The Stratigraphy and Hydraulic Properties of Tills in Southern New England

U.S. GEOLOGICAL SURVEY

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Prepared in cooperation with the

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

WASTE MANAGEMENT DIVISION, REGION I

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By Robert L. Melvin, Virginia de Lima, and Byron D. Stone

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For additional information, write to:

Chief, Connecticut District
Water Resources Division
U.S. Geological Survey
450 Main St., Rm. 525
Hartford, CT 06103

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CONVERSION FACTORS

Multiply	By	To obtain
	Length	
millimeter (mm)	0.0394	inch
centimeter (cm)	0.3937	inch
meter (m)	3.281	foot
kilometer (km)	0.6214	mile
	Flow	
centimeter per second (cm/s)	2,834	foot per day
	Mass	
kilogram (kg)	2.205	pound

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ABSTRACT

The two widely recognized tills of southern New England were deposited during two late Pleistocene continental glaciations. The surface (upper) till consists of relatively sandy tills deposited during the late Wisconsin glaciation and includes compact subglacial lodgement and meltout units and a thin overlying supraglacial meltout (ablation) unit. The drumlin (lower) till is the locally preserved till deposited during the Illinoian glaciation and consists chiefly of a compact subglacial lodgement unit. These tills are highly variable in texture, composition, thickness, and structural features, reflecting the composition of the local bedrock and older surficial materials from which they were derived and the different modes of deposition.

The hydraulic properties of tills in this region are also variable because of the differences in texture, composition, and structural features that result from different provenance and genesis. Data on hydraulic properties at 92 sites were compiled from readily available sources. The horizontal hydraulic conductivities of tills derived from crystalline (metamorphic and igneous) rocks range from 1.4×10^{-6} *to* 2.3×10^{-2} *centimeters per second, whereas the vertical hydraulic conductivities of tills derived from these rock types range from* 4.7×10^{-6} *to* 3.4×10^{-2} *centimeters per second. The porosities and specific yields of 15 undisturbed till samples, also composed of crystalline-rock detritus, range from 22.1 to 40.6 percent and from 3.9 to 31.2, respectively.*

The horizontal hydraulic conductivities of tills derived from the Mesozoic (Triassic and Jurassic) sedimentary rocks of central Connecticut and west-central Massachusetts range from 2.8×10^{-7} *to* 1.2×10^{-3} *centimeters per second, whereas the vertical hydraulic conductivities range from* 1.8×10^{-7} *to* 1.2×10^{-3} *centimeters per second. The porosity of 58 samples of till derived from these sedimentary rocks ranges from 18 to 40.1 percent.*

INTRODUCTION

Till is the most extensive glacial sediment in southern New England. It mantles most of the uplands and also extends beneath stratified drift in valleys and lowlands. This ice-deposited sediment is highly variable in texture, composition, thickness, and structural features, and the variability is commonly reflected in hydraulic properties. Geologic studies over the last century have described the textural and structural features of tills and identified the genetic variants of till in most of the region. The establishment of stratigraphic relationships between tills of southern New England has been more difficult than in the midcontinent of North America where distinct lithostratigraphic units related to bedrock source and glacial ice lobes are recognized. Recently, work by Pessl and Schafer (1968), Stone (1974), Newton (1978), and Smith (1984), has led to development of a regional till stratigraphy, described in this report, that provides a framework for organizing and categorizing geotechnical data.

Till is not a major aquifer in southern New England, but nevertheless is an important geohydrologic unit because of its widespread occurrence and relation to bedrock and stratified-drift aquifers. Till generally extends from the land surface to the top of the underlying bedrock aquifers except in valleys underlain by stratified drift. In these valleys a thin (less than 3 m) layer of till commonly separates the stratified drift from the underlying bedrock. Over most of southern New England this geohydrologic unit, therefore, affects rates of recharge from precipitation and natural ground-water discharge from bedrock, as well as the subsurface transport of contaminants which may have been applied, spilled, or buried near the land surface. Till is also at most of the major sites of point-source contamination that are subject to investigation and remediation under Federal and State programs.

Knowledge of the hydraulic properties of till that control the movement of water and transport of contaminants in this region is sparse. A recent summary of regional hydrogeology (Randall and others, 1988) cited only three references containing limited data on the conductivity and storage properties of till. This type of information is useful to hydrologists and engineers investigating ground-water contamination and flow of ground water between hydrologic units or evaluating the suitability of potential disposal sites. In order to meet this need, the U.S. Geological Survey (USGS), in cooperation with the U.S. Environmental Protection Agency Region 1, Waste Management Division (USEPA), initiated a study of the hydraulic properties of tills in southern New England.

Purpose and Scope

The purpose of this report is to describe the stratigraphic framework for tills in southern New England and to summarize available information on their hydraulic properties. The stratigraphic framework consists of two tills, derived from two glaciations, that display textural and structural variability related to genesis and provenance. Hydraulic properties include reported values of hydraulic conductivity, porosity, and specific yield. The clay and silt content of the till matrix is also included in the reported data. These hydraulic properties, together with hydraulic gradient, are the principal controls on the rate and velocity of ground-water flow, whereas clay and silt content affects hydraulic conductivity and is an indicator of the type of till. Only existing data were compiled and no new data were collected for this study. The location of sites for which data were obtained are shown in figure 1.

Sources of Data and Methods

Data were compiled from published geologic, engineering, hydrologic, and soil science literature; consultants' reports on Superfund and Resource Conservation and Recovery Act (RCRA) sites prepared for the USEPA; unpublished theses and dissertations; and unpublished data from files of the USGS, U.S. Department of Agriculture Soil Conservation Service (SCS), and the Connecticut Department of Transportation (DOT). The hydraulic properties were determined by several laboratory and in-situ methods that have not been critically reviewed for this report with respect to accuracy of measurement, validity of analysis, or other possible sources of error. No attempt was made to calculate independently hydraulic conductivity from coefficients of consolidation determined by soil-mechanics laboratories. However, 56 values of porosity for Connecticut tills derived from Mesozoic sedimentary rocks, previously calculated from measurements of bulk and particle mass density by the USGS, are included in this compilation.

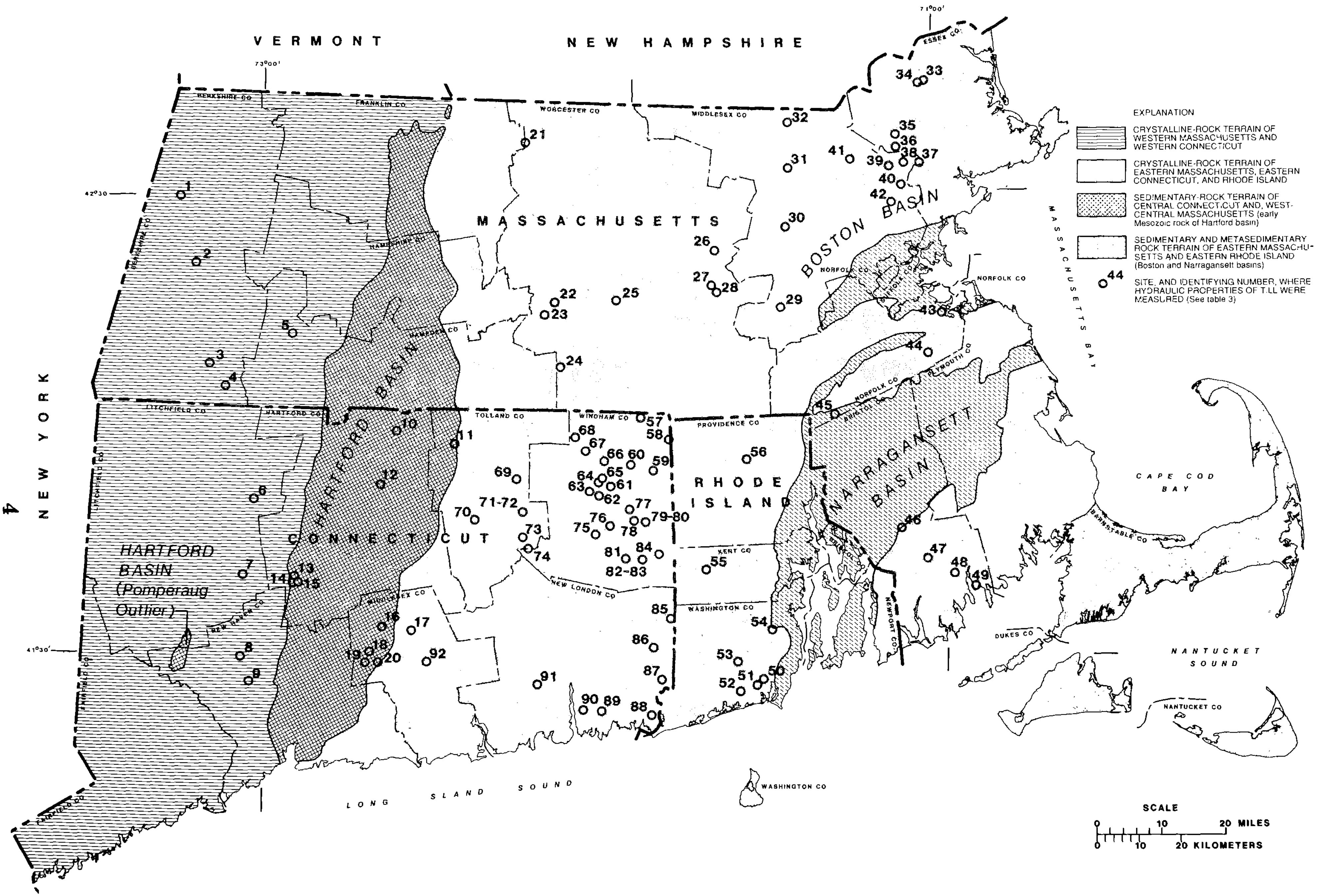
Acknowledgment

Mr. Rudy Chlanda of the SCS provided valuable assistance by reviewing, collating, and copying relevant SCS data for Massachusetts.

STRATIGRAPHY OF TILLS

Terminology

The tills of southern New England are correlated with two late Pleistocene continental glaciations of the region (Schafer and Hartshorn, 1965; Stone and Borns, 1986). Presently the tills of each glaciation are designated by informal stratigraphic names or by proposed formal names for local varieties of till (Stone and Borns, 1986). No regional study of lithologically distinct members of the surface (upper) till of late Wisconsinan age or the drumlin (lower) till of probable Illinoian age supports an inclusive formal nomenclature. In the field, physical criteria differ-



Base from U.S. Geological Survey
Scale 1:500,000

Figure 1.--Sites where hydraulic properties of till were measured and approximate boundaries of differing provenance areas for the tills in southern New England.

entiate local varieties of the tills, when comparisons are made of similar characteristics in areas of similar bedrock type. Bedrock control of till grain size, color, and composition is related to the very local distribution of bedrock units and physiography (Flint, 1930, 1961; Smith, 1984; Force and Stone, 1990). Because of the close relation of till composition and texture to local bedrock types, differences within one till unit may be greater in some areas than differences between varieties of both units.

