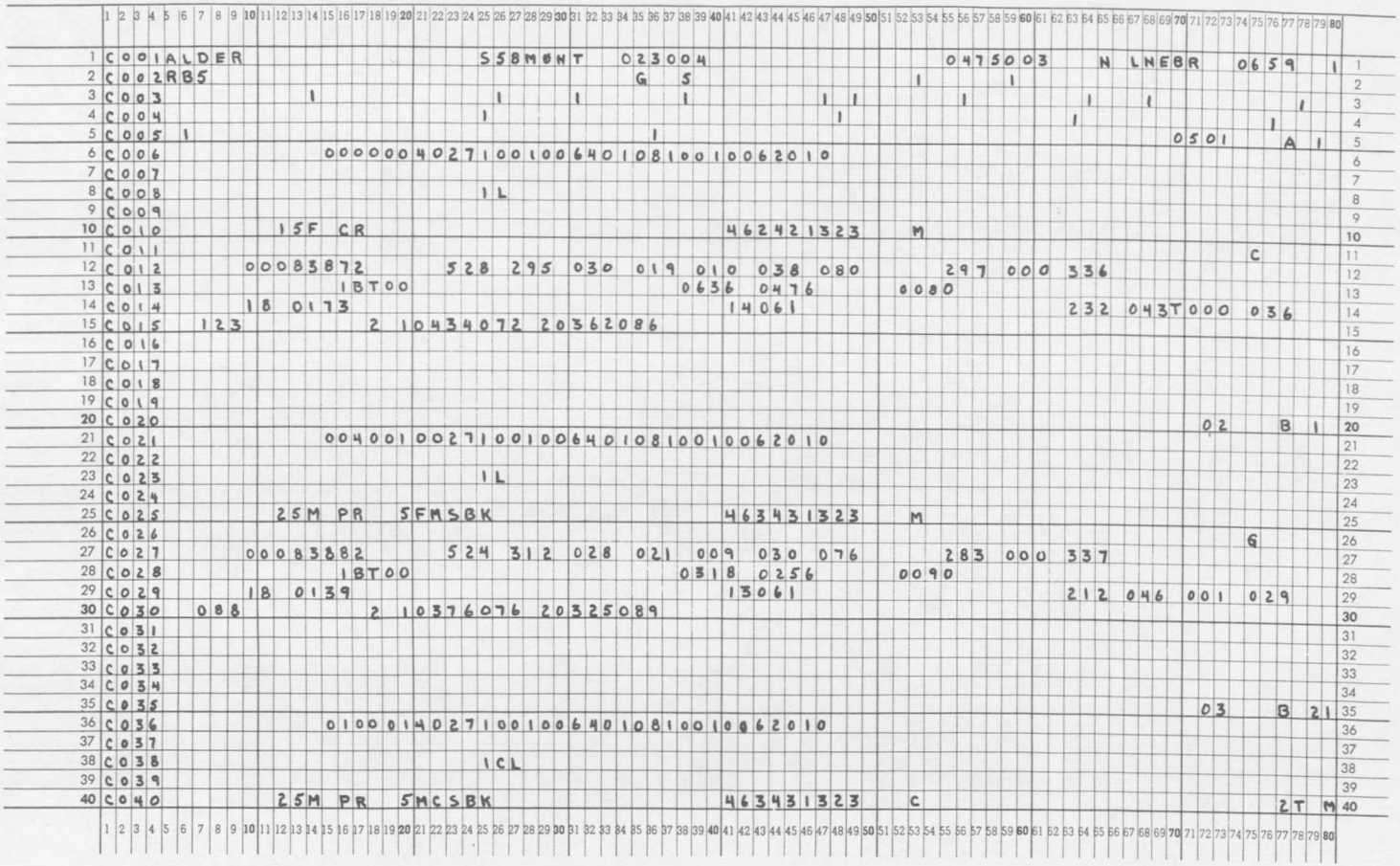
APPENDIX FIGURE 18. Formats used for encoding the remaining engineering test data and mineralogy data. The last 9 columns of card 20 are used to encode the next horizon designation before returning to card 6 and using the same formats.

APPENDIX III

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ALDER SERIES

80 Column Data Form



APPENDIX FIGURE 19. Encoded characterization data using encoding Method 1. Cards 1 through 5 (cols. 2-4) contain the site and environmental data, laboratory methods, and part of the first horizon designation for Pedon C (col. 1). Cards 6 through 20 contain the morphological, laboratory, engineering, and mineralogy data for the first horizon plus part of the second horizon designation on card 20.

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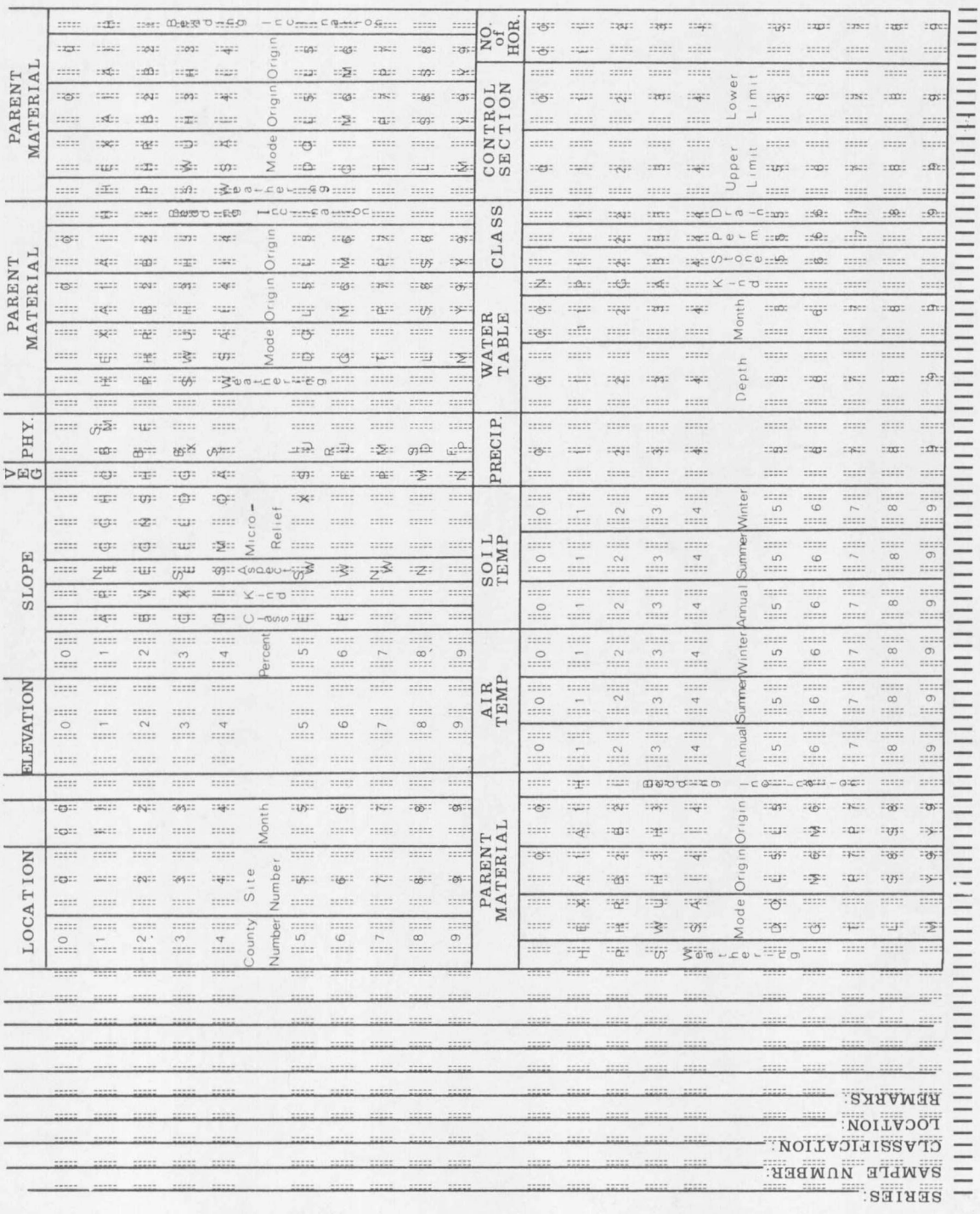
80 Column Data Form

CARD TYPE 6 - COLOR

	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80	
1	A006 0000000302810010062520710010065020	1
2	A021 0030010028100100630407100100640020	2
3	A036 0100001602810010063040710010064020	3
4	A051T 0160019038 10063540610064040710064520	4
5	A066CA 0190024028100100645307100100680020	5
6	A081CA 0240035028100100660307100100680030	6
7	A096 0350	7
8		8
9	B006 0000003528100100620207100100635020	9
10	B021 0035008038 10062020510065030710064520	10
11	B036 0080014038 10063030610063040710065020	11
12	B051T 0140023028100100640355100100645300	12
13	B066CA 0230026028100100650257100100680030	13
14	B081CA 0260037028100100650307100100680020	14
15	B096	15
16		16
17	C006 0000004027100100640108100100620100	17
18	C021 0040010027100100640108100100620100	18
19	C036 0100014027100100640108100100620100	19
20	C051 0140021027100025550208100025530200	20
21	C066 0210027047 02555020702555602080255404080255302020	21
22		22
23	D006 0000005027100100640108100100620100	23
24	D021 0050013027100100640108100100620100	24
25	D036 0130017027100100650208100100620200	25
26	D051 0170022027100100650208100100630300	26
27	D066 0220027027100100640208100100630300	27
28	D081 027004000	28
29		29
30	E006 0000003018100025540200	30
31	E021 0030009018100100640200	31
32	E036T 0090018018100100645300	32
33	E051 0180030018100100650300	33
34	E066CA 0300039018100025650300	34
35	E081CA 0390055018100025550300	35
36		36
37		37
38		38
39		39
40		40

APPENDIX FIGURE 20. Encoded characterization data using encoding Method 2. This represents data encoded by the format on card 6 for all horizons in Pedons A through E. The first 3 horizons (numbers 6, 21 and 36 in cols. 2-4) in Pedon C (Col. 1) are identical to the same card number in Figure 22.

