Bulletin 580 January, 1954

# Significance of Sand and Gravel in the Classification, Mapping and Management of Some Coarse-Textured Soils

by C. L. W. Swanson
A. Ritchie, Jr.

THE CONNECTICUT AGRICULTURAL EXPERIMENT STATION, NEW HAVEN

## CONTENTS

# Significance of Sand and Gravel in the Classification, Mapping and Management of Some Coarse-Textured Soils

**C. L. W. Swanson and A. Ritchie, Jr.**[1]

In making mechanical analyses of soils, usually only the material <2 mm in size is considered. The material retained on the 2 mm sieve is rejected or at most reported only as a percentage of the air-dry weight of the whole sample (17, 18). For most soils, this procedure is satisfactory since they contain only small amounts of gravel or pebbles. Some soils, however, contain a high percentage of materials >2 mm. Because of the effect these larger fragments exert on soil properties such as structure, aeration, consistence, permeability, and the like, a knowledge of their content is useful in soil classification and in predicting soil behavior in the growing of crop plants and trees. Information on the amount of larger particles present is also useful in ascertaining the suitability of given soils as sources of sand and gravel, or for use by engineers for highway purposes, airport construction, housing developments, and similar developmental work.

Since most soils contain only small amounts of coarse materials, investigations on the composition of these coarse fractions have been few. Because of their large size, these coarse fragments function as separate particles (24). For this reason they are not considered a part of the soil but as the skeleton of soils. These *skeletal soils,* a term given them by Robinson (27) and deSigmond (9), are not usually important agricultural soils although they often pose a problem in classification and mapping.

One such soil is the Hinckley, which occurs rather extensively in New England and in parts of New York. Another soil, more important agriculturally, but thought to have some of the *skeletal* features of the Hinckley and usually found concomitantly with it, is the Merrimac.

The detailed soil survey initiated in Hartford County, Connecticut, in July, 1948, (36) offered an opportunity for studying these soils. These two series exhibit somewhat similar genetic and morphological characteristics, and problems arise in separating them uniformly in the field. The method of study used may also be applicable in other areas having similar problems, especially where the soils are farmed intensively.

Farmers generally know that sandy and gravelly soils are droughty and subject to excessive leaching in seasons of high rainfall. Experiments at the Tobacco Laboratory in Windsor on Merrimac sandy loam (2, 25) show rather high losses of nitrogen and potash from leaching. Excessive

---

[1] Department of Soils. Grateful acknowledgment is made to A. E. Shearin of the Soil Survey Division, Soil Conservation Service, United States Department of Agriculture, for helpful suggestions on the morphology, classification, and mapping of the Hinckley and Merrimac soils and for his assistance in locating some of the sampling sites.

leaching and drought injury have occurred on the Hinckley loamy coarse sand[1] (4). The degree of droughtiness and leaching is dependent on the distribution of sand and gravel in the profile.

On a classification basis, because of their predominantly coarse texture, it may be thought that there is no practical need for separating soils high in sand and gravel into more than one series. However, in an intensive agriculture, as in Hartford County, special soil management problems arise in the use of these coarse-textured soils. Long-time use has shown that, for best crop yields, sandy and gravelly soils with more fine materials must be managed differently than those that are coarser in texture.

One soil may have a deep surface horizon high in sands but relatively free of gravel particles while another may have a thin, coarse-textured surface. Yet the subsoil and substrata of the two soils may be similar. Predictions as to the use and management aspects of these soils with regard to droughtiness, leaching losses, and erodibility may be made from a study of the soil profile.

In order to supplement field observations of mappable soil characteristics, a quantitative study of the sand and gravel fractions of 10 representative profiles of each series was made. It was believed a study of the frequency distribution of the separates could be checked against the following field observations: (a) the depth of the solum over the underlying gravelly substratum, (b) the amount and distribution of sand and gravel in the profile, especially in the substratum and (c) the topographic (slope) position of these soils. These studies should provide a better basis for differentiation of these soils in the field as well as information on their productivity for crops. Data obtained on their physical composition would reflect their porosity, permeability, droughtiness, consistence, and other physical properties.

## HISTORICAL

Some years ago a question arose as to the need for both the Hinckley and Merrimac series[2] in soil classification and mapping. If they were to be considered as separate series, upon what basis should the separations be made? Do they exhibit enough different profile characteristics to warrant two series? Was topography the chief basis of differentiation being used in mapping these two soils? On this basis, the soils occurring on kames, eskers and terrace escarpments would be mapped as Hinckley and those on the nearly level glaciofluvial terraces as Merrimac.

If there actually was not much difference in morphology between the two, it has been suggested that the Hinckley be mapped as slope phases of the Merrimac (1). On the other hand, if the differences in profile characteristics between the two were great, then two series should be recognized (1). Several field conferences on this problem have been held. Field problems in the mapping of these soils have been discussed by Goodman (13).

Information on the criteria used for separating the Hinckley and Merrimac soils is available in published soil survey reports for New Eng-

---

[1] Formerly in the Hinckley series but now included in the Carver, a tentative series in Connecticut.

[2] Lyford, W. H. Soils developed on glaciofluvial deposits in the Northeast. Division of Soil Survey, U.S.D.A. April 23, 1947 (Mimeographed).

land and New York. Only a few of the reports, selected to give a representative coverage of the area, will be cited (20, 21, 22, 29, 30, 31, 32, 39). A brief review of these major criteria used in mapping these soils and their management is given below.

Characteristics of the Merrimac series which set it apart from the Hinckley include a deeper solum with depth to gravel ranging from 20 to 30 inches, a well drained profile, and level to gently undulating relief. From 60 to 90 percent of the soil is cleared and used for general crops, tobacco, vegetables and hay; the remainder of the area is forested. The Hinckley series ranges from 6 to 24 inches to gravel, it has an excessively

FIGURE 1

Typical undulating hummocky topography on which Hinckley soils are developed. The slopes are complex and vary from 3 to 15 percent. Timothy and red clover hayfield in the foreground with a predominance of timothy. Trees in the background are white and pitch pine, hemlock, black and white oak, white birch and red maple. Shrubs are sumac, mountain laurel, low bush blueberry and chestnut sprouts. Photograph taken 1000 feet northeast on Holcomb Road at intersection of Holcomb Road and Barndoor Road, August 6, 1953.

drained profile, occurs on hilly, hummocky relief, and is principally in forest with some areas cleared for pasture or general crops. Even in an early report (39) the Hinckley is described as being predominantly in forest, hilly, and gravelly, in contrast to the more extensively cultivated Merrimac with its deeper solum and more level relief.

The earlier reports (20, 21, 22) did not seem to confuse these major characteristics and later ones (29, 30) were even clearer in their differentiation between the two soils. In one report (32), however, the characteristics used for the two soils are practically identical. Not all of the Hinckley occurs on hilly topography for some was mapped in New Hampshire (32) and Rhode Island (30) on gently undulating relief. In the Hartford County survey, although the major Hinckley areas occur on 3-15 percent slopes (some areas are found on steeper slopes), small areas are found on 0-3 percent slopes. Most of the Merrimac is found on 0-3 percent slopes but small areas are being mapped on 3-8 and 8-15 percent slopes.

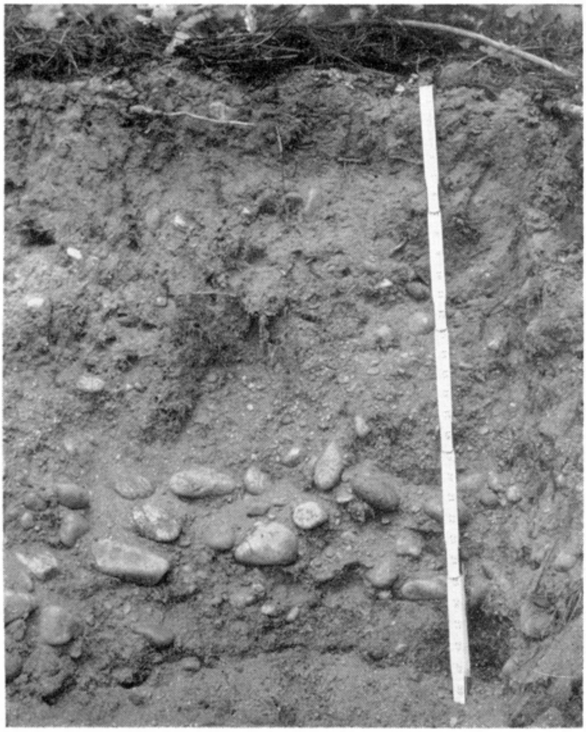

FIGURE 2

A typical Hinckley sandy loam profile developed under the forest vegetation shown in Figure 1. A layer of leaves, pine needles and twigs covers the $A_p$. An old plow layer about 5 inches thick can be faintly seen. The B horizon grades into the D at about 8 to 10 inches. The lower part of the D at about 18 inches contains numerous gravel fragments $>2$ inches in size. Roots are distributed throughout the solum and are less numerous in the D.

In the earlier soil surveys, mapping was not as detailed nor were the criteria for separating soils as distinctly drawn. A scale of one inch to the mile was used in Rhode Island (30), two inches in New Hampshire (31), and four inches in the current Hartford County survey. With the latter scale more attention can be given to detail. One criterion which can be considered in more detail is depth of the profile, especially depth to the gravel. Therefore, small areas of Hinckley and Merrimac, which previously were included with the dominant soil series, can be shown on the larger scale maps.

## GENERAL DESCRIPTION OF THE SOILS STUDIED

The Merrimac soils (36) are developed on glaciofluvial terraces and plains of Late Wisconsin glacial drift (10, 11); the Hinckley soils are generally found on kames and eskers. The parent materials consist of stratified sands and gravels derived principally from granite, gneiss, or schist. In Hartford County, some Triassic sandstone and shale may make up a small part of the soil material. Additional information on the physiography, geology, climate, and vegetation of the area in which these Brown Podzolic soils occur is given elsewhere (36).

The sandy loam, very fine sandy loam, and loamy sand[1] types of the Merrimac were sampled. The sandy loam type is well drained with very low surface runoff and rapid internal drainage. Surface runoff on the very

FIGURE 3

Hinckley gravelly sandy loam developed on an esker east of Hedgehog Mountain on east side of Hedgehog Lane now used as a source of gravel. White pine is the principal vegetation. Photograph taken August 6, 1953.

fine sandy loam is slow to medium but with moderate internal drainage. This type is not very extensive. Surface runoff in the coarse-textured type (loamy sand) is low; the soil profile is somewhat excessively drained; and the rate of movement of excess water through the profile is very rapid. All of these physical features combined produce a droughty soil.

The moderately coarse-textured type (sandy loam) of the Hinckley series is well to excessively drained and the coarse-textured type (loamy sand) is excessively drained. The surface runoff is slow to moderate and

[1] Formerly in the Merrimac series but now included in the Carver, a tentative series in Connecticut.

the internal drainage on all types is rapid. Field observations show the Hinckley to be more droughty than the Merrimac.

The textures sampled represent the range of these soils in Hartford County. In general, the Merrimac samples were taken on slopes of 0 to 3 percent and the Hinckley on 3 to 15 percent. Photographs of typical Merrimac and Hinckley profiles, their topography, natural vegetation, and crops grown are shown in Figures 1 to 6. The descriptions of the profiles are given in the Appendix.

A large percentage of the Merrimac soils are cleared and used mainly for tobacco (Figure 5), vegetables, and corn production (Figure 5). The loamy sand Merrimac[1] is usually not cleared to the extent of the other

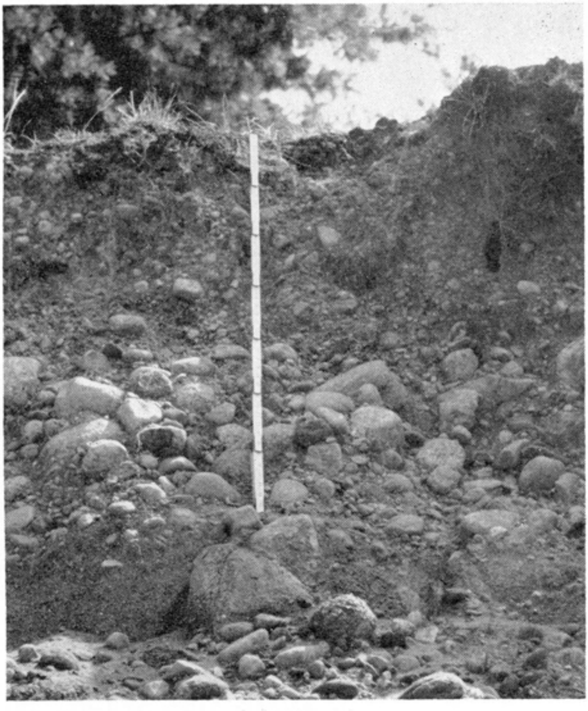

FIGURE 4

Close-up of Hinckley gravelly sandy loam profile shown in Figure 3. The A horizon is very thin, being less than 3 inches, and the B is likewise of shallow depth. Numerous gravel fragments >2 inches occur throughout the D horizon; cobbles are plentiful in the lower D. Roots are concentrated in the top 12 inches of the profile.

Merrimac types and is not farmed as intensively. The Hinckley soils are not cleared (Figures 1-4) and farmed as intensively as the Merrimac. Many of the cleared areas of the Hinckley are idle or in hay (Figure 1) or pasture but some are used for tobacco and, to a lesser extent, vegetables, where they are closely associated with the Merrimac and other more productive soils.

---

[1] See footnote on previous page.

FIGURE 5

A Merrimac fine sandy loam on gently sloping (0-3%) topography cropped to Broadleaf tobacco in foreground and corn in background. The forest vegetation in the far background consists mainly of oaks with a few scattered white pines, hemlock, red maple, beech, and a sparse understory of shrubs, and oak and pine seedlings. Photograph taken at the Tobacco Laboratory Farm, The Connecticut Agricultural Experiment Station, Windsor.

## EXPERIMENTAL PROCEDURE

### Collection of Samples[1]

Five sites for each series were selected for sampling. Each of the sites was at least a mile from any other. The locations of the sampling sites are shown in Figure 7. Each site was sampled in duplicate by digging profile pits about 200 feet apart. These duplicate profiles were selected at random within the site areas selected as representative of the series in question. The sites for sampling were selected from areas previously mapped or located from field inspection trips and represent a range in characteristics of the two series so cannot be considered as modal areas or profiles. Profile descriptions were written at the time of sampling.

Each profile pit was sampled at six-inch intervals to a 36-inch depth. The six-inch sampling depth was selected for two reasons: (a) for convenience in sampling since it would not be practical to obtain variable volumes depending on the differences in horizon thickness, and (b) in

[1] Grateful acknowledgment is made to J. F. Gamble for sampling the soils and writing the profile descriptions included in the Appendix.