The general terms "upper till" and "lower till" used by several recent investigators (Schafer and Hartshorn, 1965; Pessl and Schafer, 1968; Koteff and Pessl, 1985; Stone and Borns, 1986; discussion by Stone, in Weddle and others, 1989) refer to the chronostratigraphic relation between the two tills and, locally, to their stratigraphic position. The two-till stratigraphy evolved over more than a century of study of the glacial deposits of southern New England. Upham (1878) and Crosby (1891) ascribed all tills in the region to a single glaciation. Fuller (1906) first suggested that compact drumlin tills beneath the surface till are Illinoian in age. Judson (1949) proposed that the drumlin till in Boston was of early Wisconsinan age and this age assignment was retained in regional summaries (Muller, 1965; Schafer and Hartshorn, 1965; Stone and Borns, 1986). Further consideration of radiocarbon age constraints on the late Wisconsin glaciation (Stone and Borns, 1986), dated sediments of middle Wisconsinan and late "Eowisconsinan" ages on Long Island (Belknap, 1979, 1980; Sirkin, 1982), and weathering characteristics of the drumlin till (Stone, 1974; Newton, 1978; and Newman and others, 1990) has led to correlation of the drumlin till with the lower till at Sankaty Head on Nantucket Island, Massachusetts, which is of probable Illinoian age. The development and evolution of the two-till stratigraphy and related terminology is summarized in figure 2 and will aid in placing till discussed in earlier reports within the stratigraphic framework used in this report.

The upper till, referred to in this report as the surface till, comprises the relatively sandy surface tills that form the till sheet of the late Wisconsin glacial episode, which extended from about 24,000 BP (years before present) to deglaciation of the region about 14,000 BP. The till is dated by radiocarbon dating of preglacial subtill materials incorporated in the glacial sediments and of postglacial materials that overlie the sediments (Stone and Borns, 1986). The surface till is highly variable in composition, reflecting the composition of local bedrock and older surficial materials from which it is derived. The compact and weathered lower till, referred to in this report as the drumlin till, is the locally preserved till of the late Illinoian glaciation (Stone, *in* Weddle and others, 1989; Newman and others, 1990), which extended from about 180,000 BP to 150,000 BP (Richmond and Fullerton, 1986). Drumlin tills in drumlins throughout the region are correlated on the basis of the depth and degree of the weathering, and are further correlated with the Sankaty lower till which lies beneath dated marine beds of Sangamonian age on Nantucket Island, Massachusetts (Oldale and others, 1982). The weathering zone in the upper part of the drumlin till is the result of a relatively long or intense period of weathering that postdated drumlin formation.

The surface and drumlin tills are not laterally extensive, superposed, sheet-like bodies in the region. Throughout most of southern New England, only the sur-

Stage	Substage	SINGLE GLACIATION[1] 1880-1958 *Southern New England New Hampshire and Long Island*	MULTIPLE GLACIATIONS[2] 1900-1949 *Southern New England*	MULTIPLE WISCONSIN GLACIATIONS[3] 1949-1986 *Southern New England and Long Island*	THIS REPORT WISCONSIN AND ILLINOIAN GLACIATIONS[4] *Southern New England and Long Island*
WISCONSIN	Late	Till, Drumlin till	Thin till, Surface till, Upper till	Upper till, Surface till, New till, Proposed local formal units	Surface till
WISCONSIN	Middle				
WISCONSIN	Early			Lower till, Drumlin till, Montauk Till, Proposed local formal units	
ILLINOIAN			Drumlin till, Lower till, Montauk Till	Lower till at Sankaty Head	Drumlin till, Montauk Till, Lower till at Sankaty Head

References:

1 Upham (1878, 1880, 1897)
Crosby (1891, 1908)
Alden (1924)
Flint (1930)
LaForge (1932)
Denny (1958)

2 Woodworth (1901)
Fuller (1901, 1906, 1914)
Clapp (1908)
Woodworth and Wigglesworth (1934)

3 Judson (1949)
Flint (1953)
Kaye (1961, 1982)
Muller (1965)
Schafer and Hartshorn (1965)
Newton (1978)
Sirkin (1982)
Oldale and others (1982)
Koteff and Pessl (1985)
Stone and Borns (1986)

4 Stone, *in* Weddle and others (1989)

Figure 2.--Evolution of till stratigraphy in southern New England and Long Island. (Modified from Stone, *in* Weddle and others, 1989, fig. 2.)

face till is present. Thick, compact, gray surface till is present above oxidized and weathered drumlin till in relatively few exposures (Pessl and Schafer, 1968). More frequently, the superposed stratigraphy of the two tills consists of a sandy and stoney surface till less than 1 m thick overlying a mixed-till zone that contains discrete angular fragments of the drumlin till within a sandy matrix, which, in turn, overlies weathered and nonweathered drumlin till at depth.

Genetic Classification

Variants of tills of the region are also recognized within the framework of the genetic classification of tills (Till Work Group of the International Union for Quaternary Research Commission on Genesis and Lithology of Quaternary Deposits, in Dreimanis, 1989). As defined by the Commission, till is "sediment deposited by or from glacier ice without the intervention of running water" (Dreimanis, 1989, p. 35). In New England, areally extensive compact tills reported in mapping studies, hydrologic investigations, and topical research studies are subglacial (basal) lodgement till or subglacial meltout till of the genetic classification. The distinction of these compact tills is based on structural features and possibly grain-size distribution (Smith, 1984). Although the drumlin till consists entirely of a lodgement unit, studies of the surface till (Drake, 1971; Pessl and Schafer, 1968; Newton, 1978; Smith, 1984, 1988) have differentiated an upper, loose, sandy unit, containing boulders and cobbles and lenses of stratified sediments, from an underlying compact sandy unit. The loose, sandy unit is recognized genetically as a supraglacial meltout (ablation) till composed of debris of englacial or supraglacial origin. The compact varieties of surface tills are of subglacial lodgement or meltout origin, distinguished by clast fabrics and by minor differences in silt and clay content (Smith, 1984). A mixed-till zone, composed of eroded fragments of drumlin till in a sandy surface-till matrix, that overlies weathered drumlin till has been described throughout the region (Pessl and Schafer, 1968; Pease, 1970; Koteff and Stone, 1971; Stone, 1980; Mickelson and Newman, 1987; and Newman and others, 1987, 1990). Minor flowtill is found locally in stratified-drift deposits (Hartshorn, 1958; Smith, 1984); genetically, this is a supraglacial mass movement till.

Distribution and Thickness of Stratigraphic Units

The late Wisconsinan surface till forms an irregular blanket over bedrock uplands and beneath stratified-drift deposits. It is highly variable in composition and thickness because of differences in the composition and erodability of local bedrock and older surficial materials from which the till is derived. In areas of numerous or extensive bedrock outcrops, the topography of the till surface is controlled by bedrock-surface relief (fig. 3). Here the till is discontinuous, probably averaging less than 2 m thick, and contains numerous boulders. In other areas on north-facing lower valley slopes, the till forms smooth-to-bumpy patches of true ground moraine, ranging from 3 to 10 m thick. In these areas, the compact basal facies of lodgement and meltout origin form the bulk of the deposit. Loose, sandy, bouldery till of ablation origin forms a thin and discontinuous overlying unit in bedrock outcrop areas and areas of thicker till; locally, it is thick enough to form hummocky surface topography. In most drumlins in the region, the surface till consists of a thin mixed-till zone that overlies the weathered older till (as shown in fig. 3) but, in a few drumlins in the Cape Cod area, the surface till is apparently more than 15 m thick (Koteff, 1974). The late Wisconsinan surface till is the till unit mapped on State surficial geologic maps in the region and on numerous 7 1/2-minute-quadrangle geologic maps in southern New England.

The drumlin till is preserved almost exclusively in drumlins and related bodies of glacially smoothed and streamlined thick till which were resistant to subsequent late Wisconsin glacial erosion (fig. 3). The drumlin till is generally 10 to 30 m thick in these bodies and has a maximum reported thickness of 70 m. Exposures of weathered (oxidized) and some unweathered (nonoxidized) drumlin till are known widely across the region (Lougee, 1957; Castle, 1958; Flint, 1961; Kaye, 1961; Oldale, 1962; Pessl and Schafer, 1968; Stone, 1974; Thompson, 1975; Mulholland, 1976; Newton, 1978; Stone, 1980; Newman and others, 1990).

The distribution of the surface and drumlin tills with contrasting physical characteristics strongly reflects the local bedrock provenance. Four broad bedrock provenances are distinguished in this report (fig. 1): crystalline- (metamorphic and igneous) rock terrain of western Massachusetts and western Connecticut; sedimentary-rock terrain of the early Mesozoic Hartford basin in central Connecticut and west-central Massachusetts; crystalline-rock terrain of eastern Massachusetts, eastern Connecticut, and Rhode Island; and sedimentary- and metasedimentary-rock terrain of the Boston basin in eastern Massachusetts and the Narranganset basin in southeastern Massachusetts and Rhode Island. This report does not treat the Narragansett and Boston basins as a separate till source area. Only one site (number 45) is in the Narragansett basin, and because it is at the northern boundary, the till may be derived from the crystalline rocks to the north. Till at three sites (numbers 43, 46, and 54), which are in the crystalline-rock terrain, are just south of the Boston or Narragansett basins and may be composed largely of sedimentary and low-grade metasedimentary rocks from these basins. However, because these four sites have not been field-checked by the authors and the origin of the till is not certain, none was categorized as being of sedimentary and metasedimentary rock provenance.

There are local variations in rock type within each provenance. For example, there is a marble belt within the crystalline-rock terrain of western Massachusetts and western Connecticut, and there are areas of schists and phyllites within the crystalline-rock terrains. These variations affect the physical characteristics, such as grain size, of the tills.

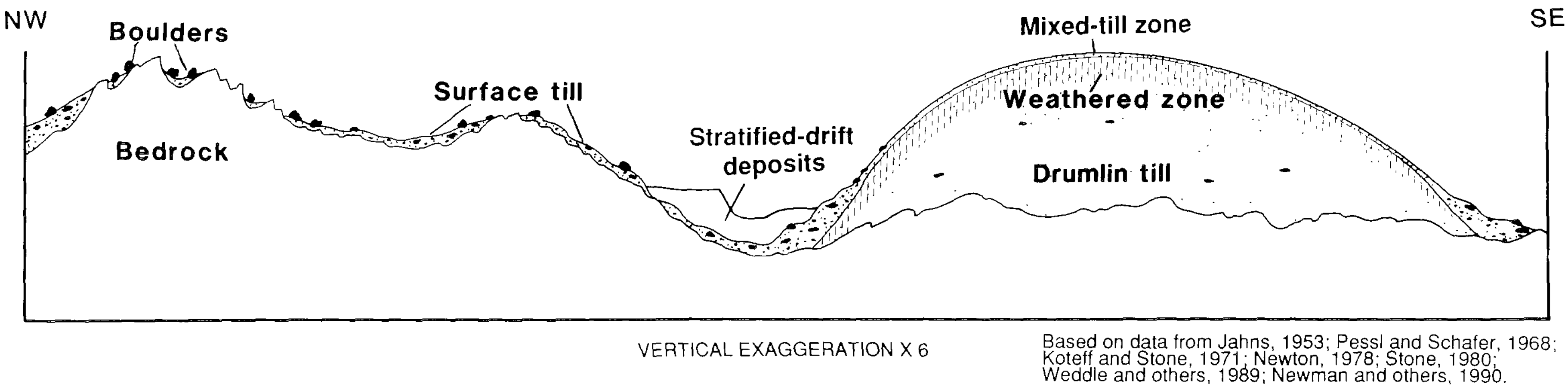


Figure 3.--Generalized geologic section showing distribution of surface and drumlin tills and weathered and mixed-till zones.