APPENDIX IV

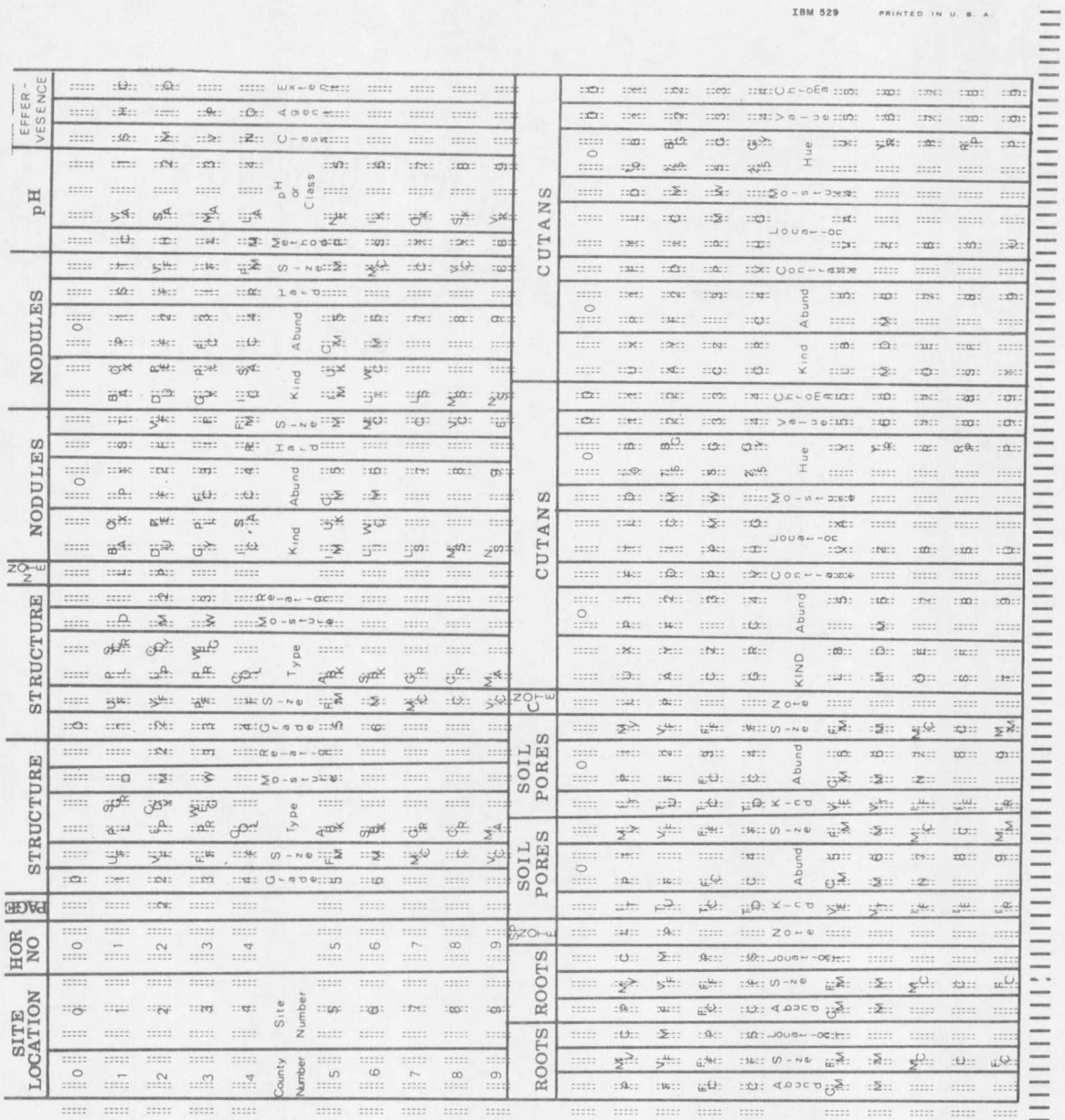


APPENDIX FIGURE 21. Site and environmental data encoding form.

SITE LOCATION		HOR. NO.	PAGE	HORIZON DESIGNATION						HORIZON LIMITS		Lower Boundary	SOIL COLOR				SOIL COLOR				
County Number	Site Number			Roman	Capital	Arabic	Lower Case	Lower Case	Lower Case	UPPER	LOWER	Distinctness	Location	Moisture	HUE	Value	Location	Moisture	HUE	Value	Chroma
SOIL COLOR				SOIL COLOR			TEXT. MOD.	HORIZON TEXTURE		TEXT. MOD.	HORIZON TEXTURE	CONSISTANCE					STRUCTURE				
Location	Moisture	HUE	Value	Chroma	Location	Moisture	HUE	Value	Chroma								Grade	Size	TYPE	Moisture	Reaction

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APPENDIX FIGURE 22. Field morphological data encoding form (page 1).



APPENDIX FIGURE 23. Field morphological data encoding form (page 2).



APPENDIX FIGURE 24. Field morphological data encoding form (page 3).

SITE LOCATION		LAB. ID		YEAR ANAL	LABORATORY METHODS					
0	0			0	0 A K 0 a	0 A K 0 a	0 A K 0 a	0 A K 0 a	0 A K 0 a	0 A K 0 a
1	1	B		1	1 B L 1 b	1 B L 1 b	1 B L 1 b	1 B L 1 b	1 B L 1 b	1 B L 1 b
2	2	L		2	2 C M 2 c	2 C M 2 c	2 C M 2 c	2 C M 2 c	2 C M 2 c	2 C M 2 c
3	3	M		3	3 D N 3 d	3 D N 3 d	3 D N 3 d	3 D N 3 d	3 D N 3 d	3 D N 3 d
4	4	R		4	4 E O 4 e	4 E O 4 e	4 E O 4 e	4 E O 4 e	4 E O 4 e	4 E O 4 e
County Number	Site Location	Lab.	State							
5	5	E		5	5 F P 5 f	5 F P 5 f	5 F P 5 f	5 F P 5 f	5 F P 5 f	5 F P 5 f
6	6	O		6	6 G Q 6 g	6 G Q 6 g	6 G Q 6 g	6 G Q 6 g	6 G Q 6 g	6 G Q 6 g
7	7			7	7 H R 7 h	7 H R 7 h	7 H R 7 h	7 H R 7 h	7 H R 7 h	7 H R 7 h
8	8			8	8 I S 8 i	8 I S 8 i	8 I S 8 i	8 I S 8 i	8 I S 8 i	8 I S 8 i
9	9			9	9 J T 9 j	9 J T 9 j	9 J T 9 j	9 J T 9 j	9 J T 9 j	9 J T 9 j

LABORATORY METHODS																							
0 A K 0 a	0 A K 0 a	0 A K 0 a	0 A K 0 a	0 A K 0 a	0 A K 0 a	0 A K 0 a	0 A K 0 a	0 A K 0 a	0 A K 0 a	0 A K 0 a	0 A K 0 a	0 A K 0 a	0 A K 0 a	0 A K 0 a	0 A K 0 a	0 A K 0 a	0 A K 0 a	0 A K 0 a	0 A K 0 a	0 A K 0 a	0 A K 0 a	0 A K 0 a	0 A K 0 a
1 B L 1 b	1 B L 1 b	1 B L 1 b	1 B L 1 b	1 B L 1 b	1 B L 1 b	1 B L 1 b	1 B L 1 b	1 B L 1 b	1 B L 1 b	1 B L 1 b	1 B L 1 b	1 B L 1 b	1 B L 1 b	1 B L 1 b	1 B L 1 b	1 B L 1 b	1 B L 1 b	1 B L 1 b	1 B L 1 b	1 B L 1 b	1 B L 1 b	1 B L 1 b	1 B L 1 b
2 C M 2 c	2 C M 2 c	2 C M 2 c	2 C M 2 c	2 C M 2 c	2 C M 2 c	2 C M 2 c	2 C M 2 c	2 C M 2 c	2 C M 2 c	2 C M 2 c	2 C M 2 c	2 C M 2 c	2 C M 2 c	2 C M 2 c	2 C M 2 c	2 C M 2 c	2 C M 2 c	2 C M 2 c	2 C M 2 c	2 C M 2 c	2 C M 2 c	2 C M 2 c	2 C M 2 c
3 D N 3 d	3 D N 3 d	3 D N 3 d	3 D N 3 d	3 D N 3 d	3 D N 3 d	3 D N 3 d	3 D N 3 d	3 D N 3 d	3 D N 3 d	3 D N 3 d	3 D N 3 d	3 D N 3 d	3 D N 3 d	3 D N 3 d	3 D N 3 d	3 D N 3 d	3 D N 3 d	3 D N 3 d	3 D N 3 d	3 D N 3 d	3 D N 3 d	3 D N 3 d	3 D N 3 d
4 E O 4 e	4 E O 4 e	4 E O 4 e	4 E O 4 e	4 E O 4 e	4 E O 4 e	4 E O 4 e	4 E O 4 e	4 E O 4 e	4 E O 4 e	4 E O 4 e	4 E O 4 e	4 E O 4 e	4 E O 4 e	4 E O 4 e	4 E O 4 e	4 E O 4 e	4 E O 4 e	4 E O 4 e	4 E O 4 e	4 E O 4 e	4 E O 4 e	4 E O 4 e	4 E O 4 e
5 F P 5 f	5 F P 5 f	5 F P 5 f	5 F P 5 f	5 F P 5 f	5 F P 5 f	5 F P 5 f	5 F P 5 f	5 F P 5 f	5 F P 5 f	5 F P 5 f	5 F P 5 f	5 F P 5 f	5 F P 5 f	5 F P 5 f	5 F P 5 f	5 F P 5 f	5 F P 5 f	5 F P 5 f	5 F P 5 f	5 F P 5 f	5 F P 5 f	5 F P 5 f	5 F P 5 f
6 G Q 6 g	6 G Q 6 g	6 G Q 6 g	6 G Q 6 g	6 G Q 6 g	6 G Q 6 g	6 G Q 6 g	6 G Q 6 g	6 G Q 6 g	6 G Q 6 g	6 G Q 6 g	6 G Q 6 g	6 G Q 6 g	6 G Q 6 g	6 G Q 6 g	6 G Q 6 g	6 G Q 6 g	6 G Q 6 g	6 G Q 6 g	6 G Q 6 g	6 G Q 6 g	6 G Q 6 g	6 G Q 6 g	6 G Q 6 g
7 H R 7 h	7 H R 7 h	7 H R 7 h	7 H R 7 h	7 H R 7 h	7 H R 7 h	7 H R 7 h	7 H R 7 h	7 H R 7 h	7 H R 7 h	7 H R 7 h	7 H R 7 h	7 H R 7 h	7 H R 7 h	7 H R 7 h	7 H R 7 h	7 H R 7 h	7 H R 7 h	7 H R 7 h	7 H R 7 h	7 H R 7 h	7 H R 7 h	7 H R 7 h	7 H R 7 h
8 I S 8 i	8 I S 8 i	8 I S 8 i	8 I S 8 i	8 I S 8 i	8 I S 8 i	8 I S 8 i	8 I S 8 i	8 I S 8 i	8 I S 8 i	8 I S 8 i	8 I S 8 i	8 I S 8 i	8 I S 8 i	8 I S 8 i	8 I S 8 i	8 I S 8 i	8 I S 8 i	8 I S 8 i	8 I S 8 i	8 I S 8 i	8 I S 8 i	8 I S 8 i	8 I S 8 i
9 J T 9 j	9 J T 9 j	9 J T 9 j	9 J T 9 j	9 J T 9 j	9 J T 9 j	9 J T 9 j	9 J T 9 j	9 J T 9 j	9 J T 9 j	9 J T 9 j	9 J T 9 j	9 J T 9 j	9 J T 9 j	9 J T 9 j	9 J T 9 j	9 J T 9 j	9 J T 9 j	9 J T 9 j	9 J T 9 j	9 J T 9 j	9 J T 9 j	9 J T 9 j	9 J T 9 j

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APPENDIX FIGURE 25. Laboratory methods encoding form for the pedon.