Brown Podzolic soils it is difficult to distinguish accurately between horizons.

One-eighth cubic foot boxes (6 x 6 x 6 inches) made of 20-gauge galvanized sheet iron were used for obtaining samples of uniform volume. The box was driven into the soil to the desired depth and then carefully removed by cutting under the edges with a knife or spade. When the gravel interfered with driving the box into the soil, the soil material was shoveled into it, taking care to obtain a sample of the dimensions of the container.

**FIGURE 6**

Profile of a typical cultivated Merrimac fine sandy loam. The $A_p$ is about 10 inches thick. The B horizon extends from 10 to 21 inches, grading into the D. Small and medium-sized roots are fairly evenly distributed throughout the solum; very few roots are in the sand and gravel substratum. Only a few stones or gravel are present in the B with the D becoming more gravelly with depth. Some profiles are more gravelly, especially in the D. This profile was dug just east of the area shown in Figure 5 and is similar to the profiles sampled in site 1 described in the Appendix. Photograph taken December 23, 1953.

In each case, all of the protruding soil was removed with a knife, making the soil surface flush with the edges of the box. The soil samples were placed in cloth bags, taken to the laboratory and air dried before making the sand and gravel analyses.

Since it is not feasible to sieve fragments larger than about three inches in diameter, profiles containing these large fragments were not sampled. In gravelly soils these areas are easily observed. Actually, the

Merrimac only occasionally has fragments this large. In the Hinckley, where the three-inch fragments occur, they usually are so numerous and large that they preclude sampling for sieve analyses.

The authors realize that it is impossible to take samples of uniform volume in sandy, gravelly soils. All sampling, however, was done under the same conditions and reasonably similar unit volumes were obtained.

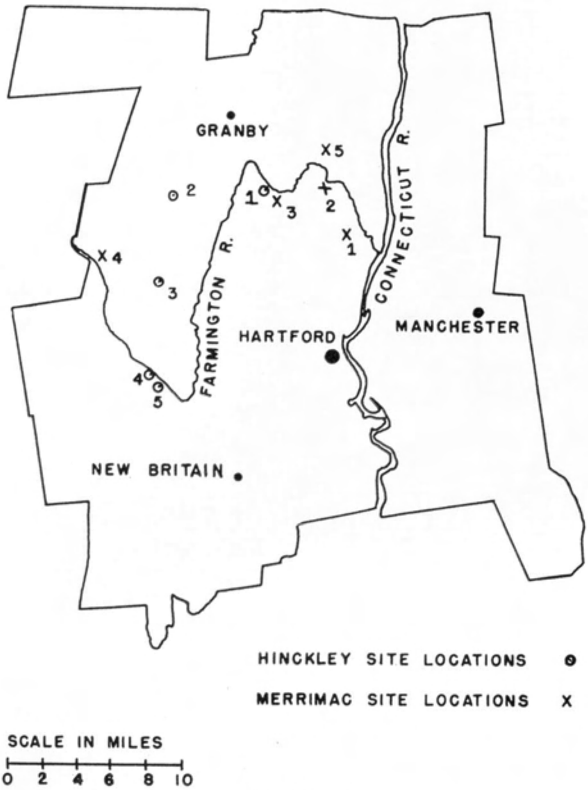


FIGURE 7

Location map of the Hinckley and Merrimac profile sampling sites, Hartford County, Connecticut.

## Method of Analyses

When air dry, the samples were transferred from the sample bags into pans and weighed. The samples were then oven dried (105°C) for 24 hours and again weighed. The moisture content was calculated from these data (Table 7). The oven-dry samples were placed immediately in a nest of eight-inch diameter sieves and sieved for 15 minutes in a Tyler automatic "Ro Tap" shaking apparatus in a manner described by Krumbein and Pettijohn (19). It has been shown (37) that a mechanical sieve shaker which includes a jarring action is better than one with only a horizontal motion. A Tyler electric timer was used to regulate the sieving time. After shaking, the material from each sieve was weighed. The results for each size class are expressed as percentages based on the oven-dry weight of the whole sample (gravel >2 mm and soil <2 mm).

No chemicals were used for dispersing these soils since they have practically no aggregation, being essentially structureless (single grained). When a sample contained a large amount of <0.25 mm material, the sample was divided into two separate sievings to insure complete separation. This usually occurred for the 0-6″ horizon samples.

The following sieve diameter sizes were used: 2″, 1″, 0.5″, 5 mm, 2 mm, 1 mm, 0.5 mm, and 0.25 mm. The 2 to 0.5″ sieves were round hole brass stone sieves of A.S.T.M. specification E-11. Brass round hole plate type sieves were used for the remaining smaller sizes with the exception of the 0.25 mm which was a 60 mesh Tyler wire screen.

Since for the purposes of this study, it was believed that the size-ranges set up for gravel separates[1] were too broad; the fine gravel and gravel separates were each separated into coarse and fine fractions. Geologists use several grade scales (19), but none of these scales were found to be suitable because the size ranges did not fit the categories mentioned above. These sieve separations represent the following separates as based on the U.S. Department of Agriculture standards (34).

1. 2″ + .................... coarse gravel
2. 2 – 1″ .................... gravel (coarse fraction)
3. 1 – 0.5″ .................. gravel (fine fraction)
4. 0.5″ – 5 mm ............... fine gravel (coarse fraction)
5. 5 – 2 mm .................. fine gravel (fine fraction)
6. 2 – 1 mm .................. very coarse sand
7. 1 – 0.5 mm ................ coarse sand
8. 0.5 – 0.25 mm ............. medium sand
9. < 0.25 mm ................. fine sand, very fine sand, silt and clay

The gravel size pebbles larger than 0.5″ in diameter were counted and tabulated according to the size ranges above. The volume represented by the size classes larger than 2 mm was determined by measuring their displacement in water and the percent of the total volume represented by each size class was calculated.

Total porosity and bulk density were calculated (6) using the volume of the sampling box as the unit of measurement. It is not possible to use small cores as is done for determining these physical characteristics in soils of 2 mm materials. In many cases, the gravel fragments are larger than the small cores. It is believed that the method employed measured the range of differences between these two soils.

Results from the laboratory analyses are presented as average values (Tables 1, 3, 4, 7 and 8) obtained from the 10 profiles sampled for the respective Hinckley and Merrimac soils. Statistical analyses (33) of the data are presented in Tables 2, 5 and 6. (For the convenience of the reader, all tables are placed in a separate section on pages 42 to 46.)

[1] Soil Survey Division, U.S.D.A. Progress report of Committee on Soil Texture (Mimeographed), Oct. 18, 1949.

## RESULTS

### Gravel Composition of the Profile

The distribution of the individual gravel separates, as determined in this study, are shown in Figures 8 and 9. The gravel fractions of all the Hinckley horizons are greater than those of the Merrimac. This is apparent in Figures 2, 4 and 6. Since it was not possible to sample Hinckley profiles containing the larger size gravels, it can be expected that the total amount of gravel is even greater than is indicated by the data.

The first three horizons of Merrimac were very low in gravel, consisting chiefly of the 0.5″-5 mm and 5-2 mm sizes. There was no dis-

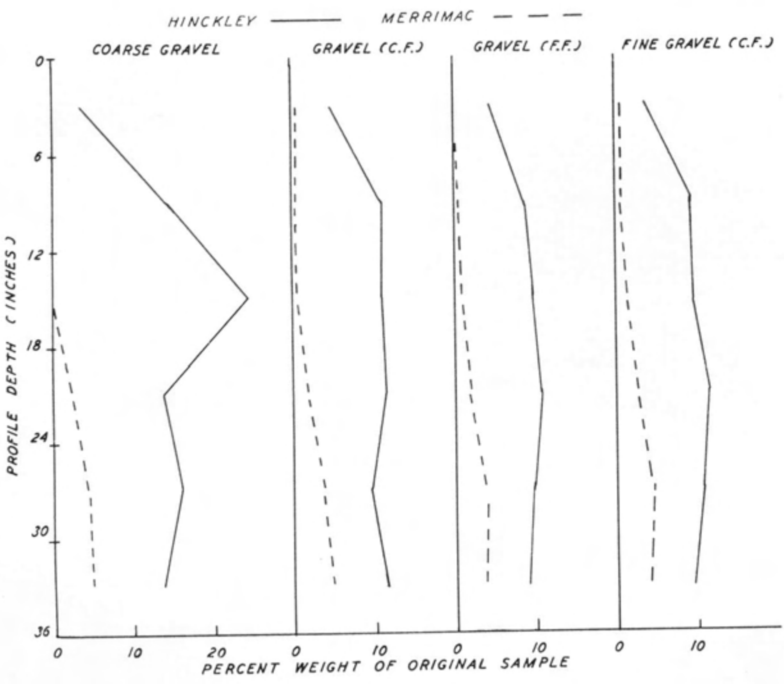


FIGURE 8

Distribution of the coarse gravel (>2″); gravel, coarse fraction (2 - 1″); gravel, fine fraction (1 - 0.5″); and fine gravel, coarse fraction (0.5″ - 5 mm) in the Hinckley and Merrimac profiles. The data are based on the average oven dry weights of the original samples (gravel >2 mm + soil <2 mm).

tinct accumulation of any gravel fraction in the Hinckley with the exception of the coarse gravel size in the 12-18 inch horizon.

When all of the gravel separates are considered together (Figure 11, Table 1), the Hinckley 0-6 inch horizon contained 8.6 times more and the 12-18 inch horizon 11.4 times more gravel on a weight basis than did similar horizons in the Merrimac. In the Merrimac, the total gravel increased only slightly to the 12-18 inch depth, then increased rather sharply with depth. For the Hinckley, the gravel increased rapidly to a maximum in the 12-18 inch sample; beyond this depth the gravel decreased slightly. Part of this increase is due to the greater amount of gravel in two of the soils at this depth.

Calculations show that statistically the differences in gravel between the two soils are significant in the first four horizons, except for the coarse gravel and the gravel (coarse fraction) sizes in the surface (Table 2).

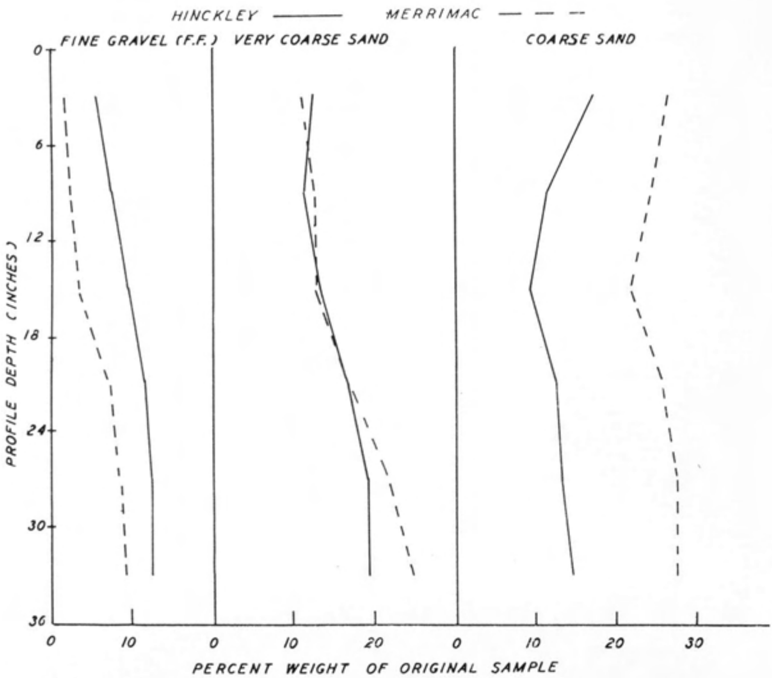


FIGURE 9

Distribution of the fine gravel, fine fraction (5 - 2 mm); very coarse sand (2 - 1 mm); and coarse sand (1 - 0.5 mm) in the Hinckley and Merrimac profiles. The data are based on the average oven dry weights of the original samples (gravel >2 mm + soil <2 mm).

## Coarse Gravel, Gravel and Fine Gravel Separates

In combining the data (Table 1) for the coarse and fine fractions of the gravel and fine gravel separates, respectively, the distribution of the standard size ranges (34) used for gravel is brought out in Figure 12. Since no coarse gravel occurred in the Merrimac and only 3.7 percent in the Hinckley, the coarse gravel was combined with the gravel separate.

The coarse gravel (>2″) and gravel (2-0.5″) in the Hinckley is considerably greater than in the Merrimac. The peak amount is at the 12-18 inch depth in the Hinckley. There is practically none in the Merrimac to this depth, it then increases to a maximum at 30-36 inches.

In the Hinckley, the fine gravel (0.5″-2 mm) does not increase as sharply with depth as the coarse gravel and gravel, especially in the 12-18 inch horizon. The Merrimac, however, contains more fine than coarse gravel in the first three horizons, increasing to about equivalent amounts in the last two horizons.

### Distribution of Sand in the Profile

The distribution pattern of sand is the converse of gravel (Figures 8, 9, 10 and 11); the Merrimac contains the most sand, and the Hinckley the most gravel. This is also evident in Figures 2, 4 and 6. All of the Merrimac

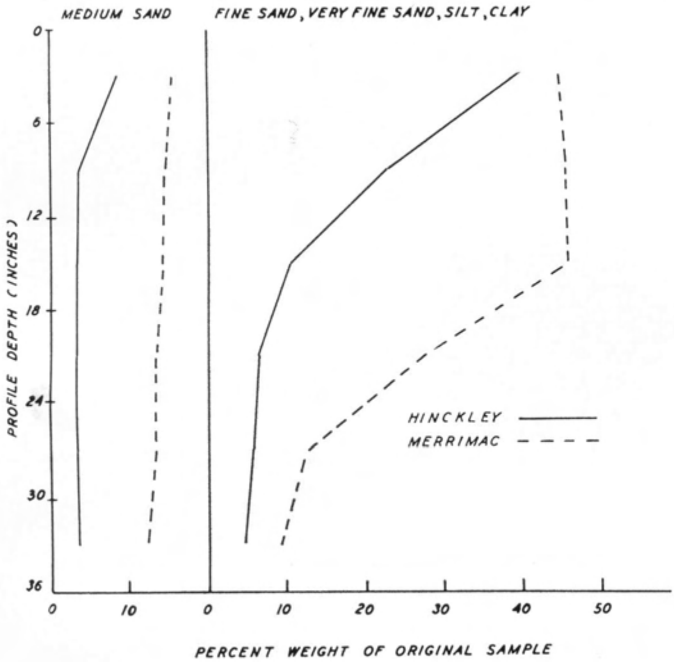


FIGURE 10

Distribution of the medium sand (0.5 - 0.25 mm) and the combined fine sand, very fine sand, silt and clay fractions (<0.25 mm) in the Hinckley and Merrimac profiles. The data are based on the average oven dry weights of the original samples (gravel >2 mm + soil <2 mm).

horizons contained more <2 mm materials than the Hinckley. In the 0-6 inch horizon, the Merrimac contained 97 percent; the Hinckley, 77 percent (Table 1). In the 12-18 inch horizon the amounts were 94 and 37 percent, respectively.

