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GUIDE FOR INTERPRETING ENGINEERING USES OF SOILS

UNITED STATES DEPARTMENT OF AGRICULTURE
Soil Conservation Service

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Introduction

Soils Memorandum SCS-45 (Rev. 2) sets forth the policy of the Soil Conservation Service in making engineering interpretations from soil surveys and gives an outline of the content of the section on engineering uses of soil that is included in published soil surveys. Properly prepared engineering interpretations, an important part of each completed soil handbook and published soil survey, are useful to people engaged in planning and construction work.

This Guide has been prepared especially for the authors who prepare the soil-engineering interpretations to be contained in published soil surveys. It sets forth the information the engineering section should contain and suggests a format for presentation that helps to make the engineering interpretations consistent and more easily understandable to users of the surveys.

The following pages outline the material to be included in the engineering section of soil surveys, show methods for estimating and entering engineering data in the standard engineering tables, and set forth instructions for writing the text of the engineering section.

Part I. Items To Be Included In The Engineering Section

Introductory statement

An introductory statement tells the readers what information the engineering section contains, why it has been prepared, and that certain properties of soils are of special interest to engineers and others since those properties affect the planning of construction and maintenance of engineering works.

Statement on limitations of the applicability and use of the information given

This statement specifies the limitations to users of the engineering information given and cautions that detailed onsite investigation is needed to verify the data given and, for many locations, to collect additional data. Advise that information given for any specific soil is generalized but that it is the best available estimate of the engineering properties of that soil. Explain that a soil designated by a given name varies somewhat from place to place and, thus, at some sites may have properties that differ slightly from those listed as representative. Explain further that, on soil maps at a scale of 3 to 4 inches to the mile, small spots of contrasting soils are not shown. Note for readers that, unless otherwise indicated, information is given for soil to a depth of 5 or 6 feet, whichever depth is appropriate for the survey area.

Statement on how the information can be used

This statement lists the ways in which the soil-engineering information can be used but lists only those ways of value to users in the survey area. Indicate that the information is not intended to be specific enough for detailed design of engineering installations but that it is specific enough to make possible good, though general, evaluation of limitation or suitability for selected uses.

Statement on terminology used

Explain that there are some differences between the terminology of soil science and that of engineering and that the terms used in soil surveys are those used in soil science, that terms used in more than one section of a published survey are defined in the glossary to the survey, and that terms significant in a specific section of a published survey are defined and explained in that section. Generally used terms are soil, sand, silt, clay, subsoil, substratum, aggregate, granular, and others, which are defined in the glossary; such terms as shrink-swell potential, plasticity index, and liquid limit are defined in the engineering section, where explanation is made of how each term applies or can be used in planning engineering works.

Discussion of soil classifications important to engineering

Discuss briefly the three ways soils are classified. The USDA textural classification, the Unified system, and the AASHO (American Association of State Highway Officials) system.

Explanation of standard engineering tables

Three engineering tables generally are included in a published soil survey. The data and interpretations given are those for taxonomic units in the system of soil classification. Information about fertility, color, and other details generally useful in identifying a soil but of little or no direct value for engineering uses are not included in the engineering section.

In the first table, as in table A in this Guide, list the individual kinds of soil and give estimates of their properties significant to engineering. To make estimates for a specified kind of soil, use test data for samples of the soil taken in the survey area (county) or, if necessary, for samples of that series obtained in another county. If test data are not available for the series, base the estimates on other information collected in surveying the soils and, for general guidance, use available test data for similar soil series.

This first table (see sample table A) is intended mainly for engineers. It should enable them to make considerable use of soil surveys without being fully conversant with soil science.

In the second table, as in table B in this Guide, list engineering interpretations for each of the soils listed in the previous table. Base the interpretations on the information given in the first table, on available test data for the soils, on knowledge of the soil properties that affect engineering uses, and on observations of soil behavior made during field work.

This table, though useful to engineers, is intended also to be helpful to others as well and especially to community planners.

The first and second tables, as in tables A and B, should contain data on all soils in the survey area. In preparing these tables do not lose sight of the facts that soil complexes, undifferentiated units, and associations are variable in behavior and that one set of engineering interpretations cannot be recorded for such units. The interpretations must be given for each individual soil taxonomic unit.

In the third table, as in table C, present available engineering test data for samples of soil taxonomic units of the survey area.

Where needed for any of the three tables, write a headnote that refers readers to the section "Descriptions of the Soils," explain that absence of data indicates (unless otherwise noted in a footnote) that the specified soil is too variable to be rated or that no estimate could be made and also define special symbols used in entries throughout a table.

Discussion of general soil conditions and of features not included in standard engineering tables

Supplement information given in the tables with a short narrative section on general soil conditions, geology of the area, unusual site factors, problem areas for engineering works, or other features unique to the survey area. If geologic and other physical features of the area are described in another section of the publication, refer readers to that section. A brief statement on the features important to engineering also may be useful. Cite relevant special literature on geology, ground water, and the like.

Include, where important to the survey area, engineering interpretations not routinely made for all parts of the country. Among such interpretations are "potential frost action" and "piping in undisturbed soils." Such interpretations may be given in narrative or in table columns. Those interpretations and others not shown in the sample tables are discussed in this Guide under the heading "Interpretations not shown in sample tables A and B."

Part II. Preparing And Presenting Data In Engineering Tables

This part of the Guide gives instructions for estimating and entering engineering data in the standard engineering tables included in published surveys. For guidance, sample tables A, B, and C at the back are discussed column by column in the pages that follow.

Sample table A.--Estimated soil properties significant to engineering

Not all columns shown in sample table A are needed to describe the soils in some areas, and in other survey areas additional columns are needed. Try to keep the number of columns to the minimum essential. If a significant property is about the same for all or nearly all the soils in a survey area, omit a column for it and instead describe that property in the text. If a property varies between many soils, include a column for it. If an important property applies to only a few mapping units, omit the column and use footnotes to the table, placing the footnote references after the indicated map symbols.

Data entered in this table should be for those characteristics most nearly representative of the series. Because uniformity or variation of each property can be of importance in engineering uses, where possible the data for each characteristic should be shown in a range of values. For example, the range for properties of a given layer of soil derived from loess may be narrow, whereas the range for a given layer of soil derived from glacial till may be wide. Keep the range as narrow as practicable. Generally, however, data for extreme variation within a mapping unit are not included nor are data for minor inclusions in the unit.

Column 1.--Soil series and map symbols. List the soil series alphabetically (see table A). Within each series, group together phases having similar behavior and commonly having the name of a single taxonomic unit; generally place the group of map symbols adjacent to the series name; and, in the columns that follow, give one set of ratings, respectively, for each major soil layer. If important differences in engineering properties occur between the phases of the series, record as individual entries, under the series name, groups of map symbols for phases having like properties and behavior and, in the columns that follow, give one set of ratings, respectively, for each major layer of the soils noted by each group of map symbols. In some survey areas the map symbol for one phase alone may be a separate entry because that phase has one or two properties that differ from those of other phases.

In listing multitaxa mapping units in this column, it is important that they be listed in such a way that it is possible for the data for each individual taxonomic component of a unit to be entered independently in the table, yet in such a way that each component can be identified in the stub (column 1) as part of the multitaxa mapping unit to which it belongs. Following is a visual aid that shows the details for entering these soil complexes, undifferentiated groups, and soil associations in column 1. Note that the soil names and their map symbols are hypothetical.

(Column 1)
Soil series and map symbols

Allis -------------------------------
Mapped only in complexes with Tullen soils.
(Soils in the Allis series have not been mapped separately in the survey area (county). A phase of this series is a component in two multitaxa mapping units, TuB and TuC, which are complexes that have been mapped in the area. NOTE THAT THE MAP SYMBOLS FOR THE MULTITAXA UNITS ARE NOT SHOWN HERE WITH THE ALLIS SERIES BUT ARE IN ALPHABETIC PLACE WITH THE TULLEN SERIES.)

Amana -------------------------------
Mapped only with Dancer soils.
(Soils in the Amana series have not been mapped separately in this county. A phase of this series is a component in the multitaxa mapping unit DbA, which has been mapped in the area. NOTE THAT THE MAP SYMBOL FOR THE MULTITAXA UNIT IS NOT SHOWN HERE WITH THE AMANA SERIES BUT IS IN ALPHABETIC PLACE WITH THE DANCER SERIES.)

Barnum: BaB, BaB2 -----------------
(A phase of the Barnum series is a component in the multitaxa mapping unit DcB. NOTE THAT THE MAP SYMBOL FOR THE MULTITAXA UNIT IS NOT SHOWN HERE WITH THE BARNUM SERIES BUT IS IN ALPHABETIC PLACE WITH THE DANCER SERIES.)

Benson: BeA, BeA2, BhA ------------
For properties of Thurloo part of BhA, see Thurloo series.
(A phase of the Benson series is a component in two multitaxa mapping units, BhA and DfB. NOTE THAT THE MAP SYMBOL FOR THE UNIT BhA IS SHOWN HERE IN ALPHABETIC PLACE WITH THE BENSON SERIES AND THAT HERE CROSS REFERENCE IS MADE TO THE OTHER COMPONENT IN THE UNIT, A THURLOO SOIL. ALSO, NOTE THAT THE MAP SYMBOL FOR THE UNIT DfB IS NOT SHOWN HERE WITH THE BENSON SERIES BUT IS IN ALPHABETIC PLACE WITH THE DANCER SERIES.)

Dancer: DaA, DbA, DcB, DfB, DoC ----
For properties of Amana part of DbA, of Barnum part of DcB, of Benson part of DfB, and of Tolson part of DoC, see those series, respectively.
(A phase of the Dancer series is a component in four multitaxa mapping units. NOTE THAT ALL THE MAP SYMBOLS FOR THE MULTITAXA UNITS ARE SHOWN HERE IN ALPHABETIC PLACE WITH THE DANCER SERIES AND THAT HERE CROSS REFERENCES ARE MADE TO THE OTHER COMPONENTS IN THOSE UNITS--AMANA, BARNUM, BENSON, AND TOLSON SOILS.)

Made land --------------------------
Too variable to be rated.
(This land type is a component in the multitaxa mapping unit Wm, which has been mapped in the county. NOTE THAT IN THE TABLE THERE USUALLY WILL BE NO DATA FOR THIS COMPONENT BECAUSE IT COMMONLY IS TOO VARIABLE TO BE RATED. ALSO, NOTE THAT THE MAP SYMBOL FOR THE MULTITAXA MAPPING UNIT IS NOT SHOWN HERE WITH MADE LAND BUT IS IN ALPHABETIC PLACE WITH THE NAME OF THE COMPLEX, WAYNE-MADE LAND COMPLEX.)

Sharon: Sh, Sm, Sn, So, Sr ---------
For properties of Tolson parts of Sn, So, Sr, see Tolson series.
(A phase of the Sharon series is a component in three multitaxa mapping units that commonly have the same two components, a Sharon soil and a Tolson soil. NOTE THAT ALL THE MAP SYMBOLS FOR THOSE MULTITAXA UNITS ARE SHOWN HERE IN ALPHABETIC PLACE WITH THE SHARON SERIES AND THAT HERE CROSS REFERENCE IS MADE TO THE OTHER COMPONENT COMMONLY IN THOSE UNITS.

Also, a phase of the Sharon series is a component in a fourth multitaxa mapping unit Tr. THE MAP SYMBOL FOR THAT UNIT IS SHOWN IN ITS ALPHABETIC PLACE WITH THE THURLOO SERIES AND THERE CROSS REFERENCE IS MADE TO THE COMPONENT IN THIS [SHARON] SERIES.)

Thurloo: Th, Tr -------------------
For properties of Sharon part of Tr, see Sharon series.
(A phase of the Thurloo series is a component in the multitaxa mapping unit Tr. NOTE THAT THE MAP SYMBOL FOR THE UNIT IS SHOWN HERE IN ALPHABETIC PLACE WITH THE THURLOO SERIES AND THAT HERE CROSS REFERENCE IS MADE TO THE OTHER COMPONENT IN THE UNIT, A SHARON SOIL.)

Tolson ------------------------------
Mapped only with Dancer and Sharon soils.
(Soils in the Tolson series have not been mapped separately in this county. A phase of this series is a component in four multitaxa mapping units that have been mapped in the area. NOTE THAT THE MAP SYMBOLS FOR THE MULTITAXA UNITS--DoC, Sn, So, Sr--ARE NOT SHOWN HERE WITH THE TOLSON SERIES BUT ARE IN ALPHABETIC PLACE WITH THE DANCER [DoC] AND SHARON [Sn, So, Sr] SOILS.)

Tullen: TuB, TuC ------------------
Mapped only in complexes with Allis soils.
(Soils in the Tullen series have not been mapped separately in this county. A phase of this series is a component in two multitaxa mapping units that are complexes that have been mapped in the area. NOTE THAT THE MAP SYMBOLS FOR THOSE UNITS ARE SHOWN HERE IN ALPHABETIC PLACE WITH THE TULLEN SERIES AND THAT HERE CROSS REFERENCE IS MADE TO THE OTHER COMPONENTS IN THE UNITS, BOTH OF THE ALLIS SERIES.)

Wayne-Made land complex: Wm --------
Mapped only in a complex with Made land, which is too variable to be rated.
(The only Wayne soil mapped in this county is a component in the multitaxa mapping unit Wm. NOTE THAT THE MAP SYMBOL FOR THAT UNIT IS SHOWN HERE IN ALPHABETIC PLACE WITH THE NAME OF THE COMPLEX AND THAT AGAIN THE READER IS ADVISED THAT THE OTHER COMPONENT, MADE LAND, IS TOO VARIABLE TO BE RATED.)

Column 2.--Depth to bedrock, and Column 3.--Depth to seasonal high water table. Give these depths in a range of feet, but for depths in excess of 5 or 6 feet, enter "> 5 feet" (more than 5 feet). Enter figures for greater depths, such as "> 10 feet," only if there is complete confidence in their validity.

Column 2 can be omitted if depth to bedrock for most soils in the survey area is well beyond depths to which soils were investigated in the field mapping. In such instances use footnotes to designate those few kinds, if any, of soil where bedrock is within a few feet of the surface.

Column 3 can be treated similarly. Also, note in column 3 the soils that are subject to flooding by references to footnotes to the table.

Column 4.--Depth from surface (representative profile). List the limits of major horizons that are to be described in the columns that follow. Generally, depth from the surface for the major layers (A, B, C, and sometimes IIC) is the only depth given in column 4 and should be the same for layers of a soil as given, respectively, for major horizons of the representative profile of its series and as discussed in the section "Descriptions of the Soils." List special horizons that have engineering properties significantly different from an adjacent horizon. If adjacent horizons have the same engineering properties, as in windblown sands or in other soils of only slight profile development, list limits for the combined horizons.

Columns 5, 6, 7.--Soil classification. In these columns give classifications of the soils in the survey area in accordance with the USDA textural classification system (column 5), the Unified system (column 6), and the AASHO (American Association of Highway Officials) system (column 7). (Classification is given in the Unified and AASHO systems because many engineers unfamiliar with the USDA textural classification know one or both of these engineering systems, and seeing the classification in a system they know is of great convenience to them. Moreover, much engineering knowledge about soils has been related to the two systems.

The soil classes listed in these columns (see table A) are based not only on careful field observation but on test data from engineering laboratories, the soil survey laboratories, or others. Reports from engineering laboratories commonly indicate the engineering class of each sample and the data important to determining that class. These data should be used as benchmarks to aid in estimating the classes of other soils.

The estimated classes in columns 6 and 7 must be in agreement with the data given in columns 8 through 11.

In column 5 give the USDA textural classification, using the standard nomenclature as defined in the Soil Survey Manual (see Chart 1 in Appendix 1) and as used in the text of published soil surveys. In this system the basic textural name of a soil is preceded by a "coarse" modifier (gravelly, cobbly, or cherty) if 20 percent or more of the soil material is particles larger than 2.0 mm.

In column 6 give the Unified classification, using Chart 3 and Guide Sheet 15 in Appendix 1 for general guidance. In this column if two regular symbols are needed for an entry, the symbols should be written with "or," as "ML or CL." If more than two symbols are needed, use commas to separate all except the last two, as in "GM, GC, SM or SC."

In the Unified system, soils that are on the borderline between two classes are indicated by two regular symbols connected by a hyphen, as in "ML-CL" and "SP-SM." The range in characteristics connoted by such hyphenated symbols is narrow, generally too narrow for such symbols to serve as estimated classes in column 6. (Hyphenated symbols, however, can be used in the third standard table, as in sample table C, where classification is based on laboratory analyses.)

In the Unified system the term "organic soils" connotes those soils that have enough organic matter to adversely affect their engineering behavior but not enough for those soils to be classed as peat or muck, which are the highly organic soils. Organic soils generally are identified by color and odor when a wet sample is heated. If this test is inadequate for identifying such soils, they can be identified more surely by determining the liquid limit on airdried samples and on the samples after they are ovendried. If $\frac{\text{LL ovendry}}{\text{LL airdry}}$ has a ratio of less than 0.7, the soil material is considered organic--OL or OH, depending on liquid limit; if the ratio is 0.7 or more, the soil material is nonorganic.

In column 7 give the AASHO classification, using Guide Sheet 15 in Appendix 1 for guidance if laboratory test data are not available. Generally, give only the main soil group symbols, such as "A-2" or "A-7." If, however, enough data are available to show that soil material is generally in a specific subgroup, such as "A-2-4," give the subgroup estimate. Do not estimate group index values. If two symbols are needed, use "or" between the symbols, for example, "A-2 or A-4." If more than two symbols are needed, use commas to separate all except the last two, as in "A-2-5, A-2-6 or A-2-7."

If laboratory data are available, use Chart 4, Appendix 1, for guidance in determining AASHO classes. (To use Chart 4, proceed from left to right; the first group into which the test data fit is the classification sought.)

Column 7a.--Coarse fraction greater than 3 inches. If most soils in a survey area have fragments larger than 3 inches in diameter, use this column to list percentages, by weight, of the coarse fractions of the soil mass. Give each percentage as a range, such as "10-25" or "40-60." If only a few soils in the area have such fragments, use footnotes to show the estimated percentages. (Guide Sheet 1 can be used as a basis for converting to percentage, by weight, from percentage, by volume.)

Columns 8, 9, 10, and 11.--Percentages of particles less than 3 inches passing sieves. Give information on grain-size distribution as estimated percentage of material passing through No. 4 sieve--4.7 mm. (column 8), No. 10 sieve--2.0 mm. (column 9), No. 40 sieve--0.42 mm. (column 10), and No. 200 sieve--0.074 mm. (column 11). Give these estimates as a range in values, such as "15-25" or "90-100," unless it is clearly evident that 100 percent of the material will pass through a given sieve. These estimates are based on the assumption that material up to and including 3 inches in diameter equals 100 percent. This limit coincides with that used in both the AASHO and the Unified engineering soil classification systems.

Other sieve designations can be substituted or added as column headings, depending on the soil material of the specific survey area. For example, for an area having considerable gravel and coarser grained material, an estimate of percentages passing the 1-inch sieve may be useful; whereas for other areas having no coarse sand or gravel the column for the No. 4 sieve (or for others with larger openings) should be omitted.

Even though laboratory data are available for a soil, the estimated percentage should cover the range that might be expected if a large number of samples were tested. (Guide Sheet 2 gives the percentages of soil material that generally passes the specified sizes of sieves.)

Guide Sheet 1.--Coarse fragment conversion from percentage, by volume, to percentage, by weight[1/]

Percent, by volume	Percent, by weight			
	Bulk density of soil			
	1.3	1.5	1.7	2.0
10	19	17	15	13
15	27	25	22	19
20	34	31	28	25
25	41	38	34	31
30	47	44	40	37
35	53	50	46	42
40	58	55	51	47
45	63	60	56	52
50	68	64	61	57
55	72	69	66	62
60	76	73	70	67
65	80	77	75	71
70	83	81	79	76

1/ Using formula $\frac{2.7G}{\text{B.D. } (100-G) + 2.7G} \times 100$:

Where G is percent of coarse fragments (by volume) and 2.7 is assumed average specific gravity of coarse fragments and B.D. is bulk density of fine earth fraction (less than 2 mm).

For bulk densities other than those above, the approximate adjustment is 3 percent for each bulk density change of 0.2 gm/cc in the soil.

Similar adjustment for coarse fragment densities other than 2.7 (granitic equivalents) can be made; adjust the basic formula to the appropriate coarse fragment density.

To use this table for conversion of material coarser than 3 inches, appropriate adjustment, generally upward, must be made in the assumed bulk density to include material, if any, between 2 mm and 3 inches.

Guide Sheet 2.--Percentage of material commonly passing specified sieve sizes[1/]

USDA textural class	Percent passing sieves			
	No. 4 (4.76 mm)	No. 10 (2.0 mm)	No. 40 (0.42 mm)	No. 200 (0.074 mm)
Clay	100	100	90-100	75-95
Silty clay	100	100	95-100	90-95
Silty clay loam	100	100	95-100	85-95
Clay loam	100	100	90-100	70-80
Loam	100	100	85-95	60-75
Silt loam	100	100	90-100	70-90
Silt	100	100	100	90-100
Sandy clay	100	100	85-95	45-60
Sandy clay loam	100	100	80-90	35-55
Sandy loam	100	100	60-70	30-40
Fine sandy loam	100	100	70-85	40-55
Very fine sandy loam	100	100	85-95	50-65
Loamy very fine sand	100	100	90-95	40-60
Loamy sand	100	100	50-75	15-30
Fine sand	100	100	65-80	20-35
Sand	100	100	50-70	5-15
Very fine sand	100	100	75-90	35-55

1/ To be used where engineering test data are not available.

NOTE: To determine texture class, material larger than 2.00mm is removed. Therefore, all material from textural class determination passes both No. 4 and No. 10 sieves. Above percentages, therefore, must be adjusted to include the percent of material coarser than 2.0 mm.

EXAMPLE: Gravelly loam texture with 20 percent, by weight, of soil material larger than 2.0 mm and 30 percent of tested material coarser than 0.074 mm. Then, 80 percent of total sample is less than 2.0 mm. Coarse soil material is 30 percent of 80 = 24 percent of total material + 20 percent. Fifty-five percent would pass No. 200 sieve (report would show 50-60 percent) and 80 percent would pass the No. 10 sieve (report would show 75-85 percent).

