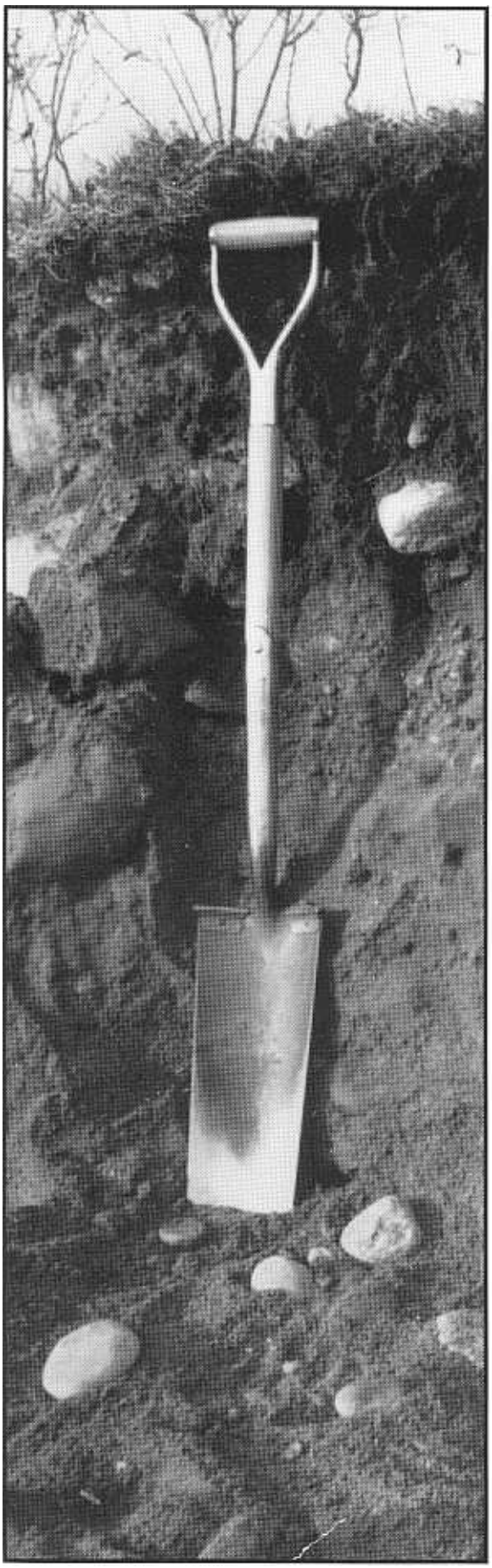

SOIL MANUAL FOR SITE EVALUATIONS IN NEW HAMPSHIRE

2d EDITION

BY
USDA SOIL CONSERVATION SERVICE
DURHAM, NH
AND
NH DEPARTMENT OF
ENVIRONMENTAL SERVICES
WATER SUPPLY AND POLLUTION
CONTROL DIVISION
CONCORD, NH

All Soil Conservation Service programs and services are offered on a nondiscriminatory basis, without regard to race, color, national origin, religion, sex, age, marital status, or handicap.

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FOREWORD

Images of New Hampshire: "Golden Pond", Silver Lake, Diamond River. Postcard scenes reflect our state's environmental quality. As New Hampshire grows, protection of our countryside will enable future generations to enjoy the same caliber of life.

After a decade, a paragraph in the foreword of the original *Soil Manual for Site Evaluations in New Hampshire* is still appropriate:

> "New Hampshire's growth can be accommodated without wanton sacrifice of the very environment which makes it so desirable. Its valuable rural and urban development and timber harvesting can and should be positive aspects of New Hampshire's culture."

Robert W. Varney
Commissioner
NH Department of
Environmental Services
Concord, NH

Through careful evaluation and use of our soils, we can continue to develop in an environmentally protective manner. Wise use of our soils will protect the state's water quality and other natural resources.

This manual has been published to enhance this effort through increased knowledge of site evaluation. Assessment of site attributes and potential problems is an important step in the development process of protecting the environment. This manual offers general guidance for those involved with small residential and commercial site evaluation and development.

David L. Mussulman
State Conservationist
USDA Soil Conservation Service
Durham, NH

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David L. Mizenhiner
State Conservationist
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Durham, NH

PREFACE

Development in New Hampshire is increasing dramatically. This rate of activity raises concerns about future water quality and the need to further protect our water and other natural resources. Continued and more intensive management of resources, including water quality protection, is necessary.

The degree of impact that this rate of growth has on water resources is directly related to the use of onsite soils. New Hampshire has many kinds of soils that are distributed widely. Development sites may involve several of them. Many of these soils have limited capability for development; some are not suitable for development at all.

It is essential to provide intensive evaluation of onsite soils for development. Thorough evaluation is the first key step in the evaluation - design- construction process that tailors development to the capabilities of the soils.

This manual is in response to a need for more intensive soil evaluation. It is intended primarily as a generalized guide for evaluators and others that are involved with soils for site development in New Hampshire. It addresses soil science and soil engineering in terms of site evaluation for common residential and commercial development.

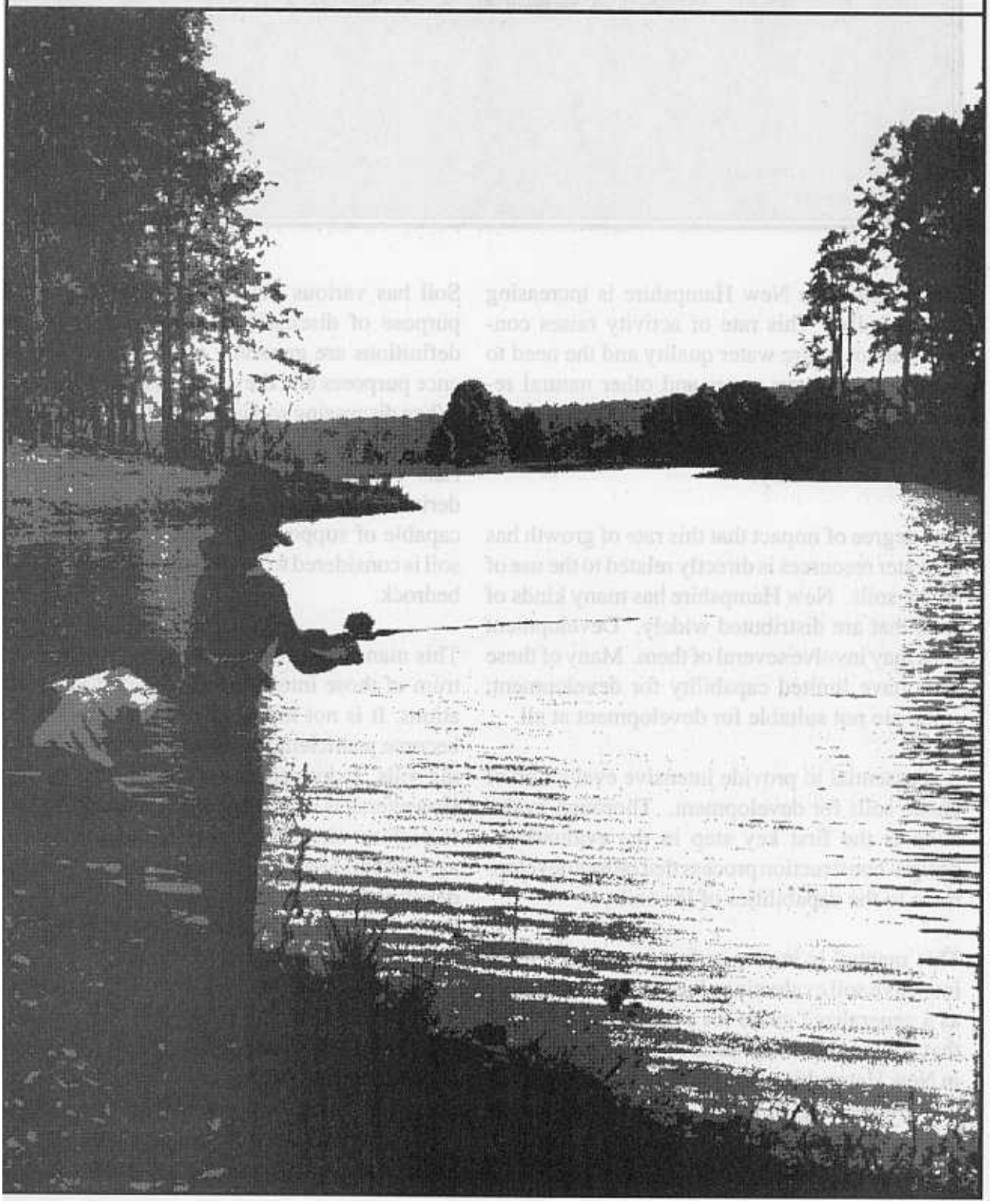
Soil has various definitions depending on the purpose of discussion. For this manual, two definitions are generally used: one for soil science purposes and the other for soil engineering. When discussing soil in terms of soil science, soil is considered to be the collection of earthy materials within 65 inches of the planet's surface, derived from natural soil- forming processes and capable of supporting plants. For engineering, soil is considered to be all earthen material above bedrock.

This manual is presented to serve a broad spectrum of those interested in soils for site evaluations. It is not intended to train individuals to become proficient in various disciplines involving soils. It does not cover all soil aspects either. However, it is written to assist in increasing skills to perform site evaluations for subsurface sewage systems as well as other elements of small site development. It also attempts to illustrate to those not directly involved with evaluations the need for professional involvement.

This second edition is a complete revision of *The Soil Manual for Site Evaluations in New Hampshire*. The Soil Manual was published several years ago by the New Hampshire Water Supply and Pollution Control Commission, now the Department of Environmental Services, Water

Supply and Pollution Control Division, and the State Conservation Committee. It was written by the USDA Soil Conservation Service in New Hampshire. This edition uses material from the Soil Manual, USDA Soil Conservation Service National Engineering Handbook, manuals, and soil surveys, and other publications. This edition also adds a new feature. Chapter 12 has been developed to aid in understanding soil aspects of subsurface and subdivision regulation requirements.

SITE EVALUATION IS NECESSARY FOR HARMONIOUS DEVELOPMENT



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The Soil Conservation Service would appreciate comments and notice of errors and omissions pertaining to this manual. Please send correspondence to: USDA Soil Conservation Service, Federal Building, Durham, NH 03824.

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NEED FOR SITE EVALUATION

1

Concern for the environment, especially water quality, is bringing about more careful use of the land for development in New Hampshire. Market demand for environmentally sound residential and commercial construction is also encouraging more consideration of site soil limitations.

NEED FOR SITE EVALUATION

Sites with soils less suitable for construction are being utilized more often for building, increasing the need for thorough investigation and site evaluation. The impact of development and the need for evaluation is substantially greater when soils with less favorable characteristics are used. Refer to Figure 1-1. Investigation and evaluation of soils are basic steps in achieving overall quality construction and environmental harmony.

There are several facets of development and the environment that are of major concern. Water resources are important for health as well as environmental and aesthetic reasons. Subsurface sewage disposal is of major importance because public sewers are not available for a large percentage of sites in New Hampshire. Erosion and sediment control is also important to keep streams and lakes clear. Stormwater management is required to control the greater runoff that is generated from constructed impervious surfaces.

WATER RESOURCES

Awareness and concern for water pollution in its many aspects brought about a mandate to protect water resources during and after construction. A major factor in protecting New Hampshire's water quality is the proper use of soils. Development should be carefully implemented within the capabilities of the land to avoid adverse impacts. Quality of water may be degraded even from construction of minor development.

The quality of water in, and downstream of, development may be adversely impacted by:

- improper onsite sewage treatment and disposal
- inadequate construction site erosion and sediment control
- ineffective post construction erosion and sediment control

FIGURE 1 - 1 IMPACT OF DEVELOPMENT DEPENDS LARGELY ON SOILS

IMPACT OF DEVELOPMENT IS LOW FOR SOILS THAT:	IMPACT OF DEVELOPMENT IS HIGH FOR SOILS THAT:
• Do not flood	• Flood
• Are not wet (adequate drainage)	• Are wet (poor drainage)
• Have adequate permeabilities	• Are not very permeable
• Have suitable textures	• Have fine textures
• Have relatively deep water tables	• Have high water tables
• Have adequate depths to bedrock	• Have shallow depths to bedrock
• Have mild slopes	• Have steep slopes

- poorly planned stormwater management

- flooding

Subsurface systems that impose large hydraulic loads on small areas require technical investigations and evaluations. Careful evaluation of receiving soils and adjacent areas is needed to protect water quality. See Figure 1-2. Hardpan, bedrock at relatively shallow depths, and rapid permeability increase the possibility of sewage contamination of adjacent wells. Evaluations may require accurate assumptions and predictions of groundwater flow.

Proper evaluation of soils is also essential when long term protection of new well fields is considered. Many areas in New Hampshire rely on community or development wells for potable

FIGURE 1 - 2 SOIL EXPLORATION AND EVALUATION ARE ESSENTIAL FOR MAINTAINING WATER QUALITY FOR DEVELOPMENT

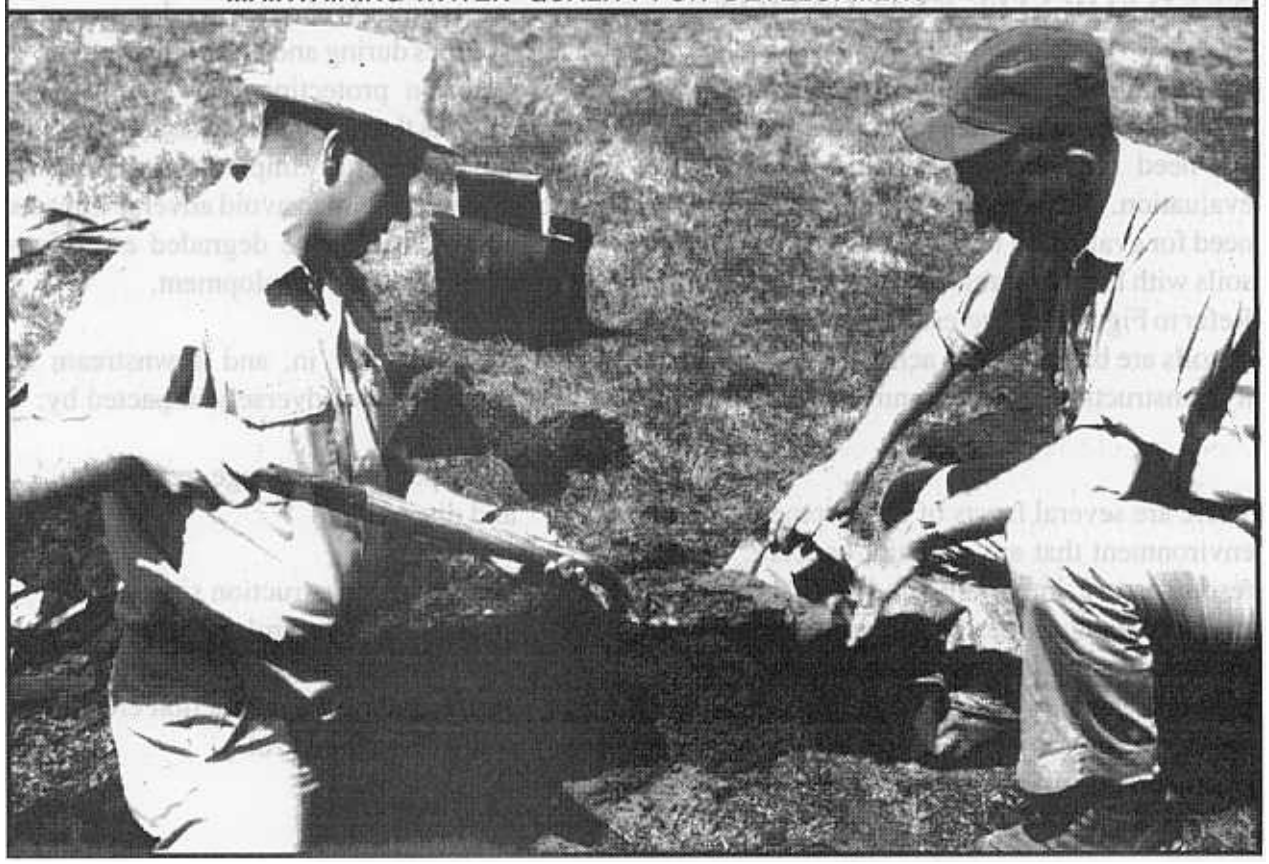
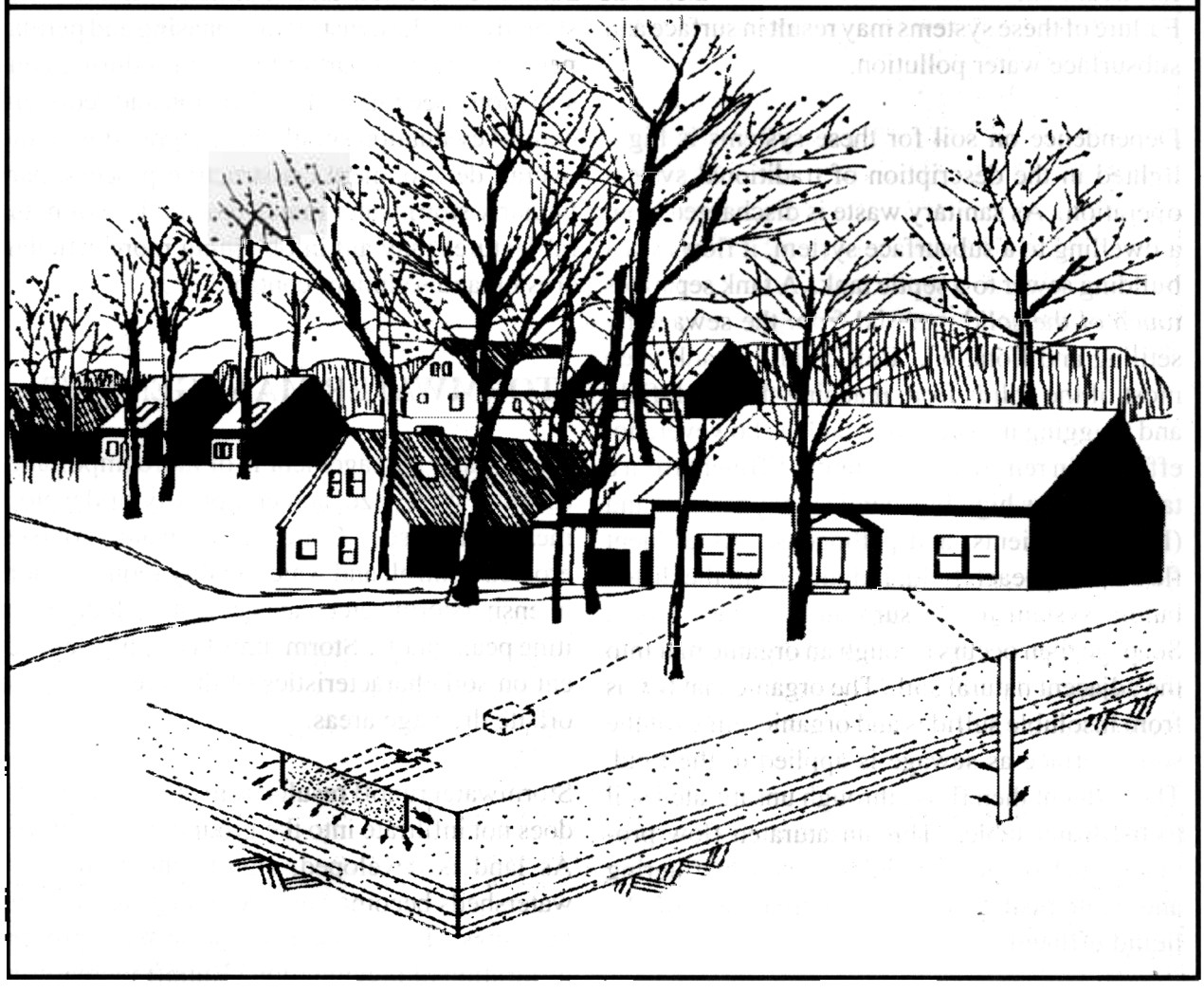


FIGURE 1 - 3 THE RECEIVING SOILS AT SUBSURFACE SEWAGE SYSTEMS ARE CRITICAL FOR PURIFYING SEWAGE



water. Pathogens and other contaminants may travel great distances in some soils and could have serious consequences for water users. Offsite potential pollution sources require investigation and evaluation. Pollution may not appear for several years after well construction.

Soils should be carefully evaluated to ensure adequate erosion and sediment control. Turbidity caused by sediment obscures sunlight, suffocates fish, destroys habitats, and harms wetlands. Sediment can carry chemicals such as pesticides that are released in water and cause further stream pollution. Surface water may also be polluted with organic materials that decrease dissolved oxygen and thereby endanger fish and aquatic animals.

SEWAGE DISPOSAL

Onsite sewage treatment and disposal is a major concern when planning most development. Since municipal sewers are not available in many areas, onsite systems become necessary. Current technology, economics, and concern about effluent discharge dictate subsurface waste disposal systems in most cases. The dominant onsite systems used in the state are septic tank leach field systems. See Figure 1-3. Even though these systems require considerable care, they do have two advantages. They eliminate negative aspects of disposing of effluent in surface water and provide some recharge of groundwater.

Subsurface systems are dependent on onsite soils for treatment of effluent as well as disposal. Failure of these systems may result in surface and subsurface water pollution.

Dependence on soil for these systems is highlighted in the description of traditional system operation. As sanitary waste is discharged from a dwelling to a subsurface system, it flows via a building sewer to a septic tank. A tank separates much of the solid material from the sewage by settling and flotation. Baffles in the tank keep most of the solids from reaching the leach field and plugging it. The septic tank is, however, not efficient in removing pollutants. Effluent from a tank contains high biochemical oxygen demand (BOD), nutrients, and pathogens. As effluent flows to the leach field, it drains from the distribution system to the surrounding leach stone. Seepage then occurs through an organic mat into the adjacent natural soil. The organic mat forms from insoluble sulfides and organic slimes at the soil interface as sewage is applied to the field. The effluent then flows through unsaturated soil to the water table. This unsaturated flow provides much of the essential treatment by filtering and biological and chemical treatment of the liquid effluent.

This treatment is necessary prior to the effluent reaching the water table. Pathogens and other harmful elements of sewage may travel long distances, if treatment is not provided above the groundwater table. Large sewage loadings may increase the elevations of the water tables under the systems. This hydraulic mounding requires raising systems in order to maintain the required depth of unsaturated soil to effectively treat the sewage.

EROSION AND SEDIMENT

Erosion of soil and resulting sedimentation in surface waters is a concern. It is well known that some soils erode more quickly than others and that there are a variety of soil factors involved in this process.

Evaluation of soils is essential to plan for the control of erosion and sediment. Evaluations should consider construction phasing and permanent measures as part of the control during construction. See Figure 1-4. Erosion and sediment control evaluation should be integrated with the overall development construction process, particularly stormwater management. Use of natural features may aid in obtaining more efficient erosion and sediment control.

STORMWATER MANAGEMENT

Stormwater management is of more importance as congestion, size, and complexity of developments increase. Concern for water courses, erosion control, and water quality requires more intensive stormwater management, including limiting peak runoff. Storm runoff is highly dependent on soil characteristics of the site, as well as offsite drainage areas.

Stormwater runoff results from precipitation that does not infiltrate into the ground or evaporates. As land is developed, significant portions of watersheds become covered with pavement and buildings. These impermeable surfaces prevent infiltration of precipitation. Runoff increases as the ratio of impervious surfaces increases. The volume of runoff may increase dramatically.

Urbanization commonly increases the peak rate of runoff due to shorter travel time in the drainage area. This results from faster flow over pavements, in constructed channels, and in storm sewers.

Runoff rates and volumes depend on the types of soils, kinds of soil cover such as trees and pavement, soil moisture conditions, slopes, and the magnitude of precipitation and snowmelt. Sandy soils provide the greatest infiltration and reduce runoff considerably. Clayey soils and soils shallow to bedrock or that have hardpan provide much less infiltration. Management of stormwater is most effective when infiltration is maxi-

FIGURE 1 - 4 CONSTRUCTION SITES WITH HIGH EROSION POTENTIAL MAY BECOME COMMUNITY LIABILITIES

mized. Evaluation of soils and cover are necessary to properly plan stormwater management. Refer to Figure 1 - 5.

FLOODING

Areas that flood are not suitable for most development construction. These areas may be subject to erosion, water damage, and sedimentation. Flooding may produce dangerous velocities, pollution of wells, and malfunction of subsurface sewage systems.

Certain soil characteristics indicate a tendency towards flooding. Soils affected by flooding over several thousands of years may indicate current flooding potential from their historical record. Soils that have been transported by water may also indicate flooding. Soils do not indicate all flooding conditions, however. Flooding due to development or manmade restrictions in watercourses are not indicated by soils. Also, some soils that indicate historical flooding may not flood because of prevention structures. Careful evaluation will assist in planning to avoid flood problems.

WETLANDS

Wetlands are a very important consideration with any development proposal. Awareness of wetlands and their values and functions has increased dramatically in recent years. As a result, protection of wetland areas has become an important issue. Any activity proposed in a wetland may require a permit from the state and federal government and approval from the municipality. Setback requirements from wetlands for certain development activities may also apply. Because of the natural values of wetlands and their poor suitability for development, alternatives should be considered that will not impact them.

FIGURE 1 - 5 SOIL CHARACTERISTICS AFFECT THE AMOUNT OF PEAK RUNOFF FROM DEVELOPMENT

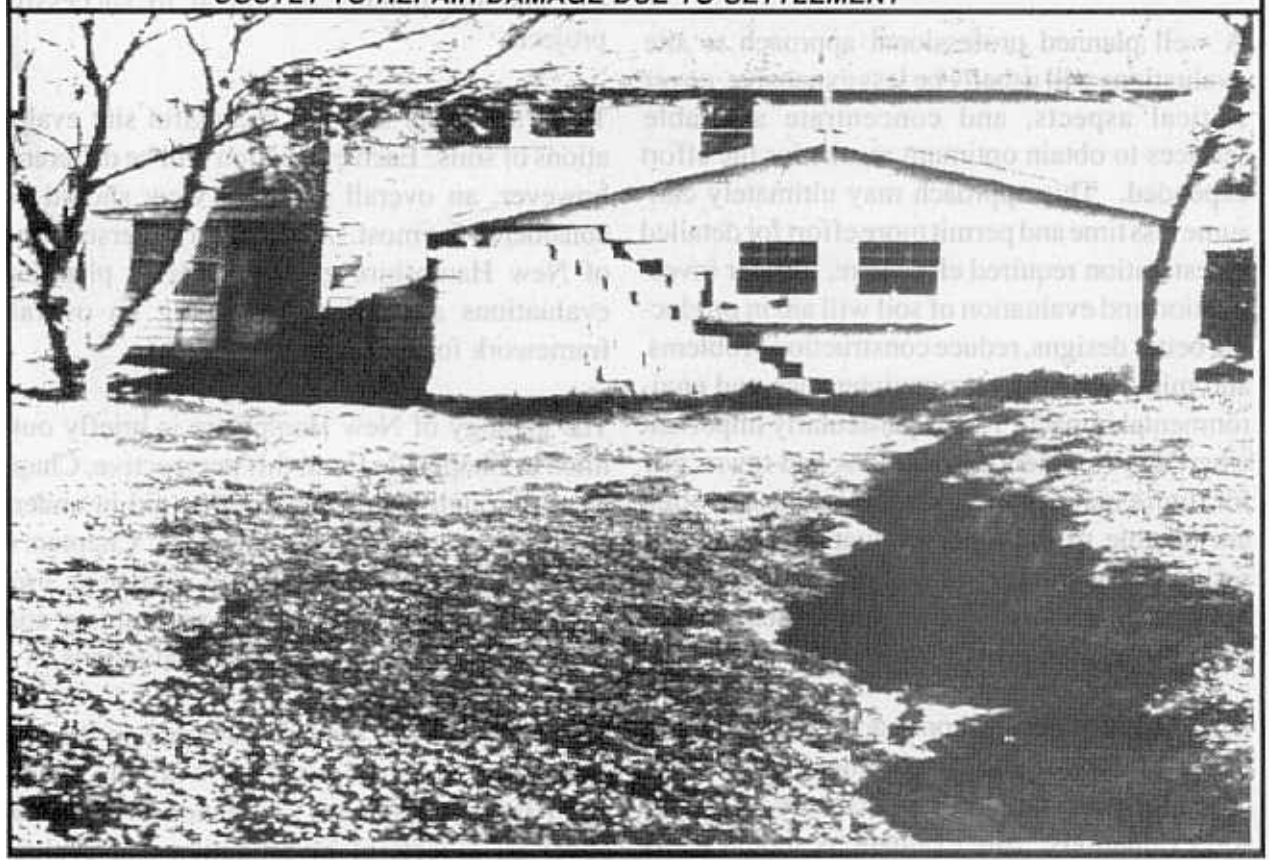
Wetlands are identified in three ways—soils, vegetation, and hydrology. Some wetland definitions use one of the above mentioned parameters and some may use a combination of two, or all three. Some wetland definitions use poorly and very poorly drained soils and often refer to the Soil Conservation Service soil survey maps. Other wetland definitions refer to hydric soils. Hydric soils have high water tables and generally provide a saturated condition near the surface during the growing season in which water tolerant plants prevail. Wetland vegetation, often referred to as hydrophytic plants, is used in some cases for identifying a wetland. Physical evidence of flooded or ponded conditions (such as water stained leaves or reddish hues along root channels) or water tables near the soil surface (hydrology) are also used as an indication of a wetland.

FARMLANDS

Farmlands are an important resource in New Hampshire even though they represent a small percentage of the land area for the state. Most of the best farmlands occur in the major river valleys. This is also where most of the development is located. Because much of the farmland is suitable for development, there is pressure to convert it to urban uses.

The types of soil that are productive for agricultural crops are classified into three categories. They are: prime farmland soils, soils of statewide importance, and locally important farmland soils. Prime farmland soils are the very best and meet national criteria for the designation of "prime." Prime farmland soils are best suited for producing food and fiber on a sustained basis. Soils of statewide importance usually are soils that narrowly miss making the criteria for prime farmland for one soil property and are important in New Hampshire for farming. Locally important farmland soils are identified at the local level as important to agriculture in that particular area.

FIGURE 1 - 6 STRUCTURES REQUIRE SUITABLE SOIL SUPPORT. IT MAY BE VERY COSTLY TO REPAIR DAMAGE DUE TO SETTLEMENT



Consideration should be given to farmlands in a development proposal. Alternatives to converting farmland to urban uses should be considered. Conservation easements, purchase of development rights, and cluster developments are some ways of preserving farmlands.

SOILS AND DEVELOPMENT

Soil is a major component of all development. Whether in its natural form as the "ground" or excavated and manipulated as fill, it has a broad range of attributes. Soil is the support for development structures, including buildings, sewage systems, and roads. Refer to Figure 1-6. Soil provides the growing medium for lawns and plants. It provides a wide range of environments from wetlands to prime farmlands, and from forests to beaches.

Soil has a major role in the earth's hydrologic cycle, intercepting, storing and releasing precipitation to streams. It provides the mechanism for the subsurface treatment and disposal of onsite sewage and provides the reservoir for subsurface water supplies.

There is a great variety of soils in New Hampshire. About 160 soils have been identified in terms of the National Soil Survey Classification System. Many development uses of soil, however, require determinations of soil attributes that go far beyond delineation of soils by soil survey classification. Soil parameters such as texture, density, permeability, and gradation need to be determined and evaluated. These vary considerably both horizontally and vertically and may change greatly in short distances. In addition, soil moisture conditions vary widely both horizontally and vertically with time and climatic conditions. The great variation in soil characteristics and evolving aspects of development make site evaluation challenging.

SITE EVALUATION

A well planned professional approach to site evaluations will usually be less expensive, cover critical aspects, and concentrate available services to obtain optimum results for the effort expended. This approach may ultimately consume less time and permit more effort for detailed investigation required elsewhere. Proper investigation and evaluation of soil will aid in producing better designs, reduce construction problems, and minimize long term maintenance and environmental impact. This is particularly important where development associations and towns pay for future maintenance. Cost overruns are often attributable to improper evaluation and use of soils. The variability of soil properties and behavioral characteristics over short distances justifies the need to provide thorough evaluations.

Knowledge of design, construction, and maintenance aspects of site development and knowledge of soil and the land, are necessary for proper soil evaluations. Site evaluations should be as extensive, comprehensive, and detailed as required by the site and the development. Communication between the soils investigator, evaluator, and the planner is crucial to successful projects.

There are many steps to successful site evaluations of soils. Each evaluation will be different, however, an overall geologic view should be considered for most. A thorough understanding of New Hampshire geology aids in planning evaluations as well as providing an overall framework for investigations.

The geology of New Hampshire is briefly outlined in Chapter 2. From this perspective, Chapters 3 through 5 are introduced to aid in understanding the soil in New Hampshire. Chapters 6 through 8 discuss soil surveys and their use. Chapters 9 through 12 discuss preliminary and detailed investigations and soil evaluations.

This manual gives general guidance to the site evaluator and others involved with site evaluation and development. It obviously does not cover all aspects of investigation and evaluations.

GEOLOGY AND SITE EVALUATION

2

Geology is one of the most important of many factors which determine the best use and/or limitations of a particular site. A basic knowledge of New Hampshire's geology, especially surficial geology, and related processes is essential for proper site evaluation.

This chapter contains general information on bedrock and surficial deposits of New Hampshire and their history. The transporting agents of ice, water, wind, and gravity are discussed. Such information assists in understanding the physical environment, including the development of site soils from various "parent materials", so that realistic, comprehensive inventories and site evaluations may be made.

Geologic factors which affect the planning, design, construction, operation, and maintenance of sites include the following:

- Distribution and thickness of various geologic materials, such as bedrock, till, ice-contact deposits, proglacial deposits, and alluvium
- Depth and configuration of the underlying groundwater and bedrock surfaces
- Engineering and other properties of these materials, including strength, permeability, durability, and workability
- Drainage and slope stability

When such factors are ignored, overlooked, or not adequately investigated or interpreted, the consequences can be very costly and may include the following:

- Environmental degradation
- Higher initial construction costs
- Expensive contract modifications
- Total or partial loss of design function
- Expensive remedial measures or design changes to restore the function
- Excessive operation, maintenance, and replacement costs

PHYSIOGRAPHY

New Hampshire contains three separate physiographic units. The "Coastal Lowlands" unit is a 20 to 45-mile wide zone in the southeastern corner of the state. It has rather poor drainage, low relief, and elevations typically less than 500 feet.

The "Connecticut Valley" unit occurs only in a narrow band along the Connecticut River as far north as Woodsville. Topography is flat to rolling and relief is low. Elevation increases gradually northward to about 500 feet.

The "Central Highlands" unit occupies the remainder of the state. Drainage is well developed and relief is moderate to high. Elevations are typically between 500 and 2,000 feet. Some mountains, particularly in the Presidential Range of the White Mountains, have elevations in excess of 3,000 feet. Mount Washington (elev. 6,288 feet) is the highest mountain east of the Mississippi River and north of the Carolinas.

GEOLOGIC TIME

A brief discussion of the vastness of geologic time and the relative ages of bedrock and surficial deposits is helpful to an appreciation of New Hampshire's geology. An abbreviated geologic time scale is shown in Figure 2-1.

The earth is estimated to be about 4.5 billion years old. The state's bedrock was formed between about 900 million and 75 million years ago (Late Proterozoic to Cretaceous time). The record is not a continuous one; many gaps or discontinuities exist which represent periods of erosion instead of deposition.

The last 1.6 million years of geologic time is known as the Quaternary period. During that period's Pleistocene epoch, cyclical climatic changes caused continental ice sheets to advance and recede over much of Canada and the northern United States at least four times. These glacial stages were separated by three interglacial stages when the climate was similar to that of today.

Most of the state's surficial materials were deposited in the last 100,000 years during the last glacial stage, called the Wisconsinan. The last 10,000 years, since the arbitrary end of the Pleistocene epoch, is known as the Holocene epoch, or "Recent".

BEDROCK GEOLOGY

Geologically, New Hampshire is centrally located in the Appalachian Province, which extends from Alabama to Newfoundland. It is midway between older metamorphic and igneous rocks of the Canadian Shield to the west and younger sedimentary Coastal Plain rocks on the continental shelf to the east.

The state's stratified (layered) rocks began as sandy, silty, and limy oceanic sediments and as volcanic debris deposited primarily from Late Proterozoic through Early Devonian time. These original rocks were deformed, metamorphosed, and intruded by several different suites of granitic igneous rocks during several mountain-building episodes.

Plutonic igneous rock suites were emplaced through Middle to Late Ordovician and Silurian time, (during formation of Vermont's Taconic Mountains), and through Early to Late Devonian time, during the last severe deformation of the area's rocks. Intrusive and volcanic rock suites were emplaced during Jurassic and Cretaceous time.

This bedrock and particles derived from it are usually hard, sound, and durable. Some coarser-grained crystalline rocks and some thinly stratified rocks may have an unacceptable amount of mechanical breakdown. This degradation results

FIGURE 2 - 1 ABBREVIATED GEOLOGIC TIME SCALE

EON	ERA	PERIOD	EPOCH	MILLION YEARS AGO
Phanerozoic	Cenozoic	Quaternary	Holocene (Recent)	
				0.01
			Pleistocene	
				1.6
		Tertiary	Pliocene	
				5.3
			Miocene	
				23.7
			Oligocene	
				36.6
			Eocene	
				57.8
			Paleocene	
				66.4
	Mesozoic	Cretaceous		
				144
		Jurassic		
				208
		Triassic		
				245
	Paleozoic	Permian		
				286
		Carboniferous		
				360
		Devonian		
				408
		Silurian		
				438
		Ordovician		
				505
		Cambrian		
				570
Proterozoic				
				2500
Archean				
				3800 ±
(Unknown, no geologic evidence)				
				4500 ±

from fracturing along cleavage planes within individual mineral crystals, especially feldspars, and along bedding and cleavage planes in the stratified rocks.

The depth to bedrock, particularly if deeper than 2 to 3 feet, is very unpredictable. Younger glacial deposits may mask completely the underlying unconsolidated deposits and irregular bedrock surface. This irregularity of the bedrock surface has been further exaggerated by the abrasion and plucking that took place at the base of active glacial ice. These factors highlight the need for detailed, onsite investigations.

ECONOMIC GEOLOGY

With but few exceptions, mines in New Hampshire were relatively short-lived and were never a major industry. Small mines produced minor quantities of copper, diatomite, fluorite, garnet, gold, graphite, iron, lead, marble, molybdenum, peat, quartz, silver, talc, tin, and zinc. The state was once a leading producer of feldspar and mica.

Some of the old, long-term mineral industries are still in operation. Clay is mined for brick manufacture and granite is quarried for dimension stone. Traprock and granite are quarried in

several locations and crushed for use as concrete and bituminous aggregate. Construction sand and gravel, the state's leading mineral commodity, is obtained from glacial deposits in every county.

QUATERNARY HISTORY

The Wisconsinan stage was well under way 50,000 years ago. Mountain or alpine glaciers were already modifying the landscape in the higher elevations. Large cirques such as Tuckerman's Ravine, deep U-shaped valleys, and other glacial landforms still exist there. Most of the depositional evidence of earlier stages of Pleistocene glaciation was obscured or destroyed by the last continental glacier, the Laurentide ice sheet.

Centered east of Hudson Bay, Canada, Laurentide ice flowed radially under the influence of gravity. It spread slowly south and east (within the southeast quadrant) across New Hampshire, reaching its maximum extent on Long Island, New York by about 18,000 years ago. Calculations of theoretical ice surface profiles for that time indicate that at least 3,000 feet of ice covered Mt. Washington. Boulder "erratics" (boulders "from away") and till are both found at the top of Mt. Washington. The state's land surface was depressed as much as 700 feet by the weight of the ice sheet.

The glacier scoured the underlying terrain, gathered up soil and rock debris, and left behind new deposits. Much of the state is covered by compact basal till deposited during glacial advance. Most existing surficial materials were deposited between 50,000 and 10,000 years ago.

As the climate slowly began to warm about 17,000 years ago, the rate of glacial melting exceeded the rate of advance. The ice margin gradually receded northward to southern New Hampshire by about 14,000 years ago. Even though the margin was receding northward, the ice sheet was still flowing southward. Basal till was still being deposited in the Androscoggin Valley of New Hampshire and Maine at that time. The ice sheet thinned, so that the top of Mt. Washington had probably emerged by the time the ice margin was at Manchester, New Hampshire. It appears that regional stagnation occurred in the most mountainous areas, with actively retreating ice margins to the east and west. In New England, the main ice sheet never did flow northward, even though some isolated stagnating masses did eventually flow in that, or another, direction as a result of controlling topography.

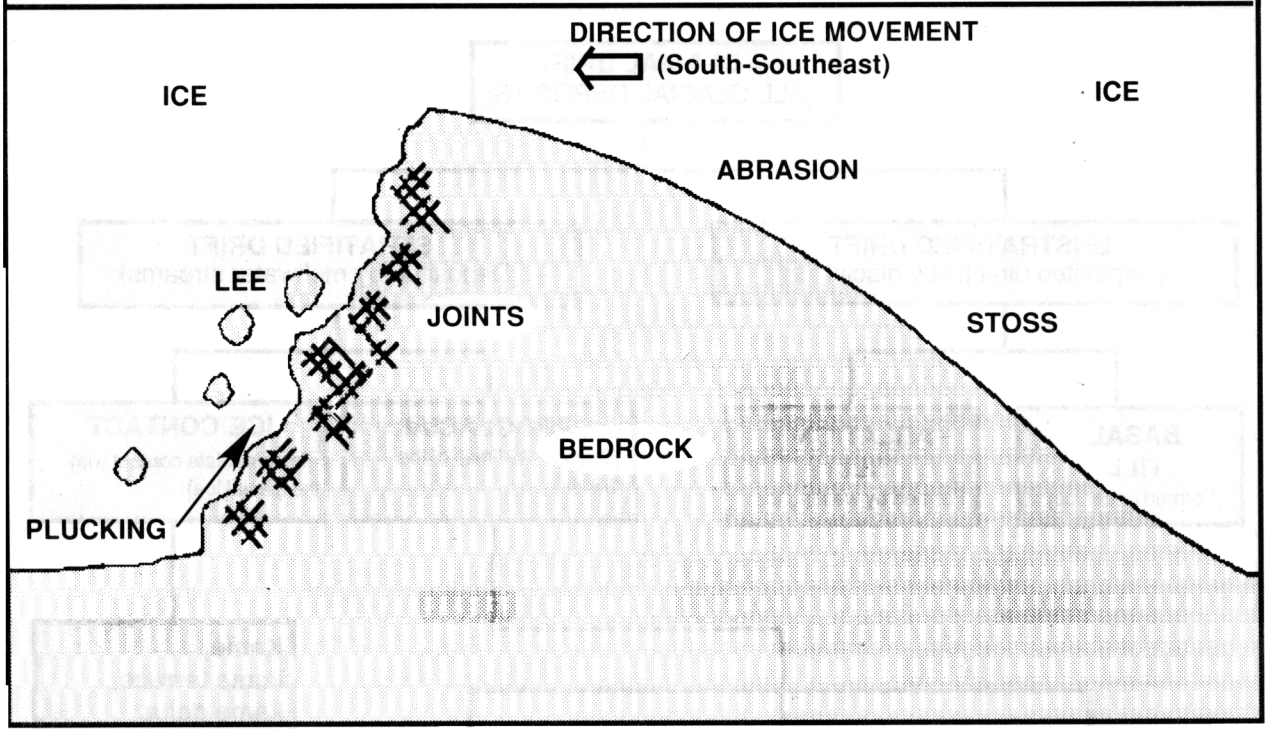
By 11,000 years ago, the ice had probably disappeared from even the northern part of New Hampshire. While highly advanced civilizations inhabited other, warmer parts of the earth, New Hampshire was just emerging from the Ice Age.

Large volumes of glacial meltwater raised sea levels worldwide, temporarily flooding a 10 to 50-mile wide band of the Coastal Lowlands. Glaciomarine silts and clays were deposited during this relatively short period of submergence before the land rebounded above sea level.

Many other types of glacial deposits were formed during the retreat and final downwasting of the ice sheet. Deposits such as end moraines, kames and kettles, kame terraces, kame deltas, crevasse fillings, and eskers were formed in contact with the ice. Proglacial deposits such as outwash plains, valley fill, and deltas were formed downstream of the ice margin. Glaciolacustrine sediments were deposited in large, ice-dammed lakes in the Connecticut, Merrimack, and Ashuelot River valleys. Lake, swamp, marsh, bog, and beach deposits and stream alluvium have formed since deglaciation.

Tundra vegetation became established very quickly in ice-free areas. Softwoods such as spruce and fir appeared 2,000 to 3,000 years after deglaciation. Pine followed, and hardwoods such as oak and hickory dominated later. Humans and other animals arrived soon after the

FIGURE 2 - 2 TYPICAL STOSS AND LEE TOPOGRAPHY



vegetation was established.

GLACIAL EROSION

Abrasion, or glacial scour, results from the friction between the debris carried at and near the base of the glacier and the underlying bedrock or other material over which the glacier flows. The results of this scour may be seen in many of the state's "notches", such as Crawford and Franconia Notches. The smooth, unweathered surface of the "stoss", or up-ice, slopes of many rock outcrops is further evidence of the erosive power of glacial ice. It is believed that the Laurentide ice sheet eroded the land surface an average of about 20 feet in New Hampshire.

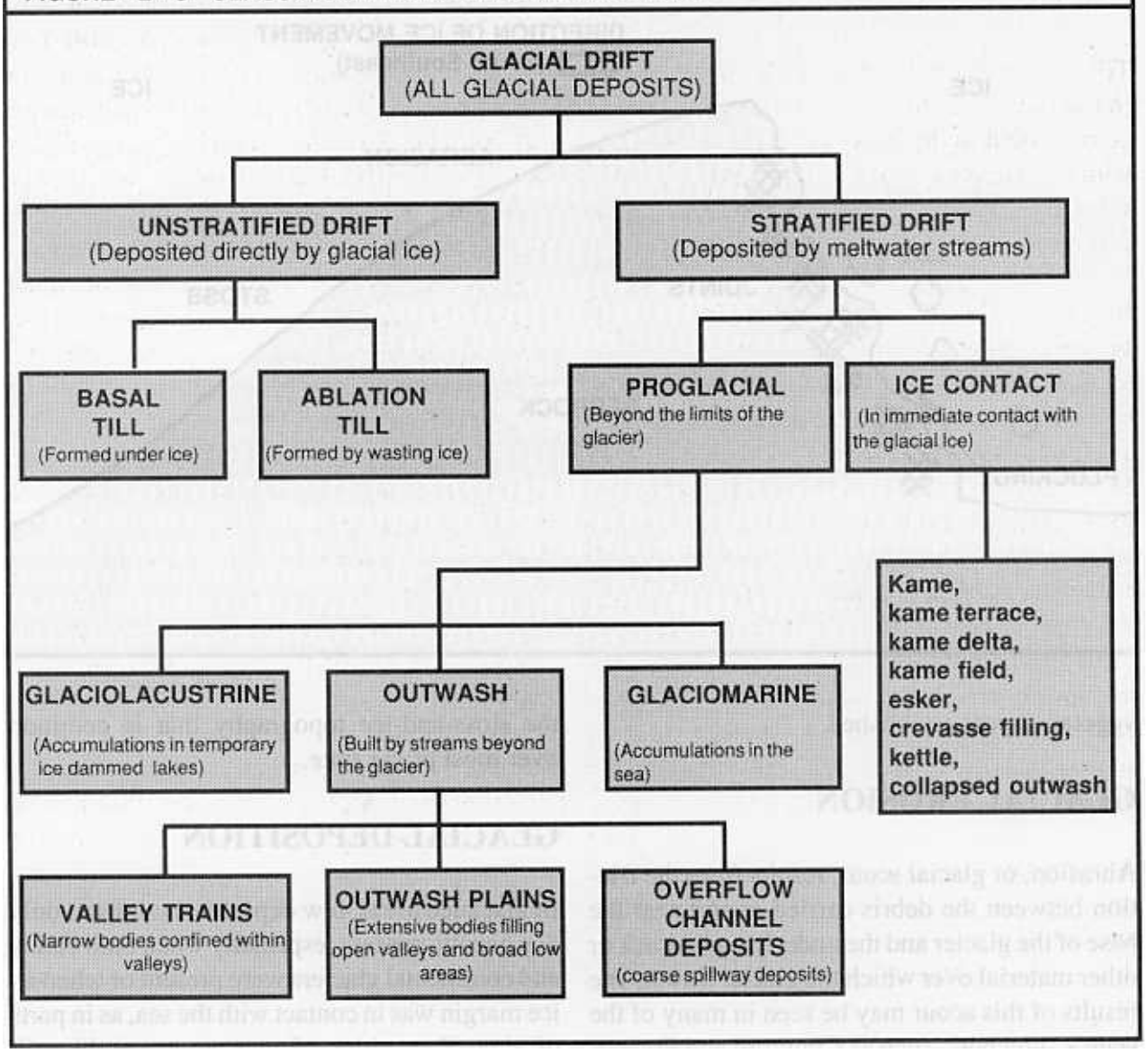
Plucking is the process by which the glacier quarries large blocks of jointed bedrock from the "lee", or down-ice, (southerly in New Hampshire) slopes of bedrock knobs. Unlike abraded surfaces, the bedrock surfaces resulting from plucking are typically angular and irregular, with significant relief. New Hampshire's logo, the "Old Man of the Mountain", is a spectacular example of glacial plucking. Figure 2-2 shows the stoss-and-lee topography that is common over most of the state.

GLACIAL DEPOSITION

In glaciated areas, few deposits result from only one genetic process, especially when both valley and continental glaciers were present or when an ice margin was in contact with the sea, as in parts of New Hampshire. Some processes, like till deposition, began perhaps 100,000 years ago and continued until 10,000 years ago. (Remember that the prefix "glacio" implies an age, as well as a process, to a particular deposit.) Other processes began 10,000 years ago and are still ongoing, like lacustrine sedimentation and beach and dune formation.

The broad, general term for all Pleistocene glacial deposits, regardless of grain (soil particle) size, which exist in deglaciated areas is "drift". Drift is further subdivided based on its degree of stratification. The unsorted, unstratified material deposited directly by or from the ice is known as "unstratified drift" or "till". Material deposited by meltwater streams flowing adjacent to or

FIGURE 2 - 3 CLASSIFICATION OF GLACIAL DEPOSITS



beyond the ice margin is known collectively as "stratified drift" since it is sorted and stratified to some degree by the fluvial transport process. Figure 2-3 diagrams the classification of glacial deposits in further detail.

Unstratified Drift (till)

Till is formed from ground-up rock debris which was carried and deposited directly by or underneath the glacier, without subsequent reworking by meltwater, into a compact, often unconsolidated mass of particles ranging widely in size, shape, and angularity. Its outstanding characteristic is that, by definition, it is neither sorted nor stratified.

In New Hampshire and adjacent states and provinces, till is by far the most widespread of all surficial deposits. Till covers about 85 percent of New Hampshire. It has been reported to average 14 feet thick in valleys and on slopes, and to exceed 200 feet in thickness in places. Till generally overlies bedrock and underlies other types of glacial deposits. The sequence of till overlying stratified drift is an exception, but it does occur in the complex glacial geology of New Hampshire. Till may occur as a sheet-like deposit with little topographic expression, such as ground moraine; or it may occur as linear or

streamlined forms, such as end moraines or drumlins.

Till may be deposited directly from the bottom (basal) layers of moving ice (basal till) or it may be deposited as the material on the surface and within the upper portion of the ice settles downward during melting or sublimation (ablation till).

Basal Till This till was deposited directly from the basal layers of a moving glacier upon bedrock or older glacial deposits. In New England, basal till usually is finer-grained (but not necessarily clay-rich), is more dense, and contains fewer large fragments than other tills. However, the cobbles and boulders are more abraded and less angular. Its high density has been explained both by the weight of overriding ice and by the moisture content at the time of placement. Permeability is low so this till is often a barrier to downward percolating water. Colors vary because of degree of weathering, composition of source rocks, and water table elevations, but are usually shades of brown or gray.

A particular type of basal till, known as lodgment till, has a very compact, fissile structure and contains cobbles or boulders oriented with their long axes generally parallel to the direction of ice movement. It generally overlies the bedrock surface.

Ablation Till Loosely consolidated rock debris, formerly in or on a glacier, that accumulated in place as the surface ice melted or sublimated is called ablation till. This is a sandy textured, moderately compact, and somewhat pervious till containing a large number of angular cobbles and boulders near or on its surface. It is typically some shade of brown and lighter in color than basal till.

Till Landforms Till deposits are nearly always found in landforms called moraines. Moraines are mounds, ridges, or other distinct accumulations of predominantly till which were deposited chiefly by direct action of glacial ice. Their topographic expression is varied and not controlled by the surface on which the drift lies. Moraines may contain basal till, ablation till, or glaciofluvial deposits. They may be interbedded with marine or lacustrine deposits. Many different types of moraines have been recognized. The more common are described below.

Ground moraine is an accumulation of either basal or ablation till which forms an extensive, sheet-like deposit. It lacks transverse linear elements and has generally low relief. Most New Hampshire till is ground moraine.

End moraines are ridge-like moraines deposited at the lower or outer margin of an actively flowing glacier at any given time. Those formed during glacial advance are nearly always overridden and destroyed, while those formed during glacial retreat (see recessional moraine) often remain, at least in part.

A terminal moraine is an end moraine that marks the farthest advance or maximum extent of a glacier or ice sheet. It forms at or near a more or less stationary edge, or at a place marking the cessation of an important glacial advance. Part of the terminal moraine of the Laurentide ice sheet forms Long Island, New York and Cape Cod, Massachusetts.

Recessional moraines are end or lateral moraines built during a temporary but general recession of the ice margin.

A lateral moraine is a low, ridge-like moraine carried on, or deposited at or near, the side margin of a mountain glacier. It is composed chiefly of rock fragments loosened from the valley walls by glacial abrasion and plucking, or fallen onto the ice from the bordering slopes.

Glacially streamlined till landforms are also found in New Hampshire. Oval, streamlined hills of glacial till that were deposited and shaped by an advancing ice sheet are called drumlins. They

resemble the inverted bowl of a teaspoon, with the long axis parallel to the direction of ice movement. In size, they are seldom over three-quarters of a mile long, a half-mile wide, and 150 feet in height. They are composed chiefly of basal till, but ablation till is sometimes found along their flanks.

Drumlinoids and drumloids are formed by the same process, but they are further and further removed, respectively, from the classic teaspoon shape and dimensions. Only a small percentage of New Hampshire's glacially streamlined landforms are true drumlins.

Stratified Drift

Deposits composed of sediment transported by meltwater streams which were flowing from wasting glacier ice are called "stratified drift". All such sediments have been sorted and stratified to various degrees as a result of the fluvial transport process. Those which accumulated in immediate contact with glacial ice to form distinct landforms are known as "ice-contact deposits". Sediments deposited beyond the downstream limits of the glacier are termed "proglacial" deposits.

The in-place strength and bearing capacity of stratified drift are highly variable and dependent in part on grain size. Ice-contact and outwash deposits are generally considered to be pervious to very pervious, but increasing silt and/or clay content reduces their permeability. The much finer grained glaciolacustrine and glaciomarine sediments are relatively less permeable, but not impervious.

Ice-contact Stratified Drift Ice-contact deposits typically are not well sorted or well stratified and often display an extreme range and frequent and abrupt changes in grain size. They occupy a considerably smaller part of our landscape than do the more extensive proglacial deposits of outwash plains, glacial lakes, and glacial-marine sediments. In places, ice-contact deposits may grade directly into proglacial deposits or till.

The processes of formation of the different, and often distinct, landforms associated with ice-contact deposits are outlined below. Also refer to Figure 2-4.

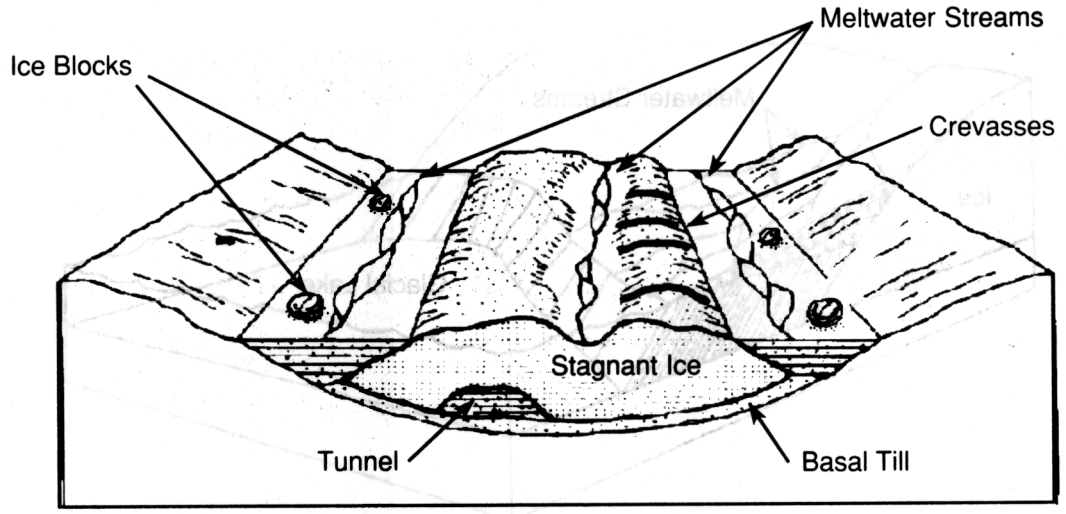
Depositional landscape features from ice-contact deposits include collapsed outwash, crevasse fillings, eskers, esker deltas, kames, kame deltas, kame fields, kame terraces, and kettles. When the ice melts out from beneath the accumulating sediment, or from a supporting position beside it, sagging, collapse, slumping, faulting, and earth flow may occur. The features also may be folded, faulted, and deformed as a result of overriding and pushing during glacial readvances. In some cases, these sediments are closely associated with till.

Ice-contact Landforms Collapsed outwash results from meltwater streams depositing outwash sand and gravel onto large areas of stagnant ice. The subsequent melting of the buried ice causes the surface of the outwash to collapse, leaving an irregular surface of low relief.

Crevasse fillings are short, linear ridges of stratified sand and gravel (elongated kames) deposited in crevasses of a wasting glacier and left standing after the ice melted. They may also occur as long sinuous ridges and linear complexes of till and stratified drift.

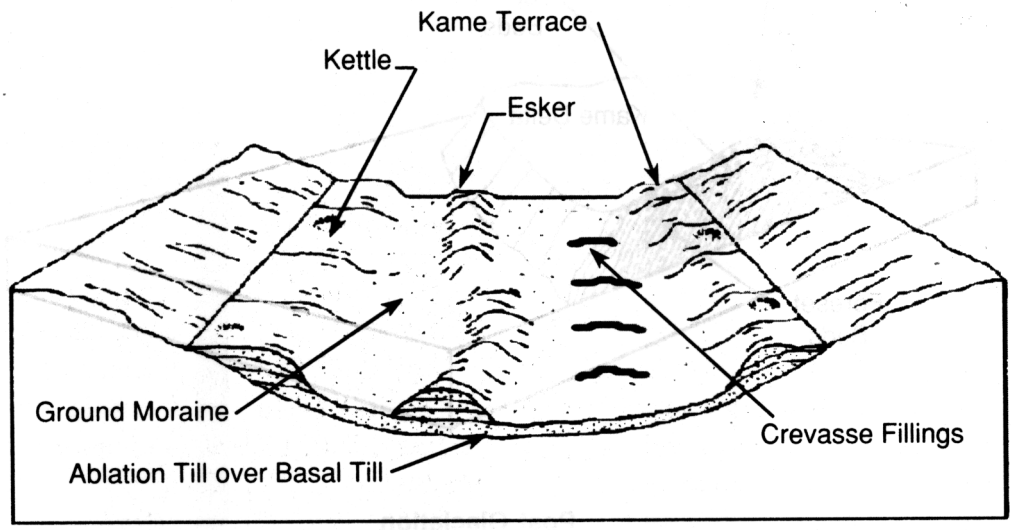
Eskers are long, narrow, sinuous, steep-sided ridges composed of irregularly stratified sand and gravel which are often associated with kames. The Pine River esker in Ossipee and Effingham is an example. It was formed by meltwater streams depositing coarse material within channels in or under a stagnant or retreating glacier and was left behind when the ice melted. Esker systems are commonly branching or discontinuous, and may range in length from a few hundred feet to several miles, and in height from 30 to 100 feet. Their course is usually at a high angle to the edge of the glacier.

FIGURE 2 - 4 GLACIAL ORIGINS OF U - SHAPED VALLEYS, GROUND MORAINE, KAME TERRACES, KAMES, KETTLES, ESKERS AND CREVASSE FILLINGS



U - shaped valley resulting from glacial scour

During Glacial Retreat



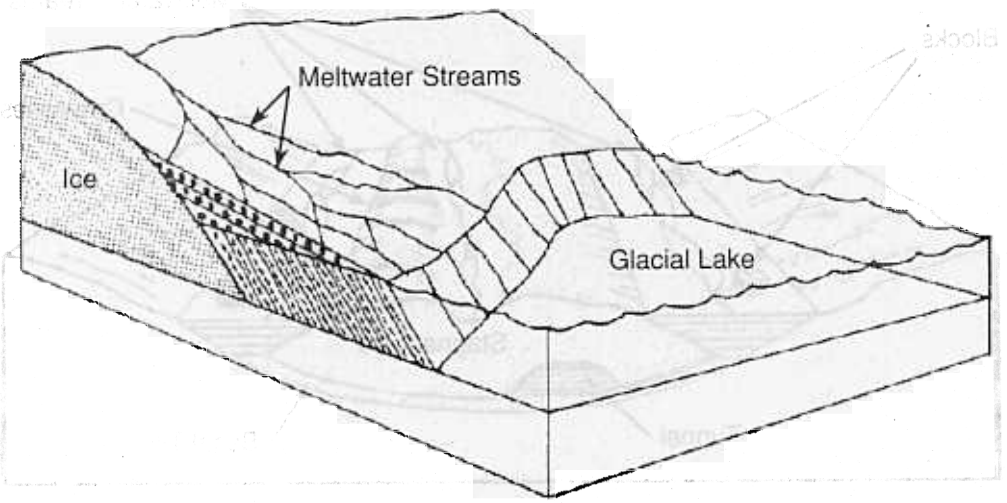
Post Glaciation

Esker deltas are flat-topped deposits of sand and gravel formed by a glacial stream at its mouth as it issued from an ice tunnel and flowed into standing water. They are associated with an esker made at the same time.

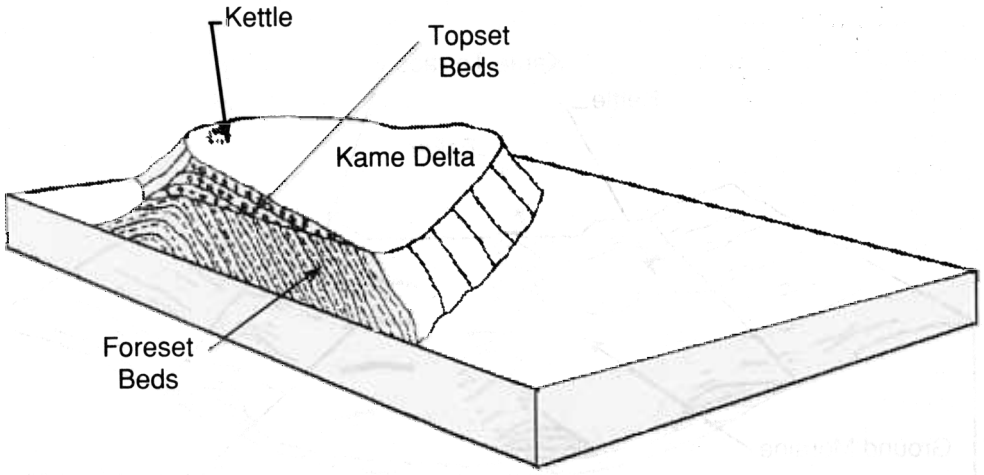
Kames are steep-sided mounds, knobs, hummocks, or short, irregular ridges of stratified sand and gravel deposited within depressions in the ice and left behind with subsequent melting.

Kame deltas are flat-topped, steep-sided deltas or fans of well-sorted sand and gravel deposited by a meltwater stream flowing into a proglacial or other ice-marginal lake. They were built outward from the ice front with the proximal (upstream) margin of the delta in contact with glacier ice. See Figure 2-5.

FIGURE 2 - 5 FORMATION OF A KAME DELTA



During Glacial Retreat



Post Glaciation

Kame fields are groups of closely spaced kames, interspersed in places with kettles and eskers. Their characteristic hummocky topography is a result of deposition of stratified material onto stagnant ice.

Kame moraines are end moraines which contain numerous kames.

Kame terraces are terrace-like ridges of stratified sand and gravel deposited by meltwater streams flowing between glacial ice and the valley wall and left after melting of the glacier. They are commonly pitted with kettles and have an irregular ice-contact slope. See Figure 2-4.

Kettles are circular depressions in meltwater deposits that are formed due to the melting out of buried ice blocks. When kettles occur in groups or in such large numbers that the stratified drift in

which they occur appears as a maze of hillocks and depressions, it is described as "kame-and-kettle topography".

Proglacial Stratified Drift Stratified drift deposited immediately in front of or just beyond the outer limits of a glacier or ice sheet is called a proglacial deposit. Such deposits were formed by a meltwater stream or settled from suspension in a body of quiet water adjoining the glacier. There are three kinds of proglacial deposits: outwash, glaciolacustrine deposits, and glaciomarine deposits. They accumulated respectively in streams, lakes, and the sea.

Proglacial deposits typically are well stratified and well sorted. The attitude of individual layers (beds) may vary from horizontal to steeply dipping, or they may exhibit cross-bedding. In other places the beds may be thick and uniform. Individual beds and deposits may run the gamut of grain sizes, including well-graded sands or gravels; various sand and gravel mixtures, some dirty, some clean; thin alternating layers of sand and silt; varved or laminated silts or clays; and massive clayey silts.

Outwash is a proglacial deposit, resulting from the combined action of glaciers and streams, which is washed out beyond the edge of wasting glacier ice. These deposits resemble those made by streams that are so heavily loaded they continually drop more sediment than they pick up. Variations in grain size are sharp and numerous both horizontally and vertically. The average grain size of outwash diminishes downstream, while the degree of roundness rapidly increases.

Outwash occurs in several distinct landforms depending on its mode of deposition.

Outwash fans are fan-shaped accumulations of outwash deposited by meltwater streams in front of an end moraine. The simplest landform taken by a mass of outwash is that of a single outwash fan resting against the terminus of a glacier with its apex at the point of emergence from the ice. More commonly the outwash mass consists of coalescent fans.

Outwash plains are broad, gently sloping sheets of outwash deposited by meltwater streams flowing in front of or beyond a glacier, and formed by coalescing outwash fans. See Figure 2-6.

Kettles are near-circular, steep-sided, usually basin- or bowl-shaped holes or depressions developed on outwash plains due to the melting of ice blocks which have been wholly or partially buried. They range in depth from a few feet to tens of feet, and in diameter to as much as a few miles. Kettles that intersect the water table form kettle hole lakes which are commonly without surface drainage. White Pond in Ossipee and Willand Pond in Somersworth are examples.

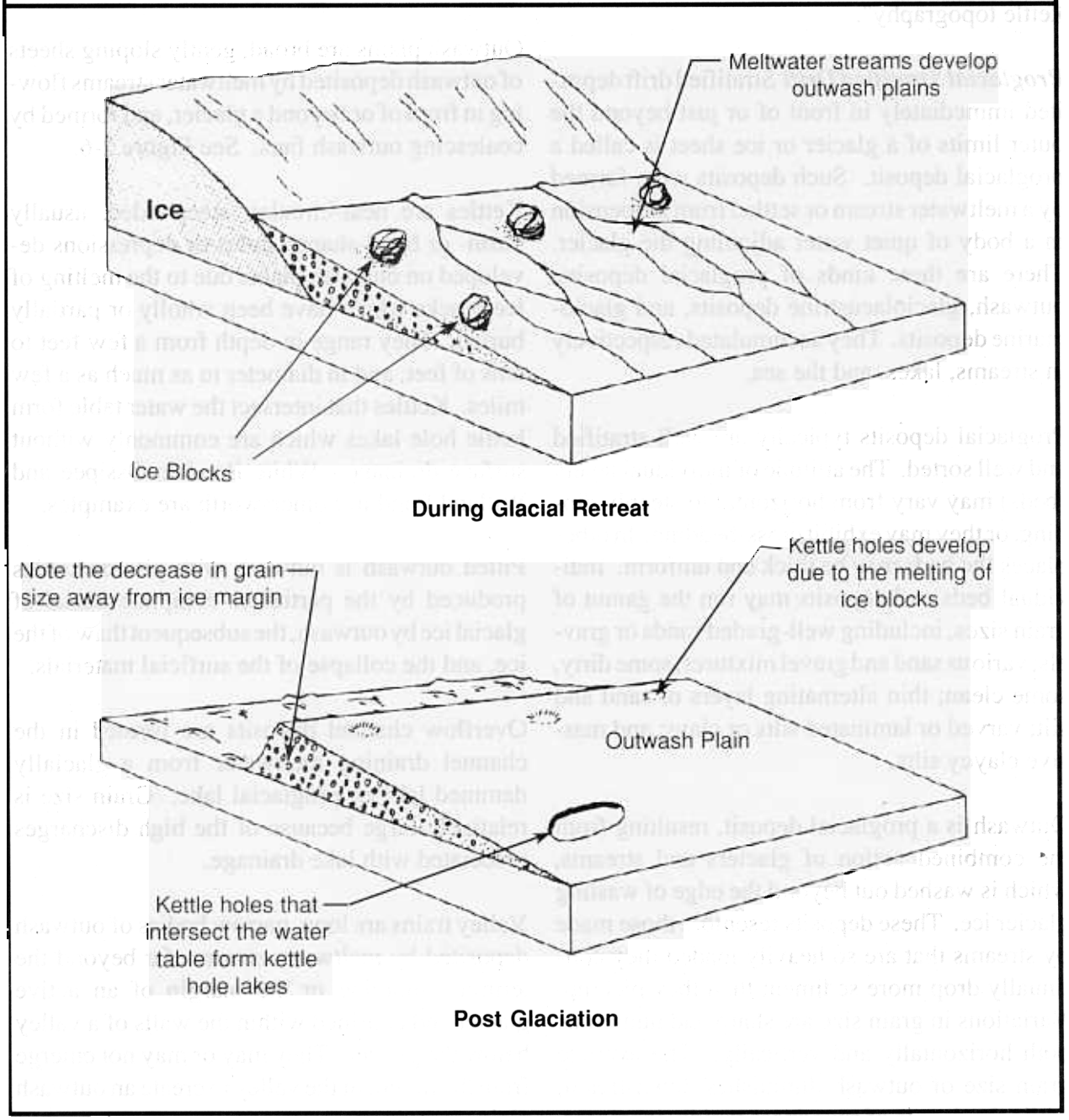
Pitted outwash is outwash with pits or kettles produced by the partial or complete burial of glacial ice by outwash, the subsequent thaw of the ice, and the collapse of the surficial materials.

Overflow channel deposits are formed in the channel draining meltwater from a glacially dammed lake or proglacial lake. Grain size is relatively large because of the high discharges associated with lake drainage.

Valley trains are long, narrow bodies of outwash deposited by meltwater streams far beyond the terminal moraine or the margin of an active glacier and confined within the walls of a valley below the glacier. They may or may not emerge from the mouth of the valley to create an outwash plain.

Glaciolacustrine deposits are a type of proglacial stratified drift which accumulated in temporary glacial lake basins. In some basins, thick deposits of well-sorted silt and clay particles settled out in very quiet water to form thin alternating bands of silt and clay called "varved" sediments. Other glaciolacustrine deposits include thin or thick, alternating layers of well-sorted silts and clayey silts, silts and fine sand, and occasionally strati-

FIGURE 2 - 6 DEVELOPMENT OF OUTWASH PLAINS BY PROGLACIAL MELTWATER STREAMS



fied sands and gravels.