APPENDIX FIGURE 26. Laboratory methods encoding form for the pedon (continued.)

SITE LOCATION		HOR NO	PAGE	SAMPLE IDENTIFICATION	DATA BASE	PARTICLE SIZE (PERCENT)											
County Number	Site Number					Note	Total Silt	Note	Total Clay	Note	V Co. Sand	Note	Co. Sand	Note	Med Sand	Note	Fine Sand
0	0	0		0 0			0.		0.		0.		0.		0.		0.
1	1	1	1	1 1	A	T	1.	T	1.	T	1.	T	1.	T	1.	T	1.
2	2	2		2 2	B	N	2.	N	2.	N	2.	N	2.	N	2.	N	2.
3	3	3		3 L 3	C		3.		3.		3.		3.		3.		3.
4	4	4		4 4	D		4.		4.		4.		4.		4.		4.
5	5	5		5 5	E		5.		5.		5.		5.		5.		5.
6	6	6		6 6	F		6.		6.		6.		6.		6.		6.
7	7	7		7 7	G		7.		7.		7.		7.		7.		7.
8	8	8		8 8			8.		8.		8.		8.		8.		8.
9	9	9		9 9			9.		9.		9.		9.		9.		9.

PARTICLE SIZE (PERCENT)										COARSE FRAGMENTS													
Note	V. F. Sand	Note	Co. Silt	Note	INT III	Note	INT II	Note	2.0-0.10 mm		Kind	Note	%		Kind	Note	%		Kind	Note	%		Kind	Note	%
0.	0.	0.		0.		0.		0.			0				0				0				0		
T 1.	1.	T 1.		T 1.		T 1.		T 1.		A T	1			A T	1			A T	1			A T	1		
N 2.	2.	N 2.		N 2.		N 2.		N 2.		B N	2			B N	2			B N	2			B N	2		
3.	3.		3.		3.		3.		3.	C	3			C	3			C	3			C	3		
4.	4.		4.		4.		4.		4.	E	4			E	4			E	4			E	4		
5.	5.		5.		5.		5.		5.	G	5			G	5			G	5			G	5		
6.	6.		6.		6.		6.		6.	J	6			J	6			J	6			J	6		
7.	7.		7.		7.		7.		7.	L	7			L	7			L	7			L	7		
8.	8.		8.		8.		8.		8.	N	8			N	8			N	8			N	8		
9.	9.		9.		9.		9.		9.		V 9				V 9				V 9				V 9		

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APPENDIX FIGURE 27. Laboratory data encoding form (page 1).

APPENDIX FIGURE 28. Laboratory data encoding form (page 2).

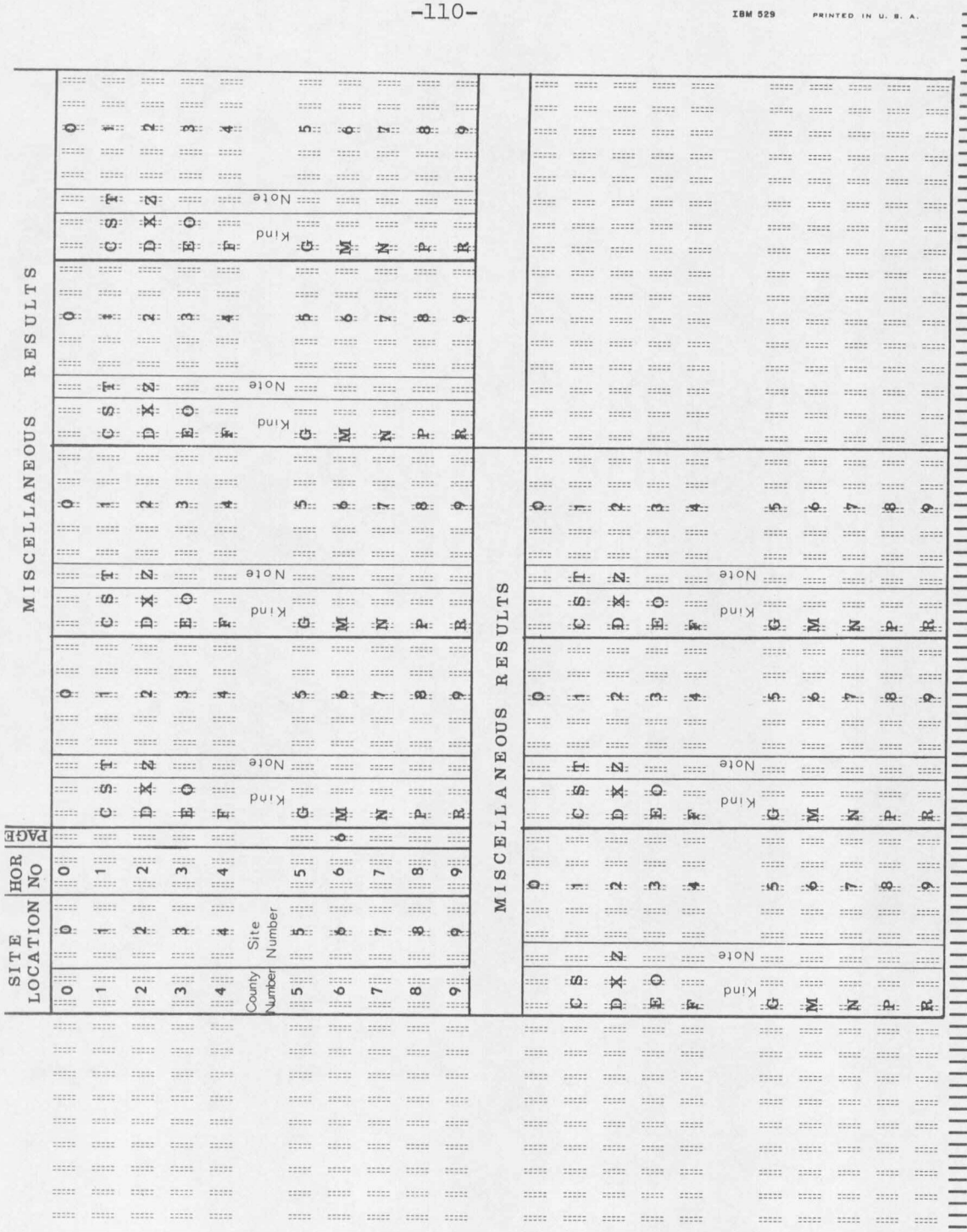
IBM 529 PRINTED IN U.S.A.

IBM 5520 PRINTED IN U.S.A.

APPENDIX FIGURE 29. Laboratory data encoding form (page 3).

APPENDIX FIGURE 30. Laboratory data encoding form (page 4).

APPENDIX FIGURE 31. Laboratory data encoding form (page 5).



APPENDIX FIGURE 32. Laboratory data encoding form (page 6).

APPENDIX V

APPENDIX TABLE 19. Alphabetical listing by county, of soil pedons stored in Montana's soil pedon data record

SERIES	SOIL SAMPLE	SURVEY NUMBER	SITE NUMBER	CLASSIFICATION
				BIG HORN COUNTY
Allentine	S66MONT	2 1	2	Haplustollic Natrargids; fine, montmorillonitic, mesic
				BLAINE COUNTY
Bearpaw*	S62MONT	3 1	8	Typic Argiborolls; fine-loamy, mixed
Bearpaw	S62MONT	3 2	9	Typic Argiborolls; fine, montmorillonitic
Bearpaw	S62MONT	3 5	13	Typic Argiborolls; fine, montmorillonitic
Bearpaw	S62MONT	3 6	14	Typic Argiborolls; fine, montmorillonitic
Bowdoin	S67MONT	3 3	23	Ustertic Torrifluvents; very fine, montmorillonitic (calcareous), frigid
Elloam	S62MONT	3 8	4	Borollic Natrargids; fine, montmorillonitic
Elloam	S62MONT	3 11	12	Borollic Natrargids; fine, montmorillonitic
Phillips	S62MONT	3 7	5	Borollic Paleargids; fine, montmorillonitic
Phillips*	S62MONT	3 10	15	Borollic Paleargids; fine-loamy, mixed
Phillips*	S67MONT	3 1	16	Borollic Paleargids; fine-loamy, mixed
Scobey*	S62MONT	3 14	17	Aridic Argiborolls; fine-loamy, mixed
Scobey	S62MONT	3 15	18	Aridic Argiborolls; fine, montmorillonitic
Telo	S62MONT	3 9	10	Borollic Natrargids; fine, montmorillonitic
Telo	S62MONT	3 12	11	Borollic Natrargids; fine, montmorillonitic
Thoeny*	S67MONT	3 2	21	Borollic Natrargids; fine-loamy, mixed
Thoeny	S67MONT	3 13	22	Borollic Natrargids; fine, montmorillonitic
Williams	S62MONT	3 3	19	Typic Argiborolls; fine-loamy, mixed
Williams	S62MONT	3 4	20	Typic Argiborolls; fine-loamy, mixed

APPENDIX TABLE 19 (cont.)

SERIES	SOIL SAMPLE	SURVEY NUMBER	SITE NUMBER	CLASSIFICATION
				CARBON COUNTY
Charlos	S55MONT	5 1	2	Argic Cryoborolls; fine-loamy over sandy or sandy skeletal, mixed
Charlos	S55MONT	5 2	3	Argic Cryoborrols; fine-loamy over sandy or sandy skeletal, mixed
				CASCADE COUNTY
Glikon	S64MONT	7 3	13	Udic Argiborolls; fine, mixed
Glikon	S64MONT	7 4	14	Udic Argiborolls; fine, mixed
Marias	S67MONT	7 2	15	Ustertic Torriorthents; fine, montmorillonitic (calcareous), frigid
Monad	S64MONT	7 2	16	Mollic Cryoboralfs; fine-loamy, mixed
Monad	S64MONT	7 5	17	Mollic Cryoboralfs; fine-loamy, mixed
Pendroy	S67MONT	7 1	18	Ustertic Torriorthents; very fine, montmorillonitic (calcareous), frigid
Terrad	S67MONT	7 3	19	Typic Argiborolls; fine, mixed
Tigeron	S64MONT	7 1	20	Cryic Paleboralfs; loamy-skeletal, mixed
Tigeron	S64MONT	7 2	21	Cryic Paleboralfs; loamy-skeletal, mixed
				DAWSON COUNTY
Manning	S57MONT	11 1	3	Typic Haploborolls; coarse-loamy over sandy or sandy-skeletal, mixed
Manning	S57MONT	11 2	4	Typic Haploborolls; coarse-loamy over sandy or sandy-skeletal, mixed
Shambo*	S57MONT	11 3	2	Typic Haploborolls; fine-loamy, mixed

APPENDIX TABLE 19 (Cont.)