Table 1.--*Selected characteristics of surface and drumlin tills that are derived from crystalline bedrock* (Modified from Stone, *in* Weddle and others, 1989, table 1)

[m, meter; mm, millimeter; %, percent; <, less than; >, greater than; USDA, SCS, U.S. Department of Agriculture, Soil Conservation Service]

CHARACTERISTIC	SURFACE TILL (late Wisconsinan)	DRUMLIN TILL (Illinoian)
Color (naturally moist material, Munsell color symbols)	Gray to light gray (2.5-5Y 6-7/1-2), to olive gray to light olive gray (5Y 4-6/2)	Olive to olive gray (5Y 4-5/2-3) to olive brown (2.5Y 4-5/3-5) in weathered zone, dark gray (5Y 3.5-5/1) in unweathered till
Texture of matrix (<2 mm range, fig. 4)	62-80% sand 20-38% silt and clay <1-7% clay	35-60% sand 40-65% silt and clay 11-38% clay
Stone content	10-54% >2 mm 5-30% >76 mm	19-42% >2 mm 1-11% >76 mm
Layering	Textural layering common, generally subhorizontal; consists of thin, lighter-colored sandy layers	Textural layering not common; thin, oxidized sand layers and vertical sand dikes locally with darker, silty layers; layering is laterally discontinuous
Jointing	None; subhorizontal parting is related to layering and fabric of till matrix	Well developed; closely-spaced subhorizontal joints and less numerous subvertical joints impart a blocky or thin platey structure to till
Distribution and thickness	Lies directly on bedrock; generally less than 3 m thick in areas of rock outcrop; commonly 3 to 6 m thick on lower valley slopes	Forms cores of drumlins and related bodies of thick till; generally >10 m thick, commonly 20 to 30 m thick; maximum reported thickness 70 m
Soils and weathering (representative USDA, SCS soil series)	Canton series, Charlton series (Typic Dystrochrepts)	Paxton series (Typic Dystrochrepts); soil developed in mixed-till zone that overlies weathered zone in drumlin till; weathered zone <9 m thick; zone is oxidized, leached in some areas, and contains altered clay minerals and iron-bearing minerals

Physical Characteristics Useful for Field Identification

Physical characteristics differentiate the two tills of southern New England (table 1). The color, texture, stone content, weathering and soil development, and geotechnical properties of the tills are related to source materials, glacial erosional and depositional processes, and weathering effects.

Color

The surface till in areas underlain by fresh, crystalline rocks consisting of granites, gneisses, schists, or quartzose metasedimentary rocks is generally gray below the present B horizon of the soil, reflecting composition of fresh, nonoxidized minerals. Local staining by iron minerals, probably limonite, may be controlled by water movement through materials of contrasting texture or around clasts. In the area of the Hartford basin of central Connecticut and west-central Massachusetts, the surface tills range from reddish brown to brownish red. In scattered areas of weathered-sulphitic schists, the tills are yellowish brown, and in other areas of weathered or stained rock, the tills are commonly pale brown.

The olive color of the weathered zone in the drumlin till is a pervasive oxidation stain that affects all parts of the silty till matrix. It commonly extends to depths of 5 to 9 m and through the zone of leached carbonate minerals in some exposures. The stain is darker around iron-bearing minerals. Dark iron-manganese staining is present on joint surfaces and around stones, but generally does not extend as deeply as the pervasive iron stain. In areas of crystalline-rock provenance the color of fresh, unweathered drumlin till commonly is dark gray, reported locally as blue gray. In the Hartford basin, the drumlin till is generally reddish brown to brownish red.

Texture and Stone Content

Particle-size analysis of the surface and drumlin tills (fig. 4) show that whole-till samples differ in stoniness, proportion of the dominant sand-sized particles, and silt and clay content. These analyses also show differences in grain-size characteristics within each of these tills that can be ascribed to differences in the lithology of the source rocks (fig. 4B). The volumetric content of stones larger than 5.1 cm in drumlin till is less than 10 percent and probably about 5 percent (Crosby, 1891; Pessl and Schafer, 1968; Fuller and Holtz, 1981). Boulders larger than 1 m are rare in large excavations of drumlin till. The stoniness, including large boulders, of the compact, surface till is 5 to 30 percent by weight. Boulders 1 to 2 m long are common in large excavations of compact surface till--these and smaller boulders are common in the ablation material at the surface of the late Wisconsinan till. The grain-size curves shown in figure 4A include these visual esti-

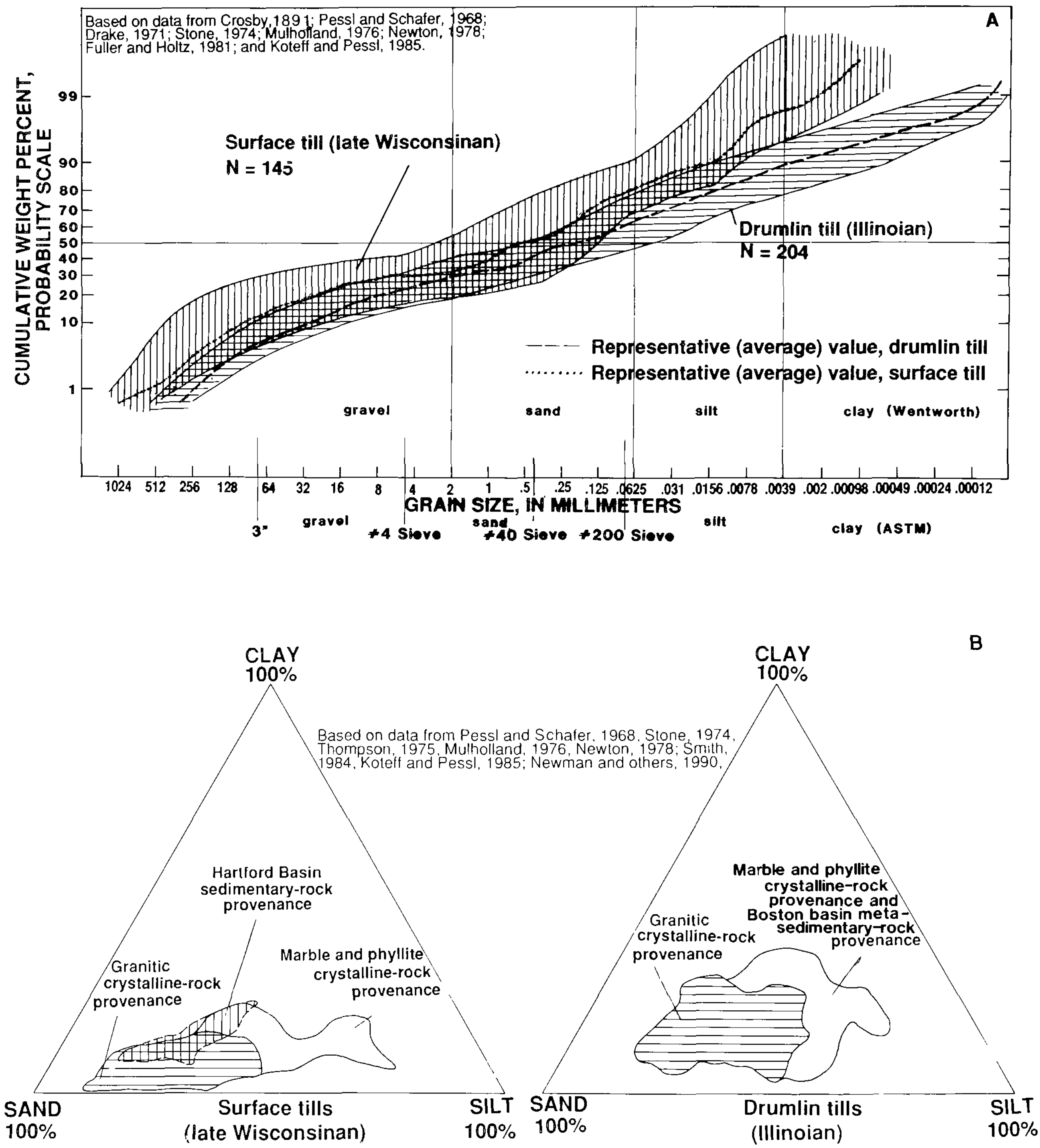


Figure 4.--Grain-size characteristics of the surface till and drumlin till: (A) ranges of cumulative-frequency curves of grain-size distributions of whole-till samples; and (B) ternary diagrams of sand-silt-clay percentages of the till matrix (particle sizes less than 2 millimeters).

mates of stone content and sieved gravel data, adjusted for differences in densities of rock clasts and till matrix.

Fields of sand-size particles of the two till units overlap (fig. 4A). The proportion of sand differs greatly within each of the two till units, and locally more so than in samples between units. This variation in the relative amount of sand is related chiefly to the grain size and fabric of the local bedrock, and to the degree of comminution of the glacially eroded fresh rock fragments (Smith, 1984, 1988; Force and Stone, 1990).

The silt and clay contents of whole-till samples are distinguishing characteristics of the two tills. Although the ranges of the distributions overlap (fig. 4A), representative "average" values do not. Extreme values show that the surface till contains 9 to 31 percent silt and clay (69 to 91 cumulative weight percent, as shown in the figure), whereas the drumlin till contains 22 to 55 percent (45 to 78 cumulative weight percent). The proportion of clay likewise distinguishes the tills; surface till contains less than 1 percent to 6 percent clay, while drumlin till contains 6 to 24 percent clay. The drumlin till also contains a measurable amount of very fine clay (less than 0.2 microns in diameter) (Stone, 1974).

The silt and clay contents of the till matrix only (particles less than 2 mm in diameter) (fig. 4B) are different in samples of the till. The surface-till matrix contains 20 to 38 percent silt and clay, whereas the drumlin-till matrix contains 40 to 65 percent. The proportion of clay in the surface-till matrix is 1 to 7 percent, and in the drumlin-till matrix it is 11 to 38 percent.

Weathering and Soil Development

Soils developed in the upper 0.6 to 1.2 m of the surface till, mixed-till zone, and drumlin till (fig. 3) since late Wisconsinan deglaciation are inceptisols, characterized by B-horizons, which contain less than 20 percent more clay than overlying horizons, and weakly modified clay mineralogy. Typically Canton and Charlton soils series develop in the surface tills, and the Paxton soil develops in the mixed-till zone on drumlins (Fuller and Holtz, 1981 and Fuller and Francis, 1984).

The weathered zone in the upper part of nearly all drumlin-till exposures is 3 to 9 m thick. It is developed in the drumlin till, below the mixed till zone and the modern soil. The base of the weathered zone is subparallel to the surface of the landform, indicating soil genesis after glacial smoothing. Weathering effects are progressive upward through the zone; pH values decline (Stone, 1974), amount of leaching increases (Crosby and Ballard, 1894), color values of matrix stain increase (Crosby, 1891; Pessl and Schafer, 1968), degree and darkness of iron-manganese stain on joint faces increase, and blocky structure increases and is more densely developed (Pessl and Schafer, 1968). Laboratory data showing alteration of clay minerals and iron-bearing minerals further define the weathering gradient through the 3- to 9-m-thick zone. The weathering zone is the upper part of the C horizon of a probable well-developed soil (Stone, 1974; Newton, 1978; Newman and others, 1990), the A and B horizons of which were removed by late Wisconsin glacial erosion.