Glaciomarine sediments are another type of proglacial stratified drift. These were deposited as rising seas flooded coastal lowlands, not only to our present seashore, but 10 to 50 miles inland over what is now southeastern New Hampshire. These deposits are locally, but incorrectly, referred to as "blue clay." They are stiff and quite plastic, but unlike varved glaciolacustrine deposits, they are actually massive clayey silt deposits. Varves do not form because sea water, an electrolyte, causes the clay in suspension to flocculate and settle along with the silt.

POST-GLACIAL EROSION

Following the disappearance of the ice and the accumulation of meltwater deposits, streams have

been dissecting the upland slopes and clearing the proglacial drift from the valley bottoms. The vertical and lateral erosion by the major rivers in New Hampshire have transported large volumes of sediment to the Atlantic Ocean and Long Island Sound.

POST-GLACIAL DEPOSITION

Recent deposition consists primarily of organic materials deposited in wetlands and of mineral materials deposited by water, wind, and gravity. These materials continue to be deposited to some degree during contemporary time.

Organic Deposits

Bogs These are areas of waterlogged, spongy ground, consisting of mosses, and often with unique plants which contain acidic, decaying vegetation that may develop into peat.

Marshes Water-saturated, poorly drained areas which are intermittently or permanently water-covered and have aquatic and grasslike vegetation, are called marshes.

Swamps These areas of low, waterlogged ground which have shrubs and trees formed in organic or mineral soils are swamps.

Alluvial Deposits

Deposits made by flowing water during Recent (or Holocene) time are called recent alluvial deposits. They occur in several different forms.

Alluvial Fans These are low, outspread, relatively flat to gently sloping masses of loose rock and soil which are shaped like an open fan or segment of a cone. They are deposited by a stream where it issues from a narrow mountain valley upon a plain or broad valley, and may also form at or near where a tributary joins a main stream, and where a constricted valley widens or its gradient suddenly decreases. Alluvial fans are steepest near the mouth of the valley where the apex points upstream. Their slope decreases gradually away from the apex.

Colluvium - This is a general term applied to any loose, heterogeneous, and incoherent mass of soil material and/or rock fragments deposited by unconcentrated runoff or sheet erosion, usually at the base of a slope.

Flood Plain Alluvium Sandy to clayey sediment deposited by river water that was spread out over a flood plain is called alluvium. The sediment is thicker and coarser near the river than toward the valley slopes.

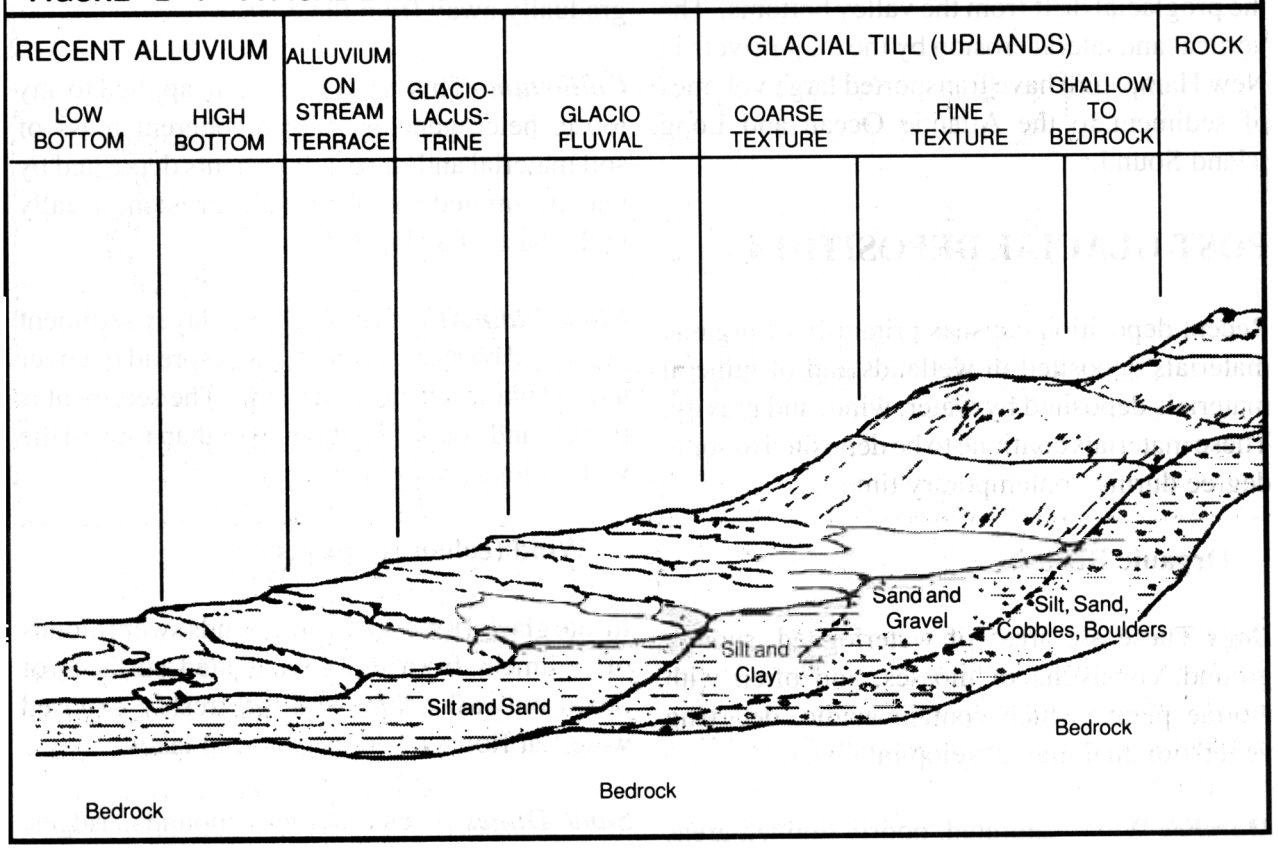
Wind (eolian) Deposits

In late glacial time, gale force winds swept clouds of sediment from the unvegetated surfaces of broad outwash plains and the freshly exposed wide flat floors of drained glacial lakes.

Sand Dunes These are low mounds, ridges, banks, or hills of loose, windblown granular material, either bare or covered with vegetation, which are capable of movement from place to place, but always retain their characteristic shape. Late glacial dunes often cannot be readily distinguished from low, sandy kames by their external form, but the uniform coarseness of the sand particles identify them as windblown. These are very minor and insignificant features on the landscape. Dunes also are found landward of the sand beaches along the present day coastline.

Loess Where sediments were predominantly silt and very fine sand, glacial winds picked up this material and deposited it downwind as a homogeneous fine-grained blanket called "loess". It is commonly nonstratified, porous, friable, slightly coherent, and without surface expression. In the Connecticut River valley, this deposit is only a foot or two thick and limited to valley bottoms and adjacent slopes.

FIGURE 2 - 7 TYPICAL LANDSCAPE SHOWING THE RELATIONSHIP TO PARENT MATERIAL



Gravity Deposits

Rock falls, topples, slides, and avalanches are more commonly found in the more mountainous areas of the state. Earth flows, slumps, and lateral spreads are not restricted geographically, but are more likely to occur in weaker materials such as glaciolacustrine and glaciomarine sediments. These slope failures occur rapidly.

In contrast, the slow, more or less continuous downslope movement of mineral, rock, and soil particles is know as creep.

Figure 2-7 shows the relationship of various geologic materials to the landscape.

ORIGIN AND NATURE OF SOIL

3

Soil has different meanings to different people. To many engineers, it is all earthen material above bedrock. The farmer considers soil as a habitat for plants, whereas the homeowner looks at soil as a support for a house and a medium for growing a lawn. To the soil scientist, soil is the collection of earthy materials on the surface of the planet that contains living matter and supports or is capable of supporting plants. In most instances, this collection of earthy materials called soil is derived from natural soil-forming processes. In places, however, these earthy materials have been partially modified or are entirely a result of human activities. Generally, the soil scientist's definition of soil applies to the upper 65 inches of the earth's surface.

SOIL FORMATION

Properties of soil vary greatly from place to place, depending upon the interactions of the five soil-forming factors. Each soil is a unique collection of earthy materials with a distinct morphology from a unique combination of climate, plant and animal life, parent materials, topography, and time. The morphology of each soil, as observed by a vertical section through the different layers or horizons, reflects the combined effects of the soil-forming factors responsible for its development.

The factors of soil formation are so closely interrelated that few generalizations can be made about the effects of only one. The relative influence of each factor differs from place to place, and each modifies the effect of the other four.

In New Hampshire, the five soil-forming factors have been active in specific ways. The characteristics and properties of a soil at any given place in the state are determined by:

- The physical, chemical, and mineralogical composition of the parent material
- The climate under which the soil material has accumulated and existed since accumulation
- The plant and animal life on and in the soil, including dead organisms, organic debris, and waste products
- The topography, relief, or lay of the land
- The length of time the forces of soil development have acted on the soil material

FIGURE 3 - 1 ONE OF MANY NEW HAMPSHIRE SOILS

One of the many New Hampshire soils is shown in Figure 3-1.

Parent Material

Parent material is the mineral or organic material from which a soil is formed. In New Hampshire, most parent material was deposited by glaciers or is glacial material that has been reworked and redeposited as a result of the forces of wind and water.

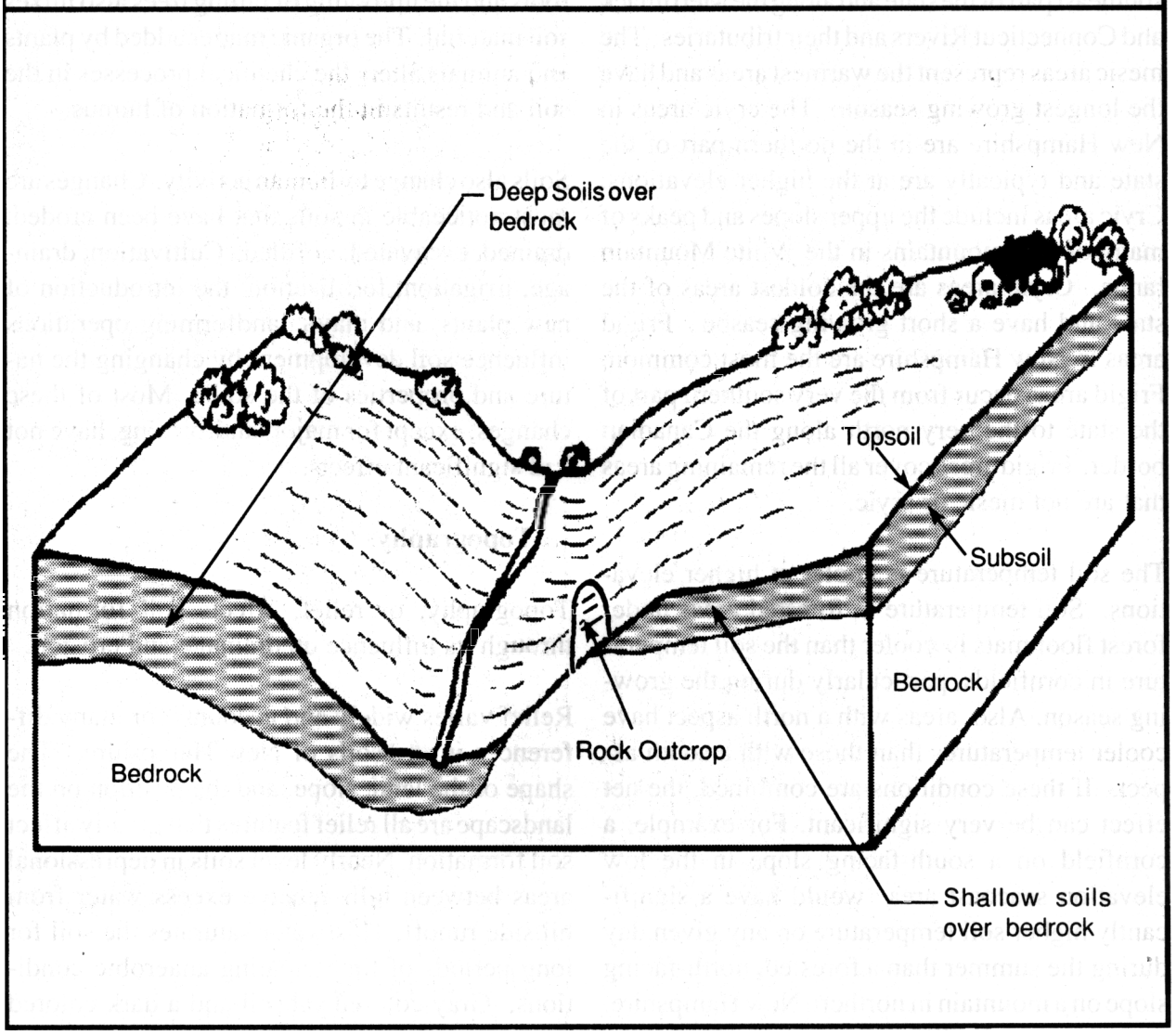
Eight different kinds of natural parent materials have been documented as existing in New Hampshire. They are alluvium, glacial outwash, glaciolacustrine deposits, glaciomarine deposits, glacial till, weathered bedrock, eolian, and organic materials. Another type of material existing in New Hampshire is fill from human activities. Figure 3-2 shows typical soil materials above bedrock.

The approximate proportions of parent materials existing in New Hampshire are: glacial till 85 percent, glacial outwash 8 percent, organic material 4 percent, alluvium 2 percent, and glaciolacustrine, glaciomarine deposits and weathered bedrock each less than 1 percent. Eolian sediments are recognized in New Hampshire, but have not been officially mapped by the National Cooperative Soil Survey.

Climate

Climate affects the physical, chemical, and biological properties of a soil, primarily through the

FIGURE 3 - 2 SOIL MATERIALS ABOVE BEDROCK



influence of precipitation and temperature.

Water from precipitation supports biological activity and dissolves and transports minerals and organic residues down through the soil. It influences the weathering of rocks and minerals and the removal and deposition of material. The amount of water that moves through the soil is determined by the amount of precipitation, the relative humidity, and the temperature. The degree of slope, the rate of infiltration, and the permeability of the soil are also factors.

Temperature influences the kinds and amounts of plants and the kinds of animals and their activities. Temperature also affects the rate of chemical and physical processes that are part of weathering and soil formation.

The cool, humid climate of New Hampshire provides conditions for leaching of readily soluble bases out of the soil, making most soils acid in reaction. Chemical weathering proceeds at a very slow rate during the winter months, but physical weathering continues in the form of alternate freezing and thawing.

Although the climate is cool and humid overall, there is variation within the state such as vegetative cover, elevation, aspect, and latitude that influence the soil temperature. Soil temperature regimes are mesic, frigid, and cryic.

The mesic areas in New Hampshire are in the southeast part of the state and along the Merrimack and Connecticut Rivers and their tributaries. The mesic areas represent the warmest areas and have the longest growing season. The cryic areas in New Hampshire are in the northern part of the state and typically are at the higher elevations. Cryic areas include the upper slopes and peaks of many of the mountains in the White Mountain range. Cryic areas are the coldest areas of the state and have a short growing season. Frigid areas in New Hampshire are the most common. Frigid areas occur from the very southern part of the state to the very north along the Canadian border. Frigid areas cover all the remaining areas that are not mesic or cryic.

The soil temperature is cooler at higher elevations. Soil temperature in forested areas under forest floor mats is cooler than the soil temperature in cornfields, particularly during the growing season. Also, areas with a north aspect have cooler temperatures than those with a south aspect. If these conditions are combined, the net effect can be very significant. For example, a cornfield on a south-facing slope in the low elevation seacoast area would have a significantly higher soil temperature on any given day during the summer than a forested, north-facing slope on a mountain in northern New Hampshire. Soils will be quite different at these two locations because of their climatic differences.

Plant and Animal Life

The native vegetation in New Hampshire is mostly forests of either hardwood trees, coniferous trees, or a mixture of both. Most of the soils formed under this type of vegetation.

Earthworms, insects, and small animals mix soil material and add organic matter. Bacteria, fungi, and other microorganisms break down plant and animal residues. Trees and other plants bring plant nutrients from the lower part of the soil to the upper layers, add organic matter, provide protective cover that retards the erosion process, and influence soil temperature. Channeling by roots and the uprooting of falling trees also mixes soil material. The organic matter added by plants and animals alters the chemical processes in the soil and results in the formation of humus.

Soils also change by human activity. Changes are most noticeable in soils that have been eroded, drained, excavated, or filled. Cultivation, drainage, irrigation, fertilization, the introduction of new plants, and major landforming operations influence soil development by changing the nature and properties of the soils. Most of these changes, except for major landforming, have not had significant effects.

Topography

Topography, or relief, affects soil formation through its influence on drainage and erosion.

Relief varies widely and accounts for many differences in the soils of New Hampshire. The shape of the land, slope, and the position on the landscape are all relief features that greatly affect soil formation. Nearly level soils in depressional areas between hills receive excess water from hillside runoff. This water saturates the soil for long periods of time creating anaerobic conditions. Gray colored subsoil and a dark colored organic enriched surface layer result from these conditions. Gently sloping and strongly sloping areas on the sides and crests of hills where water runs off or infiltrates into the soil, generally produce unsaturated soil conditions. An aerobic state produces yellowish brown and reddish brown colors in the subsoil. Some steep soils show little development because geologic erosion proceeds almost as fast as the formation of the soil.

Time

Time is an important factor in soil formation. Generally, the soils in New Hampshire have developed since the last ice sheet started melting in the southern part of the state about 14,000 years ago. This exposed the soils to the other four

FIGURE 3 - 3 SOIL HORIZONS

soil-forming factors. The last glacial ice melted in the northern part of the state about 11,000 years ago.

Whether or not a mature soil develops in this length of time is determined by all the other major factors of soil formation. For example, if the slope is steep and the geologic erosion rate is rapid, the soil will be immature. Also, some alluvial soils are immature because of the continual accumulation of floodplain sediments.

A soil is generally said to be mature when it has acquired well developed characteristics. These soils have distinct layers and the soil aggregates (groups of particles) in them have a definite arrangement in relation to each other.

SOIL HORIZONS AND PROFILES

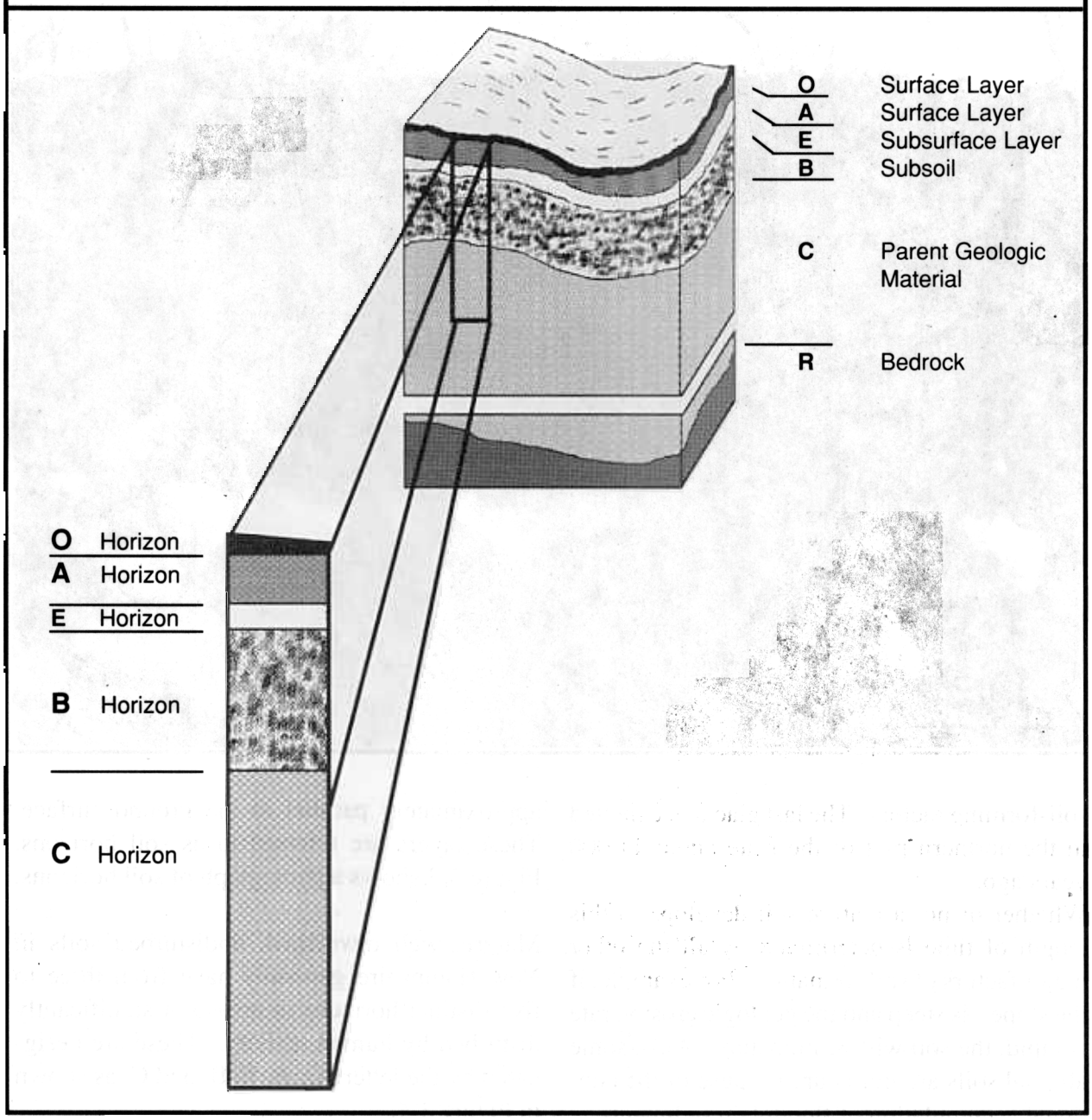
As the parent material is altered by the four other factors, different layers are formed that are approximately parallel to the ground surface. These layers are referred to as soil horizons. Figure 3-3 shows a photograph of soil horizons.

Mature, well developed, undisturbed soils in New Hampshire generally have from three to five distinct horizons in areas not significantly disturbed by human activity. These are designated by the letters O, A, E, B, and C as shown in Figure 3-4.

The O horizon is a dark organic surface layer composed mostly of plant material in various stages of decay. This layer is commonly 2 to 5 inches thick and is often referred to as the forest floor mat.

The A horizon commonly includes the surface layer of the soil. Usually it is the original top layer or a plowed layer. This layer is 2 to 10 inches thick in most places. This horizon also is commonly referred to as topsoil or surface soil.

FIGURE 3 - 4 MAJOR SOIL HORIZONS



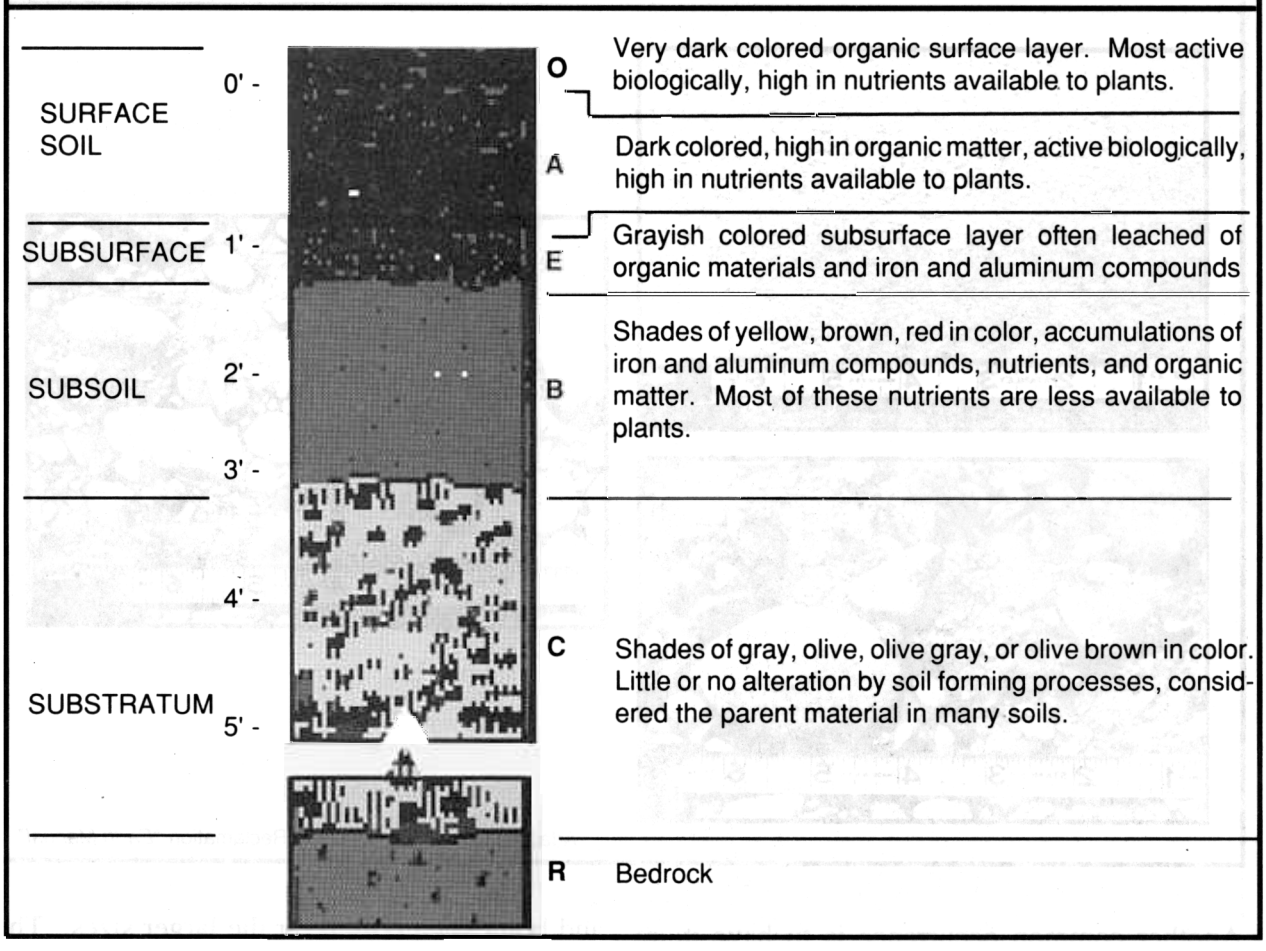
The E horizon is a grayish colored subsurface horizon. It occurs below an O or A horizon and is often discontinuous across a landscape.

The B horizon, or the subsoil, is a zone of accumulation of nutrients and organic matter that have moved down from the A horizon. This layer is generally 10 to 30 inches thick, but varies considerably from this range in many areas.

The C horizon, or substratum, lies below the subsoil and is commonly the parent material from which the A and B horizons formed. This horizon is little affected by soil-forming processes.

A soil profile is the sequence of horizons extending from the surface down into the parent material (to a depth of 65 inches for soil science purposes) or bedrock, whichever is shallower. Figure 3-5 is a hypothetical soil profile illustrating the major soil horizons in a New Hampshire soil. Characteristics for each horizon, include depth, color, texture, structure, consistence, and roots. All of these characteristics collectively

FIGURE 3 - 5 HYPOTHETICAL SOIL PROFILE



comprise the soil profile.

COMPOSITION OF THE SOIL

Solid particles make up approximately 50 percent of a sample of an average soil. The remaining 50 percent is pores (voids), which are filled with air and water.

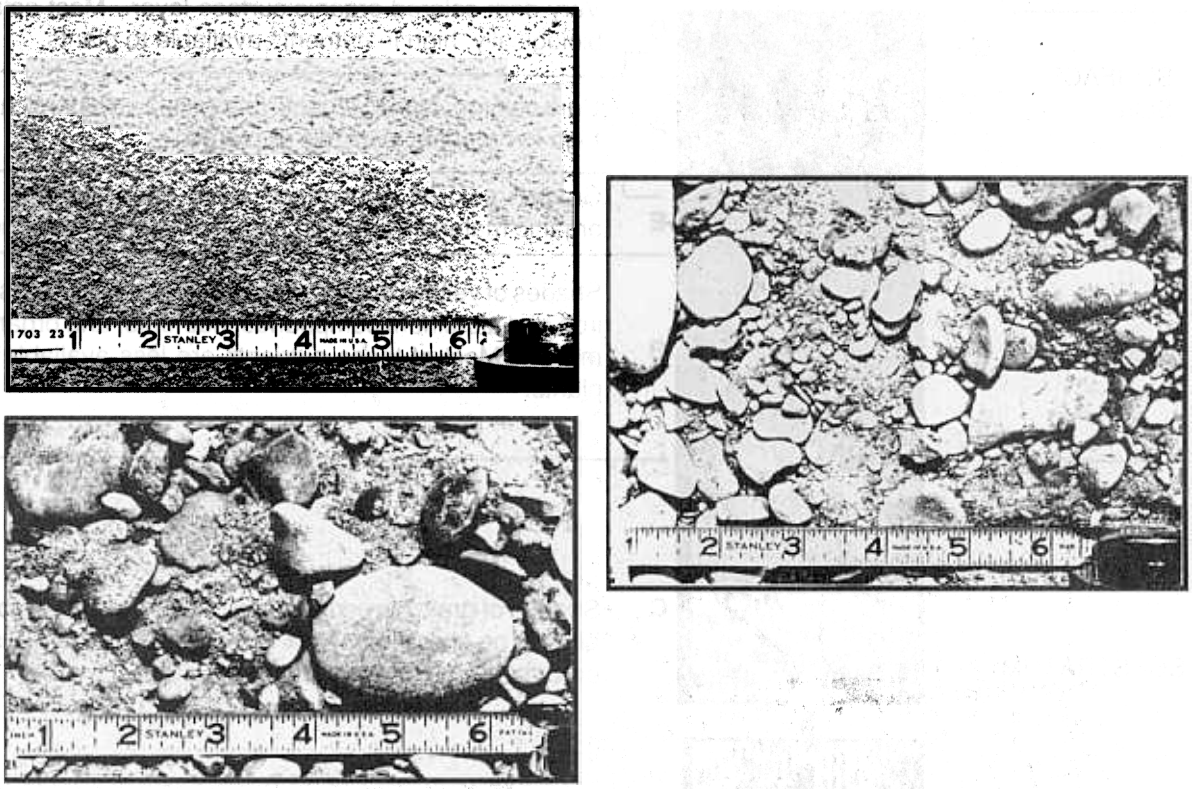
The solid half of soil is made up of mineral particles and organic particles. These solid particles occur in varying proportions, depending on the soil horizon from which they are obtained and the soil. In general, New Hampshire soils have up to 50 percent organic particles in the A horizon, decreasing to near 0 percent in the lower C horizon. Conversely, mineral particles constitute about 45 percent of an A horizon sample and about 100 percent of a C horizon sample.

The role and composition of the mineral particles in soil are radically different from that of organic particles. The mineral particles in a soil are composed of a wide variety of complex minerals such as feldspars, micas, hematites, quartz, etc.

These mineral particles vary considerably in size. The size is dependent on the resistivity of the individual minerals to weathering and the size of the individual mineral crystals in the parent rock.

Basically, the composition is the same as the bedrock from which the particles were weathered. In New Hampshire, the mineralogy of the soil may be quite different than the underlying bedrock. This is because glaciation has transported the soil material many miles from its bedrock source. In some cases, the source bedrock from which the soil weathered is miles away. Glacial mixing may have caused the mineral particles to be from several different parent bedrock formations.

FIGURE 3 - 6 VARIOUS KINDS OF SOIL TEXTURES



Adapted from USDI Bureau of Reclamation *"Earth Manual"*

Another common occurrence is to have more than one type of parent material in the soil overlying bedrock. There may be glacial outwash overlying glacial till. In this situation, the mineralogy of the outwash may be quite different than the till.

The size of the mineral particles in a soil can range from that of a single molecule up to the largest boulder. Physical and chemical properties vary significantly within this range of mineral particle sizes.

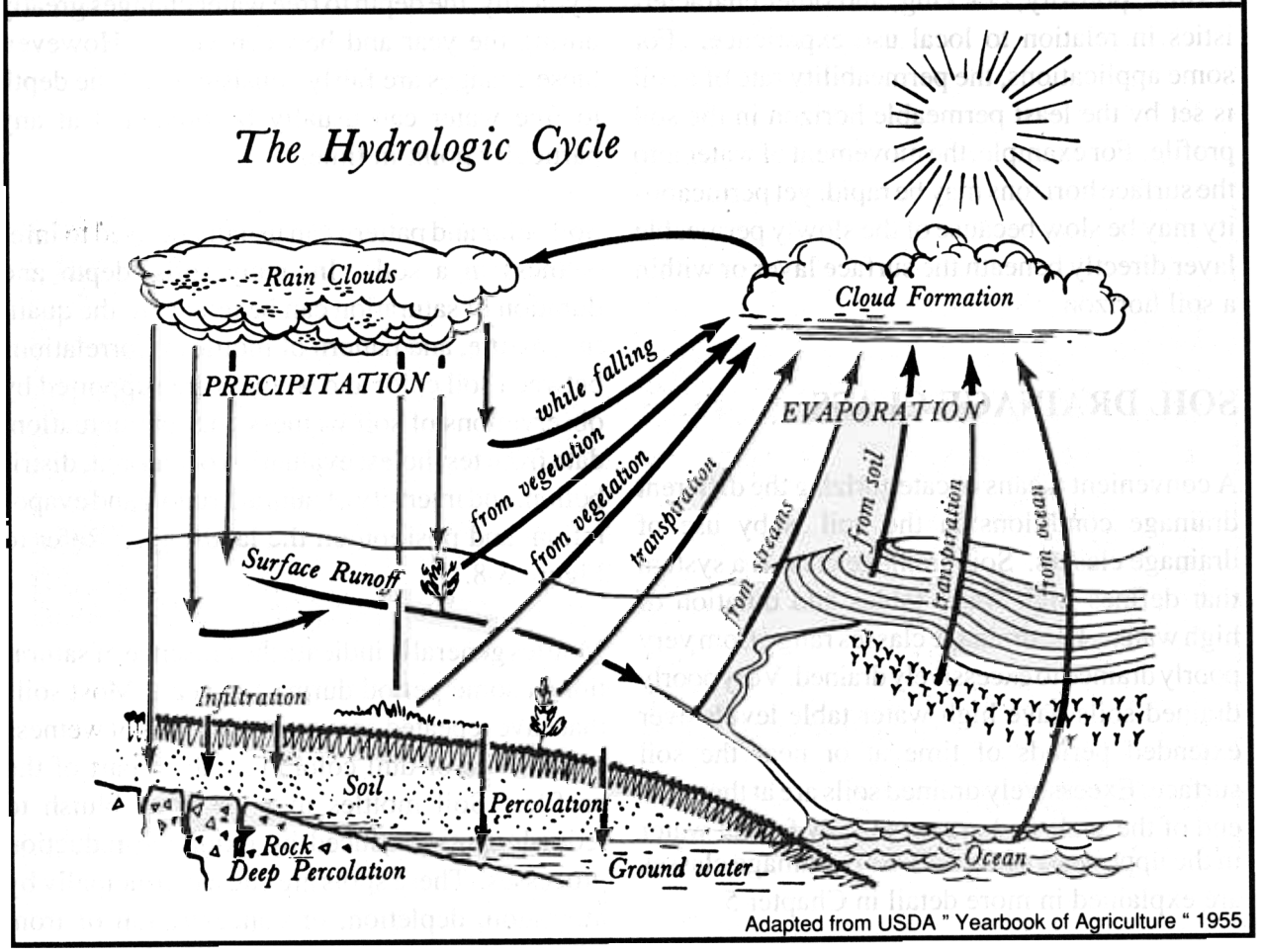
SOIL TEXTURE

Soil texture refers to the relative proportions of particles (soil grains) of various sizes in a given soil. Since soils are composed of particles varying greatly in size and shape, specific terms are used to conveniently describe each separate (group of particle sizes). Gravel, cobblestones, stones, and boulders are used for the larger sizes. The smaller mineral soil particles are termed sand, silt, and clay according to size from largest to smallest. Figure 3-6 shows soils of various textures.

Sand and gravel particles are visible with the naked eye and they do not stick together well. The pore spaces between the sand particles are usually large and continuous. They have a low capacity to retain water, are a poor source of nutrients, and are chemically unreactive.

The term clay is used to describe the finest particle sizes. Clay particles are so small that they cannot be seen without a microscope. The pore spaces between the clay particles are very small and frequently are blind pockets. Clay is able to absorb considerable quantities of water, but at a much slower rate than silt. Also, when wet, clay has a tendency to swell. Another property of clay (and not sand or gravel) is plasticity. This means clay can be molded into

FIGURE 3 - 7 WATER CYCLE AND SOIL DRAINAGE



Adapted from USDA " Yearbook of Agriculture " 1955

shapes when wet and the shape and strength is retained when the water evaporates.

Silt is the term used to describe intermediate particle sizes. Silt particles are between sand and clay in size and in their properties. Silt is able to absorb considerable quantities of water without swelling (as does clay). Silt is a good source of nutrients for plants and is chemically reactive. Silt may have low plasticity.

DRAINAGE

Drainage refers to the rapidity and extent of the removal of water by surface runoff and by flow through the soil to underground spaces. Soil drainage, as a condition of the soil, refers to the unsaturated condition in the upper part of the soil. Surface runoff, or external soil drainage, refers to the relative rate at which water is removed by flow over the surface of the soil. This includes rainwater and water from snowmelt. Runoff is determined mainly by the type of soil, slope, climate, and the type of cover on the surface of the soil. Figure 3-7 shows the water cycle and soil drainage.

Internal drainage is the quality that permits the downward flow of excess water through the soil. It is determined by the texture, the structure of the soil, and by the height of the water table.

Permeability is the quality of a soil that enables it to transmit water or air. It is one of several factors that control how fast water is removed by flow through the soil. In the absence of actual measurements, soils can be placed into relative

permeability classes through studies of structure, texture, porosity, cracking, and other characteristics in relation to local use experience. For some applications, the permeability rate of a soil is set by the least permeable horizon in the soil profile. For example, the movement of water into the surface horizons may be rapid; yet permeability may be slow because of the slowly permeable layer directly beneath the surface layer or within a soil horizon.

SOIL DRAINAGE CLASS

A convenient means of categorizing the different drainage conditions in the soil is by use of drainage classes. Soil drainage class is a system that defines high water tables and duration of high water. The drainage classes range from very poorly drained to excessively drained. Very poorly drained soils have high water table levels over extended periods of time at or near the soil surface. Excessively drained soils are at the other end of the scale and are essentially free of water in the upper part of the soil. Soil drainage classes are explained in more detail in Chapter 5.

SOIL MOISTURE

Soil moisture relationships are important in evaluating behavior and in understanding soil development. Soil moisture is influenced by climate, slope, and landscape position as well as by properties of the soil. Precipitation, runoff, amount of water entering the soil, and rate of water movement through the soil affect the degree and duration of wetness. Precipitation, plant roots, temperature gradients, evaporation, and transpiration cause the soil moisture conditions to constantly change. They may change significantly in a few hours or more. They may change so slowly that they appear to be constant.

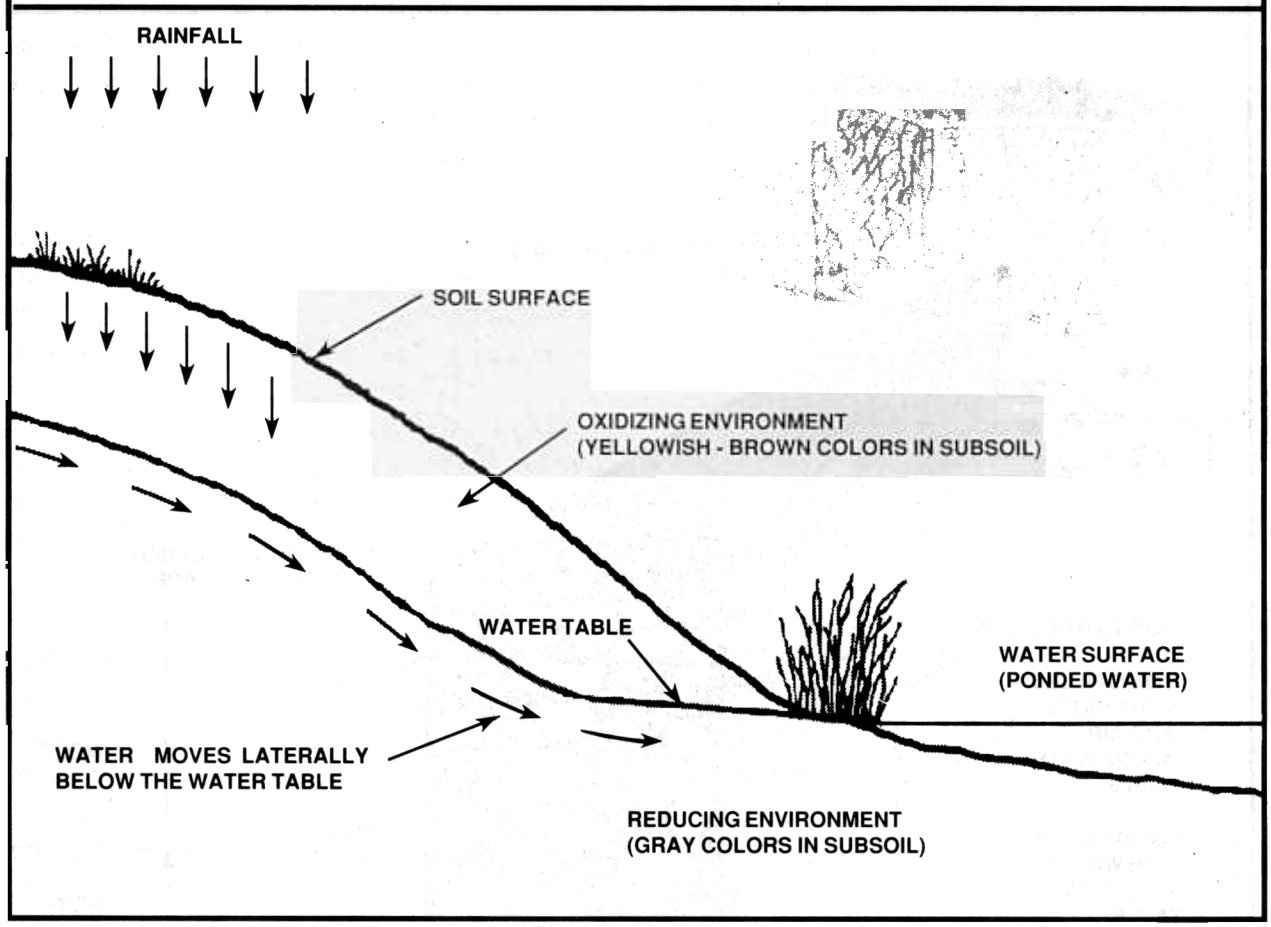
Knowledge of the times and depths at which a soil is dry, moist, or wet is important in using and understanding the soil. Free water exerts a strong influence on biological and chemical processes. Typically, the depth to free water changes greatly during the year and between years. However, these changes are fairly consistent and the depth to free water can usually be predicted at any particular point in time.

Soil color and pattern can usually be used to infer wetness in a soil. In many soils, depth and duration of saturation can be related to the quantity, nature, and pattern of mottles. Correlations between soil color and wetness are supported by observations of soil wetness and its fluctuation; data from test holes; evaluation of amount, distribution, and intensity of rainfall, runoff and evaporation, and position on the landscape. Refer to Figure 3-8.

Mottles generally indicate the presence of saturation at some period during the year. Most soils that have repeated or extended periods of wetness are mottled or dull colored in all or part of the profile. Soil mottles may be gray, bluish to reddish spots produced by oxidation-reduction processes. These spots are caused principally by migration, depletion, or concentration of iron. When soil is saturated with water in the presence of organic matter, strong reducing conditions can exist. Iron reduction produces bluish colors and migration of reduced iron leaves gray zones. After reduced iron reaches a zone having a higher oxygen content, such as along root channels or other large pores connected with an aerated layer, the iron oxidizes and turns reddish. Red, iron-rich domains may also form as the soil dries. Moisture conditions in a soil or soil layer are described by the terms wet, moist, and dry. A soil is wet when it is completely saturated with water, all the pores are filled with water, and generally water is free to move downward under the force of gravity or into an excavated hole. These moisture conditions usually occur below the depth of the water table. A sample of wet soil, when squeezed, will usually result in water running out of the sample. Refer to figure 3-9.

A soil is moist when it is partially saturated with

FIGURE 3 - 8 RELATIONSHIP OF SLOPE, SOIL COLOR, AND DRAINAGE



water, not all of the pores are filled with water, and water does not move downward under the force of gravity or into an excavated hole. This moisture condition usually occurs above the depth of the water table. A sample of moist soil, when squeezed, will usually form a ball (if not too sandy) with no water flowing out.

A soil is dry when none of the pores are filled with water. The only water in the soil exists as a thin film around the individual soil particles. Plants growing in a soil under this condition show signs of lack of moisture, usually by wilting. A sample of dry soil will be dusty when exposed to a puff of air. Also, in sandy soils, the individual sand grains will usually not adhere to each other. Dry soil conditions are not common in vegetated soils in New Hampshire, but can be observed in gravel and sand pits and on coastal beaches.

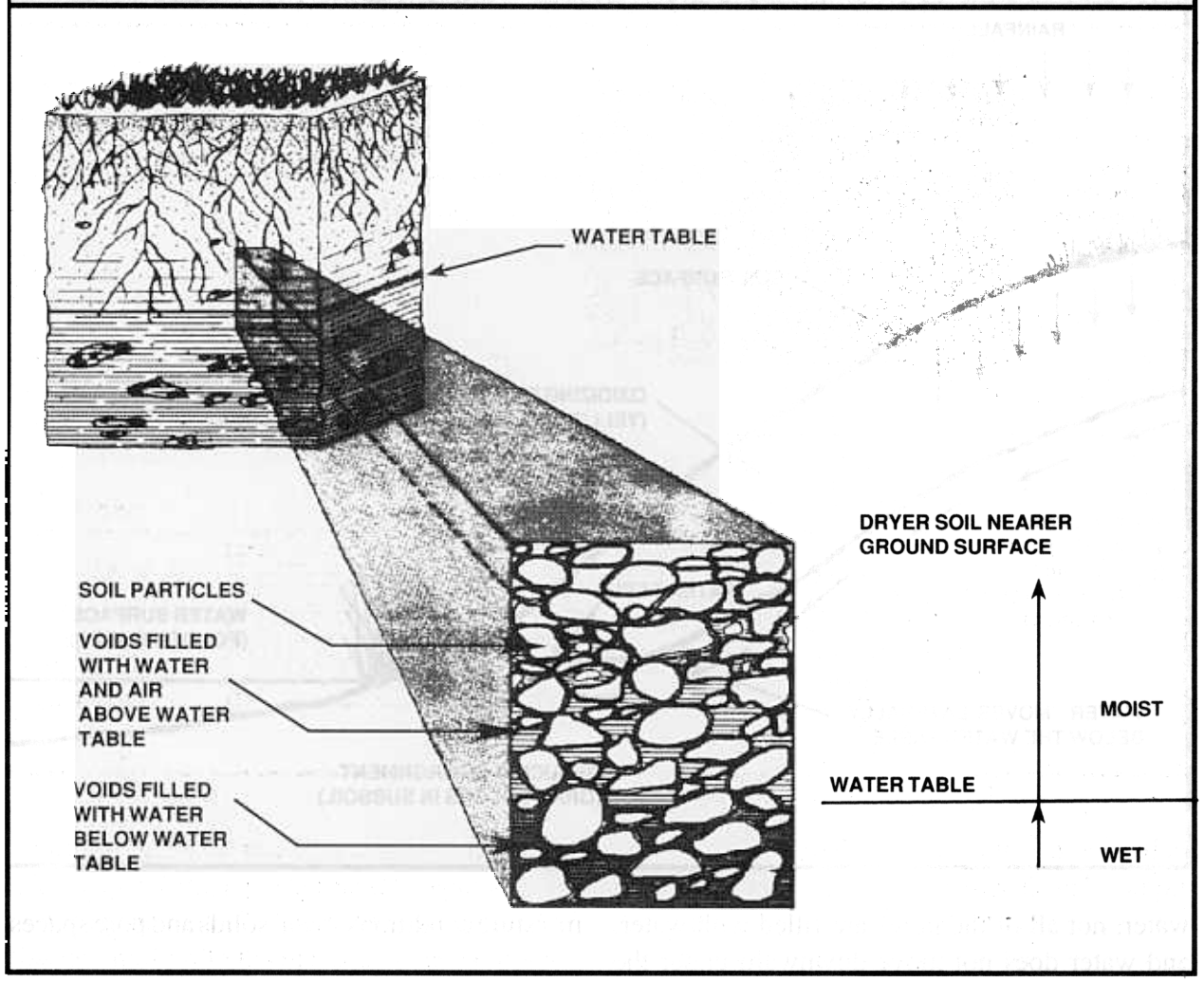
Figure 3-10 illustrates the relationship of soil moisture conditions to soil solids and pore spaces.

STRENGTH

The structural stability of soils results from shearing strength. Shearing strength gives soil the ability to support structures and embankments and remain in equilibrium when not level. Vertical cuts may be made in clay soils and sands may be stockpiled because of shear strength.

Soils differ from most engineering materials in that their shear strength is variable. It varies with such characteristics as gradation, plasticity, and particle shape, but probably more significant is the fact that the strength of a given soil may vary over a wide range. It is because of this variation that the definition of the shear strength of soil is associated with a condition. Change in shear strength with varying conditions has been experienced by everyone who has made sand castles

FIGURE 3 - 9 SCHEMATIC DIAGRAM OF WATER IN SOIL AT A GIVEN TIME



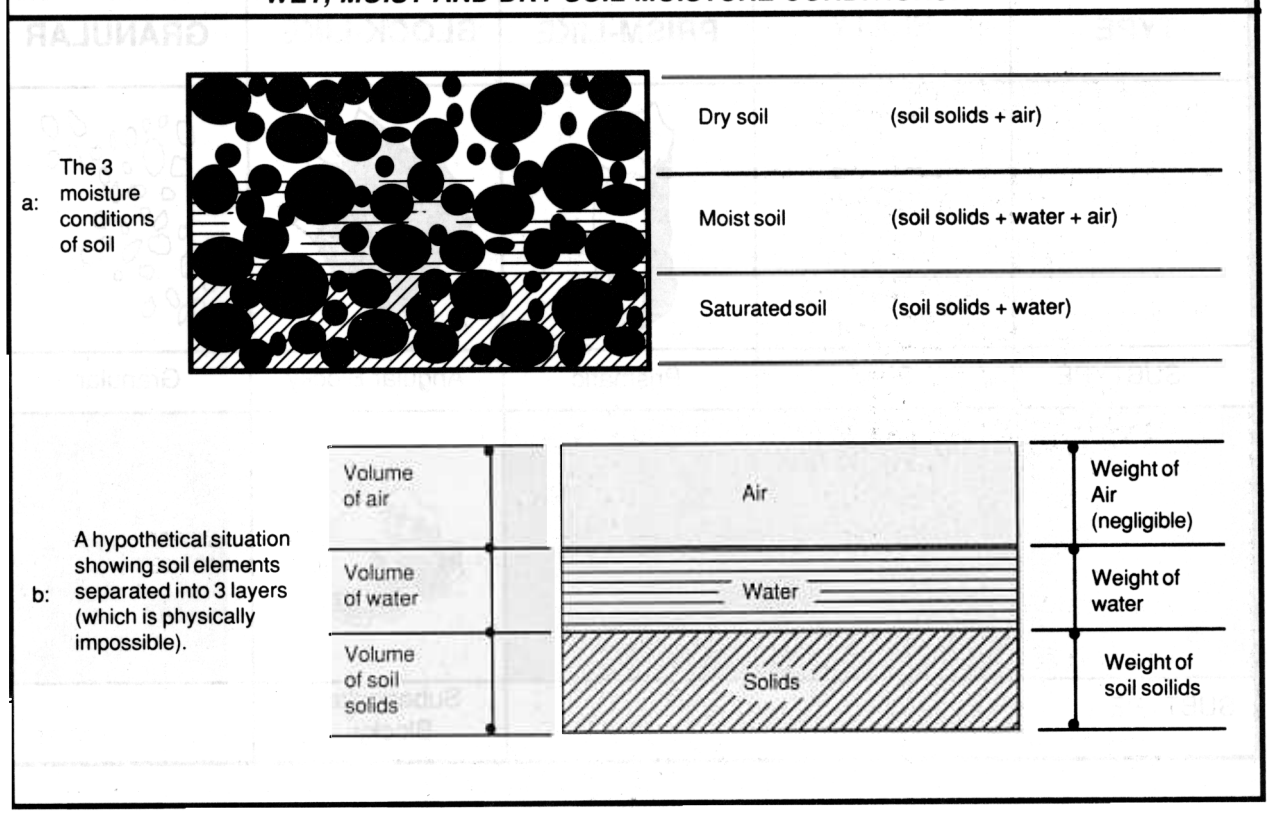
at the beach or has walked in fine-grained soils when they are wet. Sand must be moist to be molded. Dry soils support weight with less penetration than wet soils. In both instances, the change in strength results from a change in moisture content. A change in the density of a soil also alters the shear strength.

Shear strength of soil is made up of two elements: friction and cohesion. In its simplest form, friction is the resistance to sliding of one block of nonplastic soil against another. It is similar to and can be assumed to have the same action as the resistance of a block of wood sliding across a wooden floor. The greater the weight placed on the sliding block, the greater the force necessary to slide the block. Likewise, as load is applied to the soil, the frictional resistance or frictional shear strength increases. The friction in soil is different from simple friction because of such factors as the irregularity of the planes, interlocking of particles, and size and shape of the soil grains. The shear strength of clean sands and gravels and nonplastic silts is due to friction.

Cohesion is the result of the magnetic-like attraction of particles that is noted in one form as the plasticity and stickiness of soils. It resists the shearing of a block of soil. Cohesive strength does not increase with increased load in the soil. Highly plastic clays have mostly cohesive shear strength. Silty and sandy clays can have a combination of both cohesive and frictional strength.

Over a long time period, clay soil that has mostly

FIGURE 3 - 10 EXAMPLE OF RELATIONSHIP BETWEEN SOIL SOLIDS, PORE SPACES, WET, MOIST AND DRY SOIL MOISTURE CONDITIONS.



cohesive strength may creep like a highly viscous liquid. This is why a retaining wall for clay may tip over after 20 years even though the soil supported itself vertically while the wall was being built.

Silt-size particles are larger than clay particles and generally do not have significant cohesive attraction, as clay does. Silt particles act more like sand, having frictional strength, but being smaller, have less strength than sand. Some soils are a mixture of sand, gravel, silt, and clay and exhibit characteristics of both cohesive and noncohesive soil. Silts and sands with water seeping from them and soft clays present difficult stability problems.

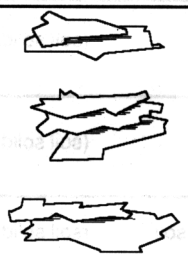
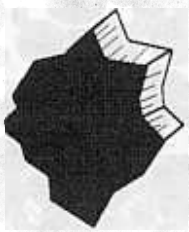
The allowable bearing capacity of a soil is the maximum average load per unit that will not produce failure by rupture of the supporting soil or produce excessive settlement. Bearing capacity depends not only on the soil, but on the footing size, shape, and depth and on the maximum settlement the structure can take without excessive damage. Bearing capacity is most often controlled by settlement. Settlement problems sometime occur as the result of building on soils with different settlement characteristics, such as undisturbed soil and loose backfill. Relatively heavy, rigid structures should be set on strong uniform foundations to avoid differential settlements that can cause cracking.

SOIL STRUCTURE

Soil structure refers to the arrangement of particles into groups or aggregates. Structure affects ease of air and water movement in the soil.

Field descriptions of soil structure give the shape and arrangement, size, and the distinctness and durability of visible aggregates or peds. Figure 3-11 shows the four primary types of structure: platy, prism-like, block-like, and granular.

FIGURE 3 - 11 SOIL STRUCTURE

TYPE	PLATY	PRISM-LIKE	BLOCK-LIKE	GRANULAR
				
SUBTYPE	Platy	Prismatic	Angular Blocky	Granular
SUBTYPE			Subangular Blocky	

The movement of water downward through different soils is greatly influenced by the arrangement of the particles, the structure, and the texture. In soils with similar texture, the structure will largely determine the rate of water movement. In general, soils with well developed blocky structure will have a more rapid permeability rate than soils of similar texture with a platy structure. The degree of overlap of the individual plates in soils with platy structure has a strong influence on the rate of the downward movement of water. Also, the size and degree of development of the aggregates in blocky structure have an influence on permeability. Consequently, structure, degree of cementation of soil particles, and soil texture are used together to infer or estimate permeability of soils.

Some soils in New Hampshire lack structure and are referred to as structureless, single grain, or massive. Beach sand is an example of single grain because there is no cohesion among individual grains. In a structureless massive soil, soil particles cohere, but without an evident type of structure such as platy or blocky. This condition may or may not have a significant influence on vertical water movement. A soil layer that is massive and has close packing of soil particles may strongly influence vertical water movement.

SOIL CONSISTENCE

Soil consistence is the feel of the soil and the ease with which a clod (ped) can be crushed by manual pressure. The terms commonly used to describe consistence relate to three standard moisture conditions: dry, moist, and wet. Figure 3-12 briefly illustrates how to classify consistence.

Dry Soil Condition

Consistence is classified as hard if there is moderate resistance to pressure, and a clod can be broken with difficulty between thumb and forefinger. Consistence is soft if the clod breaks into

FIGURE 3 - 12 SOIL CONSISTENCE	
CLASSIFY CONSISTENCE AS	**IF CLOD PRESSED BETWEEN THUMB AND FINGERS**
FOR DRY SOIL CONDITION	
HARD	Has moderate resistance to pressure and can be broken with difficulty
SOFT	Can be broken into powder or individual grains under very slight pressure
FOR MOIST SOIL CONDITION	
LOOSE	Has lack of cohesion by particles Does not hold together in a mass
FRIABLE	Can be crushed evenly under gentle pressure Can be pressed together into a lump
FIRM	Has distinctly noticeable resistance
VERY FIRM	Can be crushed by strong pressure
FOR WET SOIL CONDITION	
PLASTIC	Readily deforms by moderate pressure Can be pressed into a lump Will form "wire" when rolled
STICKY	Adheres to thumb and finger Tends to stretch somewhat and pull apart rather than pulling free
FOR ANY MOISTURE CONDITION	
CEMENTED AND HARD	Is bound together very strongly Is little affected by moistening

powder or individual grains under very slight pressure.

Moist Soil Condition

Consistence for the moist soil condition has four classifications. Soil is classified as loose if there is lack of cohesion by soil particles and it does not hold together in a mass. It is considered friable if soil crushes easily under gentle pressure between thumb and forefinger and can be pressed together into a lump. Firm describes a clod that crushes under moderate pressure between thumb and forefinger, but resistance is distinctly noticeable. It is very firm if the soil is barely crushable under strong pressure between thumb and forefinger.

Wet Soil Conditions

For wet soil conditions, consistence is considered plastic when a clod is readily deformed by moderate pressure, can be pressed into a lump, and will form a "wire" when rolled. It is sticky when a wet clod will adhere to both thumb and forefinger and tends to stretch somewhat and pull apart rather than pulling free.

FIGURE 3 - 13 PLASTICITY TEST IN FIELD		
PLASTICITY	BALL OF WET SOIL WITH PARTICLES < 2 mm ROLLED INTO 3 mm THREAD	
	THREAD FORMED	THREAD AT BREAKING POINT DEFORMED WITH:
NONPLASTIC	NO	----------
SLIGHTLY PLASTIC	YES	VERY SLIGHT PRESSURE
PLASTIC	YES	SLIGHT PRESSURE
VERY PLASTIC	YES	MODERATE OR STRONG PRESSURE

Any Moisture Condition

Consistence is termed cemented and hard when soil particles are bound together very strongly and not affected by moistening. This occurs most commonly in sand or sand and gravel material.

PLASTICITY

Plasticity in soil causes it to be pliable or molded when moist or wet. Dry soils do not exhibit plastic properties.

The Unified and the American Association of State Highway and Transportation Officials (AASHTO) soil classification systems explained in Chapter 4 use plasticity as a criteria. Sandy soils are usually slight to nonplastic and are less affected by soil moisture conditions.

Soil particles up to approximately 2 mm in diameter can be used to test for plasticity in the field. Roll a ball of wet soil between the hands until a thread 3 mm in diameter can be formed. If a 3 mm thread can be formed, reform the ball and roll it to 3 mm again. Rolling decreases the moisture content. Continue the process until the thread begins to break. The thread breaks at the approximate plastic limit. Plasticity terms are based on degree of resistance to deformation at the moisture content just before the thread breaks. The soil is considered nonplastic if no thread can be formed. Slightly plastic is the term used for soil that will form a thread and can be deformed by very slight force. A soil is plastic if a thread can be formed and the soil can be deformed by slight force. It is very plastic if a thread can be formed and soil can be deformed by moderate or strong force. Figure 3-13 indicates terms used to classify plasticity in the field.

RESTRICTIVE LAYERS

A restrictive soil layer is one that impedes penetration of gases, liquids, or plant roots. Individual soil properties can be used as clues to identify possible restrictive layers. Examples include a soil with a clayey texture or a soil with a platy structure. However, it is quite common to consider a combination of soil properties in the identification of a possible restrictive layer. For example, a soil with loamy texture, granular structure, and friable consistence is unlikely to have a restrictive layer. If this same loamy texture soil has a platy structure and firm consistence, it may very well be a restrictive layer. It is useful, therefore, to consider not only single soil properties, but combinations of properties. Figure 3-14 illustrates the use of single and combined properties to determine restrictive soil layers.

PERMEABILITY

Soil permeability expresses the ease with which

FIGURE 3 - 14 CLUES TO IDENTIFYING RESTRICTIVE SOIL LAYERS USING TEXTURE, STRUCTURE, AND CONSISTENCE

Any combination of texture, structure, and consistence within the shaded areas may indicate a restrictive soil layer.

GENERAL TEXTURE	STRUCTURE	CONSISTENCE (MOIST SOIL)
Sandy	Single grain (no structure)	Loose
Loamy	Granular	Friable
Clayey*	Platy*	Firm
	Prismatic*	Very firm*
	Blocky*	Cemented*
	Massive	
GENERAL TEXTURE	STRUCTURE	CONSISTENCE (MOIST SOIL)
Sandy	Single grain (no structure)	Loose
Loamy	Granular	Friable
Clayey*	Platy*	Firm
	Prismatic*	Very firm*
	Blocky*	Cemented*
	Massive	
GENERAL TEXTURE	STRUCTURE	CONSISTENCE (MOIST SOIL)
Sandy	Single grain (no structure)	Loose
Loamy	Granular	Friable
Clayey*	Platy*	Firm
	Prismatic*	Very firm*
	Blocky*	Cemented*
	Massive	

* Probably a restrictive layer based on this single property

liquids pass through a mass of saturated soil or a soil layer. Texture, structure, and presence or absence of cemented or other restrictive layers directly affect soil permeability.

Soil permeability is not the same as soil percolation. Permeability can be measured quantitatively as the rate of flow of water through a cross section of saturated soil in unit time. Percolation tests measure the rate at which the soil absorbs water.

The major factors that affect permeability rate are soil texture and structure. Soils high in clay and silt have slower permeability rates than do sandy soils having similar soil structure. Silty and clayey soils have smaller sized pores that

restrict the downward movement of water. Sandy soils have larger pores and, therefore, allow water to move downward more rapidly. As stated earlier, the type of soil structure strongly influences the rate of movement of water through soils of similar texture. Soils with platy structure usually have a slower rate of permeability than do soils with well developed blocky structure. In fact, some sandy soils with platy structure may have a slower rate of permeability than loamy soils because the structure restricts downward movement of water. Also, soils with hard, compact layers can restrict the downward movement because of their compact condition. Solid bedrock also restricts the downward movement of water.

SOIL COLOR

Color is an obvious and easily determined soil property. It has little known direct influence on the functioning of the soil. However, color is one of the most useful properties for soil identification and appraisal, mainly because other, more important characteristics that are not so easily and accurately observed can be inferred from it.

Within a limited area, color can be reliably associated with important soil properties. Color of the surface layer, for example, may be used to judge the content of organic matter. Color is a clue to wetness. It may be a mark of the effects of past vegetation or use of the soil. Some soils exhibit color directly inherited from the parent rock. These and other relationships are clues for identifying soils and evaluating their properties.

Commonly in New Hampshire, dark colors suggest more organic matter than light colors. The relationships may be quite good locally, but there are exceptions. Humified organic material is commonly dark; however, raw organic materials such as peat are not necessarily dark. Where mean annual temperature is high, soils that are high in organic matter are commonly less dark than soils in cool regions having similar amounts of organic matter.

Light gray or grayish colors in soils commonly indicate reducing conditions, alternate wet and dry periods either now or in the past. Gray or grayish colors may indicate wet conditions, but not without qualifications. In wooded areas, some soils have a whitish gray horizon over bright red soil. The gray results from soil formation processes, not wetness. Also, in some areas of New Hampshire gray colors are a result of the gray color of parent rock from which the soil weathered.

In some environments, yellowish or reddish mottles indicate alternating oxidizing and reducing conditions associated with a fluctuating water table. Mixed soil colors can also result from differential weathering of the parent material instead of impeded drainage. Such soils are usually described as "variegated".

Within a local area, reddish and yellowish colors can be related to different parent materials, different positions in the landscape, and other factors. The differently colored soils may behave differently in use.

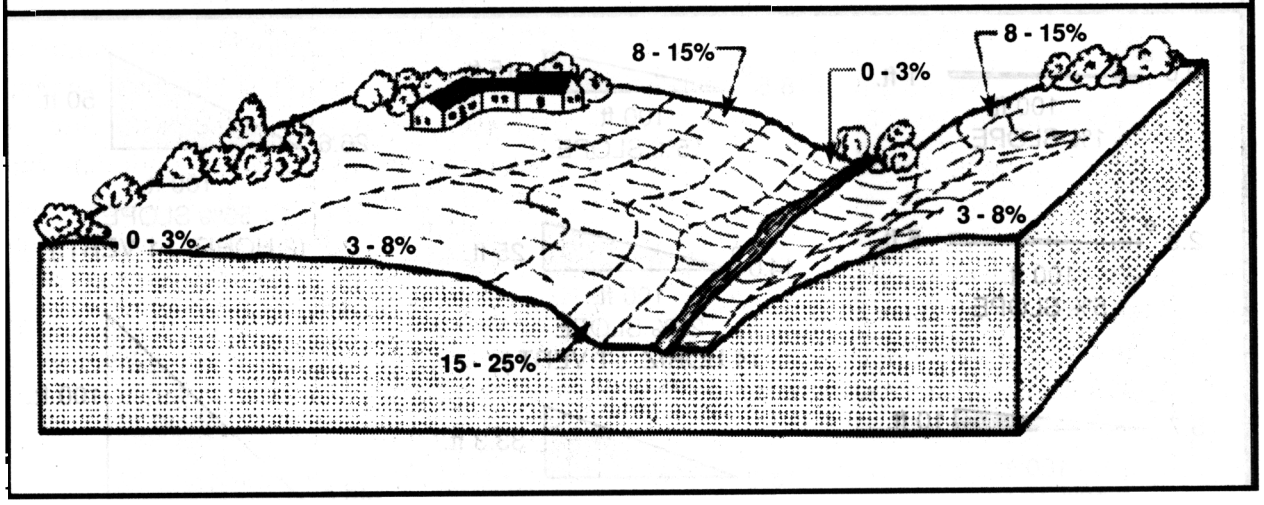
The number of soil properties indicated by color or that are easily distinguished because of color differences within the soils is large. Many of the relationships are based on empirical correlations. Empirical correlations are most useful when applied within the perspective of soils and environments in a small area, such as a county.

The Munsell Soil Color chart is a useful guide for determining specific soil colors. Munsell notations are arranged by three variables: hue, value, and chroma. 10 YR 6/4 would be 10 YR hue, value of 6, and chroma of 4. Refer to Chapter 10 for more detail.

SLOPE

The slope of the soil surface has several distinct factors: gradient, configuration, length, and

FIGURE 3 - 15 SLOPE RELATED TO THE LANDSCAPE



aspect. Figure 3-15 indicates slope across a landscape.

Slope influences the retention and movement of water, transfer of heat, movement of soil material, rate and amount of runoff, potential for soil slippage and accelerated erosion, and ease with which machinery can be used.

Slope Gradient

Slope gradient is the inclination of the surface of the soil from the horizontal. The difference in elevation between two points may be expressed as a percentage of the distance between those points. If the difference in elevation is 1 unit over a horizontal distance of 100 units, the slope is 1 percent. A slope of 45 degrees is a slope of 100 percent. Slope is also expressed as a ratio of horizontal distance to vertical distance. A 1 horizontal to 1 vertical slope is a 45-degree slope. Figure 3-16 shows examples of various slopes and the relationship between percent gradient, degree of slope, and ratio of side slopes.

Surface Configuration

Surface configuration is an important component of slope. The shape or form of the surface is the three dimensional aspect of slope. Configuration has an important bearing on overall surface drainage. A convex shape is where the land slopes away in more than one direction. Knolls and drumlins are familiar land shapes that have convex surfaces and good surface drainage. Topographic depressions are the most common examples of concave surfaces similar to a bowl. A concave shape is where the surface water tends to accumulate. These low areas between knolls and hills are less well drained.

Slope Length

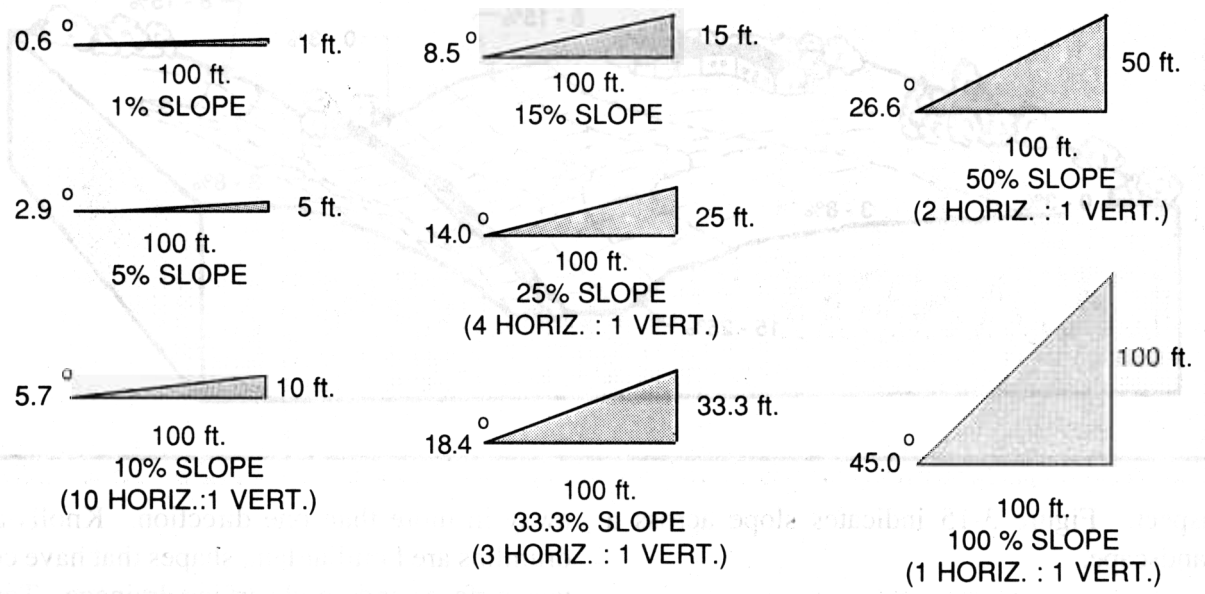
Slope length greatly affects the flow of water and the potential for erosion. The longer the slope the greater the potential for runoff and erosion. However, the relationship is not the same for all soils nor for all conditions at a given place. Soil structure, porosity, texture, gradation and amount of rock fragments are soil properties which also influence the amount of runoff and erosion.

