

ENGINEERING CLASSIFICATION OF PEDOLOGIC SOIL GROUPS  
IN KNOX COUNTY, TENNESSEE,  
FOR RESIDENTIAL HOUSING

by

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### III. INTRODUCTION

One of the important factors that govern the performance of structures is the soil encountered on the site. Heavy structures require detailed subsurface exploration and testing to characterize the foundation soil. Many advanced techniques for such investigations have been made and reported (Hvorslev, 1949). These advanced exploration methods involve high costs. Such expense is prohibitive for most light structures. There is need, therefore, to obtain and make available inexpensive preliminary subsurface investigation data covering broad areas. It might be feasible to process for engineering purposes the information contained in geologic and pedologic maps and reports that cover broad areas. In this way adverse site conditions such as flooding, frost action, expansive and shrinkage soils, and unsuitable sewage disposal locations, which are currently causing widespread failures (Henry, 1960) in residential developments, might more often be avoided. Preliminary work (Byers, 1961; Krebs and Hunter, 1961; and Miles, 1961) has demonstrated that it is possible to relate engineering properties of soils directly to pedologic classification by means of physical tests and field investigation and in that way provide the inexpensive data so badly needed to predict soil performance.

This study is concerned with the investigation of the feasibility of obtaining adequate data on soils in large areas using United States Department of Agriculture reports and maps. These maps and reports differ from those commonly used in engineering. Still, they may furnish

valuable information to the engineer as to topography, geology, drainage condition, particle size distribution, consistency, and depth to bedrock from the earth's surface. The USDA classification system might be adopted for initial engineering field identification, since it is practical to determine the engineering properties of soils in the USDA mapping units. Then, the data on the engineering characteristics determined for any one mapping unit occurring in any one area might later be used in other locations for which pedologic maps are available.

For this investigation, field and laboratory studies were made on soils from Knox County, Tennessee, where large amounts of construction activity is going on. Here, there is the advantage of the availability of an agricultural soil survey report and detailed map with a detailed description of each soil type in the county. On the basis of this information, tentative decisions were made on important soil engineering problems in the area. Subsequently, field investigation was conducted during November, 1961, with the aid of soil scientists and engineers from Virginia Polytechnic Institute, soil scientists from the Soil Conservation Service and the University of Tennessee, and engineers from the Federal Housing Administration. Soil samples were taken for such laboratory testing as the determination of grain size distribution, plasticity, and the expansive character of the soils. Finally, the various soils were assigned to definite engineering suitability categories on the basis of the literature, field, and laboratory studies. Methods of transferring this information to maps that can be easily read have been published (Hunter and Krebs, 1961; Moulthrop, 1961).

## IV. EARTH MATERIALS IN KNOX COUNTY, TENNESSEE

Knox County is in the eastern portion of Tennessee. The rock exposures are chiefly dolomitic limestone and a complex of limestones and shale derived from sediments of the Cambrian, Ordovician, and Silurian systems. The rock formations are severely faulted and folded. Most of the rugged ridges in the county consist of interbedded sandstone and shale and calcareous sandstone. The extensive valleys have formed in soft shale and argillaceous limestone.

The total area of the county is approximately 515 square miles. The general slope of the land is predominantly rolling and hilly, but there are some steep and rugged areas. Soils on uplands compose 76 percent of the county, 14 percent of the soils are on alluvial foot slopes and along drainageways, and stream terraces occupy 3 percent and first bottoms (recent floodplains) 7 percent of the county. The larger plains are alluvial, lying along the Tennessee, French Broad, Holston, and Olinch Rivers. The first bottoms lie as narrow strips along stream channels. The stream terraces range from 15 feet to 140 feet above the adjacent bottoms. These terraces lie as discontinuous areas near large streams. The alluvium along the river courses is generally a mixture of materials derived from shale, limestone, and sandstone. The soils in the uplands have formed over high grade limestone, cherty limestone, clayey or argillaceous limestone, calcareous shale, interbedded shale and limestone, calcareous sandstone, and acid shale.

About 20 per cent of the county has a steep slope of more than 25 per cent, lying largely in uplands. In other upland areas, the slope is undulating to steep. Undulating and rolling terrain is found on stream terraces, on foot slopes, and along drains. Soils on first bottoms are nearly level. Soils having a depth from the surface of more than five feet to bedrock occupy 57 per cent of the county, soils with a depth of 18 inches to five feet to rock are in 14 percent of the county, and 29 per cent of the county has a depth to bedrock of less than 20 inches. The drainage system is well developed because of the highly dissected terrain. However, impeded drainage occurs in some small tracts along drainageways, first bottoms, and on the floors of some geologic sinks (U.S.D.A., 1955). Topography exerts a strong influence on the thickness of the weathered residuum overlying bedrock and on the ability of surface water to penetrate the rock strata.

The properties of the weathered residuum overlying the relatively soluble limestone in Knox County vary widely, depending on whether the limestone is shaley, sandy, or cherty. The soil may be very high in clay in the case of a high grade limestone, high in silt in the case of a shaley limestone, sandy in the case of limestone high in sand, and cherty or cobbly in the case of a cherty limestone. In addition, the depth to bedrock or sound underlying substratum may be highly variable. Solution channels and cavities tend to develop in the highly calcareous rock. Such development is usually accelerated along natural joint or crack systems in the rock. This leads to the development of substantial cavities, which, if caving from the surface occurs, may become sink

holes. Such cavity and sink development is most extensive in valleys and on nearly level areas where the infiltration of water tends to be greatest.

Sandstone is usually the most resistant of the sedimentary rocks in humid areas. This seems to hold true for Knox County in most places. The weathered residuum that develops over the intact rock is predominantly sandy soil. The presence of appreciable quantities of shale tend to make the residuum more fine-grained. The depth of the soil derived from sandstone in Knox County normally does not exceed ten feet. The substratum is generally relatively high in permeability.

Shale often weathers to moderately plastic silty clay, but in Knox County there are variations in soil character depending on variations in the character of the shale bedrock. Where calcareous material is associated with the shale, the soils tend to be more plastic. Where the shale is especially intact, the depth of weathering is not great and the soil tends to contain large amounts of shale fragments. A noteworthy feature of shale is that much of its constituent represents the end product of a previous weathering cycle. Hence, chemical weathering is often not as important in its breakdown as mechanical disintegration. This disintegration tends to occur most easily along bedding planes so that planes of weakness develop near the surface of the rock. Where these are associated with lenses of plastic clay, which may develop from argillaceous limestone in the case of interbedded sediments, the instability of the planes of weakness is augmented. Accordingly,

interbedded limestone and shale may partially weather to produce dangerous engineering situations, especially where the individual beds are thin.

## V. CLASSIFICATION OF KNOX COUNTY SOILS

Most of the available literature concerning Knox County soils relates to their pedologic classification. This classification is basic in that it reflects such soil-forming factors as geology, topography, age, and climate. In as much as climate and vegetation are relatively uniform throughout the county, their contribution to soil differences is slight at best, but geology, topography, and age have had much to do with soil differences. This is shown in Table 1.

The pedologic classification of the soils in Knox County divides them into three main groups, zonal, intrazonal, and azonal, depending on the nature and amount of pedologic profile development shown. Zonal soils are considered as mature soils in equilibrium with their environment. They characteristically have well differentiated soil profiles and horizons. Zonal soils differ in nature from one climatic zone to another, but within any one zone, a particular type of zonal soil may be found over a large area where the land is well drained, but not too steep. Intrazonal soils have well developed profile characteristics resulting from and limited by the influence of some local factor such as relief, water table, or parent rock type. They are usually local in occurrence. Azonal soils are relatively young and reflect pedological soil-forming processes in their profile to a minimum degree. Again, some local factor such as steep, erodable slope, or periodic flooding and sedimentation has inhibited their development and widespread occurrence.