SERIES	SOIL SAMPLE	SURVEY NUMBER	SITE NUMBER	CLASSIFICATION
				FERGUS COUNTY
Danvers	S57MONT	14	1 2	Typic Argiborolls; fine, montmorillonitic
Doughty	S57MONT	14	2 5	Udic Argiborolls; fine-loamy, mixed
Sipple	S57MONT	14	3 6	Udic Argiborolls; fine-loamy, mixed
				FLATHEAD COUNTY
Kalispell	S65MONT	15	3 4	Typic Haploborolls; coarse-loamy, mixed
Somers	S65MONT	15	2 5	Aquic Haploborolls; fine-silty over sandy or sandy skeletal, mixed
				GOLDEN VALLEY COUNTY
Hanson	S61MONT	19	1 1	Calcic Cryoborolls; loamy-skeletal, carbonatic
Hanson	S61MONT	19	2 2	Calcic Cryoborolls; loamy-skeletal, carbonatic
				GRANITE COUNTY
Donald*	S65MONT	20	2 6	Boralfic Cryoborolls; fine-loamy, mixed
Gaylord	S65MONT	20	4 3	Boralfic Cryoborolls; fine, montmorillonitic
(Loberg)	S61MONT	20	3 4	Typic Cryoboralfs; loamy-skeletal, mixed
Loberg	S61MONT	20	4 5	Typic Cryoboralfs; clayey-skeletal, mixed
Philipsburg	S65MONT	20	1 7	Argic Cryoborolls; fine-loamy, mixed
Philipsburg	S61MONT	20	5 8	Argic Cryoborolls; fine-loamy, mixed
Philipsburg	S61MONT	20	6 9	Argic Cryoborolls; fine-loamy, mixed
Pintlar	S61MONT	20	1 10	Cryic Paleborolls; fine-loamy, mixed
Pintlar	S61MONT	20	2 11	Cryic Paleborolls; fine-loamy, mixed

APPENDIX TABLE 19 (Cont.)

SERIES	SOIL SAMPLE	SURVEY NUMBER	SITE NUMBER	CLASSIFICATION
				JUDITH BASIN COUNTY
Acushnet	S58MONT	23 6	8	Typic Haploborolls; fine-loamy over sandy or sandy skeletal carbonatic
Acushnet	S57MONT	23 1	10	Typic Haploborolls; fine-loamy over sandy or sandy skeletal carbonatic
Alder	S58MONT	23 4	6	Udic Argiborolls; fine, mixed
Alder	S58MONT	23 5	7	Udic Argiborolls; fine, mixed
Suffolk	S58MONT	23 7	9	Typic Argiborolls; clayey over loamy-skeletal, montmorillonitic
Terrad	S58MONT	23 2	11	Typic Argiborolls; fine, mixed
Terrad	S58MONT	23 3	12	Typic Argiborolls; fine, mixed
Teton	S58MONT	23 1	13	Typic Cryoborolls; fine-loamy, mixed
				LAKE COUNTY
Crow*	S65MONT	24 9	4	Mollic Eutroboralfs; fine, mixed
McDonald	S65MONT	24 5	1	Boralfic Udic Argiborolls; fine, mixed
McDonald	S65MONT	24 4	5	Boralfic Udic Argiborolls; fine, mixed
Post	S65MONT	24 7	3	Typic Natriborolls; very fine, mixed
Post	S65MONT	24 6	6	Typic Natriborolls; very fine, mixed
Ronan	S65MONT	24 1	7	Borollic Natrargids; very fine, mixed
Round Butte	S65MONT	24 2	8	Borollic Natrargids; fine, mixed
Round Butte	S65MONT	24 3	9	Borollic Natrargids; fine, mixed
				LEWIS AND CLARK COUNTY
Brocko	S65MONT	25 2	2	Borollic Calciorthids; coarse-silty, mixed

APPENDIX TABLE 19 (Cont.)

SERIES	SOIL SAMPLE	SURVEY NUMBER	SITE NUMBER	CLASSIFICATION
				MINERAL COUNTY
Craddock	S64MONT	31	5 2	Andic Cryochrepts; loamy-skeletal, mixed
Drexel	S64MONT	31	4 3	Udic Ustochrepts; loamy-skeletal, mixed, frigid
Truefissure	S64MONT	31	1 4	Entic Cryandepts; medial over loamy-skeletal, mixed
Truefissure	S64MONT	31	2 5	Entic Cryandepts; medial over loamy-skeletal, mixed
Wishard	S64MONT	31	3 6	Aquic Cryoborolls; loamy-skeletal, mixed
				MISSOULA COUNTY
Greenough	S61MONT	32	1 1	Typic Eutroboralfs; fine-silty, mixed
Greenough	S61MONT	32	2 3	Typic Eutroboralfs; fine-silty, mixed
Holloway	S61MONT	32	5 4	Andic Cryochrepts; loamy-skeletal, mixed
Holloway	S61MONT	32	6 5	Andic Cryochrepts; loamy-skeletal, mixed
Tarkio	S61MONT	32	3 2	Typic Eutroboralfs; very fine, mixed
Tarkio	S61MONT	32	4 7	Typic Eutroboralfs; very fine, mixed
Wishard*	S64MONT	32	1 6	Typic Cryumbrepts; loamy-skeletal, mixed
Yourame	S61MONT	32	7 8	Typic Eutroboralfs; loamy-skeletal, mixed
				PHILLIPS COUNTY
Illiad	S67MONT	36	1 1	Aridic Argiborolls; fine-loamy, mixed
Thoeny*	S67MONT	36	2 2	Aridic Natriborolls; fine-loamy, mixed

APPENDIX TABLE 19 (Cont.)

SERIES	SOIL SAMPLE	SURVEY NUMBER	SITE NUMBER		CLASSIFICATION
				POWDER RIVER COUNTY	
Hesper	S63MONT	38	1	1	Ustollic Haplargids; fine, montmorillonitic, mesic
Hesper	S63MONT	38	4	2	Ustollic Haplargids; fine, montmorillonitic, mesic
Hesper*	S63MONT	38	2	4	Ustollic Haplargids; fine-silty, mixed
Fort Collins	S66MONT	38	3	3	Ustollic Haplargids; fine-loamy, mixed,mesic
Hydro*	S66MONT	38	1	5	Ustollic Paleargids; fine, montmorillonitic
Hydro*	S63MONT	38	2	6	Ustollic Paleargids; fine, montmorillonitic
				RAVALLI COUNTY	
Bass	S55MONT	41	4	1	Udic Argiborolls; coarse-loamy, mixed
Gird	S65MONT	41	2	2	Typic Haploborolls; coarse-silty, mixed
Gorus	S55MONT	41	1	3	Boralfic Cryochrepts; fine-loamy, mixed
Gorus	S55MONT	41	2	4	Boralfic Cryochrepts; fine-loamy, mixed
Haccke	S65MONT	41	1	5	Leptic Natriborolls; fine-silty, mixed
Ravalli	S65MONT	41	3	6	Borollic Natrargids; fine-loamy, mixed
Sula	S55MONT	41	3	7	Typic Cryoborolls; coarse-loamy, mixed
Sula	S55MONT	41	5	8	Typic Cryoborolls; coarse-loamy, mixed
Sula	S55MONT	41	6	9	Typic Cryoborolls; coarse-loamy, mixed
				RICHLAND COUNTY	
Farland	S57MONT	42	1	1	Typic Argiborolls; fine-silty, mixed

APPENDIX TABLE 19 (Cont.)

SERIES	SOIL SAMPLE	SURVEY NUMBER	SITE NUMBER	CLASSIFICATION
				ROOSEVELT COUNTY
Flynn	S50MONT 43	1	2	Vertic Haplaquepts; very fine montmoril-lonitic (calcareous), frigid
Flynn	S50MONT 43	2	3	Vertic Haplaquepts; very fine montmoril-lonitic (calcareous), frigid
Flynn	S50MONT 43	5	4	Vertic Haplaquepts; very fine montmoril-lonitic (calcareous), frigid
(Frazer)	S51MONT 43	5	5	Fluventic Haploborolls; fine-loamy, mixed
Glendive	S51MONT 43	1	6	Ustic Torrifluvents; coarse-loamy, mixed (calcareous), frigid
Harlem	S51MONT 43	2	10	Ustic Torrifluvents; fine, montmorillonitic (calcareous), frigid
Inga	S51MONT 43	3	7	Ustic Torrifluvents; fine-silty, mixed (calcareous), frigid
Inga	S51MONT 43	6	8	Ustic Torrifluvents; fine-silty, mixed (calcareous), frigid
Inga	S50MONT 43	3	9	Ustic Torrifluvents; fine-silty, mixed (calcareous), frigid
Inga	S51MONT 43	7	13	Ustic Torrifluvents; fine-silty, mixed (calcareous), frigid
(magnus)	S51MONT 43	8	11	Cumulic Haploborolls; fine, montmorillonitic
Marvan	S50MONT 43	7	12	Ustertic Torriorthents; fine, montmorillonitic (calcareous), frigid
Marvan	S50MONT 43	4	15	Ustertic Torriorthents; fine, montmorillonitic (calcareous), frigid
Vanda	S50MONT 43	6	14	Ustic Torriorthents; fine, montmorillonitic (calcareous), frigid
(Wolf Point)	S51MONT 43	4	16	Ustic Torrifluvents; clayey over sandy or sandy skeletal, mixed

APPENDIX TABLE 19 (Cont.)