Slope Aspect

Slope aspect is the direction the soil surface faces. The direction is expressed as an angle between 0 and 360 degrees measured clockwise from north, or as a compass point such as east or north-northwest.

When aspect is the principal variable, soils on the north-facing slopes are cooler and have lower evapotranspiration than soils on south-facing slopes. In some critical areas, this may favor trees

FIGURE 3 - 16 EXAMPLES OF SLOPE



on north-facing slopes and grass on south-facing slopes.

Slope aspect is also important in areas of strong winds. These areas usually experience the winds blowing from one general direction at least seasonally. Evapotranspiration is higher in areas facing the prevailing winds. Strong winds favor low-growing vegetation, such as grasses or shrubs. Also, soil temperature may be altered, depending on whether the winds are warm or cool.

BIOLOGICAL ACTIVITY

The surface layer of soil is full of life. Many animals, such as moles and woodchucks, use the soil to find food and shelter. Earthworms and many insects also live in the soil. As these animals burrow and tunnel, they mix the soil, allowing air and water to penetrate beneath the ground surface. Plant roots extend down through the soil to absorb the air, water, and nutrients needed for growth.

The subsoil also has a considerable amount of biological activity, although much less than the surface layer. The amount of biological activity decreases with depth. Generally, in the substratum, the amount of biological activity decreases to a point where little activity takes place and the effect of biological activity on soil development is insignificant.

In addition to plants and animals, billions of microscopic organisms, such as bacteria and algae, inhabit the soil. They, along with fungi, earthworms, and other soil creatures, play an important role in the decomposition of organic material. Decomposers help break down dead plant and animal tissue. Nutrients are returned to the soil, where they become available for plant use again.

TEXTURE AND TEXTURAL CLASSIFICATION

4

In ordinary word usage, the connotation of texture is the surface smoothness or graininess of a material. When working with soil, texture indicates the graininess or sizes of individual particles making up the soil mass. For instance, a soil may be described as sand or sandy textured due to the sand size particles of the soil. However, soils predominantly are not composed of particles of one size. Soils normally include a range of particle sizes: from those not visible to the naked eye to boulder sizes. See Figure 4-1. Soil descriptions are difficult without a system to define precise particle sizes. The term "gravel" for example, is vague if not precisely defined. Sand with some gravel sizes is commonly considered gravel to the lay person, but an engineering classification system would define it as sand.

TEXTURE

The texture of a soil is, perhaps, its most nearly permanent characteristic. Texture is one of the principal properties that affects the potential uses and limitations of soils.

The textural class name defines the proportion of particle size ranges in the soil. This, in turn, can be generally interpreted in terms of permeability, available moisture capacity, infiltration rate, bearing capacity, shear strength, and other similar properties and qualities.

Soil behavior is an interaction between the solid particles and the air or water in the voids. The composition and condition of the solids, influences, or is associated with, certain types of soil behavior.

Particles in the 3-inch and larger size range are generally stable. Many of these particles are sound and durable. Depending on the mineralogic makeup, however, they may be susceptible to deterioration due to weathering. In this case, engineering behavior may be quite difficult to predict, and evaluation for engineering use may require testing and additional study. Particle shape is significant. Oblong angular particles are more difficult to handle than rounded ones. Angularity of particles, however, tends to increase stability, but makes it more difficult to pack particles close together.

Particles in the 0.05 mm to 3-inch range behave similarly. However, small percentages of the extreme sizes in a soil mixture have considerably different influences. Soils consisting of particles exclusively from this range are considered coarse-grained and relatively easy to densify. Particles generally act separately, as opposed to bonding

together with other particles. Behavior is usually not affected by moisture.

Fine particles, or fines (particles generally finer than 0.05 mm), behave in a manner considerably different from the coarse particles. There is a wide spectrum of behavior within this category. The finer particles frequently bond together in aggregates rather than act as single particles. Particles in this size range are called clay and silt. Clays are those materials which, through a wide range in moisture content, can be deformed without elastic rebound, volume change, cracking, or crumbling. For silts, there is either no range or a narrow range in moisture content where such behavior is possible. Organic fines are grouped according to this same system.

Certain characteristics are common in all fine-textured soils. The behavior of fines is highly dependent on moisture content. Small percentages of fines may have very important effects on the engineering characteristics of the soils. Soils containing high percentages of fines are the most troublesome soils for engineering. They may shrink due to drying or swell when wet. These soils may also be quite strong when dry, but lose their strength when wet.

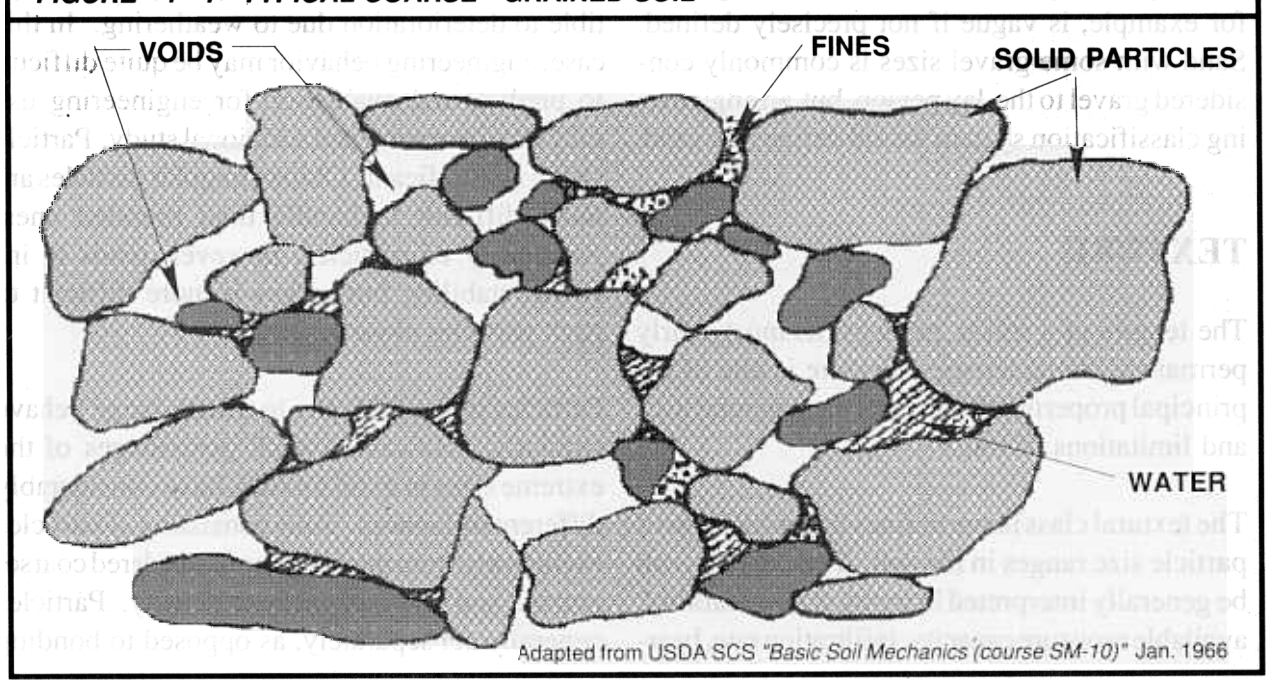
Nonplastic or low plasticity fines usually consist of particles that are roughly equidimensional. Occasionally, as in the case of fine mica, particles may be plate shaped. Silts may or may not be impervious to water.

Clay fines have low resistance to deformation when wet, but when dry, they offer much higher resistance to deformation than do the silt particles. Clay soils can be expected to be rather impervious to water. An especially important factor in the behavior of plastic fines is the existence of electro-chemical forces between particles or units of particles. This is most important among the "clay minerals", or ultra-fine clays. Electro-chemical forces are very weak or nonexistent in silty, nonplastic fines.

GRADATION

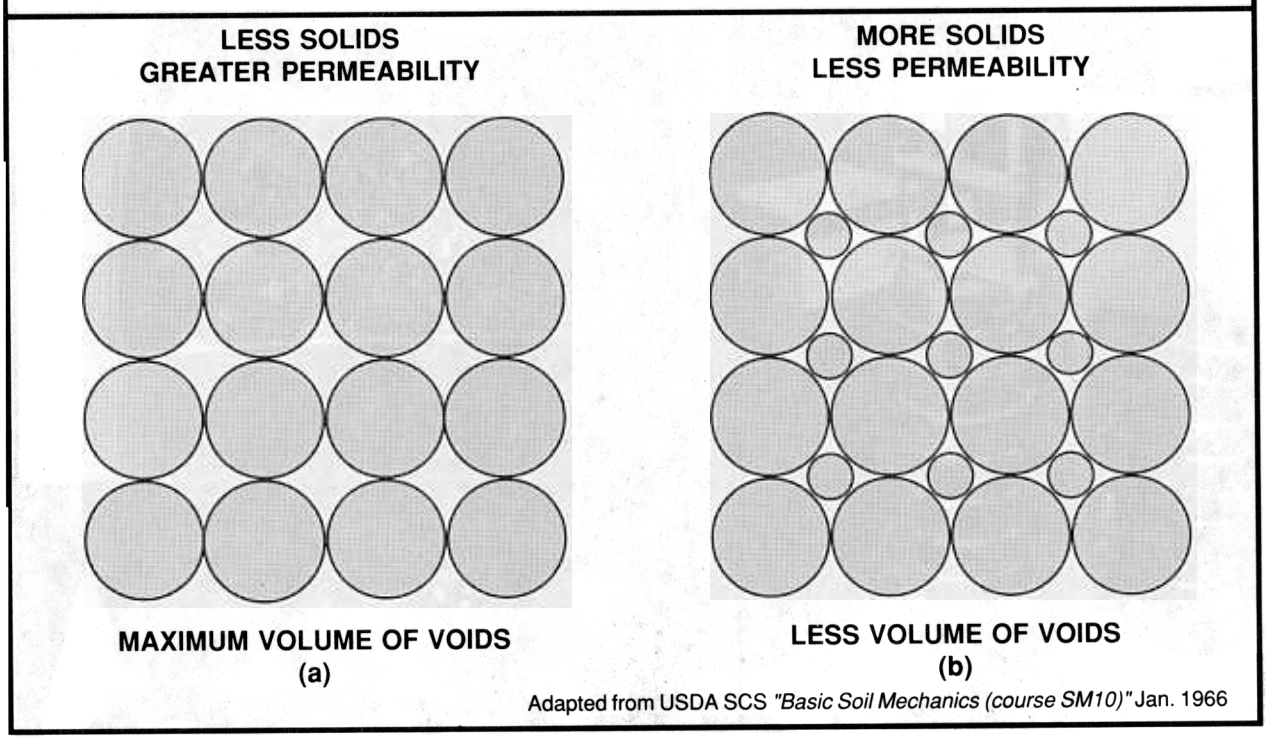
The distribution of the various size particles or grains of soil is referred to as its texture, gradation, or grain size distribution. Rarely are soils made up entirely of particles of one size. Many soils do not even consist of particles falling exclusively within one particle size range.The variations of gradations in most natural soils

FIGURE 4 - 1 TYPICAL COARSE - GRAINED SOIL



Adapted from USDA SCS *"Basic Soil Mechanics (course SM-10)"* Jan. 1966

FIGURE 4 - 2 EFFECT OF GRADATION ON VOID - SOLID RELATIONSHIPS



Adapted from USDA SCS *"Basic Soil Mechanics (course SM10)"* Jan. 1966

seems infinite and is an important aspect of soil.

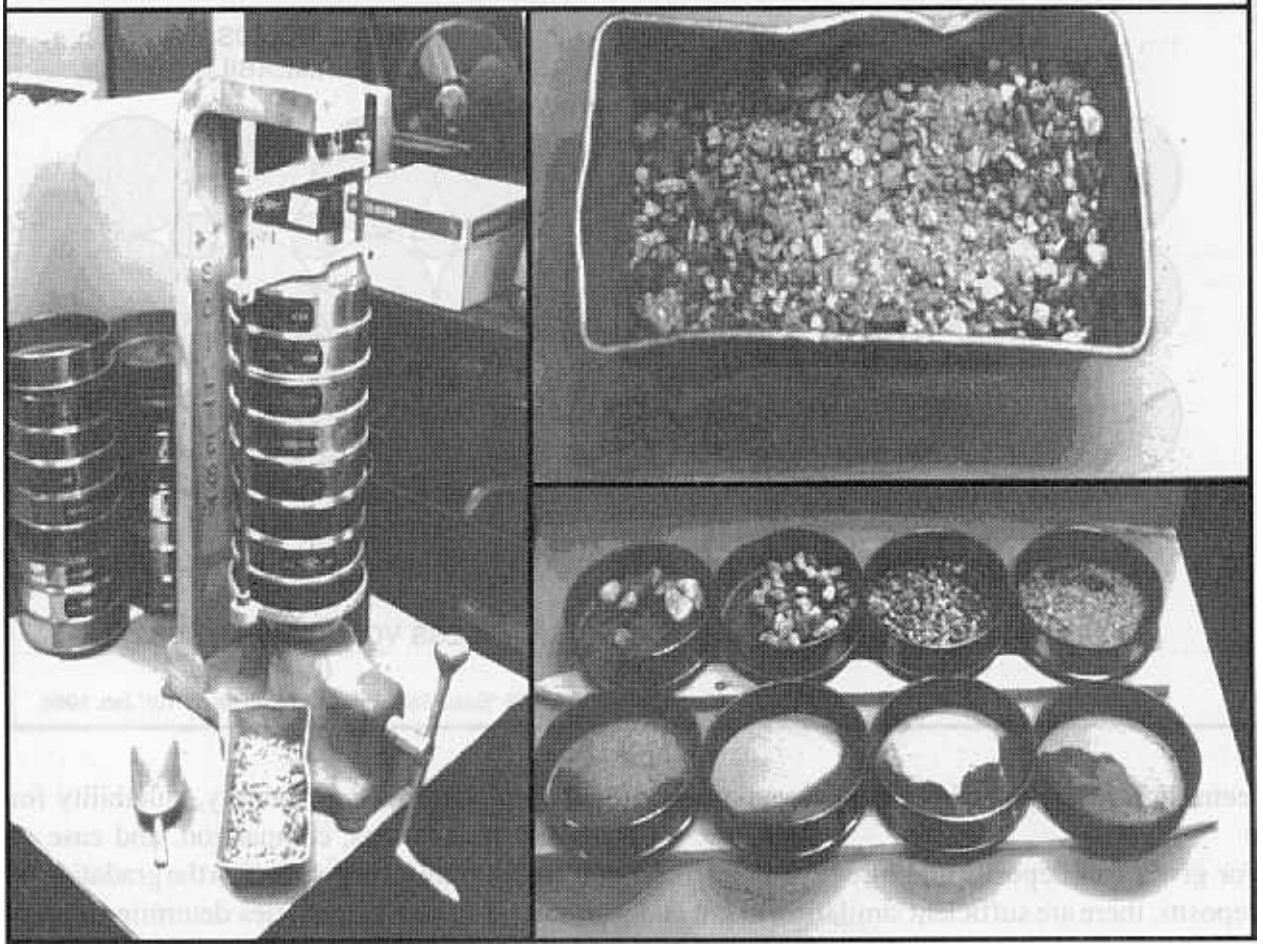
For given soil deposits and often for unrelated deposits, there are sufficient similarites in gradation; however, to make gradation a good technique for identifying and comparing soil. Unfortunately, none of the significant engineering characteristics trace solely either to particle size or gradation. To a limited degree, however, correlations can be made between engineering behavior and gradation. It is possible to identify a soil by its gradation and apply prior experience with soils having similar gradation, at least partially.

Some broad definitions are used to describe gradations. "Well graded" is used to define coarse-grained soils that have a wide range in particle sizes. These soils have a proportionate distribution among particle sizes. "Poorly graded" soils do not have a wide range and proportionate distribution of sizes. "Skip graded" soils have a deficiency in particle size or sizes within the total range of its particle sizes.

Gradation directly and indirectly affects most of the soil properties. Permeability, suitability for fills and foundations, compaction, and ease of construction are all dependent on the gradation of the soil. The size of particles determines interparticle reactions such as gravity, weight, surface tension of particle water films, and electro-chemical activity of clay. Permeability for instance, varies greatly depending on gradation. It generally decreases as the size of finer particles in the soil decreases. In poorly graded or skip graded material, the soil will usually have higher permeabilities than well graded soil with the same fine particle sizes. Well graded soils will generally have higher densities than poorly graded soils. Figure 4-1 shows the gradation of a typical coarse-grained soil.

Figure 4-2 shows the influence of gradation on several soil properties. In (a), the two-dimensional view shows an arrangement of equal sized spheres that are poorly (in this case uniformly) graded. This condition produces a maximum volume of voids. In (b), a wider range of sizes (broadly graded material) allows more solid material to be packed into the same volume as in (a). This results in a decrease in the volume of

FIGURE 4 - 3 GRADATION IS DETERMINED BY SIFTING THROUGH STANDARD SIEVES



voids and permeability of the soil.

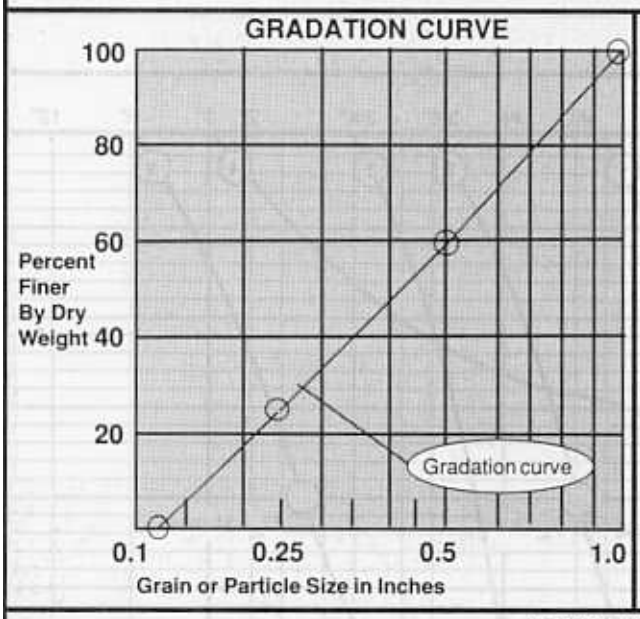
Figure 4-2 also shows that gradation influences the size as well as the amount of void spaces. If one of the large particles in (b) were replaced with smaller particles, the volume of voids in the total system would increase. This is because the space of the large particle could not be completely filled with smaller particles since voids exist between the small particles. Generally, void volume increases as particle size decreases.

Gradations for soils with particles in the 0.05 mm to 3-inch range can be determined by sifting samples through a series of progressively finer standardized wire sieves (mesh screens). See Figure 4-3.

Gradation may be expressed by accumulative percentages of material finer than each sieve in a series of sieves. Suppose that a 100-pound sample of dry soil consists of 25 pounds of particles coarser than 1/8 inch diameter and finer than 1/4 inch, 35 pounds of particles coarser than 1/4 inch and finer than 1/2 inch, and 40 pounds of particles coarser than 1/2 inch and finer than 1 inch. The gradation of this sample may be presented in tabular form and graphically as a gradation curve as shown in Figure 4-4. Figure 4-5 shows a visual schematic of this sieve analysis.

Without a special technique, gradation curves are difficult to compare. Certain percentile sizes (D sizes) are used as a basis of comparison. The letter D is used to indicate the diameter of a soil particle. The subscript is used to indicate what percentage of material is finer than the D size specified. This provides a means of comparing gradation characteristics. For example, the D_{60} size indicates the diameter of the soil particle at which 60 percent of the sample in Figure 4-4 is finer. The D_{60} size is 1/2 inch for the soil sample

FIGURE 4 - 4 EXAMPLE OF SIEVE ANALYSIS AND GRADATION CURVE



SIEVE ANALYSIS

Diameter (inches)	Percent Finer	Percent Retained on each Sieve	Percent Total Retained
1	100	0	0
1/2 (0.50)	60	40	40
1/4 (0.25)	25	35	75
1/8 (0.125)	0	25	100

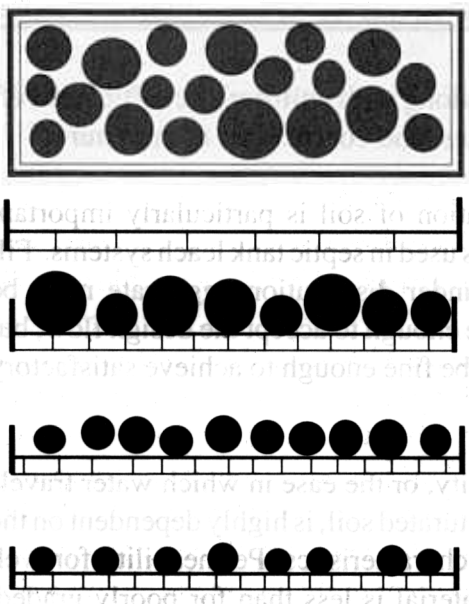
Adapted from USDA SCS *"Basic Soil Mechanics (course SM10)"* Jan. 1966

shown. Generally, the D_{10}, D_{30}, and D_{60} sizes are used. These sizes are usually used only for comparing soils with particles larger than 0.074 mm or soils with significant contents of these components.

Figure 4-6 shows gradation curves with D sizes, plotted in terms of percent finer by dry weight of the soil and grain size. Curves 2,3, and 5 show typical natural soils that are well graded. Curve 1 indicates a poorly graded soil. A skip graded material is shown by curve 4.

The D_{10} size is referred to as the effective size of the material. The ratio, D_{60}/D_{10}, is called the uniformity coefficient (Cu). The values of the effective size and uniformity coefficient indicate the nature of the dominant soil fraction.

FIGURE 4 - 5 VISUAL SCHEMATIC OF SIEVE ANALYSIS IN FIGURE 4 - 4



TOTAL SOIL SAMPLE

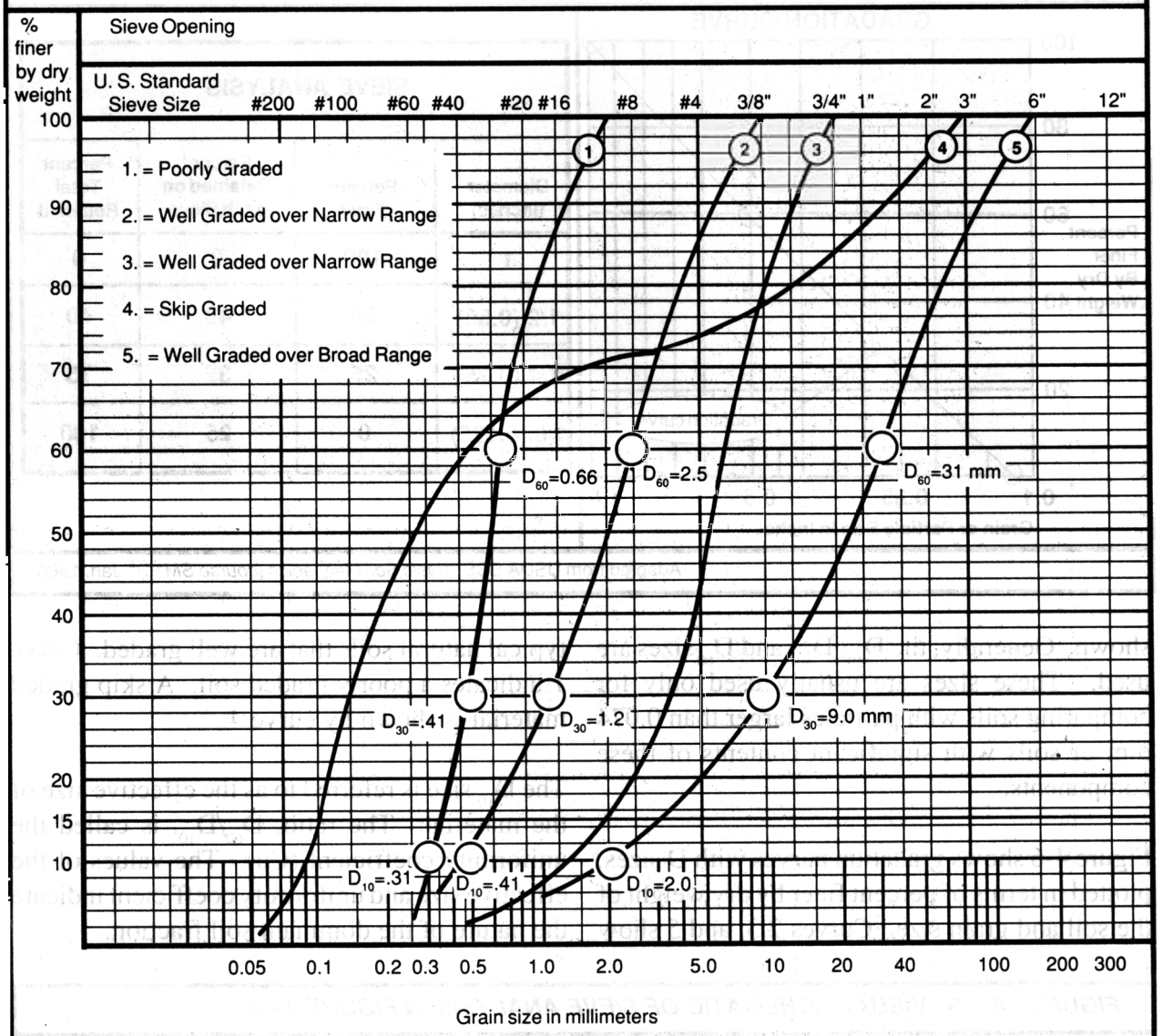
1" SIEVE. 100% FINER - 0% RETAINED

1/2" SIEVE. 60% FINER - 40% RETAINED (BY WEIGHT) ON THIS SIEVE
40% TOTAL RETAINED

1/4" SIEVE. 25% FINER - 35% RETAINED (BY WEIGHT) ON THIS SIEVE
75% TOTAL RETAINED

1/8" SIEVE. 0% FINER - 25% RETAINED (BY WEIGHT) ON THIS SIEVE
100 % TOTAL RETAINED

FIGURE 4 - 6 GRADATION CURVES



Adapted from USDA SCS *"Basic Soil Mechanics (course SM-10)"* Jan. 1966

A high uniformity coefficient indicates that there is a wide range in particle sizes whereas a low value indicates a narrow range. Uniformity coefficients vary upward from 1. A value of 1 indicates a material with one size of particles.

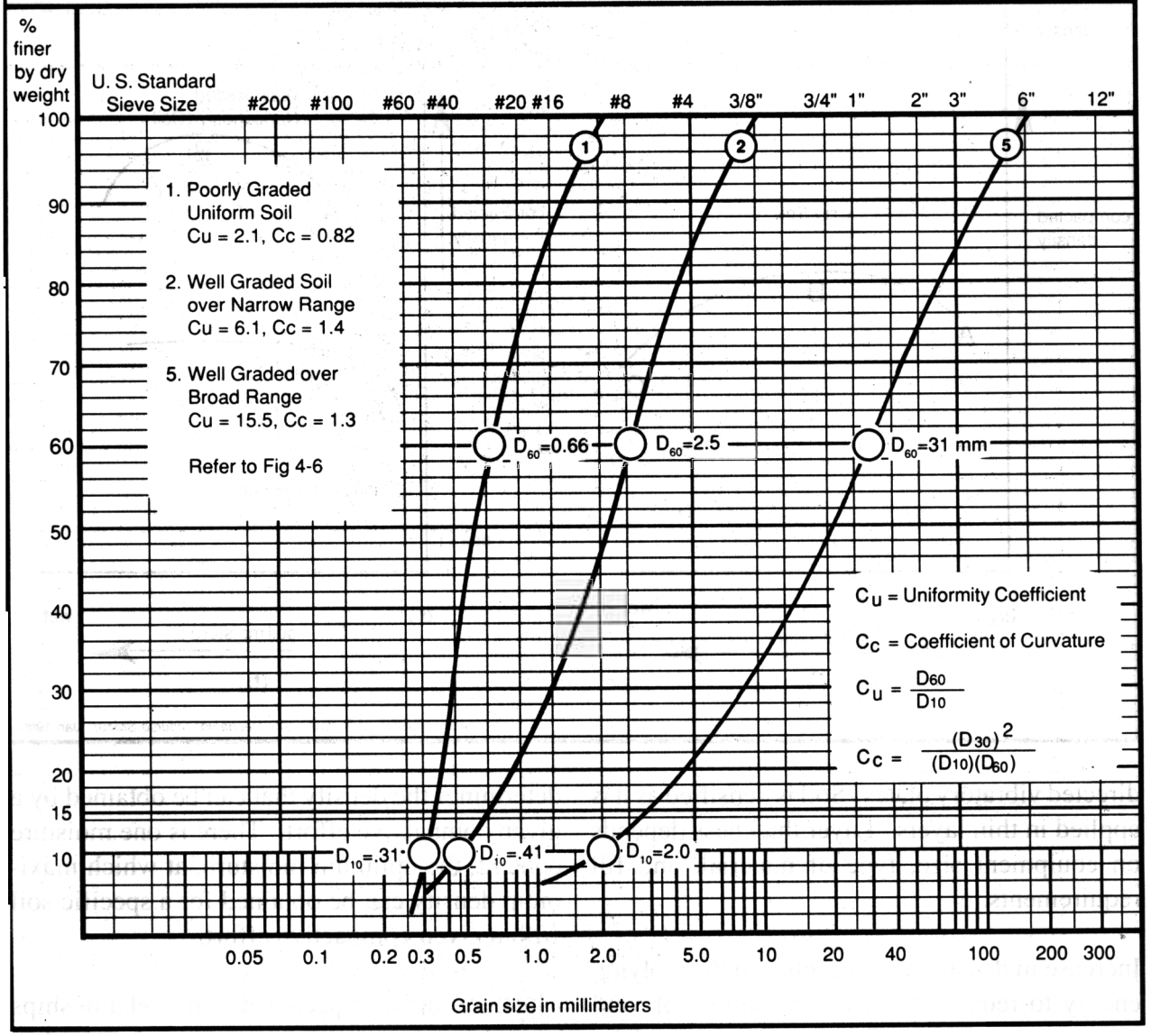
Neither uniformity coefficient nor effective size indicate the distribution of the particles between the D_{10} and the D_{60} sizes. A second coefficient is often used to define this variation. This coefficient, called the coefficient of curvature (Cc), is defined as $(D_{30})^2 / (D_{10} \times D_{60})$

Figure 4-7 gives an example of the gradation of materials along with uniformity coefficients, effective sizes, and coefficients of curvature.

The gradation of soil is particularly important when fill is used in septic tank leach systems. Fill required under distribution aggregate must be permeable enough to accept the design flow, but must also be fine enough to achieve satisfactory treatment.

Permeability, or the ease in which water travels through saturated soil, is highly dependent on the gradation characteristics. Permeability for well graded material is less than for poorly graded.

FIGURE 4 - 7 GRADATIONS, EFFECTIVE SIZES, AND UNIFORMITY COEFFICIENTS



Permeability of filter sands can sometimes be roughly expressed in terms of the D_{10} size.

Even a small amount of fines (material passing the number 200 sieve) greatly affects saturated permeability rates. As an example, soil containing only 5 to 10 percent fines may have greatly reduced saturated permeability, especially when it is well graded. Air in the voids and surface tension will affect unsaturated flow.

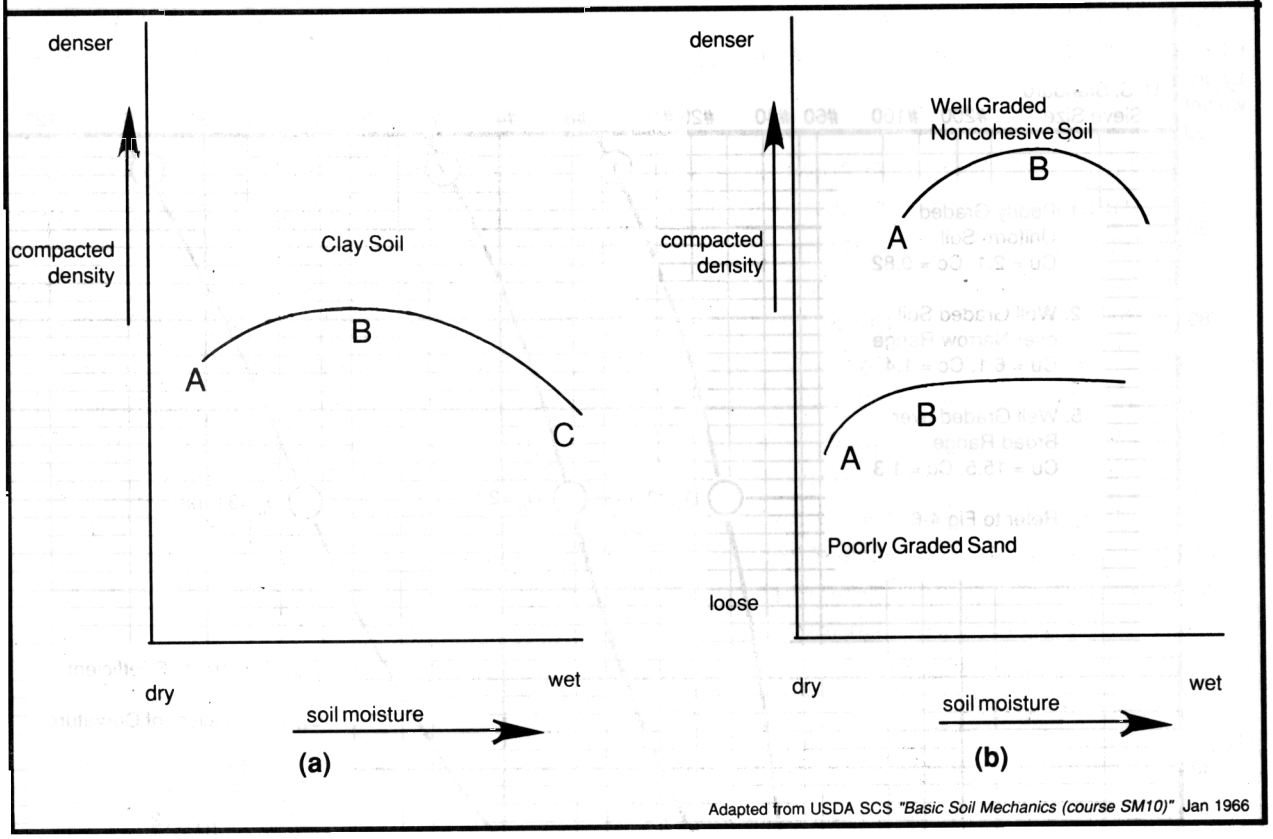
GRADATION AND COMPACTION

Compaction is an important factor in development construction since it applies to all soil materials removed from their natural state and used as site fill. Some properties of the soil in the natural state change as compaction is applied.

Compaction refers to the physical manipulation of soil to densify it. It increases the strength of soil to resist gravitational and seepage forces and reduces compressibility. Uneven and excessive settlement, slope instability, increased structure loading, and distress may result from improperly compacted soil.

Compaction is normally accomplished with typical construction equipment such as smooth-wheeled rollers, vibratory rollers, and manually

FIGURE 4 - 8 RELATIONSHIP OF SOIL MOISTURE AND COMPACTED DENSITY



Adapted from USDA SCS *"Basic Soil Mechanics (course SM10)"* Jan 1966

directed vibratory plates. Soil is densified as it is applied in thin layers. Layer thickness depends on equipment size, type of material, and fill requirements.

Increase in density is accomplished by applying energy to reduce the size and number of void spaces in the soil. This is accomplished by rearranging particles and filling void spaces with smaller particles, breaking bonds between particles, and orienting clay into parallel arrangements. Final density that can be accomplished for any given soil depends upon its moisture content, gradation, plasticity, and compactive effort applied.

The density of most soils cannot be significantly increased in a dry state, regardless of compactive effort. Saturated soils are also difficult to compress unless water drains out as fast as pressure by compaction is applied, as with clean sand and gravel.

Moisture content at which a soil is compacted determines the density that can be obtained by a given compactive effort. There is one moisture content, the optimum moisture, at which maximum density can be obtained for a specific soil with a given compactive effort.

Moisture and compacted density relationships are indicated by the curves shown in Figure 4-8. The characteristic curves were developed by increasing the moisture contents of equal volumes of dry soils and compacting each sample with the same energy.

Compaction of plastic, cohesive soils (clay) in Figure 4-8a is primarily accomplished by reorienting or realigning particles. At low moisture content (point A), there is considerable resistance to particle reorientation and increased density. As the moisture content is increased, resistance to particle reorientation reduces, and applied effort is more effective (point B). When the moisture content is increased to a point near saturation, interparticle forces are almost completely repulsive and the voids are almost completely filled

with water (point C). At this moisture content, it is impossible to pack in as many particles per unit volume as at the optimum moisture content at point B.

Compaction of noncohesive-nonplastic soils is attained primarily by rearrangement of grains with or without progressive filling of voids with smaller particles. At low moisture contents, (point A in Figure 4-8b) capillary tension in moisture films is high. This increases interparticle contact pressures and increases frictional resistance to particle rearrangement. As the moisture content is increased, capillary tension decreases, and compactive effort becomes more effective. At point B in Figure 4-8b, density increases to a maximum. As the moisture content exceeds optimum and reaches saturation, practically all void spaces are full of water. This prevents full effectiveness of the compactive effort, therefore density decreases.

Gradation characteristics have a definite effect on the shape of moisture density curves for noncohesive soils as shown in Figure 4-8. The optimum moisture-maximum density phenomena in soils containing coarse and fine particles results from the combination of factors influencing compaction of cohesive and noncohesive soils.

TEXTURAL CLASSIFICATION

Soils are composed of particles that usually vary greatly in size. When working with soil materials, it is convenient to establish ranges or categories of particle sizes to more easily describe soil texture or gradation. This helps catalog the influence of gradation on engineering and other physical behavior. A soil classification system provides a common basis for describing general characteristics and behavior of soil materials. Many soil classification systems have been devised and each system is tailored to a set of needs, requirements, or uses. The properties of soils are so numerous that one system is not adequate to serve all purposes. Soil classification systems were developed by empirical correlation of the physical properties of the soil materials with their behavior characteristics.

Three classification systems of soil material are commonly in use throughout the country, including New Hampshire. Two systems used in classifying samples of soil for engineering are the Unified Soil Classification System (USCS or shortened to Unified System) and the AASHTO system adopted by the American Association of State Highway and Transportation Officials. The USDA Soil Texture Classification System is used for environmental and agronomic purposes, among other uses.

UNIFIED CLASSIFICATION

The Unified Soil Classification System identifies coarse-grained soils primarily on the basis of gradation. It classifies fine-grained soils primarily on the basis of plasticity characteristics. These groupings have proven adaptable to a variety of uses, especially for embankments, foundations, and for drainage and filter materials. Yet, it is relatively simple to apply. Most soils can be classified reasonably well using this system based on judgment and experience without laboratory tests. More accurate identification requires performing mechanical analysis, liquid limit, and plastic limit tests.

Soils passing a 3-inch sieve are divided into three broad categories, namely coarse-grained, fine-grained, and highly organic soils. Particles larger than 3 inches are not part of the Unified System, but their presence is reflected by modifying the soil description. Coarse-grained soils are classified using grain size and distribution, quantity of fines, and character of fines. An approximate visual guide to the Unified System particle sizes is given in Figure 4-9. Fine-grained soil classification is based on the liquid limit and plasticity index. Classification symbols are made up of basic and modifying symbols as shown in Figure

FIGURE 4 - 9 APPROX. VISUAL GUIDE TO UNIFIED SYSTEM PARTICLE SIZES		
UNIFIED TERM	**PARTICLE SIZE**	**APPROXIMATE VISUAL EQUIVALENT**
BOULDERS	12" +	Medicine Ball +
COBBLES Large Small	 12" - 6" 6" - 3"	 Medicine Ball+ to Cantaloupe Cantaloupe to Orange
GRAVEL Coarse Fine	 3" - 3/4" 3/4" - No. 4 Sieve	 Orange to Grape Grape to Pea
SAND Coarse Medium Fine	 No. 4 - No. 10 Sieve No. 10 - No. 40 Sieve No. 40 - No. 200 Sieve	 Pea to Rock Salt Rock Salt to Table Salt Table Salt to Powdered Sugar
FINES	Less than No. 200 Sieve	Individual grains not visible without magnification
Partially adapted from USDA SCS *Engineering Field Manual, Chapter 4*, August 1990		

4-10. These symbols may be combined into 12 principal inorganic classes and three organic classes as shown in Figure 4-11. This figure shows a method for field classification. Field tests for dilatancy, toughness, and dry strength aid in determining plasticity of fine-grained soil. More exact laboratory classification methods are indicated in Figure 4-12.

FIGURE 4 - 10 UNIFIED SYSTEM SYMBOLS	
SYMBOLS	**NAMES**
G gravel **S** sand **M** silt **C** clay **O** organic **PT** peat **W** well graded **P** poorly graded **H** high liquid limit **L** low liquid limit	The names are mostly two or three-word names that have modifiers when needed. The names, with their two-letter symbols are: **Coarse - grained soils** GW well graded gravel — SW well graded sand GP poorly graded gravel — SP poorly graded sand GM silty gravel — SM silty sand GC clayey gravel — SC clayey sand These names may be modified by adding "with silt," "with clay," "with organic fines," with sand, and / or "with gravel." **Fine - grained soils** CL lean clay — ML silt CH fat clay — MH elastic silt CL - ML silty clay — OL / OH organic soil These names may be modified by adding: "sandy", "gravelly", "with sand", "with gravel." **Highly organic soils** PT peat Adapted from USDA SCS *Engineering Field Manual Chapter 4*, August 1990

FIGURE 4 - 11 FIELD IDENTIFICATION FOR UNIFIED SYSTEM BY VISUAL-MANUAL METHODS

Estimates should be to the nearest 5 percent		0, trace or 5% fines	well graded		GW	well graded gravel
			poorly graded		GP	poorly graded gravel
COARSE GRAINED SOIL less than 50% fines a	GRAVEL % gravel greater than % sand b,f	10% fines	clayey fines	well graded	GW-GC	well graded gravel with clay
				poorly graded	GP-GC	poorly graded gravel with clay
			silty fines	well graded	GW-GM	well graded gravel with silt
				poorly graded	GP-GM	poorly graded gravel with silt
		15% to 45% fines	clayey fines		GC	clayey gravel
			silty fines		GM	silty gravel
	SAND % sand equal to or greater than % gravel c,f	0, trace or 5% fines	well graded		SW	well graded sand
			poorly graded		SP	poorly graded sand
		10% fines	clayey fines	well graded	SW-SC	well graded sand with clay
				poorly graded	SP-SC	poorly graded sand with clay
			silty fines	well graded	SW-SM	well graded sand with silt
				poorly graded	SP-SM	poorly graded sand with silt
		15% to 45% fines e	clayey fines		SC	clayey sand
			silty fines		SM	silty sand
FINE GRAINED SOIL 50% to 100% FINES a,g,h	CLAYS AND SILTS with low liquid limit d,i	plastic fines			CL	lean clay
		low plastic fines with very low liquid limit			CL-ML	silty clay
		nonplastic and low plastic fines			ML	silt
		plastic fines with significant organics			OL	organic soil
		non or low plastic fines with significant organics			OL	organic soil
	CLAYS AND SILTS with high liquid limit d,i	plastic fines			CH	fat clay
		nonplastic and low plastic fines			MH	elastic silt
		plastic fines with significant organics			OH	organic soil
		non or low plastic fines with significant organics			OH	organic soil
HIGHLY ORGANIC SOIL		primarily organic matter dark in color, organic odor			PT	peat

Footnotes:

a. Soils that have 45%, 50%, or 55% fines may be classified with a borderline symbol, such as silty gravel GM/ML.

b. If the soil contains 15% or more sand, add "with sand" to the group name.

c. If the soil contains 15% or more gravel, add "with gravel" to the group name.

d. Soils that have liquid limits near 50 may be classified with a borderline symbol, such as lean to fat clay CL/CH; silt ML/MH.

e. If the fines have significant organic matter, add "with organic fines" to the group name; for example, silty gravel with organic fines GM, clayey sand with organic fines.

f. Soils that have nearly the same percentage of sand and gravel may be given a borderline classification , such as well graded gravel with sand GW/SW.

g. If the soil has 15% to 25% sand or gravel, add "with sand" or "with gravel" to the group name, such as lean clay with sand CL; silt with gravel ML.

h. If the soil has 30% to 45% sand or gravel, add "sandy" or "gravelly" to the group name, such as gravelly organic soil OL; sandy fat clay CH.

i. Soils that fall close to the border between silt and clay may be given a borderline classification, such as silty clay CL/ML; clayey silt ML/CL.

Adapted From USDA SCS *Engineering Field Manual, Chapter 4*, August 1990

FIGURE 4 - 12 CRITERIA FOR UNIFIED SOIL CLASSIFICATION SYSTEM USING LABORATORY TESTS

Based on the material passing the 3 - in. sieve			$Cu = D_{60}/D_{10}$ $Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$	Group Symbol	Group Name	a
COARSE-GRAINED SOILS more than 50% retained on No. 200 sieve	GRAVELS more than 50% of coarse fraction retained on No. 4 sieve	CLEAN GRAVELS Less than 5% fines b	$Cu \geq 4$ and $1 \leq Cc \leq 3$	GW	Well graded gravel	d
			$Cu < 4$ and / or $1 > Cc > 3$	GP	Poorly graded gravel	d
		GRAVELS WITH FINES More than 12% fines b	Fines classify as ML or MH	GM	Silty gravel	d,e,f
			Fines classify as CL or CH	GC	Clayey gravel	d,e,f
	SANDS 50%or more of coarse fraction passes No. 4 sieve	CLEAN SANDS Less than 12% fines c	$Cu \geq 6$ and $1 \leq Cc \leq 3$	SW	Well-graded sand	
			$Cu < 6$ and / or $1 > Cc > 3$	SP	poorly graded sand	g
		SANDS WITH FINES More than 12 % fines c	Fines classify as ML or MH	SM	Silty sand	e,f,g
			Fines classify as CL or CH	SC	Clayey sand	e,f,g
FINE-GRAINED SOILS 50% or more passes the No. 200 sieve	SILTS AND CLAYS Liquid limit less than 50	inorganic	PI > 7 and plots on or above "A" line h	CL	Lean clay	i,j,k
			PI < 4 or plots below "A" line h	ML	Silt	i,j,k
		organic	$\frac{\text{Liquid limit (oven dried)}}{\text{Liquid limit (not dried)}} < 0.75$	OL	Organic clay Organic silt	i,j,k,l i,j,k,m
	SILTS AND CLAYS Liquid limit 50 or more	inorganic	PI plots on or above "A" line	CH	Fat clay	i,j,k
			PI plots below "A" line	MH	Elastic silt	i,j,k
		organic	$\frac{\text{Liquid limit (oven dried)}}{\text{Liquid limit (not dried)}} < 0.75$	OH	Organic clay Organic silt	i,j,k,n i,j,k,o
HIGHLY ORGANIC SOILS		Primarily organic matter, dark in color, and organic odor		PT	Peat	

Footnotes

a. If field sample contained cobbles and / or boulders, add "with cobbles and /or boulders" to group name.

b. Gravels with 5 to 12% fines require dual symbols
GW-GM well graded gravel with silt
GW-GC well graded gravel with clay
GP-GM poorly graded gravel with silt
GP-GC poorly graded gravel with clay

c. Sands with 5 to 12% fines require dual symbols
SW-SM well graded sand with silt
SW-SC well graded sand with clay
SP-SM Poorly graded sand with silt
SP-SC Poorly graded sand with clay

d. If soil contains > 15% sand, add "with sand" to group name

e. If fines classify as CL-ML, use dual symbol GC-GM, SC-SM.

f. If fines are organic, add "with organic fines:" to group name.

g. If soil contains ≥15% gravel, add "with gravel" to group name.

h. If the liquid limit and plasticity index plot in hatched area on plasticity chart, soil is a CL-ML, silty clay. See Fig. 4-13.

i. If soil contains 15 to 29% plus No. 200, add "with sand" or "with gravel," whichever is predominant.

j. If soil contains ≥ 30% plus No. 200, predominantly sand, add "sandy" to group name

k. If soil contains ≥ 30% plus No. 200 predominantly gravel, add "gravelly" to group name.

l. PI ≥ 4 and plots on or above "A"line.

m. PI < 4 or plots below "A" line

n. PI plots on or above "A" line.

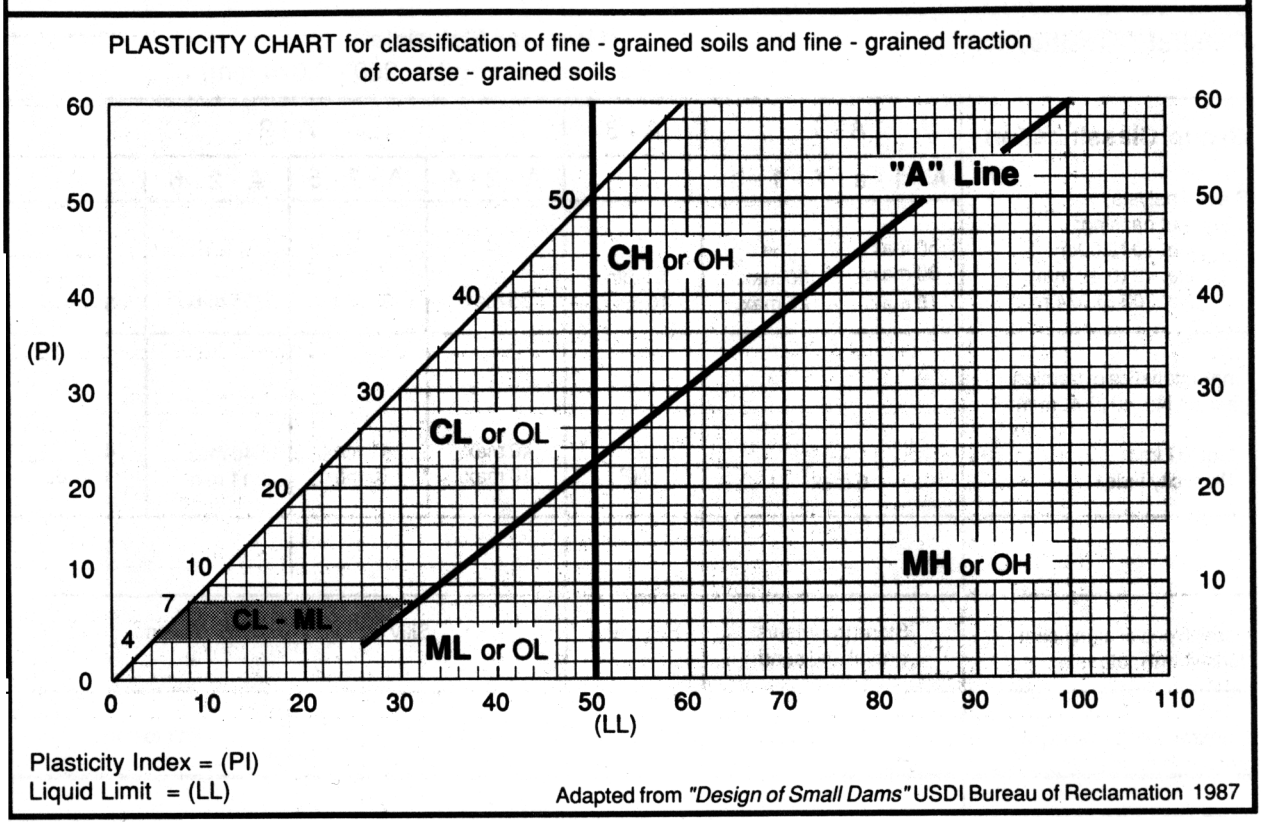
o. PI plots below "A"line.

Adapted from *"Design of Small Dams"* USDI Bureau of Reclamation 1987

Figure 4-13 shows the plasticity chart required for laboratory classification for fine-grained soils or the fine-grained fraction of coarse-grained soils. Atterberg limits and indexes, particularly liquid limit and plasticity index, are used. These are relatively easy to determine in the laboratory and other more significant soil properties correlate well with them. Using the Unified Soil Classification System, the coarse-grained soils with gradation curves shown in Figure 4-6 are classified using laboratory tests as follows for:

curve number 1 - is poorly graded sand
curve number 2 - is well graded sand
curve number 3 - is well graded gravel
curve number 4 - is skip graded sand
curve number 5 - is well graded gravel

FIGURE 4 - 13 PLASTICITY CHART FOR UNIFIED SOIL SYSTEM



AASHTO CLASSIFICATION

The American Association of State Highway and Transportation Officials (AASHTO) System classifies soils according to those properties affecting their use in highway construction. This system places soil in one of seven basic groups ranging from A-1 through A-7 on the basis of grain-size distribution, liquid limit, and plasticity index. See Figure 4-14 for a description of the different classes and the definitions.

Gravelly soils with high bearing strength are the best soils for subgrade (foundation) and classified group A-1. At the other extreme, clay soils that have low strength when wet are classified as A-7. The best soils for subgrade are, therefore, classified as A-1, the next best as A-2, and so on to class A-7, the poorest soils for subgrade. Where laboratory data is available to justify a further breakdown, the A-1, A-2, and A-7 groups are divided into subgroups.

USDA TEXTURAL CLASSIFICATION

This system classifies soil materials into textural classes on the basis of the relative proportions of sand, silt, and clay sizes in the soil fraction that is less than 2.0 mm in diameter.

Soil Particle Sizes

Specific terms are used to describe each size separate or group of particle sizes. Excluding gravel, cobbles, stones, and boulders, soil particles are classified as sand, silt, and clay according to size.

Sand Sand grains (2mm - 0.05mm) are visible with the naked eye and do not stick together well. The pore spaces between sand particles are usually large and continuous. Soils dominated by sand possess good drainage and aeration, and are usually in a loose and friable condition.

FIGURE 4 - 14 AASHTO SOIL CLASSIFICATION SYSTEM

General Classification	Granular Materials (35 percent or less passing No. 200 - 0.074 mm)						
Group Classification	A - 1		A - 3	A - 2			
	A - 1 - a	A - 1 - b		A - 2 - 4	A - 2 - 5	A - 2 - 6	A - 2 - 7
Sieve Analysis; Percent passing:							
No. 10 (2.00 mm)	50 max.	---	---	---	---	---	---
No. 40 (0.42 mm)	30 max.	50 max.	51 min.	---	---	---	---
No. 200 (0.074 mm)	15 max.	25 max.	10 max.	35 max.	35 max.	35 max.	35 max.
Characteristics of fraction passing No. 40 (0.42mm):							
Liquid Limit	---		---	40 max.	41 max.	40 max.	41 max.
Plasticity index	6 max		NP	10 max.	10 max.	11 min.	11 min.
Usual types of significant constituent materials	Stone fragments gravel and sand		Fine sand	Silty or clayey gravel and sand			
General rating as subgrade	Excellent to good					Fair to poor	

General Classification	Silt - Clay Materials (more than 35 percent passing No. 200 - 0.074 mm)				
Group Classification	A - 4	A - 5	A - 6	A - 7	
				A - 7 - 5	A - 7 - 6
Sieve Analysis: Percent passing:					
No. 10 (2.00 mm)	---	---	---	---	---
No. 40 (o.42 mm)	---	---	---	---	---
No. 200 (0.074 mm)	36 min.	36 min.	36 min.	36 min.	36 min.
Characteristics of fraction passing No. 40 (0.42 mm)					
Liquid limit	40 max.	41min.	40 max.	41 min.	41 min.
Plasticity Index	10 max	10 max.	11 min.	11 min.*	11 min.*
Usual types of significant constituent materials	Silty soils		Clayey soils		
General rating as subgrade.	Fair to poor				

*PI of A - 7 - 5 subgroup is equal to or less than LL minus 30.
PI of A - 7 - 6 subgroup is greater than LL minus 30.

Adapted from USDA SCS *"Soil Mechanics Level 1"*, 1985

FIGURE 4 - 15 USDA SOIL TEXTURAL CLASS NAMES AND PERCENTAGES				
General Terms	Basic Soil Textural Classes	Sand Size 2 mm to 0.05 mm percent	Silt Size 0.05mm to 0.002 mm percent	Clay Size < 0.002 mm percent
SANDY	Sand	> 85	< 15	< 10
	Loamy Sand Loamy Coarse Sand Loamy Sand Loamy Fine Sand	70 - 90	< 30	< 15
LOAMY	Sandy Loams Sandy Loam Fine Sandy Loam Very Fine Sandy Loam	43 -85	< 50	< 20
	Loam	23 - 52	28 -50	7 - 27
	Silt Loam	20 - 50	50 - 80	12 - 27
	Silty Clay Loam	< 20	40 - 73	27 - 40
CLAYEY	Silty Clay	< 20	40 - 60	40 - 60
> = more than < = less than				

Silt Silt particles (0.05mm-0.002mm) are between sand and clay in size and in their other properties. The presence of silt and especially clay in the soil, commonly referred to as fines, imparts to it a fine texture and slow water and air movement.

Clay Clay particles (less then 0.002mm) are so small, they can't be seen without a microscope. The pore spaces between the clay particles are very small and frequently are blind pockets.

The amount of each soil separate contained in a soil sample will determine its texture. Figure 4-15 lists the broad and basic USDA soil textural classes that are most commonly used in New Hampshire and the composition of each in terms of sand, silt, and clay. The proportion of various size soil particles determines the name of the textural class. The presence of coarse particles larger than very coarse sand and smaller than 3 inches is recognized by rock fragment modifiers of the textural class names, like gravelly loam or gravelly sandy loam. Classes of still larger particles, cobbles, stones, or boulders, are used as a prefix with the basic textural class, such as fine sandy loam, very stony, or fine sandy loam, extremely stony. A key to USDA texture abbreviations is given in Figure 4-16.

Tips on USDA Texture Identification

Hand texturing is the common field method of determining the class name of a soil. Much can be judged about texture by rubbing it between the thumb and fingers. For hand texturing, the sample is wetted to estimate plasticity and stickiness more accurately. The way a wet soil "slicks out" indicates the amount of clay present. Sand particles are gritty, whereas silt has a floury or talcum powder-like feel when dry. Silt has a buttery-feel when wet, while clay particles feel

FIGURE 4 - 16 KEY TO USDA TEXTURE ABBREVIATIONS					
Modifier	**Abbrev.**	**Texture Class**	**Abbrev.**	**Texture Class**	**Abbrev.**
Channery	cn	very coarse sand	vcos	very fine sandy loam	vfsl
Very channery	cnv	coarse sand	cos	loam	l
Gravelly	gr	sand	s	silt	si
Very gravelly	grv	fine sand	fs	silt loam	sil
Very stony	stv	very fine sand	vfs	clay loam	cl
Extremely stony	stx	loamy coarse sand	lcos	silty clay loam	sicl
Very bouldery	byv	loamy sand	ls	sandy clay loam	scl
Extremely bouldery	byx	loamy fine sand	lfs	silty clay	sic
		sandy loam	sl	clay	c
		fine sandy loam	fsl		

sticky. Determining the soil texture in the field requires skill and experience. Good accuracy can be obtained if frequent checks are made against laboratory results or reference samples.

The basic USDA textural classes in order of increasing proportions of fines (silt and clay), are: sand, loamy sand, sandy loam, loam, silt loam, silty clay loam, and silty clay. The basic class "sandy loam" is modified with the term very fine or fine depending on the dominant size of the sand in the textural class. "Loamy sand" classes are modified with the terms coarse and fine for the same reason.

USDA Texture Identification

The following guidelines are provided for determining texture in general terms and the basic USDA Soil Textural Classes. Figure 4-17 shows a field procedure to identify textures.

Sand
Very gritty
Does not form ball
Does not stain fingers

Loamy Sand
Very gritty
Forms easily broken ball
Stains fingers slightly

Sandy Loam
Moderately gritty
Forms fairly firm ball that is easily broken
Definitely stains fingers but does not ribbon
See Figure 4-18 for using ribbons to aid in determining texture

Loam
Neither very gritty nor very smooth
Forms firm ball
Stains fingers but does not ribbon

Silt Loam
Smooth or slick "buttery" feel
Forms firm ball
Stains fingers and has a slight tendency to ribbon with flaky surface

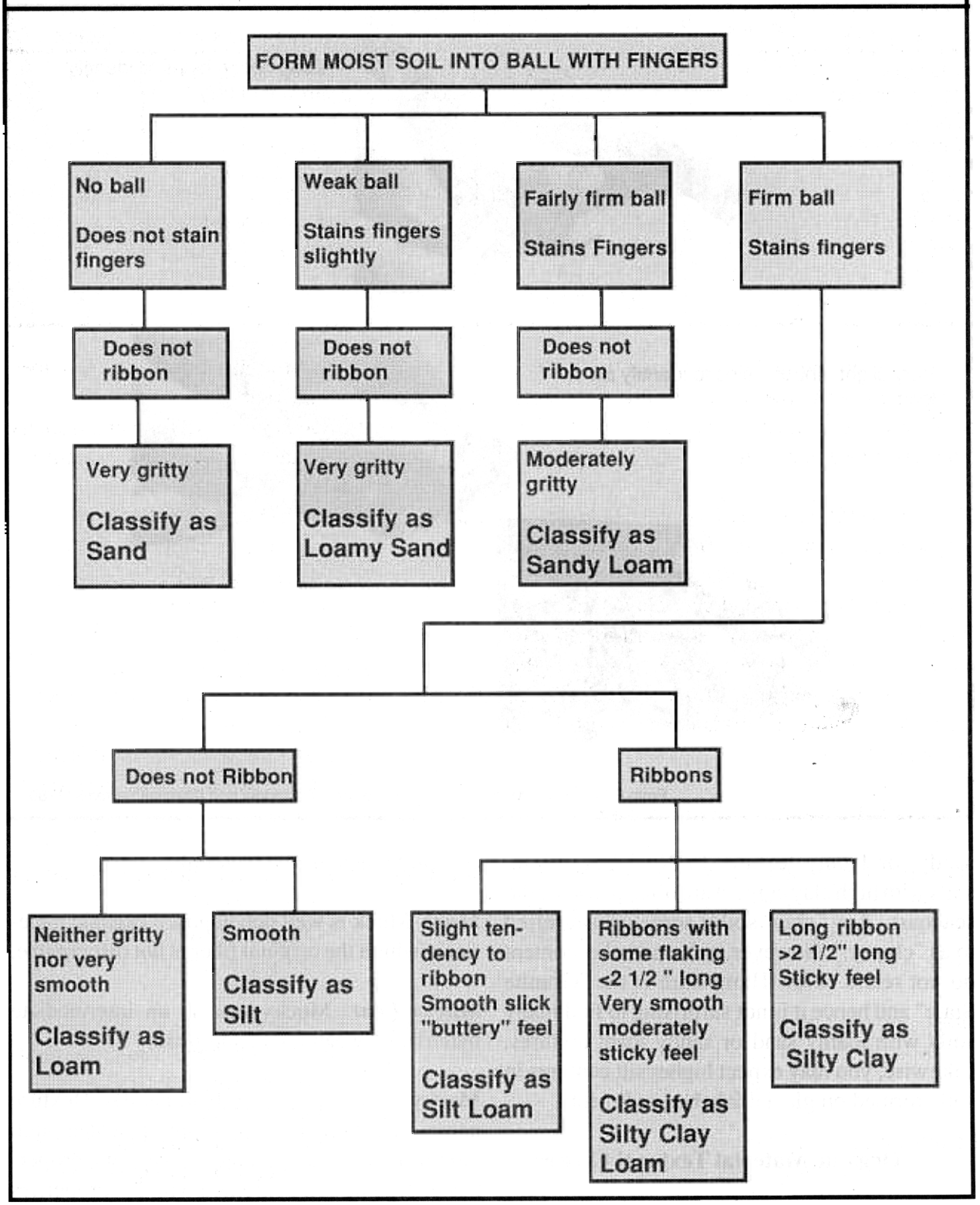
Silty Clay Loam
Moderately sticky, very smooth
Stains fingers
Will ribbon out with some flaking on ribbon surface

Silty Clay
Sticky feel
Forms ball that, when dry, cannot be crushed with fingers
Stains fingers
Squeezes out at right moisture content into a long ribbon

Another guide in chart form is provided in appendix C that also assists in determining texture in the field.

A more accurate and fundamental method used by the USDA for the textural naming of soils is

FIGURE 4 -17 A FIELD PROCEDURE FOR DETERMINING USDA TEXTURAL CLASSIFICATION



based on the mechanical analysis in the laboratory. Figure 4-19 is a guide for the USDA soil texture when the proportions of sand, silt, and clay have been determined in the laboratory. It also can serve as a guide to the field determination or the interpretation of texture once the textural class name is known.

Knowledge of geology and soil-forming factors can help in understanding why a soil has a clayey,

FIGURE 4 - 18 MAKING SOIL RIBBONS TO AID IN DETERMINING USDA TEXTURE

From EPA *"Design Manual, Onsite Wastewater Treatment and Disposal Systems"* 1980

sandy, or loamy texture. In New Hampshire, soils with high clay content are often found by the seacoast. Any "gray" soil is sometimes referred to as "clayey." However, color and clay content do not relate. New Hampshire is the "Granite State" and hence it is not surprising to find many soils with loamy sand or sandy loam textures. Likewise, you may expect higher silt contents in soils formed on glacial lakebed sediments.

Organic Material Textural Classes

The terms peat, muck, and mucky peat are used to classify organic materials in a manner similar to the mineral soil textural classes.

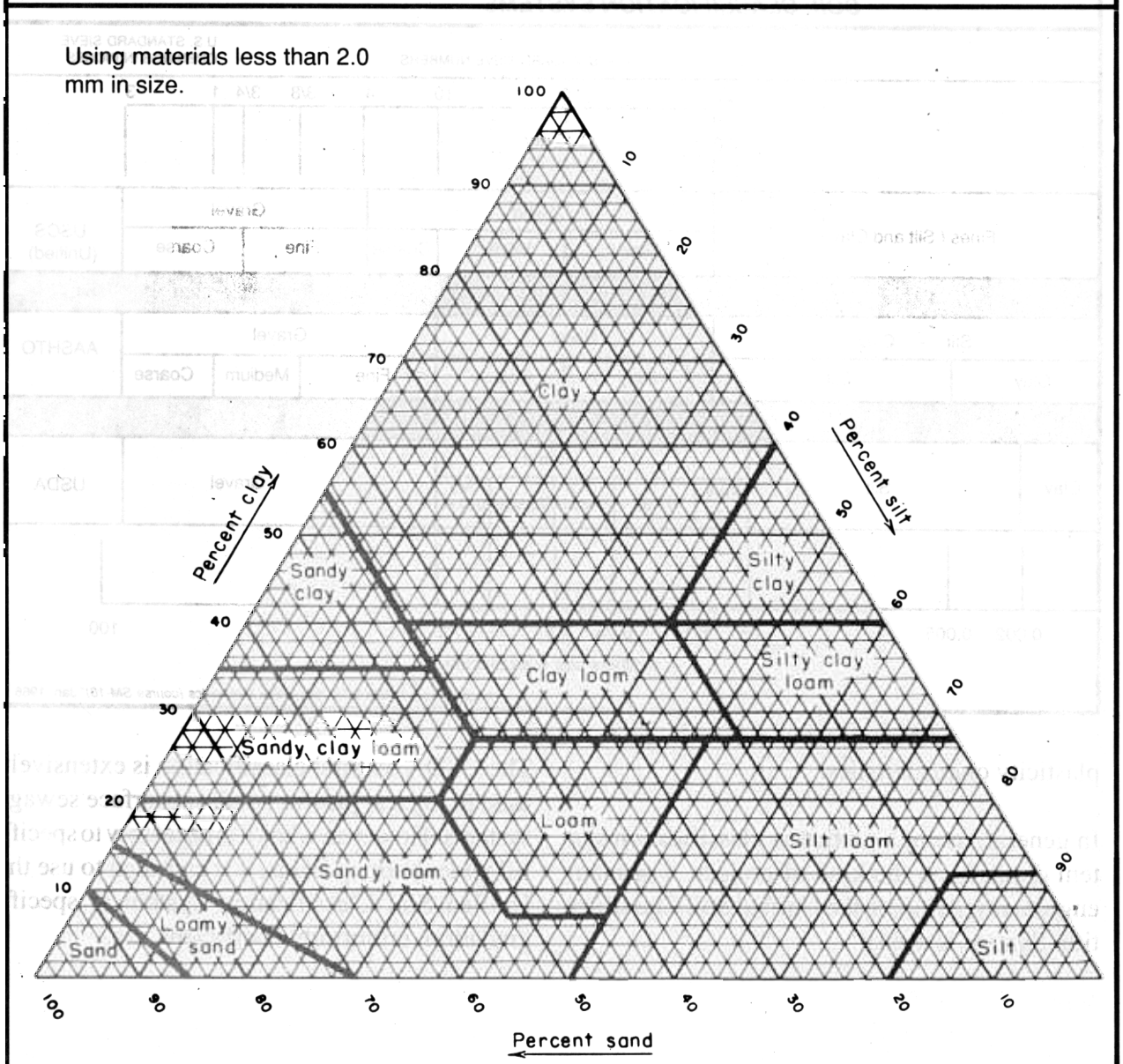
Peat Peat is raw undecomposed organic material in which the original fibers can be discerned and constitute most of the material.

Muck Muck is well decomposed organic material in which the original fiber is not discernable.

Mucky Peat Mucky peat is an intermediate material between muck and peat.

Mucky is also used to modify mineral soil texture names. The term implies the presence of enough organic matter that the material has some properties of organic soil combined with the properties of the mineral material. The material does not have enough organic matter to be "muck". Mucky material is usually dark, friable, and retains moisture, but it is mineral in basic composition. The organic matter content is commonly more than 10 percent.

FIGURE 4-19 GUIDE FOR USDA SOIL TEXTURAL CLASSIFICATION



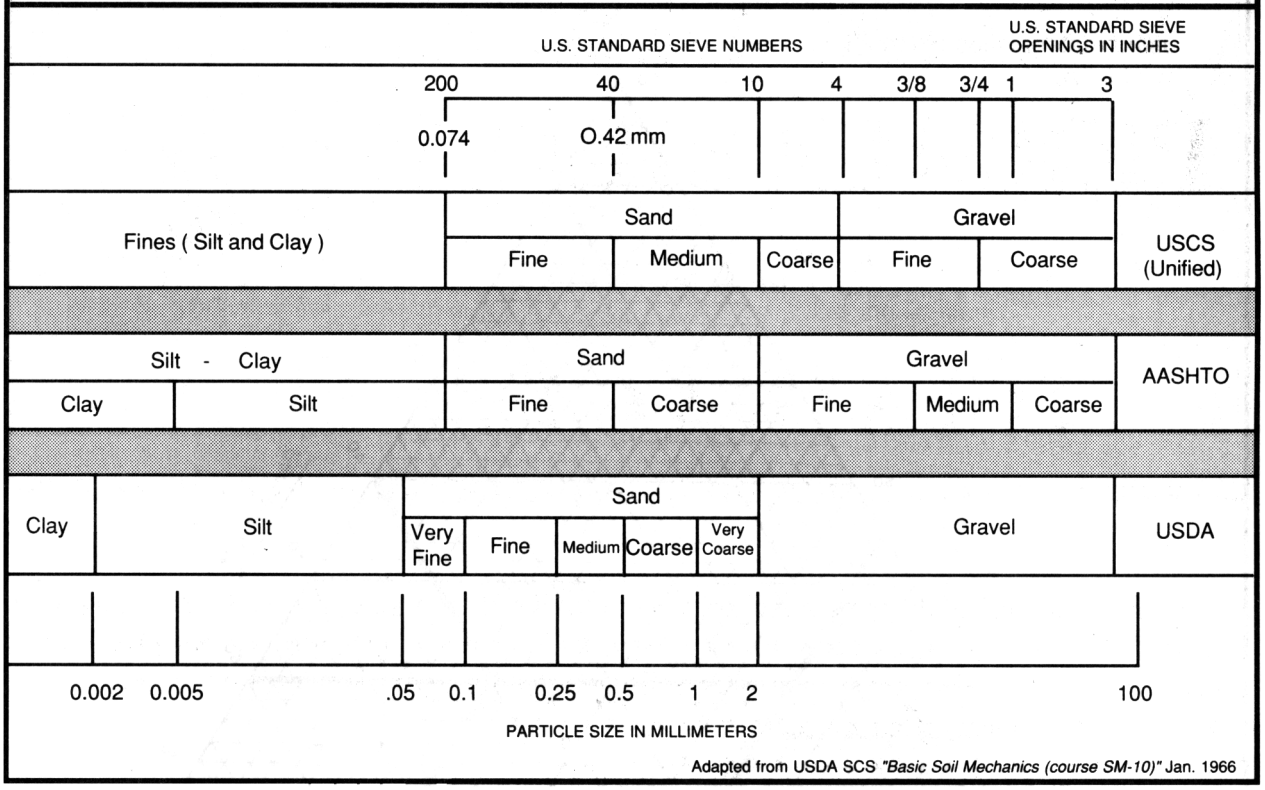
Adapted from USDA SCS *"Soil Taxonomy Handbook," 436* 1975

Descriptions of organic layers include the kinds of organic material and their proportions. It is important to identify and estimate the volume occupied by sphagnum fibers, as they have extraordinary water retention characteristics. When organic material is squeezed firmly to remove water, sphagnum fibers appear lighter in color than fibers of hypnum and most other mosses.