The distribution of the very coarse sand in the two soils is strikingly similar (Figure 9). Statistically, these differences were not significant (Table 2). Both the coarse and medium sand fractions were statistically significant in all of the horizons of the two soils, except for the 1-0.5 mm size in the surface.

The coarse sand in the Merrimac decreased with depth to 12-18 inches and then increased slightly in the last three horizons. About the same situation exists in the Hinckley except that this soil contains less coarse sand.

In both the Merrimac and Hinckley, the amount of medium sand is largest in the surface horizons. It then decreases slightly and remains fairly constant for the next five horizons (Figure 10).

Combining the very coarse and coarse sands (Figure 13) produces a distribution pattern much similar to that of coarse sand (Figure 9), except that in the lower horizons in Figure 13 the sand content increases more rapidly.

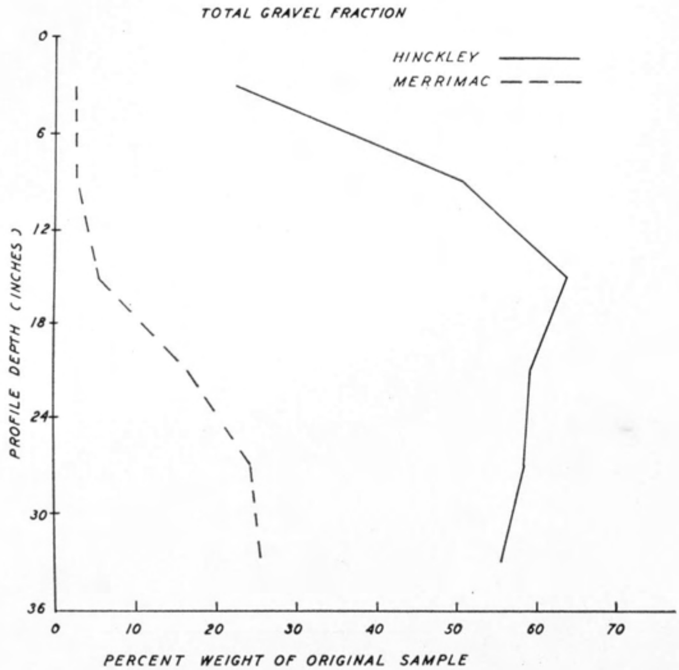


FIGURE 11

Distribution of the total gravel fraction (>2 mm) in the Hinckley and Merrimac profiles. The data are based on the average oven dry weights of the original sample (gravel >2mm + soil <2 mm).

## Material <0.25 mm in Diameter

In the top three horizons of the Merrimac, the amount of particles <0.25 mm is about the same, then abruptly decreases in the remaining three horizons (Figure 10). In the Hinckley, this separate decreases rather abruptly to 12-18 inches; then decreases slightly for the remaining horizons until the content for the two soils in the last horizon is about the same. In actual amount, about 45 percent of the top three horizons of the Merrimac profile is composed of <0.25 mm material while in the Hinckley it ranges from about 40 to 10 percent in these respective horizons (Table 1). In the next three lower horizons, the amounts are from 27 to 9 percent with increasing depth for the Merrimac and from 8 to 6 percent for the Hinckley.

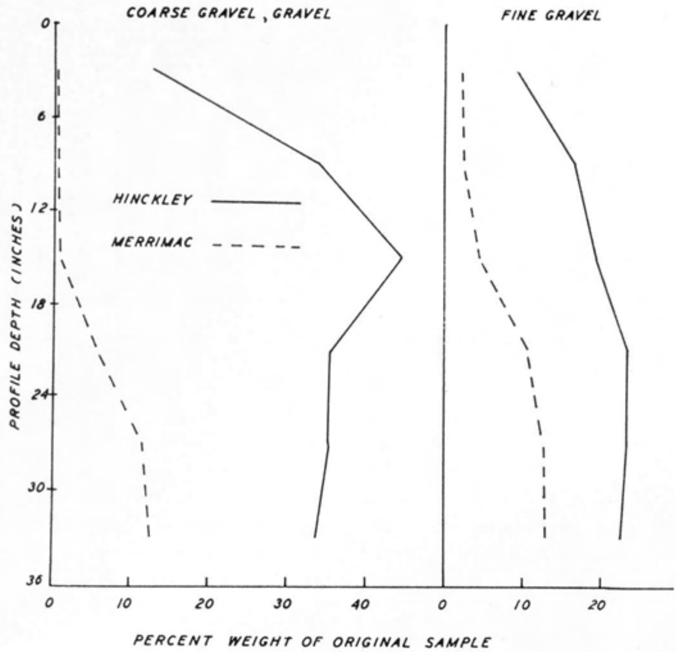


FIGURE 12

Distribution of the coarse gravel (>2″) and gravel (<2 - 0.5″) fractions and fine gravel (0.5″ - 2 mm) fractions in the Hinckley and Merrimac profiles. The data are based on the average oven dry weights of the original sample (gravel >2 mm + soil <2 mm).

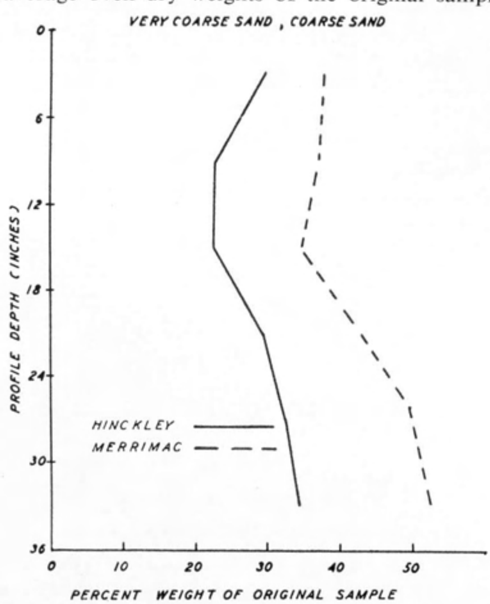


FIGURE 13

Distribution of the combined very coarse sand (2 - 1 mm) and the coarse sand (1 - 0.5 mm) fractions in the Hinckley and Merrimac profiles. The data are based on the average oven dry weights of the original samples (gravel >2 mm + soil <2 mm).

The differences in content of material <0.25 mm were statistically significant in all horizons except the 0-6 and 30-36 inch ones (Table 2).

Additional separations were not made of the material <0.25 mm. An idea of the amounts of fine sand, very fine sand, silt and clay occurring in a representative Merrimac fine sandy loam profile may be had from published (36) and unpublished data.[1] This Merrimac profile (36) contained about 16 percent fine sand, 12 percent very fine sand, 40 percent silt, and 6 percent clay in the surface 8 inches. In the 12-20 inch horizon, the amounts were 14, 18, 41 and 4 percent, respectively. At 20-26 inches, the amounts were 24, 9, 18 and 1 percent, respectively.

Mechanical analyses data are available on a Hinckley gravelly sandy loam (20). This profile contained 17 percent fine sand, 13 percent very fine sand, 23 percent silt and 7 percent clay in the surface five inches. In the 13-30 inch horizon, the amounts were 12, 2, 1 and 2 percent, respectively. Unpublished[1] mechanical analyses data of two other Hinckley profiles in Rhode Island show about the same relationships of these separates, namely medium amounts of silt and little clay.

The horizon depths and the basis used for calculating the above data and those obtained in this study are not comparable. The above data are based on material <2 mm while the data in this bulletin include both the soil and gravel fractions. Nevertheless, the data on the above soils do show that the Merrimac series can be expected to be high in silt and low in clay and the Hinckley series lower in both.

## Distribution Patterns of the Separates by Horizon

In general, the distribution patterns of the various separates for the two soils are not similar (Figures 14 and 15). Even the 0-6 inch horizons have dissimilar shape curves, though from field observations (Figures 2, 4 and 6) it might be expected they would be somewhat similar.

The patterns for the 0-6, 6-12, and 12-18 inch horizons for the Merrimac are very similar. The Merrimac horizons are more uniform with respect to their sand and gravel fractions than the Hinckley, especially in the first three horizons.

A greater content of gravels in the Hinckley produces a higher summation curve in the left hand side of the graph in contrast to the Merrimac. The three lower Hinckley horizons are characteristically high in gravel and very coarse sand, and low in particles <0.25 mm. These lower horizons differ chiefly from the two lower Merrimac horizons in having a larger amount of gravel, smaller amounts of coarse and medium sand, and smaller amounts of <0.25 mm material (Figures 2, 4 and 6).

### Transition Horizons of the Hinckley

In the Hinckley, the 6-12 inch horizon may be considered a transition between the surface and the third horizon (Figures 2, 4 and 14, Table 1). The 6-12 inch horizon differs from the 0-6 in having 42 percent less <0.25 mm material, 58 percent less medium sand, and 32 percent

[1] Mechanical analyses data, Soil Survey Division, U.S.D.A.

less coarse sand. All of the gravel fractions in the 6-12 inch horizon are greater in amount than in the surface, ranging from 37 percent more for the 5-2 mm fraction to 286 percent more for the >2 inch gravel size.

The third horizon may be considered a continuation of the transition of the second horizon to the last three for this third layer has more gravel, less sand and less <0.25 mm particles than the second. Strikingly, almost one-fourth of the material in the 12-18 inch horizon consists of gravel >2 inches in diameter. None of the other horizons in either the Hinckley or Merrimac profiles contains as much of this particular separate.

**Transition Horizons of the Merrimac**

The Merrimac 18-24 inch horizon may be considered a transition between the three upper horizons and the two lower ones (Figures 6 and 15, Table 1). The three top layers on an average have about 66 percent

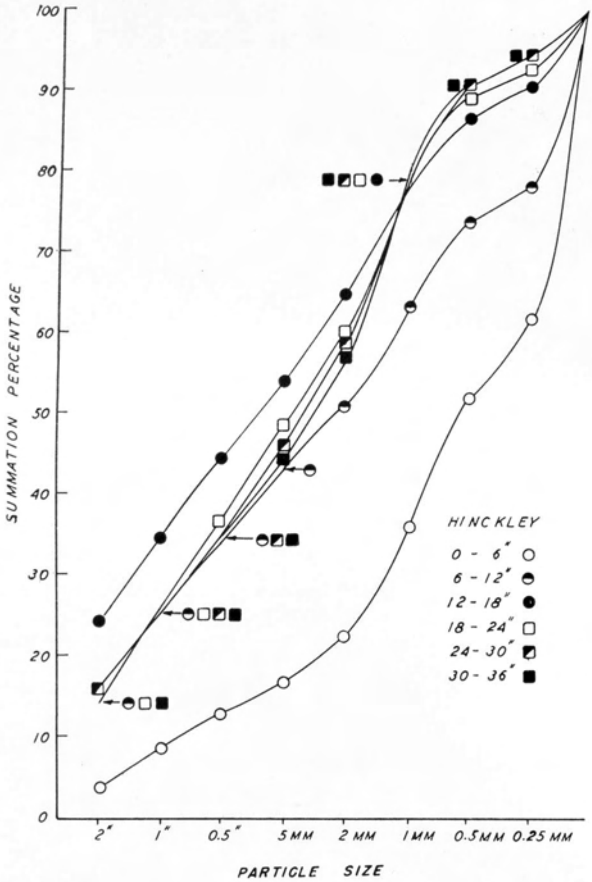


FIGURE 14

Summation curves showing the distribution of all gravel (>2 mm), sand (<2->0.25 mm), and particles <0.25 mm in the Hinckley profile.

more particles <0.25 mm than the fourth one. The 18-24 inch horizon also differs from the two horizons below in having 62 percent more <0.25 mm material and slightly less coarse sand, very coarse sand and gravel.

The two lower Merrimac horizons are similar in composition. Their chief characteristics are the high amounts of very coarse sand and coarse sand and the lower content of particles <0.25 mm.

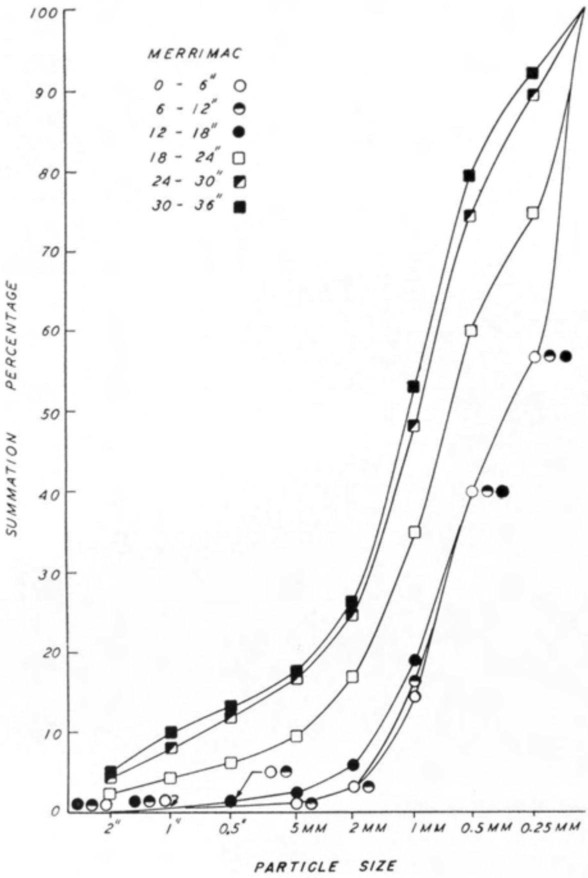


FIGURE 15

Summation curves showing the distribution of all gravel (>2 mm), sand (<2 - >0.25 mm), and particles <0.25 mm in the Merrimac profile.

## Volume Occupied by Gravel

The volume occupied by the gravel separates in the Hinckley and Merrimac soils is shown in Figure 16 and Table 1. It is realized that measuring the volume of each separate does not actually represent the distribution of the separates in the profile. Actually, the smaller particles occupy the voids between the larger separates, tending to achieve closest packing of the various size materials. Also, the method used for determining the displacement of the gravel separates in water was limited since it was possible to read their displacement to an accuracy of only about 10 cc of water. Furthermore, it was not possible to measure the volume occupied by the material below gravel size. For these reasons, it is believed that a better idea of the distribution of the various separates can be obtained from their weights.