Columns 12 and 13.--Liquid limit (column 12), and Plasticity index (column 13). If knowledge is such that liquid limit and plasticity index can be estimated, enter the estimates in the respective columns. Express estimates as ranges of values; enter "NP" for soils that are nonplastic. Make entries in these columns only if laboratory-determined liquid limit and plasticity index are available for enough soils so that entries are reliable estimates. The laboratory data do not have to be for soils in the survey area, but, if not, they must be for soils like those in the survey area. Omit these columns if reliable estimates cannot be made for most soils in the survey area.

Column 14.--Permeability. Soil permeability is that quality of soil that enables it to transmit water and air. Accepted as a measure of this quality is the rate at which soil transmits water while saturated. That rate is the "saturated hydraulic conductivity" of soil physics. In line with conventional usage in the engineering profession and traditional usage in the published soil surveys, this rate of flow, principally downward, continues to be expressed as "permeability." The definition and basis for estimating permeability should be given in the Glossary in published soil surveys. Use a footnote to direct readers to the glossary.

To rate soil permeability; use the numerical ranges shown below:

Permeability class	Numerical range (inches per hour)
Very slow	Less than 0.06
Slow	0.06-0.2
Moderately slow	0.2-0.6
Moderate	0.6-2.0
Moderately rapid	2.0-6.0
Rapid	6.0-20
Very rapid	More than 20

Column 15.--Available water capacity. Express available water capacity in inches of water per inch of soil. Limit entries to values considered reliable. Use a range to indicate a span of capacity, e.g., 0.15-0.17. Caution: Base estimates not only on soil texture, making appropriate adjustment for coarse fragments, but also on structure, consistence, and bulk density.

Do not enter estimates of available water capacity for hardpans or other dense layers from which roots are excluded, and do not enter estimates for soil layers below them either. Instead, enter a reference to a footnote which explains that roots of most plants are excluded from these layers and water in them therefore is not available to plants.

In some dense layers, as in many fragipans, root penetration is restricted and roots are not altogether excluded. Enter estimates for such layers but, depending on the ability of roots to penetrate the material and extract the moisture, make the estimates 25 to 75 percent less than estimates for similarly textured material that is friable. Explain in the text, or in a footnote to the table, the reason for the reduced values.

Column 16.--Reaction. If most soils in the survey area have the same range in reaction, this column can be omitted. If omitted, the information should be stated in the text, listing exceptions if any. Reaction is defined in the glossary at the back of the published survey.

To show pH, use the numerical ranges shown below:

Reaction description	pH range
Extremely acid	Below 4.5
Very strongly acid	4.5-5.0
Strongly acid	5.1-5.5
Medium acid	5.6-6.0
Slightly acid	6.1-6.5
Neutral	6.6-7.3
Mildly alkaline	7.4-7.8
Moderately alkaline	7.9-8.4
Strongly alkaline	8.5-9.0
Very strongly alkaline	Above 9.0

If more than one range is needed to cover the normal pH of a soil, omit the intermediate limits, as in 6.1-7.3.

Column 17.--Salinity. In this column give ratings for the salinity of soils, based on the electrical conductivity of the saturation extract, as expressed in millimhos per centimeter (mmhos/cm) at 25° C. The following ranges in millimhos per centimeter should be used for guidance.

Salinity classes (10)[1/]	Numerical ratings (millimhos per centimeter
None	Less than 2.0
Low	2.0-4.0
Moderate	4.0-8.0
High	8.0-16.0
Very high	More than 16.0

Omit this column if salinity is not significant to the engineering practices in the survey area or if salinity is minor in nature and a general statement on the subject is included in the text.

1/ Underscored numbers in parentheses refer to "Literature Cited" in this Guide.

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In some soils layers of gypsum present a problem to engineering practices. That these layers are present should be noted in a separate column if many soils in the survey area have such layers or by footnotes if only a few soils have such layers.

Column 18.--Shrink-swell potential. Give the ratings for shrink-swell potential in accordance with the information that follows. Use a range where needed.

Shrink-swell behavior is that quality of the soil that determines its volume change with change in moisture content. Building foundations, roads, and other structures may be severely damaged by the shrinking and swelling of soil. The volume change of soil is influenced by the amount of moisture change and the amount and the kind of clay. Knowledge of the kind and the distribution of clay helps in predicting the behavior of a soil.

Methods for determining shrink-swell behavior of soil are both quantitative and qualitative. The quantitative methods are (1) the coefficient of linear extensibility (COLE) used by soil scientists (5, 6) and (2) the potential volume change (PVC) used by the Federal Housing Administration (7, 8).

COLE is an estimate of the vertical component of swelling of a natural soil clod. COLE is defined as

$$\frac{Lm-Ld}{Ld}$$

where Lm = length of moist sample;

where Ld = length of dry sample.

Bulk density is determined for a natural soil clod and volume changes measured at different moisture contents. Since volume rather than length is measured, COLE is calculated

$$COLE = \left[\frac{Dbd}{Dbm}\right]^{1/3} - 1$$

where Dbd = dry bulk density of <2 mm fabric;

where Dbm = moist bulk density (field capacity) of <2 mm fabric.

Instead of coefficient of linear extensibility (COLE), some laboratory reports may show linear extensibility (LE) expressed as percentage (LEP). To convert LE to COLE, simply divide LE by 100

$$COLE = \frac{LE}{100}$$

PVC is a measure of the potential volume change in a compacted soil when placed in a confining ring and wetted.

The shrink-swell interpretations are relevant to structures, such as houses and other low buildings, streets and roads, and parking lots. Five classes have been developed to express shrink-swell behavior. In most instances, however, three classes are used. Very low and low are combined into low (<0.03 COLE); and high and very high are combined into high (>0.06 COLE). Moderate has a COLE of 0.03-0.06.

Following are definitions and examples of the five shrink-swell classes. (The Unified classification given for each soil series included in the examples pertains to the finest-textured horizon of each series sample tested by the Bureau of Public Roads, state highway laboratories, or soil survey laboratories.)

Very low. Generally includes soils that are loamy sand and sand and that contain any kind of clay mineral, and sandy loam, loam, and silt loam that contain kaolinite or other low shrink-swell clay minerals. These soils have a COLE of 0.01 or less and a PVC of 1.0 or less. The Unified classes to which most of these soils belong generally are SP, SM, SP-SM, and GP, but the class for some of the soils is ML. Following are examples of soil series that have very low shrink-swell potential in the B horizon or control section:

Gloucester	(SM)	Plainfield	(SP)
Hubbard	(SP-SM)	Tivoli	(SP-SM)
Lakeland	(SP-SM)	Valentine	(SP-SM)

Low. Generally includes soils that are silt loam, silty clay loam, clay loam, silty clay, sandy clay, and clay that contain mainly kaolinite or other low shrink-swell clay minerals. These soils have a COLE of 0.01-0.03 and a PVC of 1-2. Following are examples of soil series that have low shrink-swell potential in the B horizon or control section:

Alford	(CL)	Norfolk	(SC)
Blichton	(SC)	Nunda	(CL)
Burdett	(CL)	Maury	(MH)
Hayesville	(ML-CL)	Scantic	(ML-CL)
Karro	(ML)	Tripp	(CL)
Kenyon	(CL)	Wartrace	(CL)

Moderate. Generally includes soils that are silty clay, silty clay loam, clay loam, sandy clay loam, and clay containing mixed clay minerals that include some montmorillinite or other high shrink-swell minerals. These soils have a COLE of 0.03-0.06 and a PVC of 2-4. Following are examples of soil series that have moderate shrink-swell potential in the B horizon.

or control section:

Adolph	(CL)	Hagerstown	(CH)
Allison	(CL)	Hayden	(CL)
Etowah	(CL)	Holdrege	(CL)
Fayette	(CL)	Hosmer	(CL)
Frederick	(MH-CH)	Miami	(CL)
Gothard	(CL)	Muscatine	(CL)
Tama	(CL)		

High. Generally includes soils that are clay loam, silty clay loam, silty clay, sandy clay, and clay that are made up of a large percentage of montmorillinite or other high shrink-swell clay minerals. These soils have a COLE of 0.06-0.09 and a PVC of 4-6. Following are examples of soil series that have very high shrink-swell potential in the B horizon or control section:

Cowden	(CH)	Sacramento	(CH)
Hastings	(CH)	Taintor	(CH)
Mahaska	(CH)	Wilson	(CH)

Very high. Generally includes soils that are clay, silty clay, and sandy clay that are made up mainly of montmorillinite or other high shrink-swell minerals. These soils have a COLE of more than 0.09 and a PVC of more than 6. Following are examples of soil series that have very high shrink-swell potential in the B horizon or control section:

Archer	(CH)	Houston	(CH)
Crete	(CH)	Iredell	(CH)
Darwin	(CH)	Seymour	(CH)
Dayton	(CH)	Susquehanna	(CH)
Edina	(CH)	Willows	(CH)

Columns 19 and 20.--Corrosivity. Various metals and other materials corrode when on or in the soil, and some metals and materials corrode more rapidly when in contact with specific soils than when in contact with others. To be meaningful, corrosivity must be rated in relation to specific structural material. In these columns the soils of the survey area are given ratings on potential for inducing corrosion of uncoated steel (column 19)and of concrete (column 20). Guidance that can aid in determining and rating the soils on such potential is given in discussions of the two materials.

Column 19.--Uncoated steel. In estimating corrosivity potential in relation to uncoated steel, do not use the general term "metal" for "uncoated steel" and do not extend interpretations based on criteria for uncoated steel to other materials, such as cast iron, even though they also are made principally of iron.

The corrosion of uncoated steel, such as uncoated steel pipe, is a physical-biochemical process that converts iron into its ions. Before corrosion can take place, soil moisture is needed to form solutions of soluble salts. Any factors that influence the soil solution or the oxidation-reduction reactions taking place in the soil also influence the operation of the corrosion cell. Some of these factors are the amount of soil-moisture content, the conductivity of soil solution, the hydrogen ion activity of soil solution (pH), the oxygen concentration (aeration), and the activity of organisms capable of causing oxidation-reduction reactions.

The estimation of corrosivity for untreated steel pipe is commonly based on (1) resistance to flow of electrical current, (2) total acidity,[2/] (3) soil drainage, (4) soil texture, and (5) conductivity of saturation extract. Criteria are based on available research data, particularly on data in "Underground Corrosion," National Bureau of Standards Circular 579. The principal source for limits for resistivity and for total acidity is table 99 in that publication. The limits for conductivity of saturation extract are from the SCS Soil Survey Laboratory at Lincoln, Nebraska.

Soils generally are assigned to one of three classes of corrosivity: low, moderate, or high. Criteria are given for five classes, however, but the five can be used only if knowledge of a specific soil warrants their use for proper interpretation. In the classes commonly used, low and high are combined with very low and very high, respectively.

Very low. Generally includes somewhat excessively drained to excessively drained coarse-textured soils that have little clay in the control section. Water and air move through the soil rapidly and very rapidly. The total acidity is below 4.0 meq per 100 g of soil, or electrical resistivity of the soil at moisture equivalent[3/] is above 10,000 ohm-cm at 60° F, or electrical conductivity of the saturation extract (Method 9A1, SSIR No. 1) is less than 0.1 mmho per centimeter at 25° C[4/] (noncorrosive).

2/ Total acidity is roughly equal to extractable acidity (as determined by soil survey laboratories Method 6H1a in Soil Survey Investigations Report No. 1).

3/ Moisture equivalent approximates field capacity. Resistivity of fine and medium-textured soils measured at saturation (Method 8E1, SSIR No. 1) is similar to that measured at moisture equivalent. Resistivity at saturation for coarse-textured soils is generally lower than that obtained at moisture equivalent and may cause the soil to be placed in a higher corrosion class.

4/ The relationship between resistivity of a saturated soil paste and electrical conductivity of the saturation extract is influenced by variations in the saturation percentage, salinity, and conductivity of the soil minerals. These two measurements generally correspond closely enough to place a soil in one corrosion class.

Low. Generally includes well-drained soils that have a moderately coarse textured and medium-textured control section and somewhat poorly drained soils that have a coarse-textured control section. The soils are moderately permeable to rapidly permeable. The total acidity ranges from 4.0 to 8.0 meq per 100 g of soil, or electrical resistivity at moisture equivalent is 5,000 to 10,000 ohm-cm at 60° F, or electrical conductivity of the saturation extract is 0.1 to 0.2 mmho per centimeter at 25° C (slightly corrosive).

Moderate. Generally includes well-drained soils that have a moderately fine textured control section and moderately well drained soils that have a medium-textured control section. Also included are somewhat poorly drained soils that have a moderately coarse textured control section, and very poorly drained soils, including peats and mucks, in which the water table remains at the surface throughout the year. Permeability is moderately slow to slow. The total acidity ranges from 8.0 to 12.0 meq per 100 g of soil, or electrical resistivity at moisture equivalent is 2,000 to 5,000 ohm-cm at 60° F, or electrical conductivity of the saturation extract is 0.2 to 0.4 mmho per centimeter at 25° C (moderately corrosive).

High. Generally includes well-drained and moderately well drained fine-textured soils; moderately well drained, moderately fine textured soils; somewhat poorly drained soils that have medium-textured and moderately fine textured control sections; and poorly drained soils that have coarse-textured to moderately fine textured control sections. Very poorly drained soils are included where the water table fluctuates within one foot of the surface sometime during the year. The total acidity ranges from 12.0 to 16 meq per 100 g of soil, or electrical resistivity at moisture equivalent is 1,000 to 2,000 ohm-cm at 60° F, or electrical conductivity of the saturation extract is 0.4 to 1.0 mmho per centimeter at 25° C (severely corrosive).

Very high. Generally includes somewhat poorly drained to very poorly drained fine-textured soils. Mucks and peats that have a fluctuating water table are included. Total acidity is greater than 16 meq per 100 g of soil, or electrical resistivity at moisture equivalent is below 1,000 ohm-cm at 60° F, or electrical conductivity of the saturation extract is greater than 1.0 mmho per centimeter at 25° C. (very severely corrosive).

Because soil reaction (pH) correlates poorly with corrosion potential, pH is not included in the preceding features. Yet, there are some significant exceptions. A pH of 4 or less, almost without exception, indicates a high or very high soil corrosion potential. The most favorable pH for sulfate-reducing bacteria is 7; progressive departures in either direction indicate less and less favorable pH conditions. In wet or moist soils with anerobic conditions, especially in clays that contain some organic matter and sulfur, a pH of about 7 is corroborating evidence for a rating of high or very high--ratings that such soils also would receive on the basis of drainage and texture.

Ratings, based on a single soil property or quality, that place soils in relative corrosivity classes must be tempered by knowledge of other properties and qualities that affect corrosion. A study of soil properties in relation to local experiences with soil corrosivity helps soil scientists and engineers in making soil interpretations. Special attention should be given to those soil properties that affect the access of oxygen and moisture to the metal, the electrolyte, the chemical reaction in the electrolyte, and the flow of current through the electrolyte. A constant watch should be maintained for the presence of sulfides or of minerals such as pyrite that can be weathered readily, thus causing a high degree of corrosion in metals.

The probability of corrosion is greater for extensive installations that intersect soil boundaries or soil horizons than for installations that remain in one kind of soil or in one soil horizon. (This probability should be mentioned in the text.)

Using soil corrosivity interpretations without considering the size of the metallic structure or the differential effects of using different metals may lead to wrong conclusions. Construction, paving, fill and compaction, surface additions, etc., that alter the soil can increase probability of corrosion by creating an oxidation cell that accelerates corrosion. Mechanical agitation or excavation that results in aeration and in nonuniform mixing of soil horizons may also accelerate the probability of corrosion.

Column 20.--Concrete. Concrete materials placed in soil deteriorate to varying degrees. Special cements and methods of manufacturing may be used to reduce the rate of deterioration in soils of high corrosivity. The rate of deterioration is related to (1) the amount of sulfates and (2) soil texture and acidity. Three corrosivity classes are used by the Soil Conservation Service in making soil interpretations. These classes are:

Low. Generally includes (1) coarse-textured and moderately coarse textured soils, organic soils that have pH greater than 6.5 or medium- and fine-textured soils that have a pH greater than 6.0, and (2) soils that contain less than 1,000 parts per million of water-soluble sulfate (as SO_4).

Moderate. Generally includes (1) coarse-textured and moderately coarse textured soils and organic soils that have a pH of 5.5 to 6.5 and medium- and fine-textured soils that have a pH of 5.0 to 6.0, and (2) soils that contain 1,000 to 7,000 parts per million of water-soluble sulfate (as SO_4).

High. Generally includes (1) coarse-textured and moderately coarse textured soils and organic soils that have a pH of 5.5 or less, and medium- and fine-textured soils that have a pH of 5.0 or less, and (2) soils that contain more than 7,000 parts per million of water-soluble sulfate (as SO_4).

Sample table B.--Interpretations of engineering properties

The second standard engineering table gives, as in table B, engineering interpretations for the soils shown on the soil map. It lists limitation ratings for some uses and suitability ratings for other uses and notes specific soil features or characteristics that can affect selection, design, or application of treatment measures. These listings are based on the estimated engineering properties given in the first standard engineering table, as in table A; on engineering test data given in the third standard engineering table, as in table C; and on field experience.

The kind of information given in sample table B is intended as a guide. The information in this second engineering table should fit the needs and problems of the area surveyed. The principal detrimental or unfavorable features of the soils are listed along with ratings of moderate, severe, fair, or poor. All interpretations given in the table should be consistent with those given in related state guides on drainage, irrigation, and other such subjects.

If a column heading in table B is not applicable to a particular soil or to some few soils in a survey area, or if information on such soils is not adequate for drawing conclusions and absence of the rating is not covered in the headnote, place only a footnote reference in the relevant column space. The footnote should explain why no interpretation is given. Columns can be added or omitted, depending on the survey area.

The first major division of Table B, as in columns 2 through 7, shows degree of limitation for specific uses that include septic tank absorption fields, sewage lagoons, shallow excavations, dwellings without basements, sanitary landfill, and local roads and streets. In these columns express degree of limitation as slight, moderate, or severe, and in some instances very severe; and give restrictive features if degree of limitation is more than slight.

Slight soil limitation is the rating given soils that have properties favorable for the rated use. The degree of limitation is minor and can be overcome easily. Good performance and low maintenance can be expected.

Moderate soil limitation is the rating given soils that have properties moderately favorable for the rated use. This degree of limitation can be overcome or modified by special planning, design, or maintenance. During some part of the year the performance of the structure or other planned use is somewhat less desirable than for soils rated slight. Some soils rated moderate require treatment such as artificial drainage, runoff control to reduce erosion, extended sewage absorption fields, extra excavation, or some modification of certain features through manipulation of the soil. For these soils, modification is needed for those construction plans generally used for soils of slight limitation. Modification may include special foundations, extra reinforcement of structures, sump pumps, and the like.

Severe soil limitation is the rating given soils that have one or more properties unfavorable for the rated use, such as steep slopes, bedrock near the surface, flooding hazard, high shrink-swell potential, a seasonal high water table,or low bearing strength. This degree of limitation generally requires major soil reclamation, special design, or intensive maintenance. Some of these soils, however, can be improved by reducing or removing the soil feature that limits use, but in most situations it is difficult and costly to alter the soil or to design a structure so as to compensate for a severe degree of limitation.

A rating of very severe must be a subdivision of the severe rating, and the criteria used to separate moderate and severe must stand. A soil rated very severe has one or more features so unfavorable for the rated use that the limitation is very difficult and expensive to overcome. Reclamation would be extremely difficult, requiring the soil material to be removed, replaced, or completely modified. Very shallow soils over hard rock or deep, wet organic soil material, for example, have very severe limitations for houses with basements or for onsite sewage disposal. A rating of very severe should be confined to soils that require extreme alteration and that, for the most part, are not used for the purposes being rated.

In rating soils for nonfarm uses, it is important to remember that engineers and others can modify natural soil features or can design or adjust the plans for a structure to compensate for most degrees of limitation. Most of these practices, however, are costly. The owner must be willing to live with a few limitations, providing the use does not violate community codes or regulations. The final decision in selecting a site for a particular use is a personal one and generally involves weighing the costs for site preparation and maintenance.

Examples of how degree of limitation ratings should be entered in columns 2 through 7 are: pertaining to septic tank absorption fields, "Severe: moderate permeability 8 and 40 inches;" and pertaining to dwellings without basements, "Moderate if slope is less than 15 percent,severe if slope is more than 15 percent."

In the second major division of table B, as in columns 8 through 10 in the sample table, the soils are rated for suitability as a source of materials that include road fill, sand and gravel, and topsoil. (Note that suitability ratings also are commonly used where general statements are needed about suitability of the soils for plant growth; and where knowledge of suitability is needed pertaining to growth of individual kinds of plants or groups of plants having common growth habits and management requirements as with field crops, fruit crops, trees, shrubs, tame pasture, and native range plants.)

In the second standard engineering table, as in table B, express suitability as a source of the specified materials as good, fair, or poor, and in some instances very poor. An exception to this set of terms is permitted for rating soils for their suitability as sources of sand and gravel; here unsuited is used where appropriate. A statement of explanation can be added to a rating. Examples of how suitability ratings should be entered in columns 8 through 10 are: pertaining to source of road fill, "Good if slope is less than 15 percent, fair if slope is more than 15 percent"; pertaining to source of topsoil, "Poor: less than 8 inches of suitable material; stones"; and where the specified material is not available in the soil being rated, "Unsuitable: no sand."

A rating of very poor is a subdivision of the rating poor, but the criteria originally used to separate the ratings of fair and poor must stand. Obviously, where the suitability rating is given for a soil as source of a specified material, the rating of very poor reflects the scarcity and extremely poor quality of the specified material available in that soil.

In the last major division of table B, as in columns 11 through 15 in the sample table and unlike entries in the other two major divisions of that table, no ratings are given. In this division are listed the soil features that especially affect engineering measures pertinent to embankments, dikes, and levees; drainage of cropland and pasture; irrigation; and terraces and diversions. List particularly those features that planners and designers might overlook. For example, in column 14 the features affecting irrigation of mapping unit KtE of the Kent series are given as "Steep slopes; slow intake rate; slow permeability; high available water capacity." In these columns do not use ratings such as good, fair, poor, high, moderate, or low. Exceptions may be permitted if regional criteria exist. If ratings are given, shift the affected columns so as to place them under the proper heading for groups of columns.

Using sample table B as a guide, the second engineering table in a published soil survey should be presented column by column as follows:

Column 1.--Soil series and map symbols. Information given in this column should be identical to that in column 1 of sample table A.