TABLE 1

Soil Series of Knox County, Tennessee, Classified by Soil Orders and Great Soil Groups, and Factors that Have Contributed to Differences in Soil Morphology\*

ZONAL			
Great Soil Group and Series	Relief	Parent Material	Time <sup>(1)</sup>
Red-yellow Podzolic:		Residium <sup>(a)</sup> weathered from -	
Decatur	Undulating to hilly	High grade limestone	Long
Dewey	Undulating to steep	"	"
Bolton	Rolling to steep	Arenaceous limestone or limestone with sandy beds	"
Fullerton	Undulating to steep	Moderately cherty limestone	"
Talbott	Undulating to hilly	Moderately argilla- ceous limestone	"
Farragut	"	High grade limestone over shale	"
Sequoia <sup>(2)</sup>	"	Interbedded shale and limestone and calcareous shale	"
Cumberland	"	Mixed general alluvium strongly influenced by - Limestone	"
Etowah	"	"	Medium
Waynesboro	"	Shale, sandstone and limestone	Long
Nolichucky	Rolling	"	"

TABLE 1 (cont'd)

ZONAL			
Great Soil Group and Series	Relief	Parent Material	Time <sup>(1)</sup>
Alcoa	Undulating to rolling	Local alluvium chief- ly from - Tellico soils	Medium to long
Bland <sup>(3)</sup>	Rolling to steep	Residuum weathered from - Dusky-red shaly limestone	Short to long
Tellico <sup>(3)</sup>	"	Calcareous lime- stone	"
Clarksville	"	Cherty limestone	Long
Sequatchie	Undulating to rolling	Mixed general alluvi- um derived largely from - Sandy rocks	Medium
Jefferson	"	Colluvium and local alluvium chiefly from - Muskingum and Lehigh soils	Medium to long
Leadvale	"	Dandridge, Armuchee, Litz, Sequoia, Montevallo, Muskin- gum and Lehigh soils	Long
Colbert <sup>(3)</sup>	Undulating to hilly	Residuum weathered from - Argillaceous lime- stone	Short to long
INTRAZONAL			
Planosols:		Mixed alluvium strong- ly influenced by -	
Wolftever	Undulating to rolling	Limestone, shale and sandstone	Long

TABLE 1 (cont'd)

INTRAZONAL			
Great Soil Group and Series	Relief	Parent Material	Time <sup>(1)</sup>
Guthrie <sup>(4)</sup>	Nearly level	Chiefly limestone	Very long
Tyler	"	Chiefly shale	"
AZONAL			
Alluvial soils:		General alluvium, strongly influenced by-	
Huntington	Nearly level	High grade limestone	Very short
Roane	"	Cherty limestone	"
Lindside	"	Limestone	"
Congaree	Nearly level to very gently undulating	Micaceous rocks	"
Chewacla	Nearly level	"	"
Staser	Nearly level to very gently undulating	Chiefly shale	"
Hamblen	Nearly level	"	"
		Local alluvium chiefly from -	
Emory	Undulating to rolling	Decatur, Dewey and Farragut soils	Very short to long
Greendale	"	Fullerton and Clarksville soils	"
Camp	Gently sloping to rolling	Bland soils	"
Abernathy	Nearly level	Decatur, Dewey and Farragut soils	Very short
Coltawah	"	"	"
Whitesburg	Undulating to rolling	Dandridge, Armuchee, Litz, and Sequoia	"

TABLE 1 (cont'd)

AZONAL			
Great Soil Group and Series	Relief	Parent Material	Time <sup>(1)</sup>
Alluvial soils:		Local alluvium chiefly from -	
Ootaco	Undulating to rolling	Muskingum, Lelew and Jefferson soils	Very short
Neubert	Undulating to rolling	Tellico soils	"
Melvin <sup>(5)</sup>	Nearly level	Limestone	Short
Prader <sup>(5)</sup>	"	Shale	"
Lithosols:		Residuum weathered from-	
Armuchee	Hilly to steep	Interbedded limestone and shale	Medium to very short
Dandridge	"	Calcareous shale	"
Litz	"	Leached shale	"
Montevallo	Undulating to steep	Acid shale	Short to very short
Muskingum	Hilly to steep	Chiefly sandstone	Medium to very short
Lelew	"	Dusky-red sandy shale	"

\* From U.S.D.A., 1955.

(1) The length of time that the materials have been in place as indicated by the degree of profile development.

(2) The Sequoia profile is partly within the range of red members and partly within that of the yellow members.

(3) These soils are relatively shallow to bedrock, have weakly differentiated or thin B-horizons, and are considered, therefore, to be intermediate between zonal soils and azonal lithosols. They are frequently described as being lithosolic.

TABLE 1 (cont'd)

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(4) Some of the Guthrie soil as mapped in Knox County classifies as alluvial soil with a gley horizon.

(5) These soils have gley horizons. Under recent refinements in classification, they would be classed as Low Huzic Gley soils.

(a) Residuals are materials that have been weathered or developed in place. These materials have not been moved from their original position.

(b) Alluvium is sand, mud and other sediments deposited on land by streams.

Colluvium is a mixed deposit of rock fragments and coarse soil material near the bases of steep slopes and deposited by gravity.

Podzolic soils are zonal soils that have developed in temperate, humid climates under the influence of forest vegetation. They are normally well developed in a pedologic sense and well drained. The red-yellow podzolic members of the podzolic group consist of organic topsoil and a thin, slightly bleached layer forming the so-called A horizon, with red, yellow or yellow-red clay and silty clay below forming the B horizon, and deep weathered fine-grained soil below forming a so-called C horizon. Although clay is common in such soils, it is generally considered to be kaolinitic and therefore not highly plastic in nature (U.S.D.A., 1938).

Planosols are intrazonal soils in which certain soil horizons are abruptly separated from adjoining horizons and form "clay pans". A "pan" is a layer or horizon of soil that is firmly compacted or markedly rich in clay. Planosols are usually light in color and occur on nearly level upland surfaces under grass or forest vegetation in humid areas. The individual soil horizons are more dense or compact than in the case of zonal soils. Planosols are usually moist with B horizons of plastic clay containing little pore space.

Lithosols are azonal soils without any clearly developed soil horizons. The soil material consists of fresh or imperfectly weathered rock fragments contained in a loose matrix of finer materials. They are confined largely to steep slopes and are subjected to geologic erosion due to their precarious topographic position. As a result, soil material is removed from the surface of the profile at least as

quickly as weathering and soil-forming processes allow it to accumulate. One may think of such soils as being young in a pedologic sense.

Alluvial soils consist of materials derived from the transportation and deposition of sediment by water. The soils characteristically receive new layers of material during each successive cycle of flooding and sedimentation, which may be as often as annually. Hence, alluvial soils are recent or young in age and possess little discernable profile development. They are generally found along the recent floodplains or first bottoms of streams, in depressions, and, with the very similar recent colluvium, along intermittent drainageways.

The United States Department of Agriculture Soil Conservation Service publishes maps and reports that provide information on soils from the agricultural point of view, with particular emphasis on pedologic classification. Preliminary attempts to use this available pedologic information for engineering purposes have met with some success. Health officials and the Federal Housing Administration have drawn upon the agricultural information for help in the location of individual sewage disposal systems. The need for this and further engineering use of this information is increasing. Recognizing this, the Soil Conservation Service (SCS) is now including a chapter on the engineering properties of the agricultural soil units in their reports. Certain of these soil units, called series, have been tested for engineering classification (U.S.D.A., 1959, 1961, and FHA, 1959). In addition, for Knox County, Wright (1960) conducted engineering tests on the Sequoia

and Decatur series. His conclusions, however, relate to highway engineering and are largely negative. Unfortunately, the SOS report for Knox County contains no chapter on soil engineering properties.