SERIES	SOIL SAMPLE	SURVEY NUMBER	SITE NUMBER	CLASSIFICATION
				STILLWATER COUNTY
Maddux	S55MONT	48	1	1 Typic Argiborolls; fine-loamy over sandy or sandy-skeletal, mixed
Sweetgrass	S55MONT	48	2	2 Typic Argiborolls; clayey over sandy or sandy skeletal, montmorillonitic
				SWEETGRASS COUNTY
(Blue Creek Varient)	S57MONT	49	4	4 Abruptic Cryoborolls; fine, mixed
Maddux	S57MONT	49	3	2 Typic Argiborolls; fine-loamy over sandy or sandy-skeletal, mixed
Melville	S57MONT	49	1	1 Argic Cryoborolls; clayey over loamy-skeletal, montmorillonitic
Michelson	S57MONT	49	2	5 Argic Cryoborolls; fine-loamy, mixed
				TOOLE COUNTY
Joplin*	S62MONT	51	1	1 Aridic Haploborolls; fine-loamy, mixed
Joplin*	S62MONT	51	2	2 Aridic Haploborolls; fine-loamy, mixed
				TREASURE COUNTY
(Bascom)	S63MONT	52	1	7 Ustertic Torriorthents; very fine, montmorillonitic
Gilt Edge	S66MONT	52	1	8 Haplustollic Natrargids; clayey over sandy sandy-skeletal, montmorillonitic
(Nunn)	S56MONT	52	7	9 Ustollic Camborthids; fine-silty, mixed, mesic
(Nunn)	S56MONT	52	8	10 Ustollic Camborthids; fine-silty, mixed, mesic

APPENDIX TABLE 19 (Cont.)

SERIES	SOIL SAMPLE	SURVEY NUMBER	SITE NUMBER	CLASSIFICATION
				TREASURE COUNTY (Cont.)
(Nunn)	S56MONT	52 9	11	Ustollic Camborthids; fine-silty over clayey, mixed, mesic
(Nunn)	S56MONT	52 10	12	Ustollic Camborthids; fine, montmorillonitic, mesic
Promise*	S56MONT	52 5	13	Vertic Haplustolls; fine, montmorillonitic, mesic
Promise*	S56MONT	52 6	14	Vertic Haplustolls; fine, montmorillonitic, mesic
Vananda	S56MONT	52 1	15	Ustertic Torriorthents; fine, montmorillonitic (calcareous), mesic
Vananda	S56MONT	52 2	16	Ustertic Torriorthents; fine, montmorillonitic (calcareous), mesic
Vananda	S56MONT	52 3	17	Ustertic Torriorthents; fine, montmorillonitic (calcareous), mesic
Vananda	S56MONT	52 4	3	Ustertic Torriorthents; fine, montmorillonitic (calcareous), mesic
				VALLEY COUNTY
Marias	S62MONT	53 1	1	Ustertic Torriorthents; fine, montmorillonitic (calcareous), frigid
Marias	S62MONT	53 2	2	Ustertic Torriorthents; fine, montmorillonitic (calcareous), frigid
Phillips*	S67MONT	53 2	3	Abruptic Aridic Argiborolls; fine montmorillonitic
Thoeny*	S67MONT	53 1	4	Aridic Natriborolls; fine, montmorillonitic

APPENDIX TABLE 19 (Cont.)

SERIES	SOIL SAMPLE	SURVEY NUMBER	SITE NUMBER	CLASSIFICATION
				WHEATLAND COUNTY
Maddux	S57MONT	54 6	5	Typic Argiborolls; fine-loamy over sandy or snady-skeletal, mixed
Martinsdale	S57MONT	54 5	1	Typic Argiborolls; fine-loamy, mixed
Reedpoint	S57MONT	54 1	3	Typic Argiborolls; fine montmorillonitic
Reedpoint	S57MONT	54 4	4	Typic Argiborolls; fine montmorillonitic
Shawmut	S57MONT	54 2	6	Typic Calciborolls; loamy-skeletal, mixed
Shawmut	S57MONT	54 3	7	Typic Calciborolls; loamy-skeletal, mixed
				YELLOWSTONE COUNTY
Absarokee	S56MONT	56 8	3	Typic Argiborolls; fine, montmorillonitic
Absarokee*	S56MONT	56 7	9	Typic Argiborolls; fine-loamy, mixed
Absher	S63MONT	56 3	10	Borollic Natrargids, fine, montmorillonitic
Allentine	S66MONT	56 1	11	Haplustollic Natrargids; fine, montmoril-lonitic, mesic
Arvada	S51MONT	56 4	12	Ustollic Natrargids; fine, montmorillonitic, mesic
Arvada*	S52MONT	56 25	13	Ustollic Natrargids; fine-silty, mixed, mesic
Arvada*	S52MONT	56 26	14	Ustollic Natrargids; fine-silty, mixed, mesic
Bone	S51MONT	56 5	15	Ustic Torriorthents; fine, montmorillonitic (calcareous), mesic
Colby	S56MONT	56 4		Ustic Torriorthents; fine-silty, mixed (calcareous), mesic
Colby	S53MONT	56 5	31	Ustic Torriorthents; fine-silty, mixed (calcareous), mesic
Danvers	S56MONT	56 1	18	Typic Argiborolls; fine, montmorillonitic
Danvers	S56MONT	56 2	19	Typic Argiborolls; fine, montmorillonitic
(Gilt Edge)	S53MONT	56 8	21	Typic Eutroboralfs; fine, montmorillonitic

APPENDIX TABLE 19 (Cont.)

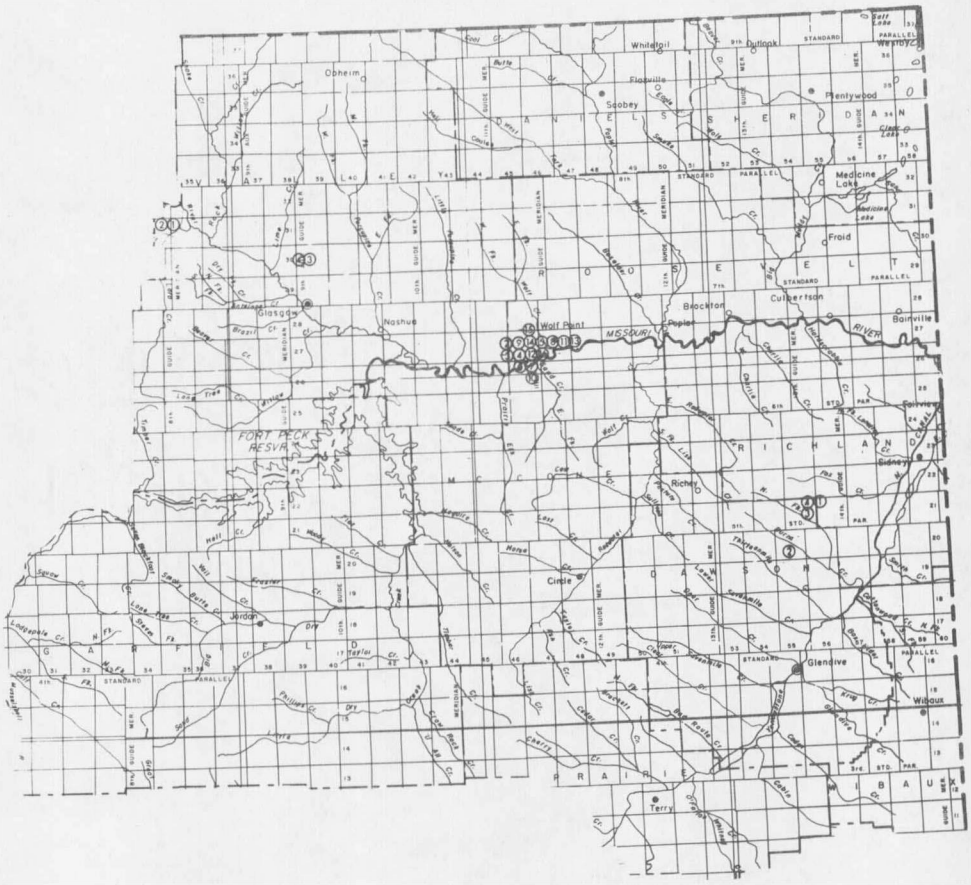
SERIES	SOIL SAMPLE	SURVEY NUMBER	SITE NUMBER	CLASSIFICATION
		YELLOWSTONE COUNTY (Cont.)		
Haverson*	S51MONT 56	10	22	Ustic Torrifluvents; coarse-silty, mixed (calcareous), mesic
Haverson	S51MONT 56	3	37	Ustic Torrifluvents; fine-loamy, mixed (calcareous), mesic
Haverson*	S52MONT 56	27	38	Ustic Torrifluvents; fine-silty, mixed (calcareous), mesic
Heldt	S51MONT 56	9	16	Ustertic Camborthids; fine, montmorillonitic, mesic
Heldt	S51MONT 56	1	39	Ustertic Camborthids; fine, montmorillonitic, mesic
Hesper	S53MONT 56	9	2	Ustollic Haplargids; fine, montmorillonitic, mesic
Hesper	S53MONT 56	1	23	Ustollic Haplargids; fine, montmorillonitic, mesic
Hesper	S53MONT 56	7	24	Ustollic Haplargids; fine, montmorillonitic, mesic
Hopley*	S51MONT 56	7	25	Typic Haploborolls; fine-loamy, mixed
Hopley*	S51MONT 56	3	26	Typic Haploborolls; fine-loamy, mixed
Hopley*	S53MONT 56	12	27	Typic Haploborolls; fine-loamy, mixed
Hysham*	S52MONT 56	28	28	Ustic Torriorthents; fine-silty, mixed (calcareous), mesic
Hysham	S53MONT 56	6	29	Ustic Torriorthents; fine-loamy, mixed (calcareous), mesic
Keiser	S53MONT 56	2	6	Ustollic Haplargids; fine-silty, mixed, mesic
Keiser*	S51MONT 56	2	30	Ustollic Haplargids; fine-silty, mixed, mesic
Keiser	S53MONT 56	10	32	Ustollic Haplargids; fine-silty, mixed, mesic

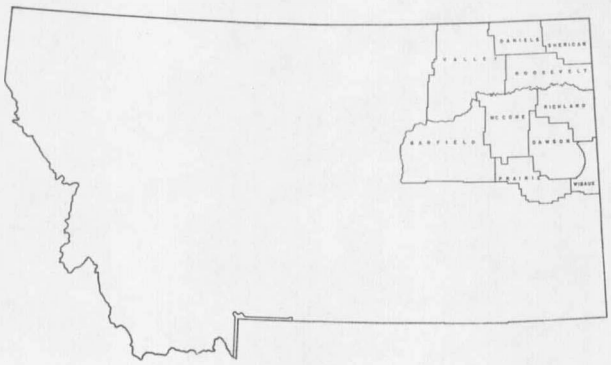
APPENDIX TABLE 19 (Cont.)