Column 2.--Septic tank absorption fields. A septic tank absorption field is a soil absorption system for sewage disposal. It is a subsurface tile system laid in such a way that effluent from the septic tank is distributed with reasonable uniformity into the natural soil. Criteria used for rating soils (slight, moderate, and severe) for use as absorption fields are based on the limitations of the soil to absorb effluent. Use Guide Sheet 3 for guidance in determining limitation ratings for this use.

Guide Sheet 3.--Soil limitation ratings for septic tank absorption fields

Item affecting use	Degree of soil limitation		
	Slight	Moderate	Severe
Permeability class[1/]	Rapid[2/], moderately rapid, and upper end of moderate	Lower end of moderate	Moderately slow[3/] and slow
Hydraulic conductivity rate (Uhland core method)	More than 1 in.hr[2/]	1-0.6 in./hr	Less than 0.6 in./hr
Perculation rate (Auger hole method)	Faster than 45 min/in.[2/]	45-60 min/in.	Slower than 60 min/in.
Depth to water table	More than 72 in.	48-72 in.	Less than 48 in.
Flooding	None	Rare	Occasional or frequent
Slope	0-8 pct	8-15 pct	More than 15 pct
Depth to hard rock,[4/] bedrock, or other impervious materials	More than 72 in.	48-72 in.	Less than 48 in.
Stoniness class[5/]	0 and 1	2	3, 4, and 5
Rockiness class[5/]	0	1	2, 3, 4, and 5

1/ Class limits are the same as those suggested by the Work-Planning Conference of the National Cooperative Soil Survey. The limitation ratings should be related to the permeability of soil layers at and below depth of the tile line.

2/ Indicate by footnote where pollution is a hazard to water supplies.

3/ In arid or semiarid areas, soils with moderately slow permeability may have a limitation rating of moderate.

4/ Based on the assumption that tile is at a depth of 2 feet.

5/ For class definitions see Soil Survey Manual, pp. 216-223.

Some factors important in determining the limitation of a soil for use as an absorption field are: (1) local experience and records of performance for existing filter fields, (2) permeability of the subsoil and substratum, (3) depth to consolidated rock or other impervious layers, (4) flooding, (5) seasonal and annual ground-water level, and (6) slope. These factors are discussed in more detail in the following paragraphs.

Recorded observations of correctly designed and installed septic tank systems that failed within a few years after installation indicate severe soil limitation as cause of failure. Clues to watch for, besides those given in information from the homeowner, are rank plant growth, seepage, or odor in the vicinity of the absorption system.

Soils with moderate to very rapid permeability are rated as having slight limitation. Soils with a permeability at the slower end of the moderate range (about 1.0 to 0.60 inches per hour) are rated as having moderate limitation (unless measured results or experience show slight limitation). Soils with a permeability rate of less than 0.60 inches per hour are rated as having severe limitation if used as absorption fields for septic tanks.

Although soils with rapid permeability have slight soil limitation, it should be noted that a contamination hazard may exist if water supplies, streams, ponds, lakes, or water courses are nearby and receive seepage from the absorption field (see coarse-textured soils below).

Experience has shown that soils having percolation rates (1) faster than 45 minutes per inch function satisfactorily, (2) between 45 and 60 minutes per inch have moderate limitation, and (3) slower than 60 minutes per inch have severe limitation when used as absorption fields for septic tanks. The field determinations on which these ratings are based were obtained by the auger hole method.

Field percolation tests made by local health departments generally are conducted under a wide range of soil moisture conditions, and the results, therefore, should be interpreted with caution. Results are reliable only if the moisture is at or near field capacity when the test is run. In fact, nearly impermeable soils on which absorption fields have failed can give high percolation test results after periods of drought. In addition to soil properties that influence percolation rates, changes in the microorganisms in the soil may also help or hinder the functioning of the absorption field after it is in operation. Because the methods of measuring percolation and permeability are different, the correlation between the two values is imperfect. Use the information in Guide Sheet 3 cautiously.

A seasonal water table should be at least 4 feet below the bottom of the trench at all times for soils rated as having slight limitation (12). Soils with a water table less than 2 feet below the bottom of the trench for extended periods have a severe limitation. In humid areas, soil drainage classes provide clues to soil limitation.[5/] Well-drained and some moderately well drained soils that are readily permeable have slight limitation. Some somewhat poorly drained soils and most moderately well drained soils that are permeable have moderate limitation. Poorly drained and very poorly drained soils have severe limitation.

Impervious layers, including rock formations, should be 4 feet or more below the bottom of the tile trench floor.

Creviced or fractured rock without an adequate soil cover permits unfiltered sewage to travel long distances through old or new aquifers, as in deeply cracked limestone. At least 4 feet of moderately coarse or finer textured soil material should be between the bottom of the tile trenches and such rock.

Very coarse textured soil materials (coarse loamy sand, coarse sand, and gravel) are relatively poor filtering materials. These soil materials permit unfiltered sewage to travel long distances. Ratings are based on permeability alone. A footnote to the table should warn that contamination of nearby water supplies is a hazard if these soil materials are used for sewage disposal.

Soils that are subject to flooding have severe limitation even if the permeability is satisfactory and the ground-water level is below 4 feet. Floodwaters interfere with the functioning of the filter field and carry away unfiltered sewage. Without protection, areas subject to flooding should not be considered for onsite sewage disposal systems.

Soils with slopes of less than 8 percent are the best sites for sewage disposal systems from the standpoints of construction and successful operation of an absorption field. Mechanical problems of layout and construction, however, increase with steepness of slope. Lateral seepage or down-slope flow is a problem on sloping soils, especially where bands of impermeable material occur within the 4-foot depth. Large rocks, boulders, and rock outcrops increase construction costs. The tile grade is difficult to maintain if the obstacle cannot be removed. Trench lines can be installed and grade maintained around these obstacles on nearly level soils.

Detergents in solution are readily transmitted through some soils and may contaminate ground water supplies. Sodium salts from water softeners and other sources tend to disperse the clay in the soil and to reduce the effectiveness of the absorption field.

5/ Where relief permits, the effective depth above a water table can be increased by appropriate fill.

Column 3.--Sewage lagoons. A sewage lagoon (aerobic) is a shallow lake used to hold sewage for the time required for bacterial decomposition. Sewage lagoons require consideration of the soils for two functions, (1) as a vessel for the impounded area and (2) as soil material for the enclosing embankment. The requirements for this embankment are the same as for other embankments designed to impound water (see table B, col. 12--Embankments, dikes, and levees). Enough soil material that is suitable for the structure must be available, and, when the lagoon is properly constructed, it must be capable of holding water with minimum seepage. The material should be free of coarse fragments (over 10 inches in diameter) that interfere with compaction.

Soils placed in the Unified soil classification groups GC, SC, and SM are satisfactory for the lagoon bottom. The coarse groups with few fines (GW, GP, SW, and SP) have severe limitation and are poorly suited. The groups consisting of soils high in organic matter (OL, OH, and Pt) also have severe limitation and also are poorly suited. Soil material of the other Unified classification groups (GM, CL, CH, ML, and MH) are suitable if properly compacted or if used in combination with soils classified as GC, SC, and SM.

Soil requirements for basin floors of lagoons are (1) slow rate of seepage, (2) even surface of low gradient and low relief, and (3) little or no organic matter. Official specifications for lagoons state that the depth of liquid should be not less than 2 feet and generally not more than 5 feet, that the floor should be level or nearly so, and that the materials for the basin floor should be so nearly impervious as to preclude excessive loss of liquid (13). The relatively impervious soil material should be at least 4 feet thick. This is especially important where the local water supply comes from shallow wells that may become contaminated.

In using Guide Sheet 4, the features noted in the next paragraph are of importance in evaluating the "degree of limitation" of soils considered for sites of lagoon impoundment.

In the Unified classification system soils are grouped into three classes according to their degree of limitation to use as sites of sewage lagoons. The slight limitation class includes soils that are effective in functioning as sealed basin floors and that are low in organic matter. Soils in the moderate limitation class are those that require special practices or treatment to modify limitations to their use as sites for sewage lagoons. Soils placed in the severe limitation class are those that are very porous, or that are high in organic matter, or that have other limitations that prevent their use as sites for sewage lagoons.

Guide Sheet 4.--Soil limitation ratings for sewage lagoons

Item affecting use	Degree of soil limitation		
	Slight	Moderate	Severe
Depth to water table (seasonal or year-round)	More than 60 in.	40-60 in. 1/	Less than 1/ 40 in.
Permeability	Less than 0.6 in./hr	0.6-2.0 in./hr	More than 2.0 in./hr
Depth to bedrock	More than 60 in.	40-60 in.	Less than 40 in.
Slope	Less than 2 pct	2-7 pct	More than 7 pct
Coarse fragments, less than 10 inches in diameter: percent, by volume	Less than 20 pct	20-50 pct	More than 50 pct
Percent of surface area covered by coarse fragments more than 10 inches in diameter	Less than 3 pct	3-15 pct	More than 15 pct
Organic matter	Less than 2 pct	2-15 pct	More than 15 pct
Flooding 2/	None	None	Soils subject to flooding
Soil groups (Unified) 3/ (rated for use mainly as floor of sewage	GC, SC, CL, and CH	GM, ML, SM, and MH	GP, GW, SW, SP, OL, OH, and PT

1/ If the floor of the lagoon is nearly impermeable material at least 2 feet thick, disregard depth to watertable.

2/ Disregard flooding if it is not likely to enter or damage the lagoon. (low velocity and the depth less than about 5 feet.)

3/ For interpretations for material for embankments see "Embankments, dikes, and levees."

Limitation classes for slope and relief are determined by the specification that the liquid body of a sewage lagoon (aerobic) be not less than 2 feet or generally not more than 5 feet deep. Slope must be low enough and soil material thick enough over bedrock to make smoothing for uniformity of lagoon depth practical. Greater slope is allowable if soil material is more than 6 feet deep, but generally smoothing is impractical where slope is more than 7 percent. If the soil is nearly level and hence requires little or no smoothing, it need not be more than 4 to 6 feet deep.

If floodwaters overtop embankments they interfere with functioning of the lagoons and carry away polluting sewage before sufficient decomposition has taken place. Ordinarily, therefore, soils susceptible to flooding have a severe limitation for sewage lagoons. If, however, floodwaters are slow flowing and rarely, if ever, more than about 5 feet deep--not deep enough to overtop lagoon embankments--the limitation rating is not severe because of susceptibility to flooding.

Depth to water table is disregarded if the lagoon floor consists of soil material at least two feet thick that is impermeable or nearly so; but, if the material is permeable, even if no more than slowly permeable, depth to water table is critical. A water table that is below a depth of 60 inches at all times permits a rating of slight. If seasonally between depths of 40 and 60 inches, it imposes a rating of moderate; and, if at a depth of less than 40 inches for extended periods, it imposes a rating of severe. These ratings are based on the requirements that

(1) The liquid body of a sewage lagoon must be not less than 2 feet or generally not more than 5 feet deep.

(2) The only water in the lagoon, other than from precipitation, must be that of the sewage; and therefore the water table must never rise high enough to contribute water to the lagoon.

(3) There must be at least 4 feet of slowly permeable material between the bottom of the lagoon and the seasonal water table or the cracked and creviced bedrock.

Soils containing moderate to high amounts of organic matter are unsuitable for the basin floor even if the floor is underlain by suitable soil material. The organic matter promotes growth of aquatic plants, and they are detrimental to proper functioning of the lagoon.

Soils that contain fragments of more than 10 inches in diameter are undesirable as sites for sewage lagoons because such fragments interfere with the manipulation and compaction needed to prepare the basin floor.

Column 4.--Shallow excavations. These excavations require excavating or trenching to a depth of 5 or 6 feet. Note that limitation ratings for shallow excavations alone, though highly relevant, are insufficient for interpretations for ultimate uses, such as for dwellings with basements, sanitary landfills, cemeteries, and underground utility lines--sewers, pipelines, and cables. Additional soil features must be considered in evaluating soils for those uses. For example, additional interpretations concerning shrink-swell potential and corrosivity are needed for giving ratings for the ultimate use of soils for pipelines. Backfilling is required in most uses but not for basements or open ditches.

In soils used for shallow excavations, desirable characteristics are good workability, moderate resistance to sloughing, gentle slopes, absence of rock outcrops and big stones, and no flooding hazard. Use Guide Sheet 5 for guidance in determining limitation ratings for these uses.

Column 5.--Dwellings (with/) without basements. In sample table B, column 5, the soils are given limitation ratings for use for dwellings without basements. If, however, the survey area is one in which dwellings are commonly built with basements, head this column "Dwellings with basements." (Guide Sheet 6 is pertinent to both kinds of interpretations.)

In this column give ratings for undisturbed soils on which single-family dwellings or other structures with similar foundation requirements can be built. Buildings of more than three stories and other buildings requiring a foundation load in excess of that of a three-story dwelling are not considered in the entries in this column.

The emphasis in rating soils for dwellings is on the properties that affect foundations, but also considered beyond the effects related exclusively to foundations are slope, susceptibility to flooding, seasonal wetness, and other hydrologic conditions. The properties influencing foundation support are those affecting bearing capacity and settlement under load and those affecting cost of excavation and construction. Properties affecting bearing strength and settlement of the natural soil are density, wetness, flooding, plasticity, texture, and shrink-swell potential. Properties influencing the amount and ease of excavation are wetness, slope, depth to bedrock, stoniness and rockiness. Also considered are soil properties, particularly depth to bedrock, that influence installation of utility lines, such as the lines between dwellings and trunklines. It is important to note that onsite investigations are needed for interpretations relevant to detailed design of foundations and to specific placement of buildings and utility lines.

It also is important to note that interpretations for soil-induced corrosivity of steel and concrete are not included in these ratings. Those interpretations are given separately in the first standard engineering table, as in sample table A. Also, interpretations for use of soils as septic tank absorption fields are not included in the ratings in this column; those interpretations are given in a separate column in this second table, as in sample table B.

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Guide Sheet 5.--Soil limitation ratings for shallow excavations

Item affecting use	Degree of soil limitation		
	Slight	Moderate	Severe
Soil drainage class	Excessively drained, somewhat excessively drained, and well drained	Moderately well drained	Somewhat poorly drained, poorly drained. and very poorly drained
Seasonal water table	Below a depth of 60 in.	Between depths of 30 and 60 in.	Above a depth of 30 in.
Flooding	None	Rare	Occasionally or frequent
Slope	0-8 pct	8-15 pct	More than 15 pct
Texture of soil to depth to be excavated1/, 2/	fsl, sl, l, sil, sicl, scl	si3/, cl, sc; all gravelly types	c4/, sic4/, s, ls; organic soils; all very gravelly types
Depth to bedrock5/	More than 60 in.	40-60 in.	Less than 40 in.
Stoniness class6/	0 and 1	2	3, 4, and 5
Rockiness class	0	1	2, 3, 4, and 5

1/ Texture is used here as an index to workability and sidewall stability.

2/ If soil contains a thick fragipan, duripan, or other material difficult (but not impossible) to excavate with handtools, increase the limitation rating by one step unless it is severe.

3/ If soil stands in vertical cuts like loess, reduce rating to slight.

4/ If the soil is friable, as are some kaolinitic Paleudults, reduce rating to moderate.

5/ If bedrock is soft enough so that it can be dug out with ordinary handtools or light equipment, such as back hoes, reduce ratings of moderate and severe by one step.

6/ For class definitions see Soil Survey Manual, pp. 216-223.

Guide Sheet 6.--Soil limitation ratings for dwellings[1/]

Item affecting use	Degree of soil limitation[2/]		
	Slight	Moderate	Severe
Soil drainage class[3/]	With basements: Excessively drained, somewhat excessively drained, well drained Without basements: Excessively drained, somewhat excessively drained, well drained, moderately well drained	With basements: Moderately well drained Without basements: Somewhat poorly drained	With basements: Somewhat poorly drained, poorly drained, very poorly drained Without basements: Poorly drained, very poorly drained
Seasonal water table (Seasonal means for 1 month or more)	With basements: Below a depth of 60 in. Without basements: Below a depth of 30 in.	With basements: Below a depth of 30 in. Without basements: Below a depth of 20 in.	With basements: Above a depth of 30 in. Without basements: Above a depth of 20 in.
Flooding	None	None	Rare, occasional or frequent
Slope[4/]	0-8 pct	8-15 pct	More than 15 pct
Shrink-swell potential	Low	Moderate	High
Unified soil group	GW, GP, SW, SP, GM, GC, SM, SC, CL with PI[6/] less than 15	ML, CL with PI[6/] 15 or more	CH, MH[5/], OL, OH,
Potential frost action[7/]	Low	Moderate	High
Stoniness class[8/]	0 and 1	2	3, 4, and 5
Rockiness class[9/]	0	1	2, 3, 4, and 5
Depth to bedrock[9/]	With basements: More than 60 in. Without basements: More than 40 in.	With basements: 40-60 in. Without basements: 20-40 in.	With basements: Less than 40 in. Without basements: Less than 20 in.

1/ If slope limits are reduced 50 percent, this table can be used for evaluating soil limitation for shopping centers and for small industrial buildings with foundation requirements not exceeding those of ordinary three-story dwellings.

2/ Some soils given limitation ratings of moderate or severe may be good sites from the standpoint of esthetics but require more preparation or maintenance.

3/ For class definitions see Soil Survey Manual, pp. 169-172.

4/ Reduce slope limits 50 percent for those soils susceptible to hillside slippage.

5/ Upgrade to moderate if MH is largely kaolinitic, friable, and free of mica.

6/ PI means plasticity index.

7/ Use this item only where frost penetrates to assumed depth of footings and where soil is moist during freezing weather. See section "Potential Frost Action" for guidance in determining classes.

8/ For class definitions see Soil Survey Manual, pp. 216-223.

9/ If bedrock is soft enough so that it can be dug out with light power equipment, such as backhoes, reduce ratings of moderate and severe by one step.

Column 6.--Sanitary landfill. In sample table B, column 6, the soils are given limitation ratings for use for sanitary landfill. The column is intended only as an illustration since there is more than one type of sanitary landfill. A landfill can be trench-type or area-type. If both types prevail in the survey area, then use two columns: one headed "Sanitary landfill, trench-type" and the other headed "Sanitary landfill, area-type." If two columns are used, a third, headed "Cover material for area-type landfill," also may be needed because cover material for the area-type generally must be obtained from a source away from the site. Whether the second standard engineering table in the survey to be published has one, two, or three columns for this subject depends on landfill practices in the survey area. Use Guide Sheet 7 in making interpretations of soil properties for trench-type (for which material from the trench itself is used as cover). Use Guide Sheet 8 for guidance in making interpretations for area-type landfills and Guide Sheet 9 in making interpretations for the cover material.

For determining the limitations of soils for sanitary landfills, the data given in a published soil survey cannot be a substitute for geologic investigations because soil survey interpretations are based on borings commonly limited to a depth of 5 or 6 feet whereas many sanitary landfills are made to depths of 10 to 15 feet. Yet, those interpretations are useful. They, for example, can guide geologic investigations to promising areas and thereby save the cost of such investigations in areas already determined to have serious soil restrictions. In some areas, soil properties can be predicted with reasonable confidence to depths below 5 or 6 feet on the basis of information gathered in the course of soil survey. Predictions relative to probable depth to a seasonal high water table or to bedrock can be useful in planning for detailed investigation of those potential sites that warrant further consideration. The design engineer must determine actual soil conditions to the depth proposed in order to obtain sufficient data for design purposes.

In the following paragraphs soil limitations for both types of landfill and for cover material are discussed.

The trench-type sanitary landfill is a dug trench in which refuse is buried daily, or more frequently if necessary, the refuse is covered with a layer of soil material at least 6 inches thick. That material is the soil excavated in digging the trench. When the trench is full, a final cover of soil material at least 2 feet thick is placed over the landfill.

Because trenches as deep as 15 feet or more are used for many landfills, geologic investigation is needed to determine the potential for pollution of ground water as well as to ascertain the design needed. These investigations, generally arranged for by the landfill user, include examination of stratification, rock formations, and the like that might lead to the conducting of leachates to aquifers, wells, water courses, and other water sources. The presence of hard nonrippable bedrock, or creviced bedrock, or sandy or gravelly strata in or immediately underlying the proposed trench bottom is undesirable from the standpoints of excavation and potential pollution of underground water.

Guide Sheet 7.--Soil limitation ratings for trench-type sanitary landfills[1/]

Item affecting use		Degree of soil limitation		
		Slight[2/]	Moderate[2/]	Severe
Depth to seasonal high water table		Not class determining if more than 72 in.		Less than 72 in.
Soil drainage class		Excessively drained, somewhat excessively drained, well drained, and some[3/] moderately well drained	Somewhat poorly drained and some[3/] moderately well drained	Poorly drained and very poorly drained
Flooding		None	Rare	Occasional or frequent
Permeability[4/]		Less than 2.0 in./hr	Less than 2.0 in./hr	More than 2.0 in./hr
Slope		0-15 pct	15-25 pct	More than 25 pct
Soil texture[5/] (dominant to a depth of 60 in.)		Sandy loam, loam, silt loam, sandy clay loam	Silty clay loam[6/] clay loam, sandy clay, loamy sand	Silty clay, clay, muck, peat, gravel, sand
Depth to bedrock	Hard	More than 72 in.	More than 72 in.	Less than 72 in.
	Rippable	More than 60 in.	Less than 60 in.	Less than 60 in.
Stoniness class[7/]		0 and 1	2	3, 4, and 5
Rockiness class[7/]		0	0	1, 2, 3, 4, and 5

1/ Based on soil depth (5-6 feet) commonly investigated in making soil surveys.

2/ If probability is high that the soil material to a depth of 10-15 feet will not alter a rating of slight or moderate, indicate this by an appropriate footnote, such as "Probably slight to a depth of 12 feet," or "Probably moderate to a depth of 12 feet."

3/ Soil drainage classes do not correlate exactly with depth to seasonal water table. The overlap of moderately well drained soils into two limitation classes allows some of the wetter moderately well drained soils (mostly in the Northeast) to be given a limitation rating of moderate.

4/ Reflects ability of soil to retard movement of leachate from the landfills; may not reflect a limitation in arid and semiarid areas.

5/ Reflects ease of digging and moving (workability) and trafficability in the immediate area of the trench where there may not be surfaced roads.

6/ Soils high in expansive clays may need to be given a limitation rating of severe.