Geotechnical Properties and Classification

Geotechnical properties of the surface and drumlin tills depend on the grain-size and plasticity-index (the water-content range of the material at which it is plastic) characteristics that are distinctly different in the two tills. The Unified Soils Classification System of soils for engineering purposes (American Society of Testing Materials, 1990) is commonly used to group soils on the basis of texture and plasticity-compressibility characteristics (table 2). In this classification system, the surface tills are either SM (silty sand with gravel with 3 to 17 percent cobbles and boulders by volume) or SP-SM (poorly graded sand with silt and with gravel and with 3 to 17 percent cobbles and boulders by volume). Reported variations in the textures of drumlin tills have led to their classification into four groups: SC (clayey sand with gravel, with 1 to 15 percent cobbles and boulders by volume); SM and SC-SM (silty sand with gravel, with 1 to 15 percent cobbles and

Table 2.--*Selected geotechnical properties of the surface and drumlin tills*

[S, sand; G, gravel; SP, poorly graded sand; SM, silty sand; SC, clayey sand; ML, sandy silt; <, less than; >, greater than]

	Unified Soil Classification System Group				
	SP-SM	SM	SC-SM	SC	ML
Relative fractions of sand and gravel	S>G	S>G	S>G	S>G	S>G
Percent fines	5-12	>12	>12	>12	>50
Percent (by volume) cobbles and boulders	3-17	3-17	1-15	1-15	1-15
Liquid limit (weight percent liquid content)	<10	>10		<30	<50
Plasticity index	low	low		10-30	low
Description	poorly graded sand with silt and gravel	silty sand with gravel		clayey sand with gravel	sandy silt with gravel
	surface till (SP-SM, SM)				
		drumlin till (SM, SC-SM, SC, ML)			

boulders by volume); and ML (sandy silt with gravel and with 1 to 15 percent cobbles and boulders by volume). Because clay content of surface tills is relatively low (fig. 4B), they are typically described as being nonplastic; whereas, the more clayey drumlin tills have plasticity indexes of 10 to 30 percent. In the field, naturally moist samples of the surface till exhibit low dry strength (a measure of "compaction" of fragments): fragments crumble or "pop" with some finger pressure. Drumlin till has medium dry strength; considerable finger pressure is required to pop fragments.

In most field and laboratory investigations of engineering properties, tills are described by criteria of the Unified Soil Classification System, without reference to stratigraphic units. In subsurface boring logs and in test-pit descriptions, tills are described as loose to loose and sandy, compact and sandy with boulders, or very compact and clayey. In the stratigraphic framework of the tills of southern New England, these materials are inferred to be surface till of supraglacial-meltout origin, surface till of subglacial lodgement or meltout origin or mixed-zone surface till, and drumlin till of subglacial-lodgement origin.

HYDRAULIC PROPERTIES OF TILLS

Hydraulic conductivity, porosity, and specific yield[1] are the hydraulic properties affecting the flow of ground water through till. The rate of flow depends on hydraulic conductivity if the flow is steady, and on both hydraulic conductivity and specific yield if flow is nonsteady. The average velocity of ground water is dependent on hydraulic conductivity, hydraulic gradient, and effective porosity (interconnected pore space) which, in the case of unconsolidated porous media, is considered identical to porosity (Todd, 1980, p. 27). Ground-water movement, including the governing equations, is described in detail in standard texts such as those by Bear (1972), Freeze and Cherry (1979), and Todd (1980).

This compilation is limited to data on hydraulic conductivity, porosity, and specific yield, although other till properties, such as dispersivity, can strongly affect transport of contaminants. Furthermore, if extensive secondary permeability and porosity has developed in tills through fracturing or other processes, the data on primary (matrix) hydraulic conductivity, porosity, and specific yield obtained from laboratory tests may not be representative of the "bulk" values required to analyze a flow problem. Secondary permeability and porosity are well developed in fractured till that underlies the Interior Plains Region of Canada. The hydraulic properties of the extensively fractured till that underlies this area and the effects of the secondary permeability on ground-water flow have been described by Grisak and others (1976) and Keller and others (1986, 1988).

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[1] Specific yield is considered equivalent to storage coefficient in the case of unconfined aquifers (Freeze and Cherry, 1979, p. 61).

The values for hydraulic properties of tills at 92 sites in southern New England are presented in table 3 (beginning on page 19). The data are organized into three broad groups that reflect geography and source area. The first group includes sites located in the western part of southern New England where the tills are derived from erosion of various types of crystalline rocks. The second group includes sites within or immediately adjacent to the Hartford basin where the distinctly red to brown tills consist mostly of material eroded from sedimentary rocks (largely sandstone and shale). The third group includes sites located in the eastern part of southern New England where tills also are derived from crystalline rocks. Parts of eastern Massachusetts and Rhode Island underlain by sedimentary and metasedimentary rocks of the Boston and Narragansett basins contain texturally distinct tills. Although none of the sites in table 3 have till which is known to be derived from rocks in these basins, they are shown as a separate till source area in figure 1.

Within each broad category, an attempt has been made to identify the stratigraphic unit (surface, surface-mixed zone, or drumlin till) and, in some cases, the general type of till (ablation, meltout, basal, and flow till). Criteria used to identify the stratigraphic unit and type of till include geomorphic and geologic setting of the sample sites as shown on detailed maps of surficial geology, depth of the sampled or tested interval, field descriptions of the till, and textural information (particularly the percents of silt and clay) contained in the source references. In most cases, the stratigraphic and genetic identifications given in table 3 are not certain because diagnostic features have not been adequately described in the references.

Values for hydraulic properties in table 3 were obtained from the referenced source material. The only changes are the conversions of all hydraulic-conductivity values to units of centimeters per second and depths to units of meters. All values are rounded to one decimal place.

Hydraulic Conductivity

Hydraulic conductivity values are organized into four categories in table 3. The first two are horizontal hydraulic conductivity (k_h) and vertical hydraulic conductivity (k_v). The third category (k_r) includes hydraulic-conductivity measurements made on repacked samples. Most of the repacked samples contain only till particles less than 0.42 mm (40 mesh) in diameter that have been compacted. The fourth category (k_u) includes hydraulic-conductivity measurements where the orientation and (or) degree of disturbance are unknown.

The type of test and method of analysis, if known, are given for the hydraulic-conductivity values in table 3 to assist the user of this report in judging their relevance to field problems. Stephenson and others (1988) have pointed out several factors that influence the hydraulic conductivity measurements of tills and their comparability, with consequent implications for field studies of flow and transport. Factors cited by Stephenson and others (1988) include (1) in-situ values of hydraulic conductivity determined in the field from aquifer tests and single-well waterlevel response tests (slug tests and constant-head tests) are commonly much greater than values determined in the laboratory for the same material; (2) laboratory-determined values can be representative of the till matrix but not of the bulk mass of the till; and (3) different laboratory methods can produce different values.

Comparisons of field- and laboratory-determined values of hydraulic conductivity have not been made using data in table 3. In fact, the suitability of the data for making such comparisons has not been evaluated. A number of features could increase hydraulic-conductivity values calculated from in-situ tests; these include fractures (both jointing and a subhorizontal fissility), widely observed and often well developed in drumlin till and locally (and less developed) in the compact basal facies of the surface till (Smith, 1984, p. 8 and table 1 of this report); macropores, such as root casts that are produced by soil-development processes in the zone 1 to 1.5 m below land surface; and small lenses or layers of stratified drift within the till. If secondary permeability and porosity are well developed locally in the tills of southern New England, the laboratory-determined values of till-matrix properties could differ considerably from the bulk values that control the rate and velocity of ground-water flow.

Weathered-till deposits are also recognized to have greater hydraulic conductivity than that of similar unweathered till (Stephenson and others, 1988, p. 309). Nearly all of the extensive drumlin-till exposures in southern New England contain a weathered zone at least 3 m thick. It has not been determined if this weathering has increased the hydraulic conductivity.

The laboratory-determined hydraulic conductivity of the till matrix has also been observed to have a strong relation to grain-size distribution (Stephenson and others, 1988, p. 306). The major effect of grain size appears to be related to the clay content; contents of 15 to 20 percent mark a threshold above which hydraulic conductivities are uniformly low. The clay content of the surface-till matrix in southern New England ranges from less than 1 percent to 7 percent, whereas the clay content of the drumlin-till matrix ranges from 11 to 38 percent (fig. 4). Data on the combined silt and clay content are available for most of the samples where hydraulic conductivity was estimated by laboratory analysis (table 3). The grain-size scales used by geologists, soil scientists, and engineers commonly differ and the boundary used to divide silt from sand size is, therefore, indicated in the table.

Porosity and Specific Yield

Porosity and specific-yield data are in two adjacent columns in table 3 to facilitate comparisons. The porosity values are all total porosities measured in or calculated for laboratory samples. The most extensive porosity data are the 58 values for tills derived from Mesozoic sedimentary rocks of the Hartford basin (sites 10-12, 16, and 18-20). Fifty-six of these values had been calculated by the USGS from the bulk mass density and particle mass density of the samples, using the formula given in Freeze and Cherry (1979, p. 337). Only 15 measurements of specific yield were found in the referenced sources. All these measurements were made on undisturbed samples of tills derived from crystalline bedrock that were collected and analyzed by the USGS.

The values in table 3 represent only the porosity and specific yield of the till matrix. If the till is fractured or contains other secondary openings, these matrix values from laboratory tests apply to till blocks between the secondary openings and not to the bulk mass of the till (Grisak and others, 1976, p. 311). In such cases, the storage (specific yield) and porosity characteristics imparted to the bulk of the till must also be determined if the ground-water-flow system and the directions, rates, and velocities of ground-water flow are to be understood.

Table 3.--*Hydraulic conductivity, porosity, and specific yield values for till in southern New England*

Site number: A unique sequential number assigned to each locality where hydraulic conductivity has been determined. Site numbers are shown in figure 1.

Site name and location: Place name or facility name associated with the test site. Includes town and state, such as Durham-Middlefield Landfill, Durham, Conn.

Sample or well number: Number or alphanumeric characters used by the referenced sources to identify a till sample or well where a test was conducted to determine hydraulic conductivity.

Type of till: Estimated from physical descriptions, textural information, topographic setting, published geologic maps, and depth. Types include surface (undifferentiated), surface-ablation, surface-mixed, surface-basal, surface-morainal, drumlin, flowtill, unknown (estimate could not be made largely because of imprecise location).

Hydraulic conductivity:

k_h	measured in horizontal direction
k_v	measured in vertical direction
k_r	measured in repacked (disturbed) sample
k_u	measurement in sample where orientation and degree of disturbance (undisturbed to repacked) are not specified.