SERIES	SOIL SAMPLE	SURVEY NUMBER	SITE NUMBER	CLASSIFICATION
		YELLOWSTONE COUNTY (Cont.)		
Kim	S56MONT 56 5		34	Ustic Torriorthents; fine-loamy, mixed (calcareous), mesic
Laurel*	S52MONT 56 24		35	Aquic Ustifluvents; fine-silty, mixed (calcareous), mesic
McRea	S51MONT 56 8		20	Ustollic Camborthids; fine-loamy, mixed, mesic
McRea*	S56MONT 56 3		40	Ustollic Camborthids; coarse-loamy, mixed, mesic
McRea*	S56MONT 56 6		41	Ustollic Camborthids; coarse-loamy, mixed, mesic
Shaak	S63MONT 56 4		45	Abruptic Argiborolls; fine, montmorillonitic
Shaak	S63MONT 56 2		17	Abruptic Argiborolls; fine, montmorillonitic
Shaak	S63MONT 56 1		36	Abruptic Argiborolls; fine, montmorillonitic
Thurlow	S52MONT 56 21		42	Ustollic Haplargids; fine, montmorillonitic, mesic
Thurlow*	S53MONT 56 4		43	Aridic Argiustolls; fine, montmorillonitic, mesic
Thurlow*	S53MONT 56 11		44	Aridic Argiustolls; fine, montmorillonitic, mesic

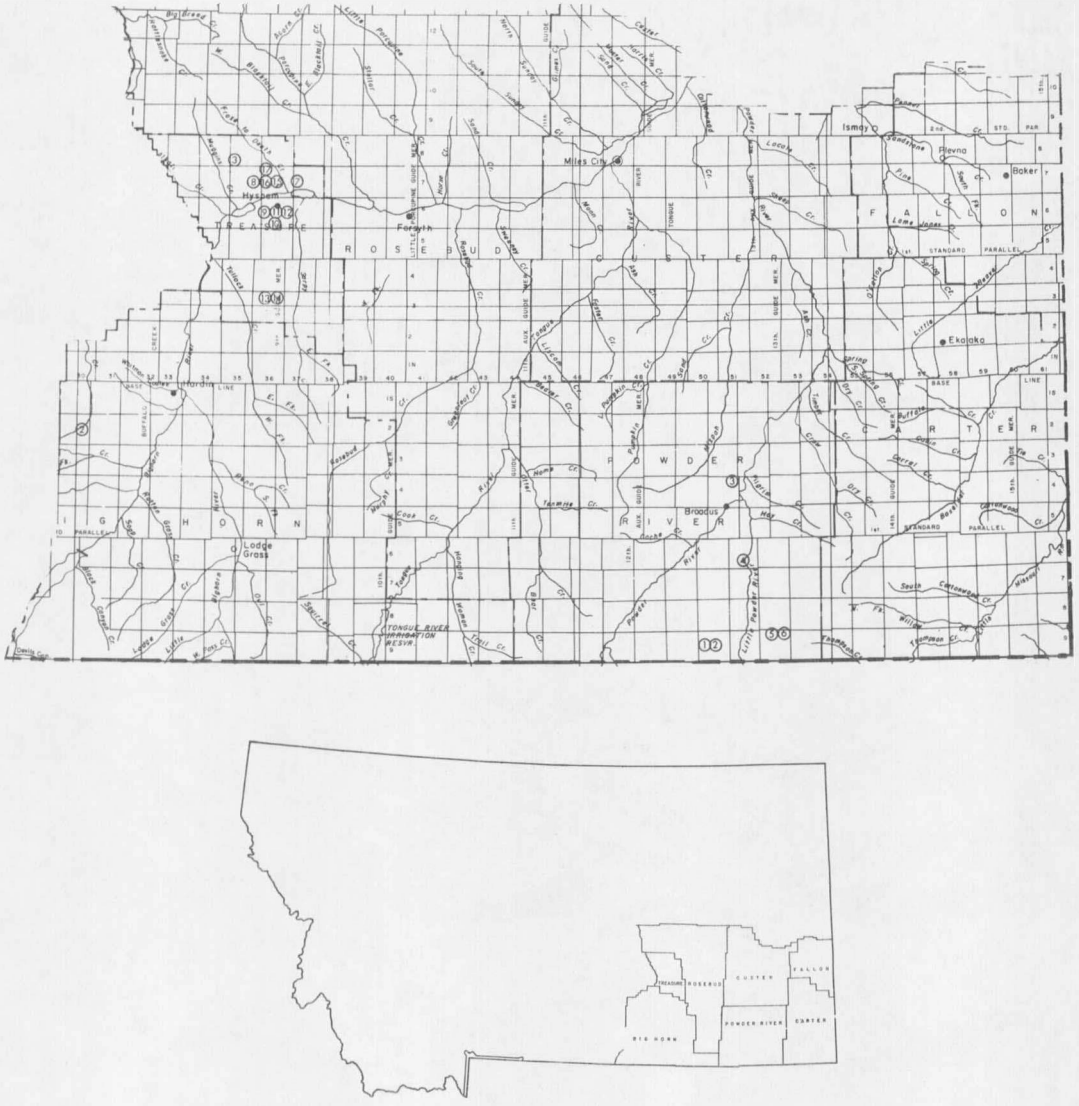
* Varient

APPENDIX VI

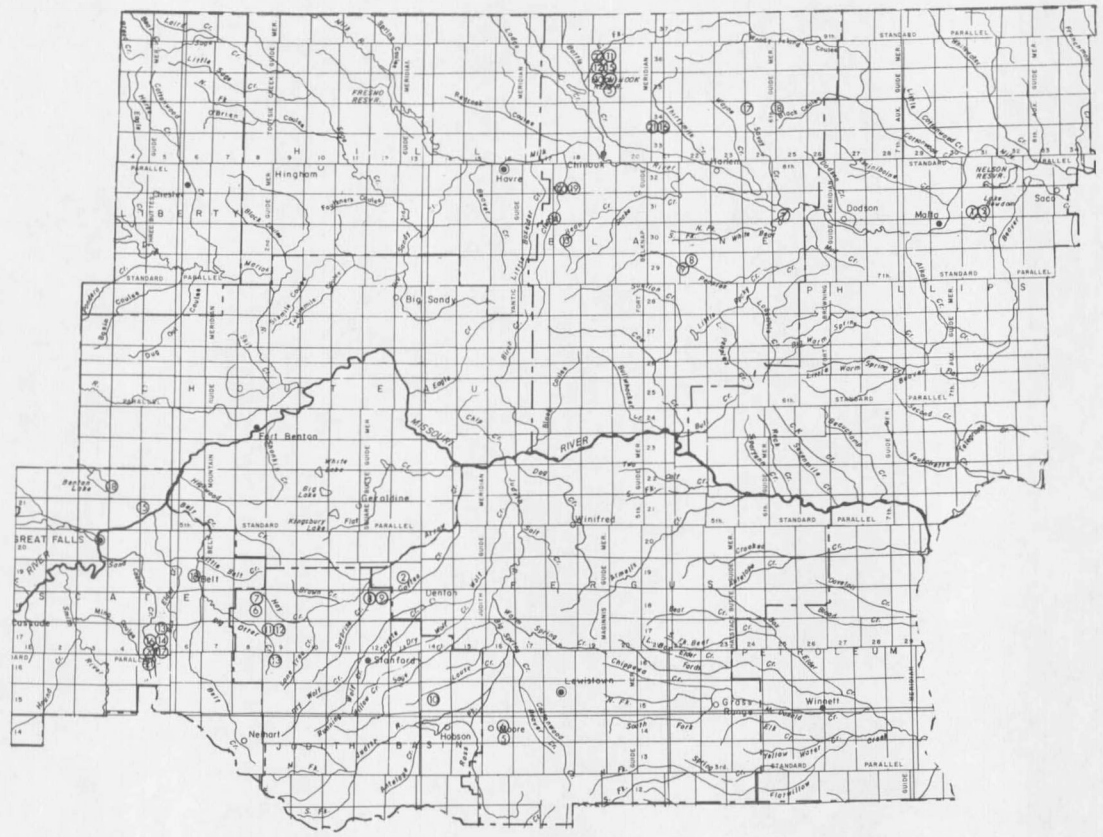


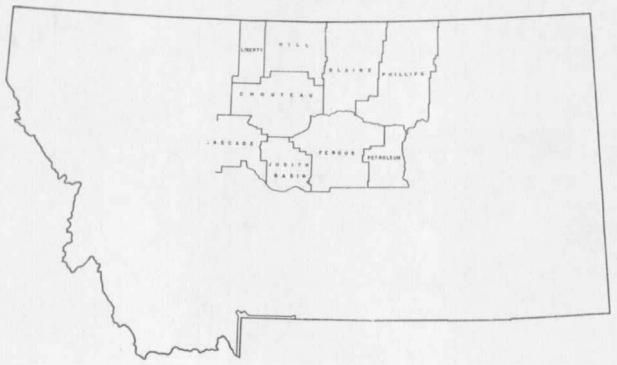


APPENDIX FIGURE 33. Characterization data locations in northeast counties of Montana. The numbers correspond to site numbers, by county, listed in Appendix V Table 19.