7/ For class definitions see Soil Survey Manual, pp. 216-223.

Guide Sheet 8.--Soil limitation ratings for area-type sanitary landfills

Item affecting use	Degree of soil limitation		
	Slight	Moderate	Severe
Depth to seasonal[1/] water table	More than 60 in.	40-60 in.	Less than 60 in.
Soil drainage[1/] class	Excessively drained, somewhat excessively drained, well drained, and moderately well drained	Somewhat poorly drained	Poorly drained and very poorly drained
Flooding	None	Rare	Occasional or frequent
Permeability[2/]	Not class determining if less than 2 in./hr		More than 2 in./hr
Slope	0-8 pct	8-15 pct	More than 15 pct

1/ Reflects influence of wetness on operation of equipment.

2/ Reflects ability of the soil to retard movement of leachate from landfills; may not reflect a limitation in arid and semiarid areas.

Guide Sheet 9.--Suitability ratings of soils as sources of cover material for area-type sanitary landfills

Item affecting use	Degree of soil suitability		
	Good	Fair	Poor
Moist consistence	Very friable, friable	Loose, firm	Very firm, extremely firm
Texture[1/]	Sandy loam, loam, silt loam, sandy clay loam	Silty clay loam, clay loam, sandy clay, loamy sand	Silty clay, clay, muck peat, sand
Thickness of material (Usually uppermost part of profile)	More than 40 in.	20-40 in.	Less than 20 in.
Coarse fragment: percent, by volume	Less than 15 pct	15-35 pct	More than 35 pct
Stoniness class[2/]	0 and 1	2	3, 4, and 5
Slope	Less than 8 pct	8-15 pct	More than 15 pct
Drainage class (wetness)	Not class determining if better than poorly drained		Poorly drained and very poorly drained

1/ Soils having a high proportion of non-expansive clays may be given a suitability rating one class better than is shown for them in this table.

2/ For class definitions see Soil Survey Manual pp. 216-223.

The size and character of landfills are such that it is not practical to remove refuse if a pollution problem should arise. Consequently, thorough evaluation of site hydrology is essential beforehand.

In the area-type sanitary landfill, refuse is placed on the surface of the soil in successive layers. The daily and final cover material generally must be imported. A final cover of soil material at least 2 feet thick is placed over the fill when it is completed.

The soil under the proposed site should be investigated so as to determine the probability that leachates from the landfill can penetrate the soil and thereby pollute water supplies.

Since cover material for the area-type landfill generally must be obtained from a source away from the site, soils from another area may need to be given limitation ratings for use as cover. Required soil characteristics relative to both daily and final cover material are nearly enough alike for one rating to serve.

Suitability of a soil for use as cover is based on properties that reflect workability; ease of digging, moving, and spreading over the refuse daily during both wet and dry periods; slope; wetness; and thickness of the soil material. Also, not only must a soil rated as having slight limitation as a source of cover have favorable properties but the area from which it is borrowed must be reclaimable. Some damage to the borrow area is expected, but if revegetation and erosion control could become serious problems in that area, then the soil should be rated as having a severe limitation for use as cover material for the fills.

Information is given in the following paragraphs about the significance of several criteria used to determine limitation ratings for sanitary landfills.

Soil drainage classes and depths to seasonal water table are of primary consideration in interpreting these ratings. The degree of soil wetness and its duration can so affect earth-moving operations as to make a soil severely limiting for the trench-type landfill or for use as cover material for the area-type landfill. Moreover, the probable contamination of ground water by a landfill is closely related to depth to the seasonal water table.

Permability of soils is an important consideration in interpreting the limitation ratings for these uses. Soils with slow permeability are most desirable because the probability of polluting ground water by vertical or lateral seepage is minimized. Permeable horizons near the bottom of a trench-type landfill can be sealed by compacting, along the sides and bottom of the trench, a blanket of relatively impervious material at least 2 feet thick.

Soil slope also is an important consideration in interpreting these limitation ratings. More grading generally is required for the roads that lead to and from landfills located on sloping to steep soils than is required for roads leading to and from landfills on nearly level soils.

Also, more care is needed on sloping to steep soils to provide for the proper disposal of surface water including that from adjacent higher elevations. In a trench-type landfill, the bottom should be kept as nearly level as possible because the bottom tends to serve as a seepage plane; the solid waste layer offers little hindrance to the movement of water. Thus, sloping trench bottoms are likely to bring about difficult seepage problems in completed fills. Trenches should be placed on the contour with bottoms level or nearly so.

Soil texture also is considered in interpreting the limitation ratings of soils for use for landfills and cover material, and especially for trench-type landfill. The ease with which the trench is dug and with which a soil can be used as daily and final cover is based largely on texture and consistence of the soil. From knowledge of texture and consistence of a soil, it is possible to ascertain degree of workability of the soil in both dry and wet conditions. Soils that are plastic and sticky when wet are difficult to excavate, or grade, or compact. To place a uniformly thick cover of wet clayey soil material over a layer of refuse is extremely difficult.

The uppermost part of the final cover should be soil material that is favorable for the growth of plants. In comparison with other horizons, the A horizon in most soils has the best workability and highest content of organic matter. Thus, in the trench-type landfill operation it is desirable to stockpile the surface layer for use in final blanketing of the fill.

<u>Column 7.--Local roads and streets</u>. The limitation ratings given in this column apply to use of soils for construction and maintenance of improved local roads and streets that have all-weather surfacing--commonly of asphalt or concrete--and that are expected to carry automobile traffic all year. The roads and streets consist of (1) underlying local soil material, whether cut or fill, that is called "the subgrade"; (2) the base material of gravel, crushed rock, lime-stabilized soil, or soil-cement-stabilized soil; and (3) the actual road surface or street pavement that is either flexible (asphalt), rigid (concrete), or, in some rural areas, gravel with binder in it. These roads and streets also are graded to shed water; and conventional drainage measures are provided. With probable exception of the hard surfaces, the roads and streets are built mainly from the soil at hand; cuts and fills generally are limited to less than 6 feet of thickness. Excluded from consideration in the ratings in this column are highways designed for fast-moving heavy trucks. Also, the ratings cannot substitute for basic soil data and for onsite investigation. Use Guide Sheet 10 for general guidance in determining limitation ratings for use of soils for local roads and streets.

<u>Column 8.--Road fill</u>. The ratings in this column pertain to suitability of soils as a source of road fill. The ratings, <u>good</u>, <u>fair</u>, and <u>poor</u>, reflect how well a soil performs after it is removed from its original location and is placed in a road embankment elsewhere. They also reflect evaluation of soil characteristics, such as slope, that determine the ease or difficulty in getting the soil out.

Guide Sheet 10.--Soil limitation ratings for local roads and streets

	Degree of soil limitation		
	Slight	Moderate	Severe
Soil drainage class 1/	Excessively drained, somewhat excessively drained, well drained, and moderately well drained	Somewhat poorly drained	Poorly drained and very poorly drained
Flooding	None	Soils flooded less than once in 5 years	Soils flooded more than once in 5 years
Slope	0-8 pct	8-15 pct	More than 15 pct
Depth to bedrock 2/	More than 40 in.	20-40 in.	Less than 20 in.
Subgrade 3/ a. AASHO group index 4/	0-4	5-8	More than 8
b. Unified soil group	GW, GP, SW, SP, GM, GC 5/, SM 5/, SC 5/	CL with PI 6/ less than 15,	CL with PI 6/ 15 or more, CH, MH 7/, OH, OL, Pt
Shrink-swell potential	Low	Moderate	High
Susceptibility to frost action 8/	Low	Moderate	High
Stoniness class 9/	0, 1, and 2	3	4 and 5
Rockiness class 9/	0	1	2, 3, 4, and 5

1/ For class definitions see Soil Survey Manual, pp. 169-172.

2/ If bedrock is soft enough so that it can be dug with light power equipment and is rippable by machinery, reduce limitation ratings of moderate and severe by one step.

3/ Use AASHO Group Index values if available from laboratory tests; otherwise, use the estimated Unified soil groups.

4/ Use Group Index values according to AASHO Designation M 145-49 and M 145-66I; for most soils with group index values below about 8, both designations (methods) give results nearly enough alike to be considered alike for the purpose of this guide.

5/ Downgrade limitation rating to moderate if content of fines is more than about 30 percent.

6/ PI means plasticity index.

7/ Upgrade limitation rating to moderate if MH is largely kaolinitic, friable, and free of mica.

8/ Use this item only where frost penetrates below the paved or hardened surface layer and where moisture transportable by capillary movement is sufficient to form ice lenses at the freezing front. See section "Potential Frost Action" for guidance in determining classes.

9/ For class definitions see Soil Survey Manual, pp. 216-223.

Since road fill is soil material used for making embankments for roads and because low embankments or the upper part of high embankments serve as the subgrade (foundation) for the road, soil material good for road fill must also be good for subgrade.

Effort is made in designing and constructing roads to have the volume of fill material equal, within short distances, to the volume of material taken from cuts. Much of the road fill, therefore, comes from nearby cuts if the material is suitable. Where cuts do not yield enough material for local embankments, the fill material is obtained from borrow pits.

Since soil survey interpretations are oriented to local roads and streets rather than to superhighways, such as those of the interstate system, the assumption is that the suitability ratings in this column are evaluations of the soils as sources of road fill for low embankments, generally less than 6 feet high and less exacting in design than high embankments.

Generally, the rating is given for the whole soil, from the surface to a depth of 5 or 6 feet, based on the assumption that soil horizons will be mixed in loading, dumping, and spreading. If the surface layer from a few inches to as much as about a foot in thickness is poorly suited as road fill, disregard the surface layer in establishing the rating. If the thickness of suitable material is less than about 3 feet because of shallow depth to bedrock or to other unsuited or poorly suited material, the whole soil is given a rating of poor, regardless of the quality of the material less than 3 feet thick.

Use Guide Sheet 11 for general guidance in determining suitability ratings for the soils as a source of road fill.

Column 9.--Sand (and gravel). In sample table B the soils are rated for suitability as a source of sand. In the second standard engineering table, whether two columns--one headed "Sand" and the other headed "Gravel"--are used or whether only one column--"Sand and gravel" is used for either item or for both depends on the nature of the materials in the survey area. Use Guide Sheet 12 for general guidance in determining suitability ratings of soils as a source of sand and/or gravel.

The main purpose of the ratings is to guide readers to local sources. These materials, used in great quantity in many kinds of construction work, are heavy and bulky and are expensive to transport. Therefore, information beforehand about where to look for nearest sources can result in substantial savings.

The ratings are based on the probability that soils generally contain sizable quantities of sand or gravel. Soft materials, such as shale or siltstone, are not considered sand and gravel for these interpretations. To qualify as a good or fair probable source, the layer of sand or gravel must be at least 3 feet thick. The entire thickness need not be in the uppermost 5 or 6 feet--the depth of the soils that are classified and mapped in published surveys. The thickness requirement for the source is

Guide Sheet 11.--Suitability ratings of soils as sources of road fill

Item affecting use1/		Degree of soil suitability		
		Good	Fair	Poor
Engineering soil class	Unified soil groups	GW, GP, SW, SP, GC2/ SM2/, SC2/	ML, CL with PI3/ less than 15 percent	CL with PI3/ more than 15 percent CH, MH4/ OL, OH, Pt
	AASHO group index5/	0-4	5-8	More than 8
Shrink-swell potential		Low	Moderate	High
Susceptibility to frost action6/		Low	Moderate	High
Slope		0-15 pct	15-25 pct	More than 25 pct
Stoniness class7/		0, 1, and 2	3	4 and 5
Rockiness class7/		0 and 1	2	3, 4, and 5
Soil drainage class8/		Excessively drained to moderately well-drained	Somewhat poorly drained	Poorly drained and very poorly drained

1/ The first three items pertain to soil after it is placed in a fill; the last four items pertain to soil in its natural condition before excavation for road fill.

2/ Downgrade suitability rating to fair if content of fines is more than about 30 percent.

3/ PI means plasticity index.

4/ Upgrade suitability rating to fair if MH is largely kaolinitic, friable, and free of mica.

5/ Use AASHO group index only where laboratory data are available for the kind of soil being rated; otherwise, use Unified soil groups.

6/ Use this item only where frost penetrates below the paved or hardened surface layer and where moisture transportable by capillary movement is sufficient to form ice lenses at the freezing front. See section "Potential Frost Action" for guidance in determining classes.

7/ For class definitions see Soil Survey Manual, pp. 216-223.

8/ For class definitions see Soil Survey Manual, pp. 169-172.

satisfied if the lowest 6 inches, approximately, of the surveyed soil is sand or gravel and if, from observations made in deep cuts and from other evidence including geological data, the sand or gravel reached at the bottom of the surveyed soil is known to extend downward several feet.

Some soils have little or no sand or gravel in the uppermost 5 or 6 feet. Yet, from observations made in deep cuts and from knowledge of local geology, that some soils are underlain by sand and gravel is an established fact. If so, rate the soil unsuited and use a footnote to call attention to the sand or gravel under the soil.

Column 10.--Topsoil. The suitability ratings in this column are intended for use by engineers, landscapers, nurserymen, planners, and others who make decisions about selecting, stockpiling, and using topsoil. The decision to stockpile surface soil at a construction site should depend on the quality of the topsoil and on the relative availability of other suitable topsoil in the immediate vicinity. The ratings in this column used in conjunction with the soil maps can indicate to engineers and others the advisability of selecting, stockpiling, and using a specific soil as topsoil.

The term "topsoil" has several meanings, but in soil survey interpretation the term describes soil material used to cover barren surfaces--generally made barren by construction--so as to improve soil conditions for re-establishment and maintenance of adapted vegetation and also soil material used to improve soil conditions on lawns and in flowerbeds and gardens where vegetation already may exist.

A soil given the rating of good as a source of topsoil has physical, chemical, and biological characteristics favorable to establishment and growth of adapted plants; it is friable and easy to handle and spread. Although a high content of plant nutrients in good balance is desirable in topsoil, of more importance is responsiveness to fertilization and to liming, too, if pH adjustment is needed.

A soil that qualifies as a good source of topsoil not only must have upper layers that have the favorable characteristics required for a rating of good or fair but is one in which the characteristics also are such that the remaining soil material is reclaimable after the uppermost soil is stripped away. Some damage to the borrow area is expected, but if the damage is great enough for revegetation and erosion control to become major problems, then the soil should be given a rating of poor as a source of topsoil--regardless of the characteristics of the surface materials. This constraint in evaluation does not apply to construction sites where soils are drastically disturbed in the construction processes; the ratings of soils in such places as a source of topsoil may be different. Unless otherwise specified, however, it is assumed that sites from which topsoil is taken are to be restored.

Also considered in rating soils as a source of topsoil are features that determine the ease or difficulty of excavating, particularly soil slope, wetness, and thickness of the suitable material.

Guide Sheet 12.--Suitability ratings of soils as sources of sand and gravel

Soil groups in Unified system	Probable source		Improbable source	
	Good	Fair	Poor	Unsuited
	SW SP GW GP	SW-SM SP-SM GP-GM GW-GM	SM SW-SC SP-SC GM GP-GC GW-GC	All other groups

Generally, only the surface layer is given a rating for this use; but if that layer is less than about 8 inches thick, assume that it will be mixed with the adjacent layer to make up a thickness of at least 8 inches, then give a rating to the mixture. If the subsoil is better suited than the surface layer, give a second rating and indicate that it is for the subsoil between depths of 8 and 30 inches or whatever depth limits apply.

Use Guide Sheet 13 for general guidance in determining the suitability ratings of soils as a source of topsoil. Some soil characteristics that affect suitability for this use, however, are not included in Guide Sheet 13. The following paragraph discusses some of those characteristics.

If a soil contains toxic substances, it should be given a rating of poor, as should a soil that contains sulfides--which in themselves might not be toxic but which induce a very low pH upon aeration. If a soil has rock outcrops that are so spaced and arranged as to make excavation difficult or impractical, this soil also should be given a rating of poor even though the soil between the outcrops is satisfactory as a source of topsoil. Soils for which true texture cannot be determined with confidence, such as Andepts, should be given ratings through comparison of their relative suitability with that of soils for which ratings have been determined by using Guide Sheet 13.

Columns 11, 12, 13, 14, and 15. In these columns list the principal soil features that are unfavorable for the construction, operation, or maintenance of the structure or practice indicated by the column heading. Such unfavorable features serve as "red flags" when soil is considered for the uses noted in these columns. Desirable features also may be listed so as to enable a better choice of soil for any of these uses.

Where no specific characteristic or comment about a characteristic is applicable, place a footnote reference in the relevant space in the column. The two footnotes to the table that mainly pertain to these columns should read "All features favorable." and "Practice not applicable on this soil."

Column 11.--Pond reservoir areas. Factors considered in selecting soils for this use are those features and qualities that affect the suitability of undisturbed soils for water impoundment. Of primary concern are soil properties that affect seepage rate.

Features and qualities affecting this use are
1. Permeability.
2. Depth to water table.
3. Depth to bedrock or to other unfavorable materials that allow seepage.
4. Soil slope (influences storage potential).

Column 12.--Embankments, dikes, and levees. Cited in this column are properties and major behavior qualities that affect, especially adversely, the performance of soils if used in constructing earthfills intended for holding back water. The evaluations noted in the column must reflect the behavior of the soils if used for these embankments. Where a soil has significant thickness for use as borrow material, both subsoil and substratum are evaluated. The evaluations

Guide Sheet 13.--Suitability ratings of soils as sources of topsoil

Item affecting use	Degree of soil suitability		
	Good	Fair	Poor
Moist consistence	Very friable, friable	Loose, firm	Very firm, extremely firm
Texture	fsl, vfsl, l, sil; sl; sc if 1:1 clay is dominant	cl, scl; sicl; sc if 2:1 clay is dominant; c and sic if 1:1 clay is dominant	s, ls; c and sic if 2:1 clay is dominant
Thickness of material (generally uppermost part of profile)	More than 16 in.	8-16 in.	Less than 8 in.
Coarse fragments: percent, by volume	Less than 3 pct	3-15 pct	More than 15 pct
Soluble salts: conductivity of saturation extract	Less than 4 mmhos/cm	4-8 mmhos/cm	More than 8 mmhos/cm
Stoniness class 1/	0	1	2, 3, 4, and 5
Slope	Less than 8 pct	8-15 pct	More than 15 pct
Soil drainage class 2/	Drainage class not determining if better than poorly drained		Poorly drained, very poorly drained

1/ For class definitions see Soil Survey Manual, pp. 216-223.

2/ For class definitions see Soil Survey Manual, pp. 169-172.

in the colum should be representative of the typical soils of the Unified soil groups in which the respective soil series have been placed. Use Guide Sheet 14 for general guidance in determining the proper entries for features affecting these compacted embankments.

Among the properties commonly affecting evaluation of soils to be used in embankments, dikes, and levees are shear strength, compressibility, permeability of the compacted soil, susceptibility to piping, and compaction characteristics. Other properties of soils that may be important enough in the survey area to be noted in column 12 are shallowness to bedrock, high shrink-swell potential, high content of gypsum or other salts, and high content of stones. Authors of soil surveys to be published should cite at least two or three of these features in the column, selecting, of course, those features and behavior characteristics most important to the use of the soils in compacted embankments.

For characteristics selected from Guide Sheet 14, limit the entry to a single adjective for that characteristic if possible and use the adjectives given in this Guide Sheet. For example, in the entries in column 12 shear strength is commonly noted as "high," "medium," or "low"; and compaction characteristics commonly are evaluated as "good," "fair," or "poor." Because behavior of the typical soil in a group may be a range in behavior, such as "medium to low," a single adjective, therefore, is not always appropriate. Where applicable, the range should be used as the entry in the column. Also, if the behavior of a given soil series differs from the span of behavior shown in Guide Sheet 14 for the typical soil in the pertinent Unified group, the entry in column 12 should be adjusted to reflect for that soil series the true scope of behavior of the specified property.

Discussed in the following paragraphs are five of the major features affecting use of soils for constructing compacted embankments. The information given is the basis for the evaluations set forth in Guide Sheet 14.

1. The shear strength of a soil indicates the relative resistance of that soil to sliding when supporting a load. The highest resistance to sliding occurs in soils that are composed of clean gravel (less than 5 percent fines). Soil strength decreases as fines increase and is lowest in fine-grained organic soils (OL and OH).

2. The compressibility of a soil pertains to the decrease in volume of the mass when supporting a load. Compressibility is lowest in coarse-grained soils having grains that are in contact; volume of the mass decreases very slightly when these soils support heavy loads. Compressibility increases as fines increase and is highest in fine-grained soils containing organic matter.

3. The permeability of compacted soil pertains to the rate at which water moves through soil after compaction. If a coarse-grained soil, after compaction, contains large continuous pores, the soil transmits water rapidly and is said to have "high" permeability. Because fine-grained soils contain very small discontinuous pores, a compacted fine-grained soil transmits water very slowly and is said to have "low" permeability

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Guide Sheet 14.--Characteristics of materials for compacted embankments

Unified classification	Shear strength	Compressibility	Permeability of compacted soil	Susceptibility to piping	Compaction characteristic
GW	High	Low	High	Low	Good
GP	High	Low	High	Low	Good
GM	High to medium	Low	Medium to low	Medium to low	Fair to good
GC	Medium	Low to medium	Low	Medium to low	Good to fair
SW	High	Low	High	Medium	Good
SP	Medium	Low	High	Medium to high	Good
SM	Medium	Low to medium	Medium to low	Medium to high	Fair to good
SC	Medium to low	Low to medium	Low	Medium to low	Good to fair
ML	Medium to low	Medium	Medium to low	High	Fair to poor
CL	Medium to low	Medium	Low	Low to medium	Fair to good
MH	Low	High	Low to medium	Medium to low	Poor
CH	Medium to low	High	Low	Low	Fair to poor
OL(1)	Low	High	Low to medium	Medium to high	Fair to poor
OH(1)	Low	High	Low	Medium to low	Poor
Pt(2)					

[1]Suitable for use in low embankments with very low hazard only.

[2]Not suitable for embankments.

4. Susceptibility to piping or to internal erosion applies to the likelihood of removal of soil particles by water moving through the pores (or cracks) in the compacted soil mass. Highly susceptible soil materials are those that have large pores through which water moves rapidly, yet in which soil grains are fine enough and sufficiently lacking in coherence so that the individual grains move readily. The most susceptible materials are fine sands and nonplastic silts (PI less than 5). Although coarse sands and gravel also may transmit water rapidly, they consist of large individual grains that, themselves, resist internal movement. Also, other soil materials of low susceptibility to piping are fine-grained, cohesive, and highly plastic; they transmit water very slowly and, thus, resist piping or internal erosion.