Type of test and analysis:

First code

P	permeameter
PT	aquifer test
PZ	piezometer
SI	slug injection
SW	slug withdrawal
O	other
U	unknown

Second code

BR	analysis by method described by Bouwer and Rice (1976) and Bouwer (1989)
H	analysis by method described by Hvorslev (1949 and 1951)
N	analysis by method described by Department of the Navy (1971, p. 7.4.8–7.4.9)
T	analysis by method described by Cooper and others (1967) and Papadopulos and others (1973) as modified by Torak (1979)
ch	constant head
fh	falling head

Percentage of silt and clay:

a	AASHO scale: silt and clay fraction less than 0.074mm (U.S. Standard Sieve number 200)
u	USDA scale: silt and clay fraction less than 0.05 mm
w	Wentworth scale: silt and clay fraction less than 0.0625 mm

References:

USDA, SCS	U.S. Department of Agriculture, Soil Conservation Service
USCOE	U.S. Army Corps of Engineers

Table 3.--*Hydraulic conductivity, porosity, and specific yield*

[--, no data; <, less than; >, greater than; ≤, less than or equal to; mm, millimeters; cm, centimeter;

Site no.	Site name and location	Sample or well number	Depth below land surface (m)	Type of till	Hydraulic conductivity (cm/s) k_h	k_v	k_r	k_u	Type of test and analysis
	Crystalline bedrock of western								
1	Rose Disposal Pit, Lanesboro, Mass.	5A-83	1.5-4.6	surface	3.2×10^{-5}				SW-BR
		5B-83	11.0-14.0	do.	2.4×10^{-5}				
		5C-83	27.7-30.8	do.	7.8×10^{-5}				
		8A-83	1.5-4.6	do.	1.2×10^{-3}				
		8B-83	9.8-12.8	do.	7.1×10^{-6}				
		8C-83	24.8-27.9	do.	4.7×10^{-4}				
		10A-83	1.5-4.6	do.	4.1×10^{-3}				
		10B-83	13.1-16.2	do.	9.5×10^{-6}				
		11A-83	1.2-4.3	do.	2.3×10^{-2}				
		11B-83	8.2-11.3	do.	1.2×10^{-5}				
		14A-83	1.5-4.6	do.	1.7×10^{-5}				
2	Washington Mountain Brook, site 3, Lee, Mass.	70W1292	0.9-3.7	surface?			1.4×10^{-5}		P-ch
		70W1290	0.9-3.7	do.			1.8×10^{-5}		
		70W1288	0.9-4.3	do.			1.4×10^{-5}		
		72W659	0.6-3.0	do.			1.4×10^{-6}		
		72W660	--	do.			7.1×10^{-6}		
3	Clam River watershed, Morley Brook site, Sandisfield, Mass.	DH No.8	4.6-4.9	surface?	4.7×10^{-3}				PT-ch
		do.	6.1-6.4	do.	9.9×10^{-4}				
4	Clam River watershed, Silver Brook site, Sandisfield, Mass.	DH-1	6.1-15.2	surface	1.2×10^{-4}				PT-ch
		65W210	--	do.			9.2×10^{-5}		P-fh?
		65W209	--	do.			8.8×10^{-6}		do.
		65W133	--	do.			2.2×10^{-5}		do.
		65W135	--	do.			1.8×10^{-6}		do.
		66W2568	--	do.			2.8×10^{-7}		do.
5	Bradley Brook watershed, Black Brook site, Russell, Mass.	70W1010	0.9-3.7	surface?			5.3×10^{-6}		P-ch
		70W1012	0.9-4.3	do.			1.4×10^{-6}		
6	Canton 1, stream cut at Bakersville Brook, New Hartford, Conn.	2C1 horizon	0.8-1.0	surface-ablation		7.5×10^{-3}			P
		2C3 horizon	1.5-1.7	do.		4.1×10^{-3}			
		2C5 horizon	2.1-2.3	do.		3.4×10^{-2}			
7	Thomaston Dam, Plymouth, Conn.	24	--	drumlin			9×10^{-6} to 8×10^{-8}		P
8	Laurel Park, Naugatuck, Conn.	TP3	0.9	surface				6.8×10^{-6}	P-fh
		TP4	0.9	surface-basal				5.3×10^{-6}	
		TP5	0.9	surface				1.5×10^{-5}	
9	Beacon Heights Landfill, Beacon Falls, Conn.	MW-14	2.4-3.9	surface	5.4×10^{-4}				SW-BR
		MW-15	2.4-3.9		1.5×10^{-4}				

values for till in southern New England

m, meter; km, kilometer; cm/s, centimeter per second; lb/ft^2, pound per foot squared]

Porosity (percent)	Specific yield	Percent silt and clay	Remarks	References
Massachusetts and Connecticut				
				Geraghty and Miller, (1984, table 4)
			hydraulic conductivity determined on minus no. 4 fraction of samples under load of 2,000 lb/ft^2	unpublished data for the Washington Mountain Brook watershed, USDA, SCS
				SCS (1964a) and unpublished data for the Clam River watershed, USDA, SCS
		21 (u) 33 (u) 23 (u) 33 (u) 37 (u)	till thickness equal to or greater than 14.6 m	SCS (1966) and unpublished data for the Clam River watershed USDA, SCS
		31 (u) 42 (u)	sample may be schistose rock or mixed till; hydraulic conductivities measured on minus no. 4 fraction of samples under load of 2,000 lb/ft^2	SCS (1969) and unpublished data for the Bradley Brook watershed USDA, SCS
		11.1 (u) 15.5 (u) 16.8 (u)	one of six samples of Canton soils collected from C horizon at three localities; orientation of cores reportedly vertical (H.D. Luce, Univ. of Conn., oral commun., 1989)	Pelletier (1982)
		40 (a)	the hydraulic conductivities represent the range of values for several samples of till matrix (≤4.75 mm grain size) after standard compaction; tests conducted by New England Division, USCOE	Linell and Shea (1961)
		43.3 (a) 36.6 (a) 37.7 (a)	analysis performed on samples trimmed from block samples by method described by USCOE manual; data on plastic and liquid limits of samples also available.	Fred C. Hart, Assoc., Inc. (1983, unnumbered worksheet), USCOE (1970, appendix VII)
			slug test data available but not interpreted (Malcolm Pirnie, 1988, figs. 1 and 2)	
			till described as loose	NUS (1985b, chap. 4, p. 18)

Site no.	Site name and location	Sample or well number	Depth below land surface (m)	Type of till	Hydraulic conductivity (cm/s) k_h	k_v	k_r	k_u	Type of test and analysis
					Sedimentary bedrock of central				
10	Suffield Meadows condominiums, between Rte. 159 and the Connecticut River, Suffield, Conn	BB1-1	1	surface-mixed or drumlin	1.0×10^{-4}				P-ch
		BB1-2	2	drumlin	7.7×10^{-7}				
		BB1-3	1.8	do.	1.5×10^{-6}				
		BB1-4	2	do.		3.8×10^{-7}			
		BB1-5	3	do	1.3×10^{-5}				
		BB1-6	3	do.		6.0×10^{-7}			
		BB1-7	2	do.	9.0×10^{-7}				
		BB1-9	3	do.	2.8×10^{-7}				
		BB1-10	4	do.	3.2×10^{-6}				
		BB1-11	2.5	do.	1.9×10^{-6}				
		BB1-12	2.6	do.		8.7×10^{-6}			
11	Parker Rd. east of Rte. 83, Somers, Conn.	E1-1	1	surface	8.9×10^{-4}				P-ch
		E1-2	2	do.	1.7×10^{-4}				
		E1-3	2	do.	1.4×10^{-4}				
		E1-4	3	do.	3.6×10^{-4}				
		E1-5	3	do.	3.8×10^{-4}				
		E1-7	2	do.		5.3×10^{-4}			
12	Day Hill, Windsor, Conn.	S48, C1 horiz	0.6	surface-mixed?				7.0×10^{-4}	P
		do.	0.6-0.7	do.				1.1×10^{-4}	
13	Superior Electric, Bristol, Conn	MW7	2.7-4.3	surface	3.5×10^{-6}				SW-H
		MW8	3.0-4.6	do.	3.5×10^{-5}				
14	Cecos, Cross St., Bristol, Conn	CR1	6.1-9.1	surface	3.7×10^{-4}				SW-H
		CR4	9.1-12.2	do.	1.2×10^{-3}				
15	Cecos, Broderick Rd., Bristol, Conn.	BR5	12.5-15.5	surface	1.2×10^{-3}				SW-H
16	Excavation for Farmers and Mechanics Bank, Main St., Middletown, Conn.	MT1-3	5	drumlin	1.0×10^{-4}				P-ch
		MT1-4	3	do.	6.0×10^{-7}				
		MT1-6	5	do.	1.3×10^{-6}				
		MT1-7	2	do.	6.6×10^{-6}				
		MT1-8	3	do.	7.5×10^{-6}				
		MT1-9	4	do.	1.6×10^{-6}				
		MT1-10	3	do.		2.5×10^{-6}			
17	Pratt and Whitney, Middletown, Conn.	MW1	23.5-25.0	surface	1.7×10^{-5}				SW-H
		MW1A	19.2-20.7	do.	8.5×10^{-5}				
		GZ5D	18.9	do.	2.8×10^{-4}				
18	Durham-Middlefield Landfill, Durham, Conn.	D1-1	--	drumlin		4.1×10^{-6}			P-ch
		D1-2	--	do.	9.5×10^{-6}				
		D1-3	--	do.		2.3×10^{-5}			
		D1-4	--	do.	3.8×10^{-6}				
		D1-5	--	do.	1.4×10^{-6}				
		D1-6	--	do.		4.8×10^{-6}			
		D1-9	--	do.	1.4×10^{-5}				
19	Town of Durham, open-space land at end of Dunn Hill Rd., Durham, Conn	D13-1	1	surface?		1.2×10^{-3}			P-ch
		D13-2	1.3	surface-mixed?		2.1×10^{-5}			
		D13-3	4.5	drumlin		8.5×10^{-5}			
		D13-4	4.6	do.		5.4×10^{-4}			
		D13-5	4.8	do.		1.1×10^{-6}			
		D13-6	5.1	do.		4.4×10^{-6}			
		D13-7	5.3	do.		9.0×10^{-5}			
		D13-8	5.6	do.		1.0×10^{-6}			
		D13-9	10.5	do.		8.2×10^{-5}			
		D13-10	11.2	do.		8.2×10^{-7}			
		D13-11	11.3	do.		1.1×10^{-6}			

Porosity (percent)	Specific yield	Percent silt and clay	Remarks	References
Massachusetts and Connecticut				
29 21 28 21 27 23 25 20 27 25 26			part of a group of 58 till samples collected in the southern part of the Connecticut Valley Lowland by USGS; analysis by Univ. of Conn., Dept. of Civil Engineering; porosity calculated from bulk mass density and particle mass density ■ sample BB1-3 contained silt layer	unpublished file data USGS, Hartford, Conn.
32 32 32 32 32 –			do.	do.
40.1 31.0		71.6 (u) 71.6 (u)	core samples analyzed by the Connecticut Agricultural Experiment Station	Bourbeau and Swanson (1954)
			till is described as red at this site	Ground Water, Inc. (1987, p. 25)
		11 (a) 22, 6, and 28 (a)	screen of CR1 may be partly in sand; percent silt and clay in CR1 from 9.1-9.4 m; three sediment samples in CR4 taken from 9.1-9.7, 10.8-11.4 (described as containing only trace silt) and 12.3-12.8 m	Goldberg Zoino Assoc. (1990b, table 2)
		29 (a)		Goldberg Zoino Assoc. (1990a, table 2)
28 24 25 27 – 23 24			part of a group of 58 till samples collected in the southern part of the Connecticut Valley Lowland by USGS; analysis by Univ. of Conn., Dept. of Civil Engineering; porosity calculated from bulk mass density and particle mass density ■ some silt laminae in samples MT1-3 and MT1-6	unpublished file data USGS, Hartford, Conn.
			underlying rock is crystalline, but till is largely derived from Mesozoic sedimentary rocks directly to the west; samples MW1A and GZ5D assumed to be in till; reference gave method as slug test; withdrawal is assumed	Charles T. Main (1990, chap. 3, table 8)
25 26 27 22 18 22 25			part of a group of 58 till samples collected in the southern part of the Connecticut Valley Lowland by USGS; analysis by Univ. of Conn., Dept. of Civil Engineering; porosity calculated from bulk mass density and particle mass density ■ sample D1-1 described as sandy and friable, others are compact	unpublished file data, USGS, Hartford, Conn.
28 27 29 25 27 21 22 25 25 20 21			do.	do.