COMPARISON OF SYSTEMS

The differences in the classification systems are important to recognize and understand. The class limits for the various systems are generally based on different grain sizes. Confusion, erroneous data, and misuse result if the classification systems are not clearly defined and understood by users. Since the size of sand, silt, and clay is not uniformly defined in the three classification systems, Figure 4-20 is included for a comparison of grain-size limits. It is important to note that "clay" in the USDA system is based only on size. The classification for "clay" in the Unified and AASHTO Systems is primarily based on

FIGURE 4 - 20 COMPARISON OF RANGE IN PARTICLE SIZES FOR SOIL CLASSIFICATION SYSTEMS



Adapted from USDA SCS *"Basic Soil Mechanics (course SM-10)"* Jan. 1966

plasticity characteristics.

In general, use of a particular classification system depends on the kind of project. For many engineering projects, the Unified Soil Classification System is used.

The USDA textural classification is extensively used to log test pits for small subsurface sewage systems. However, when it is necessary to specify fill under built up fields, it is common to use the Unified Soil Classification System to specify gradation, uniformity coefficient, etc.

WATER TABLE, PERMEABILITY, AND DRAINAGE

5

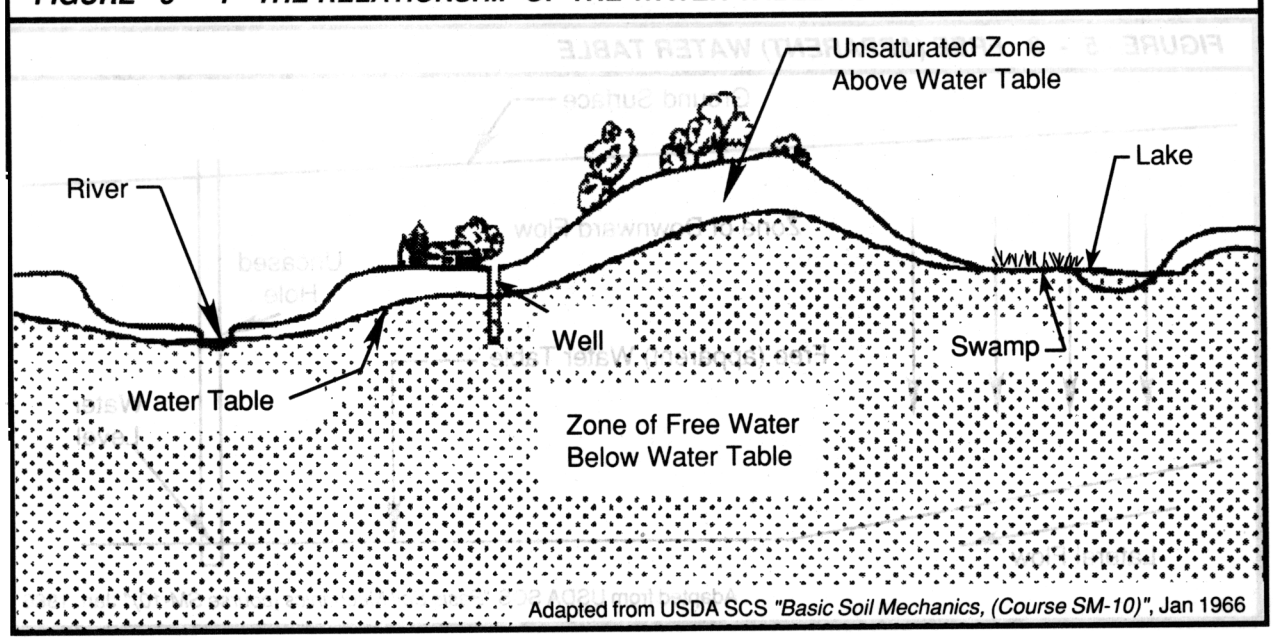
Soil moisture significantly affects the use and behavior of soils for development. It exists as gravitational water and capillary moisture. Soil moisture is particularly important when considering construction of subsurface sewage systems, foundations, roads, and other development.

Permeability is a property of soil that relates directly to gravitational water flow behavior and its impact on development. Soil moisture conditions and permeability directly impact the drainage of soil. Classification of drainage conditions facilitates communication between professionals for planning and for evaluation purposes.

GROUNDWATER AND WATER TABLE

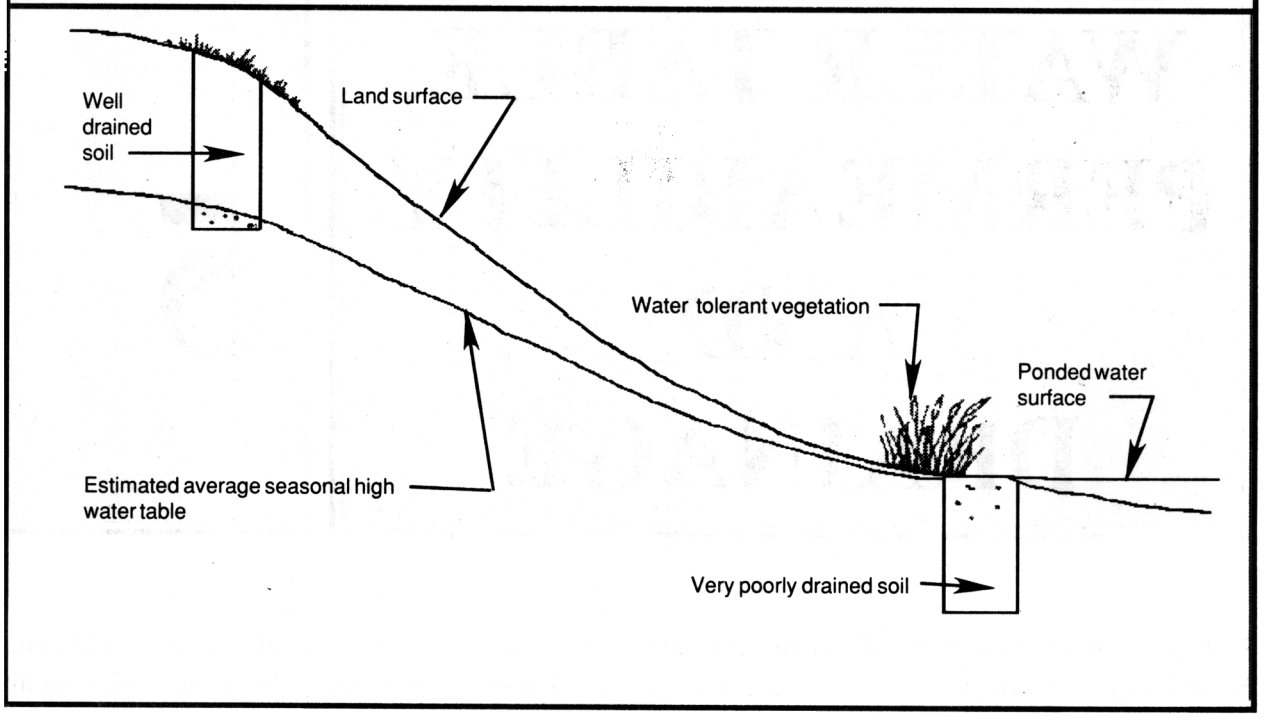
Groundwater is that portion of subsurface water that fills the joints in the bedrock and saturates the surficial deposits up to the free water table. See Figure 5-1. Groundwater is also known as gravi-

FIGURE 5 - 1 THE RELATIONSHIP OF THE WATER TABLE TO THE LAND SURFACE



Adapted from USDA SCS *"Basic Soil Mechanics, (Course SM-10)"*, Jan 1966

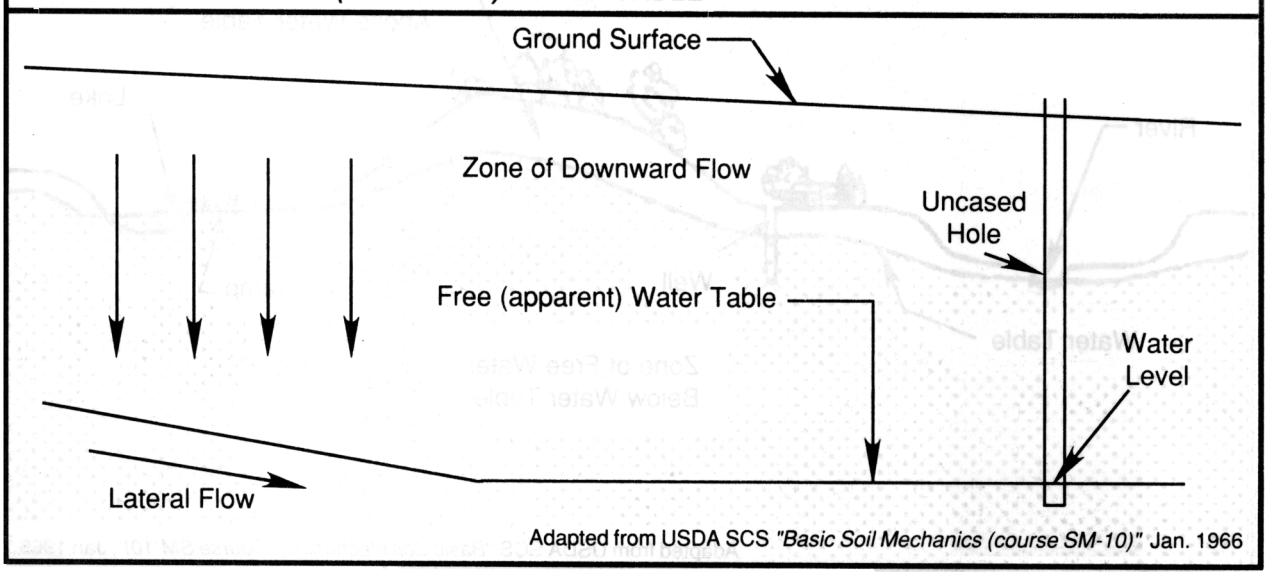
FIGURE 5 - 2 RELATIONSHIP OF SOIL DRAINAGE CONDITIONS AND WATER TABLE



tational water and free water. The water table is the upper surface of this zone of free water saturation. In this zone, water flows laterally under the influence of gravity. The water table surface generally copies the land surface. It is generally deepest beneath hills and is at or near the surface in the lowlands. The depth of the water table is dependent on the drainage conditions of the soil as shown in Figure 5-2. It is deepest for well drained soil and at or near the surface for poorly drained soil. Groundwater occurs under "watertable (unconfined)" conditions if the top of the groundwater body is at atmospheric pressure. It indicates the level water stands in an uncased hole after adequate adjustment time in surrounding soil. See Figure 5-3.

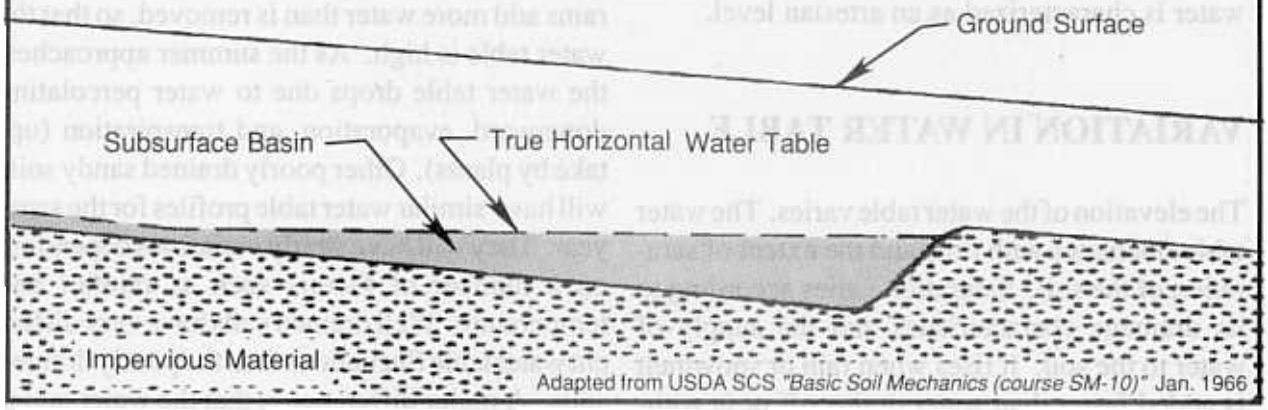
Temporary zones of free water saturation are commonly found very near the soil surface after heavy rains. This occurs where the soil and

FIGURE 5 - 3 FREE (APPARENT) WATER TABLE



Adapted from USDA SCS *"Basic Soil Mechanics (course SM-10)"* Jan. 1966

FIGURE 5 - 4 HORIZONTAL WATER TABLE



Adapted from USDA SCS *"Basic Soil Mechanics (course SM-10)"* Jan. 1966

parent material are of a silt and clayey silt character, and in the spring before the deep frost has left the ground. This temporary zone of saturation may be far above the permanent zone of free water saturation. While it lasts, it behaves like a deeper permanent zone of free water saturation.

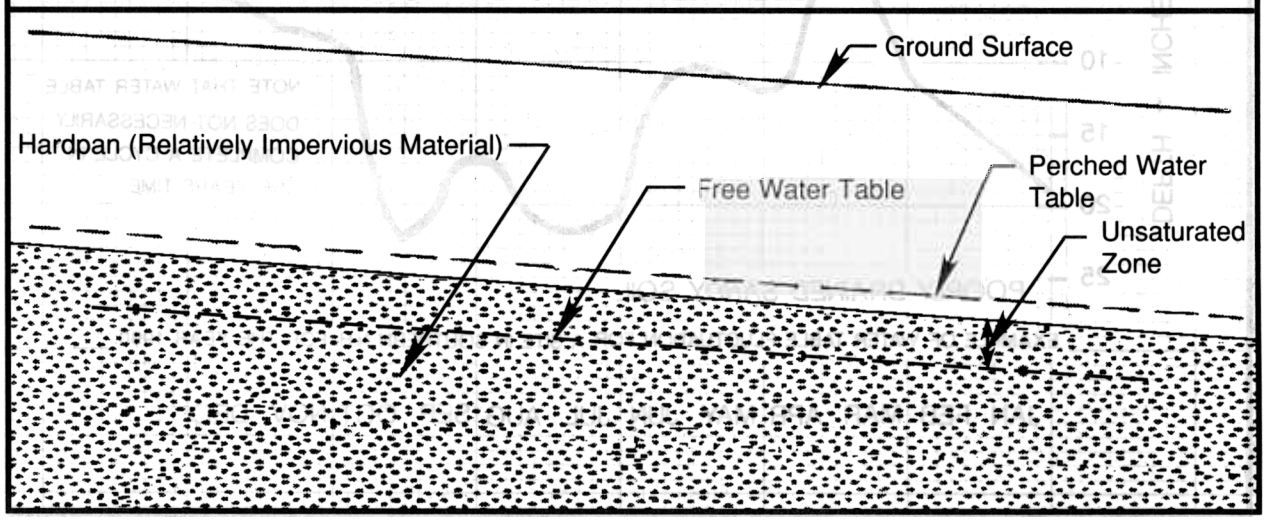
The term water table suggests a horizontal surface. However, this is correct only if there is no lateral movement of water. Normally a water table has a mild gradient and the subsurface water flows down gradient. Water generally must be trapped for the surface to be absolutely level as shown in Figure 5-4.

Groundwater is perched if it is separated from the main water table by an unsaturated zone. The upper surface of this perched zone of saturation is a perched water table. This condition typically develops above a relatively impervious layer which impedes the downward flow of water.

A perched water table may be inferred based on general knowledge of the water levels of an area, the landscape position, the permeability of soil layers, and from other evidence. To verify, it is necessary to observe the water levels in cased wells placed above, in, and below the less permeable layer. If the water in the well above the less permeable layer is consistently higher than the other two, the water table is perched. A perched water table is shown in Figure 5-5. Generally, perched tables are in marine or glaciolacustrine deposits and basal glacial till.

An artesian condition exists when there is a hydrostatic head beneath an impermeable layer.

FIGURE 5 - 5 EXAMPLE OF A PERCHED WATER TABLE



When the impermeable layer is penetrated by a cased hole, the water rises. The final level of the water is characterized as an artesian level.

VARIATION IN WATER TABLE

The elevation of the water table varies. The water table fluctuates with time and the extent of saturation of the soil. Saturation varies according to its drainage characteristics and the supply of water to the soil. It rises when rain or snowmelt is added faster than water drains off or is withdrawn. It falls when the reverse occurs. Water tables in soils fluctuate in a more or less regular manner during the course of a year. Maximum heights in seasonally wet soils can be expected in April in southern New Hampshire, just after the snow melts and the frost comes out of the soil. It persists in the soil from a few days up to about 30 days and is referred to as the seasonal high water table. Refer to Figure 5-6 for an example of water table fluctuation in a soil by season.

In Figure 5-6, the flucuations in the water table for a poorly drained sandy soil are shown for a period of a year. The water table is near the soil surface in early spring when snowmelt and spring rains add more water than is removed, so that the water table is high. As the summer approaches, the water table drops due to water percolating downward, evaporation, and transpiration (uptake by plants). Other poorly drained sandy soils will have similar water table profiles for the same year. They will have yearly variations depending on a number of factors such as rainfall and temperature. Well drained soils have very different water table flucuations than the poorly drained soils. A major difference is that the water tables will be much lower.

Very transient water tables may exist above the average seasonal high water table during spring snowmelt. The maximum depth to the water table can be expected in most years to occur in late September or early October. Besides varying by season, the elevations of the water table vary over a period of years. For instance, in a given year the seasonal high water table may vary significantly from the average established since immediate post glacial time. Refer to Figure 5-7.

FIGURE 5 - 6 EXAMPLE OF WATER TABLE FLUCTUATION

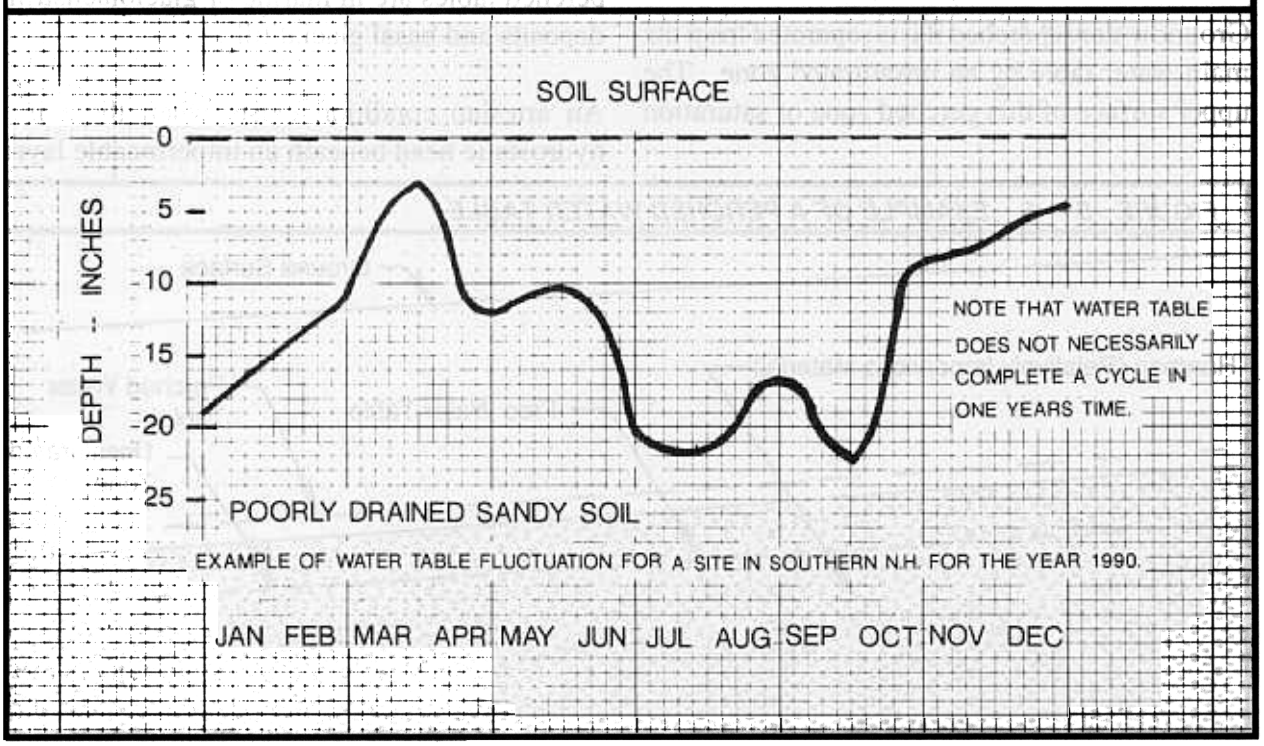
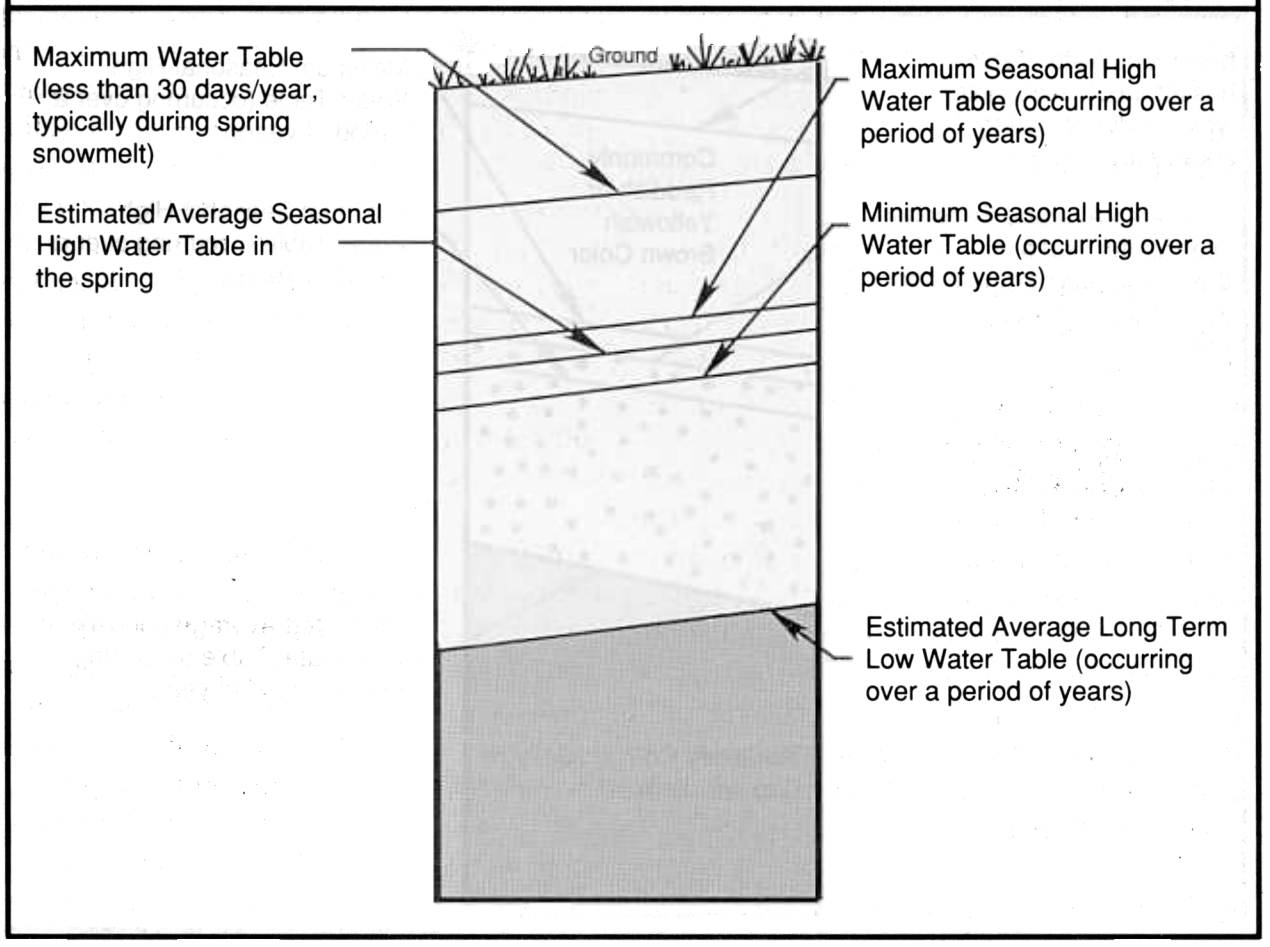


FIGURE 5 - 7 SEASONAL VARIATION IN WATER TABLE



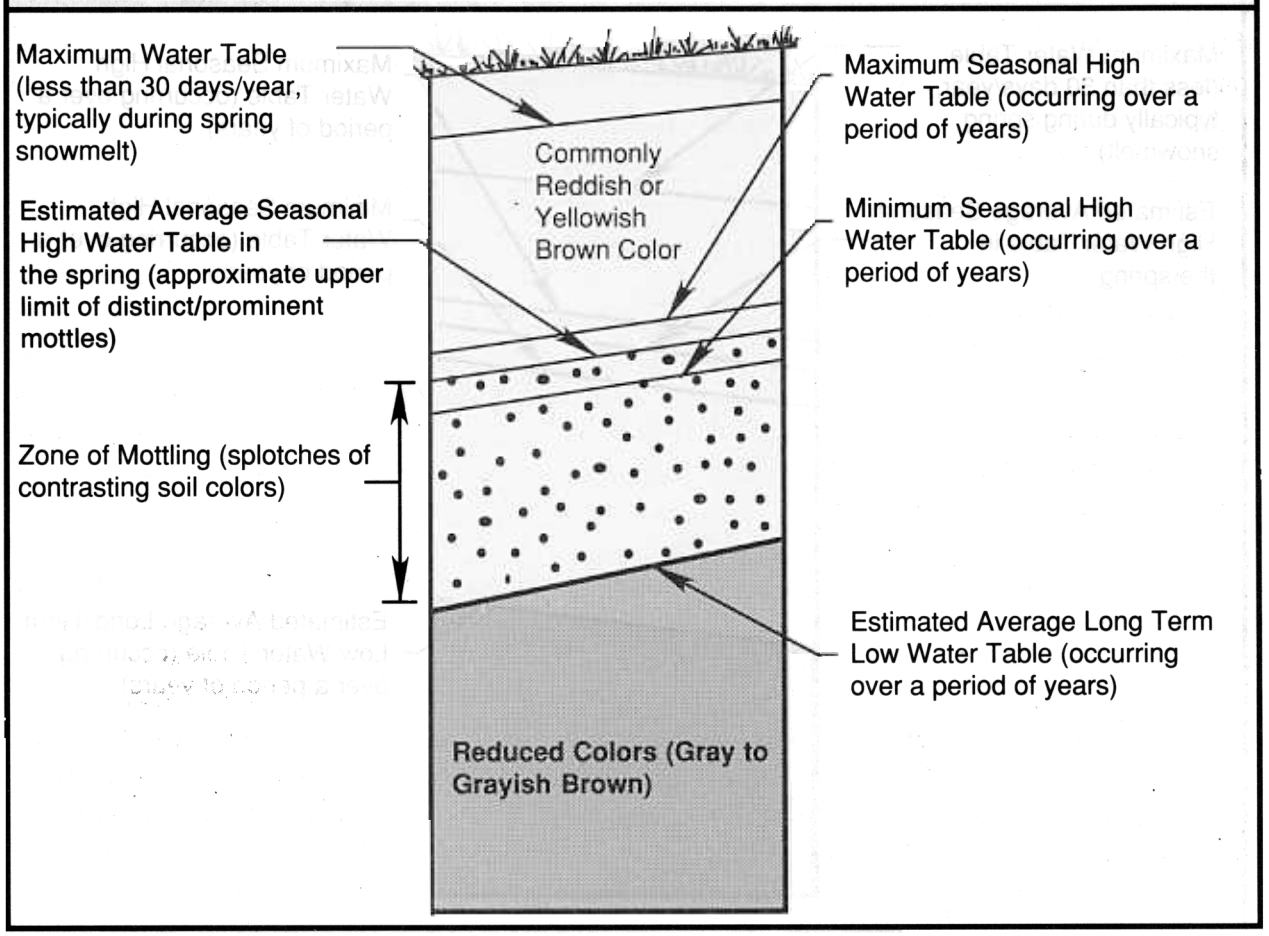
SEASONAL HIGH WATER TABLE

Accurate appraisals of the seasonal high water table are necessary in making site evaluations for subsurface sewage systems and other development construction. Appraisals can be done by directly monitoring soil water table depths over several years, but it is rarely convenient to do so for routine site investigations. A single examination of a site for the presence of soil water is of limited value if this observation is made during summer months when water table levels are low and direct evidence of poor drainage is not readily apparent. A single observation may not indicate the seasonal high water table in the spring either, if conditions at the time do not cause the water table to be at its average seasonal high water table level.

The presence of iron in the soil makes it possible to infer seasonal high water table levels and natural drainage. Inference of soil water tables is possible because when soil is saturated for extended periods, the iron in the soil may form compounds with grayish, bluish, or greenish colors or may be removed from the soil. Removal of iron results in soil color controlled by uncoated sand grains. Either occurence will create grayish soil colors. Both of these effects are the result of reduction of the iron to its divalent state. Reddish, brownish, or yellowish colors in the soil are usually created only when iron is in its oxidized, or trivalent, state. Thus, soil color makes it possible to observe soils in any season and determine whether the soil environment is primarily reducing (gray/blue/green colors predominate), or alternately reducing and oxidizing (mottling, or color "splotching" occurs). Refer to Figure 5-8.

It is important to note that soil colors characterize the relative reduction or oxidation (redox) of the

FIGURE 5 - 8 SEASONAL HIGH WATER TABLE AND SOIL COLOR



soil, but do not directly characterize soil water table levels. An inference is possible because reduction of iron is frequently associated with saturated soil conditions. However, soil redox potential results from a complex interaction of several factors, only one of which is soil saturation. Thus it is possible that a seasonally saturated soil may not display the colors associated with iron reduction because saturation may occur without reducing soil iron.

Microbial activity is the direct cause of iron reduction in soils. During processes associated with microbial nutrition and respiration, trivalent iron may be used as a "deposit" site for the electrons which are the by-products of these processes. When trivalent iron is used as an electron acceptor in this manner, it is reduced to its divalent state. Iron reduction in soil must be preceded by oxygen depletion since oxygen is the preferred, or primary, electron acceptor in microbial energy cycles. Most soil water initially contains some dissolved oxygen. This oxygen source must be consumed (reduced) before iron can be reduced.

Knowledge of these relationships makes it clear that predictions of seasonal soil saturation based solely on the presence, absence, and/or depth to gray colors are often not precise. Several situations could occur in which a saturated soil would not have grayish colors because reduction of iron did not accompany saturation. For example, there may be insufficient soil microbial activity to cause iron reduction. This could happen if a soil had no energy source (usually organic matter) for microbes, or if saturation occurred primarily during winter months when microbes were inactive because of low soil temperatures. Another possibility is a soil saturated for many brief periods during the year. Saturation duration may not be sufficient during any single episode to

allow for depletion of oxygen, so iron would not be reduced. Or a soil may be saturated for much of the year, but topographic or parent material conditions cause a constant supply of well-oxygenated soil water to move into and through the soil. Again, iron would not be reduced, even though the soil was almost always saturated. This may explain the interpretive dilemma created by a few New Hampshire soils, which are known to be poorly drained and yet have reddish brown subsoils.

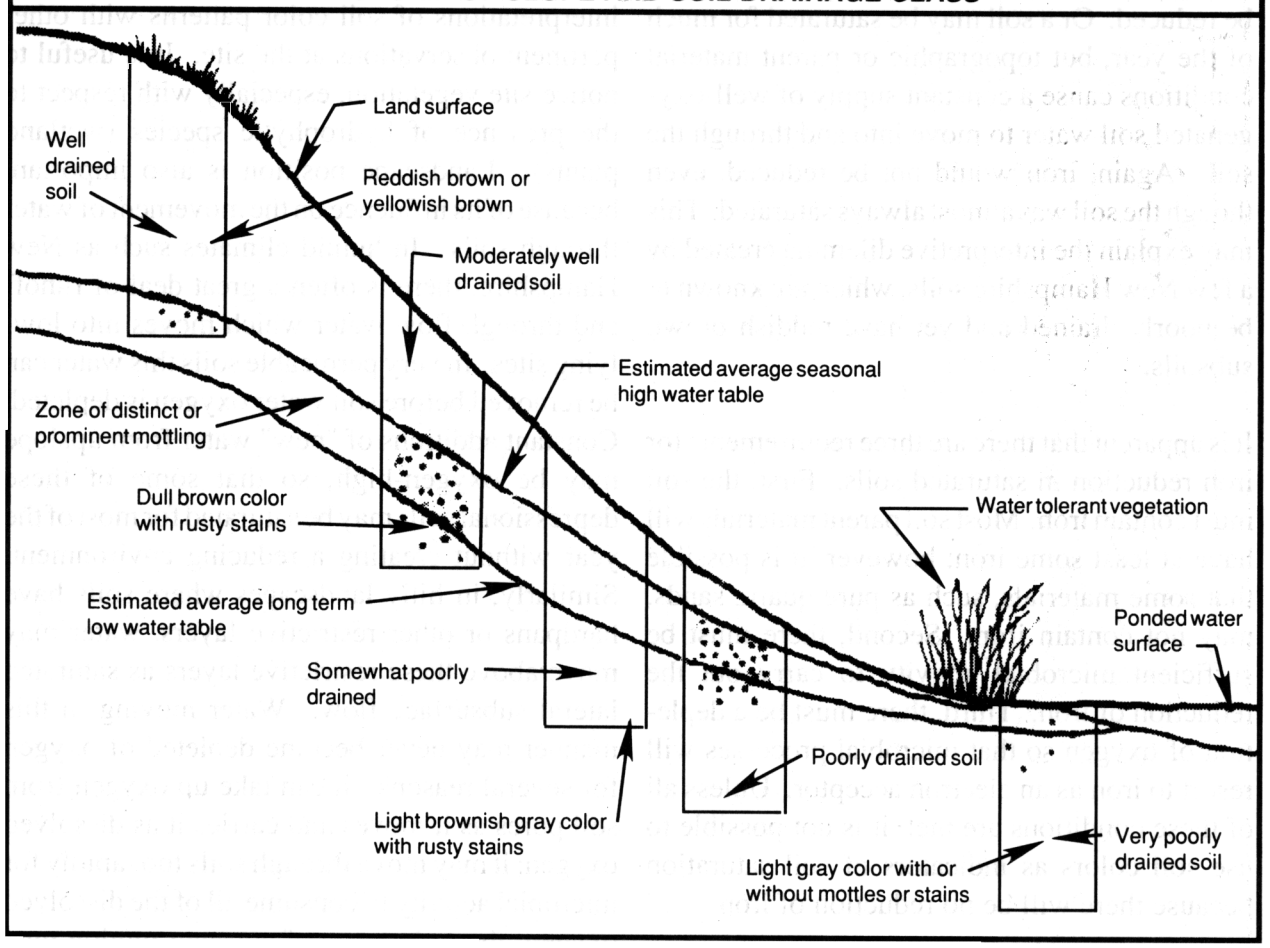
It is apparent that there are three requirements for iron reduction in saturated soils. First, the soil must contain iron. Most soil parent materials will have at least some iron; however, it is possible that some materials, such as pure quartz sands, may not contain iron. Second, there must be sufficient microbial activity to carry out the reduction of iron. Third, there must be a depletion of oxygen so that microbial processes will resort to iron as an electron acceptor. Unless all of these conditions are met, it is not possible to use soil colors as indicators of soil saturation because there will be no reduction of iron.

For the majority of soils, soil morphology is useful in making important land use interpretations. Although these criteria have limitations, some general relationships are quite sound. For example, most studies of water table and soil morphology relationships have shown that grayish colors are consistently useful for relative discrimination between soils of different drainage classes. This means that, within a given landscape, it is reasonable to assume that soils with grayish colors are saturated more often than soils without grayish colors. Also, unless the soil is derived from a grayish parent material (such as phyllite) it is reasonable to assume that gray colors indicate the presence of a water table. They may be considerably below the seasonal high water "mark". So, while gray colors in a soil horizon are almost always a certain indicator of saturation, the absence of gray colors cannot be interpreted as a guarantee that the soil is not saturated.

For the reasons stated, it is prudent to supplement interpretations of soil color patterns with other pertinent observations at the site. It is useful to notice site vegetation, especially with respect to the presence of hydrophytic species (wetland plants). Landscape position is also important because of its influence on the movement of water through soils. In humid climates such as New Hampshire, there is often a great deal of runoff and through-flow water which moves into low-lying sites. In very permeable soils this water can be removed before soil water oxygen is depleted. Constant additions of "new" water from upslope may be oxygen-high, so that some of these depressional soils may be saturated for most of the year without creating a reducing environment. Similarly, in hilly landscapes where soils have hardpans or other restrictive layers, water may move above these restrictive layers as saturated lateral subsurface flow. Water moving in this manner may never become depleted of oxygen for several reasons: it can take up oxygen from soil pores as it moves and carries it as dissolved oxygen; it may move through soils too rapidly for microbial activity to consume all of the dissolved oxygen; the turbulence of constant motion may create some opportunity for aeration. In these situations, if a site investigation is conducted during July or August and if only soil color is considered, the investigator may come to the erroneous conclusion that these soils are rarely or never saturated.

Improvement of our understanding of the relationships between soil water tables, soil aeration, and soil morphology may eventually improve the precision with which soil color can be used to infer soil saturation. Some suggestions for improvement have already been made: use of somewhat redder colors and/or use of small scale "bleached" or eluviated features as indicators of reduction; use of both iron and manganese mottles and coatings; use of both gray and red-brown mottles and their locations relative to soil voids to estimate duration of reduction. Until further data are collected to support these suggestions, those involved in making land use decisions should be

FIGURE 5 - 9 RELATIONSHIP OF SLOPE AND SOIL DRAINAGE CLASS



aware of the limitations of current standards. It is also desirable that professionals conducting site investigations seek to augment their observations of soil color patterns with understanding of soil-forming processes and soil landscape relationships.

PERMEABILITY

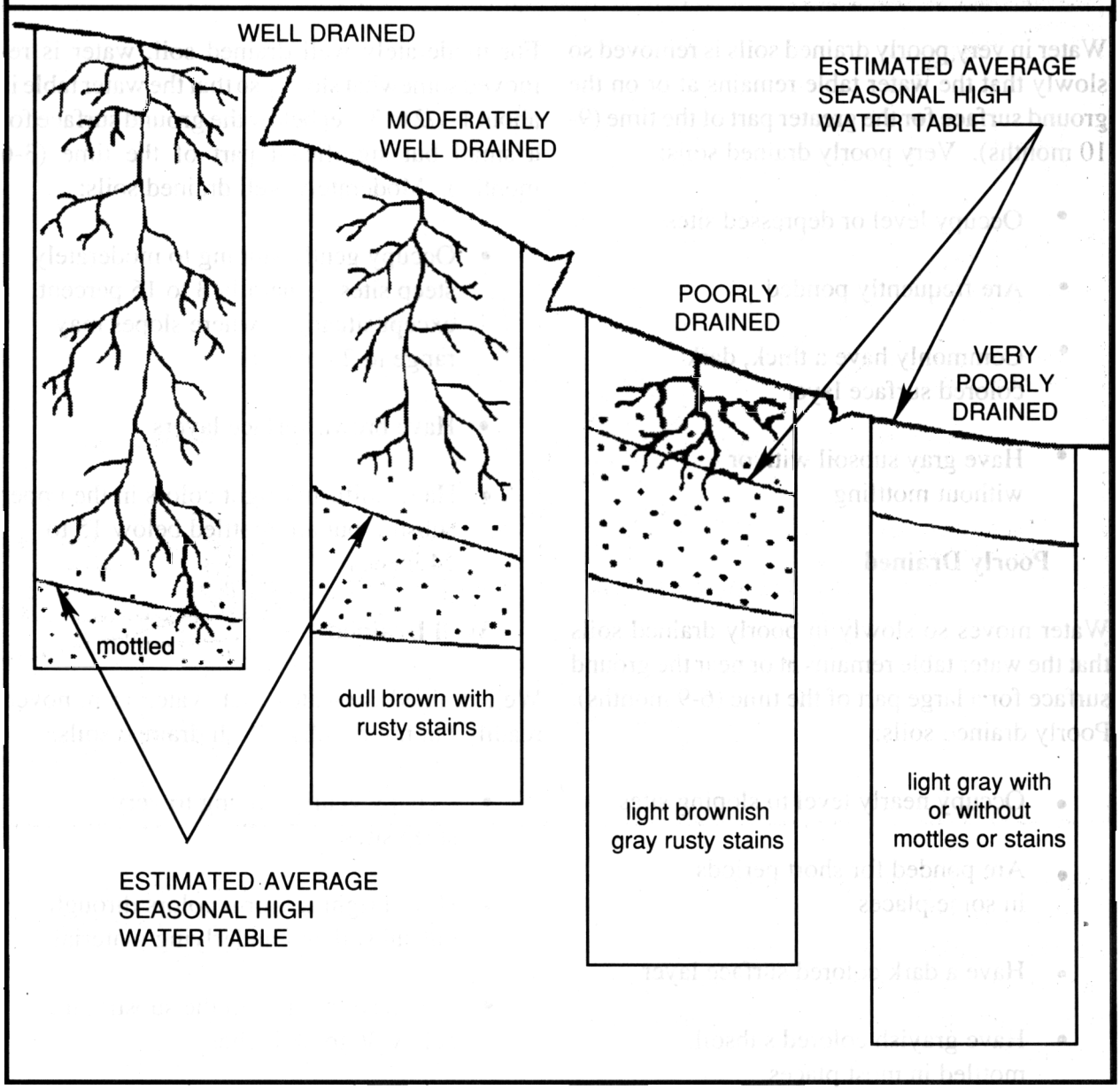
Permeability is the rate of fluid movement in saturated soils. Texture and structure properties have the greatest influence on permeability. Sandy soils transmit water faster than soils with high clay content. Platy structure in a soil layer tends to impede the vertical movement of water and instead directs flow laterally. This can be seen in the spring along road cuts in soils having a dense hardpan. The water tends to move on top of the pan layer and break out in the road cut. Soils with granular structure tend to transmit water vertically. The migration of nutrients and microbes in very porous sand and gravelly soils is a concern in siting subsurface sewage systems.

NATURAL SOIL DRAINAGE

Natural soil drainage refers to the rapidity and extent of the removal of water from the soil by nature. The removal of water by surface runoff and by flow down through the soil is especially important. Soil drainage refers to the frequency and duration of periods when the soil is unsaturated near the surface. The rate of runoff, internal soil drainage, and soil permeability are all qualities that affect the drainage class of a soil. Refer to Figure 5-9.

Runoff, sometimes referred to as surface runoff or external drainage, refers to the relative rate of water removal by flow over the surface. This

FIGURE 5 - 10 SOME NATURAL DRAINAGE CLASSES OF SOILS



includes water falling as rain, snowmelt, and water flowing onto the soil from upslope areas. Runoff is determined mainly by the type of soil, slope, climate, and surface cover.

Internal soil drainage is that quality that permits the downward flow of water through the soil. Internal drainage is reflected in the frequency and duration of periods of saturation with water. It is determined by texture, structure, and the depth to the water table.

Soils can be placed into relative permeability classes for drainage purposes through studies of structure, texture, porosity, cracking, and other characteristics. Commonly, the permeability rate is set by the least permeable horizon in the soil. For example, the movement of water into the surface horizons may be rapid; yet permeability may be slow because of the slowly permeable layer directly beneath the surface layer or beneath the subsoil horizon.

The natural drainage classes range from very poorly drained, which is the wettest class, to excessively drained, which is the best drained condition. Refer to Figure 5-10 in conjunction with the following descriptions.

Very Poorly Drained

Water in very poorly drained soils is removed so slowly that the water table remains at or on the ground surface for the greater part of the time (9-10 months). Very poorly drained soils:

- Occupy level or depressed sites

  Are frequently ponded

  Commonly have a thick, dark colored surface layer

- Have gray subsoil with or without mottling

Poorly Drained

Water moves so slowly in poorly drained soils that the water table remains at or near the ground surface for a large part of the time (6-9 months). Poorly drained soils:

- Occupy nearly level to sloping sites

- Are ponded for short periods in some places

  Have a dark colored surface layer

- Have grayish colored subsoil, mottled in most places

Somewhat Poorly Drained

Water is removed slowly enough so that the soil is wet for significant periods near the ground surface. Somewhat poorly drained soils:

  Occupy nearly level to sloping sites

- Have mottled subsoil above 15 inches, generally with dull colors

- May pond briefly

Moderately Well Drained

For moderately well drained soil, water is removed somewhat slowly so that the water table is about 1-1/2 to 3 feet below the ground surface for a small but significant part of the time (3-6 months). Moderately well drained soils:

- Occupy gently sloping to moderately steep sites (generally 3 to 15 percent, except situations where slopes may range to 25 percent)

- Have brown surface layers

- Have uniform bright colors in the upper subsoil, but are mottled below 15 to 24 inches

Well Drained

Well drained indicates that water is removed readily but not rapidly. Well drained soils;

- Occupy gently sloping to very steep sites

- Have bright uniform colors throughout subsoil and underlying material

- May have mottles in the substratum below 36 to 48 inches

Somewhat Excessively Drained

Water is removed from the soil rapidly. Somewhat excessively drained soils:

- Generally occupy gently sloping to very steep sites

- Have bright colors throughout soil profile

  Generally have no mottling within 65 inches or so

Excessively Drained

Water is removed from the soil very rapidly. Excessively drained soils:

- Occupy nearly level to very steep sites

  Have bright colors throughout the soil profile

  Have no mottling within 65 inches or so

For some soil drainage classes, careful observations for clues to seasonal high water tables are needed in the 5-to 10-foot zone. These include well drained, somewhat excessively drained, and excessively drained soils.

Direct evidence of drainage, or lack of it, may be observed in certain cases. Free water in an unlined hole after reaching equilibrium is evidence of the water table for that date of observation. This can be an indicator of drainage for the soil. However, during the dry summer months direct evidence of poor drainage is not present in many areas. It is possible, however, to predict the natural soil drainage by observing:

  The color and color patterns in the soil profile

- The type of vegetation, i.e., whether the vegetation is hydrophytic (wetland plants) or not

  The position of the soil on the landscape

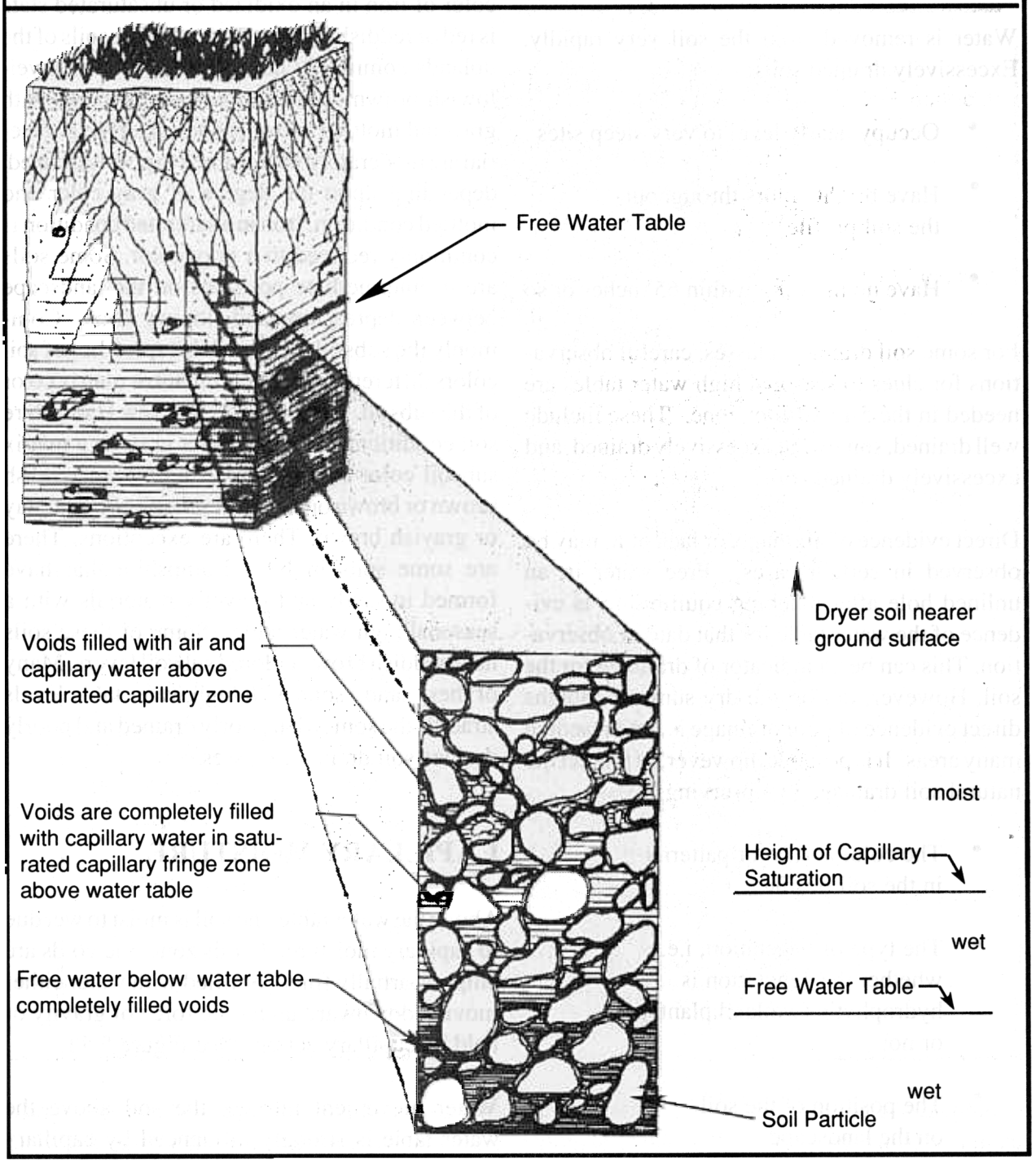
Thus the determination of natural drainage may be partly a matter of direct observation and partly a matter of inference from a large group of observations. The degree of internal drainage, permeability, and the natural drainage class are often indicated by the color and depth to mottling in the soil profile. Soils with bright and uniform colored subsoil and underlying material are commonly considered as naturally well drained. The color of iron in an oxidized or unsaturated state is red or reddish brown. Thus, sloping soils of the uplands commonly have reddish brown or yellowish brown colors in the subsoil. Soils with gray and mottled subsoils and underlying material are moderately well drained to poorly drained, depending upon the degree of gray color and mottled condition. Iron in a saturated condition is commonly reduced to a gray color. Some soils are in intermediate positions on the landscape between depressions and sloping areas. Commonly the subsoil layers exhibit splotches of soil colors different than the dominant or matrix color of the subsoil. Mottle colors for New Hampshire soil conditions often are either gray on a matrix subsoil color of a yellowish brown, or reddish brown or brown on a matrix subsoil color of gray or grayish brown. There are exceptions. There are some soils in New Hampshire that have formed in sandy and gravelly materials with a seasonal high water table. Some of these soils have reddish brown colored subsoil layers. Many of these sandy soils with high water table levels straddle the somewhat poorly drained and poorly drained soil drainage classes.

CAPILLARY MOISTURE

Above the water table, the soil is moist to wet due to capillary moisture. In this zone, the voids are empty, partially filled, or filled with water either moving downward under the force of gravity or held by capillary action. See Figure 5-11.

Water movement through the soil above the water table is strongly influenced by capillary forces. If soil water were subject to only the force of gravity, the soil above the water table would be completely dry. However, capillary forces exist which cause the soil to retain moisture. When the lower part of a dry soil comes into contact with water, the water will rise in the soil to an elevation that is higher than the free water surface. The capillary rise is caused by surface tension which exists in a very thin film of water at the air-water

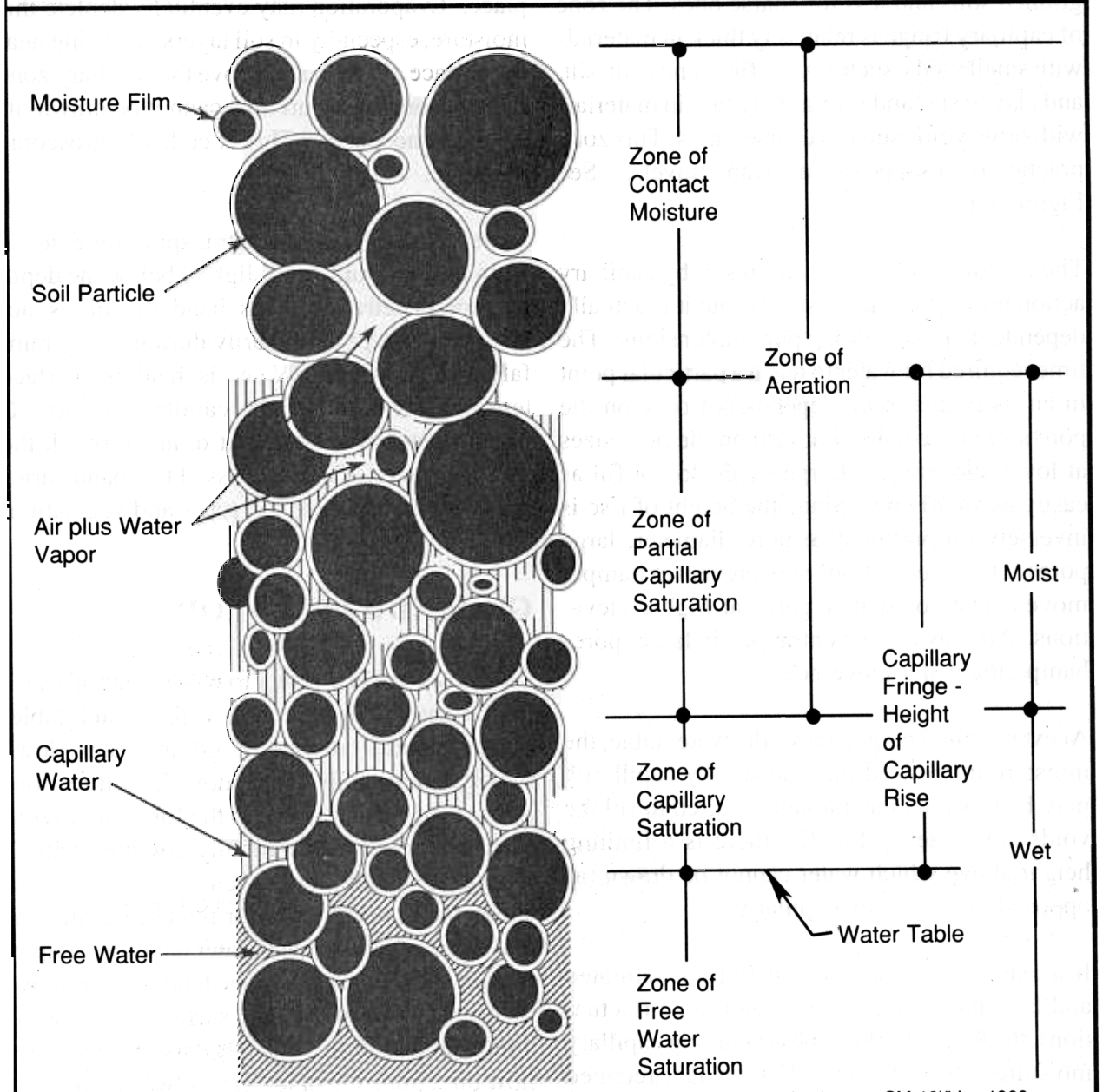
FIGURE 5 - 11 SCHEMATIC DIAGRAM OF WATER IN SOIL AT A GIVEN TIME



contact between soil particles. The interconnected pores or voids of soils act as capillary tubes and connect in all directions forming a capillary network. This network allows the development of moisture above the water table. The moisture retained due to capillary forces is called capillary moisture.

For some distance above the water table, there may be a zone of soil that is saturated, called the zone of capillary saturation. This zone only extends above the water table to the height in which capillary forces are able to fill the voids. This water is continuous with water in the zone of saturation and all capillary size openings may be filled with water with no hydrostatic pressure

FIGURE 5 - 12 SCHEMATIC DIAGRAM OF MOISTURE CONDITIONS IN THE SOIL



Adapted from USDA SCS *"Basic Soil Mechanics (course SM-10)"* Jan 1966

exhibited. At equilibrium, water reaching the capillary fringe by gravity flow will cause the immediate and equivalent discharge of water to the zone of free water saturation. For coarse-grained soils the voids are too large for the capillary saturation to extend very far. Capillary saturation may be an important design consideration for some soils used as receiving layers for subsurface sewage systems.

Another indefinite zone above capillary saturation exists where moisture contents are significantly below saturation. In this zone, the water occupies only the smaller pores and air fills the remainder of the voids. This is the zone of aeration. The combination of these zones is called the capillary fringe. As height above the water table increases, the quantity of moisture tends to decrease. See Figure 5-12.

As the finer soil grain sizes decrease, individual void size also generally decreases. As a result,

the height of capillary rise is larger for fine-grained soils and less for coarse ones. The zone of capillary fringe is relatively thick in materials with small voids, such as very fine sandy silt, silt, and clayey silt; and is relatively thin in materials with large voids such as coarse sands. This zone practically disappears in clean gravels. See Figure 5-13.

The rate of water movement in soil by capillary action may appear to be steady, but it is actually dependent on the varying pore dimensions. The time required for water to reach a particular point in an individual pore depends not only on the pore size at the point, but also on the pore sizes at lower elevations. Large pores do not fill as easily as small ones. Since the height of rise is inversely proportional to pore diameter, large pores at lower elevations may prevent or hamper movement into smaller pores at higher elevations. Air may also be entrapped in larger pores hampering water movement.

At even a small height above the water table, the moisture introduced into the soil by capillarity may be less than the amount required to fill the voids completely. Finally, there is a limiting height above which water cannot be drawn (as opposed to "held") by capillarity.

If a mass of soil has previously been saturated and later partially drained (water table fluctuation), the height of the zone containing capillary moisture will be affected. Water will be retained in many pores that could not be filled by capillary rise. This accounts for high moisture contents common in silts and sands well above the water table. This moisture could not be produced by capillary rise because of the large pores in the soils. See Figure 5-13.

Considerable quantities of capillary moisture in a form known as contact moisture may be present in finer soils. At points where soil grains touch or nearly touch, water percolating downward has a chance to collect. A small amount of water at the point of contact develops a meniscus around the contact and surface tension holds the water in place. Evaporation may eventually deplete this moisture, especially in soil layers occurring near the surface. Within and above the capillary zone there is some moisture that cannot be drawn off by the atmosphere. This is called hygroscopic moisture.

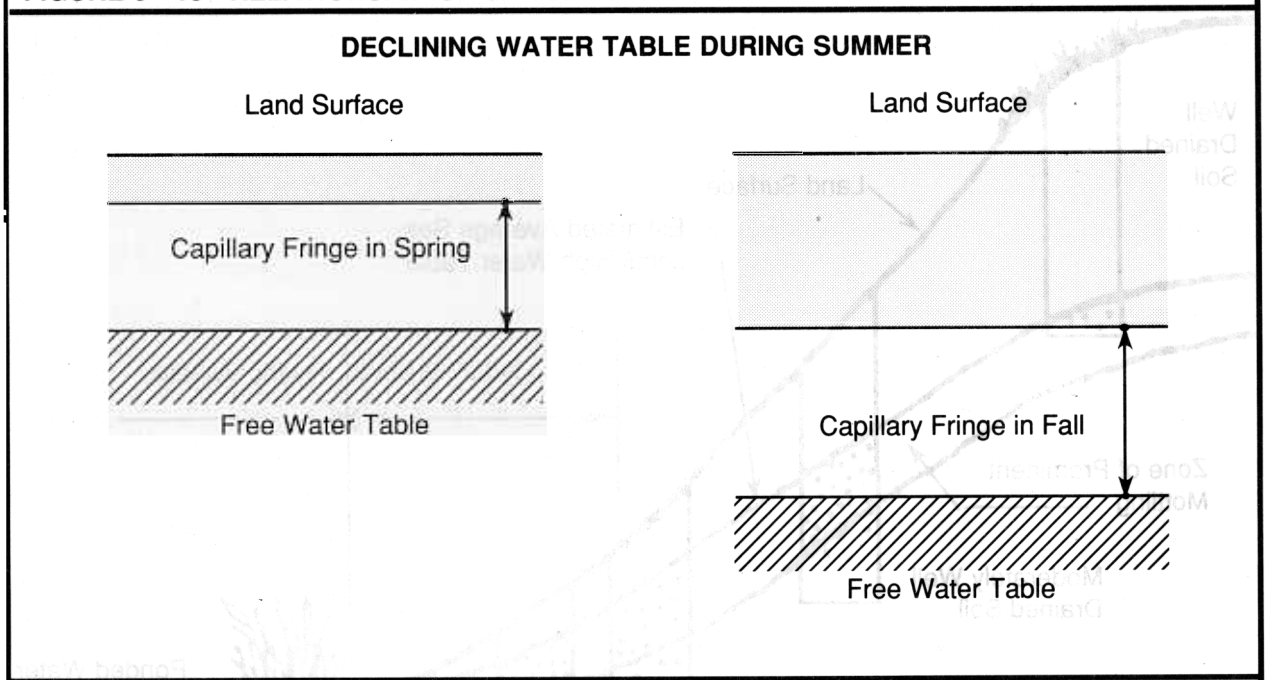
Water available for evapotranspiration extends from the land surface to slightly below the depth of root penetration. This band of soil is not saturated except temporarily during heavy rainfall and snowmelt. Water is held by surface tension and is moved by capillary action. If excess water is available, it drains through the soil by gravity. The thickness of this band varies greatly with different soil types and vegetation.

GROUNDWATER FLOW

Groundwater flow refers to movement of water in the saturated zone below the water table. Under natural conditions, groundwater flows mostly horizontally (in a "downhill" direction) rather than vertically due to the force of gravity. This movement will normally continue until it reaches a surface outlet such as a spring, seep, streambank, marsh, lake, or the ocean. In general, an area's unconfined water table topography mimics the topography of the land surface above it. So the slope of the land surface can serve as a reliable indicator of the regional groundwater flow direction. Complex groundwater flow patterns not following the general slope of the land surface can occur when the flows are confined to cracks and fissures in nonporous rock. Water table topography does not always parallel the surface, particularly for localized areas such as outwash deposits, because soil is not homogeneous.

The general direction of groundwater flow becomes very important when selecting sites for subsurface sewage systems, waste ponds, and waste disposal facilities in relation to wells. These sites should be located downhill from

FIGURE 5 - 13 RELATIONSHIP OF CAPILLARY FRINGE TO SEASONAL WATER TABLE



Typical Value of Capillary Fringe

Surficial Material (Unified Soil Classification)	Height of Capillary Fringe, Inches
Gravels	Zero
Coarse Sand	1/2 - 2
Sand	5 - 14
Fine Sand	14 - 28
Silt	28 - 60

Adapted from USDA SCS *National Engineering Handbook, Section 18,* April, 1968

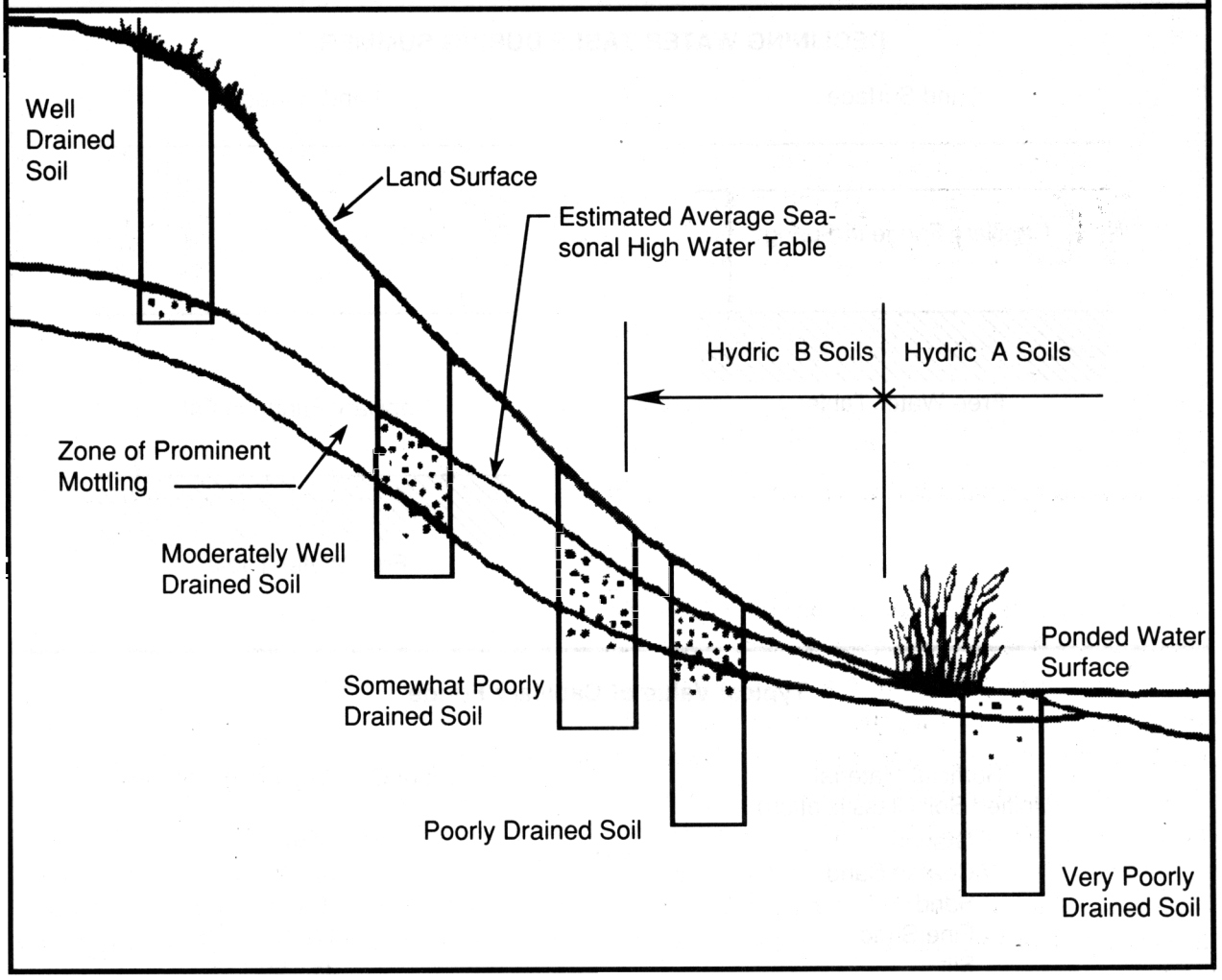
wells when general groundwater flow directions have been determined. In areas with complex flow patterns, the surface topography may not accurately indicate the water table topography. These areas may require a more detailed study to ensure that the subsurface sewage systems are installed downhill from wells.

Groundwater flow rates in a soil consisting of fine sands and silts are often only several inches to several feet per day. This flow is smooth and the water travels along paths that are relatively straight and parallel to each other. However, flow in rocks with fractures resembles flow through pipes and will be much faster and more turbulent. A groundwater aquifer with a very slow flow rate could allow a potential contaminant to pollute the water for a long period of time before it is detected in a nearby well or outlet.

HYDRIC SOILS

Hydric soils are those that meet the soil criteria for the federal definition of wetlands. For an area to be a wetland by federal definition the area will, in most cases, have to exhibit wetland plant criteria (hydrophytic plants) and have evidence of ponding, flooding (hydrology) or saturation. The area will have to exhibit wet conditions in the upper part of the soil for a given period of time during the growing season (hydrologic criteria). Hydric soils have very definitive terms and measureable standards to qualify for the hydric desig-

FIGURE 5 - 14 DRAINAGE CLASS AND HYDRIC SOILS



nation. As a general rule though, most soils that are identified as poorly or very poorly drained are hydric soils. A few somewhat poorly drained soils may also meet the hydric soil criteria. Onsite investigation is needed to determine whether or not a soil is hydric and to determine exact boundary lines. Refer to Figure 5-14. Hydric soils are saturated with water in the upper part of the profile long enough during the growing season to have anaerobic conditions and are capable of supporting hydrophytic vegetation. Hydric soils have a very specific definition because of the use by regulatory authorities. Proposed land use changes may involve the jurisdiction of a government agency concerning wetlands. Therefore, a proposed land use change should consider whether or not hydric soils occur on the site.

The state of New Hampshire, Department of Environmental Services (DES), Water Supply and Pollution Control Division has adopted hydric A and hydric B soils for receiving layer requirements for subsurface sewage systems. Hydric A and hydric B soils are very similar to hydric soils as defined by the federal government. The hydric A soils are wetter than the hydric B soils and correspond roughly to very poorly drained soils. Hydric B soils correspond for the most part with poorly drained soils.

SOIL SURVEYS 6

A soil survey provides information about the soil resources of a particular area of land. At a minimum, it is composed of three main parts: a soil survey map, a soil legend with symbols for identifying soil areas, and descriptive and/or interpretive information about the soil. Many types of soil surveys are being made throughout the world today that serve a wide variety of purposes and uses. The soil maps that are produced as part of the soil survey show different kinds of soils and portray their location, distribution, and extent. To a large extent, the scale, accuracy, and detail of the soil maps dictate the amount of descriptive and interpretive information that can be provided about the soil.

Conversely, the amount of interpretive information required for a particular parcel of land will dictate the scale, accuracy, and detail of the soil map needed in order to provide the required information.