5. Compaction characteristics indicate the relative response of soil to compactive effort. Where there is satisfactory moisture control and a soil can be compacted to a high degree with minimum effort, the compaction characteristics of that soil are evaluated as "good." The degrees to which compactive effort and construction control must be increased are reflected in the evaluations of "fair" and "poor."

Column 13.--Drainage for crops and pasture. Soil features and qualities considered in determining suitable drainage for cropland and pasture are those that affect installation and performance of surface and subsurface drainage systems.

Features and qualities affecting drainage are:

1. Permeability, texture, and structure.
2. Depth to layers such as a fragipan or claypan, bedrock, sand, etc., that influence the rate of water movement.
3. Depth to water table.
4. Slope.
5. Stability of ditch banks.
6. Flooding or ponding.
7. Salinity and alkalinity.
8. Availability of outlets.

Column 14.--Irrigation. Soil features and qualities considered in determining suitable irrigation practices for a soil are:

1. Available water capacity.
2. Depth of soil as related to rooting zone.
3. Slope (determines method of application and affects hazard of erosion).
4. Rate of water intake.
5. Need for drainage; depth to water table.
6. Susceptibility to stream overflow.
7. Salinity and alkalinity.
8. Stoniness.
9. Hazard of soil blowing.
10. Presence of fragipan or other restrictive layers.
11. Permeability below the surface layer.
12. Hazard of water erosion.

Column 15.--Terraces and diversions. Factors considered in the planning and construction of terraces and diversions are the soil features and qualities that affect stability of the soils, layout and construction of terraces and diversions, establishment and maintenance of vegetative cover, and sedimentation of channels.

Features and qualities affecting use of soils for terraces and diversions are:

1. Percent, length, and shape of slope.
2. Depth to bedrock or other unfavorable material.
3. Presence of stones or rock outcrops.
4. Hazards of soil blowing, erosion, and slipping.
5. Texture and permeability.
6. Potential for siltation of channels.
7. Difficulty in the growing of plants.
8. Availability of outlets.

Interpretations not shown in sample tables A and B

The interpretations discussed in this section are those that generally are not made for all parts of the county but that may be of value for a particular state, part of a state, or region. Because their use is thus limited, these interpretations are not included in the sample tables in this engineering guide. Discussed here are interpretations for (1) potential frost action, (2) highway location, (3) grassed waterways, (4) winter grading, and (5) piping in undisturbed soils.

If any of these features or others not discussed here or elsewhere in the guide are important to the survey area, they may be included as headings for columns in the first or second standard engineering table. Note that the entries in such columns are not to be given as suitability or limitation ratings. For example: A column in the first standard table, Estimated soil properties significant to engineering, may be headed Potential frost action; and an entry in such a column might read "Moderate" or "Low." (See item 1 in this discussion to determine classes of potential frost action.) In general, however, the additional interpretations discussed in this section are noted by entries in columns added under the third major heading, Soil features affecting, in the second table, as in sample table B. For example: In a column Highway location under that third major heading, an entry might read "Flooding hazard" or "Steep slopes; seasonal high water table; difficult to excavate; erodibility." (See item 2 in this section to determine soil features and qualities considered in selecting location for a superhighway.)

(1) Interpretations for potential frost action in soils are not made routinely but may be needed in survey areas where substantial freezing is common. As used in engineering, "potential frost action" refers to the probable effects on structures resulting from the freezing of soil material and its subsequent thawing. These probable effects are important factors mainly in selecting sites for highways and runways but also are of importance in planning any structure that is to be supported or abutted by soil that freezes. The action not only pertains to the heaving of soil as freezing progresses but also to the excessive wetting and loss of soil strength during thaw.

Damage to structures from frost action results not from the freezing of the soil itself but from the formation of ice lenses in the soil. In turn, the formation of ice lenses depends on capacity of the soil to deliver water to a stationary or slowly moving freezing front. Almost every soil with more than 3 percent of material smaller than 0.02 mm has this capacity to some extent. Soils that are nearly clayfree but that are high in silt (0.05-0.002 mm) and very fine sand (0.10-0.05 mm) have this capacity to the greatest degree and, hence, have the highest potential for frost action where a supply of water is within reach. Also, other soils that have a large capillary water capacity have high potential providing water is available for transport to the freezing front.

Where frost action is important and interpretations are needed, three classes of potential are proposed. For lack of better guidance, the three classes are based on USDA soil texture classes or on classes in the Unified system. The proposed classes listed below should be used with the understanding that the best evidence is gotten from observations made in the field and from data used in classifying and mapping soils in published soil surveys. Although grain size is obviously an important factor in frost action, it is not the only property that influences the action. Of importance also are soil structure and porosity and other properties that affect capillary conductivity and the scarcity or abundance of soil moisture during freezing weather.

The proposed three classes of potential based on USDA textures are:

Low	Moderate	High
Sand	Clay	Silt
Loamy sand	Silty clay	Silt loam
Coarse sandy loam	Sandy loam (medium)	Silty clay loam
	Sandy clay loam	Loam
	Sandy clay	Clay loam
		Very fine sandy loam
		Fine sandy loam

Note that gravel and other coarse fragments in soils tend to reduce the potential of frost action, particularly if the content of such materials is high.

Based on the Unified Soil Classification system, the proposed three classes of potential are:

Low	Moderate	High
GW	GM	ML
GP	GC	CL
SW	SC	OL
SP	CH	MH
	OH	SM

Because the proposed classes based on USDA textural classification cannot be exactly equated with proposed classes based on the Unified system, the class of some soils based on one system may differ from their class based on the other system. In such cases, base choice of the more appropriate of the two classes on other information given in preceding paragraphs in this discussion of potential for frost action.

(2) Highway location pertains to superhighways similar to those of the interstate system and not to local roads and streets. Factors considered in selecting location for such highways are the soil features and qualities that can affect design, construction, and performance.

Evaluate features for the entire profile of an undisturbed soil and assume that the surface layer, generally containing organic matter, will be removed in construction.

Soil features and qualities considered in selecting locations for a superhighway are:

a. Presence and thickness of an organic layer.
b. Depth to bedrock and presence of stones and boulders.
c. Depth to water table (permanent or seasonal)
d. Stability of slopes.
e. Potential frost action.
f. Erodibility.
g. Flooding hazard.
h. Topography (need for cuts and fills).
i. Ease of excavation.
j. Plasticity.
k. Presence of springs or seepy areas.

(3) The factors considered in selecting soils for grassed waterways are those soil features and qualities that affect establishment, growth, and maintenance of plants and the layout and construction of the waterway. These factors include:

a. Erodibility.
b. Texture and thickness of soil layers.
c. Natural drainage.
d. Presence of stones or rock outcrops.
e. Steepness of slope.
f. Potential for siltation of channels, including accumulation from soil blowing.
g. Available water capacity.
h. Presence of seepage areas.

(4) Suitability of soils for winter grading depends on the ease with which soil can be moved and traversed by conventional construction equipment during cold weather. The features and qualities affecting a soil for winter grading are:

a. Trafficability (soil texture, slope, stoniness, wetness).
b. Depth to water table, natural soil drainage.
c. Ease of excavation and compaction (moisture content and soil texture).
d. Susceptibility to formation of large frozen clods.
e. Plasticity (kind and amount of clay).

(5) Soil piping is subsurface erosion that causes the formation of tunnel-like cavities. The presence of such cavities or susceptibility to their formation can be, and frequently is, a limitation or hazard to building roads, erosion-control terraces, canals, and other structures across soils susceptible to piping.

In this discussion, "soil piping" pertains to soils undisturbed except for the 6 to 12 inches or more of surface layer that is disturbed in tillage or in other operations that leave the subsoil and substratum undisturbed. It does not pertain to piping in earthfill dams or other structures to which the soil is moved and manipulated in accordance with construction specifications.

Although the "pipes" start as tiny tunnels or elongated cavities, they may enlarge to several feet in diameter, some to more then 10 feet. In advanced stages, piping appears as a series of tubes or tunnels rather than as channels or gullies. As the pipes enlarge, the "roofs" collapse locally and the landform becomes karst-like in appearance.

Piping is limited to certain topographic situations. There must be enough slope to induce the flow of water and places, such as gullies or stream channels, that can serve as outlets for the tunnels.

Piping occurs mainly in the arid and semiarid parts of the United States, though it occurs also in loess areas of the Mississippi Valley where annual rainfall may exceed 50 inches. It takes place most commonly in valley alluvium that has been or is being trenched by gullies; but it also takes place in some soil materials on uplands.

Not enough is yet known to enable establishment of limitation or hazard classes for nationwide use, but the occurence of piping or susceptibility to it should be reported in the text of engineering sections in published soil surveys. Given in the text should be brief descriptions that include some notion of the common diameters and lengths of the tunnels and the thicknesses of the remaining material bridging them. The degree of piping and the susceptibility to piping should relate to kinds of soils only to the extent warranted by field observations.

Sample table C.--Engineering test data

The third standard engineering table gives, as in sample table C, test data for samples collected during the soil survey of the specific area. The data in table C are results of tests by the state highway department, the state experiment station laboratory, or the SCS soil mechanics laboratory. Data obtained by testing samples collected for purposes other than for published soil survey (e.g., for a highway project survey) also may be used in the table if the author can reliably apply such data to his survey area.

An explanation of each column heading should accompany the table. If other types of relevant test data are available for soils in the survey area and are needed for interpretations, those data may be presented in a separate table.

If test data of interest to engineers are presented in a table in another section of the publication, make reference to that table in the text that accompanies this third standard engineering table. Examples of test data of interest to engineers other than as shown in sample table C are for: moisture tension, salinity, chemical analysis, volume change, permeability, available water capacity, and organic-matter content.

The data in this table are useful in making estimates of engineering properties of the soils for the first standard engineering table, as in table A; and in interpreting properties of the soils for the second standard engineering table, as in table B.

In footnotes to this third table refer readers to Literature cited for listings of published authorities on the various test procedures, as in footnotes to sample table C. Place the footnote references in the pertinent column headings. In columns where data are normally expressed numerically, use a footnote to the table to explain alphabetical entries, as in table C, columns 17 and 18.

Column 1.--Soil name and location. On the first line of each entry, the full name of the soil is given and is followed by a colon. Immediately beneath the name give a reasonably detailed description of the location of the sampling site. If more than one profile has been sampled and tested, enter location of each site separately in the column. At the end of the description of each location indicate in parentheses whether the profile sampled is considered "modal" or not, and if not, indicate how it differs from the modal. (See sample table C, column 1).

Column 2.--Parent material. Indicate the presumed parent material. This column generally is of considerable value to engineers because much engineering experience, especially in highway engineering, has been related to kind of parent material (geological) as well as to kind of soil.

Column 3.--Report number. Enter in this column the number assigned to each sample by the testing laboratory. Most laboratories assign a number to each soil sample processed, and the number becomes a part of a permanent record and is useful in filing and retrieving data.

Column 4.--Depth. In this column record in inches the depths of sampled soil horizons. Do not include the depths of horizons not sampled.

Column 5 and 6.--Maximum dry density (column 5) and optimum moisture (column 6). The density to which a soil can be compacted is an important engineering property. In general the greater the density, the greater the strength of the material. For a given compactive effort the attainable density varies somewhat according to the moisture content, and that content at which the maximum dry density is attained is termed "the optimum moisture" content for that particular compactive effort. Give data on both determinations, expressing maximum dry density in pounds per cubic foot and optimum moisture in percent.

Columns 7 through 16.--Mechanical analysis. The general practice in engineering is to express the results of mechanical analysis as percentage passing certain sieve sizes for those fractions determined by sieving and as percentage smaller than certain grain sizes for those fractions determined by hydrometer or pipette analysis. The hydrometer method is used by nearly all engineering laboratories, whereas the pipette method is used by National Cooperative Soil Survey and is the official basis for determining soil texture. Because the two methods give somewhat different results, especially for percentages of particles smaller than 0.002 mm, results from the hydrometer method ordinarily should not be used for determining soil texture classes or, if used for that purpose, should be used with appropriate caution. Adjustment to the noted grain sizes in the headings of columns 7 through 16 may be needed, depending on the soils in the survey area and on the particular policy of the cooperating laboratory. If the laboratory reports mechanical analysis in a set of grain sizes that differ from those given in column headings in sample table C, the accepted practice is to use the grain sizes given by the laboratory. Add or delete columns to accommodate the components of the soils in the survey area.

Columns 17 and 18.--Liquid limit (column 17) and Plasticity index (column 18). Liquid limit and plasticity index relate to soil moisture and provide important clues to soil behavior. If water is added to a dry soil containing at least some clay and silt, the soil becomes plastic. The moisture content at which the soil becomes plastic is the plastic limit. This limit, routinely determined by laboratories, is not reported in sample table C but is needed to compute the plasticity index. If more water is added, the soil becomes fluid. The moisture content at which the soil changes from a plastic to a fluid state is the liquid limit, and this limit is reported numerically in column 17. The difference between the liquid limit and the plastic limit is the plasticity index--the range over which the soil is plastic--and this index is reported numerically in column 18. Some soils, such as those that are very sandy, do not exhibit plasticity and therefore do not have a plasticity index. For such soils "NP", meaning nonplastic, is entered in column 18.

Columns 19 and 20.--Engineering soil classification systems. Several systems of classifying soils for engineering purposes are in use. In these columns, classifications in two of these systems, the AASHO (column 19) and the Unified (column 20) are listed for horizons of the tested soil samples.

The engineering profession has standard procedures for obtaining these data, such as shown in sample table C. Engineering laboratories conventionally indicate in their reports the methods used to obtain the data given. The information about the methods used should be transferred to the third standard table, generally as footnotes, and should include the procedures (authorities) for determinations in both classification systems used in these columns. (See footnotes to sample table C.)

Part III. Writing The Text Of The Engineering Section

This part of the Guide contains instructions for writing the text of the engineering section to be included in published soil surveys and in soil handbooks. Also contained in this part of the Guide are samples of statements that may be used in the section. (Sample statements are set apart from the instructions by a line in the margin.)

A primary concern of the author should be for readers who are not engineers. Those readers can gain much practical information if the data in tables are clearly explained in the text.

Following are some suggestions for the text of engineering sections.

Title and introduction to the engineering section

The title of the section should be a few descriptive words that indicate what the section is about. Both words "soils" and "engineering" should be included. "Engineering Uses of the Soils" is one of several appropriate titles that have been used.

An adequate but brief-as-possible introduction should tell what information the section contains, how the information can be put to practical use, and what precautions are needed in applying the information for specific tracts of soil. A sample introduction follows.

Engineering Uses of the Soils

This section is useful to those who need information about soils used as structural material or as foundation upon which structures are built. Among those who can benefit from this section are planning commissioners, town and city managers, land developers, engineers, contractors, and farmers.

Among properties of soils highly important in engineering are permeability, strength, compaction characteristics, soil drainage condition, shrink-swell potential, grain size, plasticity, and soil reaction. Also important are depth to the water table, depth to bedrock, and soil slope. These properties, in various degrees and combinations, affect construction and maintenance of roads, airports, pipelines, foundations for small buildings, irrigation systems, ponds and small dams, and systems for disposal of sewage and refuse.

Information in this section of the soil survey can be helpful to those who--

1. Select potential residential, industrial, commercial, and recreational areas.

2. Evaluate alternate routes for roads, highways, pipelines, and underground cables.

3. Seek sources of gravel, sand, or clay.

4. Plan farm drainage systems, irrigation systems, ponds, terraces, and other structures for controlling water and conserving soil.

5. Correlate performance of structures already built with properties of the kinds of soil on which they are built, for the purpose of predicting the performance of structures on the same or similar kinds of soil in other locations.

6. Predict the trafficability of soils for cross-country movement of vehicles and construction equipment.

7. Develop preliminary estimates pertinent to construction in a particular area.

Most of the information in this section is presented in tables 1, 2, and 3, which show respectively, several estimated soil properties significant to engineering, interpretations for various engineering uses, and results of engineering laboratory tests on soil samples.

This information, along with the soil map and other parts of this publication, can be used to make interpretations additional to those given in tables 1 and 2 and also can be used to make other useful maps.

This information, however, does not eliminate need for further investigation at sites selected for engineering works, especially works that involve heavy loads or that require excavations to depths greater (more than 6 feet) than those generally shown in the tables. Also, inspection of sites, especially the small ones, is needed because many delineated areas of a given soil mapping unit may contain small areas of other kinds of soil that have strongly contrasting properties and different suitabilities or limitations for soil engineering.

Some of the terms used in this soil survey have special meaning to soil scientists that is not known to all engineers. The Glossary defines many of these terms commonly used in soil science.

<u>Engineering soil classification</u>
(See Appendix 1 for a discussion of classification)

This section should explain briefly the engineering soil classification systems. County commissioners, town and country planners, farmers, and many others who may not have a background in engineering should be made aware of these systems and the general characteristics of each. Experience has proved it best to explain the systems early in the text--almost as an extension of the introduction. Example of an appropriate heading for this part of the text is "Engineering soil classification systems." Following is sample text.

Engineering Soil Classification Systems

The two systems most commonly used in classifying samples of soils for engineering are the Unified system used by SCS engineers, the Department of Defense, and others and the AASHO system adopted by the American Association of State Highway Officials.

In the Unified system soils are classified according to particle-size distribution, plasticity, liquid limit, and organic matter. Soils are grouped in 15 classes. There are eight classes of coarse-grained soils, identified as GW, GP, GM, GC, SW, SP, SM, and SC; six classes of fine-grained soils, identified as ML, CL, OL, MH, CH, and OH; and one class of highly organic soils, identified as Pt. Soils on the borderline between two classes are designated by symbols for both classes, for example, ML-CL.

The AASHO system is used in classifying soils according to those properties that affect use in highway construction and maintenance. In this system, a soil is placed in one of seven basic groups ranging from A-1 through A-7 on the basis of grain-size distribution, liquid limit, and plasticity index. In group A-1 are gravelly soils of high bearing strength, the best soils for subgrade (foundation). At the other extreme, in group A-7, are clay soils that have low strength when wet and that are the poorest mineral soils for subgrade. If laboratory data are available to justify a further breakdown, the A-1, A-2, and A-7 groups are divided as follows: A-1-a, A-1-b, A-2-4, A-2-5, A-2-6, A-2-7, A-7-5, and A-7-6. As additional refinement, the engineering value of a soil material can be indicated by a group index number. Group indexes range from 0 for the best material to 20 or more for the poorest. The AASHO classification for tested soils, with group index numbers in parentheses, is shown in table 3; the estimated classification, without group index numbers, is given in table 1 for all soils mapped in the survey area.

Explanation of tables

Most of the text in an engineering section explains the column headings and kind of data generally noted in three standard engineering tables. The tables give different kinds of information; clues to the differences should be reflected in the three headings to the text that explains the tables. It is not good practice to introduce explanation of a table with a nondescriptive heading, such as "Explanation of table A." Headings to text and names of tables should reflect content.

The first standard table gives, as in sample table A in this Guide, estimates of the soil properties significant to engineering that are reasonable to include in a published soil survey. An appropriate name for this first table and heading for the text is "Estimated soil properties significant to engineering."

The third standard table--in which generally are entered test data for specified soils in the survey area--can be introduced in the text, as in sample table C, by the heading "Engineering test data."

Included in this Guide is a fourth table, sample table D, that is a partial reprint of sample table B. It is intended as a model of preferred dimensions for the standard tables in manuscript form. Instructions for authors are printed on sample table D.

The introductory paragraph to explanation of a table should tell readers briefly what is in the table and how the information was obtained. If needed, the introduction also may include necessary precautions (in addition to those given earlier in the introduction to the engineering section) pertinent to application of the information.

Following are sample introductions for text explaining each of the three standard engineering tables represented in this Guide by tables A, B, and C. Then following each of the sample introductions are samples of text that explains most of the columns, by heading. If additional columns are needed for a survey area, the explanations of headings should be modeled after the sample statements included here. Where column headings and data are selfexplanatory, no statements are needed.

Estimated Properties Significant to Engineering

Several estimated soil properties significant to engineering are given in table 1. Evaluations are made for the typical profile of each soil series by layers sufficiently different from each other to each have unique significance for soil engineering. The estimates are based on field observations made in the course of mapping, on test data for the specified soils and similar soils, and on experience with the same kinds of soil in other counties. Following are explanations of some of the columns in table 1.

Depth to bedrock is distance from the surface of the soil downward to the upper surface of the rock layer.

Depth to seasonal high water table is distance from the surface of the soil downward to the highest level reached in most years by ground water.

Soil texture is described in table 1 in the standard terms used by the Department of Agriculture. These terms take into account relative percentages of sand, silt, and clay in soil material that is less than 2 millimeters in diameter. "Loam," for example, is soil material that contains 7 to 27 percent clay, 28 to 50 percent silt, and less than 52 percent sand. If the soil contains gravel or other particles coarser than sand, an appropriate modifier is added, as for example, "gravelly loamy sand." "Sand," "clay," and some of the other terms used in USDA textural classification are defined in the Glossary of this soil survey.

Liquid limit and plasticity index pertain to the effect of water on the strength and consistence of soil material. As the moisture content of a clayey soil is increased from a dry state, the material changes from a semisolid to a plastic state. If the moisture content is further increased, the material changes from a plastic to a liquid state. The plastic limit is the moisture content at which the soil material changes from the semisolid to the plastic state, and the liquid limit from the plastic to the liquid state. The plasticity index is the numerical difference between the liquid limit and the plastic limit. It indicates the range of moisture content within which a soil material is plastic. Liquid limit and plasticity index in table 1 are estimates, in table 3 the data on liquid limit and plasticity index are based on tests of soil samples.

Permeability is that quality of a soil that enables it to transmit water or air. It is estimated on the basis of those soil characteristics observed in the field, particularly structure and texture. The estimates in table 1 do not take into account lateral seepage or such transient soil features as plowpans and surface crusts.

Available water capacity is the ability of soils to hold water for use by most plants. It is commonly defined as the difference between the amount of water in the soil at field capacity and the amount in the soil at the wilting point of most crop plants.

Reaction is the degree of acidity or alkalinity of a soil, expressed in pH values. The pH value and terms used to describe soil reaction are explained in the Glossary.