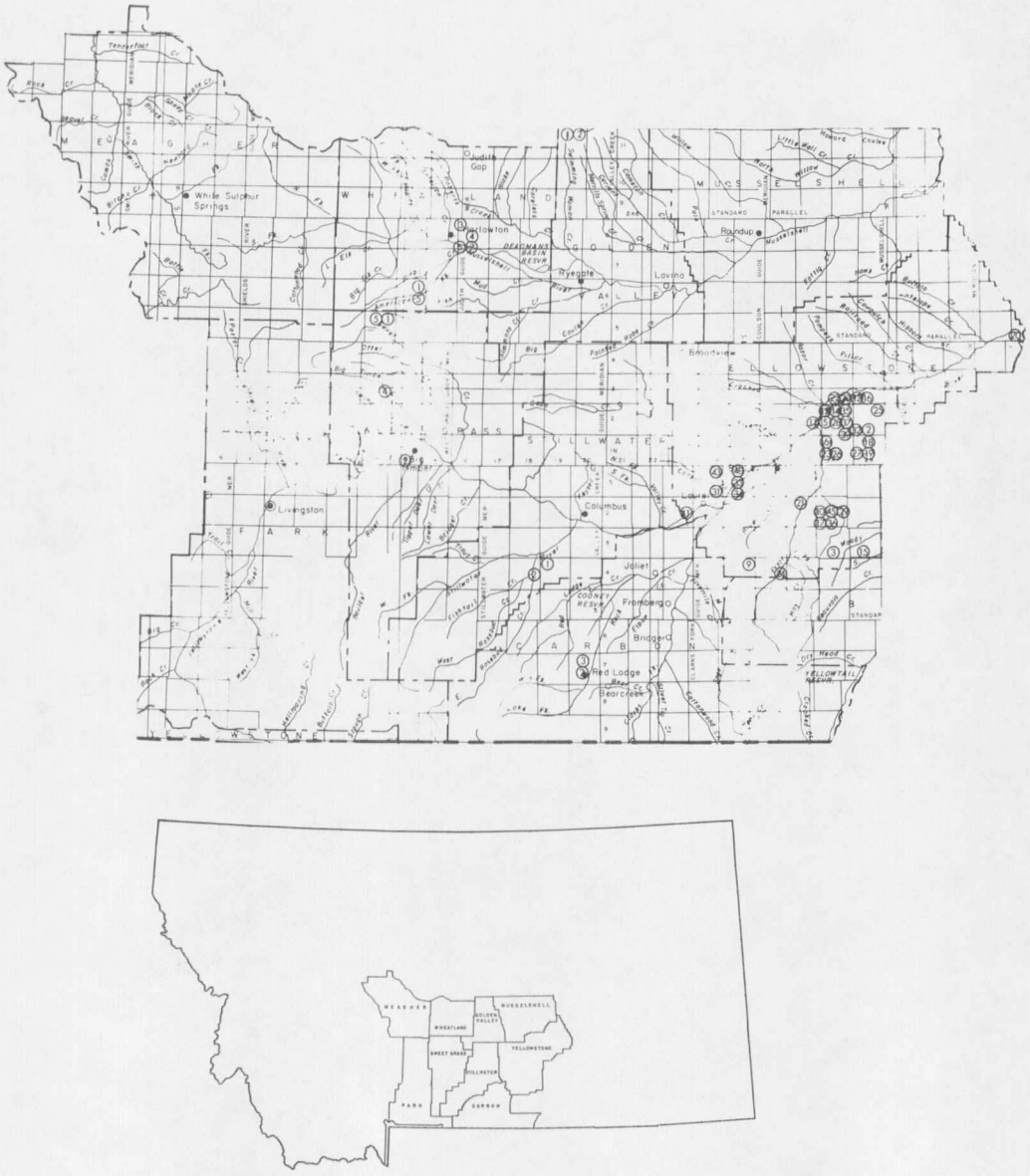


APPENDIX FIGURE 34. Characterization data locations in southeast counties of Montana. The numbers correspond to site numbers, by county, listed in Appendix V, Table 19.

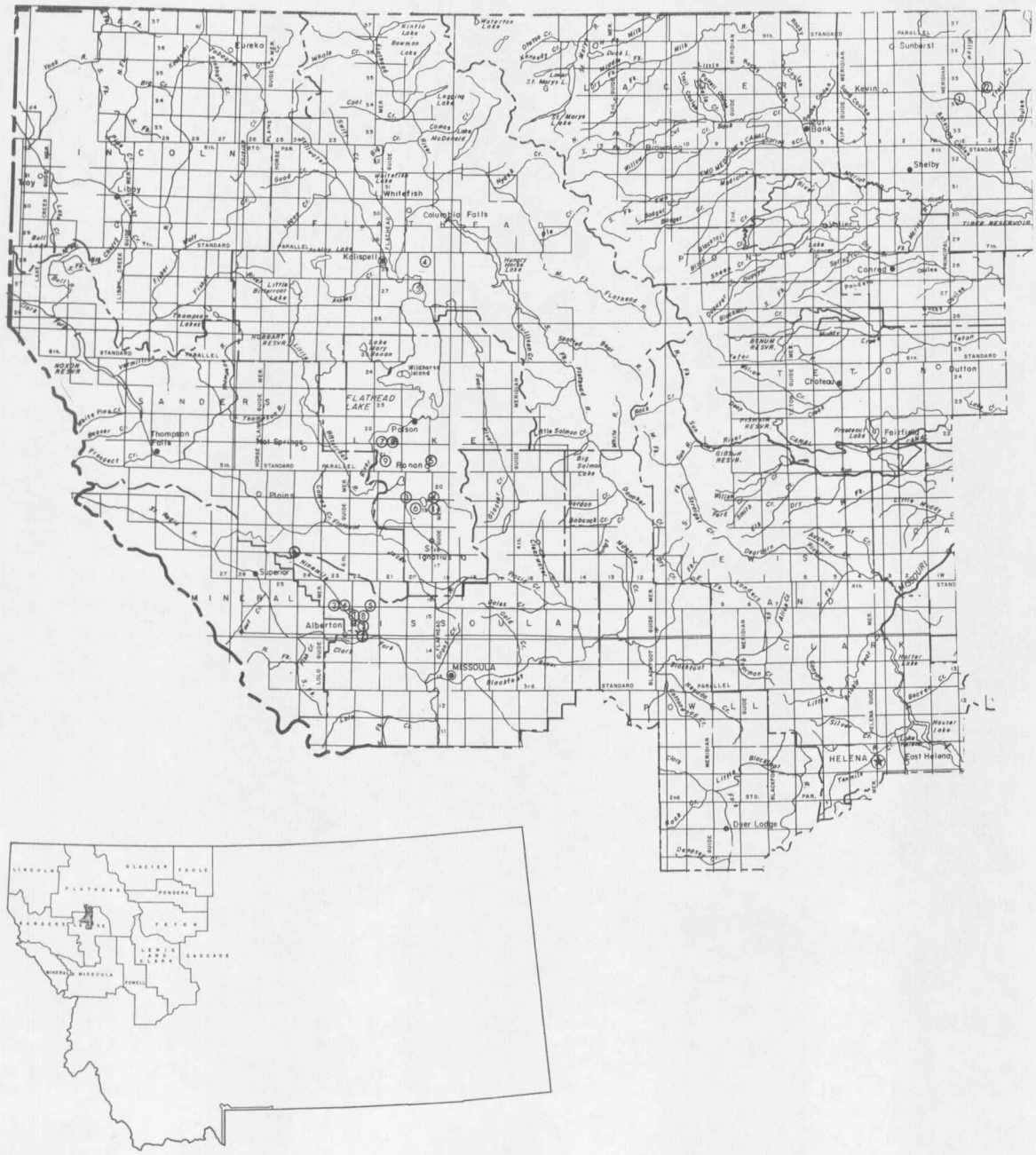




APPENDIX FIGURE 35. Characterization data locations in north central counties of Montana. The number correspond to the site numbers, by county, listed in Appendix V, Table 19.



APPENDIX FIGURE 36. Characterization data locations in south central counties of Montana. The numbers correspond to site numbers, by county, listed in Appendix V, Table 19.



APPENDIX FIGURE 37. Characterization data locations in northwest counties of Montana. The numbers correspond to the site numbers, by county, listed in Appendix V, Table 19.



APPENDIX FIGURE 38. Characterization data locations in southwest counties of Montana. The numbers correspond to the site numbers, by county, listed in Appendix V, Table 19.

APPENDIX VII

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SOIL SERIES:          ABSHER
SURVEY SAMPLE NO.:    S63MONT   56  3  ,DESCRIPTION AND LABORATORY DATA GIVEN

LOCATION:
SLOPE:
    PERCENT:          1
    KIND:             NOT RECORDED
    MICRO-RELIEF:     NOT RECORDED
    ASPECT:           NOT RECORDED
LABORATORY ANALYSIS:                    LINCOLN,  NEBRASKA
MONTH SAMPLED:        JULY
PHYSIOGRAPHY:  STREAM TERRACES
PARENT MATERIAL:

    MODE OF ACCUMULATION OR DEPOSITION: ALLUVIUM
    ORIGIN OR SOURCE OF ACCUMULATION:   LITHOLOGY AND COMPOSITION UNKNOWN, NONCALCAREOUS
    ORIGIN OR SOURCE OF ACCUMULATION:
VEGETATION:           GRASS AND FORBS
PERMEABILITY CLASS:   SLOW
SOIL DRAINAGE CLASS:  WELL DRAINED

A  2                  .0- 1.0 INCHES
                      LIGHT GRAY (10YR 7/2) EXTERIOR OF DRY PEDS,  GRAYISH BROWN  (10YR 5/2)
                      INTERIOR OF DRY PEDS,  DARK GRAYISH BROWN  (10YR 4/2) MOIST,  V DK GRAYISH BROWN
                      (10YR 3/2) MOIST,  *** COARSE CLAY LOAM    *** MASSIVE *** HARD,
                      FRIABLE,    *** MANY    FINE    ROOTS    THROUGHOUT HORIZON  *** MANY
                      VERY FINE AND FINE  VESICULAR  PORES  *** FEW CLAY FILMS
                      ON VERTICAL PED FACES  ,  MANY    UNSTAINED SAND GRAINS  *** ABRUPT  BOUNDARY    ***

B2A2                  1.0- 4.0 INCHES
                      DARK GRAYISH BROWN  (10YR 4/2) DRY,    GRAYISH BROWN  (10YR 5/2)
                      CRUSHED DRY,    V DK GRAYISH BROWN  (10YR 3/2) MOIST,  DARK GRAYISH BROWN  (10YR 4/2)
                      CRUSHED MOIST,  *** FINE CLAY LOAM  *** WEAK    COARSE  PRISMATIC   SEPARATING TO
                      WEAK    MEDIUM  PRISMATIC   SEPARATING TO   MODERATE    FINE    ANGULAR BLOCKY
                      STRUCTURE   *** VERY HARD,  FRIABLE,    STICKY, PLASTIC,    *** MANY
                      FINE    ROOTS   THROUGHOUT HORIZON  *** FEW VERY FINE AND FINE
                      TUBULAR PORES   *** MANY    DISTINCT    CLAY FILMS
                      ON HORIZONTAL AND VERTICAL PED FACES    ,  MANY
                      UNSTAINED SAND GRAINS   *** GRADUAL BOUNDARY    ***

B 21T                 4.0- 6.0 INCHES
                      GRAYISH BROWN  (10YR 5/2) DRY,    LIGHT BROWNISH GRAY (10YR  6/2)
                      CRUSHED DRY,    DARK GRAYISH BROWN  (10YR  4/2) MOIST,  *** CLAY    ***
                      WEAK    COARSE  PRISMATIC   SEPARATING TO   WEAK    MEDIUM  ANGULAR BLOCKY
                      STRUCTURE   *** EXTREMELY HARD, FIRM,   STICKY, VERY PLASTIC,   *** FEW
                      FINE    ROOTS   THROUGHOUT HORIZON  *** FEW VERY FINE AND FINE
                      TUBULAR PORES   *** MANY    FAINT   CLAY FILMS  ON PED FACES    ,  COMMON
                      UNSTAINED SAND GRAINS   *** GRADUAL BOUNDARY    ***

B 22T                 6.0- 8.0 INCHES
                      GRAYISH BROWN   (10YR  5/2) DRY,    LIGHT BROWNISH GRAY (10YR  6/2)
                      CRUSHED DRY,    DARK GRAYISH BROWN  (10YR  4/2) MOIST,  *** CLAY    ***
                      WEAK    COARSE  PRISMATIC   SEPARATING TO   WEAK    MEDIUM  ANGULAR BLOCKY
                      STRUCTURE   *** EXTREMELY HARD, FIRM,   VERY STICKY,    VERY PLASTIC,   ***
                      FEW FINE    ROOTS   THROUGHOUT HORIZON  *** FEW VERY FINE AND FINE
                      TUBULAR PORES   *** MANY    FAINT   CLAY FILMS  ON PED FACES    ,  COMMON
                      UNSTAINED SAND GRAINS   *** GRADUAL BOUNDARY    ***