About the same relationships of the gravel separates are shown by the volume method in Figure 16 as by the weight analyses in Figure 11 except that the latter method gives 10 to 20 percent larger values.

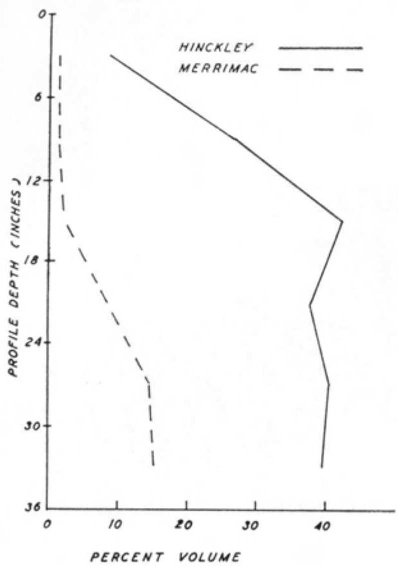


FIGURE 16

Volume occupied by the gravel fraction (>2 mm) in the Hinckley and Merrimac profiles.

## Total Porosity

Total porosity relationships are presented in Figure 17. Porosity of the surface horizons is similar. In the Hinckley, porosity progressively decreases to 12-18 inches, then remains about constant, while in the Merrimac this decrease continues to 24-30 inches before leveling off. The increase in gravel in the Hinckley is reflected in a reduction in percentage pore space but the one is not a mirror image of the other. The largest difference in porosity between the Hinckley and Merrimac horizons, 8.3 percent, occurs in the 12-18 inch depth (Table 3).

Since these soils are essentially structureless (single grain), aggregation was non-existent, with the exception of some in the surface. From this it may be concluded that very little of the porosity, with the exception of the 0-6 inch horizon, was due to aggregation.

An analysis of variance (Table 5) showed that the differences in total porosity between the respective horizons of the Hinckley profile were highly significant, and also this was true for the Merrimac horizons. In other words, the differences between adjacent horizons were highly significant. A "t" test (Table 6) shows that only differences in total porosity between the Hinckley and Merrimac 12-18 and 18-24 inch horizons were significant. This statistical test is substantiated by the plotted data in Figure 17.

From the above statements the question arises, "What may account for the differences in porosity between these two soils?" As is well known, coarse-textured soils are higher in bulk density because of the close contact of the particles, while fine-textured soils are generally lighter due to the tendency of the small particles to resist compaction (24). This means that coarse-textured soils usually contain less pore space than fine-textured ones. Pore volume increases with an increasing amount of fine-textured materials. The following statement by Tolman (38) helps to explain the

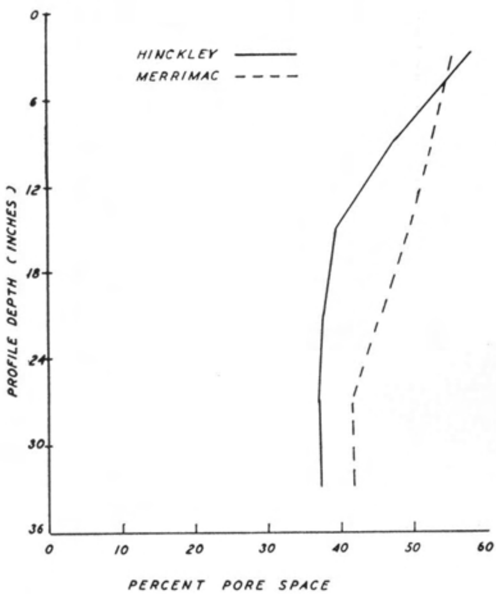


FIGURE 17

Total porosity relationships in the Hinckley and Merrimac profiles.

greater porosity of the Merrimac samples, "The larger the proportion of larger grains enclosed in the fine material, the greater the reduction in average porosity of the formation."

According to Tolman (38) weathering processes, especially of crystalline rocks, produce cracks or pore spaces, and subsequently, comminution of the rocks. Since weathering decreases with depth, this explains, in part, the decrease in pore space. It is difficult, however, to visualize weathering and soil formation processes producing all of the fine materials ($<0.25$ mm) in these soils from the sands and gravels. The comparatively short time interval of 15 to 20,000 years (12) since the recession of the Wisconsin glacier is hardly long enough for these fine soil materials to have been formed. Much of these fine materials may be of eolian origin (36) or they may have been originally in the glaciofluvial deposits. According to Chepil (7), fine sand, silt and clay particles are highly susceptible to movement by wind. Of these fractions, silt is carried into the atmosphere in much greater quantity than either fine sand or clay.

## Bulk Density

Bulk density is greater in the Hinckley with the exception of the surface where it is less than in the Merrimac (Figure 18). A higher organic matter content in the Hinckley surface may account for this. Differences in organic matter in the surface horizon of these soils, however, are not large. An average value of 2 percent has been reported for a cultivated Merrimac sandy loam (14) and 1.5 percent for a cultivated Hinckley loamy coarse sand (4).

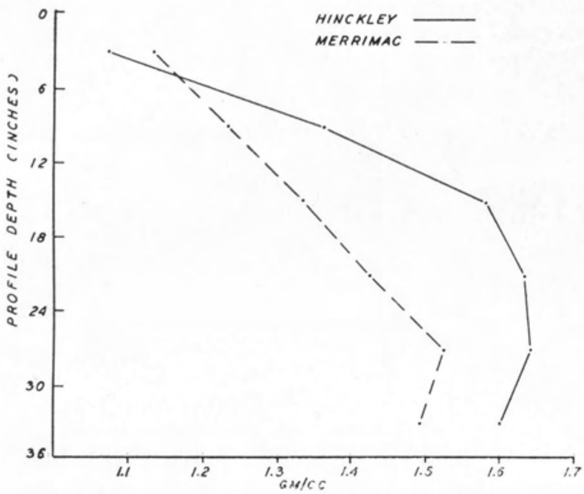


FIGURE 18

Bulk density relationships in the Hinckley and Merrimac profiles.

In the Hinckley the bulk density increased abruptly to 1.58 (Table 4) at 12-18 inches, increased slightly with greater depth, and then decreased to 1.60 at 30-36 inches. The bulk density of the Merrimac increased to a maximum of 1.53 at 24-30 inches, then decreased slightly. The highest bulk density values occur in the 24-30 inch horizons for both soils.

Bulk density is least in the Hinckley $<12$ inches and Merrimac $<24$ inches sola. A greater bulk density prevails in the substratum of the Hinckley because of the coarser nature and greater amount of gravels present. As previously discussed, less pore space exists in soils having high amounts of coarse material as compared to soils high in fine material. As expected, bulk density is inversely related to total porosity. Thus, the

Hinckley substratum contains less pore space than the Merrimac (Figure 17), resulting in a higher bulk density (Figure 18). The higher amounts of hygroscopic water in the Merrimac (Table 7) also show the effect of larger amounts of fine materials.

An analysis of variance (Table 5) shows that the differences in bulk density between the Hinckley and Merrimac were significant, and also that there were highly significant differences among the six different depths sampled. This is to say that the differences between adjacent horizons were highly significant. A "t" test (Table 6) shows that only differences in bulk density between the Hinckley and Merrimac 12-18 and 18-24 inch horizons were highly significant and for the 24-30 inch depth, significant.

## Pebble Count

Pebbles 5 mm or larger were greater in number in all horizons of the Hinckley (Table 8 and Figures 2, 4 and 6). This large number of pebbles $>5$ mm was partly responsible for the more rapid reduction of porosity with depth in the Hinckley than in the Merrimac (Figure 17). The gravels in the Hinckley and Merrimac are well rounded and spherical in shape, especially in the lower Hinckley horizons.

## Nomenclature of the Horizons of the Two Soils

When consideration is given to other characteristics of horizons such as color, structure, etc. (see Appendix: Description of Soil Profiles Sampled) in addition to differences in amount and size of the separates, porosity and bulk density, the standard genetic nomenclature may be assigned to the horizons. It should be mentioned that horizons in Brown Podzolic soils are not distinct but grade from one to the other. It is not possible, therefore, to assign horizon nomenclature within a specific depth.

The substratum of these soils has been designated a D horizon instead of the usual C. As brought out in the section on Total Porosity above and later in the section on Source of the Coarse and Fine Textured Materials, it is not believed that the solum of either soil was developed from the coarse materials in the substratum.

It may be assumed that the 0-6 inch depth in cultivated areas generally includes all or most of the $A_p$ horizons of the Hinckley and the Merrimac. Porosity values for the two soils are highest in the $A_p$. The 6-12 and 12-18 inch layers of the Merrimac probably is its B. The summation curves (Figures 14 and 15) show that the average depth of the profile over sand and gravel for the Hinckley is somewhere within the 6-12 inch depth. This depth probably represents the B of the Hinckley. The Hinckley profiles, however, are extremely variable in depth; in places the 6-12 inch horizon is the transition zone and in other places this may be the 12-18 inch depth. The average solum depth for the soils described in the Appendix is 13.7 inches for 10 Hinckley profiles and 24 inches for 10 Merrimac profiles.

The 18-24 inch Merrimac horizon apparently represents a transition between the adjacent upper and lower ones. This horizon may represent the lower B or upper D. The summation curves for the 24-30 and 30-36 inch horizons are higher in the left hand corner than those of the upper horizons. This higher gravel content suggests that these two lower layers represent the D horizon.

The four lower Hinckley horizons have similar summation curves due to their high gravel content. These horizons probably represent the D.

The highest bulk density and lowest porosity values for both soils occur in the D horizons. Also, the amount of gravel in the D horizon (12 inches +) is greater in the Hinckley than in the Merrimac equivalent (18 inches +).

According to depth classes of soil (34), these data show that the Hinckley is shallow and the Merrimac moderately deep.

## DISCUSSION

This quantitative study of the sand and gravel fractions was aimed at strengthening morphological field observations of the Hinckley and Merrimac series and to get some idea about the physical features of these soils that affect their use. This study should also be useful in similar problems arising in other soils with large amounts of sand and gravel, such as the Manchester and Hartford, the Jaffrey and Barnsted, the Schodak and Copake, and the Groton and Palmyra.

Merrimac soils in the Connecticut Valley are most commonly developed on glaciofluvial deposits. The substratum consists of stratified material with thin topset beds over deep foreset beds mainly of coarse sand. Hinckley soils most commonly develop on uneven or pitted surfaces, eskers and crevasse fillings, but some areas do occupy nearly level surfaces. Gravel in both of these series form the substratum or D horizon. The four main factors justifying a series separation for these two soils are (a) permeability and water relationships, (b) relative retention of fertilizers, (c) use for cropping and (d) topography.

Although fine distinctions are not generally made in fragments larger than very coarse sand, principally because they usually do not make up a very high proportion of the soil mass, these larger fragments nevertheless are important in the genesis, morphology, classification and behavior of soils. They influence moisture storage, infiltration and runoff (34). They affect root growth, especially through their dilution of the mass of active soil. They protect fine particles from wash and blowing. They are moved with the soil mass in tillage.

Soils high in coarse fragments are characterized by low cohesion, low plasticity, and low water-holding capacity (28). These soils because of their low field capacity and excessive drainage are apt to be droughty unless the rainfall is plentiful and well distributed. In drier sections, therefore, there would be no point in separating coarse-textured soils into two or more series. Only a small proportion of their pore volume is in the form of capillary pores. Aeration is usually good. The soils are "light," and as a result of low field capacity, warm up rather early in the spring. If the coarse substratum is deep, rapid and excessive percolation of water and a low cation exchange capacity make leaching losses heavy.

Deep coarse sandy soils, according to Lutz and Chandler (23), usually support relatively poor forest stands and, other things being equal, the site quality of sandy soils increases as the proportion of material smaller than 0.2 mm increases.

Differences in the ability of soils to retain water are shown in some lysimeter data by Morgan and Street (26). Comparisons for a five-year period were made using the surface seven inches of four soils of different textures in the Windsor lysimeters. The average annual precipitation was 36.9 inches. With respect to percentages of the total precipitation leached through these soils, the Merrimac loamy sand[1] lost 44.7 percent; the Merrimac sandy loam, 40.6 percent; the Wethersfield loam, 40.1 percent; and the Enfield very fine sandy loam, 34.8 percent. Had the entire profile been used in the lysimeters, the differences between these soils probably would have been greater. Rates of evaporation are also an index of the retentiveness of soils for water. Average rates of evaporation for these soils during the growing season from May 26 to August 12 were found to be 0.080, 0.086, 0.089 and 0.096 acre inches per day, respectively. Since the sandy soils held less water than the finer textured soils, they had less water available for evaporation.

Coile (8) has shown that gravel and stones hold appreciable quantities of water. The amount varies with the kind of rock, being least for quartz and increasing with increased weathering of the minerals. The smaller the gravel size, the more moisture absorbed. On this basis, one would expect the Merrimac to hold more moisture than the Hinckley.

### Field Observations, Laboratory Analyses, and Soil Classification

It is apparent from the data that these soils, although not differing in some respects morphologically, differ considerably in their sand and gravel composition. Both soils are structureless, except in the surface, which is weakly aggregated. They are dominantly loose, and coarse to moderately coarse-textured, especially in the lower horizons. In forested areas the color of the top inch of soil is 10 YR 3/2[2] and in cultivated areas the $A_p$ ranges from 10 YR 3/4 to 4/4. Where Triassic materials are more abundant, the color falls on the 7.5 YR 4/4 color chart. In the B, the range of color is greater, being redder where the Triassic materials occur in larger amounts with the 7.5 YR 5/6 to 5/8 color predominating. The color of the D varies from 7.5 YR 5/6-7/8 to 10 YR 5/6-7/8 depending on the amount of Triassic rocks present. Generally, the predominant color is of the 10 YR hue. Demarcation between horizons is not distinct.

From field and laboratory data, it is evident that the Hinckley is a more coarse-textured soil than the Merrimac, is more droughty, and presumably would not be as productive. The data show that the Hinckley is more gravelly and has a coarser skeleton in the B and D horizons than the Merrimac, which helps to explain its droughtiness, lower porosity, and higher bulk density. Field observations and also the coarse fragment, porosity, and bulk density data show that the Hinckley has more large pores and fewer small ones than the Merrimac, a condition conducive to low water-holding capacity (6).

It is believed these laboratory analyses coupled with field observations warrant the mapping of these closely related but agronomically different soils as separate series. Differences in the profile in their sand and gravel composition and the relationship this has to their use would seem to justify this separation.

---

[1] See footnote, p. 9.
[2] Munsell color notations (34).