Salinity refers to the amount of soluble salts in the soil. It is expressed as the electrical conductivity of the saturation extract, in mmhos per centimeter at 25° C. Salinity affects the suitability of a soil for crop production, its stability when used as construction material, and its corrosiveness to metals and concrete.

Shrink-swell potential is the relative change in volume to be expected of soil material with changes in moisture content, that is, the extent to which the soil shrinks as it dries out or swells when it gets wet. Extent of shrinking and swelling is influenced by the amount and kind of clay in the soil. Shrinking and swelling of soil causes much damage to building foundations, roads, and other structures. A high shrink-swell potential indicates a hazard to maintenance of structures built in, on, or with material having this rating.

Corrosivity, as used in table 1, pertains to potential soil-induced chemical action that dissolves or weakens uncoated steel or concrete. Rate of corrosion of uncoated steel is related to soil properties such as drainage, texture, total acidity, and electrical conductivity of the soil material. Corrosivity for concrete is influenced mainly by the content of sodium or magnesium sulfate but also by soil texture and acidity. Installations of uncoated steel that intersect soil boundaries or soil horizons are more susceptible to corrosion than installations entirely in one kind of soil or in one soil horizon. A corrosivity rating of low means that there is a low probability of soil-induced corrosion damage. A rating of high means that there is a high probability of damage so that protective measures for steel and more resistant concrete should be used to avoid or minimize damage.

Engineering Interpretations of the Soils (Table 2)

The estimated interpretations in table 2 are based on the engineering properties of soils shown in table 1, on test data for soils in this survey area and others nearby or adjoining, and on the experience of engineers and soil scientists with the soils of County. In table 2, ratings are used to summarize limitation or suitability of the soils for all listed purposes other than for drainage of cropland and pasture, irrigation, pond reservoirs, embankments, and terraces and diversions. For those particular uses, table 2 lists those soil features not to be overlooked in planning, installation, and maintenance.

Soil limitations are indicated by the ratings slight, moderate, and severe. Slight means soil properties generally favorable for the rated use or, in other words, limitations that are minor and easily overcome. Moderate means that some soil properties are unfavorable but can be overcome or modified by special planning and design. Severe means soil properties so unfavorable and so difficult to correct or overcome as to require major soil reclamation and special designs. For some uses, the rating of severe is divided to obtain ratings of severe and very severe. Very severe means one or more soil properties so unfavorable for a particular use that overcoming the limitations is most difficult and costly and commonly not practical for the rated use.

Soil suitability is rated by the terms good, fair, and poor, which have respectively, meanings approximately parallel to the terms slight, moderate, and severe.

Following are explanations of some of the columns in table 2.

Septic tank absorption fields are subsurface systems of tile or perforated pipe that distribute effluent from a septic tank into natural soil. The soil material from a depth of 18 inches to 6 feet is evaluated. The soil properties considered are those that affect both absorption of effluent and construction and operation of the system. Properties that affect absorption are permeability, depth to water table or rock, and susceptibility to flooding. Slope is a soil property that affects difficulty of layout and construction and also the risk of soil erosion, lateral seepage, and downslope flow of effluent. Large rocks or boulders increase construction costs.

Sewage lagoons are shallow ponds constructed to hold sewage within a depth of 2 to 5 feet long enough enough for bacteria to decompose the solids. A lagoon has a nearly level floor and sides, or embankments, of compacted soil material. The assumption is made that the embankment is compacted to medium density and the pond is protected from flooding. Properties are considered that affect the pond floor and the embankment. Those that affect the pond floor are permeability, organic matter, and slope, and if the floor needs to be leveled, depth to bedrock becomes important. The soil properties that affect the embankment are the engineering properties of the embankment material as interpreted from the Unified Soil Classification and the amounts of stones, if any, that influence the ease of excavation and compaction of the embankment material.

Shallow excavations are those that require digging or trenching to a depth of less than 6 feet, for example, excavations for pipelines, sewer lines, phone and power transmission lines, basements, open ditches, and cemeteries. Desirable soil properties are good workability, moderate resistance to sloughing, gentle slopes, absence of rock outcrops or big stones, and freedom from flooding or a high water table.

Dwellings, for which the soils are given limitation ratings in table 2, are those not more than three stories high and that are supported by foundation footings placed in undisturbed soil. The features that affect the rating of a soil for such dwellings are those that relate to capacity to support load and resist settlement under load, and those that relate to ease of excavation. Soil properties that affect capacity to support load are wetness, susceptibility to flooding, density, plasticity, texture, and shrink-swell potential. Those that affect excavation are wetness, slope, depth to bedrock, and content of stones and rocks.

Sanitary landfill is a method of disposing of refuse in dug trenches. The waste is spread in thin layers, compacted, and covered with soil throughout the disposal period. Landfill areas are subject to heavy vehicular traffic. Some soil properties that affect suitability for landfill are ease of excavation, hazard of polluting ground water, and trafficability. The best soils have moderately slow permeability, withstand heavy traffic, and are friable and easy to excavate. Unless otherwise stated the ratings in table 2 apply only to a depth of about 6 feet, and therefore limitation ratings of <u>slight</u> or <u>moderate</u> may not be valid if trenches are to be much deeper than 6 feet. For some soils, reliable predictions can be made to a depth of 10 or 15 feet, but regardless of that, every site should be investigated before it is selected.

Local roads and streets for which soil ratings are given in table 2, have an all-weather surface expected to carry automobile traffic all year. These roads and streets have a subgrade of underlying soil material; a base consisting of gravel, crushed rock, or soil material stabilized with lime or cement; and a flexible or rigid surface that is commonly asphalt or concrete. They are graded to shed water and have ordinary provisions for drainage. They are built mainly from soil at hand, and most cuts and fills are less than 6 feet.

Soil properties that most affect design and construction of roads and streets are load-supporting capacity, stability of the subgrade, and the workability and quantity of cut-and-fill material available. The AASHO and Unified classifications of the soil material, and also the shrink-swell potential, indicate traffic-supporting capacity. Wetness and flooding affect stability of the material. Slope, depth to hard rock, content of stones and rocks, and wetness affect ease of excavation and amount of cut and fill needed to reach an even grade.

Road fill is soil material used in embankments for roads. The suitability ratings reflect (1) the predicted performance of soil after it has been placed in an embankment that has been properly compacted and provided with adequate drainage and (2) the relative ease of excavating the material at borrow areas.

Sand and gravel are used in great quantities in many kinds of construction. The ratings in table 2 provide guidance on where to look for probable sources. A soil rated as a good or fair source of sand or gravel generally has a layer at least 3 feet thick, the top of which is within a depth of 6 feet. The ratings do not take into account thickness of overburden, location of the water table, or other factors that affect mining of the materials, nor do they indicate quality of the deposit.

Topsoil is used for topdressing an area where vegetation is to be established and maintained. Suitability is affected mainly by ease of working and spreading the soil material, as for preparing a seedbed; natural fertility of the material, or the response of plants when fertilizer is applied; and absence of substances toxic to plants. Texture of the soil material and its content of stone fragments are characteristics that affect suitability, but also considered in the ratings is the damage that will result at the area from which topsoil is taken.

Pond reservoir areas hold water behind a dam or embankment. Soils suitable for pond reservior areas have low seepage, which is related to their permeability and depth to fractured or permeable bedrock or other permeable material.

Dikes, levees, and other embankments for retention of water require soil material resistant to seepage and piping and of favorable stability, shrink-swell potential, shear strength, and compactibility. Presence of stones or organic material in a soil are among factors that are unfavorable.

Drainage for crops and pasture is affected by such soil properties as permeability, texture, and structure; depth to claypan, rock, or other layers that influence rate of water movement; depth to the water table; slope; stability in ditchbanks; susceptibility to stream overflow; salinity or alkalinity; and availability of outlets for drainage.

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Irrigation of a soil is affected by such features as slope; susceptibility to stream overflow, water erosion or soil blowing; soil texture; content of stones; accumulations of salts and alkali; depth of root zone; rate of water intake at the surface; permeability of soil layers below the surface layer and in fragipans or other layers that restrict movement of water; amount of water held available to plants; and need for drainage, or depth to water table or bedrock.

Terraces and diversions are low ridges constructed across the slope to intercept or divert runoff so that it soaks into the soil or flows slowly to a prepared outlet. Features that affect suitability of a soil for terraces are uniformity and steepness of slope; depth to bedrock or other unfavorable material; presence of stones; permeability; and resistance to water erosion, soil slipping, and soil blowing. A soil suitable for these structures provides outlets for runoff and is not difficult to vegetate.

Engineering Test Data

Table 3 contains engineering test data for some of the major soil series in (name of survey area). These tests were made to help evaluate the soils for engineering purposes. The engineering classifications given are based on data obtained by mechanical analyse and by tests to determine liquid limits and plastic limits. The mechanical analyse were made by combined sieve and hydrometer methods.

Compaction (or moisture-density) data are important in earthwork. If a soil material is compacted at successively higher moisture content, assuming that the compactive effort remains constant, the density of the compacted material increases until the optimum moisture content is reached. After that, density decreases with increase in moisture content. The highest dry density obtained in the compactive test is termed maximum dry density. As a rule, maximum strength of earthwork is obtained if the soil is compacted to the maximum dry density.

Tests to determine liquid limit and plastic limit measure the effect of water on the consistence of soil material, as has been explained for table 1.

Summary statements

The standard engineering tables and written material exactly like that given as examples in Part III of this Guide may be all that is needed for many soil survey areas. Yet, for other areas readers may find helpful a paragraph or two summarizing and highlighting those soil features widespread in extent and highly significant to engineering. If such paragraphs are needed, they may be added, preferably under a heading such as "Engineering, General." In this part of the section also may be included statements about features not mentioned in the tables or elsewhere in the text that should be brought to the attention of readers. Following are examples of statements.

Engineering, General

La Casa clay loam is undermined in many places by pockets and channels caused by the dissolving of gypsum. These pockets and channels are hazardous to engineering construction, and testing is necessary so as to avoid areas where they exist.

Rhoades clay loam and Wade silty clay loam are dispersed soils that are unstable in embankments.

Ground water in the unconsolidated formation along Turkey Creek is high in content of salts and generally is unsuitable for irrigation.

Quarries have recently been established in the southern part of the county where Hagerstown-Rock outcrop complex is prominent.

Literature Cited

If an author has used information taken from published sources, he must prepare a list of those publications and key the references in the text to that list. Instructions in the Guide to Authors of Manuscripts for Published Soil Surveys are followed in preparing the list, which eventually is part of a larger list (Literature Cited) at the back of the manuscript he submits for publication.

The following list of citations pertinent to the text and appendix of this engineering guide can be used as a model. Items 1, 3, 9, 10, 11, and 12 are representative of citations generally listed for engineering sections in soil survey manuscripts.

(1) AMERICAN ASSOCIATION OF STATE HIGHWAY OFFICIALS.

1961. standard specifications for highway materials and methods of sampling and testing. Ed. 8, 2 v., illus.

(2) ______________________

1968. interim specifications and methods adopted by aasho committee on materials, 1966-67. 243 pp., illus. Washington.

(3) AMERICAN SOCIETY FOR TESTING AND MATERIALS

1967. tentative methods for classification of soils for engineering purposes. ASTM D2487-66T. In Book of ASTM Standards, pt. 2, pp. 766-771. Philadelphia.

(4) ______________________

1967. tentative recommended practice for description of soils (visual-manual procedure). ASTM D2488-66T. In Book of ASTM standards, pt. 2, pp. 772-780. Philadelphia.

(5) FRANZMEIER, D. P., and ROSS, S. J., Jr.

1968. soil swelling: laboratory measurement and relation to other soil properties. Soil Sci. Soc. Amer. Proc. 32: 573-577.

(6) GROSSMAN, R. B., BRASHER, B. R., FRANZMEIER, D. P., and WALKER, J. L.

1968. linear extensibility as calculated from natural-clod bulk density measurements. Soil Sci. Soc. Amer. Proc. 32: 570-573.

(7) HENRY, E. F., and DRAGOO, M. C.

1965. guide to use of the fha and pvc meter, including results of nationwide soil tests and correlation with climatic factors. Fed. Housing Admin. FHA No. 595, 32 pp., illus.

(8) LAMBE, T. W.

1960. the character and identification of expansive soils. Fed. Housing Admin. FHA-701, 46 pp., illus.

(9) PORTLAND CEMENT ASSOCIATION.

1962. pca soil primer. 52 pp., illus. Chicago.

(10) RICHARDS, L. A., ed.

1954. diagnosis and improvement of saline and alkali soils. U. S. Dept. Agr. Handbook 60, 160 pp., illus.

(11) UNITED STATES DEPARTMENT OF DEFENSE

1968. unified soil classification system for roads, airfields, embankments and foundations. MIL-STD-619B, 30 pp.

(12) UNITED STATES DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE. 1967. manual of septic-tank practice. Pub. Health Serv. Pub. 526, 92 pp., illus.

(13) UNITED STATES DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT. 1968. minimum design standards for community sewerage systems: hud guide. Fed. Housing Admin. G 4518.i, 39 pp., illus.

Appendix

Systems of Soil Classification by Particle Size

Three systems of soil classification--the USDA textural classification (see Chart 2) and the Unified and the AASHO engineering soil classification systems (see Chart 3 and 4)--are briefly explained in this appendix. Some key similarities and differences between the systems (see Chart 1) are set forth, and illustrations are given of how soil samples are classified.

For detailed information about the Unified and the AASHO systems, authors of soil handbooks and soil surveys to be published should consult the publications noted in the following paragraphs.

The information given in this appendix about the two engineering soil classification systems was derived mainly from the PCA Soil Primer (10).

Chart 3 was adapted from a similar chart in Unified Soil Classification System for Roads, Airfields, Embankments, and Foundations: Mil-Std 619 B (11). This standard, issued by the U.S. Department of Defense, was adapted from The Unified Soil Classification System, Technical Memorandum 3-357, published in 1953 by the Waterways Experiment Station, Corps of Engineers.

The Unified system is explained in chapter 4 of the Engineering Field Manual for Conservation Practices, issued by SCS in 1969. Both the AASHO and the Unified systems are described in several modern textbooks on soil engineering.

In 1966 the American Society for Testing and Materials issued "Tentative Method for Classification of Soils for Engineering Purposes, ASTM Designation: D 2487-66 T" (3) and a companion release "Tentative Recommended Practice for Description of Soils (Visual-Manual Procedure). ASTM Designation: D 2488-66 T" (4). Although ASTM Designation D 2487-66 T is not identified as the Unified system, it is considered the authoritative description of this classification by SCS.

In 1968 the American Association of State Highway Officials (AASHO) issued "Interim Recommended Practice for the Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes, AASHO Designation: M 145-66 I," (2) which is a revision of "Standard Recommended Practice... AASHO Designation: M 145-49," (1) the official classification in use since 1949 and is the AASHO classification described in the PCA Soil Primer. In May 1969, however, Designation M 145-66I, together with Advisory Soils-7, was distributed to SCS soil scientists and engineers.

Until such time as the American Association of State Highway Officials issue a final decision on the revision, users of the AASHO system have the option of using the old or the new designation. During the interim, which may last a few years, SCS will defer to the wishes of cooperating state highway departments in the classification used in soil surveys. Authors should indicate the AASHO designation used.

The changes in the revised AASHO system are not drastic; the principal change is a new formula for computing the group index, which authors are advised not to use in the first standard table, "Estimated Soil Properties Significant to Engineering" (see table A). The group index is shown only in the third standard table, which gives laboratory test data as in table C. For entries in the second standard table, "Interpretations of Engineering Properties of the Soils," (see table B) it is of no consequence, therefore, whether the old or new AASHO designation is used.

The USDA, Unified, and AASHO classifications differ in several ways, and authors should be aware of these differences. The main differences are in terminology and in definitions of soil materials, especially in definitions of clay and silt. Differences in particle-size limits are shown in Chart 1. Following are key factors important in the classification systems.

USDA textural classification (see Chart 2)

a. In this classification all materials are omitted that are larger than the No. 10 sieve (2 mm) except as described by adjective modifiers of basic textural classes.

b. Material larger than the No. 10 sieve size (gravel, stones, etc.), if estimated, is estimated by volume and, if measured, is measured by weight. Estimates by volume must be converted to estimates by weight. The percentage of coarse fragments by volume generally is less than the percentage of coarse fragments by weight. For example, 35 percent coarse fragments by volume is equivalent to about 50 percent by weight.

c. Sand is material that passes the No. 10 sieve but is retained on the No. 270 sieve (2 to 0.05 mm).

d. Gravel is rounded or subangular material between the No. 10 sieve size (2 mm) and 3 inches in diameter.

e. In the USDA classification "clay" and "silt" are materials of specific grain sizes: clay, less than 0.002 mm, and silt, 0.002 to 0.05 mm.

Unified engineering soil classification (see Chart 3)

a. In this system all material up to 3 inches in diameter is classified.

b. Percentages of all materials are by weight.

c. Sand is material that passes the No. 4 sieve but is retained on the No. 200 sieve (4.76 to 0.074 mm).

d. Gravel is rounded or subangular material between the No. 4 sieve size (4.7 mm) and 3 inches in diameter.

e. Clay and silt are not defined in terms of particle size but in terms of plasticity. The terms "silt" and "clay" are used to connote "fines" exhibiting, respectively, low and high plasticity.

f. If 50 percent or more of the tested material passes the No. 200 sieve (0.074 mm), the material is classed as "fine-grained"; if less than 50 percent passes the No. 200 sieve, the material is classed as "coarse-grained."

g. Fine-grained materials are divided further on the basis of liquid limit and plasticity index; in addition, special designation is used for materials that contain enough organic matter to adversely affect behavior in engineering uses.

AASHO engineering soil classification: (see Chart 4)

a. In this system all material up to 3 inches in diameter is classified.

b. All percentages of material are by weight.

c. Sand is material that passes the No. 10 sieve but is retained on the No. 200 sieve (2 to 0.74 mm).

d. Gravel is material between the No. 10 sieve size and 3 inches in diameter.

e. If 35 percent or less of the tested material passes the No. 200 sieve, the material is classed as "granular"; if more than 35 percent passes the No. 200 sieve, the material is classed as "silt-clay."

f. Clay and silt are classified according to liquid limit and plasticity index.

Of especial importance in soil classification is the difference between "sand" as defined in the two engineering systems and as defined in USDA textural classification. In the textural classification approximately 50 percent of the material identified as "very fine sand" is smaller than the No. 200 sieve size and, therefore, in the Unified and AASHO systems would be considered "fines." Because of this difference, the soil scientist familiar with the components of a soil should determine how much of the soil material classified as "very fine sand" in accordance with USDA classification should be classed as "fine-grained" in the Unified and AASHO systems.

In the Unified system the sandy clays, sandy clay loams, and sandy loams (mostly fine sandy loams) generally are classed as "fine-grained" soils if a large percentage of the sand in the soil is "very fine sand."

Following are two examples of classifying a soil sample in accordance with specifications in the classification systems. For these examples grain-size data were available or could be estimated fairly well, but plasticity data were not available.

EXAMPLE 1--

Known:

a. Description of the soil to be classified.

b. Five percent of the total soil material is larger than the No. 4 sieve size.

c. Ten percent of the total soil material is larger than the No. 10 sieve size (omitted in USDA textural classification).

d. Soil scientists estimate that, of the material used for textural classification (90 percent of total material), 15 percent is clay, 25 percent is silt, and 60 percent is sand.

e. Of the 60 percent sand, approximately 70 percent is "very fine sand" (0.70 x 0.60 = 0.42).

f. The soil material is slightly plastic.

Solutions.

1. USDA Textural classification:

   In accordance with Chart 2, a material comprised of 15 percent clay, 25 percent silt, and 60 percent sand is "sandy loam"; as is known, 70 percent of the sand or 42 percent of the soil material smaller than 2 millimeters, is "very fine sand." THEREFORE, in USDA textural classification, the soil material is "very fine sandy loam" (vfsl).

2. Unified engineering soil classification:

   It is known that the sand content is 60 percent and that 70 percent of that 60 percent, or 42 percent of the soil material smaller than 2 millimeters, is "very fine sand." One-half of the "very fine sand," or 21 percent, will pass the No. 200 sieve. The total percentage of soil material that will pass the No. 200 sieve is 21 + 15 (clay) + 25 (silt) = 61 percent (approximately) of the 90 percent of total material used for classification. THEREFORE, 0.90 x 0.61 = 0.55 (approximately) of the total soil material will pass the No. 200 sieve and be classed as "fine-grained" material that is given the Unified classification of ML-CL or ML (see Chart 3).

3. AASHO engineering soil classification:

   It is known that the soil material is slightly plastic and that "fines" are more than 35 percent. THEREFORE, the material is classed as A-4 in accordance with AASHO specifications (see Chart 4).

EXAMPLE 2--

Known:

a. Description of the soil to be classified.

b. Ten percent of total soil material is larger than the No. 4 sieve size (and is gravel-size material in the Unified classification).

c. Thirty percent of total soil material is larger than the No. 10 sieve size (and is gravel-size material in both USDA and AASHO classifications).

d. Soil scientists estimate that, of the material used for textural classification (70 percent of total material), 20 percent is clay, 40 percent is silt, and 40 percent is sand.

e. Of the 40 percent sand, approximately 50 percent is "very fine sand" (0.50 x 0.40 = 0.20).

f. The soil material is plastic.

Solutions.

1. USDA textural classification:

   In accordance with Chart 2, a material comprised of 20 percent clay, 40 percent silt, and 40 percent sand is "loam"; it is known that 30 percent of the total material is "gravel," THEREFORE, in USDA textural classification, the soil material is "gravelly loam."

2. Unified engineering soil classification:

   It is known that the sand content is 40 percent and that 50 percent of that 40 percent, or 20 percent of the sand is "very fine sand." One-half of the "very fine sand," or 10 percent, will pass the No. 200 sieve. The total percentage of soil material that will pass the No. 200 sieve is 10 + 20 (clay) + 40 (silt) = 70 percent (approximately) of the 70 percent of total material used for classification. THUS, 49 percent (70 percent of 70 percent) of total soil material is "fines," and is close to the Unified boundary between "fine-grained" and "coarse-grained."

   ALSO, it is known that 10 percent of the total material is larger than the No. 4 sieve size, that this 10 percent is only 20 percent of the coarse fraction in the total material used for classification, and that the remaining 80 percent of the coarse fraction is classed as "sand." FURTHER, it is known that the soil material is plastic.