B  2CS                8.0- 12.0 INCHES
                      GRAYISH BROWN   (2.5Y  5/2) DRY,    LIGHT BROWNISH GRAY (2.5Y  6/2)
                      CRUSHED DRY,    DARK GRAYISH BROWN  (10YR  4/2) MOIST,  *** CLAY    ***
                      WEAK    COARSE  PRISMATIC   SEPARATING TO   WEAK    MEDIUM  ANGULAR BLOCKY
                      STRUCTURE   *** EXTREMELY HARD, FIRM,   VERY STICKY,    VERY PLASTIC,   ***
                      FEW FINE    ROOTS   THROUGHOUT HORIZON  *** FEW VERY FINE AND FINE
                      TUBULAR PORES   *** FEW CLAY FILMS  ON VERTICAL PED FACES   *** FEW FINE
                      GYPSUM  CRYSTALS    ***

C  1CS                12.0- 15.0 INCHES
                      GRAYISH BROWN   (2.5Y  5/2) DRY,    LIGHT BROWNISH GRAY (2.5Y  6/2)
                      CRUSHED DRY,    DARK GRAYISH BROWN  (10YR  4/2) MOIST,  *** CLAY    ***
                      WEAK    MEDIUM  ANGULAR BLOCKY  STRUCTURE   *** EXTREMELY HARD, FIRM,
                      STICKY, PLASTIC,    *** FEW FINE    ROOTS   THROUGHOUT HORIZON  *** FEW
                      VERY FINE AND FINE  TUBULAR PORES   *** COMMON  FINE AND MEDIUM GYPSUM  CRYSTALS    ***

C  2CS                15.0- 18.0 INCHES
                      LIGHT BROWNISH GRAY (2.5Y  6/2) DRY,    DARK GRAYISH BROWN  (2.5Y  4/2)
                      MOIST,  *** CLAY    *** WEAK    MEDIUM  ANGULAR BLOCKY  STRUCTURE   ***
                      EXTREMELY HARD, FIRM,   STICKY, PLASTIC,    *** FEW FINE    ROOTS
                      THROUGHOUT HORIZON  *** FEW VERY FINE AND FINE  TUBULAR PORES   *** MANY
                      GYPSUM  CRYSTALS    ***
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APPENDIX FIGURE 39. Morphological description written by computer from soil codes stored in the pedon data record.

SERIES: MCDONALD SAMPLE NUMBER: S65MONT 24 5 NUMBER OF HORIZONS = 11

HORIZON DEPTH (INCHES)	HORIZON	SAMPLE NUMBER	PARTICLE SIZE DISTRIBUTION T&T. SAND	T&T. SILT	T&T. CLAY	VCO. SAND	COS. SAND	MED. SAND	FINE SAND	V.F. SAND	COS. SILT	FINE SILT	V.F. SILT	INT. II
			PERCENT											
.0- 7.0	A 11	0020601	14.7	51.6	33.7	2.3	2.1	1.8	3.5	5.0	14.4	37.2	11.2	21.4
7.0- 10.0	A 12	0020602	17.5	49.8	32.7	4.2	2.6	1.4	3.8	5.5	15.9	33.9	10.6	23.6
10.0- 14.0	B&A	0020603	30.6	42.0	27.4	9.2	6.8	3.4	5.3	5.9	13.6	28.4	10.7	22.4
14.0- 19.0	B 21T	0020604	12.0	35.1	52.9	2.9	2.2	1.2	2.4	3.3	8.1	27.0	11.6	12.8
19.0- 27.0	B 22T	0020605	9.1	35.5	55.4	.9	1.1	1.0	2.7	3.4	8.5	27.0	12.6	13.5
27.0- 35.0	B 23T	0020606	10.3	38.6	51.1	1.2	1.7	1.2	2.9	3.8	8.7	29.9	13.7	14.2
35.0- 42.0	B 3	0020607	13.6	40.8	45.6	3.0	7.4	1.5	3.3	3.4	10.3	30.5	14.5	15.5
42.0- 53.0	C 1CA	0020608	11.5	48.6	39.9	2.6	1.9	1.1	2.5	3.4	11.1	37.5	15.7	16.0
53.0- 66.0	II C 2	0020609	15.9	54.0	30.1	2.2	2.5	1.6	4.0	5.6	14.2	39.8	15.3	22.3
66.0- 80.0	IIIC 3	0020610	7.6	45.2	47.7	1.5	1.3	.8	1.6	2.4	8.0	37.2	16.9	11.4
80.0- 90.0	IV C 4	0020611	25.2	54.4	20.4	6.1	4.6	2.4	4.8	7.3	15.9	38.5	15.2	26.1

HORIZON DEPTH (INCHES)	MISCELLANEOUS PARTICLE SIZES 2-0.1 MM	<.074 MM	.005-.002 U	2-.2 U	<.2 CLAY	WATER CARB CLAY	NONCAR CLAY	LAB. DET. COARSE FRAGMENTS >2-<5 WT.	>2-<19 WT.	>2 WT.	>2 VOL.	>19 VOL.	>2-<19 VOL.	>5-<19 WT.
	PERCENT													
.0- 7.0	9.7	88.8						13	15	10				
7.0- 10.0	12.0	86.3						33	45	35				
10.0- 14.0	24.7	73.4						47	55	45				
14.0- 19.0	8.7	90.3						16	30	30				
19.0- 27.0	5.7	93.2						8	10	5				
27.0- 35.0	6.5	92.3						8	10	5				
35.0- 42.0	10.2	88.7						15	20	15				
42.0- 53.0	8.1	90.9						12	15	10				
53.0- 66.0	10.3	87.9						11	15	10				
66.0- 80.0	5.2	94.1						8	15	10				
80.0- 90.0	17.9	79.9						22						

HORIZON DEPTH (INCHES)	PH KCL 1:1	SAT. PASTE	WATER 1:1	WATER 1:5	WATER 1:10	CACL2 .01	NAF SAT.	WATER CONTENT FIELD STATE	1/10 BAR	1/3 BAR	30 CM	1 BAR	2 BAR	5 BAR	15 BAR
								PERCENT							
.0- 7.0			6.3								34.0				16.6
7.0- 10.0			6.5												13.3
10.0- 14.0			6.6								22.7				8.2
14.0- 19.0			6.7								21.6				14.7
19.0- 27.0			6.8								21.6				16.0
27.0- 35.0			7.2								21.6				14.5
35.0- 42.0			7.9												13.9
42.0- 53.0			8.1								20.5				12.3
53.0- 66.0			8.2								17.0				9.6
66.0- 80.0			8.1								21.3				15.0
80.0- 90.0			8.3												6.3

HORIZON DEPTH (INCHES)	ORG. MAT.	ORG. CAR.	NIT.	FE (FE)	FE OXIDE	EXT. ACID	EXT. AL	EXT. SO4	EXTRACTABLE BASES CM	COLE	CA	MG	NA	K	CA & MG
		PERCENT									MEQ./100G				
.0- 7.0		4.34	.344			10.5			.022			4.9	.2	1.1	
7.0- 10.0		2.20	.189			7.2						4.3	.2	.9	
10.0- 14.0		.54	.059			3.3			.018			3.0	.1	.4	
14.0- 19.0		.38	.051			3.6			.025			5.4	.2	.6	
19.0- 27.0		.35				3.3			.034		10.0	5.2	.2	.5	
27.0- 35.0		.20				2.4			.038		9.7	4.5	.3	.5	
35.0- 42.0		.05									10.7	3.5	.2	.4	
42.0- 53.0		.07							.018		10.3	3.1	.2	.3	
53.0- 66.0		.01							.009		8.1	2.6	.2	.3	
66.0- 80.0									.018		9.7	3.9	.3	.4	
80.0- 90.0											6.5	2.1	.2	.3	

APPENDIX FIGURE 40. Laboratory data tables 1,2,3 and 4 printed by computer from soil codes stored in the pedon data record.

SERIES: MCD0NALD SAMPLE NUMBER: S65M0NT 24 5 NUMBER 0F H0RIZ0NS = 11

HORIZON DEPTH (INCHES)	BULK DENSITY FIELD STATE	1/10 BAR	1/3 BAR	30 CM	AIR DRY	OVEN DRY	CEC AND BASE SATURATION CATION SUM (CEC)	(SAT)	NH4OAC SUM (CEC)	(SAT)	NAOAC (CEC)	(SAT)	KOAC (CEC)	(SAT)	BACL2 (CEC)	(SAT)
		G/CC					MEQ	%	MEQ	%	MEQ	%	MEQ	%	MEQ	%
0- 7.0			1.11			1.20*	36.1		28.5	90						
7.0- 10.0						*	26.2		20.8	91						
10.0- 14.0			1.45			1.59*	14.0		11.9	90						
14.0- 19.0			1.53			1.70*	19.7		17.2	94						
19.0- 27.0			1.61			1.79*	19.2		18.8							
27.0- 35.0			1.61			1.81*	17.4		16.5							
35.0- 42.0						*			13.5							
42.0- 53.0			1.65			1.75*			12.3							
53.0- 66.0			1.82			1.87*			9.3							
66.0- 80.0			1.71			1.82*			12.9							
80.0- 90.0						*			7.5							

HORIZON DEPTH (INCHES)	CACO3 EQUIV TOT. SOIL	<2 MM	>2 MM	<2 U	<19 MM	SATURATION EXTRACT SOLUABLE CA	MG	NA	K	CO3	HCO3	CL	SO4	NO3	% AT SAT.
	PERCENT					MEQ./LITER									
0- 7.0															
7.0- 10.0															
10.0- 14.0	--														
14.0- 19.0	--														
19.0- 27.0	--														
27.0- 35.0	TR														
35.0- 42.0	5		--												
42.0- 53.0	11		TR												
53.0- 66.0	4		--												
66.0- 80.0	4		--												
80.0- 90.0	5		--												

HORIZON DEPTH (INCHES)	MISCELLANEOUS RESULTS SULFUR TOT.	AL (PYROPHOSPHATE EXT.)	CARBON	IRON	GYPSUM	MN	EXCH. NA	PHOS. TOT.	ELECT. RESIS.	ELECT. COND.	GYPSUM
	PERCENT							OHMS OR MHOS/CM			MEQ
0- 7.0											
7.0- 10.0											
10.0- 14.0											
14.0- 19.0											
19.0- 27.0											
27.0- 35.0											
35.0- 42.0											
42.0- 53.0											
53.0- 66.0											
66.0- 80.0											
80.0- 90.0											

APPENDIX FIGURE 41. Laboratory data tables 5,6, and 7 printed by computer from soil codes stored in the pedon data record.

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