SOIL MAPS

Soil maps fit into three broad categories:

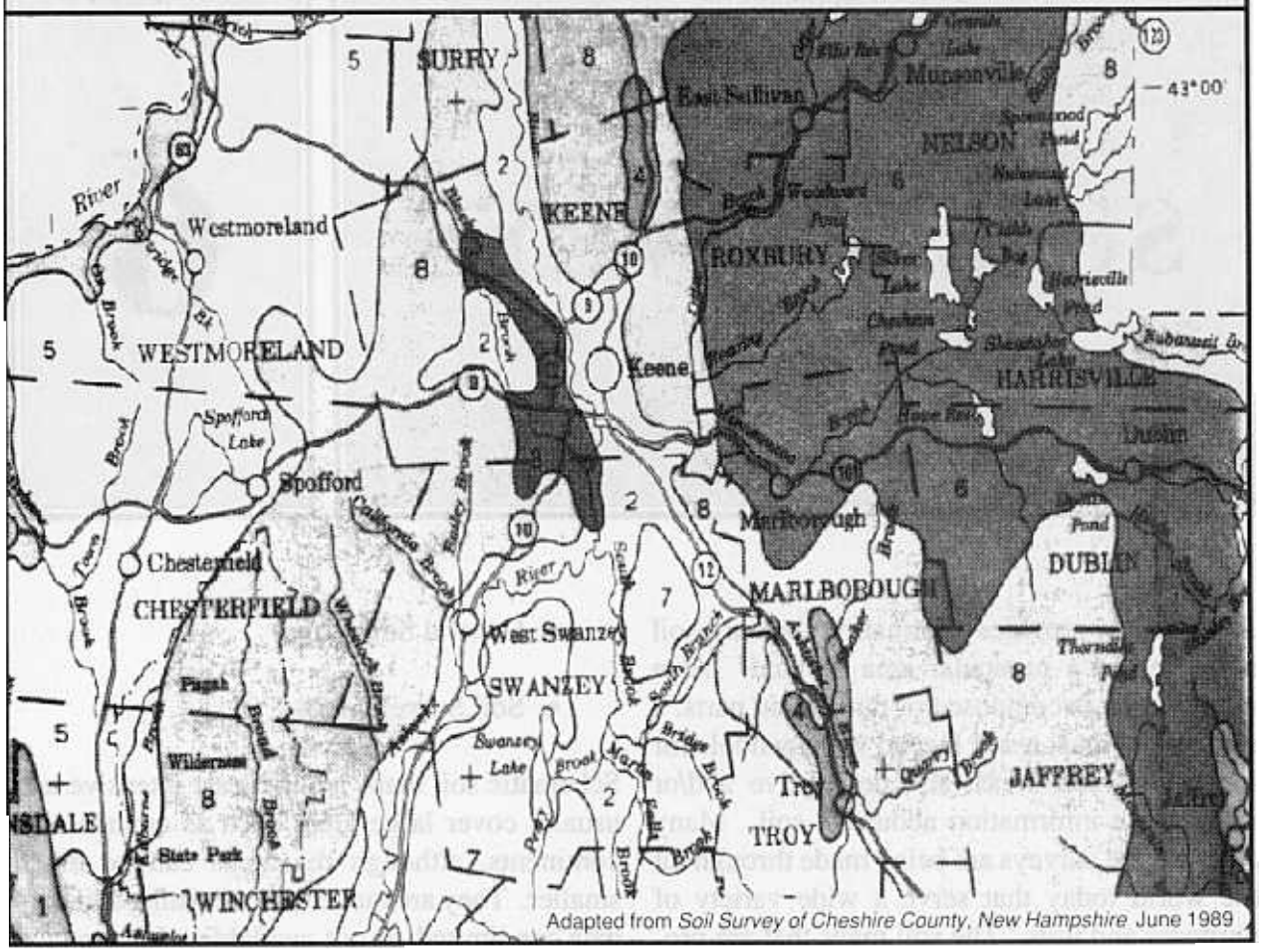
- Schematic Soil Maps
- General Soil Maps
- Soil Survey Maps

Schematic soil maps are the least intensive and usually cover large areas such as countries or continents, although the areas can be much smaller. They are made where existing soil map data are limited or not available. Information available on vegetation, climate, geology, and topography is used to help identify the soil resources on a broad scale.

General soil maps are prepared by combining or grouping delineations of similar soil types from more detailed soil survey maps. The general soil map provides information on broadly defined soil areas within large geographical areas such as states or counties. A partial copy of a general soil map is shown in Figure 6-1.

Soil survey maps are the most commonly used soil maps. They are made by soil scientists who make field observations and conduct actual investigations of the soils in place on the landscape. Representative soil samples are often collected in the field and sent to soil survey labs for analysis. The scope of the sampling project and kinds of

FIGURE 6 - 1 A GENERAL SOIL MAP



Adapted from *Soil Survey of Cheshire County, New Hampshire* June 1989

soil analysis run on samples are determined by the size of the survey area, scale and detail of mapping, intended or projected land use, and the character of the soils in the area.

Like all maps, soil maps have both merits and limitations which are generally governed by map scale and intended use. For example, a family about to make an automobile trip from Concord, New Hampshire, to San Francisco, California, to visit relatives does not select a road map at a scale of 1 inch equals 1 mile to plan their trip. They will outline their route on a road map of 1:7,500,000 scale (1 inch equals 118 miles) or smaller to determine which states to travel through.

As they travel through each state, they will select a state road map of about 1:500,000 scale showing major roads and highways. When the family reaches San Francisco, they will need a still more detailed city map with a scale of about 1:70,000 to show the individual streets, etc.

Finally, the travelers may wish to consult a sketch map at 1:5,000 scale to show the location of the house they are looking for.

The same principle of scale and use compatibility applies to soil maps. What can be shown on a soil map depends primarily on its scale. In designing soil surveys, the anticipated major use of the survey, and the complexity of the soil pattern control the selection of map scale.

Soil patterns on the ground are fixed—they do not change. What one sketches on air photo base maps is not a perfect representation of the soil pattern on the ground. Soils continually grade from one to another and are not always in bodies large enough to delineate at the map scale used.

The soil map is designed to provide the information and accuracy needed for defined uses. A 1:24,000 soil map provides the necessary data for most general land use planning purposes, such as zoning and community planning. However it does not provide enough information for all uses. The smallest soil area shown at this scale is 3 to 5 acres in size.

If soil areas as small as one quarter acre need to be identified, mapping could be at 1:1,000 scale or larger. However, if areas with a minimum size of 40 acres are to be delineated, a 1:63,360 scale map (1 inch equals 1 mile) will suffice.

It is important to recognize the different types of soil surveys and soil maps to know their merits and limitations, and to understand the relationship of map scale, map accuracy, and map detail. When these concepts and principles are considered, soil maps can be extremely valuable to both planners and users of small tracts of land, farms, communities, states, and nations.

SCALE, ACCURACY, AND MAP DETAIL

When using soil maps, one must remember that scale, accuracy, and detail are not the same. Map scale is the relationship between corresponding distance on a map (a piece of paper) and the actual distance on the ground. Map accuracy is the precision with which map information is obtained, measured, and recorded in relation to specific standards. Map detail is the amount of information per unit area shown on a map. The more information, the more detailed the map. Map detail is not related to accuracy or map scale.

Obtaining information that provides sufficient data for the purpose of making the map is more important than scale. Regardless of scale, soil maps must meet standards of accuracy if they are to be useful. Map data must lend itself to predicting soil behavior for the intended use. The degree of refinement of soil maps depends mainly on the objective or purpose for making the soil map and the complexity of the soils on the ground.

Although large-scale maps are not intrinsically more accurate or more detailed than small-scale maps, they can and frequently do show more detail than small-scale maps. The accuracy of the maps is determined largely by the procedures used as well as the knowledge and skills of the mapper. It is easier to accurately map areas of less complexity than areas of great complexity.

SOIL SURVEY MAPS

In New Hampshire, soil survey maps are prepared at four levels of mapping detail. The USDA Soil Conservation Service in New Hampshire produces three levels of detail, called mapping orders.

The fourth level, and most detailed, are various large scale soil survey maps prepared by soil consultants. They provide highly detailed maps for development including fulfilling ordinance requirements and subdivision regulations. Examples of this level of mapping are the highly detailed high intensity soil maps discussed in Chapter 8.

In the United States, the National Cooperative Soil Survey has five levels of soil survey maps designated as Orders 1 through 5. Order 1 maps provide the most information about the soils of a given area of land and Order 5 maps provide the least information. In New Hampshire, however, only three orders are used. Order 1 maps are made for special purposes such as intensive crop management or for experimental plots. Orders 2 and 3 are used by the National Cooperative Soil Survey for published soil survey maps. Most of the nonfederal land in the state has soil survey map coverage at one of these two orders.

Order 1 Soil Survey Maps

These maps have scales larger than 1:12,000. At

1:8,000 scale (1 inch equals 666 feet) the minimum size delineation is about 0.5 acre. Order 1 soil maps are used to appraise the soil resources of small areas such as farmsteads, experimental plots, or building sites.

Soil with observed properties that affect potential use, but are too small to be delineated, are normally shown by a specially defined spot symbol. Spot symbols used at this scale of mapping commonly identify areas of small wet soils, sandy or gravelly spots, or an area of rock outcrop. Mapping is generally done on a recent air photo base.

Order 2 Soil Survey Maps

These maps have scales of 1:12,000 to 1:31,680. At these scales (1 inch equals 1,000 feet to 2,640 feet), the minimum size delineation is 1.5 to 10 acres, respectively. Order 2 soil survey maps provide soil resource information needed for general land use planning purposes for community development or for conservation planning in agricultural areas. Order 2 surveys are designed for areas that require intensive management. As in Order 1 soil surveys, onsite investigations are advocated when a particular site is selected for a specific land use.

Soil scientists identify and map the soils by systematically transecting and traversing the land. Soil boundaries for Order 2 maps are plotted by observation and interpretation of air photos. These boundaries are verified at closely spaced intervals. Small areas of contrasting soils are included and some are shown by defined spot symbols.

Order 3 Soil Survey Maps

These maps are produced at similar scales as Order 2, but with less detail. Order 3 soil survey maps are produced in remote, heavily forested regions with high relief where use and management are not intensive. Order 3 soil surveys are valuable in evaluation of regional area potential and/or limitations for forestland management, recreational development, or management for wildlife habitat.

In New Hampshire, Order 3 surveys have been conducted in Grafton, Carroll, and Coos Counties. Published soil surveys of these counties contain combined Order 2 and Order 3 soil survey maps depending on the intensity of land use and projected land use trends. Map symbols and map unit interpretations reflect the different levels of mapping detail. Chapter 7 discusses soil survey in more detail.

MAP UTILITY

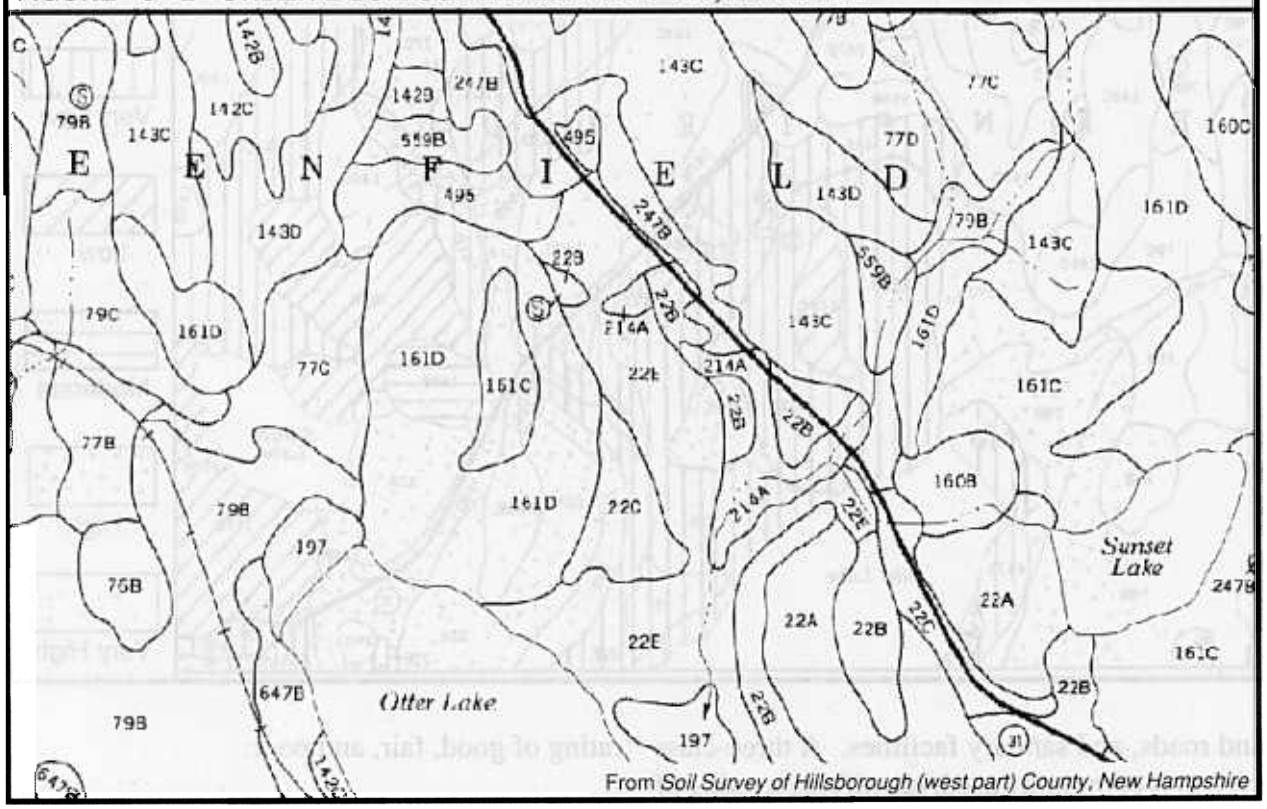
Soil maps are a very useful tool in planning the use and development of a tract of land. Soil maps, however, must be used within the purposes for which they were designed.

The generalized soil map of New Hampshire at 1:250,000 scale is useful for planning the broad use of soil resources. It should not be used to locate soils or to determine soil suitability of individual fields or for community development. As an example, the generalized soil map of Cheshire County at 1:253,440 scale, is useful in assessing proposed routing of highways or underground utility lines. It should not be used for site plan reviews or making decisions regarding urban development.

An Order 3 soil survey map at a scale of 1:20,000 is useful for forestland management and predicting yields of forestland products over broad areas. It should not be used for comprehensive land use planning or conservation planning on farmland.

An Order 2 soil survey map at a scale of 1:20,000 is useful for planning fields, farms, subdivisions, and communities. It is not useful, however, for planning 1 acre house lots or 0.1 acre research plots. See Figure 6-2 for an example of an Order 2 soil map.

FIGURE 6 - 2 ORDER 2 SOIL SURVEY MAP AT 1 : 20,000 SCALE



From Soil Survey of Hillsborough (west part) County, New Hampshire

Many landscapes consist of soils with very complex patterns. Soil differences often occur within short distances. In some instances, however, the soils grade imperceptibly to other soils. Because of this, the soil units, even on a large-scale soil survey map, are not absolutely homogeneous or pure. Thus, onsite investigations are needed for specific small land area uses.

Possibilities of misuse occur when soil maps are enlarged or "blown up" to larger scales. This does not result in more detailed or accurate maps. In fact, "blown up" maps can be misleading because more detail could be shown at larger scales.

Soil survey maps at 1:20,000 scale "blown up" to 1:12,000 are no more accurate or detailed than the original 1:20,000 maps.

Quite often, the information on soil maps is transferred to other base maps, often at different scales. This may diminish the new map's accuracy, especially if the base map is not planimetrically correct, and more so if the scale is larger than the original soil survey map. An example is transferring a 1:20,000 soil survey map to a larger scale, 1:12,000 town map.

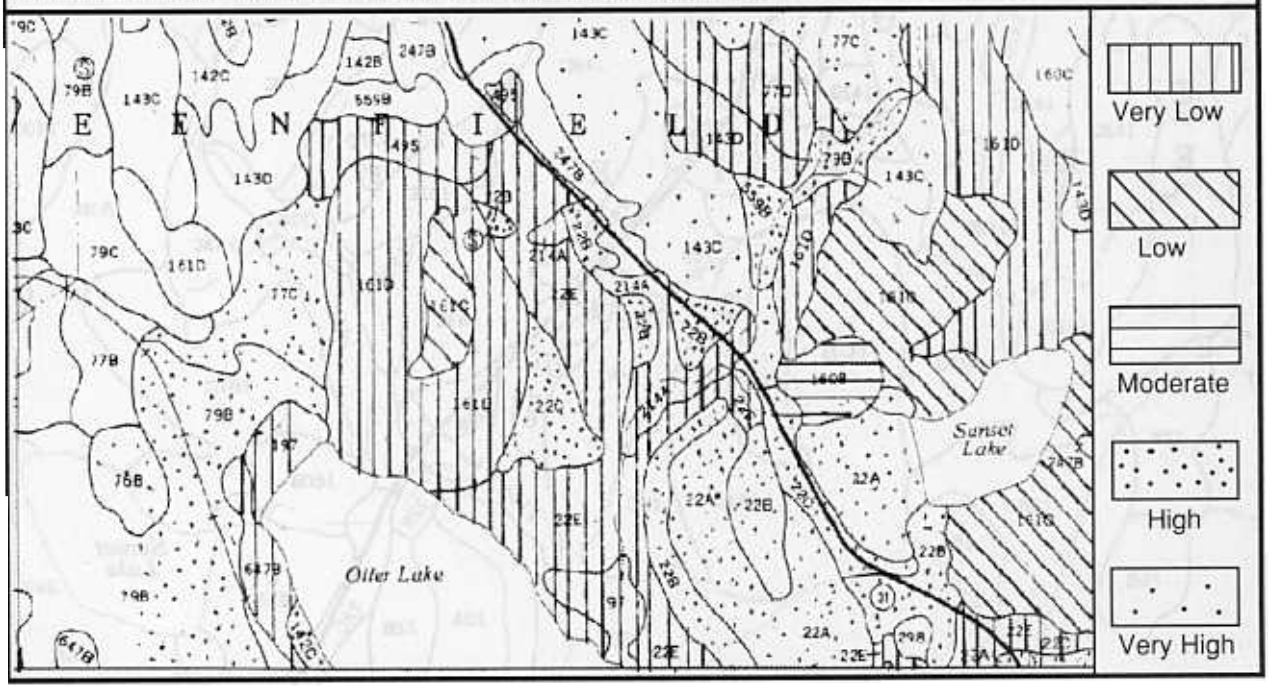
On the other hand, when the soil survey map information (1:20,000 scale) is transferred to a smaller scale map, i.e., 1:50,000, accuracy is generally maintained, but much of the information of the soil map will be lost.

FORMS OF SOIL INTERPRETATIONS

For nonagricultural uses, there are commonly three forms of soil interpretive maps produced. These are interpretive maps based on (1) soil limitation ratings, (2) soil suitability ratings, and (3) soil potential ratings.

Soil limitation ratings are usually based on the hazards, risks, or obstructions presented by the undisturbed soil for various kinds of land use such as building site development, local streets

FIGURE 6 - 3 EXAMPLE OF AN INTERPRETATION MAP



and roads, and sanitary facilities. A three-class system is commonly used, identifying a rating of slight, moderate, or severe. The rating signifies the degree to which soil properties limit the specified use.

Soil suitability ratings are usually based on the degree of suitability for soil material to be used for various purposes such as roadfill, daily cover for landfills, and topsoil. Suitability ratings are based on the characteristics of the soils as they influence any needed excavation and grading as well as performance as finally placed. A three-class system is commonly used, identifying a rating of good, fair, and poor.

Soil potential ratings provide a systematic means of evaluating the relative suitability of the soils in an area for various land uses predicting the soils performance after modern technology has been applied to overcome their limitations. Soil potential is defined as the ability of the soils to support a given structure or activity at a cost expressed in economic, social, and environmental units of value. The potentials of the soils in an area are presented as ratings, either in a set of classes or on a numerical scale. Refer to Figure 6-3 for a map that indicates soil potential ratings.

NATIONAL COOPERATIVE SOIL SURVEY

7

A National Cooperative Soil Survey(NCSS) is a field investigation of the soils of a county, supported by information from other sources. The kinds of soil in the survey area are identified and their extent shown on soil maps. An accompanying report describes, defines, classifies, and interprets the soils. Refer to Figure 7-1. Interpretations predict the behavior of the soils for different uses and the soils response to management. Information collected in a soil survey is useful in evaluating and predicting the effects of land use.

NATIONAL COOPERATIVE SOIL SURVEY PROGRAM

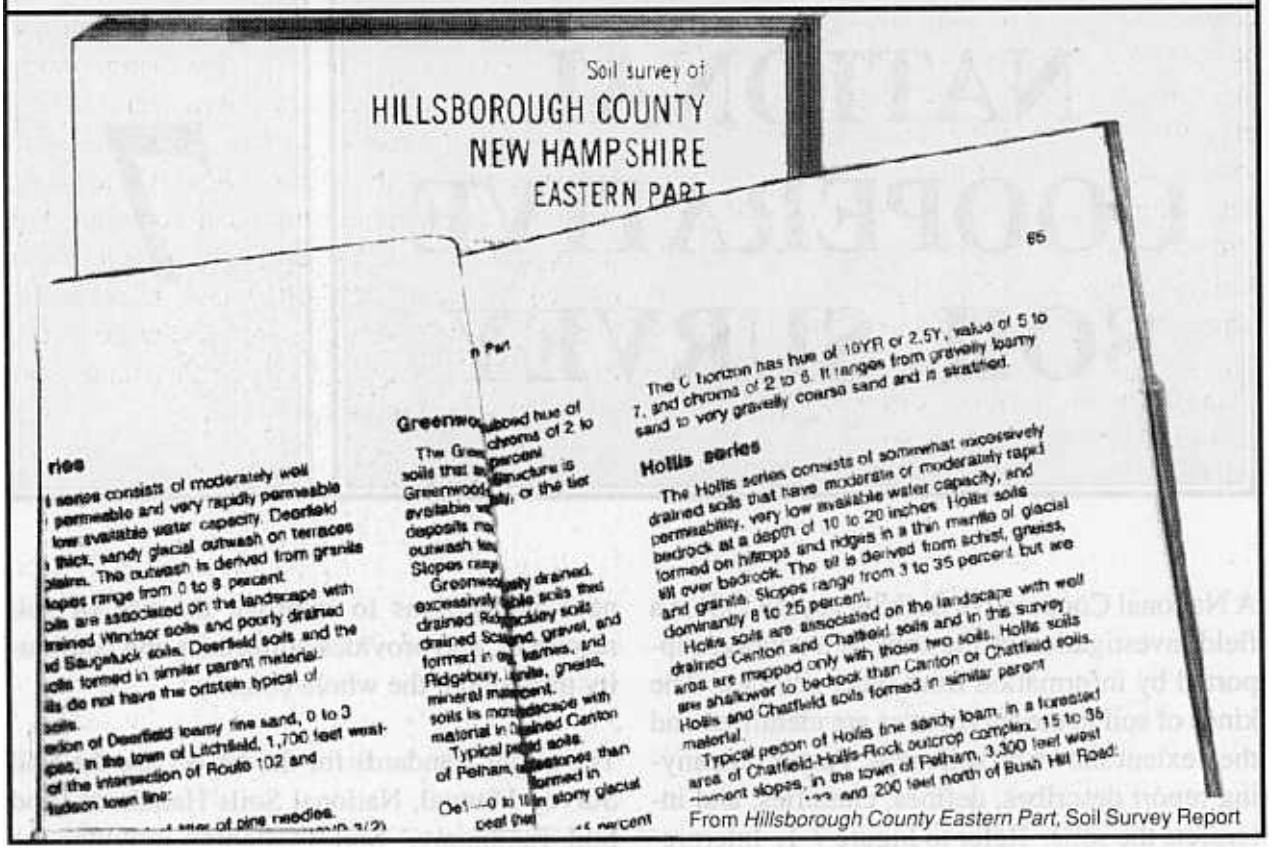
The NCSS program provides an inventory of the nation's soil resources through soil surveys and predicts soil performance under defined use and management. It is the joint effort of cooperating federal agencies, land grant universities, and other state and local agencies to map soils, collect soil data, interpret the maps and data, and promote their use. Federal leadership is provided by the Soil Conservation Service. The program defines and describes soil characteristics, maps areas of soils with similar response to defined use and management, interprets basic soil data for practical application, provides current and easily accessible surveys, investigates and develops new applications to improve the use of soil resources, and provides uniformity and continuity throughout the whole country.

The major standards for the NCSS are the Soil Survey Manual, National Soils Handbook, and Soil Taxonomy. Soil Taxonomy provides the common base for the organization of knowledge about soils and the standards for their classification. The Soil Survey Manual provides the fundamental principles and procedures for making soil surveys, and the National Soils Handbook provides working policy.

MAKING A SOIL SURVEY

Initial work in making soil surveys involves reconnaissance photographic interpretation and literature searches, as well as the collection of data by onsite investigation. Boundaries on soil maps are represented by lines drawn around areas with similar soil properties on corresponding landscapes. Soil boundaries can seldom be shown with complete accuracy; therefore, some soils are inadvertently included or excluded from delineations. Data collection is made from field notes, soil descriptions, and transecting. The descriptions are highly valuable in noting exactly what is happening at a specific site. A useful descrip-

FIGURE 7 - 1 SOIL SURVEY REPORTS INCLUDING MAPS PROVIDE SOILS INFORMATION FOR PRELIMINARY EVALUATIONS



From *Hillsborough County Eastern Part*, Soil Survey Report

tion is typical of the area and fits into the central concept of the mapping unit. Odd areas may be recognized, but are often too small to warrant detailed study.

Very rarely will a soil delineation be 100 percent of one soil. The margins of the unit often blend into the next and the soil properties may reflect some of each soil. Small inclusions also may exist in subtle pockets such as wetter depressions. Others may be obvious such as bedrock outcropping through glacial outwash. Statistical sampling determines if contrasting areas encountered are of any major extent. Analysis of the sampling will show the relative amounts of each major component as well as each inclusion.

After field work is completed, maps are compiled onto a base map which can be readily used. Reports and interpretations are then developed for each map unit or soil.

TAXONOMIC CLASSIFICATION

Soil taxonomy provides hierarchies of classes to define the relationships between soils and also between soils and the factors responsible for their character.

Taxonomy sorts the soils into different groups based on natural soil properties. The diagnostic soil horizons are the basis for separation at the higher categories. It also defines the depth of the control section, the temperature and moisture regimes, and reaction classes. Based on taxonomy, there are six categories in the system in decreasing rank. They are order, suborder, great group, subgroup, family, and series.

SOIL SERIES

The soil series category is the most homogeneous category in the taxonomy of the United States. A

series is a group of soils which have horizons similiar in arrangement and in differentiating characteristics. The soils of a series have a narrow range of properties, although the surface layer and such features as slope and stoniness may vary. Some of the properties commonly used to differentiate series are the kind, thickness, and arrangement of horizons and their structure, color, texture, reaction, consistence, and mineralogical composition. A soil series is named for a local land feature, town, or village near to where the soil was first identified. For example the Monadnock series was first identified in the Monadnock region of New Hampshire.

If a property of a series has too wide a range for the interpretations needed, or if some feature outside of the soil properties is significant for use and management, there is a basis for defining phases. Phases commonly further separate the differences made at the series level, but may also be based on attributes of the soil such as surface texture and stoniness.

SOIL SERIES VARIANT

A soil series variant has been used in many of the published soil surveys. A variant is similar to the soil series for which it is named ,but does vary in at least one significant soil property so that it classifies differently. The variant will have one or more different interpretations for land uses. A soil series variant is used instead of establishing a new series because of the low acreage involved. For example, there is a soil series called Saco and also a Saco Variant. The Saco Variant is very similar to the Saco series except that it has sand and gravel in the lower part of the substratum. The Saco series does not allow gravelly sand textures in the lower substratum. The acreage of Saco Variant that has been identified is very low. If more areas of Saco Variant had been identified and mapped, then a new soil series would have been established.

HORIZONS

Mature, well developed soils in New Hampshire generally have from three to five distinct horizons in areas that have not been significantly disturbed by human activities. These horizons are designated by the letters O,A, E,B, and C. A, B, and C horizons are the most common, but many of the wooded areas that have never been cleared for farming will often have thin O and E horizons. An R is used to indicate bedrock. Figure 7-2 shows horizons for an Adams soil series in New Hampshire.

O Horizon

The O horizon is a dark organic surface layer composed mostly of plant material in various stages of decay. This layer is commonly 2 to 5 inches thick and is referred to as the forest floor mat. In areas that have been cleared of trees for farming, the O horizon is usually plowed and mixed with mineral soil material. In this situation, the O horizon becomes part of a mineral plow layer, or A horizon. Some soils in bogs and marshes have O horizons greater than 51 inches in thickness.

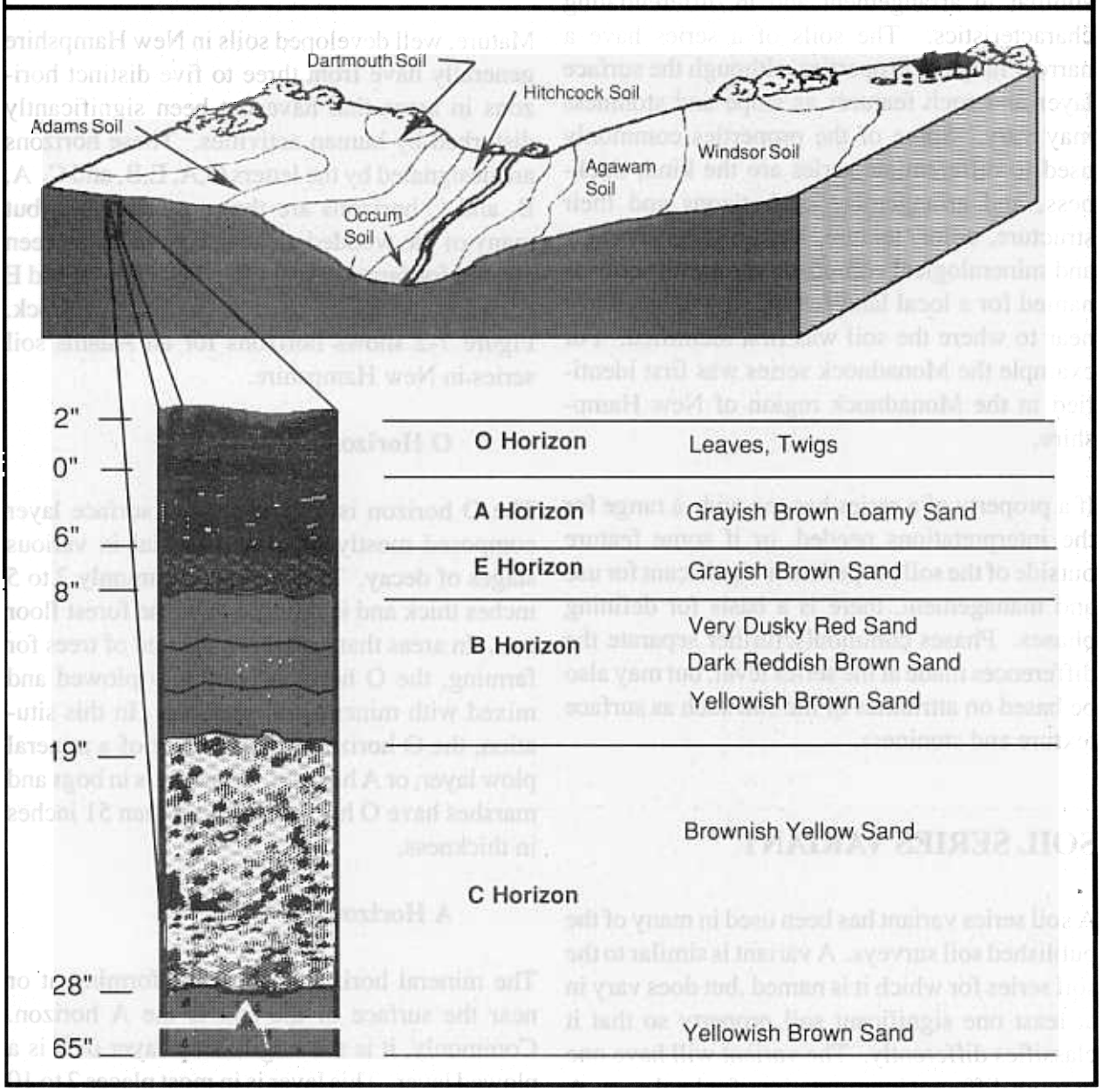
A Horizon

The mineral horizon, formed or forming at or near the surface of the soil is the A horizon. Commonly, it is the original top layer or it is a plowed layer. This layer is in most places 2 to 10 inches thick. This horizon is also referred to as topsoil or surface soil.

E Horizon

The E horizon is a grayish colored subsurface horizon. It occurs below an O or an A horizon. In New Hampshire soils, this horizon is commonly very thin (1 to 4 inches thick) and is often discontinuous across the landscape. An E horizon may be observed in one section of a test pit and just a few feet away the E horizon may be absent. The E horizon is a layer in which minerals

FIGURE 7 - 2 HORIZONS OF ADAMS SOIL



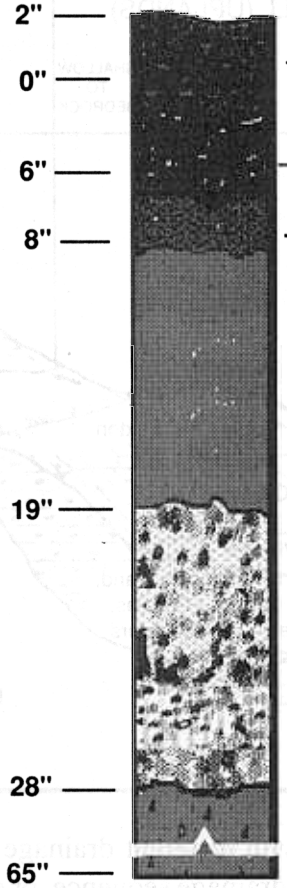
(mainly iron and aluminum) and organic matter have been lost. Minerals and organic matter leach to a lower horizon. The E horizon is often referred to as a leach layer. This horizon is relatively sterile in terms of biological and chemical activity.

B Horizon

This horizon lies just below the A or E horizons and is commonly referred to as the subsoil. The B horizon is a zone of accumulation of nutrients and organic matter that have moved down from the A and E horizons and also have undergone some chemical changes. In New Hampshire, this layer is generally 10 to 30 inches in thickness, but varies considerably outside of this range in many areas.

The B horizon is generally identified in more detail by a lower case letter after the B master horizon designation. This lower case letter represents the type of B horizon by identifying what has accumulated in that horizon or what soil development process has taken place. Examples common to New Hampshire would be Bh, Bs,

FIGURE 7 - 3 A REPRESENTATIVE SOIL PROFILE OF ADAMS LOAMY SAND



O HORIZON	Partially decomposed leaf litter
A HORIZON	0 to 6 inches; very dark grayish brown (10YR 3/2) loamy sand; granular structure; friable; strongly acid; smooth boundary.
E HORIZON	6 to 8 inches; grayish brown (10YR 5/2) sand; single grain; loose; common roots; strongly acid; broken boundary.
B HORIZON	Bh 8 to 9 inches; very dusky red (2.5YR 2/2) sand; single grain; loose; few irregular roots; very strongly acid; broken boundary. Bs 9 to 13 inches; dark reddish brown (2.5YR 3/4) sand; single grain; loose; few roots; strongly acid; gradual wavy boundary. Bw 13 to 19 inches; yellowish brown (10YR 5/6) sand; single grain; loose; 3% gravel; strongly acid; gradual wavy boundary
C HORIZON	C1 19 to 28 inches; brownish yellow (10YR 6/6) sand; single grain; loose; 5 percent fine gravel; strongly acid; gradual wavy boundary. C2 28 to 65 inches; light yellowish brown (2.5Y 6/4) coarse sand; single grain; loose; 12 % fine gravel; common bands; strongly acid

Bw, and Bg horizons. The lower case "h" represents the accumulation of organic matter, or humus, lower case "s" represents the accumulation of iron, lower case "w" represents that mineral weathering has taken place, and the lower case "g" represents gray color which generally indicates wetness in a soil. In many cases a combination of accumulations and soil development processes occur within the same soil. It is common to have a B horizon with the following sequence from the upper B horizon to the lower B horizon: Bhs, Bs, and Bw.

C Horizon

The C horizon consists of the material below the B horizon that is little affected by soil-forming processes. The C horizon is commonly referred to as parent material. The C horizon is dominantly glacial material and is commonly referred to as substratum. The A, E, and B horizons may or may not have formed from the C horizon.

R Layer

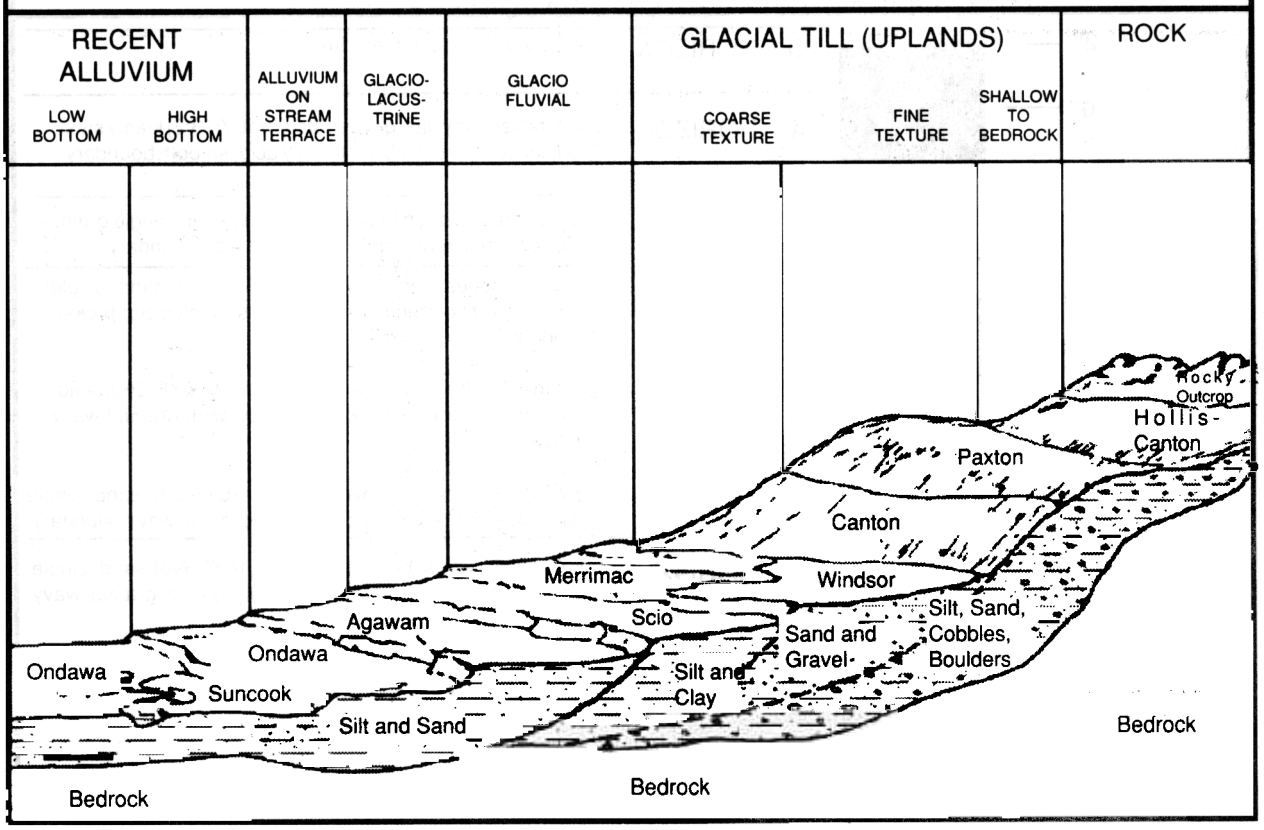
The R layer is technically not a soil horizon, but used to indicate bedrock such as granite. It usually underlies the C horizon, but may be immediately beneath any horizon.

SOIL PROFILE

A soil profile in the NCSS is the sequence of horizons extending from the surface down into the parent material to a depth of 65 inches or bedrock, whichever is shallower.

Figure 7-3 is a soil profile illustrating all the soil horizons for an Adams soil. Characteristics for each horizon, including depth, color, texture, structure, consistence, and roots, are shown.

FIGURE 7-4 RELATIONSHIP OF GEOLOGIC MATERIALS TO SOIL SERIES



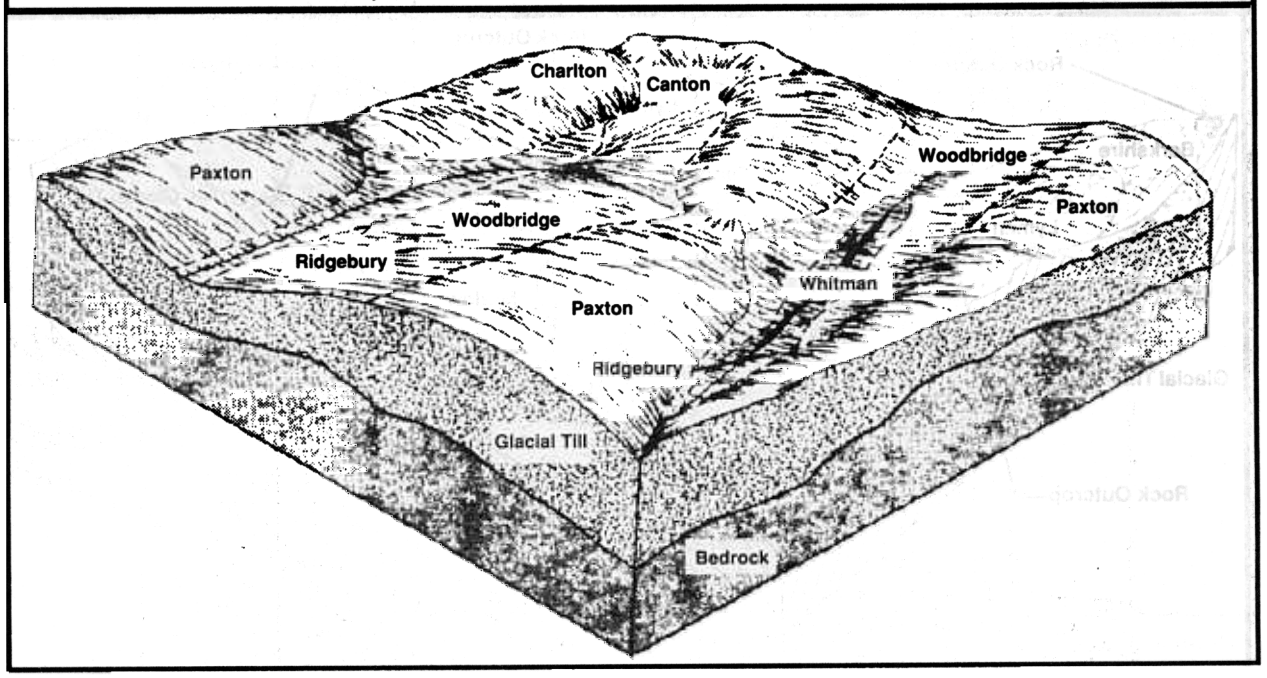
SOILS AND THE LANDSCAPE

In studying soils, it is helpful to look at the "big picture." Figure 7-4 illustrates where different kinds of soil occur in the landscape. The cross section represents an area such as the Merrimack River Valley or other valleys in southern and central New Hampshire that have floodplains. One of the key points to note is that certain soils occur on specific landscape positions. For example, the Ondawa and Suncook soils occur on the flood- plain positions. They do not occur on the glacial till materials of the uplands. There is order and relationship between the kind of soils and the landscape position.

Many soils have a common parent material. Often the difference between these soils is due only to landscape position and the corresponding water table levels and durations associated with the position. These soils have different drainage classes, but similar parent materials. This relationship between soils formed in the same parent material, but with different drainage classes, is referred to as a drainage sequence, or catena. An example of a common drainage sequence that occurs in southern New Hampshire is the Paxton-Woodbridge-Ridgebury-Whitman soil catena. These four soil series have formed in the same parent material. See Figure 7-5. In this case, the parent material is loamy textured, dense basal till derived from granite or schist bedrock. Paxton is the well drained soil member of this catena that occurs on the crest and upper slopes of hills. Woodbridge is the moderately well drained member that generally occurs on the lower side slopes of hills. Woodbridge can be on the same hill as Paxton and associated with it, but only lower on the landscape.

Ridgebury is the poorly drained soil member of this particular soil catena, or drainage sequence. Ridgebury occurs on lower foot slopes of the landscape below the Woodbridge soil. Whitman is the very poorly drained soil member of this drainage sequence or catena. Whitman soils oc-

FIGURE 7-5 TYPICAL LANDSCAPE SHOWING THE RELATIONSHIP BETWEEN SOIL SERIES, PARENT MATERIAL, AND TOPOGRAPHY



cur in the broad depressions in the lowest part of the landscape.

Some soil catenas or drainage sequences are closely related to other soil catenas. Many of the soil catenas that occur in southern New Hampshire have similar catenas in the northern part of the state. The difference, to a large degree, is due to soil temperature. The soils in northern New Hampshire are colder than those in the south. The Paxton-Woodbridge-Ridgebury-Whitman soil catena for southern New Hampshire has a similar catena Marlow-Peru-Pillsbury-Peacham in the north. Paxton is a well drained loamy soil formed in dense basal till that occurs on crests and upper slopes of hills in southern New Hampshire. Marlow is a well drained loamy soil formed in dense basal till that occurs on crests and upper slopes of hills in northern New Hampshire. Paxton soil is quite similar to Marlow soil with soil temperature being the primary difference. Figure 7-6 represents a typical upland till-bedrock controlled landscape relationship that occurs in much of New Hampshire.

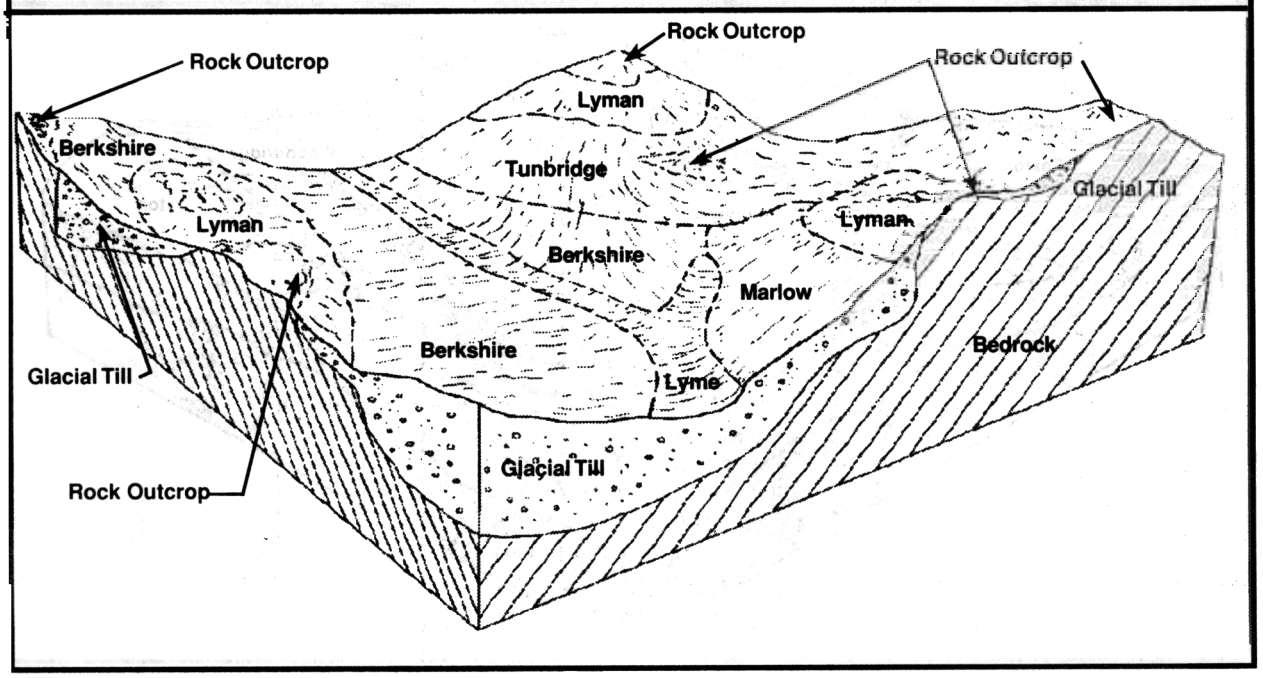
Figure 7-7 illustrates a key to New Hampshire soils.

HYDRIC SOILS

Hydric soils are based on the definition developed by the National Cooperative Soil Survey; National Technical Committee for Hydric Soils (NTCHS). Most of the hydric soils in New Hampshire qualify as wetlands due to wetness indicators below the soil surface. There are no soils currently recognized in New Hampshire that meet the hydric criteria solely on the basis of flooding or ponding during the growing season.

The hydric taxonomic units are divided into Hydric A and Hydric B as used by the New Hampshire Water Supply and Pollution Control Division. For the purposes of this soils legend, Hydric A taxonomic units are defined as those soils recognized by the Soil Conservation Service as being very poorly drained. Hydric B taxonomic units are defined as those soils that are poorly drained. They are also soils that are somewhat poorly drained that meet the additional requirements for (NTCHS) hydric soils in this drainage class. Hydric soils are listed in Figure 7-8.

FIGURE 7 - 6 TYPICAL LANDSCAPE SHOWING THE RELATIONSHIP BETWEEN SOIL SERIES, PARENT MATERIAL AND TOPOGRAPHY



MAP UNITS

The delineated soil areas on soil maps are called map units. The map units are comprised of one or two dominant kinds of soils or soil phases and are named after the dominant soil, soils, or soil phases in the map unit. Other kinds of soils, too small in area to map out, may occur within the map unit area. The symbol within the map unit area identifies the major kind of soil and all areas having the same symbol are made up of essentially the same soil.

The kinds of map units used depend primarily on the purposes of the survey and the pattern of soils in the landscape. The pattern in nature is fixed and it is not exactly the same in each delineation of each map unit. The four kinds of map units are consociations, complexes, associations, and undifferentiated groups.

In a consociation, delineated areas are dominated by a single soil. Inclusions of dissimiliar soils do not exceed 15 percent of the map unit. Complexes consist of two or more soils that are so intermixed or so small in size that it is not practical to separate them at the scale of mapping. Associations are used only in less intensive (order 3) soil mapping. The soil components occur in a regularly repeating pattern that would allow for separating them in Order 2 surveys. Inclusions may range up to 25 percent. Undifferentiated groups consist of two or more soils that are not consistently associated geographically, but have similiar use and management. Generally, they are included together because some common feature, such as steepness or flooding, determines use and management.

SOIL SURVEY MAPS

A soil map delineates areas occupied by different kinds of soils. Each soil has a unique set of interrelated properties characteristic of a natural body of the material from which it formed, its environment, and its history. The soils are identified by names which serve as references to a national system of soil taxonomy. Each soil series name corresponds to one specific taxonomic classification, which has a narrow range of characteristics. Each series is unique and is similar to all other soils mapped by the same name.

FIGURE 7 - 7 KEY TO THE SOILS OF NEW HAMPSHIRE

PARENT MATERIAL / Temperature Regime	SOIL — Drainage Class: Excess. Drained	Somwhat Excess. Drained	Well Drained	Mod . Well Drained	Somewhat Poorly Drained	Poorly Drained	Very Poorly Drained
A. Alluvial Deposits	Soils Developing on Floodplain (Bottomland) Deposits						
Strongly acid; sandy to loamy textures							
Mesic	Suncook		Occum	Pootatuck	Unnamed 974	Rippowam, Lim	Saco Var.
Frigid	Sunday		Ondawa	Podunk	Unnamed 975	Rumney	
Slightly to medium acid; silty textures							
Mesic			Hadley	Winooski		Limerick	Saco
Frigid			Fryeburg	Lovewell		Charles	Medomak
Strongly acid; loamy over gravelly textures							
Frigid			Abenaki Ondawa Var.	Metallak Podunk Var.		Cohas Rumney Var. Limerick Var.	Medomak Var
B. Glaciofluvial Ice Contact and Proglacial Material	Soils Developed on Glacial Outwash and Stream Terraces						
Stratified sand and gravel deposits							
Mesic	Hinckley	Merrimac		Sudbury 118	Sudbury 913	Walpole	Scarboro
Frigid	Colton			Duane Sheepscot	Unnamed 914 " V.Stony 910	Kinsman	Searsport
Sandy deposits							
Mesic	Windsor Caesar			Deerfield	Unnamed 915	Pipestone Wareham Saugatuck	Scarboro
Frigid	Adams			Croghan	Unnamed 916	Naumburg Au Gres	Searsport
Loamy textured material underlain by sand or gravel							
Mesic			Agawam Haven	Ninigret	Unnamed 917	Raypole	
Frigid			Groveton Salmon Var.	Madawaska 28 Nicholville Var.	Madawaska 918	Grange	
Stratified sand and gravel deposits with a high % of schist, phyllite							
Mesic	Quonset	Hoosic Warwick					
Frigid		Masardis	Stetson	Machias			
C. Marine or Glaciolacustrine Deposits	Soils Developed on Silt and Clay (Marine, Glaciolacustrine Deposits)						
Silt and clay deposits							
Mesic			Suffield	Boxford 32	Boxford 953	Scitico	Maybid
Frigid				Buxton		Scantic	Biddeford
Very fine sand and silt							
Mesic			Hartland Hitchcock Unadilla Unadilla Var. Poocham	Belgrade Dartmouth Scio	Raynham 931 Unnamed 933 Roundabout 932	Raynham 533 Raynham Var. Binghamville Roundabout 333	
Frigid			Salmon	Nicholville		Pemi	

FIGURE 7-7 KEY TO THE SOILS OF NEW HAMPSHIRE (Continued)

PARENT MATERIAL / Temperature Regime	SOILS — Drainage Class: Excess. Drained	Somwhat Excess. Drained	Well Drained	Mod. Well Drained	Somewhat Poorly Drained	Poorly Drained	Very Poorly Drained
C. Marine or Glaciolacustrine Deposits (Continued)							
Sandy or loamy material 1 - 1/2 to 3 ft thick over silt and clay deposits							
Mesic		Windsor Var.		Eldridge	Unnamed 943	Squamscott	
Frigid			Melrose	Elmwood	Swanton 936	Swanton 438	
D. Glacial Till Materials — Soils Developed on Glacial Till							
Loose till of loamy sand and sand textures							
Mesic		Gloucester Shapleigh	Canton	Newfields Acton Acton Var.	Unnamed 921 " V. Stony: 941	Leicester	
Frigid		Hermon Success	Monadnock	Waumbek Sunapee	Moosilauke 935 " V. Stony: 942	Moosilauke 414 Lyme	
Firm till of fine sandy loam and loam textures							
Mesic		Hollis	Charlton Chatfield	Sutton	Unnamed 924	Leicester Leicester Var	
Frigid		Lyman	Berkshire Houghtonville Tunbridge	Sunapee	Unnamed 925 " V. Stony: 945	Lyme	
Firm till of silt textures mainly from mica schist and phyllite							
Mesic		Kearsarge	Dutchess Cardigan Pennichuck				
Frigid		Thorndike Glover	Bangor Winnecook	Dixmont 578	Dixmont 929		
Firm, compact, platy till silt loam textures mainly from mica schist and phyllite							
Mesic			Bernardston Bernardston Var.	Pittstown Pittstown Var.	Unnamed 928	Stissing	
Frigid			Plaisted Plaisted Var.	Howland		Monarda	Peacham
Firm, compact platy till of loamy sand textures							
Mesic			Montauk Millis	Scituate	Ridgebury 926 " V. Stony: 946	Ridgebury 656 " V. Stony: 657	
Frigid			Becket	Skerry			
Firm, compact, platy till of fine sandy loam textures							
Mesic			Paxton	Woodbridge	Ridgebury 926	Ridgebury 656 " V. Stony 657	Whitman
Frigid			Marlow Mundal	Peru	Colonel	Pillsbury	Peacham

FIGURE 7-7 KEY TO THE SOILS OF NEW HAMPSHIRE (Continued)

PARENT MATERIAL Temperature Regime	SOILS Drainage Class						
	Excessively Drained	Somewhat Excessively Drained	Well Drained	Moderately Well Drained	Somewhat Poorly Drained	Poorly Drained	Very Poorly Drained
E. Weathered Bedrock							
Loose crystalline rock fragments mainly from weathered Conway granite (occurs mainly in Carroll, Grafton, and possibly Coos Counties) Frigid		Canaan Redstone					
Loose phyllite fragments Frigid			Lombard				
F. Glacial Till	Generally at Elevation Above 2,500 Feet						
Deep or very deep mineral soils with compact, platy till substrata Cryic			Sisk	Surplus	Surplus 993	Monarda Monarda Var.	
Shallow to moderately deep mineral soils over bedrock Cyric			Saddleback Stratton Glebe				
G. Organic Materials - Freshwater	Soils Developed in Organic Materials						
Undecomposed deposits over 51 in. in depth of plant remains (peat) Frigid							Borofibrists Sphagno-fibrists
Deep, decomposed deposits of plant remains over 51in. in depth (muck) Frigid							Borohemists Greenwood
Very shallow organic soils over bedrock Cyric			Ricker				
Shallow organic over sand or loamy sand (16-51 in. of organic) Frigid							Chocorua
Shallow organic over loam, sandy loam, or silt loam (16-51 in. of organic) Frigid							Ossipee
H. Organic Marsh Materials - Tidal Marsh							
Organic materials more than 51 in. thick Mesic							Ipswich
Organic materials 51 in. thick overlying sandy materials Mesic							Pawcatuck
Organic materials 16-51 in. thick overlying silty materials Mesic							Westbrook
Organic materials 16-51 in. thick overlying bedrock Mesic							Lithic Sulfihemists

FIGURE 7 - 7 KEY TO THE SOILS OF NEW HAMPSHIRE (Continued)

PARENT MATERIAL Temperature Regime	SOILS Drainage Class Excessively Drained	Somewhat Excessively Drained	Well Drained	Moderately Well Drained	Somewhat Poorly Drained	Poorly Drained	Very Poorly Drained
H. Organic Marsh Materials -Tidal Marsh Cont'd							
Organic materials less than 16 in. thick overlying sandy material Mesic							Matunuck
Low salt, organic materials thicker than 51 in. or 16-51 in. thick overlying sandy or silty materials Mesic							Ipswich low salt

Adapted from USDA SCS Statewide Numerical Soils Legend, Issue No. 3, 1992

A soil map such as in Figure 7-9 and legend are the foundations of the soil survey. The legend identifies the symbol on the map and provides the name of the dominant soil in the delineated area. The symbol 66B appears on the map in one area. The first part of the map symbol, "66", represents the soil Paxton fine sandy loam. The second part of the symbol, "B", indicates the slope class in this example. Refer to Figure 7-10. Slope classes in New Hampshire are indicated by capital letters and defined in percent of slope. This unit is comprised mainly of the Paxton fine sandy loam, 3 to 8 percent slopes, but also includes minor other soils that were too small in area to map out or to mention in the name of the unit. Every square foot of the map unit area is not necessarily Paxton fine sandy loam, 3 to 8 percent slopes. For example, small areas in the map unit may have a loam surface layer or may be less sloping or more sloping than 3 to 8 percent.

In some survey areas, two slope classes are combined within a soil phase into one slope class. This is done because there is little difference between the two slope classes in limitations and management of the soil.

Since there may be slight differences in map unit names that have the same map symbol between soil survey areas, the legend for each soil survey area should be reviewed to determine the exact name of the map unit. Examples of soil map symbols and soil series names are shown in Figure 7-11.

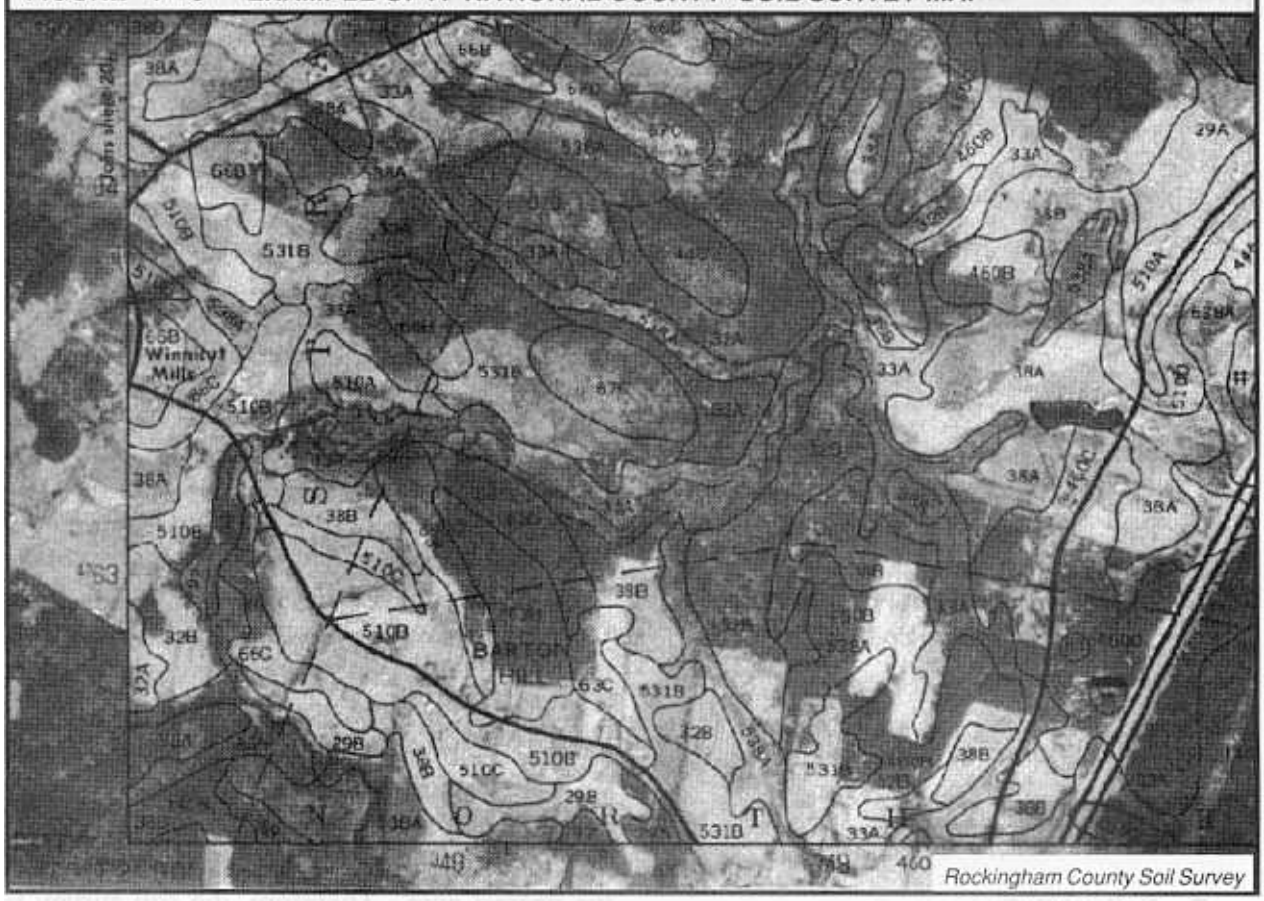
FIGURE 7 - 8 HYDRIC SOILS IN NEW HAMPSHIRE*

HYDRIC A SOILS		HYDRIC B SOILS	
Biddeford	Muck and Peat	Au Gres	Pipestone
Borohemists	Ossipee	Binghamville	Raynham 533
Chocorua	Pawcatuck	Charles	Raynham Variant
Greenwood	Peacham	Cohas	Ridgebury 656, 657
Ipswich	Saco	Grange	Rippowam
Ipswich low salt	Saco Variant	Kinsman	Roundabout 333
Matunuck	Scarboro	Leicester	Rumney
Maybid	Searsport	Leicester Variant	Rumney Variant
Medomak	Sphagnofibrists	Lim	Saugatuck
Medomak Variant	Westbrook	Limerick	Scantic
	Whitman	Limerick Variant	Scitico
		Lyme	Squamscott
		Monarda	Stissing
		Moosilauke 414, 415	Swanton
		Naumburg	Walpole
		Pemi	Wareham
		Pillsbury	

* Onsite investigation is needed to verify actual limits of hydric soils. Hydric A and Hydric B soils are based on NHWSPCD criteria.

Adapted from USDA SCS Statewide Numerical Soils Legend, Issue No. 2, 1991

FIGURE 7 - 9 EXAMPLE OF A NATIONAL COUNTY SOIL SURVEY MAP



Besides providing information on the areal extent of each soil and the kind of soil, the soil map shows other physical features. Since the map has an aerial photo background, it is possible to determine different roads, fields, buildings, lakes, streams, and airports. Streams are shown with special map symbols. Small wet spots, and sandy, gravelly, or stony spots are shown on the soil map with the standard map symbols. A partial map showing a 57B Becket fine sandy loam, with an 3 to 8 percent slopes, very stony, and a partial soil description are shown in Figure 7-12.

Once the soil is identified in an area, a large spectrum of information can be interpreted from the name. Some of the items are:

- Slope gradients
- Depth to water table as inferred from the natural drainage class

FIGURE 7 - 10 NATIONAL SOIL SURVEY MAP SYMBOLS

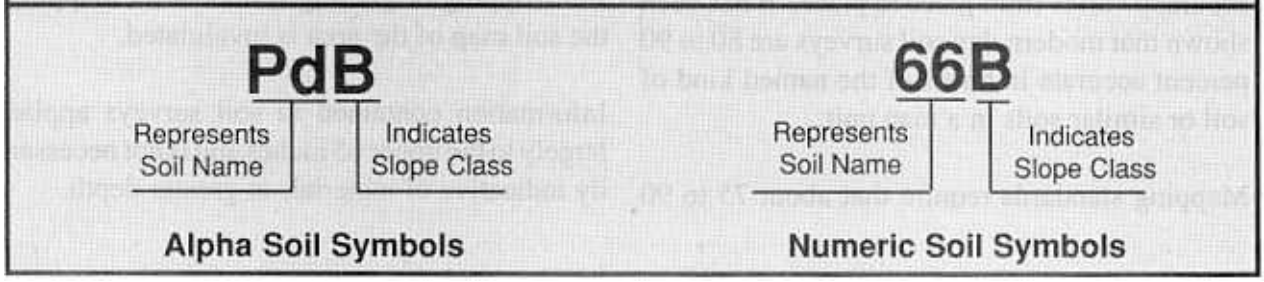


FIGURE 7-11 EXAMPLES OF SOIL LEGENDS FOR NATIONAL COOPERATIVE SOIL SURVEYS

SYMBOL	NAME	SYMBOL	NAME
AcB	Acton fine sandy loam, 0 to 8 percent slopes	15	Searsport muck
AdB	Acton fine sandy loam, 0 to 8 percent slopes, very stony	22A	Colton loamy sand, 0 to 3 percent slopes
AdC	Acton fine sandy loam, 8 to 15 percent slopes very stony	22B	Colton loamy sand, 3 to 8 percent slopes
Be	Biddeford silty clay loam	22C	Colton loamy sand, 8 to 15 percent slopes
BzA	Buxton silt loam, 0 to 3 percent slopes	27B	Groveton very fine sandy loam, 0 to 5 percent slopes
BzB	Buxton silt loam, 3 to 8 percent slopes	28B	Madawaska fine sandy loam, 0 to 5 percent slopes

- Soil texture
- Presence of any kind of limiting layers such as a hardpan, bedrock, or clay substratum
- Susceptibility to flooding
- Predicted permeability
- Soil reaction
- Stoniness

Figure 7-13 illustrates how to use the soil survey map and interpretive data.

LIMITATIONS OF SOIL SURVEY AND RELIABILITY OF MAP UNITS

Accuracy of soil maps is determined by soil complexity, detail of examination, scale of the base maps, and the skill of the mappers. The accuracy varies from place to place. It has been shown that modern day soil surveys are 80 to 90 percent accurate in terms of the named kind of soil or similar soils in a map unit.

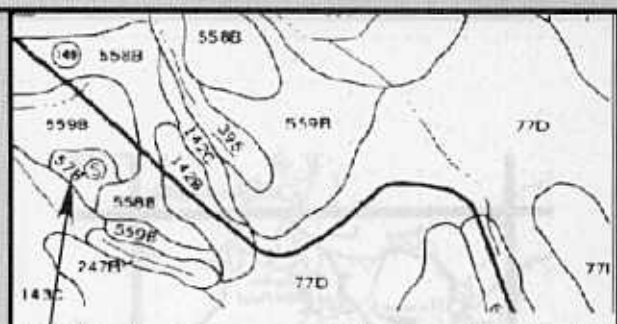
Mapping standards require that about 75 to 90 percent of a soil area must be the soil after which the area is named. The remaining percentage may be soil slightly different or contrasting from the dominant soil. Therefore, at any given spot, the chances are about five to one that the soil at that spot is the one after which the map unit is named. In the case of small individual lots, the scale of the soil map does not permit accurate classification and location of each small area of different soil. The soil survey is not accurate to the nearest acre. Therefore, the soil survey is most effective for reviewing suitability of large land areas, such as plats and subdivisions, and not for individual lots.

Soil surveys are limited to a reasonable scale due to time and cost. At the present time, the publication scale of soil surveys is commonly 1:20,000 or 1:15,840. These scales do not permit the exact drawing of soil boundaries nor the delineation of minute areas of different kinds of soil. Each map unit may have small inclusions of other kinds of soil.

A soil map reflects the natural soil landscape at the time the map was made. Where considerable site stripping or grading is done after mapping, the soil map of the area is invalidated.

Information contained in soil surveys applies largely to the upper 65 inches and is not necessarily indicative of materials at greater depth.

FIGURE 7 - 12 PARTIAL EXAMPLE OF A SOIL DESCRIPTION FROM SOIL SURVEY REPORT



"57B" indicates a map unit dominated by Becket fine sandy loam, 3 to 8 percent slopes, very stony.

Typical pedon of Becket fine sandy loam, in an area of Becket fine sandy loam, 3 to 8 percent slopes, very stony, in the town of Deering, 500 feet west on NH Route 149, 2 miles southeast of where NH Route 149 crosses the Contoocook River, in woodland:

Oi - 1 inch to 0; loose leaf litter.

Oa - 0 to 1 inch; decomposed leaf litter.

A - 1 to 5 inches; very dark grayish brown (10YR 3/2) fine sandy loam; weak fine granular structure; very friable; many fine and medium roots; 5 percent gravel; very strongly acid.

Bs1 - 5 to 9 inches; dark reddish brown (5YR 3/4) gravelly fine sandy loam; weak fine granular structure; friable and moderately smeary; common fine and medium roots; 10 percent gravel: 10 percent cobbles, and 5 percent stones; strongly acid; clear wavy boundary.

Bs2 - 9 to 28 inches; yellowish brown (10YR 5/6) gravelly fine sandy loam; weak fine granular structure; friable; few fine roots; 10 percent cobbles and 5 percent stones; very strongly acid; clear wavy boundary.

BC - 28 to 32 inches; olive yellow (2.5YR 6/6) gravelly loamy sand; weak fine granular structure; friable; 15 percent gravel, 10 percent cobbles, and 5 percent stones; strongly acid; clear wavy boundary.

C - 32 to 65 inches; light brownish gray (2.5Y 6/2) very gravelly loamy sand; weak medium platy structure; firm; 15 percent gravel, 15 percent cobbles, and 5 percent stones; strongly acid.

57B - Becket fine sandy loam, 3 to 8 percent slopes, very stony. This soil is strongly sloping and well drained. It is on hilltops and side slopes on hilly uplands. Many of the hills are smooth sided oval shaped hills called drumlins. Areas of the soil are long and narrow in shape, and range from 5 to 50 acres in size. Stones 1 to 1 1/2 feet in diameter and 5 to 30 feet apart are on the surface.

Typically, the surface layer is covered by about 1 inch of fresh leaf litter. The surface layer consists of 1 inch of moderately decomposed leaf litter over 4 inches of very dark grayish brown fine sandy loam. The subsoil, to a depth of 32 inches, is dark reddish brown gravelly fine sandy loam in the upper part, yellowish brown gravelly fine sandy loam in the middle part, and olive yellow gravelly loamy sand in the lower part. The firm substratum, to a depth of 65 inches or more, is a light brownish gray very gravelly loamy sand. In some areas the substratum in the upper part is friable..

Included with this soil in mapping are small areas of Skerry, Peru, and Pillsbury soils in depressions and scattered small areas of Tunbridge soils. Also included are some areas where stones less than 5 feet apart are on the surface. The included soils make up about 20 percent of the map unit.