   THEREFORE, in the Unified system the material is classed as SC or CL (see Chart 3).

3. AASHO engineering soil classification:

   It is known that the soil material is plastic and that "fines" are more than 38 percent. THEREFORE, the material is classed as A-6 in accordance with AASHO specifications.

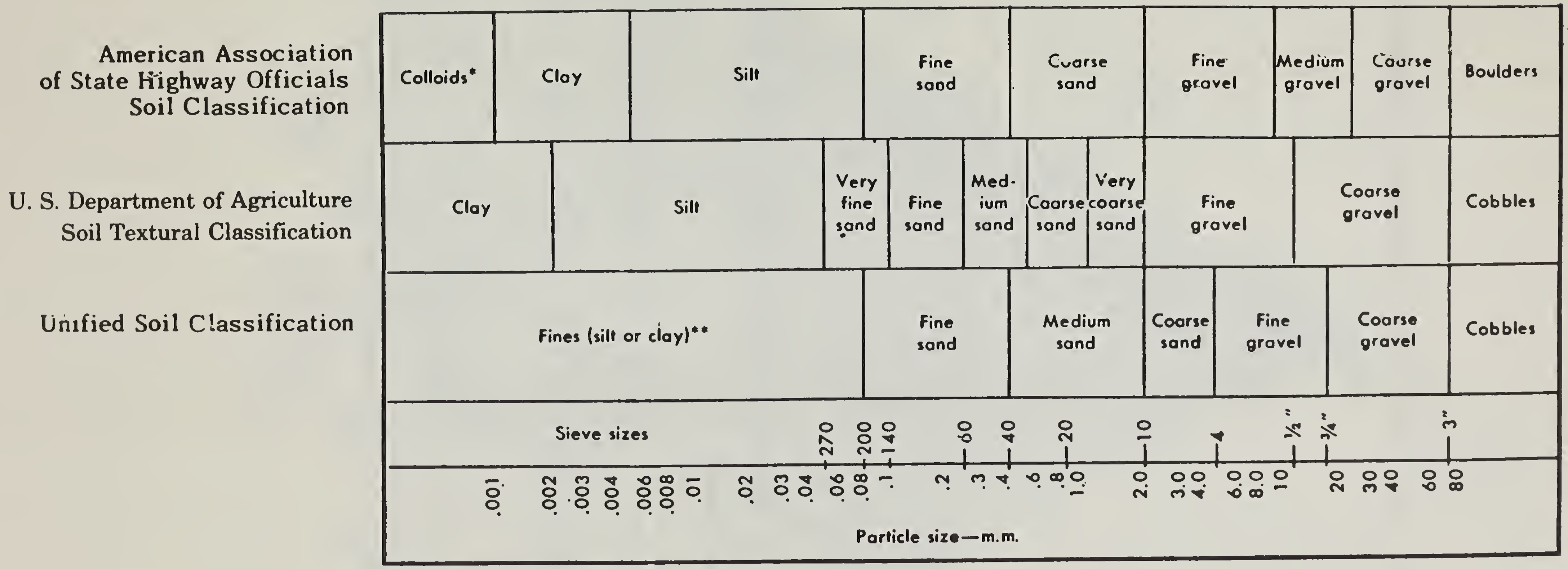
USDA textural classes are related to classes in both the Unified and AASHO systems. These relationships are not perfect. Yet, they are good enough for predicting the likely engineering class, or classes, for each textural class. Guide Sheet 15 sets forth the common, or frequently occurring, relationships. The fourth column provides additional clues to what the likely relationships are. Guide Sheet 15 should be used for those soils for which mechanical analyses are not at hand, but it should be used with the understanding that there are some exceptions to the indicated relationships. Also, it should be used along with other clues about relationships that may be uncovered in studying the soils of a survey area. Of course, if mechanical analyses data are available, they should be used in preference to Guide Sheet 15.

Guide Sheet 15.--General relationship of systems used for classifying soil samples

[This table may be used as a guide in classifying soils for which no engineering test data are available. The symbol > means "greater than;" the symbol < means "less than."]

USDA texture class and symbol	Unified symbol	AASHO symbol	Soil properties related to classifications
Clay; silty clay	CH	A-7	High shrink-swell clays.
"c"; "sic"	MH	A-7	Mica, iron oxide, kaolinitic clays.
	CL	A-7	Low LL. Generally < 45 pct clay.
Silty clay loam	CL	A-7	Low LL. Plastic. (A-6 if clay < 30 pct).
"sicl"	ML-CL	A-7	Low LL. Mod. plastic. (A-6 if clay < 30 pct).
	CH	A-7	High LL. High shrink-swell clays.
	MH	A-7	High LL. Mica, iron oxide, kaolinitic.
Clay loam	CL	A-6 or A-7	Low LL. Plastic.
"cl"	ML-CL	A-6	Low LL. Moderately plastic.
	CH	A-7	High LL. High shrink-swell clays.
	MH	A-7	High LL. Mica, iron oxide, kaolinitic.
Loam	ML-CL	A-4	Moderately plastic (A-6 if clay > 21 pct).
"l"	CL	A-6	Plastic (A-4 if clay < 22 pct).
	ML	A-4	Low plasticity (A-7 if clay > 21 pct).
Silt loam	ML-CL	A-4	Moderately plastic (A-6 if clay > 21 pct).
"sil"	ML	A-4	Low plasticity (A-7 if clay > 21 pct).
	CL	A-6	Plastic.
Silt - "si"	ML	A-4	Low plasticity.
Sandy clay	CL	A-7	Fines > 50 pct.
"sc"	SC	A-7	Fines 50 pct or less.
Sandy clay loam	SC	A-6	Plastic. Fines 36-50 pct.
"scl"	SC	A-2-6	Plastic. Fines 35 pct or less.
	CL	A-6	Plastic. Fines > 50 pct.
Sandy loam	SM	A-2-4 or A-4	Low plasticity.
"sl"	SC	A-2-4	Plastic.
	SM-SC	A-2-4	Moderately plastic.
Fine sandy loam	SM	A-4	Nonplastic. Fines 50 pct or less.
"fsl"	ML	A-4	Nonplastic. Fines > 50 pct.
	ML-CL	A-4	Moderately plastic. Fines > 50 pct.
	SM-SC	A-4	Moderately plastic. Fines 50 pct or less.
Very fine sandy loam	ML-CL	A-4	Moderately plastic.
"vfsl"	ML	A-4	Low plasticity.
Loamy sands	SM	A-2-4	Nonplastic. Fines 35 pct or less.
"ls"; "lfs"	SM-SC	A-2-4	Moderately plastic. Fines 35 pct or less.
"lvfs"	SM	A-4	Low plasticity. Fines > 35 pct.
	ML	A-4	Little or no plasticity.
Sand; fine sand	SP-SM	A-3	Fines approx. 5-10 pct.
"s"; "fs"	SM	A-2-4	Fines approx. > 10 pct.
	SP	A-3	Fines < 5 pct.
Very fine sand	SM	A-4	Low plasticity.
"vfs"	ML	A-4	Little or no plasticity.
Coarse sand	SP; GW	A-1	Fines < 5 pct.
"cs"	SP-SM	A-1	Fines 5-12 pct.
	SM	A-1	Fines 13-25 pct.
	SM	A-2-4	Fines > 25 pct.
Gravel, "G"	GP;GW	A-1	Fines < 5 pct.
50 pct passes No.200	GM or GC	A-1	Fines 5-25 pct.
50 pct of coarse	GM or GC	A-2	Fines 26-35 pct.
passes No. 4 sieve	GM	A-4	Fines > 35 pct.
	GC	A-6	Fines > 35 pct.

CHART 1. A COMPARISON OF GRAIN-SIZE LIMITS IN THE 3 CLASSIFICATION SYSTEMS.



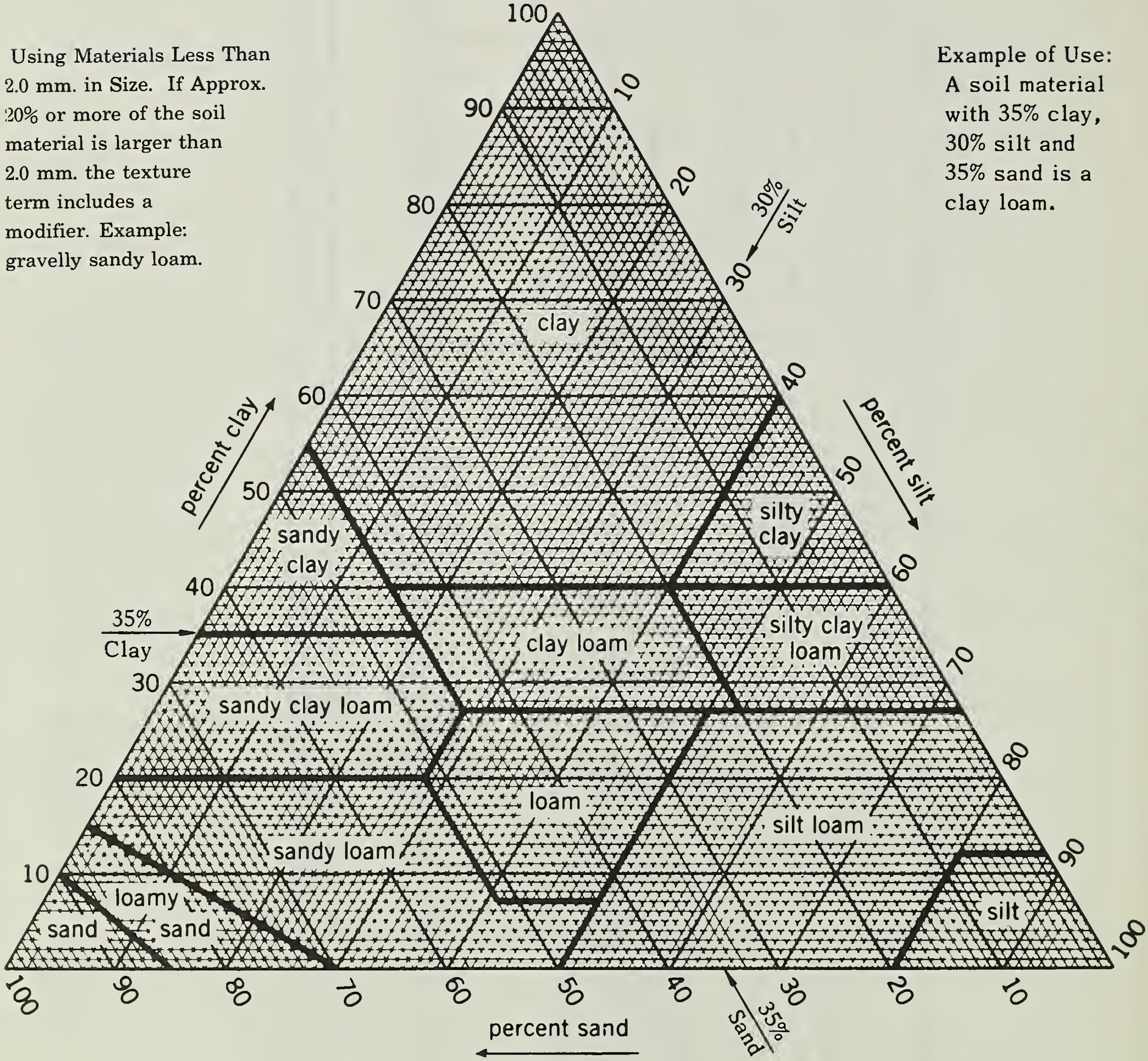
*Colloids included in clay fraction in test reports.
**The L.L. and P.I. of "Silt" plot below the "A" line on the plasticity chart, Table 4 and the L.L. and P.I. for "Clay" plot above the "A" line.

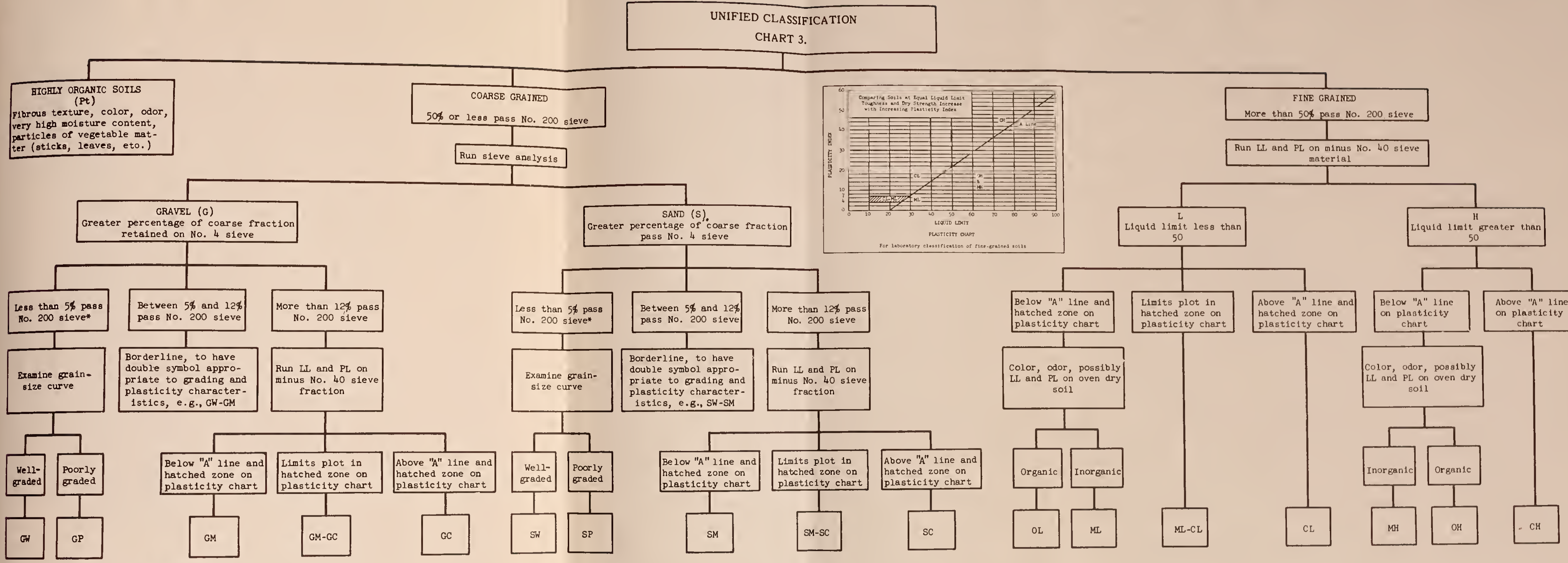
Modified from PCA Soil Primer

CHART 2. GUIDE FOR USDA SOIL TEXTURAL CLASSIFICATION.

Using Materials Less Than 2.0 mm. in Size. If Approx. 20% or more of the soil material is larger than 2.0 mm. the texture term includes a modifier. Example: gravelly sandy loam.

Example of Use: A soil material with 35% clay, 30% silt and 35% sand is a clay loam.





Note: Sieve sizes are U. S. Standard.

* If fines interfere with free-draining properties use double symbol such as GW-GM, etc.

This table is adapted from the Military Standard-Unified Soil Classification System for roads, airfields, embankments, and foundations. Mil.-Std-619B, 1968

CHART 4 CLASSIFICATION OF SOILS AND SOIL-AGGREGATE MIXTURES

General Classification	Granular Materials (35% or less passing No. 200)							Silt-Clay Materials (More than 35% passing No. 200)			
Group Classification	A-1			A-2							A-7
	A-1-a	A-1-b	A-3	A-2-4	A-2-5	A-2-6	A-2-7	A-4	A-5	A-6	A-7-5 A-7-6
Sieve Analysis, Percent passing: No. 10 No. 40 No. 200	50 max. 30 max. 15 max.	— 50 max. 25 max.	— 51 min. 10 max.	— — 35 max.	— — 35 max.	— — 35 max.	— — 35 max.	— — 36 min.	— — 36 min.	— — 36 min.	— — 36 min.
Characteristics of Fraction passing No. 40: Liquid limit Plasticity index	— 6 max.		— N.P.	40 max. 10 max.	41 min. 10 max.	40 max. 11 min.	41 min. 11 min.	40 max. 10 max.	41 min. 10 max.	40 max. 11 min.	41 min. 11 min.[a]
Usual Types of Significant Constituent Materials	Stone Fragments, Gravel and Sand		Fine Sand	Silty or Clayey Gravel and Sand				Silty Soils		Clayey Soils	
General Rating as Subgrade	Excellent to Good					Fair to Poor					

[a] Plasticity index of A-7-5 subgroup is equal to or less than LL minus 30. Plasticity index of A-7-6 subgroup is greater than LL minus 30 (see Figure 2).

From AASHO Designation: M 145-66 I <u>in</u> Interim Specifications and Methods Adopted by the AASHO Committee on Materials 1966-1967, published by the American Association of State Highway Officials in 1968.

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SAMPLE TABLE A.--Estimated soil properties significant to engineering

[Absence of data indicates that the soil is too variable to be rated or that no estimate was made. The symbol > means greater than; the symbol < means less than]

Soil series and map symbols (1)	Depth to-- Bedrock (2)	Depth to-- Seasonal high water table (3)	Depth from surface (4)	Classification USDA texture (5)	Classification Unified (6)	Classification AASHO (7)	Coarse fraction greater than 3 inches (7a)	Percentage less than 3 inches passing sieve-- No. 4 (4.7 mm.) (8)	No. 10 (2.0 mm.) (9)	No. 40 (0.42 mm.) (10)	No. 200 (0.074 mm.) (11)	Liquid limit (12)	Plasticity index (13)	Permeability (14)	Available water capacity (15)	Reaction (16)	Salinity (17)	Shrink-swell potential (18)	Corrosivity Uncoated steel (19)	Corrosivity Concrete (20)
	Ft.	Ft.	In.				Pct.							In./hr.	In./in. of soil	pH	Mmhos/cm. at 25° C.			
Alaga: AaB, AaC, AaD, AeE2-- For properties of Esto part of AeE2, see Esto series.	>5	>5	0-60	Loamy sand------	SM	A-2	-----	95-100	95-100	50-75	15-30	[1] NP	[1] NP	>6.0	0.06-0.08	4.5-6.0	-----	Low-------	-------------	
Esto: EsB, EsB2, EsC2, EtD3--	>5	>5	0-10	Loamy sand------	SM	A-2	-----	95-100	95-100	60-75	15-30	NP	NP	>6.0	0.06-0.08	6.6-6.8	-----	Low-------	-------------	
			10-43	Sandy clay or clay.	SC or CL	A-6 or A-7	-----	95-100	95-100	70-85	40-60	30-50	15-25	0.2-0.6	0.11-0.13	5.1-6.0	-----	Moderate to high.	-------------	
			43-72	Sandy loam------	SC	A-2	-----	95-100	95-100	65-80	20-30	25-40	10-20	0.2-0.6	0.08-0.10	5.1-6.0	-----	Low-------	-------------	
Gloucester: GcB, GcC, GcD-------------	>5	>3	0-4	Sandy loam------	SM	A-2	-----	60-90	55-85	45-70	25-35	NP	NP	2.0-6.0	0.08-0.13	4.5-5.5	-----	Low-------	Low-----------	
			4-13	Coarse sandy loam.	SM	A-2	15-30	75-80	65-75	40-60	20-30	NP	NP	2.0-6.0	0.08-0.13	4.5-5.5	-----	Low-------	Low-----------	
			13-44	Loamy sand and gravelly loamy sand.	SP-SM or SM	A-1	20-50	70-80	55-65	30-60	10-25	NP	NP	2.0-6.0	0.08-0.05	4.5-5.5	-----	Low-------	Low-----------	
GrB, GrC, GrD, GrE, GsD, GsE.	>5	>3	0-4	Sandy loam------	SM	A-2	10-35	60-90	55-85	45-70	25-35	NP	NP	2.0-6.0	0.07-0.12	4.5-5.5	-----	Low-------	Low-----------	
			4-13	Coarse sandy loam.	SM	A-2	20-40	75-80	65-75	40-65	20-30	NP	NP	2.0-6.0	0.07-0.12	4.5-5.5	-----	Low-------	Low-----------	
			13-44	Loamy sand and gravelly loamy sand.	SP-SM or SM	A-1	30-50	70-80	55-65	30-60	10-25	NP	NP	2.0-6.0	0.05-0.07	4.5-5.5	-----	Low-------	Low-----------	
Gullied land: Gu. Too variable to be rated.																				
Kent: KtE-------------------	>10	>10	0-10	Silt loam-------	CL	A-4 or A-6	-----	95-100	90-100	90-100	60-90	25-35	10-15	0.2-2.0	0.16-0.20	6.0-7.0	-----	Moderate to high.	-------------	Low.
			10-29	Silty clay or clay.	CH	A-7	-----	95-100	95-100	90-100	80-90	55-70	30-40	0.06-0.2	0.16-0.18	5.5-7.0	-----	High------	-------------	Low.
			29-66	Silty clay------	CH or CL	A-7	-----	95-100	95-100	90-100	80-100	45-60	20-30	0.06-0.2	0.15-0.17	7.5-8.4	-----	High------	-------------	Low.
Pond: Po--------------------	>5	>5	0-4	Loam------------	CL	A-4	-----	95-100	95-100	85-95	55-70	10-15	10-15	0.6-2.0	0.15-0.16	7.9-8.4	4-16	Moderate--	Moderate------	
			4-24	Clay loam-------	MH	A-7	-----	95-100	95-100	90-100	90-100	75-85	30-40	0.2-0.6	0.17-0.18	> 9.0	> 16	High------	High----------	
			24-66	Silt loam-------	MH	A-6	-----	90-100	90-100	90-100	85-95	75-85	35-45	0.6-2.0	0.17-0.16	> 7.9	> 16	High------	High----------	
Rubicon: RsB, RsD-----------	>10	>10	0-3	Sand------------	SP or SM	A-3 or A-2	-----	95-100	95-100	60-80	5-15	NP	NP	6.0-10.0	0.04-0.06	4.5-6.0	-----	Low-------	-------------	
			3-28	Sand------------	SP or SP-SM	A-3	-----	95-100	90-100	60-80	0-10	NP	NP	>10.0	0.02-0.04	4.5-6.0	-----	Low-------	-------------	
			28-66	Sand------------	SP	A-3	-----	95-100	95-100	60-80	0-5	NP	NP	>10.0	0.03-0.1	6.0-6.5	-----	Low-------	-------------	
Shapleigh: SgB, SgC, ShC, ShD, ShE, SoD, SoE. For properties of Gloucester parts of these units, see Gloucester series.	1-1½	1-1½	0-17	Sandy loam and loamy sand.	SM	A-2	20-50	75-90	65-85	50-70	20-35	NP	NP	2.0-6.0	0.08-0.13	4.5-5.5	-----	Low-------	-------------	
Whitman: Wa- ---------------	>5	[2] 0	0-8	Loam------------	OL or SM	A-4	10-35	80-90	75-85	60-75	40-60	----	----	0.6-2.0	0.13-0.17	4.5-5.5	-----	Low to moderate	-------------	
			8-17	Fine sandy loam-	SM	A-2 or A-4	20-40	80-90	70-80	55-65	30-40	----	----	0.6-2.0	0.13-0.17	4.5-5.5	-----	Low-------	-------------	
			17-41	Gravelly loam and gravelly sandy loam.	SM	A-2 or A-4	30-50	75-85	65-75	50-60	20-40	----	----	0.2-0.6	0.13-0.17	4.5-5.5	-----	Low-------	-------------	

[1] NP= Nonplastic.