Of particular significance to defining the engineering properties of Knox County soils are recent agricultural reports of adjacent counties. Two of these, the Blount and Loudon County reports (U.S.D.A., 1959 and 1961), contain engineering data on many of the soil mapping units described as occurring in Knox County as well. Although these data are mainly oriented toward highway engineering, in certain respects they present valuable general information such as classification according to the Unified System and Atterberg limits and indices. The data are summarized for the B horizons of these soils in Table 2.

TABLE 2

**Engineering Characteristics of Some B-Horizon Soil Materials  
in Tennessee\***

<b>Series</b>	<b>County Where Sampled</b>	<b>Unified Classification</b>	<b>L.L.</b>	<b>P.I.</b>	<b>Swell or Shrinkage Potential</b>
Colbert	Loudon	MH	69	27	Very high
		MH-OH	86	50	"
		MH-OH	80	44	"
Decatur	"	OH	62	35	High
		MH-OH	83	40	"
		MH	57	25	"
	Blount	CL	47	28	"
Dewey	"	CL	34	15	"
		CL	38	20	"
Emory	"	CL	35	14	Moderate
		CL	46	22	"
Farragut	"	MH-OH	54	25	High
Fullerton	Loudon	MH-OH	70	35	"
		ML-OL	48	22	"
		MH-OH	64	33	"
Hamblen	Blount	CL	36	14	Moderate
Jefferson	"	CL	32	13	High
		CL	24	8	"
Leadvale	"	OL	27	10	"
		OH	63	34	"

TABLE 2 (cont'd)

Series	County Where Sampled	Unified Classification	L.L.	P.I.	Swell or Shrinkage Potential
Litz	Blount	MH-OH	63	31	High
		ML-OL	32	8	"
Melvin	"	OL	35	16	"
Sequatchie	"	OL	27	9	Moderate
Sequoia	"	OL	43	21	High
		MH-OH	74	40	"
		OH	59	33	"
Staser	"	SM-SO	26	6	Low
Talbot	Loudon	MH-OH	74	41	High
	"	OH	78	45	"
	"	OH	86	51	"
	Blount	MH-OH	62	29	"
Tellico	"	ML-OL	46	19	"
	"	MH-OH	56	27	"
	"	OL	44	22	"
	Loudon	OL	36	16	"
	"	OL	38	18	"
	"	MH-OH	53	25	"

TABLE 2 (cont'd)

Series	County Where Sampled	Unified Classification	L.L.	P.I.	Swell or Shrinkage Potential
Waynesboro	Loudon	MH	68	29	High
	"	MH-OH	58	29	"
	"	MH-OH	52	23	"
	Blount	ML	46	16	"

\* Taken from the Soil Conservation Service Soil Survey Reports of Blount (U.S.D.A., 1959,) and Loudon (U.S.D.A., 1961) Counties.

## VI. MATERIALS AND METHODS

Field investigations were conducted during November, 1961, with the aid of soil and housing specialists. They centered on certain soils of the county chosen as important on the basis of their character and widespread distribution. It was considered that soils associated exclusively with alluvial materials and steep slopes could be categorized according to their suitability for residential housing without extensive sampling and laboratory testing. Soils derived as residuum from limestone, argillaceous limestone, interbedded shale and limestone, calcareous shale, and calcareous sandstone were investigated in the field. Inquiries were made with some homeowners in the area regarding any difficulty relating to soil character. Soil samples, generally of the B horizon, were taken using auger borings and road cuts. Soil profile study was made in road cuts and by examining shallow auger borings. Care was taken to sample only those soils considered by field scientists as especially characteristic of particular agricultural mapping units. The pedologic soil names were adapted for their identification in this study in keeping with previous engineering work of this nature. The soil samples identified in Table 3 were processed for laboratory testing.

The soil samples were air dried and screened through a U.S. #10 sieve, with all large aggregates being broken by hand and with a rubber tipped pestle. Particle size distribution by the hydrometer method, liquid and plastic limit by standard procedures, and swell potential

TABLE 3  
Soil Samples from Knox County

Sample No.	Soil Sample (Series)	Horizon
1	Fullerton	B
2	Decatur	B
3	Decatur	O
4	Farragut	B
5	Farragut	O
6	Tellico	B
7	Tellico	O
8	Sequoia	B
9	Colbert	B
10	Dewey	B
11	Talbott	B
12	Waynesboro	B
13	Etowah	B

using the FHA PVO device were then determined. Since the samples contained predominantly fine-grained materials, the hydrometer analysis was adopted using 50 grams of soil, distilled water, and 1.5 grams of calgon as a dispersing agent. The liquid and plastic limits were determined on soil passing the #40 sieve and cured with distilled water at approximately the liquid limit for 24 hours. The Casagrande grooving tool was used for the liquid limit determinations. The PVO (potential volume change) meter developed by Lambe (1960) was used to identify the swell potential of the soils. Air-dried samples were placed in a compaction ring in three layers. Each layer was compacted dynamically with an energy approximately corresponding to the modified AASHTO compaction test. Distilled water was added through openings in the compaction ring until the soil mass was completely submerged in water. The pressure exerted by the soil was recorded on a dial gauge at regular time intervals. The pressure exerted by the soil at the end of two hours, called the "swell index" of the sample, was recorded. Precautions were observed during the test to obtain an undisturbed result from the instrument. To help define experimental error, calibration of the proving ring was made and tests were replicated for the Colbert and Talbott soil samples, both of which were considered as highly plastic during field investigations. Iredell soil was used as a reference material and was tested to check the instrument and general procedure against results obtained by Lambe during their development. In general, the procedure followed was that given by Lambe (1960).

## VII. RESULTS

The results of the tests on Atterberg limits are given in Table 4. The limit values are influenced by the chemical and mineralogical composition of the soils, the size and shape of the soil particles, and the amount and nature of the adsorbed water. Drying of the soils drives off adsorbed water that is not completely regained upon wetting. This has the effect of making the limits values, particularly liquid limit, lower for air dried samples than for those held at field moisture conditions. Liquid limit correlates very closely with soil-water adsorption and, hence, the basic physical-chemical properties of the soil (Moore, 1960). The plasticity index helps in the estimation of such engineering properties as permeability, toughness near the plastic limit, dry strength, and swell and shrinkage potential of soil. The flow index serves to help identify the cohesive character of a soil.

Table 5 presents the particle size distribution data for the samples analyzed. This grain size analysis in combination with the Atterberg limits values is useful in the identification and classification of the soils and the determination of the activity ratio of the samples. For this study the soils were classified according to the Unified Classification System as shown in Table 5. Skempton's grouping of soils on the basis of their activity ratio into inactive, normal, and active soils (Grim, 1962) was employed in this study. If the activity ratio, which is defined as the plasticity index divided by the percent by weight of the particles less than 0.002 mm. in effective settling

TABLE 4

## Atterberg Limits of Knox County, Tennessee, Soil Samples

Sample No.	Soil Series	Horizon	Liquid Limit L.L. %	Plastic Limit P.L. %	Plasticity Index P.I. %	Flow Index I <sub>p</sub> %
1	Fullerton	B	48.4	22.3	22.0	33.0
2	Decatur	B	60.0	28.5	31.4	23.0
3	Decatur	O	62.0	51.6	10.4	30.6
4	Farragut	B	66.0	32.4	33.6	14.6
5	Farragut	O	52.0	43.4	8.6	30.0
6	Tellico	B	47.5	30.9	16.5	21.5
7	Tellico	O	46.2	30.8	15.3	6.0
8	Sequoia	B	60.0	37.2	23.5	47.4
9	Colbert	B	69.8	38.7	31.0	65.4
10	Dewey	B	59.5	30.2	29.2	35.0
11	Talbott	B	85.8	52.4	33.3	26.2
12	Waynesboro	B	48.5	33.8	15.8	10.5
13	Etowah	B	39.9	25.4	14.4	17.6