**Soil Mapping Ranges for the Hinckley, Merrimac and Associated Series in Hartford County**

A soil mapping unit consists of a principal taxonomic unit plus a small number of other units. A distinction should be made between mapping units and classification units. The latter contains only one soil. Mapping units usually consist principally of one soil but sometimes may consist of two or more similar soils too complex to map out. Therefore, it is possible for a given soil to be included in two different mapping units. Thus, mapping units serve the practical purpose of making a soil map. Mapping ranges used for the Hinckley, Merrimac and associated series in Hartford County, based on field and laboratory research, are discussed below.

The Hinckley and Merrimac series have similar genetic profiles but differ in their depth of solum over stratified sand and gravel deposits. The sola range from about 6 to a maximum of 30 inches, but only a few sites have been observed where the thickness is as much as 30 inches. For mapping purposes in Hartford County, the Merrimac solum is allowed to range from 18 to 24 inches, but may be a few inches deeper in places. For Hinckley this range is from 6 to 12 or 14 inches. Thus, the break between the Hinckley and Merrimac is made at an arbitrary depth of about 18 inches.

The Hinckley generally has a higher content of gravel on the surface and in the solum than the Merrimac. Most of the Merrimac occurs on nearly level to undulating terraces, but small areas do occur on slopes ranging up to 15 percent. The Hinckley, on the other hand, typically occurs on irregular pitted and broken surfaces, eskers and kames, with slopes ranging from 5 percent upward. Small areas of Hinckley, however, do occur on nearly level surfaces.

Glaciofluvial deposits on which these two soils are developed vary from fine gravel and coarse sand to cobble stone and coarse gravel. It is probably true that the Hinckley (especially on eskers) is more generally underlain by the coarser type of deposits than the Merrimac, but this is not a consistent criterion for the separation of these two series.

The Hinckley and Merrimac differ from the Manchester and Hartford soils chiefly in color of the solum. The Manchester and Hartford series are developed on stratified sand and gravel originating from Triassic sandstone and shale and the Hinckley and Merrimac on granitic materials. The Hinckley and Merrimac are restricted to 7.5 YR hues or lighter and the Manchester and Hartford series are 5 YR hues and redder in color.

The Agawam series differs from the Hinckley and Merrimac in being underlain by sand essentially free of gravel to a depth of five feet or more. The solum depth of the Agawam corresponds to that of the Merrimac. Small areas are included with the Agawam where stratified sand and gravel is present at 4 or 5 feet in depth, but not as a continuum. Also included with the Agawam are small areas with small amounts of gravel on the surface and throughout the solum, but with no definite underlying stratified sand and gravel.

The Enfield series differs principally from the Hinckley and Merrimac in being finer textured in the solum and in having a substratum composed mainly of Triassic rather than granitic materials. This fine material is thought to be of eolian origin. The texture of the Enfield solum is mainly a very fine sandy loam but in places it is a silt loam. Most of the Enfield in Hartford County is underlain by a D horizon composed of red stratified sand and gravel developed from Triassic sandstone and shale. Areas have been observed where these soils are underlain by glaciofluvial deposits of granitic origin. In some places, this finer-textured material is thick enough to result in a C horizon and has been observed to be as deep as five feet. The Manchester, Cheshire and soils associated with Enfield may have a thin veneer of silty material in places and the soil is mapped as a member of the respective series. Fine-textured materials less than 18 inches thick over sand and gravel are mapped as shallow Enfield.

## Source of the Coarse and Fine Textured Materials

It has been suggested (36) that an appreciable amount of the high content of silt in the A and B horizons of Merrimac is of eolian origin. This study offers some evidence of wind action. Figure 11 suggests that the high amounts of gravels below 18 inches were deposited by water action. Both Figures 10 and 11 strongly suggest a drastic change in mode of deposition. The gravels may represent the nature of water activity during the early history of Lake Hartford (10, 11), and the finer particles the later stages of drying up of this lake. With more area exposed to wind action on the drying of Lake Hartford, more materials were available for movement and deposition. Some of these fine materials evidently were deposited in Lake Hartford or after this lake had dried up and now are found in the upper 6 to 12 inches of the Hinckley and 18 to 24 inches of the Merrimac soils, respectively.

## Soil Management Aspects

The Merrimac series in the Connecticut Valley is regarded as an important tobacco[1] soil while the Hinckley series is not generally regarded as such. According to Swanback and Anderson (35) and Anderson (2), tobacco soils with gravel or coarse sandy subsoil permit excessive leaching and drought injury in dry weather. The best subsoils are fine or medium sandy loams with good water retentive capacity. On the basis of the data reported above, the Merrimac subsoil may be classed with the water retentive soil and the Hinckley with the droughty soil.

Swanback and Anderson (35) state that a tobacco crop in growing to maturity uses about 114 pounds of nitrogen per acre but to make up for leaching and other losses 200 pounds must be applied. Potash also is subject to leaching. Experiments by Anderson, Swanback and LeCompte (3) have shown that 40 to 130 pounds of potash per acre will leach out of a tobacco soil in a year. A good tobacco crop will remove about 155 pounds of potash from an acre of soil during a growing season. On the basis of leaching loss and needs by the crop, 200 pounds per acre of potash are standard applications for tobacco.

Experiments by Morgan and Jacobson (25) on vegetable production on Merrimac sandy loam indicate large amounts of nitrogen were especially

---

[1] All tobacco grown in Connecticut is used for cigars (2). The Shade type is grown primarily for cigar wrappers (the outer layer); Broadleaf and Havana Seed, the other two types grown, are used for cigar binders (the layer just under the wrapper).

beneficial in seasons with frequent heavy rainfall. In a wet season, 135 pounds of nitrogen per acre gave highest yields while in drier seasons with little or no nitrogen lost by leaching, 90 pounds gave best results.

Considering the rather high losses of nitrogen and potash from the Merrimac because of leaching, knowledge of the sand and gravel composition of soils is important. It can be expected that these losses would be even greater in the Hinckley because of its larger pores and smaller content of material $<2$ mm.

Anderson, Swanback and LeCompte (4) have described sandy knolls (Hinckley loamy coarse sand[1]) underlain at shallow depths by gravelly or coarse sandy substrata as creating a management problem on many tobacco farms in the Connecticut Valley. The crops on these sandy knolls suffer from lack of moisture in dry seasons and during wet seasons from excessive leaching of plant nutrients causing starved plants. Experiments on finding management methods for improving the yield and quality of tobacco on this unproductive soil (from one-third to one-half less than on adjacent Merrimac sandy loam) were not too successful (4, 5). None of the practices increased yields and quality sufficiently to make them comparable to the adjacent Merrimac sandy loam but some gave considerable improvement.

Stable manure applied at from 20 to 40 tons per acre annually for five years produced no important increases in yields but the quality of the leaf was improved (4, 5). The fact that stable manure increased root rot contributed to this lack of increase in yield. Organic matter increased from 1.48 to 2.48 percent at the 40-ton application, a rise of 59.7 percent for the five-year period. The following year when no manure was added, the organic matter content declined to 2.17. It is apparent that organic matter in a soil of this kind rapidly disappears unless it is renewed constantly. These high applications of manure increased the water-holding capacity of the soil. For the untreated soil, the amount was 27.9 percent and for the manured plots 30.6 (5). Application of 30 tons per acre of a commercial peat gave results similar to that of manure.

An application of clay worked into the soil to a depth of four inches in two successive years increased the productivity of the soil (4). It is questionable whether this is economically practical because of the high labor and machinery costs involved in trucking and spreading clay on a field.

Oats, rye or vetch sowed immediately after harvesting the tobacco and plowed under the following spring gave yield increases of about 200 pounds per acre (4). These cover crops absorbed the plant nutrients, especially nitrogen, available in the soil, which were later released to the plant. Since these nutrients were taken up by the plant, they could not be leached from the soil. After turning under these cover crops for six years, the organic matter content of the soil was increased on a percentage basis 0.108, 0.154 and 0.173 for oats, rye and vetch in comparison with the untreated soil.

The use of mulch paper to conserve moisture and to reduce leaching also increased tobacco yields (4).

The most promising results on growing tobacco on these sandy, gravelly soils was by fractional applications of nitrogen. The yield was increased about 10 percent and the grade index of quality 0.067 points

[1] Formerly in the Hinckley series but now included in the Carver, a tentative series in Connecticut.

(4). The data indicate that the leaching of nitrogen is more damaging than the inability of the soil to retain moisture. This theory is strengthened by the fact that this soil (Hinckley loamy coarse sand)[1] was irrigated frequently in dry weather for two seasons but the crop was not much improved.

From the standpoint of a tobacco grower, the use of Hinckley soils for tobacco growing should be avoided. If these soils must be used, rye, oats or vetch should be used as cover crops each year and readily available nitrogen should be applied after every heavy rain. Fractional application of nitrogen should be continued until the crop is at least half grown.

Since these soils have rapid to very rapid internal drainage and their surface runoff is low to very low, erosion by water is not the problem that it is on some soils. It is difficult to estimate erosion accurately on Brown Podzolic soils. The horizons grade into each other so it is not possible to determine accurately the amount of soil removed by erosion. The original A horizons were thin with the result that the plow layer (8 inches) now includes the A and the upper part of the B. The National Cooperative Soil Survey series descriptions give the Hinckley $A_1$ as 0 to 3 inches thick under virgin conditions with a 2 to 4 inch thickness range; the Merrimac $A_1$ has the same thickness with a range of 3 to 5 inches.

In the Hartford County soil survey, undifferentiated erosion is mapped on all areas of the Hinckley series because of the shallowness of its solum, the difficulties encountered in mapping erosion, and because erosion on this soil is variable. This series includes slopes ranging from 0 to 3 percent and from 3 to 15 percent with nearly all of the Hinckley occurring on the latter slopes.

In the Merrimac series, class 1 erosion is mapped on all slopes. This soil occurs most extensively on 0 to 3 percent slopes. Small areas are found on 3 to 8 and 8 to 15 percent slopes. The soils on the latter slopes usually occur on terrace margins and are largely in forests.

Class 1 erosion is used to indicate areas where little or no significant water or wind erosion has occurred. Some erosion may have occurred but it has not developed to the point that the productivity of the land is threatened nor has it become a hazard to land use. Few or no special soil management measures are necessary as the result of past or existing erosion.

Although these soils are not subject to much erosion, care should be taken that they are managed properly so that erosion is not accelerated. One soil management practice that will ensure minimum erosion is the planting of cover crops. On soils used for tobacco or vegetables, a cover crop such as rye or oats may be sown.

Cover crops have several benefits. In dry, windy weather they will keep the soil from blowing. On the more sloping areas, the roots and foliage of the cover crops will prevent erosion. They take up unused plant nutrients applied as fertilizers after the principal crop is harvested. Because of the rapid internal drainage of these soils, these nutrients will be leached into the lower horizons and become lost to the plants. In lysimeter experiments at Windsor it was found that a cover crop of oats on a Merrimac sandy loam prevented the leaching of 56 pounds of nitrogen, 44 pounds of calcium, 24 pounds of potassium and 8 pounds of magnesium to the acre in one year (2).

---

[1] See footnote, p. 31.

The turning under of a cover crop each year also maintains soil organic matter. Since those soils are low in organic matter, applications of organic material is especially beneficial in making the soil more retentive of moisture and plant nutrients.

## SUMMARY

Field and laboratory studies were made of the Hinckley and Merrimac series occurring in Hartford County, Connecticut, relative to their genesis, morphology, physical properties, classification and use. Samples were taken at 6-inch depth intervals to 36 inches. A special sieve analysis was made of the entire sample (gravel >2″->2 mm, sands <2 mm->0.25 mm, and separates <0.25 mm) since these soils are high in sand and gravel. Other analyses included total porosity, bulk density and pebble count determinations.

Although these soils do not differ in some respects morphologically, they differ considerably in their sand and gravel composition. Both soils are structureless (single grain), except in the surface horizon, which is weakly aggregated. They are dominantly loose, and coarse to moderately coarse textured, especially in the lower horizons.

Since their internal drainage is rapid to very rapid and their surface runoff low to very low, erosion is not a major problem.

The Hinckley is found most extensively on 3 to 15 percent slopes and the Merrimac on 0 to 3 percent slopes.

The gravel fraction (>2″->2 mm) of all of the Hinckley horizons was greater than that of the Merrimac, being as much as 85 times more in the 6-12 inch depth for the >0.5″ fraction.

The Merrimac contains the most sand with the largest amounts occurring in the first three horizons, then decreasing with depth.

All of the Merrimac horizons contain more <2 mm materials than the Hinckley. In the 0-6 inch horizon, the amounts are 97 and 78 percent, respectively; in the 12-18 inch layer, the amounts are 94 and 36 percent, respectively.

About 45 percent of the three upper Merrimac horizons are composed of <0.25 mm particles while in the Hinckley it decreases from about 40 percent in the surface to about 10 percent in the third horizon.

The three lower horizons of the Hinckley are higher in gravel and very coarse sand, and lower in coarse sand, medium sand, and >0.25 mm material than the Merrimac.

Field observations and laboratory analyses of the two soils suggest that the 0-6 inch depth represents the $A_p$ horizon; the 6-12 inch horizon, the B of the Hinckley; the 6-12, 12-18, and 18-24 inch horizons, the B zone of the Merrimac; the horizons below 12 inches, the D of the Hinckley and the horizons below 24 inches, the D of the Merrimac.

For the two soils, bulk density is greater for all the Hinckley horizons with the exception of the surface where it is about the same for the two soils. Bulk density reaches a maximum at the 24-30 inch depth for both Hinckley (1.64) and Merrimac (1.53). This is in accord with the known fact that coarse-textured soils are higher in bulk density than fine-textured ones.

Total porosity is higher in the Merrimac than in the Hinckley soil. This is a reflection of the larger amount of fine-textured material in the Merrimac.

Counts of the larger sized fragments (>5 mm) obtained in the sieve analyses showed a greater number in all horizons of the Hinckley. The gravels were well rounded and spherical in shape, especially in the lower horizon of the Hinckley.

It is evident from the field and laboratory data that the Hinckley is a more coarse-textured soil than the Merrimac, is more droughty, and is not as productive. The Hinckley is more gravelly in the B and D horizons, which helps explain its droughtiness, lower porosity and higher bulk density.

From the standpoint of the grower, the use of Hinckley soils for tobacco and vegetables should be avoided. If these soils must be used, a cover crop such as rye, oats or vetch should be plowed under each year. Additions of manure and other kinds of organic matter will enhance their productivity. Fractional applications of nitrogen should be made during the growing season, especially after every heavy rain.