Site no.	Site name and location	Sample or well number	Depth below land surface (m)	Type of till	Hydraulic conductivity (cm/s) k_h	k_v	k_r	k_u	Type of test and analysis
20	West side of Cherry Lane near Durham Center, Durham, Conn.	D14-1	1.2	drumlin		1.6×10^{-5}			P-ch
		D14-2	6.3	do.		2.9×10^{-7}			
		D14-3	>6.3	do.		2.6×10^{-7}			
		D15-1	0.8	do.		1.6×10^{-5}			
		D15-2	1.1	do.		1.1×10^{-6}			
		D15-3	1.3	do.		2.4×10^{-6}			
		D15-4	1.4	do.		3.7×10^{-7}			
		D15-5	1.7	do.		5.2×10^{-7}			
		D15-6	4	do.		5.7×10^{-7}			
		D15-7	4.4	do.		3.8×10^{-7}			
		D15-8	4.6	do.		5.7×10^{-7}			
		D15-9	6.1	do		6.3×10^{-7}			
		D15-10	6.7	do.		1.8×10^{-7}			
		D15-11	6 9	do.		4.2×10^{-7}			
		D15-12	7.1	do.		3.9×10^{-7}			
		D15-13	7.4	do.		$2 1 \times 10^{-7}$			
	Crystalline bedrock of eastern Massachusetts,								
21	Athol Landfill, Athol, Mass.	MW2I	6 7-7.0	surface	1.2×10^{-4}				SW-H
		do.	7.9-8.2	do.	1.2×10^{-5}				
		do.	9.1-9.4	do.	1.2×10^{-4}				
		do.	10.4-10.7	do.	7.4×10^{-6}				
		do.	11.6-11.9	do.	1.4×10^{-6}				
		MW3I	6.7-7.0	do.	6.0×10^{-4}				
		do.	8.2-8.5	do.	3.3×10^{-6}				
		do.	9.1-9.4	do.	4.5×10^{-5}				
		do.	10.4-10.7	do.	1.2×10^{-5}				
		do.	11.6-11.9	do.	9.0×10^{-5}				
22	Upper Quaboag watershed Sucker Brook, West Brookfield, Mass.	DH6	6.7-7.2	surface-mixed?				1.1×10^{-4}	PT-ch
23	Upper Quaboag watershed Lamberton site, West Brookfield, Mass.	64W2909	0.3-1.2	surface-mixed?			5.3×10^{-6}		P
24	Galileo, Sturbridge, Mass.	MW8S	2.7-5.8	surface	2.4×10^{-3}				SW-BR
		MW11S	0.8-5.3	do.	4.7×10^{-3}				
25	Upper Quaboag watershed Shaw site, Spencer, Mass.	TH No.7	3.0-3.5	surface?				1.4×10^{-5}	U
		TH No.9	7.6-8.1	do.				4.2×10^{-3}	
		TH No.14	6 7-7.8	do.				$1 4 \times 10^{-5}$	
26	SUASCO watershed North Brook (Ross) site, Berlin, Mass.	71W1078	--	surface			1.4×10^{-5}		P
		71W1074	--	do.			3.5×10^{-5}		
27	SUASCO watershed Assabet River, site A-4-C Northboro, Mass.	60W2069/ 219.1	0.5-0.8?	surface			7.1×10^{-5}		P

Porosity (percent)	Specific yield	Percent silt and clay	Remarks	References
27 21 21 28 27 26 26 25 24 25 24 24 23 25 25 25			part of a group of 58 till samples collected in the southern part of the Connecticut Valley Lowland by USGS; analysis by Univ. of Conn., Dept. of Civil Engineering; porosity calculated from bulk mass density and particle mass density	unpublished file data USGS, Hartford, Conn.
Rhode Island, and eastern Connecticut				
			description of material is similar to that for a sample of till, although the material is not called till in the report	Tighe and Bond (1988, p. 17)
				SCS (1965b) and unpublished data for the Upper Quaboag River watershed, USDA, SCS
		38 (u)	sample may not be till; hydraulic conductivity determined on minus no. 4 fraction of sample compacted to 96 percent of maximum standard dry density	SCS (1964b) and unpublished data for the Upper Quaboag River watershed, USDA, SCS
			MW11S assumed to be in till	Applied Environmental Technologies Corp. (1989, p. E3-E4)
		30 (u)		SCS (1965a) and unpublished data for the Upper Quaboag River watershed, USDA, SCS
			hydraulic conductivities determined on minus no. 4 fraction of samples under load of 500 lb/ft^2	unpublished data on soil mechanics testing, USDA, SCS
			till above rock at emergency spillway; hydraulic conductivity determined on disturbed sample compacted to 95 percent of standard proctor density; both lab and field sample identification numbers given	SCS (1962) and unpublished data for SUASCO watershed, USDA, SCS

Site no.	Site name and location	Sample or well number	Depth below land surface (m)	Type of till	Hydraulic conductivity (cm/s)				Type of test and analysis
					k_h	k_v	k_r	k_u	
28	SUASCO watershed, Assabet River site A-3-C, Northboro, Mass	62W814	1.2-1.7	surface			1.8×10^{-4}		P
29	Nyanza, Ashland, Mass	MW10A	2 1-3.6	surface	2.1×10^{-4}				SW-N
30	Southeast side of Summer Hill, Maynard, Mass.	63MAS8	1.5-1.8	drumlin?			4.7×10^{-6}		P
31	Nashoba Brook Valley, Westford, Mass.	63MAS1	1.2-1.5	surface-flow till?			2.2×10^{-3}		P
32	Charles George, Tyngsborough, Mass.	MW8A JSU-1	1.8-3.4 1.7-3.2	surface do.	1.5×10^{-5} 5.1×10^{-5}				SW
		MW9A --	11.0-14.0 --	do. ?	1.9×10^{-6} 10^{-6}-10^{-4}				SW
33	Groveland Wells, Groveland, Mass.	ERT3 ERT12A	10 8-11.1 4.0	surface do.	1.0×10^{-3} 1.3×10^{-3}				SW
34	Haverhill Landfill, Haverhill, Mass	MW6/S7 MW1/S10	29.0-29.6 18.0-18 3	drumlin do.			3.0×10^{-5}	 2.0×10^{-8}	P
35	West of Holt Hill, Andover, Mass.	3	1.8	surface	5.2×10^{-4}				P
36	Northwest corner of Reading Quad, Andover, Mass.	4	1.5	surface		9.4×10^{-5}			P
37	North side Rte. 62 near Middleton, North Reading, Mass.	6	1.1	surface?		4.7×10^{-6}			P
38	Wilmington-Reading area, Mass.	10	2 1	surface?	2.4×10^{-4}				P
39	West of confluence of Lubber Brook and Ipswich River, North Reading, Mass.	11	0 8	surface-flow till?		9.4×10^{-5}			P
40	East of North Main St and north of Forest St., Reading, Mass.	7	2.1	drumlin?	1.0×10^{-2}				P
41	Iron Horse Park, Billerica, Mass.	OW-29	10.7-17.1	surface-basal	6.6×10^{-5}				O

Porosity (percent)	Specific yield	Percent silt and clay	Remarks	References
		22 (u)	hydraulic conductivity measured on minus no. 4 fraction of sample that had been compacted	SCS (1961) and unpublished data for SUASCO watershed, USDA, SCS
				NUS (1989, unnumbered worksheet)
40.4	9.7	50.9 (w)	one of two till samples collected and analyzed in the Assabet River basin by USGS	Pollock and Fleck (1964)
29.1	10.8	9.3 (w)	do. ■ this sample taken at an ice-contact stratified-drift exposure	do.
			MW8A described as in a silty drumlin deposit; JSU1 was in a sandy till	Ebasco (1988, p. F-1)
			described as silty till range given for sandy till at the site, not at a specific well	NUS (1986, chap. 5, p. 42)
			called ablation till in report; analysis by method described by U.S. Department of Interior (1978)	NUS (1985a, p. C-3)
		55 35	dense, silty till; MW6/S7 remolded, MW1/S10 undisturbed	Perkins Jordan (1981, p.3)
36.7	30.8	40.1 (w)	part of a group of six undisturbed till samples collected and analyzed by USGS	Baker and others (1964)
34.5	29.1	36.7 (w)	do.	do.
40.6	28.0	99 2 (w)	do.	do.
35.6	29.8	62.2 (w)	do. ■ location uncertain	do.
22.1	19.6	20 (w)	do. ■ sample appears to be taken from stratified-drift exposure near till contact	do.
33.7	31.2	23.8 (w)	do. ■ high hydraulic conductivity attributed to measurement parallel to parting planes of compact till	do.
			hydraulic conductivity determined from specific capacity using figure 3 on p. 12 of Walton (1962)	Camp, Dresser and McKee, Inc. (1987, chap. 5, table 4)