TABLE 5

## Particle Size Distribution

Sample No.	Soil Series	Horizon	Particle Size Distribution %			Unified Classification System	Activity Ratio
			Sand	Silt	Clay		
1	Fullerton	B	14.0	45.5	40.5	OL	0.545
2	Decatur	B	16.5	18.6	64.9	OH	0.486
3	Decatur	O	11.0	18.7	70.3	MH	0.148
4	Farragut	B	12.0	24.3	63.7	OH	0.528
5	Farragut	O	10.2	38.8	51.0	MH	0.182
6	Tellico	B	30.0	29.2	40.8	ML	0.406
7	Tellico	O	36.2	21.2	42.6	ML	0.360
8	Sequoia	B	22.8	27.6	49.6	MH	0.474
9	Colbert	B	12.5	27.0	60.5	MH	0.514
10	Dewey	B	20.0	25.6	54.4	OH	0.537
11	Talbott	B	21.0	14.7	64.3	MH	0.524
12	Waynesboro	B	47.7	16.2	36.1	ML	0.438
13	Etowah	B	22.5	36.7	40.8	ML	0.353

diameter, is less than 0.75, the soil is considered as inactive, if it is between 0.75 and 1.25, it is normal, and if it is greater than 1.25, the soil is thought to be very active. Active is used here in the sense of gross changes in physical properties, such as volume, with changes in water content. Soils with low activity ratios tend to have low cohesion and strength due largely to internal friction. Very active soils usually have a high water-holding capacity and a high cation exchange capacity. Table 4 indicates that the soils of this study range from low plastic silts - Tellico, Waynesboro and Etowah series - to high plastic clays - Decatur, Dewey and Farragut series. The Sequoia, Colbert, and Talbott samples are high plastic silts. All of the samples fall into the category of inactive soils.

Clayey soils are subjected to volume change. The extent of volume change that can occur depends upon 1) the amount and type of clay mineral, 2) the initial density, 3) the change in moisture, 4) the load conditions, 5) the soil structure, and 6) time. In the P.V.C. meter test, the soil is compacted in the equipment dynamically with a 5.5 pound hammer with any one of the water contents specified in the following table.

Water Content	Nominal Compactive Effort (1)	Number of Layers	Blows per Layer
Dry	Modified AASHO	3	7-7-8
Moist	$\frac{1}{2}$ Modified AASHO	3	4
Wet	Standard AASHO	1	5

(1) The plastic limit approximates optimum water content for Standard AASHO compaction. Decrease in water content requires more effort to compact dry samples to the same density as wet samples.

Distilled water is added through small openings in the equipment until the soil is completely covered with an environment of water. The soil is subjected to an initial pressure of 200 psf. The pressure exerted by the soil at the end of two hours is recorded. This pressure represents the "swell index" of the soil. The factors affecting the test are 1) the fixing of the bolts of the soil container and the proving ring (the bolts might take the pressure exerted by the soil if not rigidly fixed), 2) unclean porous stones preventing escape of air from its pore space when the soil is subjected to an environment of water, 3) incorrect indications on the dial gauge, which must be calibrated. The operational factors are 1) variation in the density of the soil due to improper compaction (soil tends to be compacted more at the center than at the edges), 2) the time required for adding water to the soil mass, 3) erroneous readings of the dial gauge.

Lambe (FHA, 1960) suggests that excellent correlation exists between 1) plasticity index and volume change, 2) heave and change in volume, 3) heave and swell pressure, 4) swell index and plasticity index, 5) swell index and volume change, 6) swell index and heave and 7) swell index and swell pressure. In all these cases it is observed that the correlation exists only at lower ranges of swell index. No doubt there is correlation existing between swell index and heave, but that between swell index and plasticity index was not indicated in the tests conducted on the Knox County soils. However, tests on a larger number of samples might indicate a correlation between the

plasticity index and swell index, in which case the plasticity index would serve as a test to identify the swell potential of a soil.

A limitation existing in the use of the equipment to indicate the swell potential of a soil is the variation in the field moisture content at which the soil occurs which is not reflected in the test procedure. A test conducted at a known moisture content might not give the true character of the soil that exists in the field. Also, the density of the soil in the field differs from that of laboratory test density and the environment of soil expansion during the test is not necessarily that in the field. Expansion in the field is three dimensional whereas that of the laboratory is in one dimension.

The critical nature of a soil due to its potential volume change is categorized by Lambe into four classes as shown in the table.

<u>Swell Index (psf)</u>	<u>P.V.O. Rating</u>	<u>Category</u>
0 - 1700	0 - 2	Non-critical
1700 - 3200	2 - 4	Marginal
3200 - 4700	4 - 6	Critical
4700 /	6 /	Very critical

These ratings are based on tests conducted on highly plastic clays found to be responsible for extensive damage to structures. In this study, they are adopted to categorize the soil samples from Knox County on the basis of their estimated swell potential.

The swell index of each of the Knox County soil samples is given in Table 6. Also given in that table are the P.V.C. values and ratings based on Lambe's (FHA, 1960) classification. The ratings suggest that all the soils sampled are non-critical except Fullerton, Farragut, Colbert, and Talbott, which fall into the category of marginal soils. The Talbott sample was near the critical range. Values of the swell index of Colbert and Talbott samples varied about 30 per cent during test replications. The swell index of the reference soil, Iredell, was found to be in the very critical range. Contrary to what one might expect, the results suggest that for Knox County, MH soils have a greater swell index than some of the OH soils. Lambe's suggestion of a direct correlation between plasticity index and swell index within a range of 0 to 35 for P.I. does not seem to hold for Knox County.

TABLE 6

## Swell Index of Knox County, Tennessee, Soil Samples

Sample No.	Soil Series	Horizon	Swell Index psf	PVO Value	PVO Rating	Unified Classification
1	Fullerton	B	1718	2.05	Marginal	OL
2	Decatur	B	1560	1.82	Non-critical	OH
3	Decatur	C	2380	2.96	Marginal	MH
4	Farragut	B	1985	2.35	Marginal	OH
5	Farragut	C	3010	3.70	Marginal	MH
6	Tellico	B	1013	1.05	Non-critical	ML
7	Tellico	C	1620	1.89	Non-critical	ML
8	Sequoia	B	1450	1.65	Non-critical	MH
9	Colbert	B	1490	1.70	Non-critical	MH
			1952	2.35	Marginal	
10	Dewey	B	690	0.62	Non-critical	OH
11	Talbott	B	3100	3.85	Marginal	MH
			2460	3.00	Marginal	
			2870	3.45	Marginal	
12	Waynesboro	B	788	0.508	Non-critical	ML
13	Etowah	B	1380	1.56	Non-critical	ML
Ref. Soil	Iredell	-	3690	4.65	Critical	OH
			5220	6.65	Very critical	

## VIII. DISCUSSION

## Problems of Residential Housing Associated with Soil Conditions

The proper location of residential areas is influenced by the properties of soils. The problems encountered during such location are 1) slope stability, 2) high water table, seepage, and flooding, 3) shallow bedrock, 4) foundation suitability, 5) suitability for sewage disposal, and 6) maintenance of access roads. These problems depend upon topographic, hydrologic and geologic position and the character of the soil materials. The suitability of a soil for residential housing can be established on the basis of these problems and on the performance of buildings in the individual soil areas. The categorization of soil areas according to their suitability will reduce the expense of location investigations for housing areas.