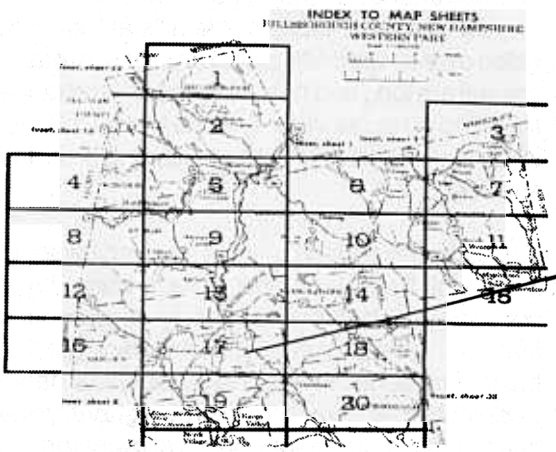
Permeability for this Becket soil is moderate in the surface layer and subsoil and slow or moderately slow in the substratum. The available water capacity is moderate. The firm substratum limits the depth of the root zone. The seasonal high water table is perched on the substratum from November through March. Depth to bedrock is more than 65 inches. Potential frost action is moderate.

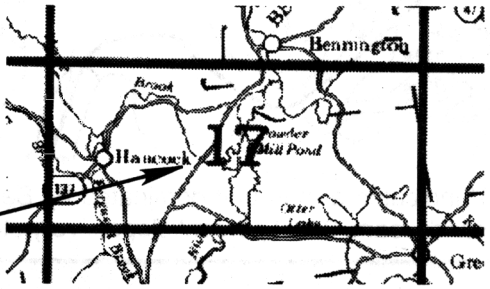
The seasonal high water table and permeability are limitations for septic tank absorption systems.

Adapted from *Hillsborough County Soil Survey*

FIGURE 7 - 13 HOW TO USE NATIONAL COOPERATIVE SOIL SURVEY REPORTS

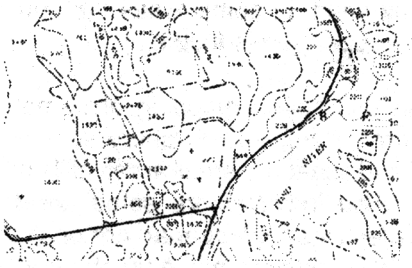
1. Locate the area of interest on the "Index to Map Sheets."

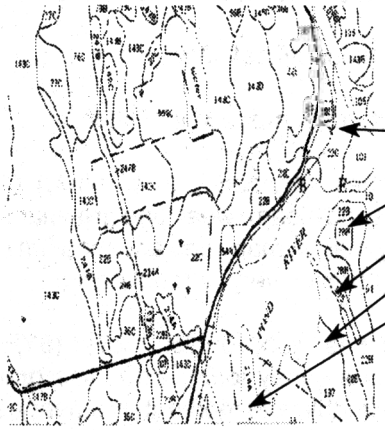




2. Note the number of the map sheet and turn to that sheet.

3. Locate the area of interest on the map sheet.

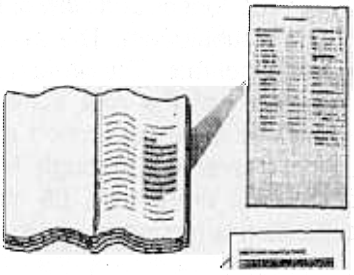




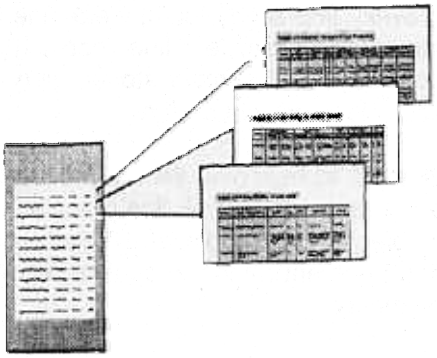
Symbols

22C
28B
105
197
214A

4. List the map unit symbols that are in the area.



5. Turn to "Index to Soil Map Units" which lists the name of each map unit and the page where that map unit is described.



6. See "Summary of Tables" (following the Contents) for location of additional data on a specific soil use.

7. Consult "Contents" for parts of the publication that give specific data required.

Adapted from *Hillsborough County (Western Part) Soil Survey Report*

SOIL INTERPRETATIONS

The organization and presentation of knowledge about the properties, qualities, and behavior of soils are called "Soil Interpretations". Soil interpretations are essential to full and effective use of the soil survey reports including the soil maps and knowledge about soils.

Soil survey interpretations provide information about engineering properties of soils, the suitability of soils as resource material, and major soil features affecting engineering uses of soils. They provide information relative to the degree of soil limitations for town and county planning and suitability for farm, woodland, recreational and wildlife uses.

Soil survey interpretations are predictions about the behavior, use, and management of each kind or group of soils under stated conditions. They are not recommendations or decisions on soil use and management. Soil interpretations indicate the alternatives in use of soils and their limitations for different uses. Interpretations pertain to the soil as a whole and not to the individual properties and qualities such as texture, permeability, and the like. The interaction and sum of all the soil properties and qualities determine its behavior and limitations. They are based on observations of soil behavior under different uses and controlled experiments, including the findings of research on selected soils. It is not possible to conduct intensive research on each individual soil. Consequently, it is necessary to compare and relate similar soils to those soils for which research data is available. For example, actual field permeability tests are not available for all soils, but permeability can be predicted on the basis of soil properties such as structure, texture, and other features in relation to the actual permeability. Although interpretive groupings rely mainly on physical and chemical features, they also must be based on economic features.

KINDS AND FORMS OF INTERPRETATIONS

Soil interpretations take many forms. One is in the form of tables with specific values for each soil. The Physical and Chemical Properties of the Soils and Engineering Index Properties as shown in Figure 7-14 are two examples.

Another form is the sorting of soils in a survey legend into groups. The interpretive groupings are groups of soils that will behave similarly and respond to management similarly for a specific use. In New Hampshire, the soils have been grouped on a statewide basis into different interpretive groups for drainage, irrigation, and other uses. Interpretive groups can be readily prepared for other uses also. The soils can be grouped according to their limitations and behavior for septic tank absorption fields, sewage lagoons, local roads, streets and parking lots, dwellings, campsites, and many other items.

A third form of interpretations is to list the limitations in terms of slight, moderate, or severe for the individual soils. This can be done in table form as included in soil surveys. Figure 7-14 shows soil evaluated for building site development.

Three degrees of soil limitations are given for development planning and recreational uses. Slight ratings are assigned to soils that have properties favorable for the intended use. The degree of limitations are minor and can be overcome easily. Soils with slight ratings are considered to have the best potential.

Moderate ratings are given to soils that have properties moderately favorable for the planned use. Limitations can be overcome or modified by special planning, design, or maintenance. These soils are considered to have intermediate potential.

FIGURE 7 - 14 PARTIAL EXAMPLES OF INFORMATION AVAILABLE FROM SOIL SURVEY

Physical and chemical properties of the soils

Depth	Clay	Moist bulk density	Permeability	Available water capacity	Soil reaction	Shrink-swell potential	Erosion factors K	Erosion factors T	Organic matter
In	Pct	G / cm^3	In / hr	In / in	pH				Pct
0 - 5	2 - 8	1.00 - 1.20	0.6 - 2.0	0.10 - 0.23	3.6 - 6.0	Low----------	0.17	3	---
5 - 28	2 - 7	1.30 - 1.60	0.6 - 2.0	0.05 - 0.16	3.6 - 6.0	Low----------	0.24		
28 - 60	1 - 5	1.65 - 1.85	0.06 - 0.6	0.03 - 0.09	3.6 - 6.0	Low----------	0.24		

Engineering Index Properties

Depth	USDA Texture	Classification		Frag-ments > 3 inches	Percentage passing sieve number-				Liquid Limit
		Unified	AASHTO		4	10	40	200	
In				Pct					Pct
0 - 5	Stony fine sandy loam	SM	A-2, A-4	10 - 20	85 - 95	75 - 90	50 - 75	30 - 50	---
5 - 28	Fine sandy loam, sandy loam, gravelly fine sandy loam	SM	A-2, A-4	5 - 15	70 - 90	60 - 85	50 - 75	25 - 40	---
28 - 60	Gravelly loamy sand, gravelly loamy fine sand	SM, SP-SM, GM, GP-GM	A-2	5 - 15	60 - 85	55 - 75	25 - 70	10 - 30	---

CONSTRUCTION MATERIALS

Roadfill	Sand	Gravel	Topsoil
Fair: wetness	Probable---------- -	Probable---------- -	Poor: small stones

BUILDING SITE DEVELOPMENT

Shallow excavations	Dwellings without basements	Dwellings with basements	Small commercial buildings	Local roads and streets	Lawns and landscaping
Moderate dense layer, wetness, slope	Moderate wetness, slope	Moderate wetness, slope	Severe slope	Moderate wetness, slope, frost action	Moderate wetness, droughty, slope

Severe ratings are given to soils that have one or more properties unfavorable for the intended use. These soils generally require major reclamation, special design, or intensive maintenance.

A rating of severe does not mean a soil cannot be used for the intended use. However, it does mean that severe limitations exist that must be overcome with proper design or operation. It commonly is more expensive to develop soils with a severe limitation than those with slight or moderate limitations. The soil survey and interpretations are helpful in selecting sites with the least limitations for the intended use.

Another form of interpretations is soil potential reports. These indicate relative potential of soil for various uses on a county basis. One example is soil potential reports for low density development. Ratings and criteria used in those reports vary by county.

The interpretations should be used only with modern soil surveys and individual field sheets of soil surveys in progress and other surveys that have recently been completed. The interpretations are for the soils in their natural condition and not for disturbed areas that have been altered by land grading operations. They will not eliminate the need for onsite sampling, testing, and study of specific sites for design and construction of engineering works. The interpretations should be used mainly for planning more detailed field studies to determine conditions of the soil at the

proposed sites. They also are helpful in appraising the suitability of large areas for different uses such as residential development, farming, recreation, woodland, and others.

When interpretations are used for delineated soil areas on soil maps, the information pertains to the dominant soil for which the soil area is named. Other unlike soils, too small in area to map out, may be present within the mapped soil area. The percentage of these included soils varies, but typically is 10 percent or less for each and no more than 15 percent total for all included soils that have a different use potential than the named soil. Interpretations do not apply to included soils. For example, a soil mapped as Charlton fine sandy loam, 8 to 15 percent slopes, also can include small unmapped areas of Hollis and Sutton soils. The interpretations apply to the Charlton part of the delineated soil area and not to the entire area.

Soil properties do not function independently of each other. The influence of any one soil property depends upon the other soil properties present. The criteria for interpretations are based upon present knowledge and may change in the future with more experience and data.

Interpretations do not consider the size and shape of mapped soil areas, nor the pattern they form with other soils on the landscape. For example, some very desirable soil areas are too small in size, too irregular in shape, or their occurrence with less desirable soils forms a pattern too complex to be utilized for the intended use. Although not considered in the interpretations, these items may influence the selection of sites.

SOME INTERPRETATIONS USEFUL FOR DEVELOPMENT

Depth to bedrock, flood hazard, depth to hardpan, potential frost action, and depth to seasonal high water table are soil features that are helpful in appraising sites.

Soil survey interpretations provide information about engineering properties of soils, the suitability of soils as resource material, and major soil features affecting engineering uses of soils. They provide information relative to the degree of soil limitations for development planning and recreational uses, and suitability for farm, woodland, and wildlife uses.

A number of items may be used to evaluate suitability of soils for dwellings, septic tank absorption fields, and other aspects of development. Permeability, water capacity, pH, flood hazard, potential frost action, and hydrologic groups are discussed below.

Permeability

Estimates of the permeability for the major horizons in the soil are useful. Permeability figures can vary from spot to spot in a soil area depending on differences in texture, structure, and presence or absence of inhibiting layers. Therefore, the range in permeability listed is the dominant range for the soil series as it commonly occurs in New Hampshire.

Permeability is the rate of flow through saturated soil. It is not the same as the percolation rate obtained by percolation test for subsurface sewage system design.

Values listed represent the estimated rate of downward movement of water through undisturbed and uncompacted soil. It does not include lateral seepage or upward movement under artesian pressure. The estimates are based mainly on structure and porosity of the soil and on tests of undisturbed cores of similar soils. The permeability classes and the rates in inches per hour for each class are listed below:

Permeability Class	*Inches Per Hour*
Slow	Less than 0.2
Moderately Slow	0.2 - 0.6
Moderate	0.6 - 2.0
Moderately Rapid	2.0 - 6.0
Rapid	More than 6.0

Available Water Capacity

The available water capacity is given in inches of water per inch of soil for the major horizons. It represents the approximate amount of capillary water in the soil available for plant growth after all free water has drained away.

Soil Reaction (pH)

Soil reaction, or the intensity of soil acidity or alkalinity, is expressed in pH values. A pH of 7.0 is neutral in reaction because it is neither acid nor alkaline. Lower values indicate acidity and higher values show alkalinity.

Flood Hazard

Flood hazard expresses a flood frequency from nearby streams. Estimates are based on characteristics of the soil. There is no attempt to define flooding as to depth, velocity, or duration. Ratings are defined as follows:

None Means that flooding is not probable.

Rare Means that flooding is unlikely, but possible under unusual weather conditions.

Occasional Means that flooding occurs infrequently under normal weather conditions.

Frequent Means that flooding occurs often under normal weather conditions.

Common is a combination of occasional and frequent.

Potential Frost Action

Frost action is estimated for the soil as it occurs in place. Frost action is the heaving caused by ice lenses forming in the soil and the subsequent loss of strength as a result of excess moisture during thawing periods. As a general rule, soils with more than 3 percent of its particles 0.02 mm and smaller are frost susceptible. Three classes are used—Low, Moderate, and High.

Hydrologic Groups

The hydrologic grouping of soils is based on infiltration rates as they affect runoff. The four groups are described as follows:

Group A These soils have high infiltration rates even when thoroughly wetted. These consist chiefly of deep, well to excessively drained sands or gravel. These soils have a high rate of water transmission and would result in low runoff potential.

Group B These soils have moderate infiltration rates when thoroughly wetted. These consist chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.

Group C Soils in this group have slow infiltration rates when thoroughly wetted. These consist chiefly of soils with a layer that impedes the downward movement of water, soils with moderately fine to fine texture, or soils with a moderately high water table (poorly drained). These soils have a slow rate of water transmission.

Group D Soils in this group have very slow infiltration rates when thoroughly wetted. They consist chiefly of clay soils with high swelling potential, soils with permanent high water tables (very poorly drained), soils with clay layers at or near the ground surface, and shallow soils over nearly impervious materials. These soils have a very slow rate of water transmission.

SOIL SURVEY DATA FOR WATER TABLE

The soil survey maps and data are quite helpful for general site evaluation including planning for detailed investigations. Soil maps are used to identify the kinds and locations of soils. Once site soils are identified, other portions of the reports provide general information on physical and chemical properties, engineering properties, soil

FIGURE 7 - 15 RELATIONSHIP OF SOIL SERIES TO PARENT MATERIAL AND WATER TABLE

SOIL	PARENT MATERIAL	KIND OF WATER TABLE	SOIL	PARENT MATERIAL	KIND OF WATER TABLE
Abenaki	alluvium	free	Houghtonville	till	free
Acton	till	free	Howland	till	perched
Acton Variant	till	free	Ipswich	organic	free
Adams	outwash	free	Ipswich low salt	organic	free
Agawam	outwash	free	Kearsarge	till	-
AuGres	outwash	free	Kinsman	outwash	free
Bangor	till	free	Leicester	till	free
Becket	till	perched	Leicester Var.	till	free
Belgrade	marine, lacustrine	perched	Lim	alluvium	free
Berkshire	till	free	Limerick	alluvium	free
Bernardston	till	perched	Limerick Var.	alluvium	free
Bernardston - Variant	till	perched	Lombard	residual	free
Biddeford	marine	perched	Lovewell	alluvium	free
Binghamville	marine, lacustrine	perched	Lyman	till	-
Borofibrists	organic	free	Lyme	till	free
Borohemists	organic	free	Machias	outwash	free
Boxford	marine	perched	Madawaska	outwash	free
Buxton	marine	perched	Marlow	till	perched
Caesar	outwash	free	Masardis	outwash	free
Canaan	residual	free	Matunuck	marine	free
Canton	till	free	Maybid	marine, lacustrine	perched
Cardigan	till	-	Medomak	alluvuim	free
Charles	alluvium	free	Medomak Var..	alluvium	free
Charlton	till	free	Melrose	marine	perched
Chatfield	till	-	Merrimac	outwash	free
Chocorua	organic	free	Metallak	alluvium	free
Cohas	alluvium	free	Millis	till	perched
Colton	outwash	free	Monadnock	till	free
Croghan	outwash	free	Monarda	till	perched
Dartmouth	lacustrine	perched	Monarda Var.	till	perched
Deerfield	outwash	free	Montauk	till	perched
Dixmont	till	free	Moosilauke	outwash/till	free
Duane	outwash	free	Mundal	till	perched
Dutchess	till	free	Naumburg	outwash	free
Eldridge	marine	perched	Newfields	till	free
Elmwood	marine	perched	Nicholville	lacustrine	free
Fryeburg	alluvium	free	Nicholville Var.	lacustrine	free
Glebe	till	free	Ninigret	outwash	free
Gloucester	till	free	Occum	alluvium	free
Glover	till	-	Ondawa	alluvium	free
Grange	outwash	free	Ondawa Var.	alluvium	free
Greenwood	organic	free	Ossipee	organic	free
Groveton	outwash	free	Pawcatuck	organic, marine	free
Hadley	alluvium	free	Paxton	till	perched
Hartland	lacustrine	free	Peacham	till	perched
Haven	outwash	free	Pemi	lacustrine	free
Hermon	till	free	Pennichuck	till	-
Hinckley	outwash	free	Peru	till	perched
Hitchcock	lacustrine	perched	Pillsbury	till	perched
Hollis	till	-	Pipestone	outwash	free
Hoosic	outwash	free	Pittstown	till	perched

FIGURE 7 - 15 RELATIONSHIP OF SOIL SERIES TO PARENT MATERIAL AND WATER TABLE (Continued) for preliminary planning

SOIL	PARENT MATERIAL	KIND OF WATER TABLE	SOIL	PARENT MATERIAL	KIND OF WATER TABLE
Pittstown Var.	till	perched	Sisk	till	perched
Plaisted	till	perched	Skerry	till	perched
Plaisted Var.	till	perched	Sphagnofibrists	organic	free
Podunk	alluvium	free	Squamscott	marine	perched
Podunk Var.	alluvium	free	Stetson	outwash	free
Poocham	lacustrine	free	Stissing	till	perched
Pootatuck	alluvium	free	Stratton	till	-
Quonset	outwash	free	Success	till	free
Raynham	lacustrine	perched	Sudbury	outwash	free
Raynam Var.	lacustrine	free	Suffield	lacustrine, marine	perched
Redstone	residual	free	Sunapee	till	free
Ricker	organic	-	Suncook	alluvium	free
Ridgebury	till	perched	Sunday	alluvium	free
Rippowam	alluvium	free	Surplus	till	perched
Roundabout	lacustrine	free	Sutton	till	free
Rumney	alluvium	free	Swanton	marine	perched
Rumney Var.	alluvium	free	Thorndike	till	-
Saco	alluvium	free	Tunbridge	till	-
Saco Var.	alluvium	free	Unadilla	lacustrine	free
Saddleback	till	-	Unadilla Var.	lacustrine	perched
Salmon	lacustrine	free	Walpole	outwash	free
Salmon var.	lacustrine	free	Wareham	outwash	free
Saugatuck	outwash	perched	Warwick	outwash	free
Scantic	marine	perched	Waumbek	till	free
Scarboro	outwash	free	Westbrook	organic, marine	perched
Scio	lacustrine	free	Whitman	till	perched
Scitico	marine	perched	Windsor	outwash	free
Scituate	till	perched	Windsor Var.	marine	perched
Searsport	outwash	free	Winnecook	till	free
Shapleigh	till	-	Winooski	alluvium	free
Sheepscot	outwash		Woodbridge	till	perched

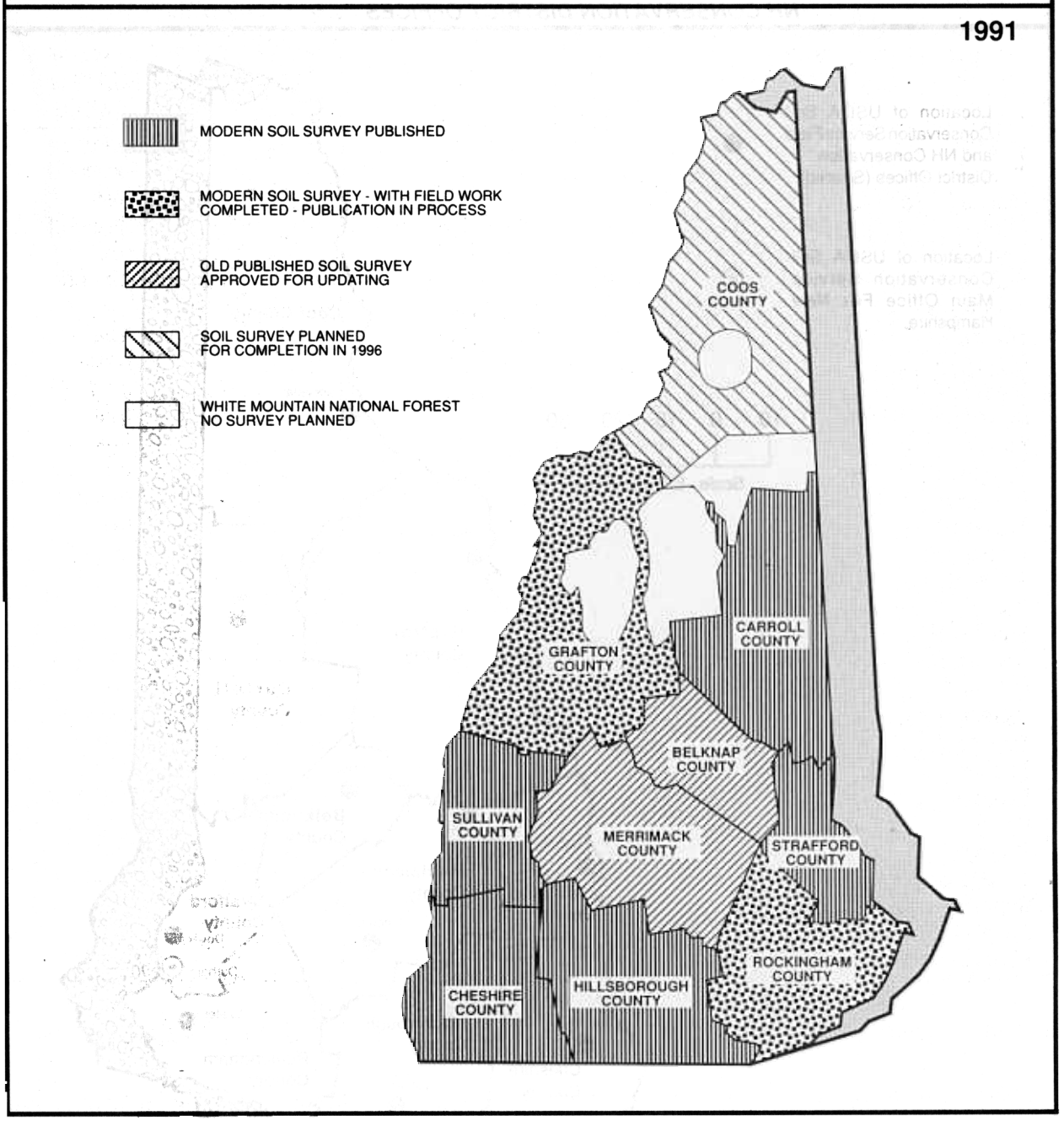
and water features, and other interpretive data.

Soil survey data was used in developing Figure 7-15. This figure shows a very general relationship of the soil series to parent materials and kinds of water tables. It may be used as an aid in preliminary planning and development of onsite investigations. However, it only provides clues as to what might be expected. This data should not be used for design puposes. The kind of water table for a particular location often requires detailed observations that are site specific.

SOIL SURVEY DATA FOR SLOPE

Slope information may also be obtained from soil maps. A range of slope, such as 3 to 8 percent, is used on these maps rather than specific values. The slope range assigned to a given area on the the map represents the dominant slope. That is, a soil delineation could have as little as 51 percent of the area with the assigned slope. This allows a range of 0 to 49 percent of the area to be other than the assigned slope range. Therefore, this data should be used as an aid in preliminary planning and not for design.

FIGURE 7 - 16 STATUS OF SOIL SURVEYS



STATUS AND AVAILABILITY OF SOIL SURVEYS

Detailed soil surveys have been completed in most counties of New Hampshire. Reports for these counties have been published in standard format and are available to the public. See Figure 7-16 for status of soil surveys.

Soil surveys are presently in progress in other counties and copies of individual field sheets of the soil survey are available for inspection. Copies of individual field sheets are available in some cases.

To find out if an area is mapped in a county and to obtain soil survey reports, contact the Soil Conservation Service field office for that county.

FIGURE 7 - 17 LOCATION OF USDA SOIL CONSERVATION SERVICE AND NH CONSERVATION DISTRICT OFFICES

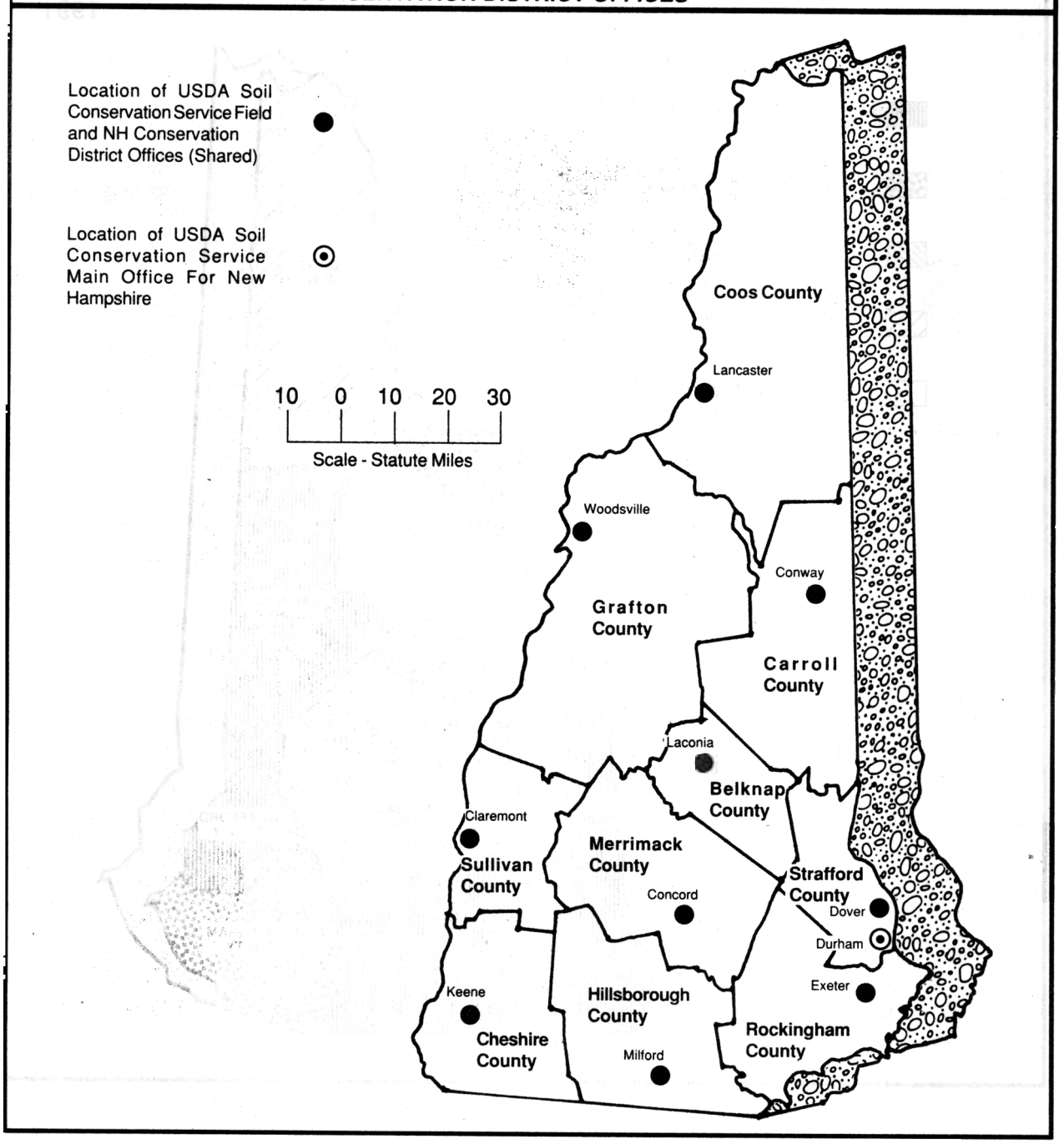


Figure 7-17 shows the location of the Soil Conservation Service and conservation district offices in New Hampshire. Conservation district boundaries coincide with county lines. The SCS works through the 10 conservation districts to assist in soil and water conservation.

Telephone numbers and addresses of the local Soil Conservation Service and conservation district offices are listed in local directories. A list is also available in Appendix A.

HIGH INTENSITY SOIL SURVEY

8

Use of soil survey information by New Hampshire towns, regulatory agencies, developers, and others significantly increased since 1965. The county soil survey information prepared by the National Cooperative Soil Survey (NCSS) is very popular, especially for town planning activities. In recent years, there has become a need for more detailed information. As part of making county maps, areas up to 3 acres are often included with other units on soil maps. These areas are important for detailed planning. For example, sometimes these small areas are wet soils in a map unit that is indicated as well drained. Information about small wet soil inclusions is needed to fully evaluate proposals for building sites, subsurface waste disposal, and wetland boundaries; thus, the need for high intensity soil (HIS) maps.

SURVEY STANDARDS

HIS maps in New Hampshire are developed in accordance with standards published by the Society of Soil Scientists of Northern New England in "Special Publication No. 1, High Intensity Soil Maps for New Hampshire, Standards and Origins". The standards provide that HIS Maps will be prepared by a certified soil scientist (state of New Hampshire, Chapter 281), by an apprentice working under the direct supervision of a certified soil scientist or a governmental soil scientist.

The criteria for HIS maps includes the use of a five-part map symbol. The individual parts include drainage class, parent material, restrictive features, slope, and an identifier symbol telling whether all standards have been followed in the map preparation process. Soil series names such as Paxton and Hinckley are not used in HIS mapping. Rather, a connotative legend of the individual parts is used. Refer to Figure 8-1 for the HIS map symbol key.

SOIL DRAINAGE CLASS

The boundary between wetlands and uplands is becoming more important. Regulatory agencies at the local, state, and federal levels are using soils information in deciding wetland jurisdiction issues concerning this boundary.

County soil survey maps are limited because some of the soil series used include both poorly drained and somewhat poorly drained soils. Commonly, the poorly drained soils are included as part of the local wetland definition. The somewhat poorly drained soils are generally excluded from the local definition. At the federal level,

FIGURE 8 - 1 HIGH INTENSITY SOIL SURVEY MAP SYMBOL KEY

HIGH INTENSITY MAP SYMBOL

523BH

DRAINAGE CLASS
5

1. Excessively drained
2. Well drained
3. Moderately well drained
4. Somewhat poorly drained
5. Poorly drained
6. Very poorly drained
7. Not determinable

IDENTIFIER
H

H. Indicates high intensity soil map

P. Indicates preliminary map

SLOPE CLASS
B

B. 0 to 8%

C. 8 to 15%

D. 15 to 25%

E. More than 25%

PARENT MATERIAL
2

1. Glaciofluvial
2. Glacial Till
3. Marine or glaciolacustrine very fine sand and silt
4. Marine or glaciolacustrine loamy/sandy over silt/ clay
5. Marine or glaciolacustrine silt and clay
6. Excavated, regraded, or filled
7. Alluvial deposits
8. Organic materials fresh water
9. Organic materials tidal marsh

RESTRICTIVE FEATURE
3

1. None
2. Bouldery, with more than 15% of surface covered
3. Mineral restrictive layer(s) are present at less than 40 in. depth.
4. Bedrock 0 in. to 40 in. depth
5. Subject to flooding
6. Does not meet fill standards

x. Depth to bedrock variable, complex of soil types

High Intensity Map Symbol 523BH indicates a poorly drained glacial till soil with a restrictive feature, on a slope of 0 to 8%.

Developed from Society of Soil Scientists of Northern New England. *"Special Publication No. 1, High Intensity Soil Maps For New Hampshire, Standards and Origins"*

however, hydric soils are used as part of the definition of wetlands. Hydric soils generally include all very poorly and poorly drained soils and some of the wetter somewhat poorly drained soils. Thus, it became apparent during the early stages of discussing soil drainage classes for HIS maps that distinct and well defined classes were needed, especially for the wet soils.

Six drainage classes are used in HIS map preparation. A seventh class is used for site conditions where soil drainage cannot be determined. A separate class was set up for somewhat poorly drained soils. Soil taxonomy is used extensively in defining the wet soil classes. The first digit of the soil map symbol indicates the drainage class. For example, the symbol "5" is used for poorly drained soils.

PARENT MATERIAL

The general categories of parent material commonly used in New Hampshire are included in the key to soil types. For example, glacial till material is indicated by the symbol "2". Also under this section are provisions to map out separately filled, excavated, or regraded areas.

RESTRICTIVE FEATURES

Many of the features listed in this part relate to soil conditions important to the proper functioning of subsurface waste disposal systems. For example, bedrock or hardpan layers within 40 inches of the soil surface are mapped out as separate features. A symbol "3" is assigned to soils with a hardpan layer.

SLOPE

Slope classes are those commonly used in the county soil survey maps, except that no A slope (0 to 3 percent) is used. Slope breaks are at 8, 15, and 25 percent.

IDENTIFIER SYMBOL

When a symbol "H" is used, it indicates that the standards for high intensity maps were used in map preparation. A symbol "P" in place of the "H" indicates a preliminary map. This indicates that not all of the standards were followed. The preliminary map is useful for planning rather than regulatory activities.

In summary, a poorly drained soil "5" developed in glacial till "2" with a restrictive hardpan "3" on a 3 percent slope is shown as "523B". If HIS standards were used in map preparation, an "H" would be used to complete the symbol. See Figure 8-2 for an example of a HIS map.

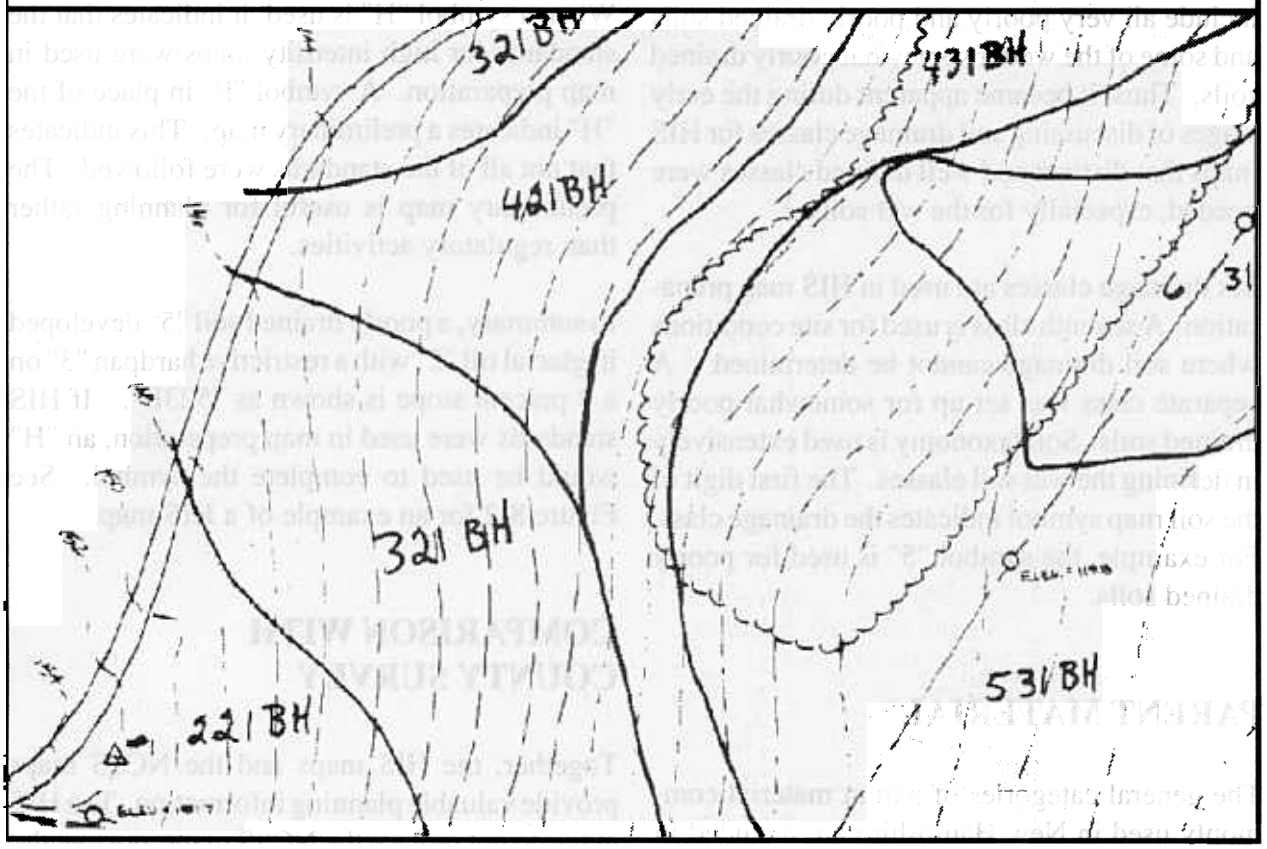
COMPARISON WITH COUNTY SURVEY

Together, the HIS maps and the NCSS maps provide valuable planning information. The HIS maps do not replace the NCSS maps, nor can the NCSS maps be properly used at the level of detail of HIS maps. Each type of soil map was developed for a specific, and entirely different, purpose.

The soil maps produced by the National Cooperative Soil Survey are multipurpose maps intended for general land use planning purposes only. Soils are identified on relatively small scale maps (as compared to HIS maps) designed to provide predictions about soil use, management, and behavior in order to make informed land use decisions on a regional or community level. Soil interpretations predict soil potential, limitations, management needs and behavior, or production capability of soils, but are not in any sense recommendations for specific parcels of land.

The High Intensity Soil Survey maps are large scale, limited purpose maps intended to provide specific soils information relating to subsurface sewage disposal, wetland boundaries, and lot size

FIGURE 8 - 2 EXAMPLE OF HIGH INTENSITY SOIL (HIS) MAPPING. NOTE GROUND CONTROL, 2-FOOT CONTOUR INTERVAL



ordinances. The maps are very site specific and are commonly made for parcels of land proposed for development. The interpretations predict soil potential and limitations and are intended to be used as recommendations for land use.

Although attempts have been made in the past to convert HIS maps to NCSS maps, and vice versa, the Soil Conservation Service does not support this practice. There is no direct conversion of the two types of mapping and any attempt to make this conversion can result in ambiguity and, in some situations, serious errors in interpretation. Nevertheless, some correlation is possible in certain circumstances.

An analogy can be made between HIS and NCSS maps by comparing a street map of Portsmouth and a highway map of New Hampshire. One could not use a street map of Portsmouth to get directions to Littleton, New Hampshire. Likewise, one could not get adequate directions to Myrtle Avenue in Portsmouth using a highway map of New Hampshire. Even though the two maps are very strikingly different, there are some correlations that can be made. Interstate 95, Route 4, and Route 1, for example, are similarly identified on both maps, and are located in the same place, within the limits of map scale.

Although some basic correlations can be made between HIS and NCSS soil maps, it is highly recommended that land use decisions not be made from attempted conversions. Assistance can be provided in soil interpretations for specific purposes by the consulting firm that developed the HIS map, or by contacting the local office of the Soil Conservation Service.

PRELIMINARY SITE EVALUATION

9

Preliminary evaluations of soils are commonly done to assist in determining initial feasibility of development sites. They also aid in preparing plans for detailed evaluations. These evaluations generally consist of inventories of onsite soils, their characteristics, and assessment of their capabilities to meet proposed requirements. In practice, part of the process is an iterative procedure that tailors evolving development plans to soil conditions.

PRELIMINARY EVALUATION

Preliminary evaluations are primarily done in the office and are based on natural resource information available to the public. They are relatively inexpensive and can be done quickly. As a rule, they are much less expensive and time consuming than detailed soil evaluations.

Evaluations are used to determine general overall suitability for proposed development. These evaluations of soils and other site conditions aid in determining development compatibility. Preliminary evaluations may reveal soil deficiencies that would prohibit or at least limit proposed plans. Soils with shallow depths to bedrock, wet soils, and those with low bearing strengths may prohibit all or portions of proposed structures, including onsite subsurface sewage systems. Steep slopes and coarse-textured soils may also be restrictive. Preliminary evaluations indicate the possibilities of problems and highlight broad areas of concern.

Preliminary evaluations also determine starting points for detailed studies. They aid in focusing on critical areas that require very detailed investigations and evaluations. These studies may save significant detailed investigative costs and reveal in early stages areas, sites, types of development, and structures that are not feasible.

RESOURCE INFORMATION

In New Hampshire, there is substantial natural resource information available for use in preliminary evaluations. Topographic maps, soil survey reports including soil maps, aerial photographs, and flood and aquifer maps are generally available. Zoning, subdivision, building, and other regulations are also available and vary greatly by municipality. Soil potential rating reports and geologic reports are available for some counties. Geographic information systems are helpful in natural resource management. Figure 9-1 indicates major source information that is available to the public for preliminary evaluations of soils.

FIGURE 9 - 1 INFORMATION FOR PRELIMINARY SITE EVALUATIONS	
Topographic Maps	Show elevations, contours, streams, wet areas,culture, vegetation, roads, and landforms. Can be used to determine slopes, drainage areas, and drainage.
Field Observation	Provides "feel" for land. Firsthand view of drainage, elevation, surface conditions, landforms, vegetation,rock, and adjacent areas.
Soil Survey Reports	Indicate areal extent of soil types and slope. Some reports show vegetative cover. Reports include engineering and physical soils data.
Aerial Photographs	Usually sharp images of vegetation,culture, and water bodies. Stereo pairs provide 3-D images using stereoscope. Aid in determining drainage divides, topography.
Geologic Maps	Indicate bedrock types and surficial materials and their areal extent.
Flood Maps	Indicate approximate areas of flooding. Elevations given in detailed study areas.
Aquifer and Groundwater Maps	Indicate boundaries between stratified drift aquifers and till uplands, thickness and overall texture of aquifer materials, and general flow direction.
Zoning, Subdivision and other Regulations	Requirements for lot size and density based on soil type. Requirements for HIS mapping, stormwater detention, erosion control, sewage systems, buildings,and zones.
Soil Potential Ratings	Aid in evaluating soils for low density development on county basis.
Geographic Information Systems	Computer program that analyzes and graphs stored resource data, such as soils and topography. Once data is stored, it is a powerful and fast tool.
Wetland Maps	Depending on detail, are helpful in assessing types.

These are discussed in the following sections.

TOPOGRAPHIC MAPS

The most widely used initial source of information for preliminary evaluations is topographic maps produced by the United States Geological Survey (USGS). These maps are often called "quad", "topo", or "GS" sheets. These are the largest scale topographic maps available covering all of New Hampshire. A main feature of these maps is the display of topography by use of contour lines and spot elevations at workable scales. Other main features are the displays of roads, manmade structures, and water bodies. These maps are available as quadrangles covering 7 1/2 or 15 minutes of latitude and longitude. Some recent maps are available that cover 7 1/2 minutes of latitude and 15 minutes of longitude. Quadrangle names for New Hampshire are shown in Appendix B.

The 7 1/2-minute maps have a scale of 1:24,000 so that 1 inch on paper represents 2,000 feet on the ground. This is generally a convenient scale, especially for large areas. The 15-minute maps have a scale of 1:62,500, translating to 1 inch equals approximately 5,208 feet on the ground. The 7 1/2-by 15-minute maps have a scale of 1:25,000 which is approximately 2,083 feet per inch. Refer to Appendix B for map scales and equivalents.

The 7 1/2-and 15-minute quadrangles generally have a 20-foot contour interval. This indicates that there is a 20-foot vertical difference between adjacent contour lines. There are a few maps that have 10-foot or 40-foot contour intervals. The 7 1/2 by 15 minute quadrangles have a 6-meter interval. Closely spaced contour lines indicate steep slopes. Widely spaced lines indicate milder slopes.

USGS topographic quadrangles are printed in color. Black is used for cultural features such as roads, buildings, and utilities. Contour lines are printed in brown. Blue is used for streams and other water bodies. Green shading indicates wooded areas and other woody vegetation. Important roads and built-up urban areas are shown in red. Some maps have purple lines and shading to indicate updated culture prior to overall updating.

USGS maps are used in several ways for preliminary evaluation. They are the only relatively large scale maps having broad coverage that indicate natural and manmade features to scale. They provide excellent location maps. Maps provide elevation, slope, and landform data for preliminary planning. Generalized wet areas such as swamps and marshes are also indicated. An example of a topographic map with some features indicated is shown in Figure 9-2.

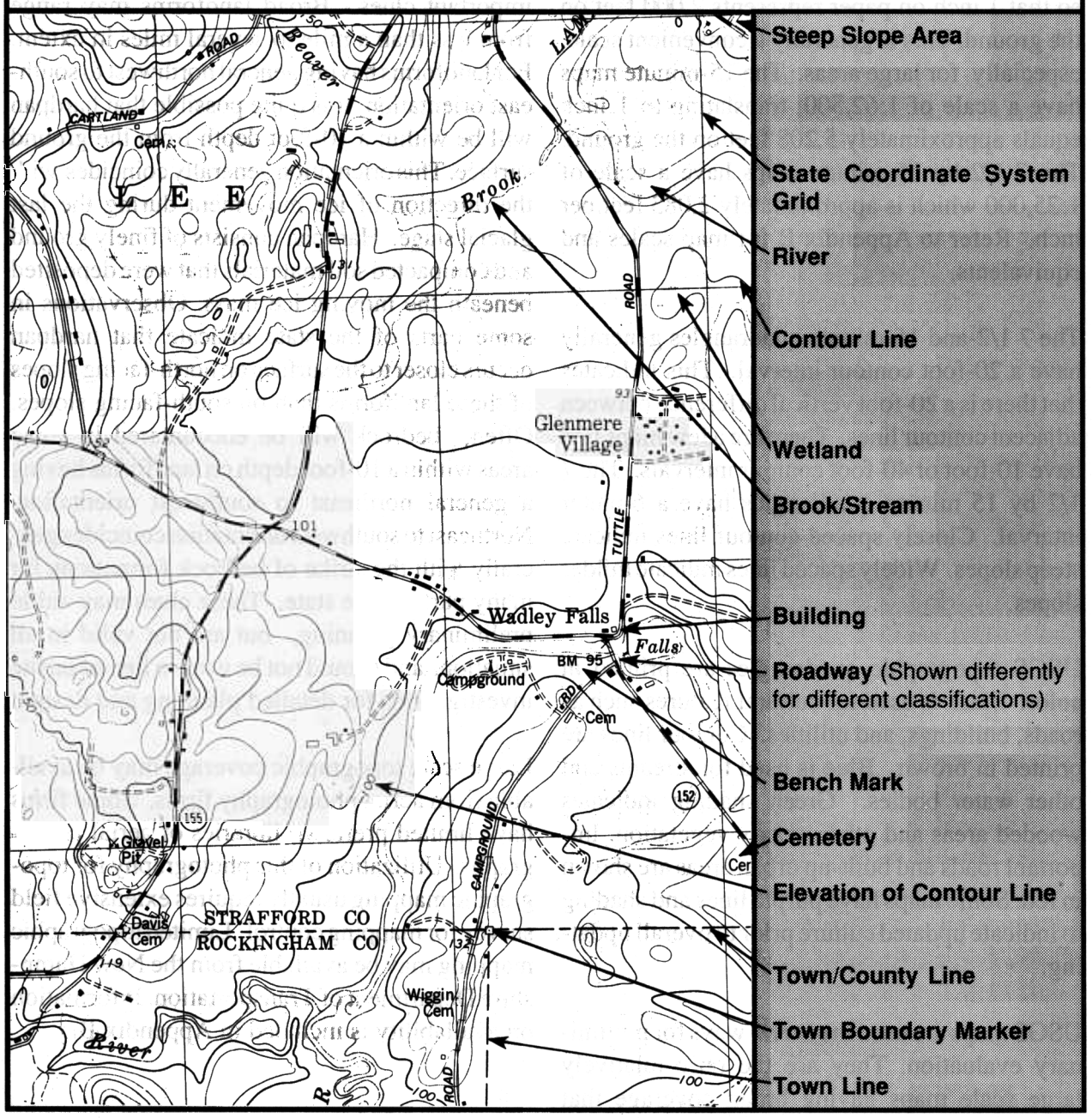
Where geologic maps are not available, topographic maps may aid in predicting the presence of hardpan layers and shallow bedrock conditions in upland areas. The orientation of any landforms within the evaluation area provides important clues. Broad landforms may range from less than a mile to several miles in extent. For landforms having general northwest to southeast orientation, it is quite possible that hardpan will be within a 10-foot depth from the ground surface. This orientation generally coincides with the direction of ice movement during the last glacial stage. Hardpan consists of finely ground and compacted soil materials that were deposited beneath the moving ice mass. Observations in some parts of the state indicate that hardpan occurs closer to the surface on north-facing slopes of these landforms than on south-facing slopes. Often, bedrock will be encountered in some areas within a 10-foot depth on landforms having a general northeast to southwest orientation. Northeast to southwest orientation coincides generally with the strike of bedrock formations for many parts of the state. These clues may aid in preliminary planning, but are not valid in all situations and should not be used in lieu of onsite investigations for detailed planning and design.

Large scale topographic coverage may be available from aerial photography firms. Some firms have limited preflown libraries of aerial photographs. Utilization of this photography for topographic mapping usually requires extensive field survey for mapping control. Limited topographic mapping may be available from the New Hampshire Department of Transportation. Information on availability is included in Appendix B.

FIELD OBSERVATION

Field observation is the main exception to accomplishing preliminary evaluations in the office. It is a major resource for site studies consisting of firsthand visual observation. For many projects, it is usually accomplished by physically traversing the area. Aerial observation has the advantage of overall plan view, but is usually not a complete substitute for walking the area.

FIGURE 9 - 2 EXAMPLE OF USGS TOPOGRAPHIC MAP AND MAP FEATURES



Walking the site provides the observer with a "feel" of the land. This method provides up-close site and adjacent offsite data that is generally not available elsewhere. For a trained observer, it provides the opportunity for a visual integration of site attributes. It also aids in more efficient use of topographic and soil maps and other resource data in the office.

Field observation should be planned to ensure satisfactory site coverage and relate to available resource maps. Optimum benefits from observation are achieved by defining objectives and studying resource maps and available data prior to the site visit. For large sites, a method of maintaining orientation is necessary. Natural features including topographic relief, streams, wetlands, and large trees on property bounds are helpful as references. Manmade features such as stone walls, remains of old barbed wire fences, ponds, ditches, etc., are useful in determining location. Where natural and manmade features are not sufficient, base lines established with a compass may be necessary. Relating positions

FIGURE 9 - 3 FIELD OBSERVATION AT A GLANCE	
Pre-planning	Optimum observation requires careful planning.
Orientation	Need methods to maintain orientation at large sites. Refer to natural features, culture, relate position to map.
Record Data	Record observations preferably on maps or key to maps.
Use Checklist	Use list of items to observe as field aid.
Clues	Study clues that may yield additional information.
Beyond Bounds	Look beyond site to determine if activity will have impact.
Flexibility	Expand observation scope. Preconceived concepts of site and proposed development may require change.

on the ground to those on topographic and soil maps are important for integrating all resource data. Uncontrolled observation does not provide maximum benefits. Concern for certain items may also reduce the observers concentration to focus on all items. A checklist is helpful.

Vegetative cover, slopes, wet areas, water bodies, and other natural features can be observed and compared with map data. More detailed observation may provide data on soils from road cuts, streambanks, and eroded areas. Care is necessary in spotting rock outcrops, springs, seeps, abandoned wells, and other small features.

Downslope soil movement may be indicated by slumped soil material. Observation of streams and the general landscape may provide clues in determining erosion potential. Seepage gives indications of soil moisture and permeability conditions.

There is a natural tendency to concentrate on the site area within its bounds. However, it is often helpful and sometimes critical to look beyond boundaries. Site activities, even though not even considered at the time of observation, may impact adjacent property in some way. Drainage, channelization, and impoundment of water may be items to consider if located near bounds. Site drainage that extends to adjacent areas will also impact the subject site.

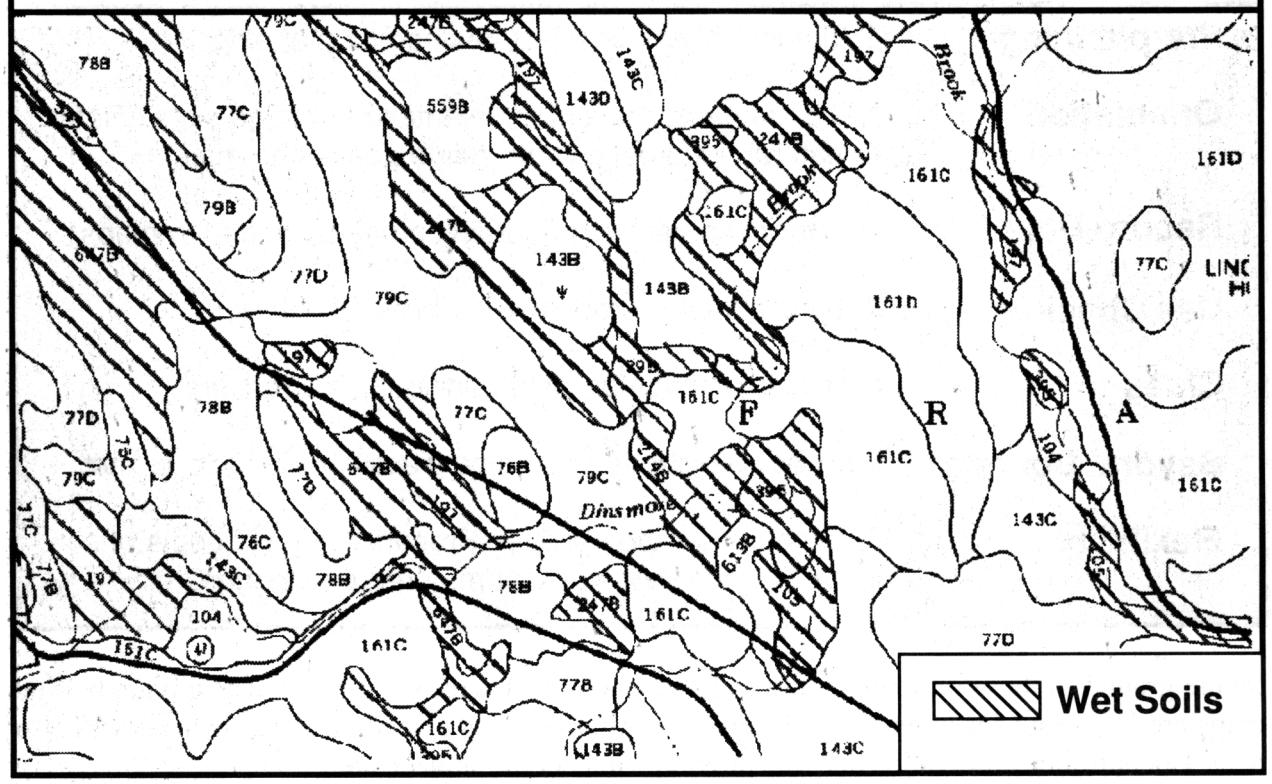
Many times when an observer goes to the field, a conceptual plan has been proposed. This provides a focus for observation; however, concepts do change and there is usually considerable benefit in trying to observe all items although they may not seem important at the time. Figure 9-3 gives a summary list of some considerations for observation.

SOIL SURVEY

The second most widely used source of information for preliminary investigations is modern published NCSS reports. These are available for most counties. These reports include soil survey maps which show the geographic distribution of the different kinds of soil. Soil reports describe, define, classify, and interpret the different kinds of mapped soils. Published reports are available as indicated in Chapter 7.

Field sheets may be available in mapped areas of counties where modern soil reports are not published. These sheets provide the most up-to-date

FIGURE 9 - 4 SOIL MAP USED TO INTERPRET WET SOILS



soil map data until county soil survey reports are published. Field sheets and accompanying soils data are also available as indicated in Chapter 7.

For preliminary planning, soil survey maps and data are quite helpful for general site evaluation including planning for detailed investigations. Soil maps are used to identify the kinds and locations of soils. They also provide generalized information on slope. Once site soils are identified, other portions of the reports provide general information on physical and chemical properties, engineering properties, soil and water features, and other interpretive data.

Soil maps with accompanying soils data are helpful in delineating wet soils, those with high water tables, and soils that are shallow to bedrock. Texture, drainage, and other soil properties may also be highlighted. Soil survey data was used in developing Figure 7-15 in Chapter 7. This figure shows the relationship of the soil series to parent material and kind of water table. Figure 9-4 shows use of a soil map to delineate wet soils.

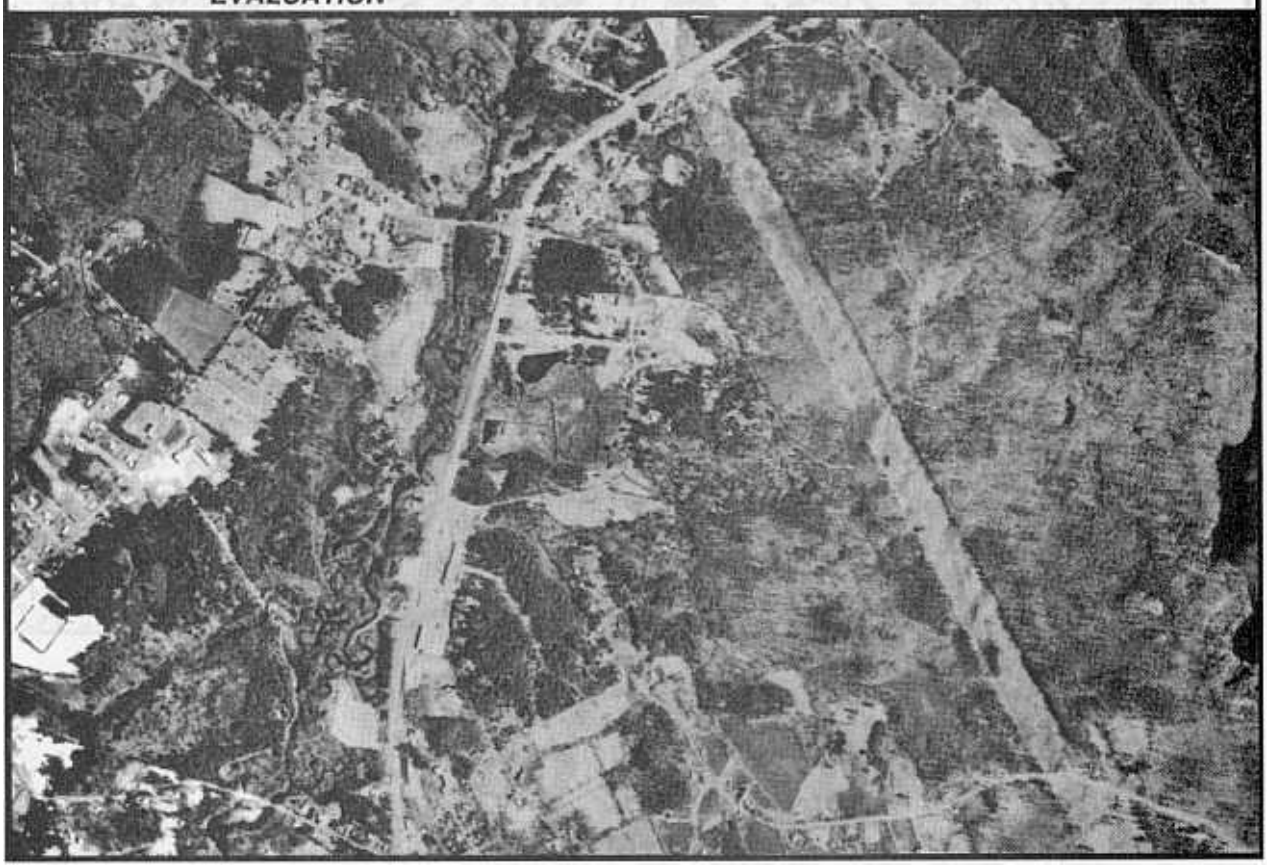
Soil maps give general indications of soil properties for broad planning. As indicated in Chapter 7, NCSS soil maps are not made on a large scale so the information is general and cannot be used in place of detailed investigations.

AERIAL PHOTOGRAPHS

Aerial photography is another useful aid for preliminary evaluations. Depending on flight altitude, season photographed, and clarity, photographs are useful in determining site conditions. Culture, vegetative cover, approximate extent of wetlands, water bodies, and drainage areas may be seen. A typical aerial photograph is shown in Figure 9-5. In addition, stereoscopic photographic pairs provide the impression of depth when viewed through a stereoscope. Stereoscopic photography aids in determining drainage area divides, stream courses, relative elevations, and topography in three dimension.

Dense evergreens, snow, leaves, and long fall

FIGURE 9 - 5 AERIAL PHOTOGRAPHS PROVIDE USEFUL DATA FOR PRELIMINARY EVALUATION



shadows limit the effectiveness of photographic coverage. Spring photography taken prior to leaf emergence provides the best aerial coverage. Higher sun angles minimize shadows. The previous season's snow cover also mats down vegetation so that photographic ground elevations are more accurate.

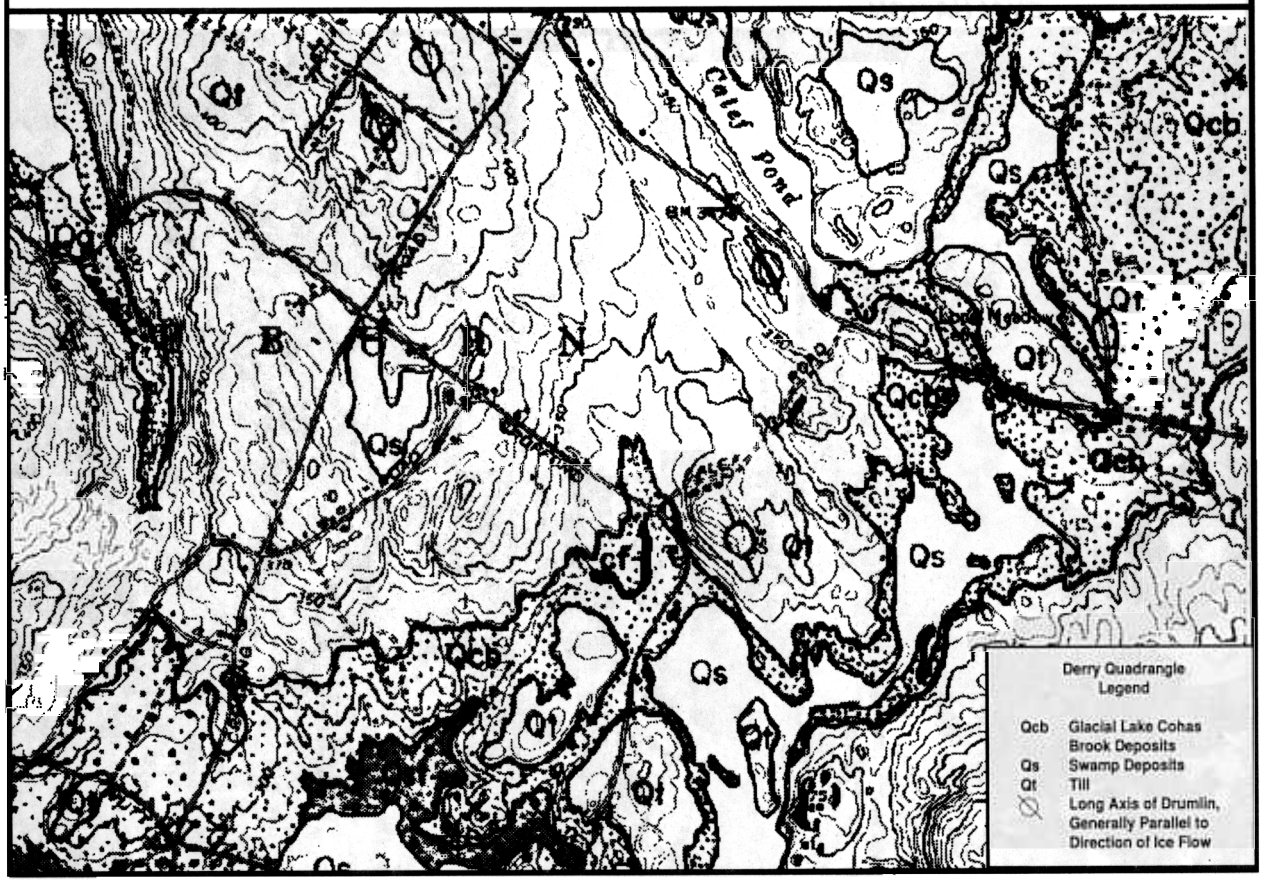
Low altitude aerial photography commonly taken to provide large scale topographic mapping may be available. There may be limited coverage available from particular studies by federal, state, and local governments. Location of this coverage may be difficult to determine and more difficult to procure. Some large scale public topography may indicate the existence of aerial photography. Large scale aerial photographic coverage is available in limited areas from private aerial photography survey firms.

Higher altitude black and white photography is available for all of New Hampshire through the USDA Agricultural Stabilization and Conservation Service (ASCS). An ASCS office is located in each county. Each office maintains a photo index of their photography.

This black and white photography is available, depending on the county, as overlapping contact prints, film negatives, or film positives at various scales. Stereoscopic coverage requires consecutively numbered prints within the line of flight. Most recent flights were in 1981 or 1982. New flights are proposed for the early 1990s. Earlier black and white photography is also available.

Black and white rectified print and film positive enlargements may also be ordered from this photography. Sizes up to 38 by 38 inches are available in scales up to approximately 1 inch equals 400 feet. This enlarged photography is rectified, resulting in nearly true to scale representations of ground features.

FIGURE 9 - 6 PARTIAL EXAMPLE OF A SURFICIAL GEOLOGIC MAP



Normal color, infrared, and other photography may be available from ASCS.

GEOLOGIC MAPS

Geologic data maps and reports are useful for preliminary evaluations. Depending on the type of development proposed, they may furnish very useful data on surficial geology, bedrock geology, and construction material inventories. Map coverage is limited, however. Geological publications are available through the New Hampshire Department of Environmental Services Public Information and Permitting Office and the United States Geological Survey. A partial example of a surficial geologic map is shown in Figure 9-6.

FLOOD STUDIES

Information is available in many communities for areas that are flood prone. Flood insurance study reports are published by the Federal Emergency Management Agency for many communities in New Hampshire. These reports contain flood insurance rate maps indicating areas that are flood prone. They may provide water surface profile data for selected streams. Some communities have flood hazard analysis reports. Others have flood hazard boundary maps that show generalized flood hazard areas. Reports may be available from the respective municipalities.

AQUIFER AND GROUNDWATER MAPS

Aquifer maps indicate approximate areas which have potential to serve as significant sources of groundwater. The mapped aquifers consist of relatively thick, saturated deposits of sand and gravel. Sand and gravel aquifers have been mapped statewide at a scale of 1:125,000. How-

ever, more detailed statewide mapping at a scale of 1:24,000 is currently being conducted by the US Geological Survey, in cooperation with the NH Department of Environmental Services. This mapping is scheduled for completion in 1993. For the purposes of the mapping project, the state has been divided into 14 different study areas whose boundaries largely coincide with natural drainage basins. Progress in each study area is illustrated by the groundwater mapping status map in Appendix B.

The aquifer boundaries, as delineated on the published maps, roughly correspond to the geological contact between soils derived from glacial till parent materials in the uplands, and those derived from parent material of glaciofluvial or glaciolacustrine origin, generally in the valley bottoms. Approximate depths to the water table and directions of groundwater flow can also be estimated from the maps by reading water table elevation contours. These maps are helpful in preliminary evaluations because they may outline areas of valuable water resources and those vulnerable to groundwater contamination.

ZONING AND OTHER TOWN REGULATIONS

Town zoning, subdivision, building, and other regulations are important sources for preliminary evaluations. These items do not provide data on natural resources of sites, but specify development limits based on soil and other site characteristics. These regulations are available from each town and vary a great deal.

The regulations may have provisions for wetland overlays, aquifer protection ordinances, flood hazard overlays, and steep slope development limits. They also provide requirements for residential lot sizes, sediment and erosion control, and storm drainage requirements based on types of soils.

SOIL POTENTIAL REPORTS

Soil potential reports for low density development have been published for several counties in New Hampshire. They are helpful for preliminary evaluations because they are planning guides indicating relative potential of soils in a county for low density development. These reports include ratings of soils, explanations of the rating system, and list criteria used.

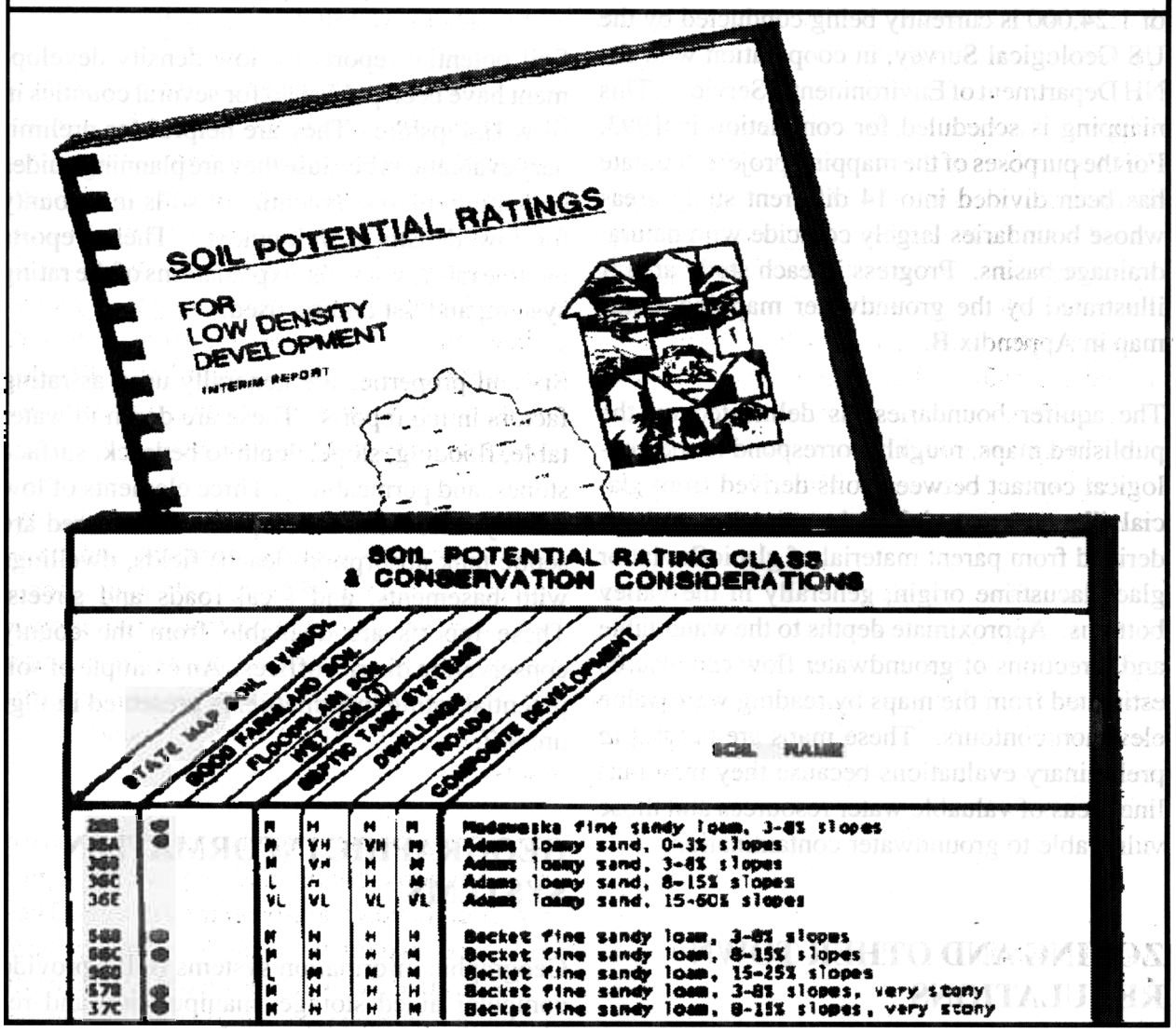
Six soil properties are generally used as rating factors in the reports. These are depth to water table, flooding, slope, depth to bedrock, surface stones, and permeability. Three elements of low density residential development considered are septic tank absorption (leach) fields, dwellings with basements, and local roads and streets. These reports are available from the county conservation district offices. An example of soil potential rating information is presented in Figure 9-7.