Cover crops are beneficial to both soils for controlling wind and water erosion, taking up excess plant nutrients, and adding organic matter.

A statistical analysis of the data for the two soils showed them to be significantly different in their content of gravel, sand (except 2-1 mm size) and material <0.25 mm. They were also significantly different in their total porosity and bulk density.

## REFERENCES


1. Ableiter, J. K. Trends in soil classification and correlation at the series level. Soil Sci. Soc. Amer. Proc. **14**:320-322. 1949.
2. Anderson, P. J. Growing tobacco in Connecticut. Conn. Agr. Expt. Sta. Bul. 564. 1953.
3. ——————, Swanback, T. R., and Lecompte, S. B. Potash fertilizer experiments. Conn. Agr. Expt. Sta. Bul. 326:357-372. 1931.
4. ——————————————————. Experiments on improving growth of tobacco on an unproductive sandy knoll. Conn. Agr. Expt. Sta. Bul. 335:224-239. 1932.
5. —————————— and Street, O. E. Manure as a supplement to commercial fertilizer. Conn. Agr. Expt. Sta. Bul. 326:384-387. 1931.
6. Baver, L. D. Soil Physics. 2nd. ed. John Wiley and Sons, Inc. New York. 1948.
7. Chepil, W. S. Factors that influence clod structure and erodibility of soil by wind: I. Soil texture. Soil Sci. **75**:473-483. 1953.
8. Coile, T. S. Moisture content of small stone in soils. Soil Sci. **75**:203-207. 1953.
9. deSigmond, A. A. J. The Principles of Soil Science. Thomas Murby and Co. London. 1938.
10. Flint, R. F. The glacial geology of Connecticut. Conn. Geol. and Nat. Hist. Survey Bul. 47. 1930.
11. ————. Late Pleistocene sequence in the Connecticut Valley. Bul. Geol. Soc. Amer. **44**:965-988. 1933.
12. ————. Probable Wisconsin substages and late-Wisconsin events in northeastern United States and southeastern Canada. Bul. Geol. Soc. Amer. **64**:897-919. 1953.
13. Goodman, K. V. Stratigraphy of the soils of the glacial outwash, York County, Maine. Soil Sci. Soc. Amer. Proc. **11**:452-457. 1946.
14. Jacobson, H. G. M. Substitutes for stable manure in commercial vegetable farming. Conn. Agr. Expt. Sta. Bul. 560. 1952.

15. Jacobson, H. G. M., Swanson, C. L. W., and Smith, E. Effect of various fertilizer cations and anions on soil reaction, leaching, nitrification of urea and related characteristics in an uncropped soil. (A report on Windsor lysimeter series E) Soil Science **65**:437-460. 1948.
16. Joffe, J. S. Pedology. Pedology Publications. New Brunswick, N. J. 1949.
17. Keen, B. A. The Physical Properties of the Soil. Longmans, Green and Co. London. 1931.
18. Kilmer, V. J., and Alexander, L. T. Methods of making mechanical analyses of soils. Soil Sci. **68**:15-24. 1949.
19. Krumbein, W. C., and Pettijohn, F. J. Manual of Sedimentary Petrography. Appleton-Century-Crofts, Inc. New York. 1938.
20. Latimer, W. J., and Lanphear, M. O. Soil survey of Berkshire County, Massachusetts. Bur. Chem. and Soils. U.S. Dept. Agr. 1929.
21. ———————————————. Soil survey of Essex County, Massachusetts. Bur. Chem. and Soils, U.S. Dept. Agr. 1930.
22. ———————— and Smith, L. R. Soil survey of Hampden and Hampshire Counties, Massachusetts. Bur. Chem. and Soils, U.S. Dept. Agr. 1932.
23. Lutz, H. J., and Chandler, R. F. Forest Soils. John Wiley and Sons, Inc. New York. 1947.
24. Lyon, T. L., Buckman, H. O., and Brady, N. C. The Nature and Properties of Soils. 5th ed. The Macmillan Co., New York. 1950.
25. Morgan, M. F., and Jacobson, H. G. M. Soil management for intensive vegetable production on sandy Connecticut Valley land. Conn. Agr. Expt. Sta. Bul. 439. 1940.
26. ———————— and Street, O. E. Seasonal water and nitrate leachings in relation to soil and source of fertilizer nitrogen. (A second report on Windsor lysimeter series "A.") Conn. Agr. Expt. Sta. Bul. 429. 1939.
27. Robinson, G. W. Soils, Their Origin, Constitution and Classification. Thomas Murby and Co. 3rd ed. London. 1949.
28. Shaw, B. T. Soil Physical Conditions and Plant Growth. Academic Press. New York. 1952.
29. Shearin, A. E., Madison, S. V., and Colvin, W. S. Soil survey of Newport and Bristol Counties, Rhode Island. B.P.I.S.A.E., U.S. Dept. Agr. 1942.
30. ————————————————————, and Shutak, V. Soil survey of Providence, Rhode Island. B.P.I.S.A.E., U.S. Dept. Agr. 1943.
31, ————————, Williams, B. H., Gladwin, F. J., and Howard, M. Soil survey of Strafford County, New Hampshire. B.P.I.S.A.E., U.S. Dept. Agr. 1949.
32. Simmons, C. S., Latimer, W. J., Layton, M. H., Coates, W. H., Lyford, W. H., and Scripture, P. N. Soil survey of Cheshire and Sullivan Counties, New Hampshire. B.P.I.S.A.E., U.S. Dept. Agr. 1949.
33. Snedecor, G. W. Statistical Methods. The Iowa State College Press. Ames, Iowa. 1946.
34. Soil Survey Staff. Soil survey manual. Agricultural Handbook No. 18. U.S. Dept. Agr. 1951.
35. Swanback, T. R., and Anderson, P. J. Fertilizing Connecticut tobacco. Conn. Agr. Expt. Sta. Bul. 503. 1947.
36. Swanson, C. L. W., Shearin, A. E., and Bourbeau, G. A. Characteristics of some Brown Podzolic profiles in the Central Lowland of Connecticut and Massachusetts. Soil Sci. Soc. Amer. Proc. **16**:203-207. 1952.
37. Swineford, A. A comparison of three sieve shakers. Jour. Sedimentary Petrology **16**:3-13. 1946.
38. Tolman, C. F. Ground Water. McGraw-Hill Book Company, Inc. New York. 1937.
39. Vanduyne, C., and Bromley, J. H. Soil survey of the White Plains Area, New York. Bur. Soils, U.S. Dept. Agr. 1922.

## APPENDIX

### DESCRIPTION OF SOIL PROFILES SAMPLED

Hinckley Series

*Site 1*

| | |
|---|---|
| Location: | On SW corner of Windsor Locks USGS[1] quadrangle about one-half mile S of Farmington River on Route 9 on W side of road. Location marked on back of aerial photo CNE 11-91. Sampled 3/20/51. |
| Vegetation: | Mostly second growth hardwoods—white birch, red maple, black birch, elm, red oak, white oak, gray birch, a few hemlocks and white pines. |
| Topography: | Nearly level, slope to E about 15%. |

*Profile No. 1—Hinckley coarse loamy sand*

| | |
|---|---|
| $A_0$[2] 1-0″ | Leaf mulch. |
| $A_p$ 0-5″ | Dark yellowish brown (10 YR 4/4)[3] coarse loamy sand. Old plow layer visible in places. |
| $B_{21}$ 5-10″ | Strong brown (7.5 YR 5/8) loamy coarse sand with small amount of fine gravel. |
| $B_{22}$ 10-15″ | Considerable fine and medium gravel. Color same as above. |
| D 15-36″ | Coarse sand and gravel; small amount of fine material. Color between a strong brown and yellowish brown (7.5 YR 5/6 and 10 YR 5/6). |

*Profile No. 2—Hinckley coarse loamy sand*

Taken about 220′ SE of profile No. 1. Same profile and cover except it is a virgin profile. $A_1$ 4-6″ Dark brown (7.5 YR 3/2) coarse loamy sand.

*Site 2*

| | |
|---|---|
| Location: | On SW corner of Tariffville USGS quadrangle by gravel pit in wooded area on S side of road just E of Hedgehog Mountain. Location marked on aerial photo CNE 3-88. Sampled 3/26/51. |
| Vegetation: | Cut-over pasture and run-out orchard; few apple trees still remaining. Young trees of white pine and red maple, wild cherry and stag horn sumac. |
| Topography: | On a rolling to level N-S terrace. East slope 8-15%, W slope about 3-8%. |

*Profile No. 3—Hinckley gravelly sandy loam*

| | |
|---|---|
| $A_p$ 0-7″ | Old plow layer. Dark yellowish brown (10 YR 3/4), texture about a gritty loam or sandy loam. |
| B 7-12″ | Strong brown (7.5 YR 5/8) coarse sand and gravel—some finer material present. Grades into layer below. |

[1] United States Geological Survey.

[2] In Connecticut, it is not unusual to find very thin $A_0$ and $A_1$ horizons in areas previously cultivated, probably 75 to 100 years or more ago (as estimated from present tree growth), and now in forest. Since the first settlement in Connecticut in 1633 at Windsor in Hartford County, the land has been cleared, farmed, abandoned and new forest growth appeared, many places probably going through 2 or 3 complete cycles. The plow layer is discernible because of the darker color of the soil compared with the B. In many places the $A_p$ is easily discernible, but in others it is not so easily seen.

[3] Munsell color notations (34).

D 12-36″ — Reddish yellow (7.5 YR 6/6) coarse sand, gravel and well rounded stones and cobbles. Most of stones are granite, gneiss or quartzite with an occasional schist present.

*Profile No. 4—Hinckley gravelly sandy loam*

Location: Approximately 200′ N of profile No. 3. The slope to the E is not quite as steep.

$A_p$ 0-7″ — Same as profile No. 3 but slightly lighter texture.

B 7-10″ — Same as profile No. 3 in color and texture.

$D_1$ 10-14″ — Definite stratum of stones appearing.

$D_2$ 14-37″ — Reddish yellow color (7.5 YR 6/6) coarse sand and fine gravel. Skeleton is actually of well rounded stones and cobbles—good sphericity. Range from 2-10″ diameter, gravel and coarse sand fill in between cobbles.

*Site 3*

Location: On Avon USGS quadrangle on E side of Route 167, 0.2 mile N of Crowleys Corner at intersection of Routes 44 and 167. Location marked on aerial photo CNE 3-91. Sampled 3/27/51.

Topography: Top of terrace running E. North slope (or NE) 20-30% S; SW slope 3-20%. Top of terrace where samples were taken is quite level.

Vegetation: Second and third growth hardwoods. White oak dominant; some gray birch, white pine, red pine, hemlock and red oak present.

*Profile No. 5—Hinckley loamy coarse sand*

$A_p$ 0-6″ — Dark brown (7.5 YR 4/4) loamy coarse sand, very light, loose; some gravel.

B 6-14″ — Strong brown (7.5 YR 5/6) loamy coarse sand and fine gravel. Definite 8″ layer of gravel 3/4-2″ in size, well rounded and spherical.

D 14-36″ — Coarse sand and fine gravel. Looser and fewer stones and coarse gravel than in 6-14″ layer. Color difficult to determine. A few garnets lend pinkish hue but reddish yellow (7.5 YR 7/8) is closest color.

*Profile No. 6—Hinckley coarse loamy sand*

Location: Approximately 200′ E-SE of profile No. 5.

$A_o$[1] 1-0″ — More of a leaf mulch here than at profile No. 5.

$A_p$ 0-6″ — Dark yellowish brown (10 YR 4/4) heavy coarse loamy sand or light coarse sandy loam.

B 6-13″ — Brownish yellow (10 YR 6/6-6/8) gravelly loamy coarse sand. Definite stratum but not as much coarse material as in profile No. 5.

$D_1$ 13-18″ — This horizon could be a lower B or $D_1$. A definite grading into coarser material—not enough fine material to be loamy. Coarse sands and fine gravel.

$D_2$ 18-36″ — Mostly fine gravel, some coarse sand, much coarse gravel, very few stones. Mainly crystalline material but some Triassic grains, with garnets, tend to add a pink tinge. Material so coarse, color is hard to pinpoint. About pink to reddish yellow (7.5 YR 7/4-7/6).

[1] See footnote 2, p. 36.

*Site 4*

Location: On NW corner of New Britain USGS quadrangle about 1.2 mile E of Unionville and 500′ N of Hyde Brook between NY NH and H RR tracks and New Britain Avenue. Location marked on aerial photo CNE 3-51. Sampled 4/4/51.

Topography: On top of a terrace, running nearly N-S, SW of Farmington River about ¼ mile to NE. Near E or NE slope of terrace which is very steep 30-40%. Terrace top is nearly level with a few irregular places.

Vegetation: The area where the sample was taken is in old pasture sod. Most of the field has recently been seeded to clover.

*Profile No. 7—Hinckley sandy loam*

$A_p$ 0-6″ Dark yellowish brown (10 YR 3/4) sandy loam, some gravel fragments. Has a gritty feel but quite coarse textured.

B 6-15″ Strong brown (7.5 YR 5/8) coarse loamy sand. All sizes of gravel appearing from 6-8″ on. Grades into D horizon.

D 15-36″ Brownish yellow (10 YR 6/6) coarse sand and gravel, frequent well rounded stones. Sod roots go to about 15-18″, very few below that depth. Rocks are mainly granites, granodiorite, pegmatite, gneiss; mainly weathered schists or granites. An occasional red sandstone is found.

*Profile No. 8.—Hinckley sandy loam*

Location: Approximately 200′ N of profile No. 7. Profile is about the same as No. 7. $A_p$ and B seem a trifle coarser textured. Upper part of B is a sandy loam. Some gray birch is coming up in old pasture sod.

*Site 5*

On NW corner of New Britain USGS quadrangle about 900′ directly S of Farmington R on E side of NY NH and H RR tracks. Location marked on aerial photo CNE 3-97. Sampled 4/6/51.

Topography: On level top of a terrace running N-S, S of Farmington River. East slope of terrace is very steep, 30-40% and on W there seems to be a slightly higher level around 200′ back, then it grades into upland soils.

Vegetation: Run-out pasture, mostly old sod of poverty grasses but growing up in red cedar, gray birch with an occasional red pine and/or white pine.

*Profile No. 9—Hinckley sandy loam*

$A_p$ 0-6″ Dark brown (10 YR 3/3) sandy loam with slight granulation.

B 6-14″ Yellowish brown (10 YR 5/8) sandy loam to about 12″ merges gradually into D from about 14 to 18″. Horizon boundary hard to distinguish. Weathered rock fragments make color fluctuate widely in lower B and D. Gravel begins at about 6″ and is frequent near lower part of B.