Soil areas containing steep slopes cause problems to residential housing from the standpoint of slope stability. Among the many factors related to slope stability are the physical nature of the soil profile, the position of the ground water, and the general climatic conditions. Slides and erosion are the chief disturbing elements of the slopes. Sliding might occur in any of several kinds of earth materials. Sliding may be defined as the downward and outward movement of a portion of the soil mass with respect to the remaining portion. The sliding surface usually occurs at some weak point. A slope failure in cohesive soil is primarily by shear failure. In stratified soil, the failure plane is often at the boundary of the strata; the upper strata may

slide down with respect to lower strata due to differential movement at the boundary, as in shaly bedrock. Loosely bonded interbedded strata slide due to a lack of cohesion between the layers or due to having the cementing material gradually weakened by rain. This is common where the strata dip downwards. Pervious material overlying relatively impervious material tends to slide due to seepage of water between such layers. Rock slides occur due to alternate freezing and thawing and an unfavorable direction of the dip of the strata. In all these cases, gravity is the force destroying the stability of the slope. The weight of the material and the superimposed loads of structures add to gravity forces. Resistance to sliding is contributed by the shearing strength of the material. Shearing strength of a cohesive material tends to decrease with an increase of water content. Water content may change due to flow of water from the water table or during precipitation. Slides usually occur during or immediately after a rainfall. Also, saturation of a soil mass during precipitation increases the weight of the material, hastening sliding effects. An effect similar to that of additional loading may be caused by the removal of soil at the toe of a slope for emplacement of a building or a road. This is a common cause of a slide. Soil creep, which is the slow motion of the upper strata with respect to the underlying area, affects to some extent the stability of slopes. Creep is generally influenced by moisture conditions. Tilted trees or fence posts are indicative of creep. Foundations in creep zones are subject to movement.

Erosion of soil is associated with both soil and meteorological conditions. Long periods of rainfall increase surface run off, thereby increasing the extent of soil erosion. The velocity of water on steep slopes will be high under such conditions. Erosion depends upon soil particle size and character. Although cohesive soils may not be subject to much erosion, in general, erosion increases with a decrease in particle size. Silts are the most erodable soil material. Coarse grained soils are not generally eroded easily but are likely to work their way down slope either by gravity or due to the force of moving water during precipitation.

The effects of sliding and erosion are increased with an increase in the degree of slope. Slopes greater than 25 percent may be considered as dangerous for the location of residential units. Buildings located on such slopes are often damaged. A huge mass of material might slide down on a building from a region above it, causing extensive damages. Buildings located on bedrock with potential slide effects will tend to slide with the rock. The landscaping of the residential area is affected to a considerable degree by constant erosion and sliding action involving costly maintenance. The unstable soil conditions will affect the integrity of sewerage systems and water mains. Access to residences is difficult in steep topography. Steep access roads are often subjected to erosion. Prohibitive expense may be required for the maintenance of such roads. Therefore, for all of the above reasons, slopes of greater than 25 percent are considered unsuitable for residential development.

Hydrologic position greatly influences the suitability of an area for residential housing. Water is one of the most unfavorable elements bearing on the location of residential developments. As mentioned, the stability of slopes is influenced by the amount of flow of water and the degree of erosion. Hydrologic effects are of great concern in such areas as foot slope positions. Alluvial deposits on stream bottoms are subject to intermittent flooding. The water table in these positions is generally high and sometimes at the surface, making the soil swampy. Such conditions are deleterious to the health of the community. Timber used in the construction of residential structures is subject to warping; as a result, damage might occur to the structure. Alternate drying and wetting of expansive soils may add to this. The masonry and other materials in foundations may deteriorate, losing its supporting capacity. Structures built below grade in such areas are unsuitable for habitation. Excavation during construction is difficult and expensive safety precautions may be necessary. Sewage disposal poses a problem in areas of high water table. Health requirements generally will not permit the discharge of sewage into ground water. Gaining access to residential areas is difficult when roads are under water or affected by it. Subgrade soil performance is influenced by the moisture content and the type of soil used. Subgrade support strength may be reduced on saturated clayey soils. Great potential trouble from frost heave exists when the ground water table is relatively close to the surface and just below the freezing zone. Ice lenses build up to a

considerable magnitude if the soil is of a high capillary potential. Silts and very fine sands are susceptible to frost action, which may cause considerable damage to roads. This involves high maintenance costs.

The depth to bedrock of soil also influences the location of residential housing areas. Bedrock near the surface, though favorable for shallow foundations, is unsuitable for sewage disposal systems. During the placement of deep foundations or access roads, excavation in bedrock is difficult and expensive. Soils with good drainage characteristics are good for individual sewage disposal systems. Bedrock at depths of greater than three feet is herein considered favorable from the sewage disposal standpoint when this rock is permeable. Deeper bedrock depths must be sought when the rock is relatively impermeable.

The performance of buildings in an area depends on foundation suitability. Suitability of soils is influenced by its bearing strength, compressibility, and potential volume change with change in water content. The cost of construction is reduced when high bearing strength allows for reduced footing size. The strongest foundation material is bedrock. However, the occurrence of shallow bedrock affects the installation of water and sewage disposal systems. The possibility of settlement is reduced in low compressible soils. Compressible soils cause unequal settlement under heterogeneous conditions. Clayey soil may be good as a supporting soil, but it has adverse effects on individual sewage disposal systems. Clayey materials swell due to the presence

of moisture. The presence of excess moisture causes loss of strength. Such soils present numerous problems. Swell and shrinkage of a soil may cause extensive damage to a building. Swelling is most prevalent in climates with a high rate of evaporation compared to rainfall. Shrinkage is prevalent in climates conducive to wet soils. The extent of shrinkage depends upon the initial water content of the soil. Trees might aggravate the shrinkage effects by taking moisture from the soil. Soils with high plasticity indices are subject to large volume changes. The water source for swelling may be from irrigation projects, faulty water and septic systems, or capillary rise from the water table. Highly expansive clays should be avoided. Damage due to swelling may be more common than due to shrinkage of soils. The heterogeneous nature of a supporting soil and non-uniform loading may cause differential settlement of a structure. Such differential settlement may be detrimental to a structure even though it is of small magnitude. Settlement may occur by shear failure and fluctuations of the water table. Settlement and subsidence cannot be ruled out in cavernous limestone regions, which are acted upon by ground water. Excavations made next to a structure might tend to cause a building to slide with the earth material. A saturated fine sand mass tends to flow horizontally, undermining the structure. Silts are susceptible to frost action, which causes damage to structures. Freezing temperatures in a soil, a close source of water, and frost susceptible soils are the factors affecting frost damage.

The location of residential areas must take into account the sewage disposal characteristics of the soil. An area may be good from the foundation viewpoint, but it may not satisfy the sewage disposal requirement. Adoption of a municipal sewerage system may not be economically feasible. In such cases, individual sewage disposal systems or sewage lagoons may be best suited. The effective functioning of a system depends upon the nature of the soil. Soil should possess good internal drainage. Soil drainage refers to the frequency and duration of the periods when the soil is free from saturation or partial saturation. Soils classified as very poorly drained, poorly drained, and imperfectly drained are unsuitable for individual sewage disposal. Moderately well drained soil is favorable only if the permeability is high. Other categories of soil classifications are favorable only if the bedrock depth is great to allow for the seepage of the sewage. Sewage lagoons may be favorable near streams. The beds of the reservoir should be impervious to prevent loss of liquid through seepage. Low berms have to be provided with relatively impervious soil. These lagoons must be at some distance away from the residences and should be screened with vegetation. The individual absorption field system creates problems in regions of a high water table. Alluvial regions, fluvial soils and sinkholes in limestone areas have poor hydrologic conditions. In steep slopes, the effluent may tend to seep out of the surface, flow on the slope, and collect at the foot slope position. This situation might tend to affect the health of the community. The limiting slope for safe performance of an individual absorption field system is often taken as 25 percent (Krebs and Hunter, 1961).

Accessibility to buildings is an essential requirement in the development of residential areas. Access roads are secondary roads. The location of these roads is influenced by the nature of the soil. Regions of shallow bedrock increase the cost involved for excavation. Silts are subjected to frost action and cause damage to roads during frost heave. In steep slopes, slide and erosion will affect the road, particularly in downward dipping strata. Subgrades require good soil for support. Subgrades are affected by high water table. Clayey material is not suitable as it is very poor in drainage characteristics. In such regions, roads are damaged due to swelling and shrinkage of the soil.