GEOGRAPHIC INFORMATION SYSTEMS

Geographic information systems (GIS) provide computer aided storage, manipulation and retrieval of natural resource information in digital form. Computer output is presented in graphical and tabular formats. These systems are currently state of the art in data manipulation and use of geographic referenced information. Soil survey map units, topography, and other resource information are stored in digital format. This facilitates retrieval in a variety of data formats and graphical forms customized for the user.

Maintaining data in digital form allows for selective processing and graphing. Data may be combined, deleted, and sorted as desired. Data can be graphed in various formats and at various scales compared to the original data.

FIGURE 9 - 7 EXAMPLE OF SOIL POTENTIAL RATINGS



These systems are able to produce soils, topographic, flood, and other maps as data becomes available. This information can be used to select certain attributes. For instance, a soils map could be produced at a desired scale that would show only poor and very poorly drained soils. Flood prone soils could be shown separately or in combination with other information.

It is important to know how the data bases were created before using them. For instance, a soils map could be produced at a scale of 200 feet to the inch, but the data base may be a NCSS report designed for preliminary evaluations and that is not sufficiently accurate for detailed studies. The conditions applying to the soil survey report maps as they were originally made also apply to the enlarged maps.

There are difficulties in properly using GIS when scales are expanded. Problems with overlay fitting have to be resolved. Differences between topographic bases and soil maps, for instance, require professional review and resolution in many cases.

The New Hampshire Office of State Planning, (OSP) through Complex Systems Research Center at the University of New Hampshire, is digitizing the county soil surveys prepared by the Soil Conservation Service. This data is being incorporated into the state's geographic information system, GRANIT. To date, Rockingham, Carroll, Strafford, eastern Hillsborough and Grafton coun-

ties have been stored in the GRANIT data base. Remaining soil surveys will be digitized as time permits and when available.

The soils layer is a key component of the NH GRANIT system and consists of the soil unit boundaries as mapped by SCS at either 1:20,000 or 1:24,000 scale. Each soil unit appearing on the soils map is digitized as a series of line segments forming a closed area or polygon which duplicates the soil unit shape. Each soil polygon is coded according to the statewide soil classification system. A soil attribute table data file containing relevant characteristics and interpretations for each soil unit is linked to the digital map through the soil code.

There are a host of applications of soils data, once it is in digitial form in a GIS. One common application is a map of a town showing location and extent of poorly drained and very poorly drained soils . These maps are useful in preparing wetland inventories and in supporting local land use regulations by identifying wetland areas.

WETLAND MAPS

Wetland maps are available from the U. S. Fish and Wildlife Service. These maps generally are at the scale of USGS topographic maps. These maps may be in the form of overlays for the quadrangles. Other maps may be available in some towns that have conducted detailed wetland mapping.

PRELIMINARY EVALUATIONS

As discussed in the initial section of this chapter, preliminary evaluation of soils is accomplished in two steps: soil investigation and evaluation of soils in relation to proposed development plans. The soil features are important factors in most developments and, therefore, play a major role in development siting. Some preliminary evaluation factors are listed in Figure 9-8.

The evaluation process for soils continues throughout the development planning process. Fortunately, soil requirements for many developments are common and do not vary a great deal. However, extreme variations in soils and / or marginal soils can occur over an entire site area. When problems occur, siting is commonly a time consuming process. Horizontal and vertical variability of soils, the number of development items, and the ability to engineer corrective measures, make it a complex task.

Some soils may be evaluated fairly easily. Wet soil areas may be excluded from structural development through a "filtering" planning process since they are protected for their environmental value. Very steep slopes may also be excluded for structural and environmental considerations, since they have little potential for buildings and roads.

These and other areas may be "filtered" out based on soil reports, zoning and subdivision regulations, flood studies, and other information. These areas then would be excluded from possible structure areas. This process could continue with the same approach for aquifer protection and other zones. Important farmland soils should be considered a natural resource that is limited and difficult to replace.

Figure 9-9 shows a schematic of a "filtering' approach.

As the evaluation process evolves, more subtle evaluation is required. Weighing soil properties (along with other nonsoil development considerations) is needed with more refined development proposals. This procedure then becomes one of "fitting" evolving development plans to the areas of the site that are, at a minimum, acceptable for at least one development requirement. Some preliminary evaluation aspects are

FIGURE 9 - 8 SOME PRELIMINARY EVALUATION FACTORS	
WET SOIL	Amount Distribution Feasibility of roads, lots, layout Adverse impacts
SLOPE	Steepness Length Stability Space and layout for proposed development Feasibility of roads, downslope lots, utilities, drainage Stability and seepage of excavated slopes Runoff diversion Erosion
DEPTH TO WATER TABLE	Feasibility of sewage systems, basements, utilities Water quality Frost heaving of pavements
DEPTH TO BEDROCK	Feasibility of sewage systems, basements, utilities, drainage Excavations for roads Water quality
TEXTURE	Feasibility of sewage systems Frost heaving Erosion Vegetation Compaction requirements Structural requirements, bearing capacity Fill compatibility Water quality
RESTRICTIVE LAYERS	Feasibility of sewage systems, drainage systems Slope seepage, stability, sloughing
FLOODPLAINS	Extent Impact on proposed development
BORROW SOURCES	Environmental concerns Restoration Quantities, quality, testing requirements
VEGETATIVE COVER	Impact on runoff Impact on erosion Ease of establishment
PERMEABILITY	Reservoir leakage Water quality Safety of hydraulic structures Feasibility of sewage systems Testing requirements Wells

FIGURE 9 - 8 SOME PRELIMINARY EVALUATION FACTORS (Continued)	
EROSION POTENTIAL	Water quality Control measures
BEARING CAPACITY	Structure design Testing requirements
EXISTING FILL	Density, composition Consolidation Slope stability, internal drainage, testing requirements Water quality Safety, health
WATER BODIES	Water quality Recreation potential
SOIL DRAINAGE	Feasibility of sewage systems, basements Site access in spring
RUNOFF POTENTIAL	Water management
AQUIFERS	Possible pollution Water source

discussed in Figure 9-10.

Wet soils should be evaluated if development construction could impact them. Wet soils are usually valuable as wetlands and disturbance may reduce their value. It may be desirable to evaluate alternative sites. Use of wetlands for constructing detention or filter areas may be unsatisfactory. Very poorly drained soils are also usually unacceptable for structural reasons due to high water, high organic content, and low bearing strength.

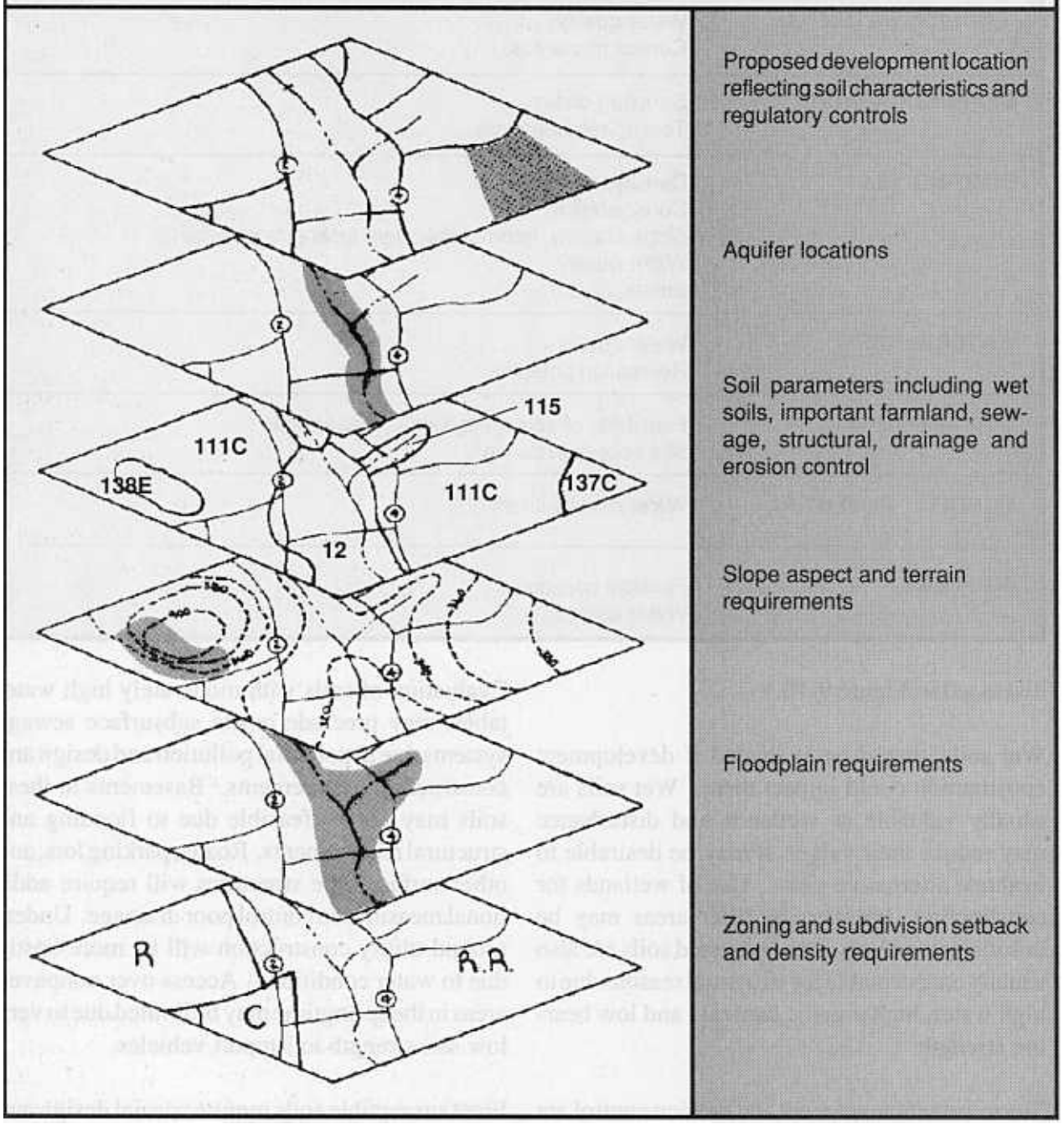
Stormwater management and erosion control are particularly critical. Slope instability and internal drainage make road and other structure design and construction difficult. Vertical sight distance, ditch stability, and water management become increasingly important as degree of slope increases. Excavation and fill become more prominent and require increased design and construction expertise. Soils with very steep slopes may be unacceptable for most structural purposes.

Evaluation of soils with moderately high water tables may preclude onsite subsurface sewage systems due to potential pollution and design and construction requirements. Basements in these soils may not be feasible due to flooding and structural requirements. Roads, parking lots, and other surface-type structures will require additional measures to control poor drainage. Underground utility construction will be more costly due to water conditions. Access over nonpaved areas in the springtime may be limited due to very low soil strength to support vehicles.

Frost susceptible soils require special design and construction measures for roads and structures to overcome frost heaving. These measures are usually expensive. Feasibility may revolve around availability of nearby suitable borrow sources for obtaining soils less susceptible to frost.

Erosive soils require extra care for both temporary and permanent erosion and sediment control measures. Some soils are so erosive that excavated and fill slopes may be severely damaged

FIGURE 9 - 9 SCHEMATIC SHOWING PARTIAL "FILTERING" APPROACH FOR INITIAL EVALUATION OF SITE DEVELOPMENT



during construction. Great care may be required for erosion and sediment control, both during and after construction, to maintain surface water quality.

In-place density of soils is important for certain structure requirements, slope stability, and existing fills. Proper compaction of constructed fill is needed for foundation stability.

Soils with high permeability may not be suitable for onsite sewage disposal because of the possibility of groundwater pollution. These soils may also require additional measures for dams and reservoirs due to piping and leakage.

Onsite soils used for embankments and other fills require evaluation to determine construction characteristics. Compaction and excavation re-

FIGURE 9 - 10 EXAMPLE OF A PRELIMINARY SOIL EVALUATION

This example includes discussion of some aspects of a preliminary soil evaluation for a hypothetical large subdivision site. It illustrates use of data sources and addresses some complexities of large subdivisions with varied landscape. This discussion obviously does not include all items that are required at actual sites.

SUBDIVISION SITE -- This site has a diverse landscape, steep slopes, wetlands, important farmlands, floodplains, and a variety of soils. It represents many opportunities, as well as problems for optimizing development.

CONCEPTUAL PLAN -- The initial concept for this development essentially involved single family housing on individual lots with separate subsurface sewage systems and private wells.

PRELIMINARY SOIL EVALUATION -- The preliminary evaluation of the soils at this site was a critical part of the overall preliminary plan. Sewage systems, road layout, protection of wetlands, steep areas and stormwater management would be crucial elements as noted during field observation.

A modern soil survey report is not available for this county. However, field sheets for the new survey had been completed and copies are available from the county conservation district office. Soils data is also available which gives up-to-date information on all the soils at the site. The soil survey field sheets are available at a scale of 1 to 20,000.

United States Geological Survey topographic maps are available for this development. The site is covered primarily by two 7 1/2-minute quadrangles at a scale of 1 to 24,000. The remaining area is on an older 15-minute quadrangle at a scale of 1 to 62,500. Contour intervals are 20 feet for all three maps.

The town has a Federal Emergency Management Agency flood insurance study available that gives information on flooding sources in the town, including the river bordering the property. The study indicates the flood levels for various frequency storms. The maps are available at a scale of 1 to 6,000.

The conservation district has a soil potential report for the county giving preliminary assessments of the county soils for development. The report gives soil potential ratings for low density housing development, including houses with basements, subsurface sewage systems, and roads.

Aquifer maps are available that show aquifers in the town. These maps are in the town's master plan, open space section, and at a scale of 1 to 62,500.

The town also has designated wetlands. These areas are delineated on the large scale town map at a scale of 1 to 6,000.

Because of the magnitude and complexity of the site, various map scales and digital data available, a geographic information system (GIS) is used as an aid in preliminary planning. It is anticipated that several planning scenarios will be required before final preliminary plans can be developed. The GIS facilitates rapid manipulation and analysis of data. The system will handle various scale maps as input and readily produce desired output in tabulated and map formats. It is realized that GIS is a planning tool and that increasing the scale of maps does not increase their accuracy. The developer notes this as a warning to any other users on the enlarged drawings.

All soil areas, topographic contours, roads, flood limits, aquifer limits, USGS swamp and seep areas, streams, and culture on adjacent properties, are digitized and stored electronically via GIS software. The data is stored in "layers" so that it is easier to manipulate and produce various outputs.

Several preliminary maps showing "overall" views of the site are created. The maps produced are:

- combined topographic map from the three USGS maps
- combined soil survey map from field sheets

FIGURE 9 - 10 EXAMPLE OF A PRELIMINARY SOIL EVALUATION (Continued)

- topographic map with soil slopes over 15 percent and floodprone areas highlighted
- topographic map with poorly drained soils, very poorly drained soils, other wetlands, USGS swamp areas and aquifer zones separately delineated
- topographic map with floodprone areas shown
- topographic map with important farmland soils highlighted
- topographic map with highly erosive soils highlighted
- soils maps with highly permeable soils, shallow to bedrock soils, hardpan soils, slowly permeable soils, high water table soils, and soils suitable for large sewage systems, selectively displayed
- map showing the rating classes for soil potential for development
- overlays of conceptual single family housing.

From the data displayed on the large array of maps, it was clear that it was not feasible to overcome site limitations for a single family subdivision. Site soil conditions indicated many problems with this concept, including:

- extensive dispersed wet soils in one major section making single lot layout impractical
- steep slopes on lots in several areas
- poor soils for sewage systems on many lots, but excellent soils in six substantially large areas for group systems
- large road fills with undesirable lots created on the downslope side
- difficulty with road layout
- excessive length of roads

PRELIMINARY EVALUATION -- Development plans are revised, using a filtering process to protect the wetlands, minimize development on steep slopes and avoid highly erosive areas. Cluster development is chosen with group subsurface sewage systems. This optimizes the use of soils for the sewage systems yet adequately protects the groundwater. Grouping of units also eliminates undesirable downslope lots, road layout problems, and saves some of the farmland. Through a trial and error planning process the final plans are harmonious with the site environment. As a result development costs and environmental impact are reduced.

quirements and consideration of erosion during construction should be evaluated. Because of possible water pollution, excavation of material near the water table is a concern.

Water tables should be investigated in relation to proposed construction. Excavation and other construction may affect water tables on and offsite.

ONSITE INVESTIGATION

10

A thorough soil investigation at a proposed site is a primary basis for development evaluation. Careful planning, skilled field exploration, and accurate and thorough reporting of data is necessary for completing efficient, environmentally sound, and cost effective evaluations. Poorly planned, inaccurate, and partial investigations may contribute to inconclusive and incorrect soil evaluations. Faulty evaluation may lead to unsatisfactory development.

Investigations are conducted at different intensities and for various purposes. Detailed investigation may be done in conjunction with, or separate from, HIS surveys.

PLANNING THE INVESTIGATION

Careful planning for field investigations is the key to satisfactory results. During planning all available information should be used to ensure a thorough investigation. The preliminary site investigation discussed in Chapter 9 not only serves as an initial step in determining the overall development feasiblity, but also aids in preparing plans for detailed investigations.

It is desirable to start field exploration after completing an investigation plan. Experience shows that unplanned approaches to investigations are costly, do not provide detailed coverage where needed, and may give an overall false sense of adequacy. For instance, a large number of test pits dug on some random grid uniformly blanketing a site may, by numbers alone, indicate intensive investigation. However, limited investigation in critical areas may result in inaccurate delineations of adverse conditions. Poor investigation can increase costs significantly and may result in unsafe or otherwise unsatisfactory conditions.

Plans should be dynamic guides to investigations from beginning to end. Planned investigations avoid duplication of effort, ensure that necessary data is obtained, speed up field work, and minimize environmental damage.

Planning should be done after topographic mapping and horizontal control are completed. Detailed topographic mapping provides a more accurate basis for planning test hole locations. Soil surveys also aid in determining locations for test pits and drill holes. Refined mapping with smaller contour intervals and more accurate horizontal control also facilitates determination of access routes. Determining these routes before starting work enables clearing to be accomplished before exploratory equipment arrives.

This saves time and minimizes test equipment usage and environmental damage. Established horizontal control is also helpful for determining actual test hole locations.

A high intensity soil (HIS) map can be a useful aid in planning the onsite investigation. HIS maps are not needed or required for all site evaluations. Complex landscapes and marginal soil conditions are examples where a HIS map may be useful for certain developments. In these cases a HIS 2-foot contour map will provide an accurate basis for planning test pit locations.

Investigations are normally required for structures, roads, utilities, dams, and reservoirs. Investigation for structures, including buildings, may be done to determine adequacy of foundation soils for bearing, settlement, frost susceptibility, and to determine water table conditions. Proposed road locations require investigation to determine adequacy of foundation materials, susceptibility to frost action, drainage characteristics, and depth to bedrock, especially in areas to be excavated.

Soil investigation is essential when evaluating sites for dams, spillways, and reservoirs. Foundations are investigated to determine characteristics of soils, bedrock conditions, and hidden stream channels. Spillways require investigation to determine material availability for construction, flow erodibility, and foundation conditions for structural elements. Investigations are also used to obtain samples for determining reservoir permeability and slope stability.

Development of plans should involve the professionals that will use the data for evaluation. This involvement of designers and others during investigation planning will help ensure that all needs are met.

A plan may partially consist of a layout sheet based on a detailed topographic or HIS map indicating proposed test holes. Access routes may be indicated. Plans should reflect anticipated use of material from development excavation and borrow areas and where soil testing is required.

Plans should note the type and size of equipment required. Equipment depends on depth of test holes, difficulty in digging, amount of cobbles and boulders, anticipated water table depths, and surface stones. Debris, slope, time schedules, and field testing are additional considerations. Local availability of equipment should be checked.

Test pitting is the normal choice for shallow exploration as it is inexpensive, fast, and provides the best opportunities for direct observation and sampling. Drilling is required for exploring beyond the practical depth of test pitting, for sampling below the water table, for doing standard penetration tests, and for permeability testing. Drilling and other special exploratory methods may be required in special circumstances. These may include hazardous waste situations, soft or ponded areas, and steep slopes.

Figure 10-1 gives brief descriptions of various common methods of field exploration and their advantages and disadvantages.

Plans should be flexible as initial results may require significant changes. Because of the need for adjustment and flexibility, it is desirable to interpret data as each test hole is completed. Interpretation and ongoing communication with designers as the process proceeds are vital for successful investigations.

If all significant soil conditions are not investigated, reported, or evaluated, omissions in evaluation can occur. These omissions may increase costs, create environmental problems, and decrease the quality of development.

It is important to plan safe investigations. Any surface and subsurface utilities should be identified, located, and protected.

FIGURE 10 - 1 SOIL EXPLORATION AND FIELD TESTING AT A GLANCE

TEST PITTING:

Description: Mostly excavating a pit with a backhoe or hydraulic excavator. Hand digging is very limited.

Depth: Generally 10 to 20 feet, depending on material and size of machine. Larger machines are more efficient for deeper holes, holes with water, and to verify bedrock.

Benefits: Permits direct observation and sampling. Permits viewing discontinuities and layers and taking large samples. Aids in determining oversize volume.

Cost: Inexpensive compared to drilling.

Disadvantages: Limited value below water table. Limited in depth by machine, material, water table, safety, caving, seeps, property restraints.

Safety: Open pits are hazardous. Should be guarded when open. Side slope stability is a concern especially with seeps, water table, layers, and surcharge.

Details: More clearing needed than for drill rig. Wheeled equipment requires better access roads during wet conditions. Generally done after topo, usually before drilling.

PROBING:

Description: Using a muck probe or a rod to determine depth to refusal.

Depth: Limited to reasonable depth with manual methods.

Benefits: Inexpensive, easy method to determine depth of muck and organic layers. Minimum disturbance.

Disadvantages: Access may be difficult. Sampling limited.

HAND AUGERING:

Description: Boring hole with an auger. Usually with hand auger.

Depth: Generally 6 feet or so by hand, but depends on stones and hole caving.

Benefits: Convenient when quick hole required without power equipment.

Cost: Personnel time.

Disadvantages: Shallow depth. Hard manual work. Small disturbed mixed samples, stones are a problem.

FIGURE 10 - 1 SOIL EXPLORATION AND FIELD TESTING AT A GLANCE (Continued))

DRILLING:

Description:	Boring hole with drill rig.
Depth:	Deep. Limited by size and type of rig.
Benefits:	Permits exploration and sampling below water table, standard penetration, permeability testing, and drilling into bedrock.
Cost:	Expensive.
Disadvantages:	Never as fast as test pitting. Small samples. Cannot view soil directly. Continuous sampling expensive. May be more difficult in winter.
Safety:	Generally safer than test pitting for certain applications.
Details:	Usually done after test pitting.

SEISMIC REFRACTION:

Description:	Measurement of induced vibratory waves refracted from various layers.
Benefits:	Quickly determines major delineations between bedrock, soil, etc. Relatively fast. Good for correlation between drill holes.
Cost:	Inexpensive compared to drilling.
Disadvantages:	Physical sampling not available. May require correlation holes, ground truthing. May be difficult to distinguish between till and bedrock. Qualified operators and experienced interpreters a must.

GROUND PENETRATING RADAR:

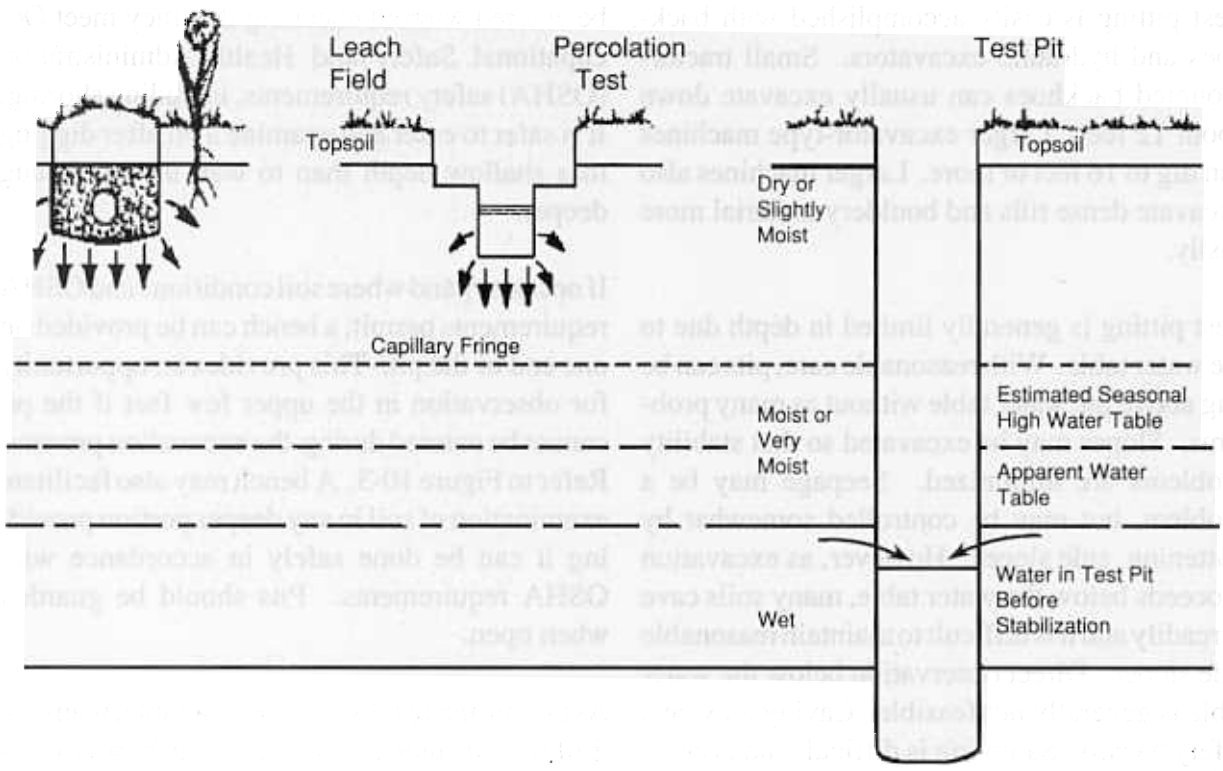
Description:	Inducing radar waves into the ground and measuring returning waves to locate bedrock, water table, utilities, etc.
Benefits:	Can quickly cover accessible areas. Readily locates shallow pipes, etc.
Cost:	Depends on availability of equipment, location, and appropriateness of method.
Disadvantages:	Equipment not readily available everywhere. Qualified operators and experienced interpreters a must.

FIELD OBSERVATION

Detailed observation of the whole site area is desirable when conducting investigations. Any additional information discovered prior to the arrival of testing equipment may affect and supplement the mechanical exploration. Field observation also checks and verifies the investigation plan.

Locations of springs and seeps, bedrock outcrops, exposure of surficial materials and similar material features should be recorded. Exposures should be described or logged just as test holes are logged.

FIGURE 10 - 2 RELATIONSHIP OF TEST PIT AND PERCOLATION TEST TO THE LEACH FIELD



TEST PITTING

An initial phase of detailed field investigations commonly involves test pitting. This is a relatively simple procedure of digging holes with excavation equipment at selected locations, observing soil materials, logging pits, and sampling. Test pitting is usually started after detailed topographic mapping and horizontal field control are available to facilitate office and field layout. It is helpful to plan test pitting after any HIS or other detailed soil mapping is available.

Test pitting is usually initiated in the early planning stages. Pits are required as part of the soils investigation for subsurface sewage systems. State regulations require test pits for subdivision approval and for detailed design of sewage disposal systems.

One primary item to evaluate when conducting the site investigation for sewage absorption systems is the receiving layer characteristics. This layer is considered to be the natural soil above any soil restrictive layers, bedrock, or a seasonal high water table. The identification of restrictive layers and the determination of seasonal high water table levels usually involve the use of test pits. Other investigations are used also. See Figure 10-2 for the relationship of test pits to percolation tests and the leach (absorption) field.

Test pitting is a way to observe soils in their natural state. Pits may be large enough to permit close visual and physical examination of in-place soils. Excavation exposes large vertical cross sections of soil permitting direct observation of profiles. Test pitting facilitates the collection of disturbed samples as pits are excavated. It also facilitates undisturbed sampling where neces-

sary. Selected piling of the excavated soil may also aid in estimating volumes of cobbles and boulders when determining borrow quantities.

Test pitting is easily accomplished with backhoes and hydraulic excavators. Small tractor-mounted backhoes can usually excavate down about 12 feet. Larger excavator-type machines can dig to 16 feet or more. Larger machines also excavate dense tills and bouldery material more easily.

Test pitting is generally limited in depth due to the water table. With reasonable care, pits can be dug above the water table without as many problems. Slopes may be excavated so that stability problems are minimized. Seepage may be a problem, but may be controlled somewhat by flattening side slopes. However, as excavation proceeds below the water table, many soils cave in readily and it is difficult to maintain reasonable side slopes. Direct observation below the water table is generally not feasible. Caving may be a safety hazard. Sampling is difficult and is compromised because of the washing action and suspension of finer-sized particles by the water.

Surface conditions and environmental factors should be considered when choosing test pitting equipment. Wheeled backhoes are not as versatile as track-mounted equipment, especially in woods, on slopes, in wet areas, and in soft material. They are faster, however, when moving on firm surfaces.

In woods, it is sometimes necessary to clear paths for test pitting equipment. This can be accomplished by cutting trees and using a dozer to smooth up very rough areas, if clear alternate routes are not available.

During test pitting operations, personnel, public, animal, and machine safety is a must. Care should be taken to locate and avoid any adjacent surface and subsurface utilities. Pits should be excavated with adequate side slopes so that they are not hazardous. Seepage, soft layers, piled excavated material, excavations below the water table, adjacent equipment, and other factors may cause sudden slope instability. Slope failure may cause sudden burial of anyone in or near the pit and instability of digging equipment. Pits should not be entered without checking that they meet Occupational Safety and Health Administration (OSHA) safety requirements, including shoring. It is safer to enter and examine a pit after digging to a shallow depth than to wait until it is dug deeper.

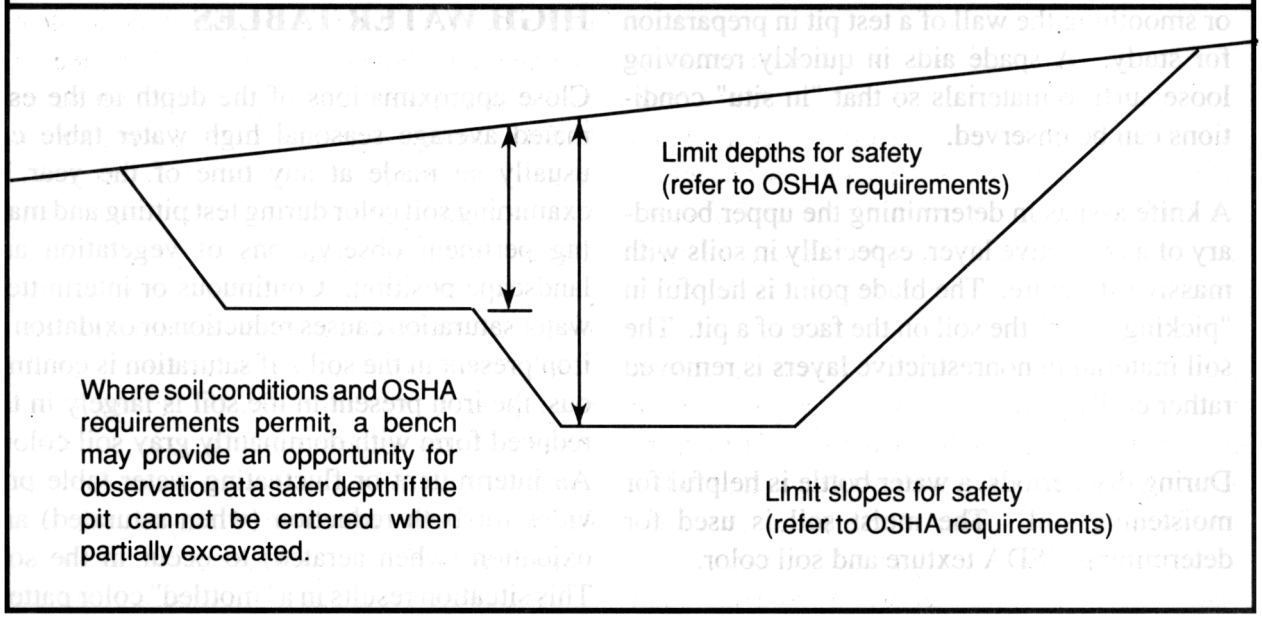
If necessary and where soil conditions and OSHA requirements permit, a bench can be provided on one end of the pit. This provides an opportunity for observation in the upper few feet if the pit cannot be entered during the excavation process. Refer to Figure 10-3. A bench may also facilitate examination of soil in any deeper portion providing it can be done safely in accordance with OSHA requirements. Pits should be guarded when open.

As test pitting results become available, plans for drilling and other investigations can be revised as needed. Since drilling investigations are usually expensive, timely analysis of test pitting results may be helpful in minimizing drilling costs. As test pitting is completed, additional field survey may be necessary to precisely locate test pits and to determine accurate elevations.

Test pits should be accurately logged by closely studying exposed pit walls to evaluate in-place soil characteristics, providing it can be done safely. Site investigations conducted from the natural ground level looking down into the pit, or sampling from the bucket of the backhoe, are less satisfactory from a logging standpoint. All major horizons should be identified and described when logging test pits. Generally the topsoil layer, if present, is readily identified. Subsoil and substratum layers or bedrock, if encountered, are also rather easily identified. These identifications are generally made by visual observations.

In addition to distinguishing major horizons, more thorough study to identify other important soil properties is also conducted. Descriptions of

FIGURE 10 - 3 SUGGESTED CROSS SECTION OF TEST PIT



materials encountered in the various layers should be recorded carefully as investigations proceed. In addition to visual observations, it is necessary to sample the soil to determine texture and consistence.

The distribution of the various soil fractions using the Unified Soil Classification System or the USDA Soil Textural Class should be recorded. A description of soil materials, especially the particle size distribution, can be very subjective and misleading in the absence of definite criteria, experience, and occasional laboratory checks. Information in Chapter 4 may assist in estimating the various soil fractions for the Unified Soil Classification and USDA Textural Classification systems.

Soil structure and any restrictive layers should be carefully noted and recorded. The observer should look for clues previously discussed as aids in identifying restrictive layers. A knife is a useful tool in determining the boundaries between restrictive layers and nonrestrictive layers.

The degree of compactness (relative density and consistency) in the absence of field or laboratory tests is relative to the observer's judgment and experience. However, estimates can be made as to whether or not a glacial till material is a loose to firm ablation variety or a compact to very dense basal type.

Particular attention should be directed towards recording the moisture associated with depth and strata. Observations such as dry, slightly moist, moist, very moist, and wet will help in determining the depth to the observed or estimated water table, the thickness of the capillary fringe, and depth to an estimated seasonal high water table. Soil color as discussed later in this chapter is also used to estimate seasonal high water table. Further, the depth to seepage planes or points should be recorded. The nature of seepage may be significant. Is it a steady or intermittent drip? Is it an increasing or decreasing flow?

TOOLS OF THE TRADE IN TEST PIT LOGGING

Some basic items are useful for logging test pits. The following list is not complete since personal preference is a factor. However, the items listed could become the basis for a "field kit" for logging test pits.

Tools

A tile spade or similar tool is useful in "facing up" or smoothing the wall of a test pit in preparation for study. A spade aids in quickly removing loose surface materials so that "in situ" conditions can be observed.

A knife assists in determining the upper boundary of a restrictive layer, especially in soils with massive structure. The blade point is helpful in "picking away" the soil on the face of a pit. The soil material in nonrestrictive layers is removed rather easily.

During dry periods, a water bottle is helpful for moistening soil. The moist soil is used for determining USDA texture and soil color.

A 25-foot carpenters' tape or survey rod is handy for measuring layer thickness and depths to the water table. A nonconducting rod is recommended if working near power lines.

Pocket Guides

The Munsell Soil Color Chart is a useful item for evaluating the color of soil. Color is perhaps the best indicator of wetness in soil. Munsell notations are arranged by hue, value, and chroma—three simple variables that combine to give all colors. Hue is the dominant spectral (rainbow) color. It is related to the dominant wavelength of the light. Value refers to the relative lightness of color and is a function of the total amount of light. Chroma (sometimes called saturation) is the relative purity or strength of the spectural color and increases with decreasing grayness. For example, a notation of 10YR 6/4 is a color of 10YR hue, value of 6 and chroma of 4. See Figure 10-4. Refer to the reference section for an address of the chart manufacturer.

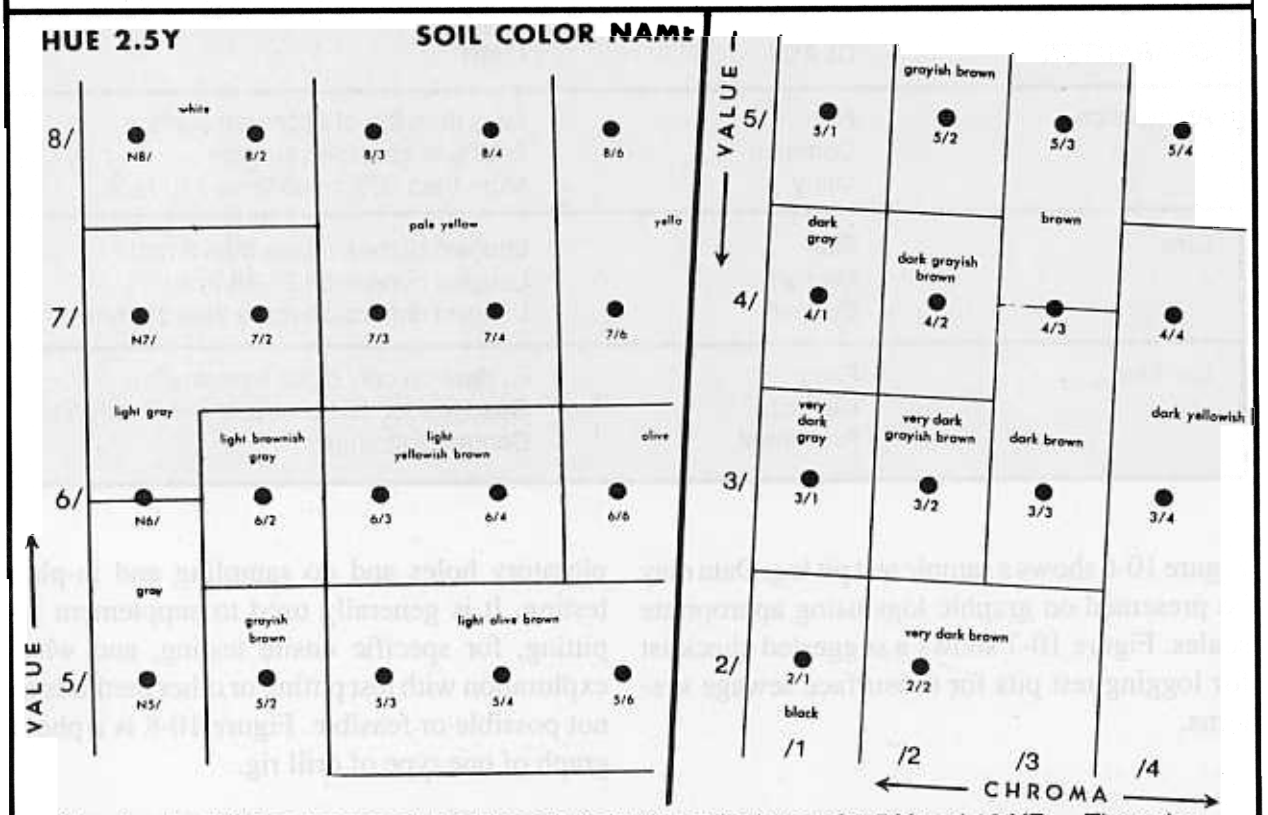
A hip pocket guide consisting of a set of small-sized charts may aid in field determination of texture and other soil properties. These may be made to individual preference. Appendix C shows a sample guide for investigating small subsurface sewage systems.

LOGGING SEASONAL HIGH WATER TABLES

Close approximations of the depth to the estimated average seasonal high water table can usually be made at any time of the year by examining soil color during test pitting and making pertinent observations of vegetation and landscape position. Continuous or intermittent water saturation causes reduction or oxidation of iron present in the soil . If saturation is continuous, the iron present in the soil is largely in the reduced form with dominantly gray soil colors. An intermittent or fluctuating water table provides for both reduction (when saturated) and oxidation (when aerated) to occur in the soil. This situation results in a "mottled" color pattern commonly with a mixture of grays, browns and red splotches. Mottle colors for New Hampshire soil conditions often are either: (1) gray on a matrix subsoil color of a yellowish brown, or (2) reddish brown or brown on a matrix subsoil color of gray or grayish brown. The location of these colors in the soil profile is useful in predicting both the height of the groundwater table and the duration of time the water remains at that height. The presence of grayish mottles chroma 2 or less is a clue that the water table is at that depth for more than about 30 days. In some soils, 3 chroma mottles with values of 6 or 7 are indicators of wetness.

The highest point of distinct mottles relates to the estimated average seasonal high water table. For any given year, the actual seasonal high water table may be significantly higher or lower than the average. This is especially true in sandy soils. Soils with dull gray or grayish brown dominant colors in the subsoil indicate saturated conditions for at least 7 to 9 months. There is an exception to the preceding discussion. Four poorly drained soils in New Hampshire have formed in sandy and gravelly materials with a seasonal high water table. Yet, all of these soils have bright colored (reddish brown) subsoil layers. These soils are: Au Gres, Naumburg,

FIGURE 10 - 4 THE MUNSELL COLOR CHART



Showing the left hand pages of the Munsell Color Chart for hues of 2.5 Y and 10 YR. The color chart is used to evaluate soil colors. The left hand pages give the descriptions for the color chips located on the right hand pages.

Pipestone and Saugatuck.

In addition to color, mottles are also described by character, class, and limit, as shown in Figure 10-5.

Dark mottles commonly do not form in soil composed of fairly clean sands and gravels. The presence of uncoated bodies of sand and silt grains in these soils is often used as a clue to a high water table elevation. The identification of mottles in these materials is often very difficult. Mottling commonly appears as small, uncoated lighter colored spherical splotches (about the size of a dime or nickel). The color is due to lack of iron and other coatings on individual sand grains. The matrix soil color will contrast with the bleached sand grain mottles. These light mottles may occur in sandy soils such as Croghan and Deerfield with a low percentage of gravels and with less than about 15 percent fines.

These light mottles form in soils with deep water tables and are generally located at depths greater than 3 feet. They are related to extreme fluctuations in the water table. These light colored mottles, however, indicate a water table that would be above the average seasonal high water table determined by dark mottles in other soils. The water table located by the light mottles would exist for a very brief time.

Some soils, especially sands and gravels, may have thin reddish brown horizontal layers below 3 or 4 feet. The origin of these reddish brown layers or "iron layers" may be related to a water table situation that was entirely different than exists today. These layers have been referred to as "relic mottles". The water table was perhaps considerably higher than present water table conditions. In site evaluation, it is important to identify the clues for estimating water table levels that relate to present conditions.

FIGURE 10 - 5 CHARACTER, CLASS, AND LIMIT OF MOTTLES		
CHARACTER	CLASS	LIMIT
Abundance	Few Common Many	Less than 2% of observed surface 2-20% of observed surface More than 20% of observed surface
Size	Fine Medium Coarse	Longest dimesion less than 5 mm Longest dimension 5 - 15 mm Longest dimension more than 15 mm
Contrast	Faint Distinct Prominent	Evident on only close examination Readily seen but contrasts only moderately Contrasts strongly

Figure 10-6 shows a sample test pit log. Data may be presented on graphic logs using appropriate scales. Figure 10-7 shows a suggested checklist for logging test pits for subsurface sewage systems.

PROBING AND AUGERING

Probing is useful in very soft materials such as organics to measure layer depth and to accomplish limited sampling. A rod with graduated markings may be used for shallow depths. For greater depths and for limited sampling, a muck probe assembled in sections with a sampler is efficient.

Hand augers are often useful in making shallow borings up to approximately 5 feet. A bucket auger usually works quite well in nonstony soils. The screw auger is convenient and easy to use, but only provides a very small mixed sample of material. A tile spade is often used for shallow observation for soils with stones and cobbles.

DRILLING

Drilling, also called boring, is a more sophisticated and expensive method of exploration. This method involves using a drill rig mounted on skids, a truck, or other equipment to drill exploratory holes and do sampling and in-place testing. It is generally used to supplement test pitting, for specific onsite testing, and where exploration with test pitting or other methods are not possible or feasible. Figure 10-8 is a photograph of one type of drill rig.

Drilling is the method commonly used for exploration at depths deeper than can be reached with test pitting. It is also used when sampling and testing is required below the water table. Standard penetration tests and permeability tests are done with a drill rig. It is the only method for obtaining bedrock samples.

Estimates of textural classes can be somewhat compromised during drilling, especially in coarse-grained soils. The common split tube sampler limits the size of gravel fragments that enter the device. This makes estimates of gradation more difficult than using methods which provide larger samples.

Drilling may also be used where it is desirable to minimize surface disturbance or where open pits are objectionable for safety or other reasons. This method is used if exploration through surface waters is necessary and where instrumentation is required.

Drilling, if required, is commonly conducted after test pitting. This permits modifcation to the

FIGURE 10 - 6 EXAMPLE OF TEST PIT LOGS FOR A SUBSURFACE SEWAGE SYSTEM

TEST PIT NO: 3 **DATE:** 9/18/90
NAME OF PERSON LOGGING:
GENERAL LOCATION: Pine Subdivision
DETAILED LOCATION: 100 Ft. North, 50 Ft. East of SW Corner, Lot 9
VEGETATION: White Pine **SLOPE:** 5%

USING USDA TEXTURAL CLASSIFICATION SYSTEM	ELEV. 204.5 (NGVD)	USING UNIFIED SOIL CLASSIFICATION SYSTEM
Topsoil, fine sandy loam, dark brown. (10YR 3/3) granular structure, many roots		Topsoil, dark brown (10YR 3/3) silty sand, with organic fines, many roots
	0.5'	
Sandy loam, yellowish-brown (10YR 5/6) granular structure, friable, no stones, moist, many roots. NONRESTRICTIVE LAYER		Silty sand with 30% nonplastic fines, 5% hard angular gravel, yellowish-brown (10YR 5/6) granular structure, friable, moist, many roots, glacial till (SM) NONRESTRICTIVE LAYER
EST SHWT	2.5'	EST SHWT
Sandy loam, light brownish-gray (2.5Y 6/2) with common distinct yellowish-brown (10YR 5/6) mottles, granular structure, friable, some stones to 12" diameter, moist, some roots. NONRESTRICTIVE LAYER		Silty sand with 35% nonplastic fines, 10% hard angular gravel, 5% cobbles, light olive gray (2.5Y 6/2) with common distinct yellowish-brown (10YR 5/6) mottles, granular structure, friable, moist, some roots, glacial till (SM) NONRESTRICTIVE LAYER
OBSERVED WATER TABLE 9/18/90	4.5'	OBSERVED WATER TABLE
Sandy loam, light olive gray (5Y 6/2) with many distinct strong brown (7.5YR 5/6) mottles, granular structure, friable, some stones to 12" diameter, wet, sidewall caving, few roots NONRESTRICTIVE LAYER		Silty sand with 35% nonplastic fines, 10% hard angular gravel, 5% cobbles, light olive gray (5Y 6/2) with many distinct strong brown (7.5Y 5/6) mottles, granular structure, friable, wet, sidewall caving, few roots, glacial till (SM) NONRESTRICTIVE LAYER
	6.3'	
Fine sandy loam, olive (5Y 5/4) platy structure, very firm (hardpan) occasional stones to 12" diameter, moist seeps at top of hardpan layer, no roots RESTRICTIVE LAYER		Silty sand with 45% nonplastic fines and 2% cobbles, olive (5Y5/4) platy structure, very dense (hardpan) moist, seeps at top of hardpan layer, no roots, glacial till (SM) RESTRICTIVE LAYER
Bedrock	10.4'	Bedrock

initial drilling plan to reflect site conditions more accurately. For some situations it may reduce planned drilling if test pits are found adequate.

Standard Penetration Testing

Standard penetration testing is often performed in conjunction with drilling. Testing is conducted by driving a split tube sampler into the soil at the bottom of a clean drill hole a total distance of 18 inches. Standard tests are done to obtain an indication of the relative density or consistency and bearing strength. The drive hammer weighs 140 pounds and free falls 30 inches at each blow. The number of blows required to drive the sampler each 6-inch increment is recorded. The "blow count", an indication of the soil's relative density, is the total number of blows required to drive the sampler the last foot.

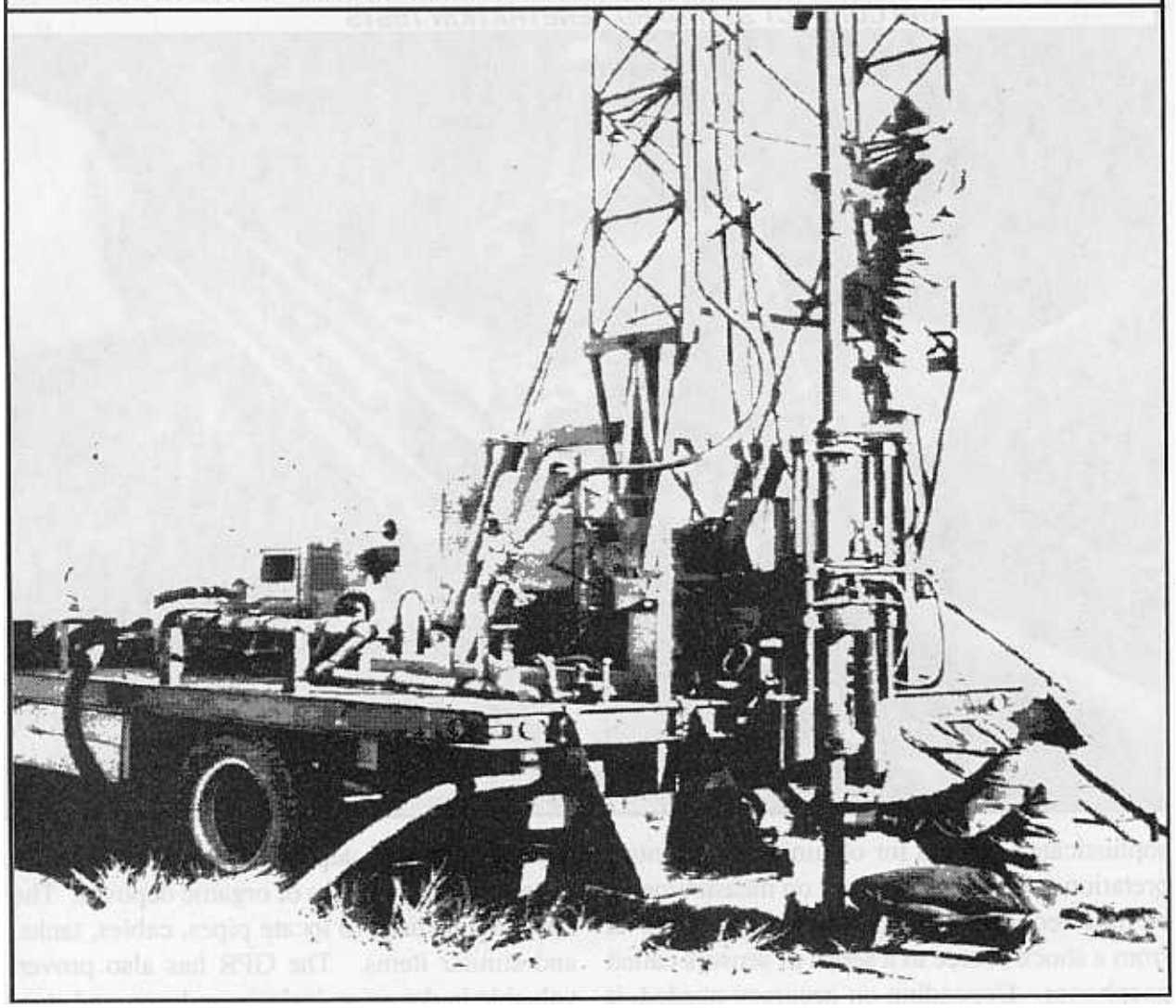
Samples may be collected by using the split tube sampler while conducting standard penetration testing. See Figure 10-9. This sampler is a split tube with an outside diameter of 1 3/8 inches,

FIGURE 10 - 7 A CHECKLIST FOR LOGGING TEST PITS FOR SUBSURFACE SEWAGE SYSTEMS

1. Test pit number or identification
2. Date of log
3. Name of individual logging pit
4. General location of test pit
5. Detailed location (reference to established points of survey)
6. Elevation of ground surface (reference to datum used).
7. Pit depths at: top and bottom of layers, horizons, or changes in soil properties
   estimated seasonal high water table
   seeps
   changes in moisture conditions
   restrictive layers
8. Depth of water table, date and time of observation
9. Textural description of material for each soil layer or horizon, using USDA or Unified Soil Classification Systems
10. Particle size distribution for coarse-grained soil, plasticity of fines for fine-grained soils, group symbol (Unified Soil Classification System)
11. Shape of gravel particles (angular, subangular, subrounded, or rounded)
12. Relative density (loose, firm, compact, very dense)
13. Structure of soil layers
14. Consistence of soil layers
15. Restrictive layers (to vertical water movement)
16. Color of moist soil (Munsell notation and standard terms)
17. Color and description of mottles at estimated seasonal high water table
18. Odor (organic or contaminated soils)
19. Moisture conditions of soil layers (dry, slightly moist, moist, wet)
20. Seeps with notation as to volume of flow (drip, low, high) and rate (steady, increasing, decreasing)
21. Condition of the excavation.
22. Geologic origin

Example using Unified Classification: Silty Sand, with gravel.. Maximum size 6 in., about 5 percent cobbles. About 20 percent gravel, 65 percent subangular to angular sand, and 15 percent low plasticity fines. Lt. olive brown (2.5Y 5/4). Moist, dense, massive glacial till (SM).

FIGURE 10 - 8 EXPLORATION USING A DRILL RIG



and a usable length of about 20 inches. Samples are obtained by carefully withdrawing and opening the sampler.

Permeability Testing

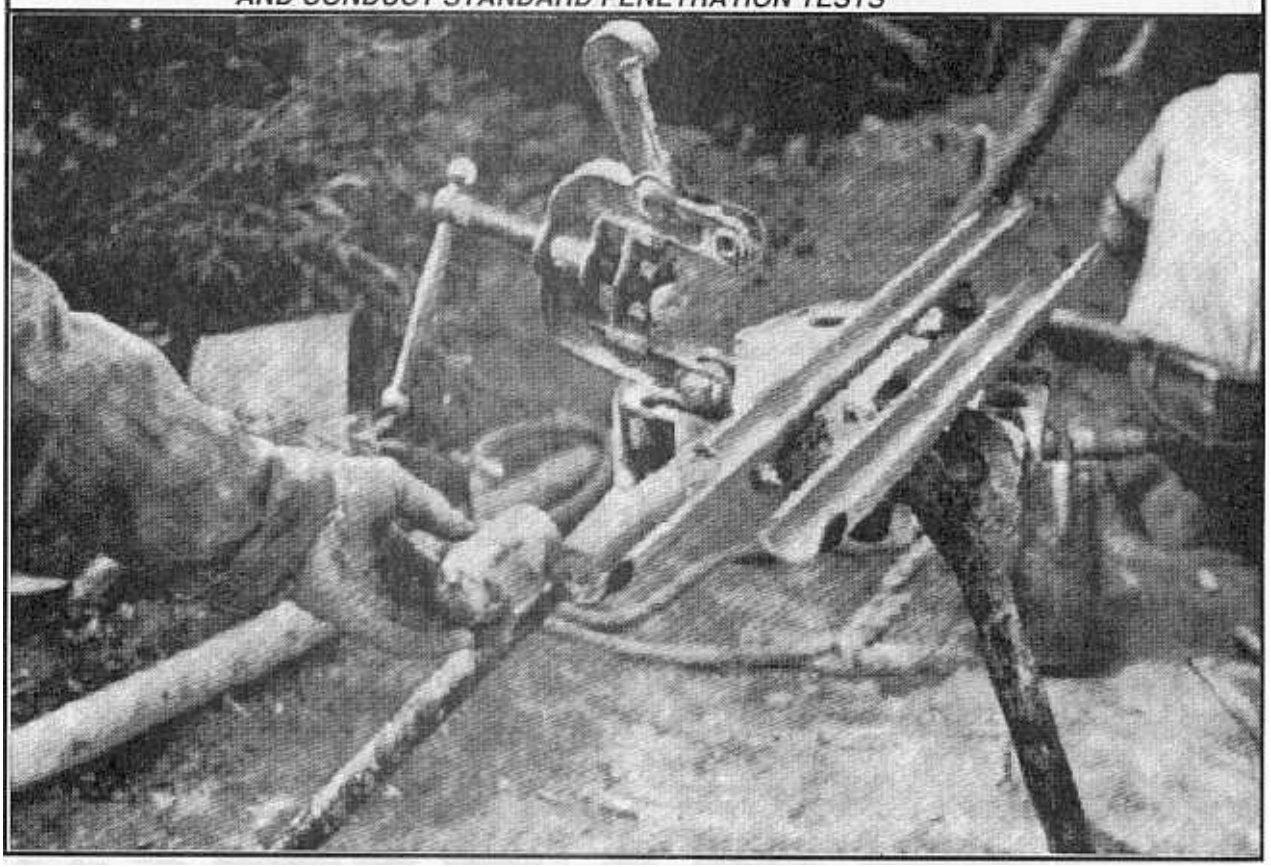
Field permeability tests are also often performed in conjunction with exploratory drilling. These tests are warranted where it is necessary to determine permeabilities of subsurface materials. In soil, the tests are usually a constant level, gravity head test where clean water is introduced into a drill hole at a rate which maintains the water at a constant level. In rock, the tests are usually a constant pressure, steady flow rate test where the section being tested is sealed at the top and bottom with expandable packers. A series of tests are run at increasing, then decreasing pressures, and the results graphed for analysis.

Soil or rock permeabilities are computed based on natural groundwater elevation, diameter, elevation and length of the test section, pressure and gravity heads, and head losses within the piping system. Refer to Figure 10-10 for an example evaluation utilizing test pitting and drilling.

SEISMIC REFRACTION SURVEY

Seismic refraction survey is an indirect method of determining depths to bedrock or depths to a refracting horizon, such as the water table, by use of seismic refraction equipment. It is a relatively

FIGURE 10 - 9 STANDARD SPLIT SAMPLER USED TO OBTAIN SOIL SAMPLES AND CONDUCT STANDARD PENETRATION TESTS



sophisticated process for obtaining data. Interpretations of depths are based on measurements of time required for vibratory waves to travel from a shock source to a series of sensors called geophones. Depending on accuracy needed, it may be quick and inexpensive. It may, in selected cases, be suitable for determining bedrock and/or water table depths between test holes.

GROUND PENETRATING RADAR

Ground penetrating radar (GPR) is a subsurface interface radar system capable of providing continuous soil profile data that indicates the location and depth of contrasting soil material or buried objects. It is based on broadcasting radar pulses into the ground and measuring the returning echoes.

Some of the projects applicable for GPR use include mapping depths to bedrock, depth to water table, and depths of organic deposits. The GPR can be used to locate pipes, cables, tanks, and similar items. The GPR has also proven valuable in detecting leaks in underground storage tanks and mapping leachate plumes. The Soil Conservation Service has used the GPR in New Hampshire to provide more accurate data on soil map unit variability, nature of bedrock topography, and water table characteristics.

The advantage of the GPR system is its speed of operation, capacity to produce large quantities of continuous subsurface data, and high resolution. Compared with conventional auger or drilling methods, GPR techniques provide continuous spatial records of the subsurface and greater areal coverage per unit sampled. Higher levels of confidence in site evaluations may be achieved if methods such as this are used to "fill in" between test holes.

FIGURE 10 - 10 EXAMPLE EVALUATION FOR A RETENTION POND

This example includes discussion of aspects of a soil evaluation for a retention pond site. It illustrates use of data sources and demonstrates a few complexities of evaluations. This discussion does not include many of the items to be considered for complete evaluations at specific sites.

RETENTION POND SITE -- As part of the conceptual plan for a large subdivision, it was planned to construct a retention pond. The permanent pool would serve the needs for fire fighting water supply, water quality, and storm runoff flow reduction.

PRELIMINARY SOIL EVALUATIONS-- A preliminary evaluation was quickly started in order to conduct the soil investigation prior to winter. A preliminary location of the dam was determined by desired reservoir size, depth, and geometry of the valley. The appropriate USGS quadrangle was used to determine preliminary pool surface area and depth. The county soil survey report map was used to obtain preliminary data on the dam foundation and the reservoir. The soil map showed dense silty sands having low permeability in the reservoir and most of the dam foundation. Some alluvial soils were indicated in the floodplain.

From the above information and the required hydraulic characteristics, it was determined that an embankment type dam would be most suited for the situation. The embankment dam would have a principal (service) spillway consisting of a riser inlet, conduit through the embankment, and an energy dissipator at the outlet. An auxiliary open channel spillway would be constructed at an abutment to protect the dam from overtopping during rare floods.

Some rock outcrops were observed in the east abutment. Preliminary planning indicated that the most economical and safest auxiliary spillway would be in the east abutment. Because of the rock outcrops, it appeared that an additional borrow area would be required. Based on soil and topographic maps and considering development concepts and environmental factors, a borrow area looked feasible about 1/4 mile from the dam location. A haul road would be required.

SOIL INVESTIGATION -- A soil investigation was planned to provide sufficient data to make a final evaluation of the site. Topographic maps of the site with 2-foot contours were developed using aerial photography. Low altitude spring photography eliminated the problems with fall shadows, low sun angles, and vegetation not flattened by snow. Field survey provided the needed horizontal and vertical control for the aerial mapping. The topographic maps were then used along with the soils data to develop the investigation plan.

Test pits and drill holes were planned and completed for the dam foundation, auxiliary spillway, and borrow area. Investigation was also completed for the very steep slope in the reservoir. Test pitting confirmed coverage of slowly permeable soils in the reservoir.

A hydraulic excavator on tracks was used to reduce erosion for the site investigation. Trees were cut to eliminate bulldozing them and creating more erosion. Access for both test pitting and drilling were planned and installed at the same time.

Test pit and drill hole coverage was designed to thoroughly cover the dam foundation area including the principal spillway conduit, core trench, and drainage location. Drill holes were closely spaced in the auxiliary spillway area to obtain the optimum layout. Test pitting was used to determine the quality and quantity of soil materials as well as to locate shallow bedrock elevations. Erosion control measures such as water bars, mulching, and vegetation were used to protect water quality. It was determined that additional fill would be required and the borrow site was fully explored. The borrow area was investigated and planned for 50 percent more material than estimated to be required.

SOIL TESTING

Soil testing is required for many evaluations and for later design and construction applications. Testing may be done in the field or the laboratory depending on test applications. Field testing commonly consists of tests performed with drilling equipment and tests done by hand and visual methods.

Field testing during drilling includes standard penetration tests and permeability tests discussed previously. Other field testing includes texture, gradation, percolation, and other classification tests.

The majority of soil testing is done in the laboratory. Laboratory testing is warranted when specific parameters are required for evaluation. Testing for small developments on good soils may be minimal. Testing for more extensive or complex developments on complex or marginally suitable soils may be a significant part of the overall evaluation process.

Soil testing may be required to determine foundation and other site conditions. Foundation testing depends on the types and sizes of structures and the foundation soils themselves. Testing requirements for water retention structures may be more extensive in order to determine consolidation potential, to estimate permeability, and to design gradations of earth fills.

Testing of existing fill materials may be needed to determine consolidation potential, gradation, slope parameters, and permeability. Testing of onsite borrow materials proposed for subsurface sewage systems and other structures may be necessary. Gradation tests aid in evaluating the suitability for proposed fills for strength and permeability. Tests to determine soundness may be required to evaluate onsite sources of drain fill and concrete aggregates to ensure durability.

SOIL EVALUATION

11

Although discussed as a separate subject in this chapter, evaluation of onsite soils is generally a continuous and evolving process from the beginning of site planning through construction. Proposed development in preliminary planning stages is based on initial assumptions of soil and other site conditions. As investigations disclose actual conditions, and as other data such as HIS mapping become available, evaluations usually change until plans fit soil conditions. The planning process continues until evaluations and development plans harmonize.

For many sites, the planning process may be abbreviated due to few site and development variables, or largely favorable soils. For complex plans and difficult site conditions, however, the process may be quite involved and time consuming.

EVALUATION

Evaluations may indicate that large scale changes in the development plan are necessary. Some site areas may lend themselves to certain aspects of a project more easily than others. High water tables or other factors may restrict the use of conventional subsurface sewage systems. Shallow to bedrock areas make it difficult to construct utilities and houses with basements. Preconceived house designs and orientations on steep slopes may be entirely inappropriate. Relating development needs to soil attributes, through evaluation, greatly assists in creating satisfactory development. Soil evaluation and refinement of development layout, design, and construction go hand in hand. Preliminary planning should not proceed to a stage where design cannot be easily changed. Doing detailed planning prior to evaluating the impacts can be inefficient and costly.

Land in some desired locations may be marginal for development. These sites are usually more difficult to evaluate. This puts a heavy burden on the evaluator and designer. Considerable study and evaluation is needed for complex developments.

Because marginal soils are more difficult to evaluate, some refinement may be necessary before definitive answers are available. Some wasted motion may result. However, this is much more tolerable in the design stage than during layout, or worse, during construction.

FIGURE 11 - 1 GENERAL STEPS IN EVALUATION FOR DEVELOPMENT

Preliminary evaluation including field observation.

Reinspect site, review, and verify preliminary evaluation as changes are made in planning.

Develop requirements for detailed high intensity soil mapping, and topographic mapping, where needed.

Develop test pitting requirements for sewage disposal, foundations, utilities, ponds, hydraulic structures, erosion control, waste management, fills, borrow, roads, sewers, slope stability, etc. Consider coordinating with soil mapping.

Determine requirements for drilling including standard penetration and permeability testing.

Develop requirements for field and laboratory soil testing.

Determine any need for ground penetrating radar and seismic refraction.

Conduct field investigation. Modify investigation plan as data is obtained.

Evaluate as investigation proceeds.

Complete investigation and testing as final planning and evaluations are completed.

STEPS IN EVALUATION

Evaluations may range from very simple to extremely complex depending on the site, proposed development, adjacent land, environmental constraints, and other considerations.

Some general steps are useful in preparing for evaluations. They may be in the order indicated in Figure 11-1. However, deviations are common and steps can be partially done at different times depending on scheduling, availability of services, and other priorities.

Preliminary evaluation is conducted to initially verify that overall conceptual design is feasible. Discussion of preliminary evaluation is included in Chapter 9. After completion of preliminary evaluation, the planning process continues with revision of development concepts to fit the site as necessary. As planning proceeds, reinspection, review, and verification of preliminary evaluations may continue as changes are made in development plans.

In early stages, requirements may be completed for site specific detailed soil mapping such as HIS mapping, where needed. Preliminary detailed mapping may be desirable as an early phase of evaluation. Soil mapping, in general, is discussed in Chapter 6, and HIS mapping information is included in Chapter 8.

As planning proceeds, requirements for onsite investigations are determined. Optimum results may be achieved by doing field investigations in reasonable sequence. As investigations proceed, modification of investigation plans may be required as site data is obtained. A discussion of

investigation and investigation planning is included in Chapter 10.

Continuous evaluation of the site is needed as field investigations proceed, especially if critical elements are involved. Crucial foundation considerations, significant problems of large areal extent, and other considerations may completely change or even cancel development plans.

EVALUATION CONCERNS

Evaluation is essential for quality development. The evaluation process should account for the many variables of the site and proposed development concepts. It should be flexible and adapt to changes in concepts and site parameters as they evolve. Many evaluations have common concerns. This section discusses a few of them. A summary of these concerns is included in Figure 11-2.

Evaluation should include areas beyond the site limits that may impact or be impacted by the proposed development. Land areas contributing runoff to proposed developments affect surface runoff and perhaps subsurface groundwater flow. Future development of these offsite areas may create larger peak runoff amounts and volumes for the proposed site. Increased runoff can influence surface and subsurface water quality. Offsite subsurface sewage systems and wells may affect setbacks and locations of systems within the proposed development.

Proposed developments may impact adjacent property in numerous ways. Increased runoff

FIGURE 11 - 2 COMMON EVALUATION CONCERNS

- Not looking beyond site boundaries
- Shotgun approach--missing detail in critical areas
- Overlooking items because of excessive detail elsewhere
- Evaluator not familiar with land
- Not involving needed professionals at beginning of planning and evaluation
- Investigating as preplanned without revising as acquired site data indicates
- Too little communication between designer, investigator, and evaluators
- Not adequately documenting results of investigations
- Not doing investigations in proper sequence
- Not adequately reviewing all site data as evaluation continues
- Evaluation based on maximizing lots without fitting to site
- Neglecting major impact on wetlands due to rigidity of layout
- Assuming problems can be taken care of during construction

may create additional flooding and stream and slope erosion. Plumes from large subsurface sewage systems may affect possible developments both upslope and downslope. Excavated slopes near property limits may create sloughing and erosion on adjacent property if not properly constructed or maintained. Both temporary and permanent excavations and impoundments may affect adjacent water table levels. Development on large depleted borrow pits may affect downslope water quality. Sediment produced during and after development construction may move downslope to offsite areas.

Evaluations may not cover critical areas in sufficient detail. Uniform coverage of a site during investigations may not provide needed data in critical areas to make the necessary detailed evaluations. Likewise, items may be missed because attention was too focused on only a portion of the site.

It is essential that the evaluator be familiar with the land. Soils, landforms, geology, water resources, and the climate of New Hampshire differ from other parts of the country and even vary from other New England states. Knowledge of soil science, soil engineering, and the overall resource base is essential for quality evaluation.

Involvement of related professionals at the beginning of planning will improve evaluations and likely prevent costly omissions or mistakes. Site attributes or problems that could be determined at early stages may be missed if the proper people are not involved. Communication between professionals is also essential. Lack of information, poor documentation, and misunderstanding create problems. Minor items such as noting the soil classification system used for recording soil texture eliminates misunderstanding.

Investigations are crucial for providing the information others use for evaluation and later for design and construction. Plans need to be revised as site data becomes available. Proper sequence is essential for adequate coverage and economical investigation.

Care should be taken to fit development to the site. This is a familiar concept, but is sometimes not fully implemented in practice. Maximizing the number of lots without regard to additional problems that could be created usually is uneconomical. Careful evaluation is essential to protect wetlands and other resources, achieve quality development, and minimize development costs.

Some items specific to individual elements of development are discussed in the following sections. Even though more detailed discussion is included as a guide in this chapter, it is not all encompassing due to the vast variety of development, site factor, soil, and environmental considerations.

SUBSURFACE SEWAGE SYSTEM CONSIDERATIONS

Evaluation of soils for subsurface sewage disposal systems is particularly important for proposed developments where municipal sewers are not available. Proper use of the soil for treatment and disposal is necessary to achieve long-term protection of groundwater and surface waters. In many communities, groundwater will still be the major source of potable water for the foreseeable future.