D 14-36″ Yellow (10 YR 7/8) coarse sand and gravel. Gravel and sand show two-toned color effect with lower part more grayish. Below 30″ mostly coarse sand.

*Profile No. 10—Hinckley coarse sandy loam*

Location: About 210′ S of profile No. 9. Profile is similar to No. 9.

| | |
|---|---|
| $A_p$ 0-7 or 9″ | Plow layer seems a little deeper. Texture is coarser—coarse sandy loam. Color same as $A_p$ in profile No. 9 (10 YR 3/3-3/4). |
| B 7 or 9″-14″ | Yellowish brown (10 YR 5/8) coarse gravelly sandy loam near $A_p$, much gravel from 12-14″, very few stones. |
| $D_1$ 14-24″ | Brownish yellow (10 YR 6/8) coarse sand and gravel grading into yellow (10 YR 7/6-7/8) around 20-22″. The two-tone color of the D has a little better definition than in Sample No. 9 but in places the darker color goes all the way to 36″. |
| $D_2$ 24-36″ | Color is mostly yellow (10 YR 7/8) and dries to light crystalline colors. Mostly coarse sand below 30″. Both profiles 9 and 10 are very loose. Frequent well rounded weathered granite, gneiss, schist and granodiorite fragments with an occasional red sandstone fragment. |

### Merrimac Series

*Site 1*

| | |
|---|---|
| Location: | Hartford North USGS quadrangle. The Connecticut Agricultural Experiment Station Tobacco Laboratory Farm in Windsor, E side of road. Marked on aerial photo CNE 11-64. Sampled 4/24/51. |
| Vegetation: | Tobacco field, oat cover crop. |
| Topography: | Level terrace. |

*Profile No. 1—Merrimac sandy loam*

| | |
|---|---|
| $A_p$ 0-11″ | Dark yellowish brown (10 YR 3/3-3/4) sandy loam to coarse sandy loam. |
| $B_{22}$ 11-21″ | Strong brown to dark yellowish brown (7.5 YR 5/6 close to 10 YR 4/4) sandy loam to coarse sandy loam. Compacted, firm in place from 11-16″ (plow sole). |
| $B_{23}$ 21-24″ | Loamy sand to loamy coarse sand. Same color as $B_{22}$ but looser in place. |
| D 24-36″ | Coarse sand, some fine gravel; very loose. Some mixing of colors from upper horizons. About a pale brown (10 YR 7/4-7/6) with many gray, crystalline sands. |

*Profile No. 2—Merrimac sandy loam*

Same kind of profile sampled 230′ S of No. 1.

*Site 2*

| | |
|---|---|
| Location: | Windsor Locks USGS quadrangle about 1400′ S-SW of dam in Farmington River SW of Rainbow at end of trail in wooded area. Location marked on aerial photo CNE 12-116. Sampled 4/24/51. |
| Vegetation: | Principally jack pine, scattered red maple, gray birch, white pine and red oak. Very little undergrowth, some poverty grasses. |
| Topography: | Level terrace. |

*Profile No. 3—Merrimac loamy coarse sand*

| | |
|---|---|
| $A_p$ 0-8″ | Dark yellowish brown (10 YR 4/4) loamy coarse sand. |
| $B_{22}$ 8-18″ | Strong brown (7.5 YR 5/8) loamy coarse sand; texture gets finer with depth. |
| $B_{23}$ 18-24″ | Texture even finer than above horizon, same color. Blends with soil at about 24″ depth. |
| D 24-36″ | Reddish yellow (7.5 YR 6/6) coarse sand and some fine gravel. Quite a bit of Triassic influence. Very few roots. Old sod roots very shallow with only 1 or 2 present at this depth. |

*Profile No. 4—Merrimac loamy coarse sand*

Sampled 250′ S of profile No. 3. This location similar to No. 3 in cover, topography and profile.

*Site 3*

Location: On SW corner of Windsor Locks USGS quadrangle near Hartford North quadrangle line about 1700′ E of BM 183 on N side of road. Marked on aerial photo CNE 11-91. Sampled 4/26/51.

Vegetation: Old hardwoods, few conifer. Dominantly beech, pin oak, white oak, red maple, some hemlock and white pine.

Topography: Level terrace.

*Profile No. 5—Merrimac sandy loam*

$A_o$ 1-0″ Matted mor. Directly under this mor there is a black, silty, friable layer about ½″ thick.

$A_1$ 0-4″ Dark yellowish brown (10 YR 3/3-4/4), very friable, weakly aggregated sandy loam.

$B_{21}$ 4-14″ Brown to strong brown (7.5 YR 4/4-5/6) friable sandy loam.

$B_{22}$ 14-20″ Hard to distinguish from above horizon. Texture seems to be a sandy loam. Color grades between a dark yellowish brown and yellowish brown (10 YR 4/4-5/4).

$B_{23}$ 20-24″ Yellowish brown (10 YR 5/6) loamy coarse sand blends in with coarse sand and fine gravel at about 24″.

D 24-36″+ Yellowish brown (10 YR 5/6) and lighter, dries out to grayish hue; very loose coarse sand and fine gravel.

Tree roots mostly in first foot, some down to 2′, none observed below 2′. A horizon has tendency to be platy. Lower level of sand and gravel (30-36″) shows stratification.

*Profile No. 6—Merrimac sandy loam*

Sampled 210′ N of profile No. 5. This location similar to No. 5 in cover, topography and profile.

*Site 4*

Location: Collinsville USGS quadrangle. N of Collinsville on W side of road about 500′ N of intersection of River Road and unnamed road crossing Farmington River. Location marked on aerial photo CNE 5-82. Sampled 4/26/51.

Vegetation: Run-out pasture land, still a fairly heavy sod cover.

Topography: Level to rolling area of outwash.

*Profile No. 7—Merrimac very fine sandy loam*

$A_p$ 0-11″ Very dark grayish brown to dark yellowish brown (10 YR 3/2-3/4) very fine sandy loam; weak aggregates near surface.

$B_{22}$ 11-18″ Strong brown (7.5 YR 5/6) very fine sandy loam. Gradually blends with $B_{23}$ which is a fine sandy loam and not as sticky. Actual boundary difficult to discern.

$B_{23}$ 18-24″ Fine sandy loam, same color as above layer. Color uncertain in D but layer of gravel quite regular.

D 24-36″+ Well rounded gravel, closely packed. Most stones are from 1-3″ in diameter. Sand fills spaces between gravel. Well stratified and difficult to shovel. Sand has about a 2.5 Y 5/6 color. Stones are crystalline- no trap or Triassic stones were seen. All show much weathering.

*Profile No. 8—Merrimac fine sandy loam*

| | |
|---|---|
| | Sampled about 230′ W of profile No. 7. |
| $A_p$ 0-10″ | Very dark grayish brown (10 YR 3/2) very fine sandy loam to fine sandy loam. |
| $B_{22}$ 10-16″ | Strong brown (7.5 YR 5/6) fine sandy loam. |
| $B_{23}$ 16-22″ | Strong brown (7.5 YR 5/6) loamy sand, some gravel present. |
| D 22-36″ | Coarse sand, fine gravel, medium gravel and coarse gravel. Color of B blends in and with weathering of gravel makes color indefinite. |

Gravel in profile No. 8 much looser, more small sizes (most gravel between ¼″-1½″ in diameter) and more coarse sand present than in profile No. 7. Entire profile is grittier and finer textured.

*Site 5*

| | |
|---|---|
| Location: | Windsor Locks USGS quadrangle on W side of Bradley Field about 1800′ S-SW of BM 169 in wooded area on N side of road. Location marked on aerial photo CNE 12-114. Sampled 5/1/51. |
| Vegetation: | Jack pine, few gray birch; very little undergrowth. Many small pine seedlings coming in. |
| Topography: | Level sand plain. |

*Profile No. 9—Merrimac loamy coarse sand*[1]

| | |
|---|---|
| $A_p$ 0-10″ | Very dark grayish brown to dark brown (10 YR 3/2-4/3) loamy coarse sand (may be light coarse sandy loam). Quite loose. New $A_1$ seems to be forming near surface. |
| $B_{22}$ 10-20″ | Strong brown (7.5 YR 5/8) loamy coarse sand, some finer material included. Slight compaction at 11-13″ from old plow sole. |
| $B_{23}$ 20-25″ | Coarse sand, brownish yellow (10 YR 6/8). This horizon may be a $D_1$ rather than a $B_{23}$. |
| D 25-36″+ | Yellow (10 YR 7/6-8/6) loose, coarse sand and fine gravel. Some Triassic material, lot of quartz and garnet. Few roots below 20″, most are in first 10″. |

*Profile No. 10—Merrimac loamy coarse sand*

Sampled 220′ W of profile No. 9. Profile similar to No. 9 except slightly coarser texture. B horizon not quite as bright colored, closer to 7.5 YR 5/6 than to 5/8.

[1] Formerly in the Merrimac series but now included in the Carver, a tentative series in Connecticut.

Table 1. Particle Size Analysis of the Sand and Gravel Fractions of the Hinckley and Merrimac Soils

| Sieve size | Volume (per cent) Hinckley Aver.[1] | Volume (per cent) Hinckley Accum. | Volume (per cent) Merrimac Aver.[2] | Volume (per cent) Merrimac Accum. | Weight (per cent) Hinckley Aver.[2] | Weight (per cent) Hinckley Range | Weight (per cent) Hinckley Accum. | Weight (per cent) Merrimac Aver.[2] | Weight (per cent) Merrimac Range | Weight (per cent) Merrimac Accum. | Average no. of pebbles Hinckley[2] | Average no. of pebbles Merrimac[2] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | *0 – 6″ Horizon* | | | | | | | |
| > 2″ | 1.1 | 1.1 | 0 | 0 | 3.7 | 16.6 | 3.7 | 0 | 0 | 0 | 0.7 | 0 |
| 2 – 1″ | 2.4 | 3.5 | 0.1 | 0.1 | 4.9 | 20.7 | 8.6 | 0.4 | 2.5 | 0.4 | 4.7 | 0.3 |
| 1 – 0.5″ | 1.8 | 5.3 | 0 | 0.1 | 4.4 | 7.9 | 13.0 | 0.1 | 0.4 | 0.5 | 30.0 | 0.8 |
| 0.5″ – 5 mm | 1.5 | 6.8 | 0.1 | 0.2 | 4.0 | 7.4 | 17.0 | 0.3 | 0.5 | 0.8 | 34.5 | 33.2 |
| 5 – 2 mm | 2.0 | 8.8 | 0.9 | 1.0 | 5.7 | 9.4 | 22.7 | 1.8 | 2.5 | 2.6 | nc[3] | nc |
| 2 – 1 mm | nd[4] | ... | nd | ... | 12.5 | 16.0 | 35.2 | 10.9 | 20.1 | 13.5 | nc | nc |
| 1 – 0.5 mm | nd | ... | nd | ... | 17.0 | 14.3 | 52.2 | 26.4 | 39.0 | 39.9 | nc | nc |
| 0.5 – 0.25 mm | nd | ... | nd | ... | 5.9 | 12.1 | 58.1 | 13.7 | 21.7 | 53.6 | nc | nc |
| < 0.25 mm | nd | ... | nd | ... | 42.1 | 20.4 | 100.2 | 46.5 | 56.6 | 100.1 | nc | nc |
| Total | | | | | 100.2 | | | 100.1 | | | | |
| | | | | | *6 – 12″ Horizon* | | | | | | | |
| > 2″ | 7.9 | 7.9 | 0 | 0 | 14.3 | 37.2 | 14.3 | 0 | 0 | 0 | 2.9 | 0 |
| 2 – 1″ | 6.1 | 14.0 | 0.1 | 0.1 | 10.8 | 22.5 | 25.1 | 0.2 | 1.5 | 0.2 | 12.0 | 0.2 |
| 1 – 0.5″ | 4.7 | 18.7 | 0.1 | 0.2 | 8.8 | 14.5 | 33.9 | 0.2 | 1.0 | 0.4 | 80.6 | 1.8 |
| 0.5″ – 5 mm | 4.4 | 23.1 | 0.2 | 0.4 | 9.1 | 12.1 | 43.0 | 0.3 | 0.7 | 0.7 | nc | 51.9 |
| 5 – 2 mm | 3.7 | 26.8 | 1.0 | 1.4 | 7.8 | 15.1 | 50.8 | 2.1 | 3.8 | 2.8 | nc | nc |
| 2 – 1 mm | nd | ... | nd | ... | 11.1 | 18.0 | 61.9 | 12.4 | 23.0 | 15.2 | nc | nc |
| 1 – 0.5 mm | nd | ... | nd | ... | 11.6 | 17.5 | 73.5 | 24.4 | 32.5 | 39.6 | nc | nc |
| 0.5 – 0.25 mm | nd | ... | nd | ... | 3.3 | 10.0 | 76.8 | 14.9 | 11.5 | 54.5 | nc | nc |
| < 0.25 mm | nd | ... | nd | ... | 23.2 | 46.5 | 100.0 | 45.5 | 62.0 | 100.0 | nc | nc |
| Total | | | | | 100.0 | | | 100.0 | | | | |
| | | | | | *12 – 18″ Horizon* | | | | | | | |
| > 2″ | 17.8 | 17.8 | 0 | 0 | 24.3 | 59.2 | 24.3 | 0 | 0 | 0 | 1.7 | 0 |
| 2 – 1″ | 7.9 | 25.7 | 0.2 | 0.2 | 10.4 | 20.2 | 34.7 | 0.5 | 3.4 | 0.5 | 11.8 | 0.6 |
| 1 – 0.5″ | 6.1 | 31.8 | 0.3 | 0.5 | 9.3 | 13.8 | 44.0 | 0.5 | 1.4 | 1.0 | 97.0 | 5.5 |
| 0.5″ – 5 mm | 5.5 | 37.3 | 0.7 | 1.2 | 9.8 | 16.0 | 53.8 | 1.3 | 3.0 | 2.3 | nc | 188.9 |
| 5 – 2 mm | 4.7 | 42.0 | 1.0 | 2.2 | 9.6 | 17.0 | 63.4 | 3.3 | 6.6 | 5.6 | nc | nc |
| 2 – 1 mm | nd | ... | nd | ... | 13.2 | 30.7 | 76.6 | 12.4 | 23.0 | 18.0 | nc | nc |
| 1 – 0.5 mm | nd | ... | nd | ... | 9.2 | 14.5 | 85.8 | 21.8 | 30.0 | 39.8 | nc | nc |
| 0.5 – 0.25 mm | nd | ... | nd | ... | 2.3 | 5.3 | 88.1 | 14.3 | 18.3 | 54.1 | nc | nc |
| < 0.25 mm | nd | ... | nd | ... | 12.0 | 21.3 | 100.1 | 45.9 | 59.3 | 100.0 | nc | nc |
| Total | | | | | 100.1 | | | 100.0 | | | | |