#### Knox County Soils in Relation to Residential Housing

The USDA Soil Survey Report of Knox County furnishes information as to soil morphology. The humid and temperate climate of Knox County, with long warm summers, and a relatively high rainfall throughout the year, has caused intense leaching of the soil. Since the soil is frozen for only short periods and only to shallow depths, the amount of weathering and translocation of materials is intensified. Consequently, the soils developed from the various parent materials have many properties in common. These soils have been grouped into three categories, alluvial deposits, recent local fluvium, and weathered residual materials from limestone, sandstone, and shale.

Alluvial deposits are water transported materials formed on first bottoms of streams and rivers. The deposits are very young soils with

no properly defined horizons. The soil materials have originated from limestone, sandstone, shale and micaceous rocks. The soils are found in heterogeneous stratified layers on terraces or as flood plains with nearly level surfaces. The flood plains are usually subjected to intermittent flooding. But, in Knox County, this flooding has been reduced by the dams constructed in the region. However, such areas are not necessarily free from floods. The internal drainage and surface run-off in these areas are generally slow. The area occupied by alluvium is 10 percent of Knox County.

Soil materials deposited by gravity and water are fluvial deposits, which are generally found on foot slopes and along drainage valleys. The fluvial materials are derived chiefly from weathered limestone, sandstone, and shale. The terrain is generally undulating to rolling, but some soil materials are formed on the level surfaces in sinkholes in limestone valleys and cherty ridges. Because of the depression of sinkhole regions due to caverns in limestone bedrock, adequate drainage is a problem during precipitation. Such areas may be flooded during wet seasons. This is intensified if the permeability of the soil is poor. Fluvial materials are widely distributed in Knox County, covering 14 percent of the county.

Residual soils with well-defined soil profiles have formed over limestone, sandstone, shale, and interbedded shale and sandstone. The soils occupy 76 percent of Knox County on uplands and have a wide range in characteristics. About 20 percent of the region is on steep slope of more than 25 percent. Large areas are shallow to bedrock.

Soil material on steep slopes over interbedded strata, particularly in regions of shale interbedded with sandstone or limestone, tend to be unstable. Failures of slopes in such areas are not uncommon. The soils in the residual group are generally recognized by their red and yellow color. These soils have good drainage characteristics.

The Soil Survey Report of Knox County presents important characteristics of each of the soils in the county related to agricultural purposes. Among the many characteristics, soil profile, topographic position, and drainage and permeability conditions may be related to problems of residential housing. Drainage and permeability data allow one to study soil with reference to individual field absorption sewage disposal systems. Five drainage classifications, very slow, slow, medium, rapid and very rapid; and seven permeability categories, very slow, slow, moderately slow, moderate, moderately rapid, rapid, and very rapid, are defined in relation to hydrologic positions. As suggested by the titles of the categories, very slow, slow, and moderately slow drainage and permeability conditions are unfavorable for individual field absorption systems. The other classifications may be favorable.

On the basis of the soil characteristics provided in the Knox County Soil Survey Report of each soil type, it is possible to subdivide the three categories discussed above into units possessing significantly different engineering characteristics as follows:

Alluvial deposits -

1. Alluvial soils on bottom lands.
2. Old alluvium on stream terraces.

Recent local fluviums -

1. Recent local fluvium in drainheads and drainage valleys.
2. Fluvium on relatively high foot slopes below ridges.
3. Soils in sinkholes in limestone valleys and cherty ridges.

Weathered residual materials from limestone, sandstone and shale -

1. Upland soils shallow to bedrock.
2. Upland soils deep to bedrock.

and Unclassified soils.

The categorization in the above groups is based on the criteria that each group is recognisable by:

1. Topographic position and field reconnaissance.
2. General morphology of the land.
3. Some engineering characteristics and considerations related to residential housing.

Alluvial soils on bottom lands.

Alluvial soils on bottom lands are those soils located on the nearly level surfaces along flood plains normally associated with recent alluvial deposits. These materials are heterogeneous materials varying in texture and properties. The bottom lands are subjected to intermittent flooding. Fresh alluvial deposits may be anticipated

during such floods. The water table in bottom lands may be very high or at the surface in places. Soils of this group in Knox County are Huntington, Lindside, Melvin, Roane, Staser, Hamblen, Prader, Congaree, and Chewacla. Due to the poor hydrologic position of the area, these soils are unsuitable for residential locations.

Old alluvium on stream terraces.

Soils on stream terraces are formed a few to many feet above the bottom lands. The deposits in Knox County are old alluvium formed in three different terraces. Cumberland, Waynesboro and Nolichucky are on high stream terraces. These soils vary from silts to sandy clay. Permeability ranges from moderate to moderately rapid. Terrain conditions are undulating to hilly. Tyler and Etowah are formed on moderately high stream terraces. Tyler is an alluvium from shale, sandstone and limestone having clay subsoil. The terrain is nearly level with very slow permeability. Etowah is strongly influenced by limestone debris. Permeability is moderate. The alluvial soils on low stream terraces are Wolftever and Sequatchie. The compact silty clay subsoil of Wolftever makes the permeability very slow. Sandy clay loam of Sequatchie is moderate to variable in permeability. All the soils in the group are favorable for residential locations except Tyler and Wolftever, whose slow permeability is unfavorable for the efficient functioning of the field absorption type of sewage disposal system.

Recent local fluvium in drainheads and drainage valleys.

Recent local fluvium is found in Knox County in drainheads and drainage valleys. This fluvium is material deposited by gravity or

local wash or by erosion. The thickness of the material in some locations is as little as six inches. As the soils are in drainheads and drainage valleys, they are subjected to seasonably high water table and seepage. Areas in natural drainage basins may be flooded for a considerable length of time. Future soil deposition should be anticipated. Emory, Greendale, Camp, Cotaco, Leadvale, Whitesburg, and Neubert are the soils in this group. The profiles of these soils do not have normal development. The poor hydrologic position of this group of soils makes them unsuitable for the location of residential housing.

Fluvium on relatively high foot slopes below ridges.

Old fluvium is the alluvial and colluvial materials deposited far enough in the past to allow soil profile development by pedologic processes. Jefferson and Alcoa soils form this group in Knox County. Their drainage condition is medium and their permeability moderately slow to moderate. These properties and the topographic position are favorable for the location of residential units. However, shallow bedrock conditions in Jefferson soil makes it unsuitable for such location.

Soils in sinkholes in limestone valleys and cherty ridges.

Sinkholes are depressions in limestone areas formed due to a soil mass sinking in the cavernous regions associated generally with limestone areas. The reaction of limestone with underground water is the cause for the removal of material, forming caverns. Soils formed in sinkholes in Knox County are Abernathy, Coltewah and Guthrie. The terrain is nearly level with very poor surface run-off characteristics.

Internal drainage is also slow. During wet seasons, the area may be waterlogged for long periods. A high water table is also common in wet months. These poor hydrologic conditions make the soil areas unsuitable for the location of residential housing.

Upland soils shallow to bedrock.

The upland soils are formed on limestone ridges and valleys, shale hills and valleys, sandy shaly ridges, and sandy ridges. The rock formations are generally folded and faulted. Armuchee, Dandridge, Montevallo, Muskingum, Bland, Colbert, Farragut, Sequoia, and Talbott are the soils grouped in this category. The soils have well defined horizons. Bedrock is met with at less than three feet from the surface. Excavations in such regions for basement foundations is often not economical. Also, installation of sewerage systems and water mains are problems in shallow bedrock regions. Efficient functioning of individual absorption field systems for sewage disposal is not possible. The construction of access roads is expensive. Differential settlement may occur when the foundation is placed partially on rock. Hence, the occurrence of shallow bedrock is a disadvantage even though it is favorable from the standpoint of supporting strength.