Site no.	Site name and location	Sample or well number	Depth below land surface (m)	Type of till	Hydraulic conductivity (cm/s) k_h	k_v	k_r	k_u	Type of test and analysis
42	Wells G + H Woburn, Mass.	G1S	8.8-11.9	surface	1.8×10^{-3}				SW-N
		G2S	2.7-5.8	do.	1.4×10^{-4}				
		G2M	7.0-8.5	do.	3.5×10^{-5}				
		G3S	6.7-11.3	do.	3.5×10^{-5}				
		G4S	4.9-7.9	do.	3.5×10^{-5}				
		G5S	3.6-6.6	do.	8.1×10^{-4}				
		G7S	1.8-6.4	do.	2.1×10^{-4}				
		G8OW	10.4-13.4	do.	3.5×10^{-5}				
		G9S	3.7-5.2	do.	4.6×10^{-4}				
		G10S	1.5-4.5	do.	2.1×10^{-5}				
		G11S	4.9-7.9	do.	3.9×10^{-4}				
		G12S	4.6-7.6	do.	9.2×10^{-4}				
		G13S	5.3-8.3	do.	1.4×10^{-5}				
		G14S	3.7-6.7	do.	1.4×10^{-5}				
		G15S	4.4-7.4	do.	2.1×10^{-4}				
		G16S	6.7-9.7	do.	3.5×10^{-6}				
		G17S	12.0-15.0	do.	1.8×10^{-5}				
		G18S	7.2-10.2	do.	2.5×10^{-5}				
		G19S	3.4-6.4	do.	1.1×10^{-4}				
		G19M	12.8-15.8	do.	7.1×10^{-5}				
		G20S	7.9-10.9	do.	1.1×10^{-4}				
		G21S	5.9-8.9	do.	2.1×10^{-5}				
		G22S	5.2-9.8	do.	2.5×10^{-5}				
		G23S	4.3-7.3	do.	1.8×10^{-4}				
		G24S	5.2-8.2	do.	3.5×10^{-5}				
		G25S	6.4-9.4	do.	3.5×10^{-5}				
		G26S	3.8-6.8	do.	7.1×10^{-5}				
		G27S	3.7-6.7	do.	3.5×10^{-5}				
		G28S	4.8-7.8	do.	1.1×10^{-4}				
		G31S	5.5-8.5	do.	7.1×10^{-6}				
		G32S	4.9-7.9	do.	1.8×10^{-5}				
		GO-1S	2.4-5.4	do.	5.3×10^{-4}				
43	Clean Harbors of Braintree, Braintree, Mass.	CHI-5B	4.6-7.6	surface	6.3×10^{-4}				SW-BR
44	Baird & McGuire, Holbrook, Mass.	903A	16.8-18.3	surface	1.7×10^{-3}				SW-H
		904A	16.2-17.7	do.	4.9×10^{-3}				
		905A	15.7-17.2	do.	7.4×10^{-3}				
		906A	16.4-17.9	do.	1.8×10^{-3}				
		907A	17.9-19.4	do.	7.0×10^{-3}				
		910A	7.0-8.5	do.	5.6×10^{-3}				
		911A	10.7-12.2	do.	9.2×10^{-4}				
		913A	1.2-5.8	do.	3.1×10^{-4}				
		914A	13.4-14.9	do.	3.2×10^{-3}				
		915A	19.2-20.7	do.	2.8×10^{-3}				
		PW-5	12.2-15.2	do.	9.2×10^{-3}				PT
		PB-1	10.7-11.3	do.	--				
45	Engelhard, Plainville, Mass.	MW23A	1.2-2.0	surface	1.3×10^{-3}				SW-BR
		MW5	--	do.	3.6×10^{-5}				
		MW1	2.7-5.5	surface	3.8×10^{-4}				SW-H
		MW4	6.4-6.7	do.	3.5×10^{-4}				
		MW7	3.4-5.8	do.	4.8×10^{-4}				
		MW8	1.2-5.8	do.	3.3×10^{-4}				
46	Polaroid, Freetown, Mass.	GZ-5	1.4-4.4	surface	2.5×10^{-5}				SW-H
47	Re-Solve, Dartmouth, Mass.	D	5.3-8.3	surface	8.8×10^{-4}				SI

values for till in southern New England--Continued.

Porosity (percent)	Specific yield	Percent silt and clay	Remarks	References
			all samples called lodgement till in report; value for percent silt and clay determined for well number G19M	Jonathan Bridge, GeoTrans, written commun., 1990
		41 (a)		
				Balsam Environmental Consultants, Inc. (1990, chap. 3, table 4)
			sandy, gravelly till with boulders; analysis by Hvorslev's method, as outlined in Lambe and Whitman (1969)	GHR (1985, chap. 3, table 1)
		11 (a)	aquifer test run in till layer, but results questionable because of recharge from overlying sand and gravel	Metcalf & Eddy (1989, p. 22-35)
		6(a)	MW5 is assumed to be in till	Environ Corp. (1990, p. F4)
			all samples assumed to be in till	Environ Corp. (1989, table 4)
			lodgement till, screen partly in sand and gravel	Goldberg Zoino Assoc. (1988, table 5)
			difficult to distinguish from outwash	Camp, Dresser, and McKee, Inc. (1983, chap. 2, p. 22)

Site no.	Site name and location	Sample or well number	Depth below land surface (m)	Type of till	Hydraulic conductivity (cm/s) k_h	k_v	k_r	k_u	Type of test and analysis
48	Sullivan's Ledge, New Bedford, Mass.	---	---	surface	1.2 x 10^{-3}				PT and (or) SW
49	Atlas Tack Corp., Fairhaven, Mass.	MW5	1.5-3.0	surface	1.9 x 10^{-4}				SW-BR
		MW7	1.2-3.4	do.	1.6 x 10^{-4}				
		MW8	0.9-4.0	do.	1.1 x 10^{-3}				
50	Upper Pawcatuck River basin, east of Tuckertown, South Kingston, R. I.	Sok 894	19.2	surface-morainal?			2.4 x 10^{-5}		P
		do.	25 2	surface-basal			4.2 x 10^{-4}		
51	North shore Long Pond, South Kingston, R. I.	Sok 889	41 9	surface-morainal			4.7 x 10^{-4}		P
		do.	52.9	surface-basal			4.7 x 10^{-5}		
52	North shore Bull Head Pond, South Kingston, R. I.	Sok 891	17.4	surface-morainal			1.4 x 10^{-4}		P
		do.	25.3	do.			2.8 x 10^{-4}		
53	Upper Pawcatuck River basin, northwest corner Kingston Quad, Richmond, R. I.	Ric 322	34.0	surface-basal			4.7 x 10^{-5}		P
54	Upper Pawcatuck River basin, east edge Slocum Quad, North Kingston, R. I.	Nok 1231	30.2	flow till?			9.4 x 10^{-5}		P
		do.	48.9	surface-basal			3.3 x 10^{-5}		
55	Picillo Farm, Coventry, R. I.	MW5	5.5-8.5	surface	1.2 x 10^{-3}				SW-H
		MW39	9.1-14.9	do.	7.8 x 10^{-4}				
		MW28	3.0-3.5	do.	5 1 x 10^{-4}				SW-H
		MW28	6.1-6.6	do.	1.7 x 10^{-5}				
56	Davis Liquid, Smithfield, R. I.	OW74	2.1-5.2	surface	1.7 x 10^{-4}				SW-H
57	Canton 3, bank cut west side of Rte. 12, 1 13 km south of Conn.–Mass border, Thompson, Conn	C1horiz	0.5-0.8	surface-ablation		9.2 x 10^{-3}			P-fh
		2C2horiz	0.8-1.1	do.		2.6 x 10^{-3}			

values for till in southern New England--Continued.

Porosity (percent)	Specific yield	Percent silt and clay	Remarks	References
			average of unknown number of samples with a range in conductivities of 1 x 10^{-3} to 1.7 x 10^{-3} cm/s; values were determined from either short-term pumping tests or slug tests	Ebasco Services, Inc. (1989, chap. 5, p. 37)
		14 (a)	both MW7 and MW8 include root zone; MW8 described as located in sandy till	Rizzo Assoc., Inc. (1989, unnumbered worksheet)
		28 (w) 6.9 (w)	group of till samples collected during drilling of wells in the Upper Pawcatuck River basin and subsequently analyzed by the USGS; till generally overlain by thick deposits of stratified drift ■ sample at 25.2 m at boundary between till and stratified drift on well log	Allen and others (1963)
		13.4 (w) 24.7 (w)	do. ■ surface morainal till in Charlestown moraine	do.
		15.9 (w) 8.6 (w)	do.	do.
		12 (w)	do.	do.
		22.4 (w) 20.4 (w)	do. ■ flowtill in "end moraine" a zone of collapsed stratified sediments and till	do.
				GCA (1985, chap. 8, p. 8)
				Mitre Corp. (1981, p. 38)
				Camp, Dresser and McKee, Inc. (1986, chap. 4, p. 19)
		61.5 (u) 27.6 (u)	one of six samples of Canton soils collected from C horizon at three localities; orientation of cores reportedly vertical (H.D. Luce, Univ. of Conn., oral commun., 1989)	Pelletier (1982)

Site no.	Site name and location	Sample or well number	Depth below land surface (m)	Type of till	Hydraulic conductivity (cm/s) k_h	k_v	k_r	k_u	Type of test and analysis
58	Quaddick State Forest, Thompson, Conn.	Th57	5.2-6.6	surface-mixed and (or) drumlin	3.1×10^{-4}				SW-T
59	Southwest corner Thompson Quad, Putnam, Conn.	Pu34a	5.4-7.8	surface?	2.2×10^{-4}				SW-T
		Pu34b	1.3-2.1	surface	3.6×10^{-3}				
60	Excavation west of Quinebaug River, Putnam, Conn.	1-L	--	drumlin?	1.1×10^{-3}				P-fh
					1.5×10^{-3}				
61	Northwest corner Danielson Quad, Pomfret, Conn.	Po7	3.2-6.6	surface-mixed?	3.0×10^{-4}				SW-T
		Po10	1.9-3.7	do.	8.4×10^{-3}				
62	Northeast corner Hampton Quad, Pomfret, Conn.	Po57	3.6-4.8	surface	1.6×10^{-3}				SW-T
		Po58	5.4-6.3	drumlin?	2.5×10^{-3}				
		Po76	0.7-6.3	surface-mixed and (or) drumlin	1.4×10^{-3}				
63	Natchaug State Forest, Eastford, Conn.	3	1.8-3.7	surface-mixed?	8.2×10^{-5}				SI-T
		4	1.8-6.5	drumlin?	1.9×10^{-6}				
		6	1.1-2.5	surface-mixed?	1.0×10^{-4}				
		8	2.0-3.0	do.	1.1×10^{-4}				
		11	1.8-3.3	do.	1.1×10^{-4}				
		14	2.1-5.2	drumlin?	3.7×10^{-4}				
		15	1.4-3.6	surface-mixed?	5.5×10^{-5}				
		17	2.4-3.3	do.	4.2×10^{-5}				
		23	2.0-3.2	do.	1.6×10^{-4}				
64	Northeast corner Hampton Quad and southeast corner Eastford Quad, Pomfret, Conn.	Po63	3.3-4.3	surface-mixed and (or) drumlin	6.3×10^{-3}				SW-T
		Po69	4.2-5.5	do.	2.1×10^{-4}				
		Sirrine	3.7-5.5	drumlin?	3.5×10^{-4}				
		Po60	4.6-5.2	do.	3.8×10^{-4}				
		Po62	2.2-3.9	surface-mixed?	6.2×10^{-3}				
		Po64	3.1-3.7	do.	1.0×10^{-2}				
65	Mashmoquet Brook, Pomfret, Conn.	4-U	1.5	surface	7.8×10^{-4}				P-fh
66	West margin Putnam Quad and east margin Eastford Quad, Woodstock, Conn.	Wk19	3.2-4.4	surface	3.4×10^{-3}				SW-T
		do.	3.3-4.4	do.	3.2×10^{-3}				
		Wk21	3.8-4.7	do.	1.6×10^{-3}				
67	Eastford Quad, West Woodstock, Woodstock, Conn.	Wk200	2.3-3.7	surface-mixed?	6.6×10^{-4}				SW-T
		Wk200a	3.0-5.0	do.	1.4×10^{-4}				
		Wk202	2.4-4.6	surface-mixed or drumlin	2.4×10^{-3}				
		Wk203	1.8-5.6	surface-mixed and (or) drumlin	8.0×10^{-5}				
		Wk204	2.0-7.4	do.	5.7×10^{-5}				

Porosity (percent)	Specific yield	Percent silt and clay	Remarks	References
			part of a group of eight dug wells originally tested by USGS (Thomas and others (1966); Randall and others (1966); data reanalyzed by Torak (1979))	Torak (1979)
			part of a group of 19 dug wells tested in eastern Connecticut	do.
		44 (w)	undisturbed sample from pit exposure	do.
			part of a group of 19 dug wells tested in eastern Connecticut	do.
			do.	do.
			group of nine small-diameter (5 cm) wells installed in Natchaug State Forest	do.
			part of a group of 19 dug wells tested in eastern Connecticut	do.
			part of a group of eight dug wells originally tested by USGS (Thomas and others (1966); Randall and others (1966); data reanalyzed by Torak (1979))	
		31 (w)	undisturbed sample collected from two-till locality described by Pessl (1966); adjacent sand lens had $k_h = 3.7 \times 10^{-3}$ cm/s	do.
			part of a group of 19 dug wells tested in eastern Conn. ■ Wk19 also tested by USGS (Thomas and others (1966); this value is from data reanalysis by Torak (1979))	do.
			do. ■ Wk200a is 53 m from Wk200	do.