TABLE 1. PARTICLE SIZE ANALYSIS OF THE SAND AND GRAVEL FRACTIONS OF THE HINCKLEY AND MERRIMAC SOILS (cont.)

| Sieve size | Volume (per cent) Hinckley Aver.[5] | Volume Hinckley Accum. | Volume Merrimac Aver.[2] | Volume Merrimac Accum. | Weight (per cent) Hinckley Aver.[2] | Weight Hinckley Range | Weight Hinckley Accum. | Weight Merrimac Aver.[2] | Weight Merrimac Range | Weight Merrimac Accum. | Average no. of pebbles Hinckley[2] | Average no. of pebbles Merrimac[2] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *18 – 24″ Horizon* | | | | | | | | | | | | |
| > 2″ | 9.8 | 9.8 | 1.1 | 1.1 | 14.5 | 39.2 | 14.5 | 2.4 | 19.8 | 2.4 | 1.4 | 0.4 |
| 2 – 1″ | 7.3 | 17.1 | 0.9 | 2.0 | 11.1 | 25.2 | 25.6 | 1.8 | 11.0 | 4.2 | 15.7 | 2.3 |
| 1 – 0.5″ | 7.0 | 24.1 | 1.0 | 3.0 | 10.9 | 9.1 | 36.5 | 1.8 | 7.8 | 6.0 | 104.0 | 14.3 |
| 0.5″ – 5 mm | 7.3 | 31.4 | 1.7 | 4.7 | 11.6 | 13.2 | 48.1 | 3.0 | 5.5 | 9.0 | nc | 440.3 |
| 5 – 2 mm | 6.4 | 37.0 | 4.2 | 8.9 | 11.7 | 21.0 | 59.8 | 7.5 | 13.0 | 16.5 | nc | nc |
| 2 – 1 mm | nd | ... | nd | ... | 16.9 | 23.4 | 76.7 | 17.0 | 30.8 | 33.5 | nc | nc |
| 1 – 0.5 mm | nd | ... | nd | ... | 12.5 | 19.5 | 89.2 | 25.9 | 33.2 | 59.4 | nc | nc |
| 0.5 – 0.25 mm | nd | ... | nd | ... | 2.8 | 5.3 | 92.0 | 13.5 | 14.1 | 72.9 | nc | nc |
| < 0.25 mm | nd | ... | nd | ... | 8.0 | 11.8 | 100.0 | 27.1 | 33.0 | 100.0 | nc | nc |
| Total | | | | | 100.0 | | | 100.0 | | | | |
| *24 – 30″ Horizon* | | | | | | | | | | | | |
| > 2″ | 12.8 | 12.8 | 2.6 | 2.6 | 16.0 | 50.6 | 16.0 | 4.2 | 41.8 | 4.2 | 2.0 | 0.7 |
| 2 – 1″ | 7.2 | 20.0 | 2.3 | 4.9 | 9.5 | 17.5 | 25.5 | 3.7 | 18.7 | 7.9 | 15.0 | 5.9 |
| 1 – 0.5″ | 6.8 | 26.8 | 2.4 | 7.3 | 9.7 | 15.0 | 35.2 | 3.7 | 27.6 | 11.6 | 114.0 | 32.7 |
| 0.5″ – 5 mm | 7.2 | 34.0 | 2.6 | 9.9 | 10.9 | 16.0 | 46.1 | 4.3 | 14.5 | 15.9 | nc | nc |
| 5 – 2 mm | 6.4 | 40.4 | 5.0 | 14.9 | 12.3 | 14.8 | 58.4 | 8.4 | 11.8 | 24.3 | nc | nc |
| 2 – 1 mm | nd | ... | nd | ... | 19.1 | 29.1 | 77.5 | 21.5 | 32.5 | 45.8 | nc | nc |
| 1 – 0.5 mm | nd | ... | nd | ... | 13.1 | 20.8 | 90.6 | 27.9 | 40.1 | 73.7 | nc | nc |
| 0.5 – 0.25 mm | nd | ... | nd | ... | 3.2 | 3.7 | 93.8 | 13.7 | 20.8 | 87.4 | nc | nc |
| < 0.25 mm | nd | ... | nd | ... | 6.2 | 7.7 | 100.0 | 12.5 | 17.9 | 99.9 | nc | nc |
| Total | | | | | 100.0 | | | 99.9 | | | | |
| *30 – 36″ Horizon* | | | | | | | | | | | | |
| > 2″ | 12.1 | 12.1 | 3.2 | 3.2 | 14.6 | 46.3 | 14.6 | 4.9 | 26.3 | 4.9 | 2.2 | 1.2 |
| 2 – 1″ | 9.1 | 21.2 | 3.3 | 6.5 | 11.2 | 24.2 | 25.8 | 5.0 | 29.3 | 9.9 | 17.1 | 6.6 |
| 1 – 0.5″ | 5.7 | 26.9 | 2.0 | 8.5 | 8.6 | 12.6 | 34.4 | 3.0 | 15.1 | 12.9 | 88.8 | 30.2 |
| 0.5″ – 5 mm | 5.6 | 32.5 | 2.4 | 10.9 | 9.6 | 10.9 | 44.0 | 3.9 | 11.1 | 16.8 | nc | nc |
| 5 – 2 mm | 7.2 | 39.7 | 4.5 | 15.4 | 12.4 | 19.3 | 56.4 | 9.2 | 24.1 | 26.0 | nc | nc |
| 2 – 1 mm | nd | ... | nd | ... | 19.4 | 30.9 | 75.8 | 24.7 | 39.2 | 50.7 | nc | nc |
| 1 – 0.5 mm | nd | ... | nd | ... | 14.9 | 31.0 | 90.7 | 28.0 | 42.1 | 78.7 | nc | nc |
| 0.5 – 0.25 mm | nd | ... | nd | ... | 3.6 | 6.4 | 94.3 | 12.2 | 22.2 | 90.9 | nc | nc |
| < 0.25 mm | nd | ... | nd | ... | 5.8 | 8.0 | 100.1 | 9.2 | 11.7 | 100.1 | nc | nc |
| Total | | | | | 100.1 | | | 100.1 | | | | |

[1] Average of profiles sampled, except profiles 2 and 4.
[2] Average of 10 profiles.
[3] nc—pebbles not counted
[4] nd—no determinations
[5] Average of profiles sampled except profiles 2, 4 and 5.

TABLE 2. STATISTICAL ANALYSES OF THE DISTRIBUTION OF SELECTED PARTICLE SIZES COMPRISING THE SAND AND GRAVEL FRACTIONS OF THE HINCKLEY AND MERRIMAC SOILS

"t" test made on the percent weight of particle size for the 10 profiles sampled of each soil.

| Sieve size | Profile — Depth — Inches 0 - 6 | 6 - 12 | 12 - 18 | 18 - 24 | 24 - 30 | 30 - 36 |
|---|---|---|---|---|---|---|
| > 2″ | 1.75 | 3.46** | 3.14* | 2.62* | 1.66 | 2.04 |
| 2 – 1″ | 2.15 | 4.10** | 3.84** | 3.31** | 2.44* | 2.15 |
| 1 – 0.5″ | 4.94** | 5.70** | 5.75** | 8.78** | 1.87 | 3.23* |
| 0.5″ – 5 mm | 5.28** | 6.02** | 3.73** | 7.41** | 2.69* | 3.37** |
| 5 – 2 mm | 3.93** | 2.89* | 2.60* | 2.28** | 1.56 | 1.06 |
| 2 – 1 mm | 0.70 | 0.44 | 0.24 | 0.02 | 0.68 | 1.09 |
| 1 – 0.5 mm | 2.10 | 3.68** | 4.70** | 3.84** | 3.90** | 3.02* |
| 0.5 – 0.25 mm | 2.42* | 6.64** | 7.70** | 5.87** | 4.91** | 3.95** |
| < 0.25 mm | 0.56 | 2.43* | 4.17** | 4.73** | 4.12** | 1.87 |

** The differences between the Hinckley and Merrimac are significant at the 1% level (or $P < 1\%$).
* The differences between the Hinckley and Merrimac are significant at the 5% level (or $1\% < P < 5\%$).

TABLE 3. TOTAL POROSITY IN THE HINCKLEY AND MERRIMAC SOILS

| Profile depth | Hinckley[1] Range | Hinckley[1] Average[2] | Merrimac[1] Range | Merrimac[1] Average[2] |
|---|---|---|---|---|
| inches | % | % | % | % |
| 0 - 6 | 19.7 | 58.1 | 26.6 | 55.5 |
| 6 - 12 | 19.0 | 47.6 | 12.1 | 52.7 |
| 12 - 18 | 33.0 | 40.9 | 16.7 | 49.2 |
| 18 - 24 | 28.1 | 37.6 | 11.4 | 45.4 |
| 24 - 30 | 18.1 | 38.1 | 14.5 | 42.4 |
| 30 - 36 | 29.6 | 37.2 | 15.2 | 41.7 |

[1] Average of 10 profiles
[2] LSD 5% 6.9
1% 12.6

TABLE 4. BULK DENSITY OF THE HINCKLEY AND MERRIMAC SOILS

| Profile depth | Hinckley[1] Range | Hinckley[1] Average[2] | Merrimac[1] Range | Merrimac[1] Average[2] |
|---|---|---|---|---|
| inches | gm/cc | gm/cc | gm/cc | gm/cc |
| 0 - 6 | 0.500 | 1.067 | 0.678 | 1.134 |
| 6 - 12 | .495 | 1.364 | .316 | 1.236 |
| 12 - 18 | .638 | 1.582 | .438 | 1.332 |
| 18 - 24 | .541 | 1.630 | .299 | 1.418 |
| 24 - 30 | .469 | 1.638 | .263 | 1.525 |
| 30 - 36 | .753 | 1.602 | .387 | 1.487 |

[1] Average of 10 profiles
[2] LSD 5% 0.08
1% 0.10

TABLE 5. ANALYSIS OF VARIANCE OF TOTAL POROSITY AND BULK DENSITY FOR THE 10 PROFILES SAMPLED OF EACH SOIL

| Source Variation | Total Porosity DF | Total Porosity SS | Total Porosity MS | Total Porosity F | Bulk Density DF | Bulk Density SS | Bulk Density MS | Bulk Density F |
|---|---|---|---|---|---|---|---|---|
| Soil | 1 | 630.19 | 630.19 | 4.30 | 1 | 0.47 | 0.47 | 5.53* |
| Replication | 9 | 604.98 | 67.22 | 0.46 | 9 | 0.36 | 0.04 | 0.47 |
| Error (a) | 9 | 1,318.18 | 146.46 | | 9 | 0.77 | 0.085 | |
| Depth, Horizon | 5 | 4,602.83 | 920.57 | 26.55** | 5 | 3.40 | 0.68 | 31.19** |
| Interaction | 5 | 382.65 | 76.53 | 2.21 | 5 | 0.30 | 0.06 | 2.75* |
| Error (b) | 90 | 3,120.54 | 34.67 | | 90 | 1.95 | 0.0218 | |
| Total | 119 | 10,659.37 | | | 119 | 7.25 | | |

*Significant at 5% level (or $P < 5\%$).
**Significant at 1% level (or $P < 1\%$).

TABLE 6. "t" TEST MADE ON TOTAL POROSITY AND BULK DENSITY FOR THE 10 PROFILES SAMPLED OF EACH SOIL

| Soil Profile | Total Porosity | Bulk Density |
|---|---|---|
| 0 - 6″ | 0.76 | 0.77 |
| 6 - 12″ | 1.96 | 1.89 |
| 12 - 18″ | 2.33* | 2.99** |
| 18 - 24″ | 2.70* | 3.09** |
| 24 - 30″ | 1.95 | 2.16* |
| 30 - 36″ | 1.35 | 1.33 |

*Significant at 5% level (or $P < 5\%$).
**Significant at 1% level (or $P < 1\%$).

TABLE 7. HYGROSCOPIC WATER OF SAMPLES TAKEN OF THE HINCKLEY AND MERRIMAC SOILS

| Profile depth | Hinckley[1] Range | Hinckley[1] Average | Merrimac[2] Range | Merrimac[2] Average |
|---|---|---|---|---|
| inches | % | % | % | % |
| 0 - 6 | 1.45 | 1.42 | 3.28 | 1.26 |
| 6 - 12 | 0.91 | 0.92 | 1.84 | 1.14 |
| 12 - 18 | 0.33 | 0.46 | 1.18 | 0.87 |
| 18 - 24 | 0.26 | 0.42 | 0.21 | 0.54 |
| 24 - 30 | 0.18 | 0.35 | 0.37 | 0.31 |
| 30 - 36 | .0.44 | 0.33 | 0.76 | 0.32 |

[1] Average of profiles sampled, except 2 and 4 and the three lower horizons of profile 5.
[2] Average of 10 profiles.

TABLE 8. AVERAGE NUMBER OF PEBBLES[1] IN THE HINCKLEY AND MERRIMAC SOILS

| Soil series | Profile depth inches | Diameter of pebbles | | | |
|---|---|---|---|---|---|
| | | >2" | 2 - 1" | 1 - 0.5" | 0.5"-5 mm |
| Hinckley . . . . . . . . | 0 - 6 | 1 | 5 | 30[2] | 345[2] |
| " . . . . . . . . | 6 - 12 | 3 | 12 | 81[2] | nc[4] |
| " . . . . . . . . | 12 - 18 | 2 | 12 | 97[2] | nc |
| " . . . . . . . . | 18 - 24 | 1 | 16[3] | 104[3] | nc |
| " . . . . . . . . | 24 - 30 | 2 | 15[3] | 114[3] | nc |
| " . . . . . . . . | 30 - 36 | 2[3] | 17[3] | 89[3] | nc |
| Merrimac . . . . . . . . | 0 - 6 | 0 | 0 | 1 | 33 |
| " . . . . . . . . | 6 - 12 | 0 | 0 | 2 | 52 |
| " . . . . . . . . | 12 - 18 | 0 | 1 | 6 | 189 |
| " . . . . . . . . | 18 - 24 | 0 | 2 | 14 | 440 |
| " . . . . . . . . | 24 - 30 | 1 | 6 | 33 | nc |
| " . . . . . . . . | 30 - 36 | 1 | 7 | 30 | nc |

[1] Only the larger gravel sizes were counted since the numbers present of the smaller sizes were too numerous to count. Average of 10 profiles for each soil.
[2] Analysis not made for two profiles.
[3] Analysis not made for three profiles.
[4] nc—pebbles not counted for number present exceeded 500.