Upland soils deep to bedrock.

This group contains soils with the bedrock position generally greater than six feet from the surface. The disadvantages found in shallow-to-bedrock regions are overcome by the greater depth of soil. Decatur, Dewey, Bolton, Fullerton, Clarksville, and Tellico soils come under this group. They are found in upland regions of Knox

County with undulating to steep slope. Since the soils are zonal soils, they have well defined horizons. The subsoils of all the soils except Tellico are silty clay. Tellico has sandy subsoil. Although the soils are classed as clay soils, tests conducted on Decatur, Dewey, Fullerton, and Tellico indicate the soils are not dangerous from the swell characteristics of their clayey subsoils. The swell index of the tested subsoils are within the non-critical range. Basement location is no problem in such regions. The permeability of the soils ranges from moderate to moderately slow. Deep to bedrock and favorable permeability for absorption field systems for sewage disposal makes this group of soils favorable for the location of residential housing. It must be realized, however, that a small percentage of Dewey, Decatur, and Tellico soils occurs on slopes of greater than 25 percent, which may be unstable.

#### Unclassified soils.

Gullied land, limestone rockland, stonyland, and made land of Knox County are not designated in the Knox County Soil Survey Report with series type and names, but are indicated by their descriptive names, as they have little agricultural value. These areas are composed of various soil associations with variable characteristics that cannot be properly described in the above categories. In view of this and the absence of information to the contrary, it is safe to consider this group of soils as unsuitable for residential housing locations. The area covered by this group is about 11.6 percent of the total area of the county.

The suitability rating of each of the pedologic soil types of Knox County for residential locations is presented in Table 7. Ratings of 1) favorable, 2) conditional, and 3) unsuitable are adopted in this classification according to criteria referred to above and outlined in Table 8. "Favorable" refers to the soils suitability for foundations, functioning of individual absorption field sewage disposal systems, and location of access roads. A "conditional" rating refers to the soils suitability for foundations and access roads, but implies that the suitability is largely undetermined due to soil character or lack of decisive information. This rating does not preclude the occurrence of soil acceptable or unacceptable for absorption field sewage disposal, but in places the soil is generally less acceptable than that rated as favorable. An "unsuitable" rating refers to foundations, access roads, and the efficient functioning of individual sewage disposal systems, and is usually assigned due to topographic, hydrologic, or geologic conditions.

Information contained in the Soil Survey Report and maps and considerations discussed above are the bases for these ratings. The Soil Survey Report is prepared by the USDA largely for agricultural purposes on the basis of data furnished by soil scientists and field surveyors. Although the characteristics of each soil type is for the use of agriculturists, they are herein interpreted in terms of engineering properties. Such interpretation might lead to errors in rating. In soils of doubtful character, the rating is based on test results. Errors might have been introduced in interpretation of Soil Survey Report,

TABLE 7

Rating of Soils of Knox County, Tennessee,  
According to Suitability for Housing

Soil Series	Map Symbol (1)	Relative Suitability (2)		
		Foundations for Residential Buildings	Secondary Roadway Subgrades	Domestic Sewage Disposal Fields
Alcoa	Aa	C	C	F
	Ab	U	U	U
Armuchee	Ac	U	U	U
	Ad	U	U	U
	Ae	U	U	U
Bland	Ba	U	U	U
	Bb	U	U	U
	Bc	U	U	U
	Bd	U	U	U
	Be	U	U	U
Bolton	Bf	C	C	C
	Bg	F	F	C
	Bh	U	U	U
	Bk	C	C	C
	Bl	F	F	C
	Bm	U	U	U
Camp	Ca	U	U	U
Chewacla	Cb	U	U	U
Clarksville	Cc	C	C	C

TABLE 7 (cont'd)

Soil Series	Map Symbol (1)	Relative Suitability (2)		
		Foundations for Residential Buildings	Secondary Roadway Subgrades	Domestic Sewage Disposal Fields
Clarksville	Od	F	F	F
	Oe	U	U	U
	Of	O	O	O
	Og	F	F	F
	Oh	U	U	U
	Ok	U	U	U
	Ol	U	U	U
	Om	U	U	U
	On	U	U	U
Congaree	Oo	U	U	U
	Op	U	U	U
	Or	U	U	U
	Os	U	U	U
Cumberland	Ot	O	O	O
	Ou	O	O	O
	Ov	O	O	O
	Ow	O	O	O
	Ox	O	O	O
	Oy	O	O	O
Dandridge and Litz	Da	U	U	U
	Db	U	U	U

TABLE 7 (cont'd)

Soil Series	Map Symbol (1)	Relative Suitability (2)		
		Foundations for Residential Buildings	Secondary Roadway Subgrades	Domestic Sewage Disposal Fields
Dandridge and Litz	Dc	U	U	U
	Dd	U	U	U
Dandridge	De	U	U	U
	Df	U	U	U
	Dg	U	U	U
Decatur	Uh	F	F	C
	Hk	F	F	C
	DI	C	C	C
	Dm	C	C	C
	Dn	C	C	C
	Do	C	C	C
	Dp	C	C	C
	Dq	C	C	C
Dewey	Dr	F	F	C
	Ds	F	F	C
	Dt	C	C	C
	Du	F	F	C
	Dv	U	U	U
	Dw	F	F	C
	Dx	C	C	C
	Dy	F	F	C
Emory and Abernathy	Ea	U	U	U
	Eb	U	U	U

TABLE 7 (cont'd)

Soil Series	Map Symbol (1)	Relative Suitability (2)		
		Foundations for Residential Buildings	Secondary Roadway Subgrades	Domestic Sewage Disposal Fields
Emory	Ec	U	U	U
Etowah	Ed	F	F	F
	Ee	O	O	C
	Ef	F	F	F
	Eg	F	F	F
	Eh	O	O	O
Farragut	Fa	U	U	U
	Fb	U	U	U
	Fc	U	U	U
Fullerton	Fd	O	O	O
	Fe	F	F	O
	Ff	U	U	U
	Fg	O	O	O
	Fh	F	F	O
	Fi	U	U	U
	Fj	O	O	O
	Fk	F	F	O
	Fl	U	U	U
	Fm	O	O	O
	Fn	F	F	O
	Fo	F	F	O

TABLE 7 (cont'd)

Soil Series	Map Symbol (1)	Relative Suitability (2)		
		Foundations for Residential Buildings	Secondary Roadway Subgrades	Domestic Sewage Disposal Fields
Fullerton	Fp	O	O	O
	Fq	F	F	O
	Fr	F	F	O
	Fs	O	O	O
	Ft	F	F	O
	Fu	F	F	O
	Fv	O	O	O
	Fw	F	F	O
	Fx	F	F	O
	Fy	O	O	O
	Fz	F	F	O
	Greendale	Ga	U	U
Gb		U	U	U
Gc		U	U	U
Gd		U	U	U
Gullied land	Ge	U	U	U
	Gf	U	U	U
	Gg	U	U	U
	Gh	U	U	U
	Gk	U	U	U

TABLE 7 (cont'd)

Soil Series	Map Symbol (1)	Relative Suitability (2)		
		Foundations for Residential Buildings	Secondary Roadway Subgrades	Domestic Sewage Disposal Fields
Guthrie	G1	U	U	U
Hamblen	Ha	U	U	U
	Hb	U	U	U
Huntington	Hc	U	U	U
	Hd	U	U	U
Jefferson and Montevallo	Ja	U	U	U
	Jb	U	U	U
	Jc	U	U	U
Jefferson	Jd	U	U	U
Leadvale and Cotaco	La	U	U	U
	Lb	U	U	U
Leadvale and Whitesburg	Lc	U	U	U
	Ld	U	U	U
Limestone Rockland	Le	U	U	U
	Lf	U	U	U
Lindside	Lg	U	U	U
Made Land	Ma	U	U	U
Melvin	Mb	U	U	U
Montevallo	Mc	U	U	U
	Md	U	U	U