[2] Subject to flooding.

Explanation: Entries in this sample table, adapted from published soil surveys, are for purposes of illustration only; they are not necessarily authoritative. Except for the column numbers, the format shown is the one to be used in preparing a table for subsequent editing. The column numbers refer to explanations in the accompanying text in this guide. If, for an entire survey area, there would be only a few entries, as in columns 17 and 20, the columns should be omitted and the information should be given in a footnote or in the text.

SAMPLE TABLE B.-- Interpretations of engineering properties of the soils

Soil series and map symbols (1)	Degree and kind of limitation for--						Suitability as source of--			Soil features affecting--				
	Septic tank absorption fields (2)	Sewage lagoons (3)	Shallow excavations (4)	Dwellings without basements (5)	Sanitary landfill (6)	Local roads and streets (7)	Road fill (8)	Sand (9)	Topsoil (10)	Pond reservoir areas (11)	Dikes, levees, and other embankments (12)	Drainage for crops and pasture (13)	Irrigation (14)	Terraces and diversions (15)
Alaga: AaB, AaC	Slight [1]	Severe: rapid permeability; slope.	Severe: sidewall instability.	Slight	Severe: rapid permeability; sandy.	Slight	Good	Poor: [2] fines [3]	Poor: sandy	High seepage potential.	Seepage potential.	Well drained	Rapid infiltration; low available water capacity.	Not suitable for terraces: erosion hazard.
AaD, AeE2. For interpretations for Esto part of AeE2, see Esto series.	Moderate [1]: slope.	Severe: rapid permeability; slope.	Severe: sidewall instability.	Moderate: slope.	Severe: rapid permeability; sandy.	Moderate: slope.	Good	Poor: [2] fines [3]	Poor: sandy	High seepage potential.	Seepage potential.	Well drained	Rapid infiltration; low available water capacity.	Not suitable for terraces: erosion hazard.
Esto: AeE2. For interpretations for Alaga part of AeE2, see Alaga series.	Severe: slow permeability.	Severe: slope	Moderate: difficult to work.	Moderate: moderate to high shrink-swell potential.	Moderate: difficult to work.	Severe: slope; moderate to high shrink-swell potential.	Fair: moderate to high shrink-swell potential.	Unsuited: no sand.	Poor: surface layer too sandy.	Slow permeability in subsoil.	Moderate strength; fair stability.	Well drained	Moderate infiltration; low available water capacity; shallow root zone.	Shallow over compact layer.
EsB, EeB2, EsC2	Severe: slow permeability.	Moderate: slope.	Moderate: difficult to work.	Moderate: moderate to high shrink-swell potential.	Moderate: difficult to work.	Moderate: moderate to high shrink-swell potential.	Fair: moderate to high shrink-swell potential.	Unsuited: no sand.	Poor: surface layer too sandy.	Slow permeability in subsoil.	Moderate strength; fair stability.	Well drained	Moderate infiltration; low available water capacity; shallow root zone.	Shallow over compact layer.
EtD3	Severe: slow permeability.	Severe: slope	Moderate: difficult to work.	Moderate: moderate to high shrink-swell potential.	Moderate: difficult to work.	Moderate: slope; moderate to high shrink-swell potential.	Fair: moderate to high shrink-swell potential.	Unsuited: no sand.	Poor: surface layer too sandy.	Slow permeability in subsoil.	Moderate strength; fair stability.	Well drained	Moderate infiltration; low available water capacity; shallow root zone.	Shallow over compact layer.
Gloucester: GcB	Slight [1]	Severe: moderately rapid permeability; stones.	Moderate: stones	Slight	Severe: rapid permeability; stones.	Slight	Good: stony in places.	Unsuited: no sand.	Poor: less than 8 inches of suitable material; stones.	Rapid permeability; stones.	Moderate permeability; fair stability; stones.	Well drained	Rapid infiltration; low available water capacity.	Short uneven slopes in places; stones.
GcC	Moderate [1]: slope.	Severe: moderately rapid permeability; stones.	Moderate: slope; stones.	Moderate: slope.	Severe: rapid permeability; stones.	Moderate: slope.	Good: stony in places.	Unsuited: no sand.	Poor: less than 8 inches of suitable material; stones.	Rapid permeability; stones.	Moderate permeability; fair stability; stones.	Well drained	Rapid infiltration; low available water capacity.	Short uneven slopes in places; stones.
GcD	Severe [1]: slope.	Severe: moderately rapid permeability; stones.	Severe: slope; stones.	Severe: slope	Severe: rapid permeability; stones.	Severe: slope	Good: stony in places.	Unsuited: no sand.	Poor: less than 8 inches of suitable material; stones.	Rapid permeability; stones.	Moderate permeability; fair stability; stones.	Well drained	Rapid infiltration; low available water capacity.	Short uneven slopes in places; stones.
GrB	Slight [1]	Severe: moderately rapid permeability; stones.	Moderate: stones	Moderate: stones.	Severe: rapid permeability; stones.	Moderate: slope; stones.	Good: stony in places.	Unsuited: no sand.	Poor: less than 8 inches of suitable material; stones.	Rapid permeability; stones.	Moderate permeability; fair stability; stones.	Well drained	Rapid infiltration; low available water capacity.	Short uneven slopes in places; stones.
GrC	Moderate [1]: slope.	Severe: moderately rapid permeability; stones.	Moderate: slope; stones.	Moderate: slope; stones.	Severe: rapid permeability; stones.	Moderate: slope; stones.	Good: stony in places.	Unsuited: no sand.	Poor: less than 8 inches of suitable material; stones.	Rapid permeability; stones.	Moderate permeability; fair stability; stones.	Well drained	Rapid infiltration; low available water capacity.	Short uneven slopes in places; stones.
GrD	Severe: slope	Severe: moderately rapid permeability; stones.	Severe: slope; stones.	Severe: slope; stones.	Severe: rapid permeability; stones.	Severe: slope; stones.	Good: stony in places.	Unsuited: no sand.	Poor: less than 8 inches of suitable material; stones.	Rapid permeability; stones.	Moderate permeability; fair stability; stones.	Well drained	Rapid infiltration; low available water capacity.	Short uneven slopes in places; stones.
GrE, GrD, GsE	Severe [1]: slope; stones.	Severe: moderately rapid permeability; stones.	Severe: slope; stones.	Severe: slope; stones.	Severe: rapid permeability; stones.	Severe: slope; stones.	Good: stony in places.	Unsuited: no sand.	Poor: less than 8 inches of suitable material; stones.	Rapid permeability; stones.	Moderate permeability; fair stability; stones.	Well drained	Rapid infiltration; low available water capacity.	Short uneven slopes in places; stones.
Gullied land: Gu. Severe limitations for most uses.														

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SAMPLE TABLE B.--Alpha County, Alabama--continued; page 2.

Soil series and map symbols (1)	Degree and kind of limitation for--						Suitability as source of--			Soil features affecting--				
	Septic tank absorption fields (2)	Sewage lagoons (3)	Shallow excavations (4)	Dwellings without basements (5)	Sanitary landfill (6)	Local roads and streets (7)	Road fill (8)	Sand (9)	Topsoil (10)	Pond reservoir areas (11)	Dikes, levees, and other embankments (12)	Drainage for crops and pasture (13)	Irrigation (14)	Terraces and diversions (15)
Kent: KtE	Severe: slow permeability; slope.	Severe: slope.	Severe: slope.	Severe: slope; high shrink-swell potential.	Severe: slope.	Severe: slope; high shrink-swell potential.	Poor: difficult to work; slope.	Unsuited: 2/ no sand.	Poor: reclamation of borrow site difficult.	Slow permeability.	Slow permeability; high volume change on wetting and drying.	Moderately well drained.	Steep slopes; slow intake rate; slow permeability; high available water capacity.	Short uneven slopes in places; difficult to work.
Pond: Po, Ps	Severe: moderately slow permeability between depths of 4 and 24 inches.	Moderate: moderate permeability at a depth of 24 inches.	Moderate: hard when dry.	Severe: high shrink-swell potential.	Slight.	Severe: high shrink-swell potential.	Poor: high shrink-swell potential; unfavorable texture.	Unsuited: 2/ no sand.	Poor: saline.	Moderately slow permeability.	Low to moderate strength; variable stability; susceptibility to piping and cracking.	Moderately well drained.	High available water capacity; moderately slow permeability.	Not needed.
Rubicon: RsB	Slight 1/	Severe: rapid permeability.	Severe: sidewall instability.	Slight.	Severe: rapid permeability; sandy.	Slight.	Good.	Good.	Poor: sandy.	Too sandy to hold water unless seal blanket is used	Poor to fair stability; high permeability; low resistance to piping.	Well drained.	Very low available water capacity; very rapid intake rate; uneven relief; poor suitability for farming.	Not needed.
RsD	Moderate if slope is less than 15 percent, severe if more than 15 percent 1/.	Severe: rapid permeability.	Severe: sidewall instability.	Moderate if slope is less than 15 percent, severe if more than 15 percent.	Severe: rapid permeability; sandy.	Moderate if slope is less than 12 percent, severe if more than 12 percent.	Good if slope is less than 15 percent, moderate if more than 15 percent.	Good.	Poor: sandy.	Too sandy to hold water unless seal blanket is used.	Poor to fair stability; high permeability; low resistance to piping.	Well drained.	Very low available water capacity; very rapid intake rate; uneven relief; poor suitability for farming.	Not needed.
Shapleigh: SgB, SgC. For interpretations for Gloucester parts of these units, see Gloucester series.	Severe: shallow over bedrock.	Severe: shallow over bedrock.	Severe: shallow over bedrock.	Severe: shallow over bedrock; stones.	Severe: shallow over bedrock; stones.	Severe: shallow over bedrock.	Poor: too shallow over bedrock.	Unsuited; no sand.	Poor: shallow; stony.	Shallowness over bedrock; stones.	Shallowness over bedrock; stones; rapid permeability.	Well drained.	Shallowness over bedrock; stones.	Shallowness over bedrock; stones.
ShC, ShD, ShE, SoD, SoE. For interpretations for Gloucester parts of these units, see Gloucester series.	Severe: exposed bedrock	Severe: exposed bedrock.	Severe: shallow over bedrock.	Severe: shallow over bedrock; stones.	Severe: shallow over bedrock; stones.	Severe: exposed bedrock.	Poor: too shallow over bedrock.	Unsuited; no sand.	Poor: shallow; stony.	Shallowness over bedrock; stones.	Shallowness over bedrock; stones; rapid permeability.	Well drained.	Shallowness over bedrock; stones.	Shallowness over bedrock; stones.
Whitman: Wa	Severe: high water table.	Severe: high water table; stones.	Severe: high water table.	Severe: high water table.	Severe: high water table; stones.	Severe: high water table.	Poor: high water table.	Unsuited; no sand.	Poor: stony; high water table.	Moderate to slow permeability; high water table.	Moderate to slow permeability; stones.	High water table; pan layer in places.	Generally not irrigated.	Not needed.

1/ Pollution is a hazard in places because of permeability in substratum.

2/ Locally, gravel occurs below a depth of 3 to 5 feet.

3/ Too much material smaller than 0.074 mm. (No. 200 sieve size).

Explanation: Entries in this sample table, adapted from published soil surveys, are for purposes of illustration only; they are not necessarily authoritative. Except for the column numbers, the format shown is the one to be used in preparing a table for subsequent editing. The column numbers refer to explanations in the accompanying text.

SAMPLE TABLE C.-- Engineering test data

(Tests made by

[Absence of an entry indicates that no determination was made])

Soil name and location (1)	Parent material (2)	Report number (3)	Depth (4)	Moisture density 1/ Maximum dry density (5)	Moisture density 1/ Optimum moisture (6)	Mechanical analysis 2/ Percentage less than 3 inches passing sieve-- 1 in. (7)	3/4 in. (8)	3/8 in. (9)	No. 4 (4.7 mm.) (10)	No. 10 (2.0 mm.) (11)	No. 40 (0.42 mm.) (12)	No. 200 (0.074 mm.) (13)	Percentage smaller than-- 0.05 mm. (14)	0.005 mm. (15)	0.002 mm. (16)	Liquid limit 3/ (17)	Plasticity index 4/ (18)	Classification AASHO 5/ (19)	Classification Unified 6/ (20)
			In.	Lb./cu. ft.	Pct.											Pct.			
Esto loamy sand: NW¼SW¼NW¼ sec. 30, T. 1 N., R. 27 E. (Modal profile)	Unconsolidated marine-deposited sand and clay.		0-5	120	9	--	100	--	99	99	68	15	--	--	8	7/NP	7/NP	A-2-6(0)	SM
			15-20	108	15	--	100	--	99	99	80	46	--	--	39	36	18	A-6(4)	SC
			20-43	118	13	--	---	--	100	99	78	42	--	--	38	41	25	A-7-6(6)	SC
			43-72	122	11	--	100	--	99	98	67	24	--	--	23	28	12	A-2-6(0)	SC
Esto soils: NE¼SE¼SE¼ sec. 28, T. 1 N., R. 26 E. (More friable than modal profile and thicker solum)	Marine deposits.		0-9	116	9	--	100	--	99	99	63	11	--	--	5	NP	NP	A-2-4(0)	SM
			15-21	116	12	--	100	--	99	98	68	30	--	--	24	27	12	A-2-6(0)	SC
			21-39	102	19	--	---	--	100	99	68	47	--	--	46	52	24	A-7-6(8)	SM-SC
			39-72	110	14	--	---	--	100	99	69	35	--	--	25	44	21	A-2-7(2)	SC
Gloucester very stony loam: 1.25 miles east and 100 yards north of Alton. (Modal profile)	Glacial till.		0-4	---	--	--	96	--	91	88	70	33	28	6	4	NP	NP	A-2-4(0)	SM
			4-13	---	--	--	83	--	75	70	52	21	17	2	2	NP	NP	A-2-4(0)	SM
			24-44	---	--	--	70	--	60	54	38	11	9	2	1	NP	NP	A-1-b(0)	SM
1 mile east of Route 28 along Alton to Merrymeeting Lake Rd. (Platy C horizon variant)	Glacial till.		0-5	---	--	--	34	--	--	30	26	13	11	3	2	NP	NP	A-2-4(0)	SM
			9-16	---	--	--	89	--	81	76	61	27	22	3	2	NP	NP	A-2-4(0)	SM
			26-40	---	--	--	98	--	94	91	76	35	29	6	3	NP	NP	A-2-4(0)	SP-SM
200 yards east of Hills Pond. (Gravelly variant)	Glacial till.		0-5	---	--	--	85	--	79	72	50	20	15	4	3	NP	NP	A-2-4(0)	SM
			5-14	---	--	--	90	--	77	66	46	18	13	4	2	NP	NP	A-2-4(0)	SM
			24-46	---	--	--	100	--	88	78	52	13	9	3	2	NP	NP	A-2-4(0)	SM
Kent silt loam: SW¼SW¼NW¼ sec. 13, T. 12 N., R. 15 W. (Modal profile)	Stratified silty clay		0-10	---	--	--	---	--	--	--	100	89	83	38	27	34	13	A-6(9)	CL
			17-29	---	--	--	---	--	--	--	---	99	99	73	58	68	42	A-7-6(20)	CH
			29-66	---	--	--	---	--	--	--	---	99	99	76	56	54	30	A-7-6(19)	CH
SE¼NE¼SW¼NW¼ sec. 10, T. 9 N., R. 11 W. (Coarser textured than modal profile)	Glacial till.		0-7	---	--	--	---	--	--	100	98	72	68	41	31	27	9	A-4(7)	CL
			14-26	---	--	--	---	--	--	--	100	90	87	58	46	56	31	A-7-6(19)	CH
			26-66	---	--	--	---	--	--	100	99	91	88	53	39	43	22	A-7-6(13)	CL
Pond loam: 40 feet east of dirt road that is 0.15 mile south of Ave. 1 and 0.25 mile west of 30th Street West; SE¼NE¼ sec. 18, T. 7 N., R. 12 W.	Granitic alluvium.		4-17	89	28	--	---	--	--	--	---	93	89	55	52	81	36	A-7-6(20)	MH
			24-44	92	29	--	---	--	--	--	---	92	89	69	68	81	43	A-7-6(20)	MH
Rubicon sand: NW¼NE¼NW¼ sec. 22, T. 10 N., R. 15 W. (Modal profile)	Sandy glacial outwash.		0-3	---	--	--	---	--	--	100	80	12	12	6	4	NP	NP	A-2-4(0)	SP-SM
			10-19	---	--	--	---	--	--	100	82	8	8	5	4	NP	NP	A-3(0)	SP-SM
			28-66	---	--	--	---	--	--	98	68	2	2	1	1	NP	NP	A-3(0)	SP
SE¼SE¼SW¼ sec. 28, T. 11 N., R. 15 W. (Grading to Grayling soils)	Sandy glacial outwash.		4-12	---	--	--	---	--	--	96	64	5	5	4	3	NP	NP	A-3(0)	SP-SM
			12-20	---	--	--	---	--	--	93	64	4	4	4	3	NP	NP	A-3(0)	SP
			24-66	---	--	--	---	--	--	95	63	1	1	1	1	NP	NP	A-3(0)	SP
NE¼NE¼SE¼ sec. 2, T. 12 N., R. 18 W. (Grading to Rousseau and Kalkaska soils)	Sandy glacial outwash.		10-15	---	--	--	---	--	--	100	84	17	15	4	2	NP	NP	A-2-4(0)	SM
			15-21	---	--	--	---	--	--	100	85	7	7	4	3	NP	NP	A-3(0)	SP-SM
			21-66	---	--	--	---	--	--	100	86	2	2	0	0	NP	NP	A-3(0)	SP

1/ Based on AASHO Designation T 99-57, Method A (1).

2/ Mechanical analyses according to the AASHO Designation T 88-57 (1). Results by this procedure may differ somewhat from the results obtained by the soil survey procedure of the Soil Conservation Service (SCS). In the AASHO procedure, the fine material is analyzed by hydrometer method, and the various grain-size fractions are calculated on the basis of all material up to and including that 3 inches in diameter. In the SCS soil survey procedure, the fine material is analyzed by the pipette method, and the material coarser than 2 millimeters in diameter is excluded from the calculation of grain-size fractions. The mechanical analyses data used in this table are not suitable for use in naming textural classes of soil.

3/ Based on AASHO Designation T 89-60 (1).

4/ Based on AASHO Designation T 90-56 and AASHO Designation T 91-54 (1).

5/ Based on AASHO Designation M 145-49 (1).

6/ Based on ASTM Designation D 2487-66 T (3).

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SAMPLE TABLE D.-- Size of manuscript tables A, B, and C

Soil series and map symbols	Degree and kind of limitation for--						Suitability as source of--			Soil features affecting--				
	Septic tank absorption fields	Sewage lagoons	Shallow excavations	Dwellings without basements	Sanitary landfill	Local roads and streets	Road fill	Sand	Topsoil	Pond reservoir areas	Dikes, levees, and other embankments	Drainage for crops and pasture	Irrigation	Terraces and diversions
Alaga:														
AaB, AaC----	Slight[1]---------	Severe: rapid permeability; slope.	Severe: sidewall instability.	Slight---------	Severe: rapid permeability; sandy.	Slight---------	Good-----------	Poor: fines[2]-----	Poor: sandy-----	High seepage potential.	Seepage potential.	Well drained----	Rapid infiltration; low available water capacity.	Not suitable for terraces: erosion hazard.
AaD, AeE2---- For interpretations for Esto part of AeE2, see Esto series.	Moderate[1]: slope.	Severe: rapid permeability; slope.	Severe: sidewall instability.	Moderate: slope.	Severe: rapid permeability; sandy.	Moderate: slope.	Good-----------	Poor: fines[2]-----	Poor: sandy-----	High seepage potential.	Seepage potential.	Well drained----	Rapid infiltration; low available water capacity.	Not suitable for terraces: erosion hazard.
Esto:														
AeE2--------- For interpretations for Alaga part of AeE2, see Alaga series.	Severe: slow permeability.	Severe: slope--	Moderate: workability.	Moderate: shrink-swell potential.	Moderate: workability.	Severe: slope; shrink-swell potential.	Fair: moderate to high shrink-swell potential.	Unsuited: no sand.						Shallow over compact layer.
EsB, EsB2, EsC2.	Severe: slow permeability.	Moderate: slope.	Moderate: workability.	Moderate: shrink-swell potential.	Moderate: workability.	Moderate: shrink-swell potential.	Fair: moderate to high shrink-swell potential.	Unsuited: no sand.						Shallow over compact layer.

Manuscript tables are preferred on paper of this size. This table, part of sample table B, is included in the Guide for purposes of illustration only.

1. Make top to bottom dimension 10½ inches, the same as that of regular typing paper used in the Federal Government. Fold in from the right as necessary for fitting the table into the soil survey manuscript. Note that folding from the bottom is not necessary.

2. Left to right dimension should not exceed 22 inches, which is 264 spaces if the table is typed on a typewriter with an elite keyboard.

3. Use continuation sheets as needed to complete each table. To identify continuation pages of a table, write in the upper left-hand corner of the page "TABLE ___.-- Survey area, State--continued; page ---." Repeat the column headings on each continuation sheet.

For this Guide, the original manuscript sheets for each table were combined, making each table one page. The single pages then were reduced about 50 percent. Sample table B, however, required two pages after reduction.