Site no.	Site name and location	Sample or well number	Depth below land surface (m)	Type of till	Hydraulic conductivity (cm/s) k_h	k_v	k_r	k_u	Type of test and analysis
68	Paxton 2, borrow pit west side Old Turnpike Rd., Woodstock, Conn.	2Cr1horiz	0.6-0.9	drumlin		4.2×10^{-4}			P-fh
		2Cr2horiz	0.9-1.3	do.		1.9×10^{-5}			
69	Willington, Conn.	--	--	unknown				1.5×10^{-3}	U
70	Near headwaters of Olsons Brook, Coventry, Conn	basal till	--	drumlin	2.2×10^{-5}				PZ
71	Paxton 1, test pit 1.21 km south of intersection of Conn., Rtes. 275 and 195, Mansfield, Conn.	2Cr1horiz	0.8-1.0	drumlin		9.4×10^{-5}			P-fh
		2Cr2horiz	1.2-1.5	do.		2.5×10^{-4}			
		2Cr3horiz	2.1-2.4	do.		6.9×10^{-5}			
		2Cr4horiz	2.4-2.6	do.		7.5×10^{-4}			
		do.	2.6-2.8	do.		2.2×10^{-4}			
72	Paxton 3, test pit 0.5 km north-northeast of intersection Horsebarn Hill Rd. and Rte. 195, Mansfield, Conn.	2Crhoriz	0.7-.9	surface-mixed?		8.6×10^{-4}			P-fh
		do.	0.9-1.1	do.		1.0×10^{-3}			
73	Chestnut Hill, southwest corner of Spring Hill Quad, Mansfield, Conn.	Paxton11 Cxhoriz	0.2-0.3	drumlin?		8.3×10^{-6}			P
						7.8×10^{-5}			
		Woodbridge 11Cxhoriz	0.3-0.4	?		8.3×10^{-6}			
						1.4×10^{-5}			
		Ridgebury11 Cxhoriz	0 3	drumlin?		5.6×10^{-4}			
						1.4×10^{-4}			
		Whitman11 Cxhoriz	0.3-0.4	surface?		1.1×10^{-4}			
						1.3×10^{-3}			
		Well 1	--	drumlin	8.3×10^{-5}				PZ
		Well 2	--	do.	3.6×10^{-5}				
		Well 3	--	do.	3.6×10^{-5}				
		Well 4	--	do.	1.4×10^{-5}				
		Well 5	--	do.	8.3×10^{-5}				
		Well 6	--	do.	4.2×10^{-5}				
		Well 7	--	do.	4.2×10^{-5}				
		Well 9	--	do.	3.6×10^{-5}				
		Well 11	--	do.	8.3×10^{-5}				
74	Northwest ninth of Willimantic Quad, Windham, Conn.	64CON3	1.5?	surface	5.7×10^{-3}				P
75	Northeast side of drumlin located south of Rte. 6 and west of Brooklyn town line, Hampton, Conn.	Paxton11 Cx1horiz	0.7-0.8	drumlin?	4.3×10^{-3}	1.6×10^{-4}			P
						1.7×10^{-3}			
						1.7×10^{-3}			
		Canton11 C21horiz	0.8-0.9	surface	4.1×10^{-3}	1.2×10^{-3}			
						1.4×10^{-3}			
						4.0×10^{-3}			
		Ridgebury11 Cxhoriz	0.6-0.9	drumlin?	1.4×10^{-5}	6.9×10^{-5}			
						4.4×10^{-4}			

Porosity (percent)	Specific yield	Percent silt and clay	Remarks	References
		42.8 (u) 41.5 (u)	one of nine samples of Paxton soils collected from C horizon at three localities; orientation of cores reportedly vertical (H.D. Luce, Univ. of Conn., oral commun., 1989)	Pelletier (1982)
			exact location is not known, one of six samples identified as till on graph titled "Summary of permeability tests as of 8-6-42" compiled by Conn. Dept. of Transportation	unpublished file data, Conn. Dept. of Transportation, Rocky Hill, Conn.
			tested by piezometer method (Kirkham (1945))	Welling (1983)
		34.2 (u) 29 (u) 26.7 (u) 36.6 (u) 41.6 (u)	one of nine samples of Paxton soils collected from C horizon at three localities; orientation of cores reportedly vertical (H.D. Luce, Univ of Conn., oral commun., 1989)	Pelletier (1982)
		34.8 (u) 35 (u)	do.	do.
			group of core samples collected from C horizons of soils developed on till	Pietras (1981)
			group of nine wells at same site tested by piezometer method; wells 1-3 and 5 are open to Paxton substratum, wells 6-9 and 4 are open to Woodbridge substratum and well 11 is open to Ridgebury substratum	do.
31.6	27.9	18.5 (w)	undisturbed sample collected and analyzed by USGS; field notes indicate minor disturbance	Thomas and others (1967) and file data from USGS, Hartford, Conn.
			group of core samples collected from C horizons of soils developed on till	Pietras (1981)

Site no.	Site name and location	Sample or well number	Depth below land surface (m)	Type of till	Hydraulic conductivity (cm/s) k_h	k_v	k_r	k_u	Type of test and analysis
76	Brooklyn, Conn.	Bk20 Bk32	2.9-4.2 1.0-2.7	surface do.	2.1×10^{-3} 1.7×10^{-2}				SW-T
77	Central part of the Danielson Quad, Brooklyn, Conn.	Bk54	3.1-4.3	surface	7.4×10^{-3}				SW-T
78	Pit, 152 m north of Ennis Rd-Allen Hill Rd. intersection, Brooklyn, Conn.	E3/63CON4	1.5?	drumlin?		3.3×10^{-5}			P
79	Pit, west of Green Hollow Rd, 152 m south of Fall Brook, Killingly, Conn.	H6/63CON5	--	surface-mixed?		2.8×10^{-5}			P
80	East of new Rte. 12 expressway, north of Killingly Drive, Killingly, Conn.	K5/63CON6	1.8	surface?		1.9×10^{-5}			P
81	Black Hill Rd, 366 m east of Exley Rd., Plainfield, Conn.	T3/63CON1	5.2	drumlin		9.4×10^{-6}			P
82	Pit, 213 m east of Conn. Turnpike, south of Moosup River, Plainfield, Conn.	L1/63CON2	2.7	surface		8.0×10^{-4}			P
83	Road cut north of Evergreen St., east of Evergreen Cemetery, Plainfield, Conn.	K4/63CON3	0.9	surface-ablation?		1.4×10^{-3}			P
84	Revere Textiles, Sterling, Conn.	MW3	14.4-17.4	surface	9.4×10^{-4}				SW-H?
85	Central part of Voluntown Quad, Voluntown, Conn.	Vo88	1.4-3.4	surface?	2.8×10^{-3}				SW-T
86	Southwest part of the Voluntown Quad, North Stonington, Conn.	NSn25	6.6-8.4	drumlin?	8.0×10^{-5}				SW-T
87	Canton 2, test pit east side of Boombridge Rd., North Stonington, Conn.	2C1horiz 3C4horiz	0.8-1.0 1.4-1.6	surface-ablation do.		8.0×10^{-3} 3.6×10^{-3}			P-fh

Porosity (percent)	Specific yield	Percent silt and clay	Remarks	References
			part of a group of 19 dug wells tested in eastern Connecticut	Torak (1979)
			part of a group of eight dug wells originally tested by USGS (Thomas and others (1966); Randall and others (1966); data reanalyzed by Torak (1979))	do.
38	4.1	48.8 (w)	part of a group of six undisturbed till samples from the Quinebaug River basin analyzed by USGS (Randall and others (1966, p. 56)); both field and lab sample identification numbers given	Randall and others (1966)
28.6	3.9	44.8 (w)	do.	do.
29.9	12.2	39.5 (w)	do.	do.
27.6	4.6	39.4 (w)	do.	do.
35	20.3	32.9 (w)	do.	do.
36.1	20.9	30.8 (w)	do.	do.
			test described as "pumpout and recovery"	Camp, Dresser and McKee, Inc. (1989, chap. 9, p. 6)
			part of a group of eight dug wells originally tested by USGS (Thomas and others (1966); Randall and others (1966); data reanalyzed by Torak (1979)) ■ sand lens reportedly present in till (Thomas and others (1966, p. 41))	Torak (1979)
			do.	do.
		19.4 (u) 26 (u)	one of six samples of Canton soils collected from C horizon at three localities; orientation of cores reportedly vertical (H.D. Luce, Univ. of Conn., oral commun., 1989)	Pelletier (1982)

Site no.	Site name and location	Sample or well number	Depth below land surface (m)	Type of till	Hydraulic conductivity (cm/s) k_h	k_v	k_r	k_u	Type of test and analysis
88	Montauk 2, bank cut 0.3 km southeast on Greenhaven Rd., from intersection with RR tracks, Stonington, Conn.	2Cr1horiz	0.9-1.4	surface-basal?		3.0×10^{-3}			P-fh
		do.	1.4-1.6	do.		3.8×10^{-3}			
		do.	1.6-1.8	do.		3.4×10^{-3}			
89	Montauk 1, test pit 0.2 km west-northwest of intersection of Noank-Ledyard Rd., and Interstate 95, Groton, Conn.	2Cr1horiz	0.6-0.9	surface-basal?		3.7×10^{-3}			P-fh
		2Cr2horiz	0.9-1.1	do.		3.3×10^{-3}			
90	New London Bypass, Groton, Conn. (?)	--	--	unknown				1.7×10^{-6}	U
91	Route 85, Waterford, Conn.	--	--	unknown				5.4×10^{-5}	U
92	Haddam, Conn.	--	--	unknown				3.8×10^{-4}	U

Porosity (percent)	Specific yield	Percent silt and clay	Remarks	References
		21.1 (u) 20.4 (u) 17 (u)	one of five core samples of Montauk soils collected from C horizon at two localities; orientation of cores reportedly vertical (H.D. Luce, Univ. of Conn., oral commun., 1989)	Pelletier (1982)
		24.4 (u) 27.3 (u)	do.	do.
			exact location is not known; one of six samples identified as till on graph titled "Summary of permeability tests as of 8-6-42" compiled by Conn. Dept. of Transportation	unpublished file data, Conn. Dept. of Transportation, Rocky Hill, Conn.
			do.	do.
			do.	do.

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