TABLE 7 (cont'd)

Soil Series	Map Symbol (1)	Relative Suitability (2)		
		Foundations for Residential Buildings	Secondary Roadway Subgrades	Domestic Sewage Disposal Fields
Montevallo	Me	U	U	U
	Mf	U	U	U
	Mg	U	U	U
Muskingum and Lehw	Mh	U	U	U
	Mk	U	U	U
	Ml	U	U	U
	Mn	U	U	U
Muskingum	Mn	U	U	U
Neubert	Na	U	U	U
	Nb	U	U	U
Nolichucky	Nc	F	F	F
Ooltewah	Oa	U	U	U
Prader	Pa	U	U	U
Roane	Ra	U	U	U
Sequatchie	Sa	F	F	F
Sequoia-Bland	Sb	U	U	U
	Sc	U	U	U
	Sd	U	U	U
	Se	U	U	U
	Sf	U	U	U

TABLE 7 (cont'd)

Soil Series	Map Symbol (1)	Relative Suitability (2)		
		Foundations for Residential Buildings	Secondary Roadway Subgrades	Domestic Sewage Disposal Fields
Sequoia	Sg	U	U	U
	Sh	U	U	U
	Slc	U	U	U
	Sl	U	U	U
	Sm	U	U	U
	Sn	U	U	U
Staser	So	U	U	U
	Sp	U	U	U
	Sr	U	U	U
Stony Land	Ss	U	U	U
	St	U	U	U
	Su	U	U	U
Talbott	Ta	U	U	U
	Tb	C	C	U
	Tc	U	U	U
	Td	U	U	U
Tellioc	Te	U	U	U
	Tf	C	C	F
	Tg	U	U	U
	Th	C	C	C
	Tk	C	C	C

TABLE 7 (cont'd)

Soil Series	Map Symbol (1)	Relative Suitability (2)		
		Foundations for Residential Buildings	Secondary Roadway Subgrades	Domestic Sewage Disposal Fields
Tellico	Tl	U	U	U
	Tm	C	C	C
	Tn	C	C	F
	To	U	U	U
Tyler	Tp	C	C	U
Waynesboro	Wa	C	C	C
	Wb	C	C	C
	Wc	C	C	C
	Wd	C	C	C
Wolftever	We	F	F	U
	Wf	F	F	U

(1) From the Soil Survey Report and Maps of Knox County, Tennessee, USDA, 1955.

(2) F - Favorable; C - Conditional; and U - Unsuitable.

TABLE 8

Criteria for Suitability Rating of Soils of Knox County, Tennessee,  
for Residential Housing

Criteria	Foundations			Access Roads			Individual Absorption Field Sewage Disposal System		
	F	O	U	F	O	U	F	O	U
Hydrologic Position			High water table and inter- mittent flood- ing			High water table and inter- mittent flood- ing			High water table and inter- mittent flood- ing
Permeability								Mod. slow	Slow
Bedrock Depth	>6'	3'-6'	<3'	>6'	3'-6'	<3'	>3'		<3'
Slope	0-12%	12-25%	>25%	0-12%	12-25%	>25%	0-15%	12-25%	>25%

F - Favorable; O - Conditional; and U - Unsuitable.

which contains information on soils only to a depth of 5 to 6 feet from the surface. Also, such Reports and Maps may not be accurate in every detail, although all precautions have been taken by the field investigators.

Frost action and its effects on the location of residential houses are not considered in this study, as Knox County soil is seldom frozen to a depth of more than two inches from the surface and rarely remains frozen for more than a few hours (USDA, 1955).

The rating provided in this study is meant to assist in the preliminary planning and investigation of residential housing locations prior to detailed investigation of field and soil conditions at the proposed sites. Also, it is hoped that it will allow engineers to use more efficiently the published Soil Survey Reports and Maps of Knox County, Tennessee, areas and help in the preparation of engineering soil maps for the area. Further, it is hoped that this demonstration of the application of Soil Survey information to engineering use will establish some guide lines for future work of this nature.

## IX. CONCLUSIONS

The Soil Survey Reports and Maps published by the USDA for agricultural purposes furnish information that can be used for engineering purposes. The Soil Survey Report and Maps of Knox County, Tennessee, are interpreted in this study in terms of engineering for the location of residential housing in Knox County. Based on the published information available, field investigations were conducted with the aid of engineers and soil scientists. Soil samples were obtained and tested in the laboratory for particle size distribution, liquid limit and plastic limit, and potential volume change properties.

On the basis of characteristics described in the Knox County Soil Survey Report for each soil type, the soils are divided into eight groups possessing significantly different engineering characteristics. The criteria for grouping are that each group is recognizable by its topographic position and by field reconnaissance and that the general morphology and certain engineering characteristics and considerations related to residential housing differ among groups.

The information relating to the hydrologic, topographic and geologic positions, depth to bed rock, and drainage and permeability characteristics as defined by the Soil Survey Report and that gathered by field investigations and laboratory test results are used in the interpretation of the suitability of the various soils for the location of residential housing. Out of eight general groups recognized for the Knox County soils, alluvial soils in first bottom positions,

recent local fluvium in drainheads and drainage valleys, and soils in sinkholes are considered as unsuitable for residential housing because of their poor hydrologic position. Soils shallow to bedrock and unclassified soils are also considered as unsuitable due to their poor geologic and topographic positions. The remaining groups, fluvium on relatively high foot slopes below ridges, old alluvium on stream terraces, and soils deep to bedrock are considered as generally favorable. However, a small portion of the soils in these favorable groups, due to poor permeability, steep slope, drainage character, or shallowness, are unsuitable for residential housing locations. These suitability ratings of "favorable", "conditional", and "unsuitable" are made with reference to foundations, access roads, and individual absorption field sewage disposal systems. Frost action is not taken into consideration as it is not a problem in Knox County.

The ratings provided in this study enable the planning and preliminary location of residential housing areas prior to detailed investigations in the field of soil conditions at specific sites. It is hoped that this application of soil survey information to engineering use will establish some guidelines for future work of this nature.

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## ENGINEERING CLASSIFICATION OF PEDOLOGIC SOIL GROUPS IN KNOX COUNTY, TENNESSEE, FOR RESIDENTIAL HOUSING

### Abstract

The proper location of residential housing sites within large areas requires preliminary investigations of soil conditions. It is possible to process for engineering purposes the information contained in geologic and pedologic maps and reports. In this way, adverse site conditions, such as flooding, frost action, expansion and shrinkage of soils, which are currently causing widespread failures in residential developments, might often be avoided.

This study is concerned with the rating of the soils in Knox County, Tennessee, as to their suitability for residential locations based on information contained in a Soil Survey Report of Knox County, field investigations, and laboratory testing. For this, the soils of Knox County are grouped into eight groups; namely, recent alluvial soils, old alluvial soils, recent local fluvial soils, old local fluvial soils, soils in sinkholes, soils shallow to bedrock, soils deep to bedrock, and unclassified soils. Each of these groups possesses characteristic engineering features. The poor hydrologic position of alluvial soils, recent local fluvium, and soils in sinkholes renders them unsuitable for residential housing. In addition, the soils shallow to bedrock and the unclassified soils are considered as being of limited suitability. Other groups are generally favorable for the location of residential housing. Each of the soils in each of the groups is rated as to its suitability with respect to foundations, access roads, and

individual absorption field sewage disposal systems. This rating is based on soil properties and test results. Suitability ratings of "favorable", "conditional", and "unsuitable" are adopted for rating the Knox County soils, but the pedologic names and map symbols are retained for the identification of each soil unit. This enables the engineer to interpret the Soil Survey Reports and Maps for engineering purposes, to locate engineering soil boundaries from those on pedologic maps, and to prepare engineering soil maps.