The following items should be addressed when evaluating subsurface sewage systems:

- Location
- Slope
- Organic mat and interface permeability
- Soil moisture conditions
- Hydraulic mounding

FIGURE 11 - 3 SOIL RELATED ASPECTS OF IN - GROUND LEACH FIELDS

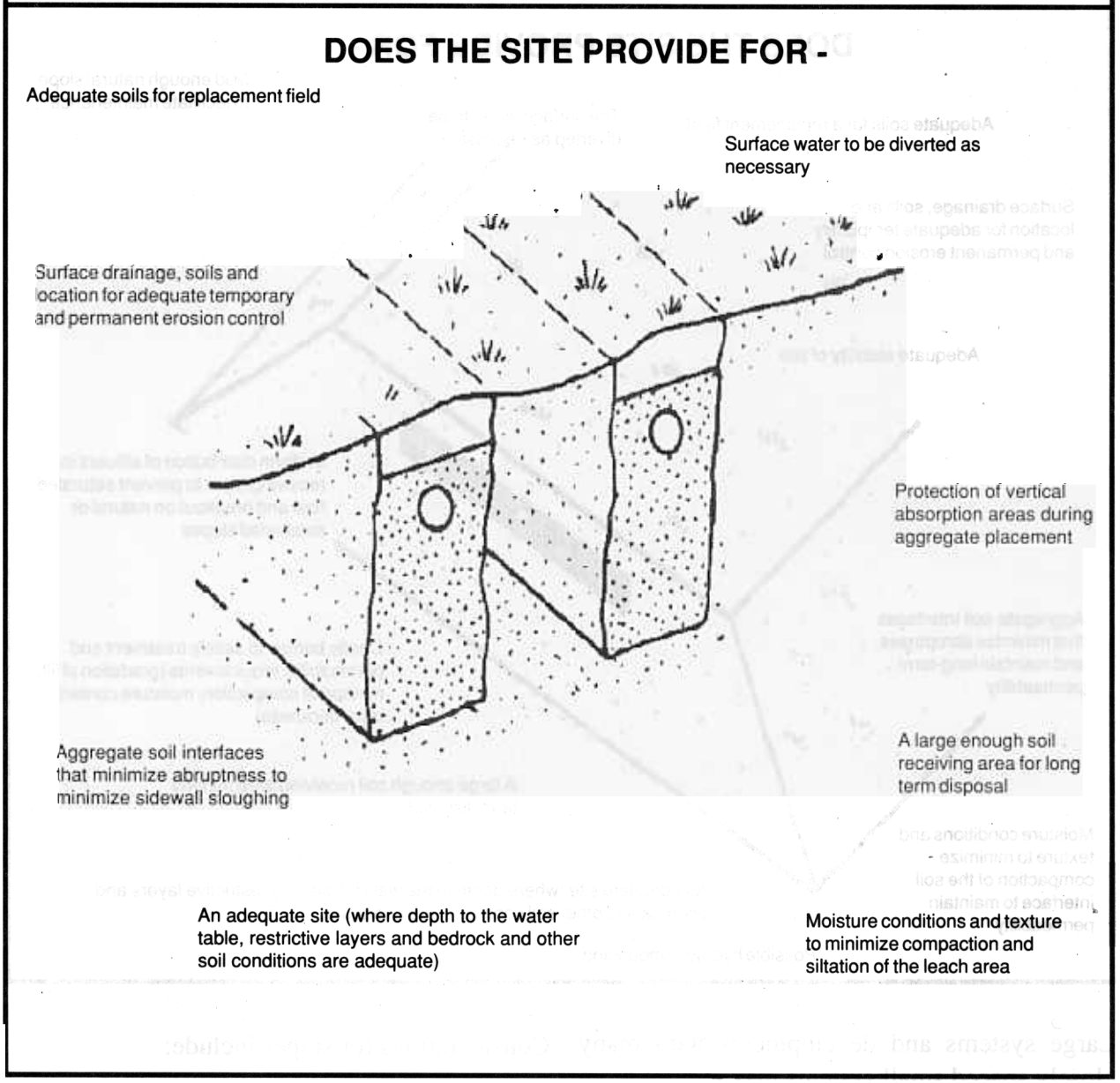


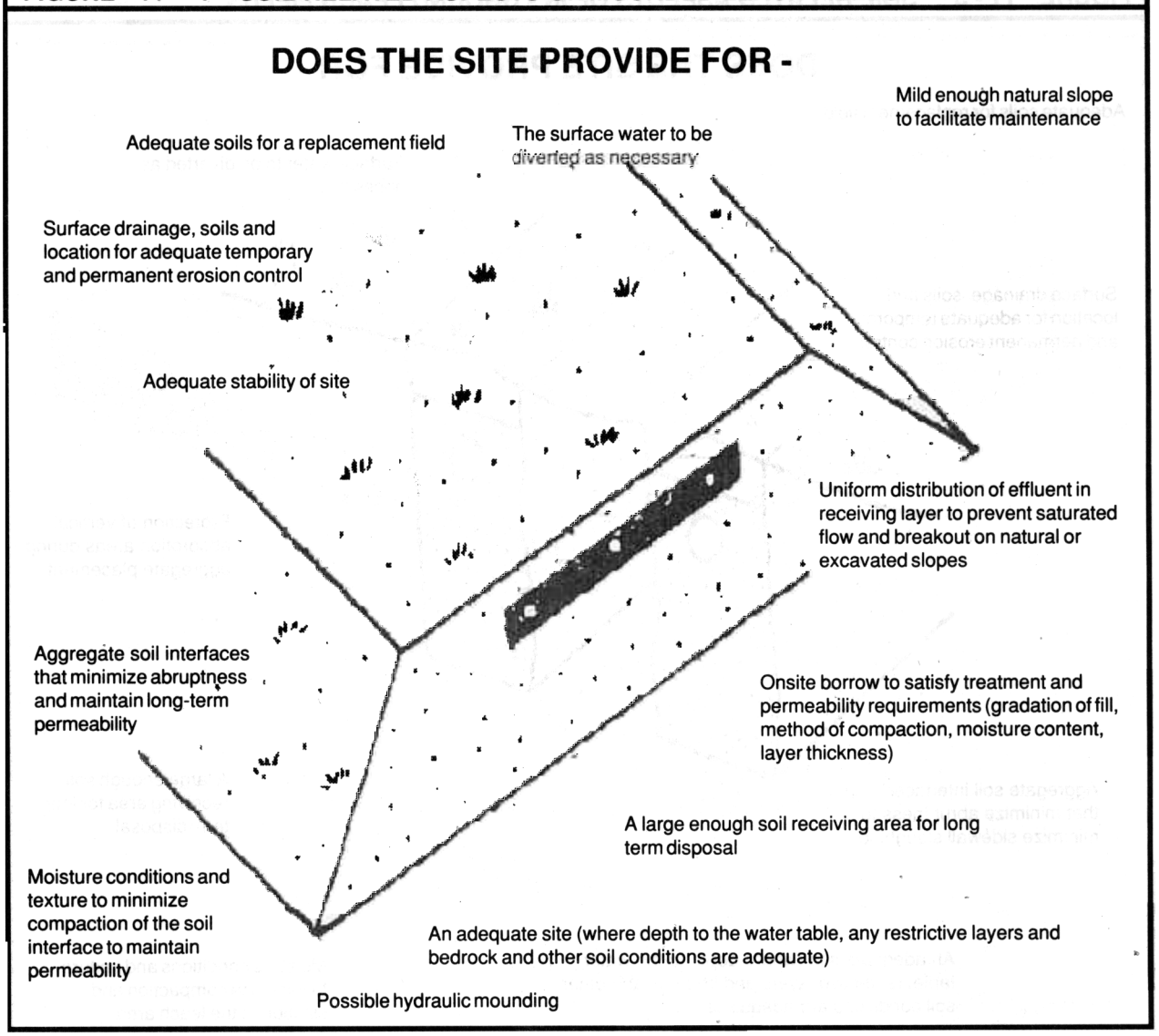
Figure 11-3 illustrates some items that may be considered when evaluating sites for inground leach fields. Some items for mounded systems are included in Figure 11-4.

Location

Siting should be carefully considered. Most elements of development are interrelated and interdependent. Structures, boundaries, roads, wells, subsurface sewage systems, drainage, and soils need to be considered as they spatially relate to one another. Even single house lots require careful location of dwellings, wells, subsurface systems (including replacement areas), and driveways. Special considerations may be needed to achieve proper spacing and setbacks, especially if portions of lots contain wet soils.

Subsurface systems should not be located in flood plains, drainageways, or near wetlands to avoid contamination of surface water and groundwater. Subsurface systems should also not be located near municipal well fields and reservoirs. Subsurface systems require careful evaluation in, or adjacent to, recharge areas.

FIGURE 11 - 4 SOIL RELATED ASPECTS OF MOUNDED LEACH FIELDS



Large systems and developments with many closely spaced small systems may require more investigation and evaluation to ensure long-term water quality. Evaluation may involve determining groundwater gradients, flow areas, and soil parameters in plume areas. Combinations of all subsurface systems, both on and offsite and future systems should not increase contaminants beyond safe limits.

Slope

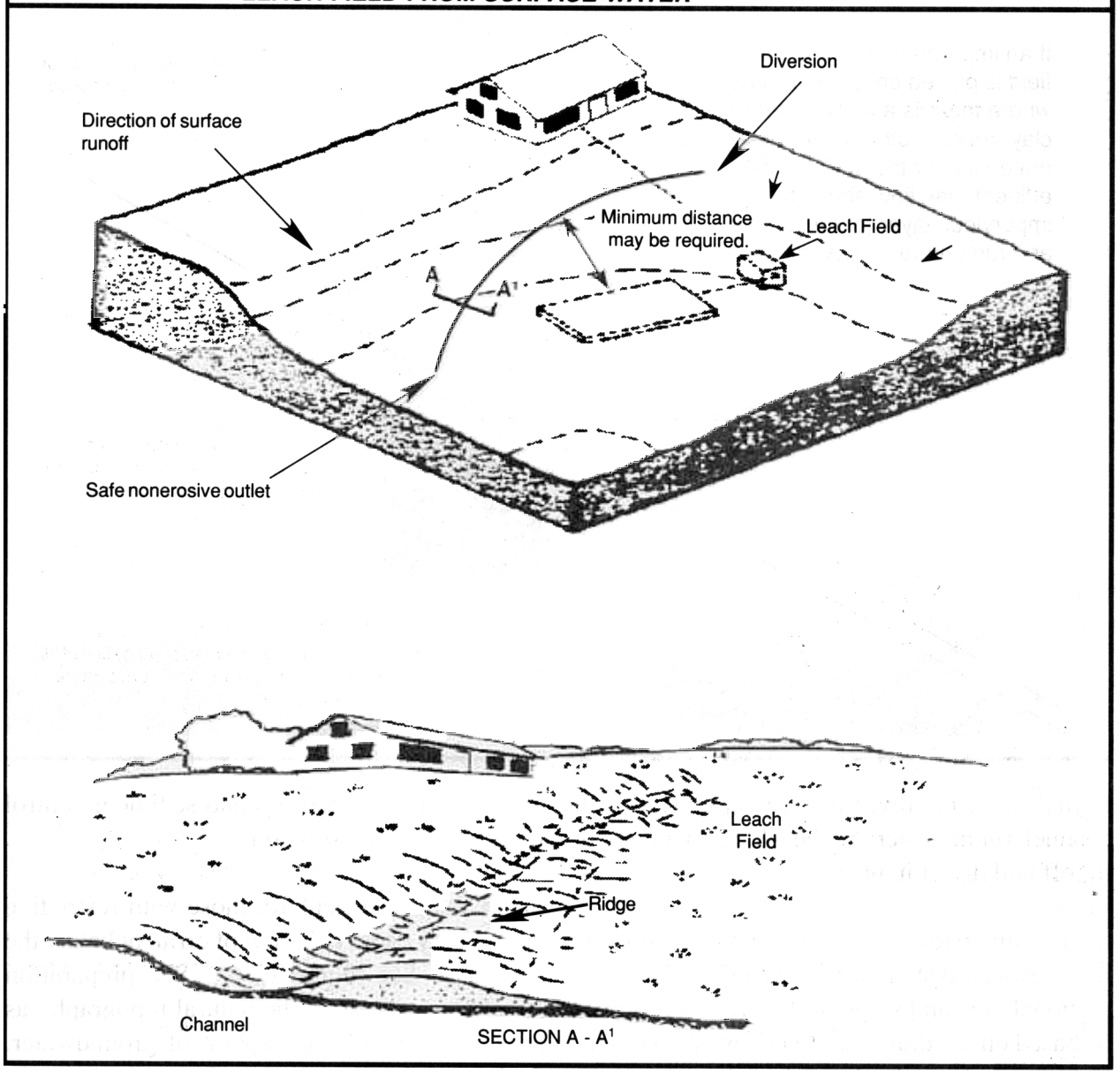
Slope should be evaluated to determine the feasibility for onsite subsurface sewage systems. As slope gets steeper than 5 percent, additional cost is involved to fit subsurface systems to the slope.

Considerations for slopes include:

- surface and subsurface water disposal
- erosion control during and after construction

  control of effluent breakouts due to subsurface restrictive and impermeable layers
- pollution hazards that might exist down gradient
- difficulties with construction

FIGURE 11 - 5 PICTORIAL VIEW AND CROSS SECTION OF DIVERSION TO PROTECT LEACH FIELD FROM SURFACE WATER



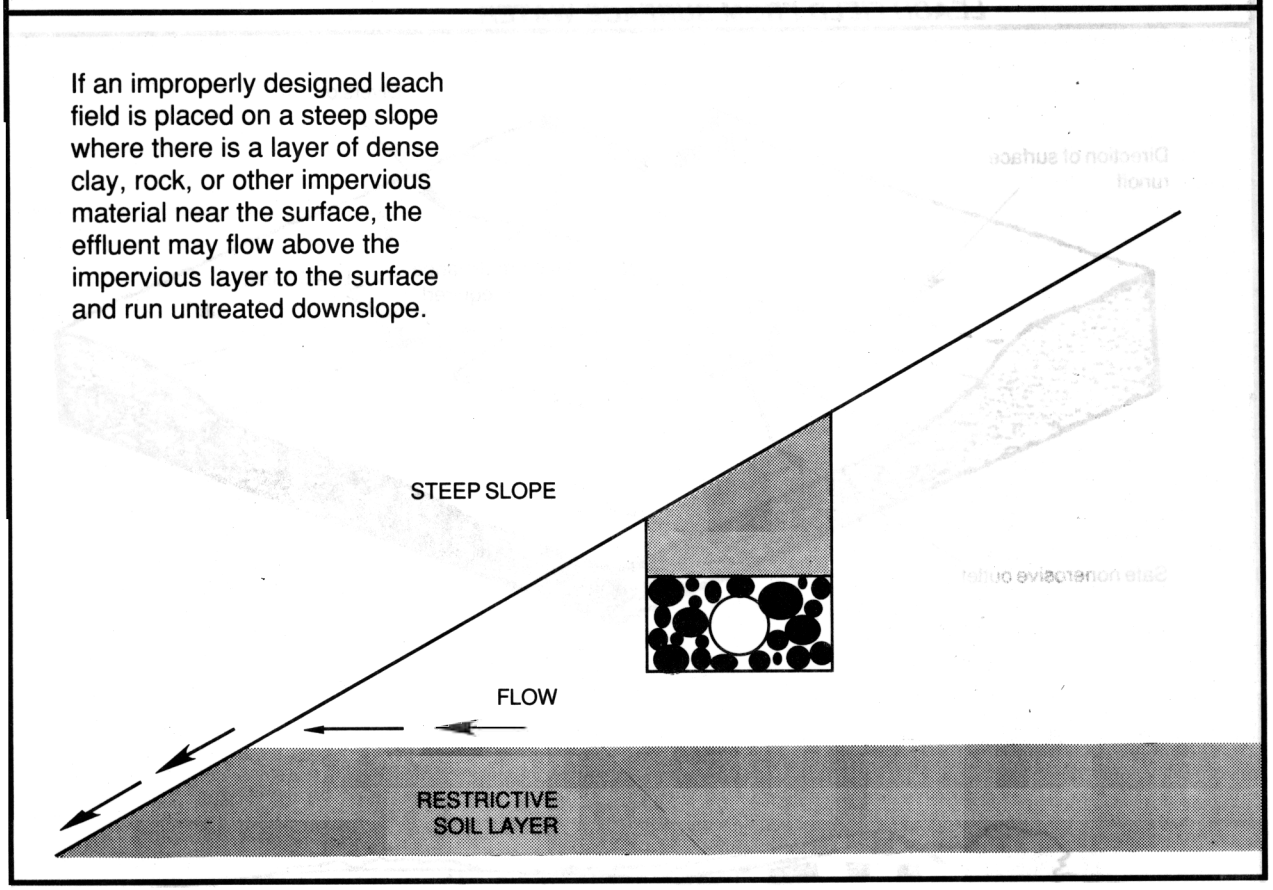
Sites with slopes steeper than 15 percent require considerable evaluation and ,in cases, may not be suitable for subsurface systems, particularly large systems.

Surface water control is important during and after construction. When slopes are greater than about 5 percent, it is increasingly desirable to direct up-slope water away from subsurface systems. Runoff should be diverted prior to construction to prevent erosion of disturbed areas. Diversions assist in preventing sediment from washing onto leaching surfaces and sealing them. Diversions are also desirable for completed systems to prevent runoff, particularly spring snowmelt, from overloading them.

Drainageways should not be blocked by system construction. Undirected drainage can back up and cause washout or siltation of systems. Ponded water may create slope instability of fills and increased hydraulic loading.

Diversions as shown in Figure 11- 5 are one of several water control measures that can be applied to subsurface sewage systems. As seen

FIGURE 11 - 6 POSSIBLE STEEP SLOPE SEEPAGE OF EFFLUENT



from the figure, a diversion is essentially a small channel running across the slope to intercept runoff and divert it away.

Include diversions as part of the overall subsurface sewage system when needed. The cross sectional area and slope of the diversion should be based on the drainage area above the system, nonerosive channel velocities, and storm runoff. Evaluation is necessary to ensure that drainage problems are not compounded.

Erosion from slopes is a problem resulting from precipitation and runoff. Runoff erodes unprotected disturbed areas causing rills and gullies. Accelerated erosion may be prevented during and immediately after construction by mulch and mulch anchoring. Permanent vegetation designed for specific site conditions will prevent long-term erosion if properly maintained.

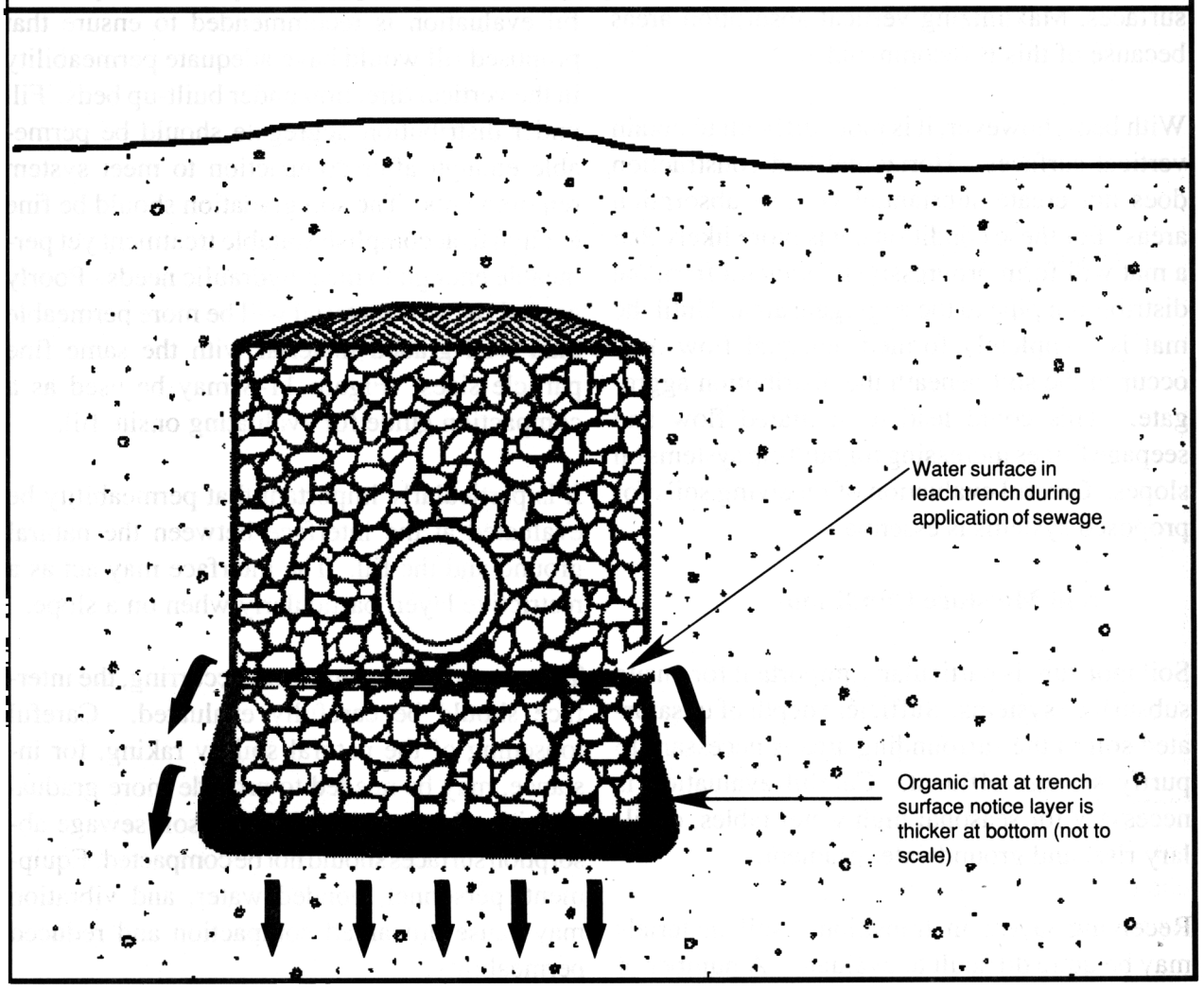
Advice on water control and vegetative practices may be obtained from SCS. Refer to the section in this chapter on erosion and sediment control for additional information.

Steep slopes, particularly those with restrictive layers, may cause breakout of effluent below the system. See Figure 11-6. Site preparation should be as close to the natural topography as possible to avoid interception of groundwater. Additional loads on subsurface systems may occur if subsurface water runs downslope due to hardpan or restrictive layers. Evaluation may be necessary to determine the need for upslope subsurface drainage.

Organic Mat and Interface Permeability

For soils with permeabilities in the normal permitted range, flow from septic tank leach (absorption) fields is usually controlled by an organic mat. The mat forms at the interface of absorption field distribution aggregate and the natural or built-up soils as shown in Figure 11-7.

FIGURE 11 - 7 SCHEMATIC CROSS SECTION OF LEACH TRENCH SHOWING THE RESTRICTIVE EFFECT OF THE ORGANIC MAT



The flow rate through a developed mat is generally less than the percolation rate of the soil.

The mat is composed of organic material that accumulates as sewage effluent flows from distribution aggregate. The mat restricts flow of the effluent to the soil. When the mat is developed over the entire field, this restriction creates a more uniform distribution of effluent. The flow through the unsaturated soil is governed by gravity and capillary forces. These forces cause the smaller voids to be filled with liquid, permitting air to fill the larger voids. This aerobic condition is necessary for satisfactory treatment.

In Figure 11-7, a leach field trench is shown with the mat developed on the bottom and sides of the trench. The mat develops over a period of time as the system is used. If the distribution of effluent is not uniform, the mat will usually develop (creep) progressively outward from the inlet to the absorption area. In the usual situation, the mat will eventually develop at all leaching surfaces.

The permeability of the mat is also affected by soil texture. Coarser soil allows deeper penetration of the mat with accompanying increases in permeability. The abruptness of the interface is also a factor in mat permeability. Coarse aggregate adjacent to fine-grained natural soils may allow siltation or sloughing of the natural soil thereby decreasing permeability at the interface. Figure 11-7 indicates that the mat at the bottom of

the trench restricts flow more than at vertical surfaces. Permeability loss is greater on bottom surfaces. Maximizing vertical absorption areas because of this is recommended.

With beds, however, it is more difficult to obtain vertical surfaces. Horizontal bed construction does not create substantial vertical absorption areas. For these conditions, it is more likely that a mat will form progressively outward from the distribution pipe to the aggregate area. Until the mat is completely formed, unequal flow may occur in the soil beneath the distribution aggregate. This could lead to saturated flow and seepage forces increasing for built-up systems on slopes. Careful evaluation of receiving soils for proposed systems is essential.

Soil Moisture Conditions

Soil moisture is particularly important for onsite subsurface systems. Sufficient depth of unsaturated soil in the surrounding area is necessary to purify sewage effluent. Careful evaluation is necessary for seasonal high water tables, capillary rise, and groundwater gradient.

Receiving layers in transitional soil materials may be quite difficult to evaluate. A number of test holes may be needed, especially for large systems, to determine receiving and adjacent area soil properties including moisture conditions. Detailed soil mapping may be necessary to determine the soil conditions of the entire area.

Leach Area Fill

Texture and other physical characteristics need special attention when evaluating onsite fill for built-up fields. Material that is too coarse will not effectively purify the effluent. Material that is too fine could cause a backup or seepage failure on the slopes of beds. Fill under distribution pipes may require restrictions on effective and maximum grain sizes, percent passing the No. 200 sieve, and uniformity coefficient.
Normal construction techniques create permeability of fill in the horizontal direction to be several times that of vertical permeability. Careful evaluation is recommended to ensure that proposed fill would have adequate permeability in the vertical direction under built-up beds. Fill under distribution aggregate should be permeable enough after compaction to meet system requirements. The soil gradation should be fine enough to accomplish suitable treatment yet permeable enough to meet hydraulic needs. Poorly graded (USCS) material will be more permeable than well graded material with the same fine particle sizes. Figure 11-8 may be used as a compaction guide for evaluating onsite fill.

It is particularly important that permeability be evaluated at the interface between the natural ground and the fill. The interface may act as a restrictive layer, particularly when on a slope.

To prevent restrictions from occurring, the interface should be carefully evaluated. Careful loosening of the natural soil by raking, for instance, may be needed to provide more gradual transition in materials. Natural soil sewage absorption surfaces should not be compacted. Equipment, personnel, ponded water, and vibration may cause unwanted compaction and reduced permeability.

Absorption surfaces should not be smeared. Wet or moist soil smears easily and smeared surfaces also reduce permeability. Work should be accomplished during periods when smearing is not a problem.

Prevent soil fines from clogging absorption surfaces. Fines from eroded soil or washed from pipe and aggregate can seal absorption surfaces. Impact of rainfall on surfaces may also seal them. Soil eroded from trench sides during installation of aggregate is a prime source of fine material causing clogging of leaching surfaces. Trench sides may be protected with plywood or other material when the aggregate is dumped. If trench aggregate is too coarse, sidewall surfaces may enter the aggregate voids by gravity, piping, or

FIGURE 11 - 8 A GUIDE TO AID IN EVALUATING FILL FOR SMALL RESIDENTIAL SUB - DIVISIONS

Earth Material (Unified Soil Classification)	Type of Compaction Equipment	Max. Layer Thickness Before Compaction (in.)	Max Rock Size (in.)	No. of Passes By Compaction Equipment	Moisture Content (%)
GW & GP	Vibratory	18	6	3	10-15
	Rubber-tired	6	4	4	
GM & GC	Sheeps Foot	9	6	4	12-17
	Rubber-tired	6	4	4	
	Vibratory	12	6	3	
SW & SP	Vibratory	18	6	3	12-17
	Rubber-tired	6	4	4	
SM & SC	Sheeps Foot	9	6	4	12-17
	Vibratory	12	6	3	
	Rubber-tired	6	4	4	
ML & CL	Sheeps Foot	9	6	4	15-20
	Vibratory	12	6	3	
	Rubber-tired	6	4	4	

Caution: This guide is only for evaluating onsite fill materials for small typical systems and does not include suggestions for compaction of soil for subsurface systems and foundations of structures.

Adapted from USDA SCS- *New Hampshire Construction Specifications for Conservation Engineering Practices*, 1986

surface water draining into the trench.

Hydraulic Mounding

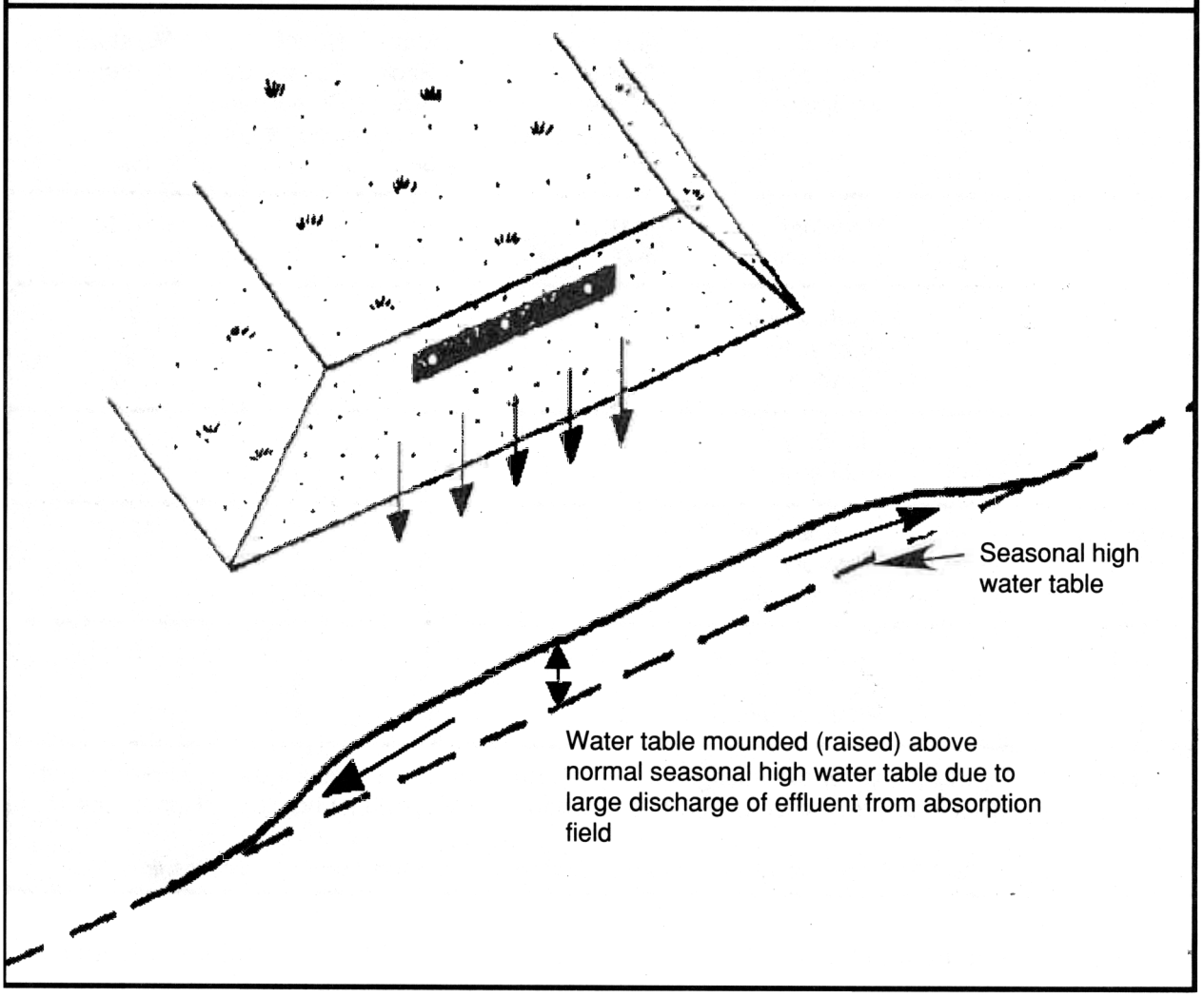
In the previous chapters, water tables are discussed in terms of natural moisture conditions. However, use of these natural water table elevations may not be conservative for design when large recharges, marginal permeabilities, or minimum depths to impervious material are involved. Hydraulic mounding may occur for individual systems on marginal soil and for large systems. The addition of effluent may increase the height of (mound) the water table. Mounding is caused by the extra head of water developed as the effluent flows laterally away from the system. This mounding reduces the thickness of available unsaturated soil below the system. In order to achieve adequate purification, the systems may have to be raised to account for this mounding. Refer to Figure 11-9. Careful investigation and evaluation are required for these conditions.

DEVELOPMENT ROAD AND DRAINAGE CONSIDERATIONS

Cost of road maintenance including drainage is a significant part of town budgets. Resurfacing, ditching, erosion control, drainage, culvert repair, snow plowing, and deicing are major maintenance items. In many cases, part of this work may be caused by inadequate road construction.

Many of the problems relate to soils. New roads in many towns are constructed through the development process. More intensive evaluation for development may assist in providing quality design, materials, and construction to achieve minimum maintenance.

FIGURE 11 - 9 HYDRAULIC MOUNDING OF WATER TABLES UNDER LARGE SUBSURFACE SEWAGE SYSTEM FIELDS



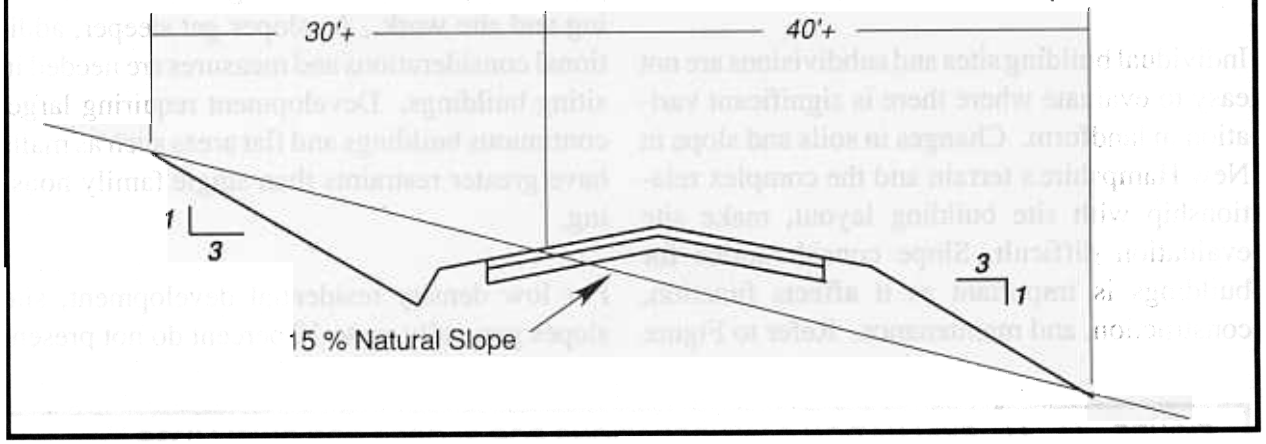
Road layout is a major aspect that affects road maintenance. Layout affects the steepness of road slopes, number of stream and wetland crossings, and length, size and number of excavations, and embankments. Foundation conditions and drainage are also affected by road placement.

As a general rule, land with slopes greater than 5 percent requires a greater design effort for roads. As slopes increase, additional considerations and measures are involved in fitting development to the land. Obviously, development requiring large, continuous, nearly level spaces, such as malls, have more rigid slope requirements than single family residential subdivisions.
Low density residential development, with site slopes generally up to 10 percent, do not present as many problems as those that are steeper. As a general rule, slopes over 15 percent are more difficult to evaluate, especially for road drainage. Development layout, including roads, on these slopes is difficult and requires extensive and detailed evaluation.

Slope greatly impacts road profiles. Alignment along the contour minimizes problems, but cut and fill and side drainage from driveways requires careful attention. Roads should be located beyond natural drainageways. For steep terrain, alignment on the contour still requires substantial excavation and fill to achieve stable and maintainable road slopes.

Steepness requires evaluation for vehicle line of

FIGURE 11 - 10 PLACEMENT OF STRUCTURES ON STEEP TOPOGRAPHY MAY REQUIRE LONG EXCAVATION AND EMBANKMENT SLOPES.



sight, drainage, erosion control, and maintenance. Care is needed for designing cross roads, curves, and driveways to prevent blind spots on steep slopes. Steep slopes require costly measures such as riprap or storm sewers to prevent ditch erosion. More expensive plowing and deicing are required annually for steep slopes.

Road layout should be evaluated for impact on wetlands and stream crossings. Bridge and large culvert installations represent significant construction and maintenance costs.

Excavated and embankment slope lengths are often not considered sufficiently when planning and evaluating roads. Plotted road cross sections at 50-or 100-foot intervals help show impacted areas. Refer to Figure 11-10.

Where excavated slopes are required, optimum conditions are often assumed for lateral space requirements. Slopes in many soils steeper than three horizontal to one vertical may cause increased problems with sloughing, water control, slope stability, slope construction, and vegetative establishment and maintenance. Hardpans, soil-bedrock interfaces, highly erodible soils, and clean sands may require additional attention. Using berms is prudent for slopes with vertical heights over 20 feet. Berms shorten slope flow lengths and provide access for vegetative construction and maintenance equipment. This decreases erosion potential and enhances establishment of vegetation.

Excavated road slopes may also have an impact on adjacent lots. Evaluation for slope stability and for vehicle and pedestrian safety may be required. Fill slopes adjacent to house lots should be evaluated. Driveway access, winter maintenance and safety, storm runoff control, space occupied by fill, visual aspects, and useful lot space are some items to consider.

Foundation conditions often create road maintenance problems. Some road surfacing materials do not provide structural strength necessary to resist traffic loads. Adequate foundation soils prevent road pavement from breaking up due to highly concentrated wheel loads. Soft soils, frost heaves, wet foundations, and inadequate internal road drainage result in broken pavement, bumps at culvert crossings, and potholes.

BUILDING SITE CONSIDERATIONS

Building site investigation and evaluation depend on characteristics of proposed structures, as well as foundation and adjacent soils. Close communication between designer, investigator, and evaluator is required to successfully evaluate

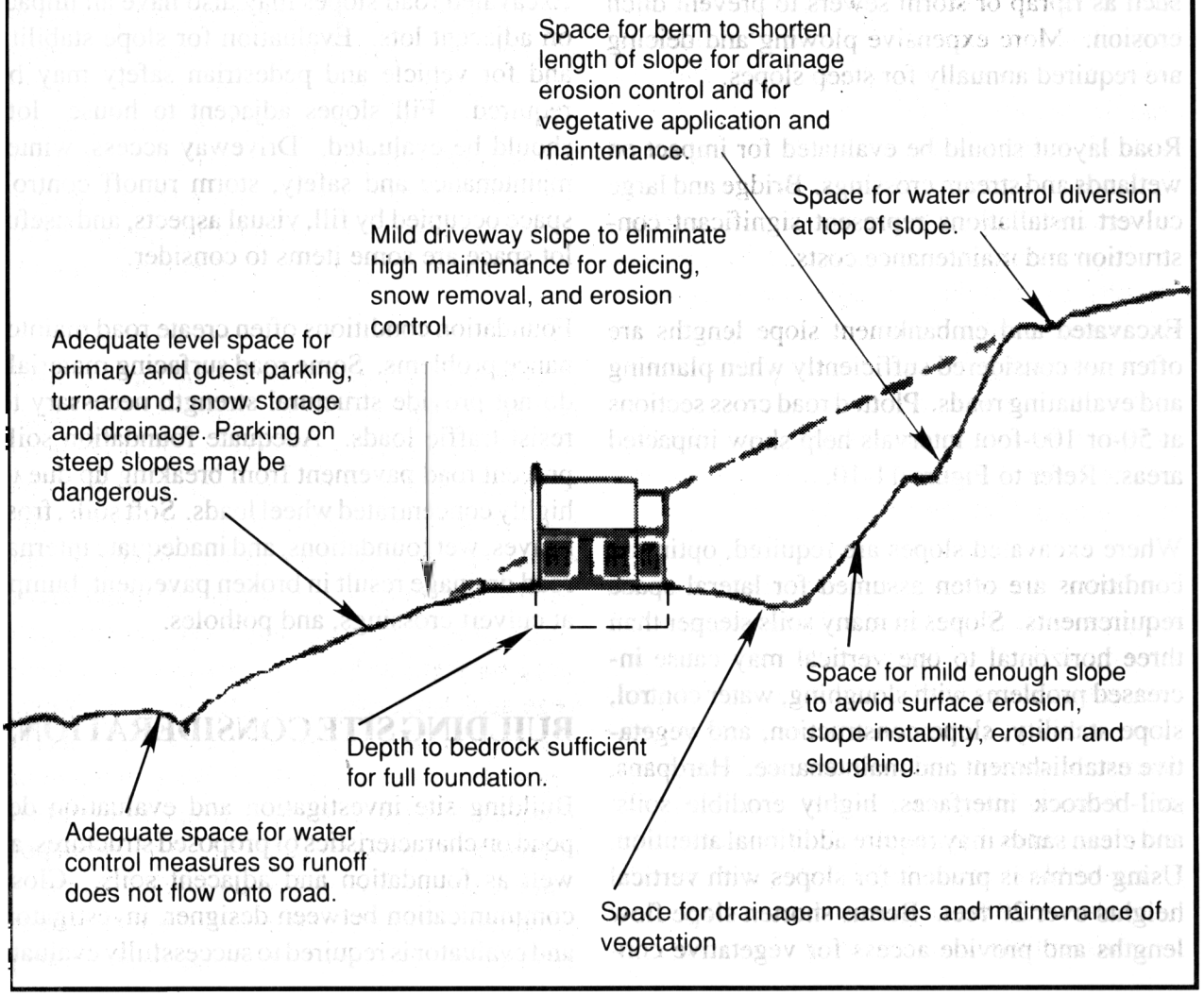
building sites. Because New Hampshire soil conditions are quite variable, at least minimal investigation and evaluation of foundations are required for even small buildings.

Individual building sites and subdivisions are not easy to evaluate where there is significant variation in landform. Changes in soils and slope in New Hampshire's terrain and the complex relationship with site building layout, make site evaluation difficult. Slope considerations for buildings is important as it affects function, construction, and maintenance. Refer to Figure 11-11

As a general rule, land with slopes greater than 5 percent requires greater design effort for building and site work. As slopes get steeper, additional considerations and measures are needed in siting buildings. Development requiring large, continuous buildings and flat areas such as malls have greater restraints than single family housing.

For low density residential development, site slopes generally up to 10 percent do not present

FIGURE 11 - 11 EVALUATION CONSIDERATIONS FOR SLOPES FOR DWELLINGS



as many problems as steeper slopes. Slopes over 15 percent are much more difficult to work with, especially for building sites with subsurface sewage systems. Overcoming problems with these slopes is difficult and requires extensive and detailed evaluation.

Depth to bedrock and water table evaluations are required for buildings. Shallow to bedrock soils may create problems if bedrock is encountered above foundation footing elevations. Blasting and rock excavation are expensive for foundations and utilities. High water tables require added measures to prevent wet basements and to reduce lateral pressures on foundation walls. Pressures are related to the texture of backfill materials. Soils with large amounts of fines may be frost susceptible and create large lateral forces on structures.

Soil texture is important for siting buildings. Organic soils are usually not suitable for foundations. Depending on structure size and weight, organic soils at depth or under fill require careful evaluation. Loose sands may not provide support necessary for structures. Vibration may cause densification and settlement. Erosion of slopes and slope stability may be problems. Loose sands and silts may be subject to liquefaction. Compact silty sands usually have good bearing strength, but may be subject to frost heaves and drainage problems. Some fine soils are highly erodible and quite susceptible to frost heaving. Clay soils require careful evaluation. Lateral pressures may be quite high for some clay soils.

For larger and heavier structures and sites with marginal soils, bearing capacity and differential settlement become increasingly important. Investigation and evaluation are necessary to characterize soil materials to sufficient depths, and determine water table elevations and soil densities. Footing design depends on density of soils and may depend on depths to the water table. Standard blow count data is often used to estimate allowable bearing pressures. Loose soils, frost susceptible materials, steep slopes, foundations adjacent to eroding banks, and existing fills require extra effort to investigate and evaluate.

Compaction of deep loose soils by vibration is feasible in certain cases. Evaluation for these conditions may require specialized expertise. Surface compaction of some soils may be satisfactory, but may not be sufficient for loose materials at depth.

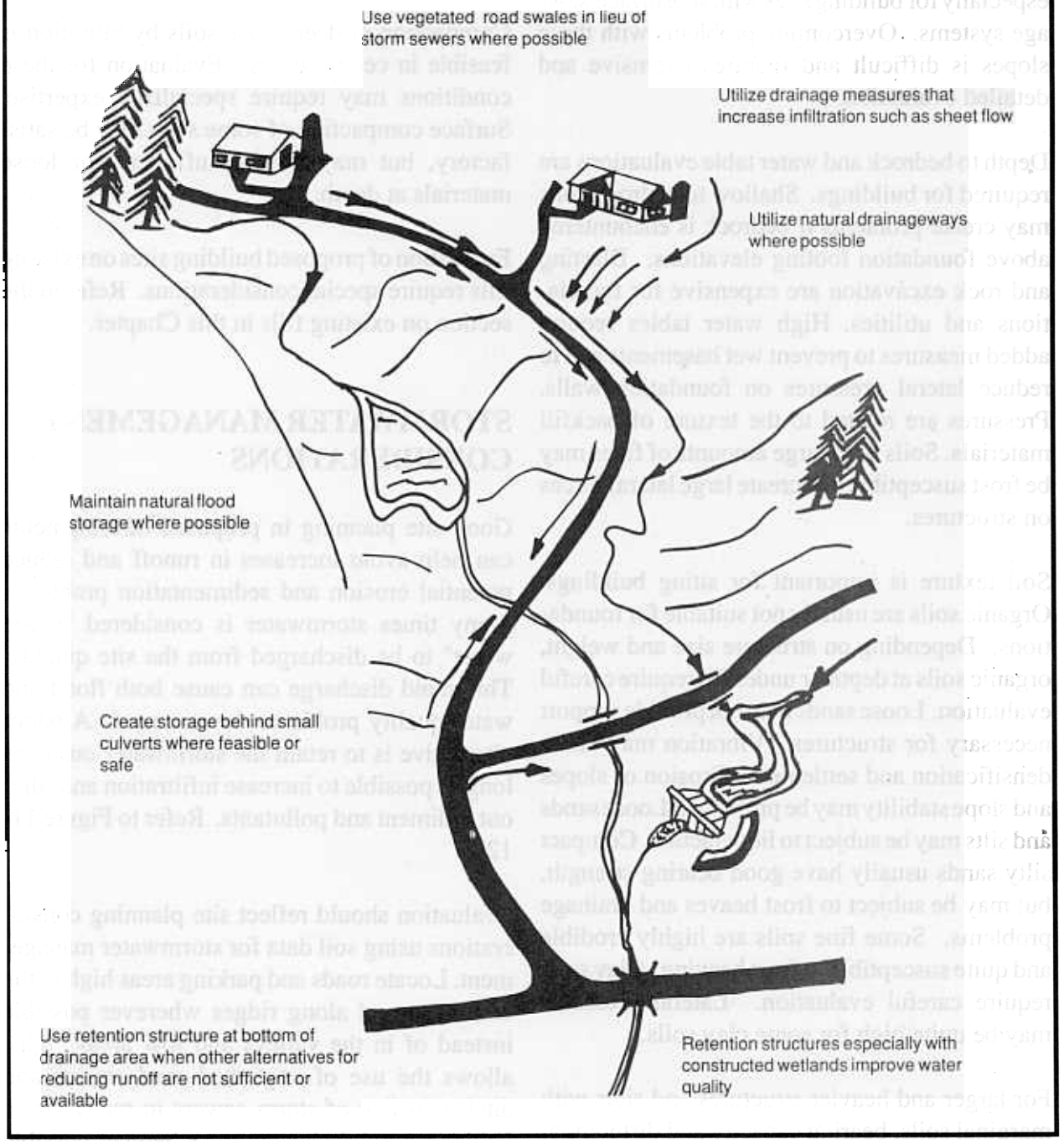
Evaluation of proposed building sites on existing fills require special considerations. Refer to the section on existing fills in this Chapter.

STORMWATER MANAGEMENT CONSIDERATIONS

Good site planning in proposed developments can help avoid increases in runoff and reduce potential erosion and sedimentation problems. Many times stormwater is considered "waste water" to be discharged from the site quickly. This rapid discharge can cause both flood and water quality problems downstream. A better alternative is to retain the stormwater onsite as long as possible to increase infiltration and filter out sediment and pollutants. Refer to Figure 11-12.

Evaluation should reflect site planning considerations using soil data for stormwater management. Locate roads and parking areas high in the landscape and along ridges wherever possible instead of in the valleys and low areas. This allows the use of vegetated road swales and ditches in lieu of storm sewers in many areas. Utilize natural drainageways wherever possible since they are stable channels and are already vegetated. Use drainage measures around impervious areas that increase infiltration such as flat vegetated areas or swales. Maintain natural storage areas and wetlands wherever possible to detain increased flows and remove potential pollutants. Create storage behind small culverts for detention, sediment traps, and water quality treatment areas. Maintain natural vegetation on steep

FIGURE 11 - 12 CONSIDERATIONS FOR STORMWATER MANAGEMENT



slopes as much as possible to reduce runoff and erosion. Use retention or detention structures at the bottom of the drainage area when other alternatives for reducing runoff are not available. Retention structures include permanent pools that provide some treatment of runoff as well as peak runoff reduction. Detention structures also provide peak runoff reduction, but do not have permanent pools for water quality. Be sure all runoff is directed into the structure for control of peak discharges. Utilize wetland vegetation in the pool for water quality treatment when possible. Consider using curbs and stormwater sewers only along steep road fill slopes where storm runoff would erode the banks.

EROSION AND SEDIMENT CONTROL

Accelerated soil erosion typically occurs when land is undergoing urban development. During construction stages, uncontrolled runoff can form rills and gullies, wash out roads, or erode cut and fill areas. The resulting sediment deposits destroy vegetation, impair aesthetic qualities, plug road culverts, and degrade water quality. These and other damages are costly and unnecessary. Careful evaluation to determine conservation measures required during and after construction can prevent or control erosion and sedimentation.

Soil erosion is the loss of soil by the action of water, ice, gravity, or wind. Water erosion is predominant in New Hampshire. The erosion process is the detachment and transport of soil particles. The impact of raindrops falling on bare or sparsely vegetated soil detaches particles. Water flowing on the ground surface picks up these particles and carries them along. Runoff water gains velocity and concentrates downslope, detaching soil particles resulting in rills and gullies cut into the soil surface.

Streambank and channel erosion occur when water undercuts banks and erodes channel bottoms. This natural process may accelerate if runoff increases due to development.

Sedimentation is the product of erosion from runoff and stream flow. Sedimentation occurs when the velocity of the water in which soil particles are suspended slows for a sufficient period of time to allow the particles to settle out. Large particles, such as sand and gravel, settle out more rapidly than fine clay and silt particles.

The inherent erosion potential of any area is determined by four principal factors: soil characteristics, vegetative cover, topography, and climate.

The vulnerability of a soil to erosion is known as its erodibility. Important soil properties affecting erodibility are: average particle size and gradation, percent of organic content, soil structure, and soil permeability.

Soils that contain high percentages of silt and very fine sand are generally the most erodible. The erodibility of these soils decreases as the percentage of clay or organic matter increases. Clay acts as a binder between particles and tends to limit erodibility. Most soils with a high clay content are relatively resistant to particle detachment by rainfall and runoff. Once eroded, however, clays are easily transported and settle out very slowly.

The least erodible soils are well drained and well-graded gravels and sand-gravel mixtures, with little or no silt. Coarse-textured soils and granular soils also have high permeabilities and good infiltration capacities which either prevent or delay runoff.

Several considerations may need to be addressed when evaluating sites for erosion and sediment control. These include:

- soil gradation and particle size
- organic content of soil
- permeability of surface layers
- structure of soil
- runoff and stream flow
- vegetative and other surface protection.

WETLAND MANAGEMENT

Many development sites contain wetlands. Careful evaluation is necessary to protect them. Potential impact from road deicing chemicals and

excessive flood storage may require detailed evaluation. Where filling is permitted, evaluation is necessary to ensure minimum impact. Measures should be carefully planned to prevent construction and post-construction sediment from damaging wetlands.

Substantial changes in site drainage that increase or decrease flow to wetlands require additional study. Changes in water level or variation may affect vegetation and wildlife. Detailed wetland evaluation should be completed to determine suitability of any enhancement proposals.

Topographic lows may provide opportunities for constructing artificial wetlands in some cases. These may be desirable in conjunction with retention ponds to enhance water quality. Wetlands constructed upstream of these ponds assist in treating runoff from pavement. Planned strip wetlands in road ditches on mild slopes may also be beneficial to water quality.

RETENTION POND CONSIDERATIONS

Small embankment dams are used in developing areas for stormwater retention, recreation, and wildlife ponds. They also provide water supply for firefighting purposes. Where foundation conditions are suitable, embankment type dams can be constructed economically, especially when quality fill materials are available. In New Hampshire, variable soils require thorough investigation and evaluation of reservoir and foundation conditions, fill materials, and auxiliary spillway suitability.

For fire pond storage, reservoir sites need to be reasonably impervious so that water loss from seepage is tolerable. Stored water may cause changes in water tables of adjacent properties.

Thorough investigation and evaluation are needed to ensure proper functioning and safety of embankments. Test pitting, drilling, and seismic refraction studies are often required to provide adequate coverage of foundations for larger structures. Aspects that require evaluation are: permeability, texture including broadly graded materials, consolidation, hidden stream channels, layers, discontinuities, and depth and variability of bedrock. Groundwater elevations, seepage, and piping are also important items to consider.

Embankment materials need to be close by for economical construction. Often, some of the material may be available from auxiliary spillways that are usually required with larger dams. Investigation and evaluation of these spillways and any additional borrow sources are needed to determine material qualities for various earth fill zones for embankment construction. Quantities of materials, ease of excavation, and environmental concerns for the borrow areas require evaluation. Knowledge of material properties is required when evaluating soils for slope, embankment zones, drainage details, and vegetative cover.

Auxiliary earth channel spillways are normally used to supplement the outlet capacity of service (principal) spillways for earth type dams. They provide the necessary discharge capability to protect embankments from overtopping. These open channel spillways are designed to resist erosion for intermediate size storms and to resist breaching for extreme storms. Investigation and evaluation may be extensive depending on hazard classification, importance of reservoirs, variability of materials, adjacent land considerations, and use of excavated materials.

ONSITE FILL MATERIAL

Fill is an integral part of most construction. It is required for roads, site grading, sewage systems, and structures. Requirements may be minimal for ordinary fill, or extensive for drainage, sewage system, and structure fill. Factors affecting the use of soil for fill include:

- stability
- compaction characteristics
- compressibility
- susceptibility to internal movement of soil particles when wet
- gradation

  shear strength
- erosiveness
- presence of stones and cobbles
- organic matter
- frost heave

Thorough investigation and evaluation are required for fill sources as well as fill materials.

Fill Sources

Sources of fill should be determined in order to investigate and evaluate borrow source areas and the fill materials. Obtaining suitable materials from required site excavations may be superior for environmental and economic reasons. Land disturbance would be minimized and hauling costs may be less than if obtained from remote borrow areas. This option may be especially appropriate if cut-fill balancing can be optimized. Fill from required excavations may also reduce the need to haul over local roads.

When fill from required excavations is not suitable or of sufficient quantity, the next best source may be onsite borrow areas. This solution may reduce hauling over local roads, but does require disturbance to create borrow areas and haul roads. Borrow areas may require extensive clearing and disposal of stumps, grubbings, and oversize stone. Upper soil layers may need to be discarded or stockpiled for later use depending on construction needs and sequencing. Considerable disturbance may be required to obtain large fill quantities.

Borrow areas require careful investigation and evaluation. To find sufficient quality and quantity of fill material with highly variable soils, it may be necessary to delineate deposits both horizontally and vertically to ensure sufficient areal extent and satisfactory working conditions. Refer to Figure 11-13.

Careful evaluation is necessary to account for construction losses of borrow material due to topsoil stripping, oversize rock, variation in soil horizons, compaction, and uncertainties in investigation. Planning for a conservative quantity of material is recommended. High seasonal water tables, seepage, highly irregular bedrock surfaces, and inclusions may affect yield and borrow area design. Environmental concerns in restoring borrow areas may result in reduced net yields. Covering rocks and stumps; providing water, erosion and sediment control; and special vegetative needs may require more borrow material than normally considered.

Fill Material

Requirements for fill materials vary widely depending on use. Fill used to provide subsurface drainage, may have far more rigid specifications than common backfill to ensure adequate permeability. Materials used for embankment retention structures require specific properties for seepage control. All fill materials require investigation and evaluation, depending on application. Determination of material properties, including in-place behavior and construction requirements, are crucial to quality cost-efficient development.

Texture is a major evaluation factor since gradation primarily determines fill performance and methods required for excavation and compaction. In New Hampshire, soils consisting predominantly of silts, sands, or gravels are com-

FIGURE 11 - 13 BORROW AREA CONSIDERATIONS

INVESTIGATION

Appropriate investigation and testing methods
Adequate number of test holes
Consider variability of materials, bedrock surface, unusable layers, water table

DEPTH

Use sufficient number of holes to determine water table, irregular bedrock surface, unusable layers.
Determine limits for future land use.

QUALITY OF FILL

Sampling requirements to adequately determine texture, oversize rock, density.
Lab testing if amount of silt, gradation, quality, etc., is of concern.

QUANTITY OF FILL

Allow for oversize rock, inclusions, topsoil stripping, compaction shrinkage, miscellaneous losses, unsuitable material.
Allow for substantially more net borrow than required.
Allow for any irregular bedrock surface losses based on excavation equipment planned.

ENVIRONMENTAL

Assume large enough clearing area so slopes can be maintained as planned and space is retained for water control, stability, and restoration.
Allow space for mild enough slopes, berms, seepage, and sloughing control, and establishment of vegetation.
Allow for stormwater management during construction and post restoration phases.
Allow for erosion and sediment control.

monly used for general fill. The amount of silt (fines) limits their use for certain types of fills due to low permeability and susceptibility to frost heaving. Soils with a large percentage of fines are not suitable for drain fills, may cause excavation problems during wet periods, and can be more difficult to compact. Figure 11-14 indicates general properties of soils for evaluation purposes.

Particles larger than 2 to 12 inches may be important when evaluating for compaction techniques and quantities. Larger stones may be required for riprap and other erosion protection. Quality of soil particles is important for certain applications. Particles that fail soundness tests will break apart over time as a result of freeze-thaw cycles. This may result in failed pavement, reduced drainage capacity, and deterioration of riprap protection.

Onsite materials may marginally meet gradation requirements for drainage uses. During evaluation it may be tempting to be optimistic and assume that testing reflects the least suitable material or that material can be field processed with minimal effort. However, the presence of only a small percentage of soil passing the No. 100 sieve (Unified System) may reduce permeability greatly and can cause the material to fail design specifications. Due to variability of deposits, processing may need to include wash screening for drainage materials.

Compaction

Compaction is an important aspect of development construction including subsurface sewage systems. Compaction refers to the physical manipulation of soil to densify it. Compaction increases the strength of soil to resist gravita-

FIGURE 11 - 14 UNIFIED SYSTEM AND RELATIVE PROPERTIES OF SOIL AS A GUIDE FOR EVALUATION

TYPICAL NAMES	Unified Soil Class.	Relative properties of compacted soil *				
		Shear Strength	Compressi-bility	Permeability	Resistance to piping	Workability as construction material
Well graded gravels, gravel-sand mixtures, little or no fines	GW	Excellent	Negligible	High	Good	Excellent
Poorly graded gravels, gravel-sand mixtures, little or no fines	GP	Good	Negligible	High	Good	Good
Silty gravels, gravel-sand-silt mixtures	GM	Good to Fair	Negligible	Medium	Poor	Good
Clayey gravels, gravel-sand-clay mixtures	GC	Good	Very low	Low	Good	Good
Well graded sands, gravelly sands, little or no fines	SW	Excellent	Negligible	High	Fair	Excellent
Poorly graded sands, gravelly sands, little or no fines	SP	Good	Very low	High	Fair to Poor	Fair
Silty sands, sand-silt mixture	SM	Good to Fair	Low	Medium	Poor to Very Poor	Fair
Clayey sands, sand-clay mixtures	SC	Good to Fair	Low	Low	Good	Good
Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity	ML	Fair	Medium to High	Medium	Poor to Very Poor	Fair
Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	CL	Fair	Medium	Medium	Good to Fair	Good to Fair
Organic silts and organic silty clays of low plasticity	OL	Poor	Medium	Medium to Low	Good to Poor	Fair
Inorganic silts, micaceous or diatomaceous fine sandy, or silty soils, elastic silts	MH	Fair to Poor	High	Medium to Low	Good to Poor	Poor
Inorganic clays of high plasticity, fat clays	CH	Poor	High to Very High	Low	Excellent	Poor
Organic clays of medium to high plasticity, organic silts	OH	Poor	High	Medium to Low	Good to Poor	Poor
Peat and other highly organic soils	Pt	Not suitable for construction				

* These are generalizations. **For evaluation purposes only. NOT FOR DESIGN.**

Adapted from USDA SCS *Engineering Field Manual, Chapter 4*, August, 1990

tional and seepage forces and reduce compressibility. Uneven and excessive settlement, slope instability, and increased structure loading may occur from improperly compacted soil. Knowledge of compaction helps in evaluating borrow sources, existing fills, and sewage system receiving areas.

Moisture content, texture, layer thickness, and placement method are important factors when considering compaction for a given soil. For clean sands and gravels, compaction is usually accomplished by vibrating forces such as produced by a vibrating roller, or to a lesser degree by a rapidly moving crawler tractor or plate vibrator. Compaction for materials with a substantial percentage of fines is commonly accomplished with wheel-type or sheepsfoot rollers.

All fills for structures and pipes that are required to remain essentially at design grade, should be compacted to the density requirements for the intended uses. Settlement of fill under pipes adjacent to structures, such as manholes, increases the loading on pipes. Excessive loading may break pipes and result in partial or complete failure of systems. Care should be taken when compacting adjacent to and over structures and pipes, as soil can transmit large vehicle loading and compaction forces. Hand compaction should be used where mechanical equipment may damage pipe and structures.

Compaction of large built-up leach fields is necessary to prevent settlement of fills. Settlement decreases layer thickness and this causes unequal distribution of effluent. Saturated flow conditions may result, causing decreased quality of treatment. Unequal distribution may also cause large seepage forces in the horizontal direction against built-up slopes and result in slope instability.

Settlement of uncompacted fills may also create depressions in the ground surface. During periods of heavy rains or snowmelt, ponded water may damage vegetation or cause increased surface flow to leach fields. Settlement of downhill trench fill may concentrate runoff and cause rill and gully erosion. Compaction of fills increases the shear resistance of the soil and reduces slope instability. This is particularly important where slope failure would affect safety, cause serious damage, and interfere with the operation of systems.

Compaction reduces permeabilities in most fills, especially those with many fines. It is necessary to evaluate fills for drainage structures and leach fields so that desired permeability will be obtained after required compaction.

Evaluation of the compaction potential of natural soil surfaces directly under absorption fields may be desirable. Surfaces may smear and compact easily, depending on texture and moisture. Reduction in permeability may decrease entire system capacity and result in premature failure.

EXISTING FILLS

On occasion, sites have existing fills that require investigation and evaluation. They may have critical features for proposed development or be at locations for proposed structures. Fills commonly vary in area, depth, and site conditions. They may include old dumps and construction waste areas. Constructed embankments may consist of a mix of mineral soils with unknown densities.

Fills are usually more difficult to investigate and evaluate than natural soils. Unless historical data is available, it may be difficult to ascertain general composition of fills prior to exploration. Clues based on landscape and other resource conditions, as with natural soils, are not available for determining composition and continuity between test holes. Composition can be highly variable due to buried boulders, stumps, wood, voids, and other items. Old dumps may contain almost anything including metal, ash, household rubbish, wood, and hazardous materials.

Several considerations may need to be addressed when evaluating fills. These depend on proposed fill uses, composition, surface problems, seepage conditions, and depths and include:

- Settlement, including differential settlement
- Slope stability
- Internal movement of materials
- Bearing capacity
- Slope erosion
- Surface drainage
- Subsurface drainage
- Safety and health

Settlement is an obvious and common concern even for relatively shallow fills. Lack of compaction when fills are placed may create large settlements alone or in conjunction with proposed loadings. Composition of fills may cause unequal settlement due to the presence of hard, soft, or decomposing materials, and voids from nested material. Differential settlement may also occur due to varying depths of fill and nonuniform compaction. Internal drainage may contribute to settlement by moving finer textured materials into voids left by the filling process. Settlement may also occur in underlying soils depending on the age, magnitude, and loadings of fills and foundation properties.

Settlement, especially differential settlement, may create uneven stresses that lead to structure cracking, broken pipes, poor surface drainage, and interference with hydraulic functions. Differential settlement may result in nonuniform distribution of sewage system effluent and localized saturation of receiving soils.

Stability of slopes and whole fill masses often are of concern. Additional loads and changes in subsurface moisture conditions, as with introduction of sewage effluent, may create stability problems. Horizontal permeabilities sometimes exist that are larger than vertical ones and result in horizontal seepage that decreases stability. Seepage planes created by uneven distribution of material may require extensive evaluation.

Internal drainage needs to be evaluated if significant sources of subsurface water are present. Seepage may carry fine materials into voids of coarse ones if fill gradations are not compatible. Seepage could interfere with proposed structures.

Bearing capacity evaluation is important because heavy structures and those of large extent may require soil of high density to support foundations.

Slopes should be evaluated. Long, presently stable slopes may be subject to erosion if slope runoff is increased. Construction could change surface drainage patterns, increase stormwater runoff, and cause accelerated slope erosion.

Evaluation for environmental corrective measures may be difficult. Some fills contain chemicals, asbestos, and other materials that could be hazardous, especially if unearthed. All possible data should be obtained prior to field investigation of old fills. Safety of investigations, especially test pitting, should be evaluated if there is potential for encountering hazardous materials. An example of a soil evaluation for an existing fill is shown in Figure 11-15.

FIGURE 11 - 15 EXAMPLE OF A SOIL EVALUATION FOR EXISTING FILL

This example discusses some aspects of a soil evaluation for a site consisting of old fill. It illustrates use of data sources and addresses some of the complexities in evaluating existing fills. This discussion obviously does not include all items that may be required at actual fill sites.

OLD FACTORY FILL SITE The site consisted of three old factory buildings constructed on a strip of fill along a river. Two large brick mill type buildings were located upstream of a low concrete block building. Mill records indicated that the brick structures were built in the late 1940's. No records of the concrete block building were found, but it was commonly assumed to have been built during the 1960's.

CONCEPTUAL PLAN The developer's conceptual plan was to convert the complex to housing. It was planned to renovate the brick buildings since they appeared to be in excellent condition. However, the concrete block building would be demolished due to severe cracking. It was planned to construct a large one-story recreation building and subsurface sewage system at the concrete block building location. Preliminary planning was required to verify the concept and to determine that the project was sound.

PRELIMINARY SOIL EVALUATION The preliminary evaluation of soils at the concrete block building and at the river bank was a critical part of the overall preliminary plan. The markedly different conditions of the brick and concrete block buildings raised a red flag about site conditions. A previous investigation confirmed that the brick buildings were on stable foundations. The preliminary evaluation for the recreation building and sewage leach system would be done primarily in the office with available data. An important supplement to the office work would be field observation to obtain clues to the site that were not available through existing data sources.

A soil survey report was obtained from the county conservation district office. A copy of the previous soil survey was also available. Even though the current report superceded the old report, both were obtained for this evaluation. A United States Geological Survey topographic map was available for the area. A current 7 1/2 minute quadrangle with 20 foot contour interval and 1:24,000 scale was obtained from the map dealer. An old 15-minute USGS 1:62,500 scale topographic map was obtained from a local engineering office and also used. Aerial photographs were obtained from the local county USDA Agricultural Stabilization and Conservation Service office. Photographic coverage for the available years 1954 and 1980 was obtained. Records from the mill's office were available, but did not offer specifics on the soils, foundations, or fill of the area. Local town records also did not yield any specific soil information.

The study began with a review of the soil survey reports. The current report confirmed that the three buildings were constructed on fill. The old report, however, did not indicate fill in the area of the concrete block building. It indicated alluvial and organic soils adjacent to the old fill. A correlation check was made to be sure of the correct soil names and data between the old and current reports.

The 7 1/2-minute topographic map indicated the fill area for the brick buildings and original ground and the wet areas at the concrete block building location. Even though the map was current, the culture base was dated 1951. The out-of-date 15-minute USGS map showed the original topography under the brick buildings.

The latest photographic coverage indicated, as expected, the presence of the mill buildings and all fill. Erosion of the streambank fill at the brick buildings was evident in the photographs. The older photographs indicated original ground conditions with several old drainageways at the location of the block building. Using stereoscopic pairs with a stereoscope greatly enhanced photographic use to observe drainageways and erosion at the riverbank.

The field observation provided vital data not available elsewhere. Observation of the brick buildings indicated no structural conditions that would indicate problems with the immediate area fill. No settlement was noticed. Surface drainage was positive and away from the buildings and no uneven or pocket areas existed. Observations by boat confirmed the gully and streambank erosion along the river by the brick buildings.

FIGURE 11 - 15 EXAMPLE OF A SOIL EVALUATION FOR EXISTING FILL (Continued)

Observation of the concrete block building, however, indicated a markedly different situation than at the brick buildings. Severe settlement and cracking of the building indicated problems with the foundation soils. Poor surface drainage and ground depressions also indicated problems with the fill. Discussion with previous maintenance personnel indicated that holes randomly appeared in the fill from time to time and required filling. It was observed that drainage from across the road disappeared under the fill.

The preliminary evaluation of the fill at the concrete block building indicated the probability of serious problems for new construction. Surface settlement, disappearance of drainage from across the road under the fill, indication of old drainage courses under the fill, and severe structural stress to the building suggested the possibility of a poor foundation for any new building. Differential settlement, low bearing strength, and poor surface water control would likely occur. The data and observations also indicated that there was the likelihood of the fill being a poor receiving layer for a septic tank leach system. Settlement, nonuniform flow, and saturated concentrated flow could occur. It was determined from this evaluation that it was imperative to do a detailed soils investigation to determine:

- if the fill had stabilized or conditions were still changing
- suitability for a building foundation
- suitability for a septic tank leach system, including adequate receiving layer
- stability of the fill for existing seepage
- stability of the fill, if sewage effluent was discharged.

SOIL INVESTIGATION Based on the preliminary evaluation, a soil investigation was planned for the concrete block building site. Detailed investigation would be required to determine adequacy for the proposed new building foundation and septic tank system. Also, it was necessary to determine if the fill would be stable with added seepage due to sewage effluent.

Using the preliminary evaluation as a guide, an investigation plan was developed for the area. Test pitting was planned to cover the area of the proposed building and septic tank system areas. A drill hole program was planned to supplement test pitting. Preliminary evaluation indicated that it was necessary to obtain complete soil information and density tests from the surface down to and into the old original ground.

The investigation plan included provisions for safety of inspection personnel and the investigation team, checking location of all utilities before digging, erosion control, and protection of water quality. It was planned to use a large hydraulic excavator so that deep test pits could be excavated to 16 feet around the area of the proposed building, at depressed areas, and for the septic tank system. Test pits were done in a selected pattern to optimize investigation results. The investigation was dynamic, changing as information was obtained. Drill holes were used to obtain fill conditions throughout the profile including density, water table, gradation, organic matter, foreign material, rock conditions, and voids. It was also important to determine the soils below the fill in the event they were contributing to the surface problems. Drill holes provided the data and enabled sampling below the water table and below what could be reached with test pits. Standard penetration tests to determine density and permeability tests were conducted as drill holes were advanced.

RESULTS OF THE INVESTIGATION It was found that:

- The upper 6-8 feet were generally broadly graded sandy soils.
- Extensive nesting of large boulders below 8 feet. Voids were extensive and mostly open.
- There was still significant thickness of organic material at original ground.
- Drainage was exiting from the fill near the bottom.

FIGURE 11 - 15 EXAMPLE OF A SOIL EVALUATION FOR EXISTING FILL (Continued)

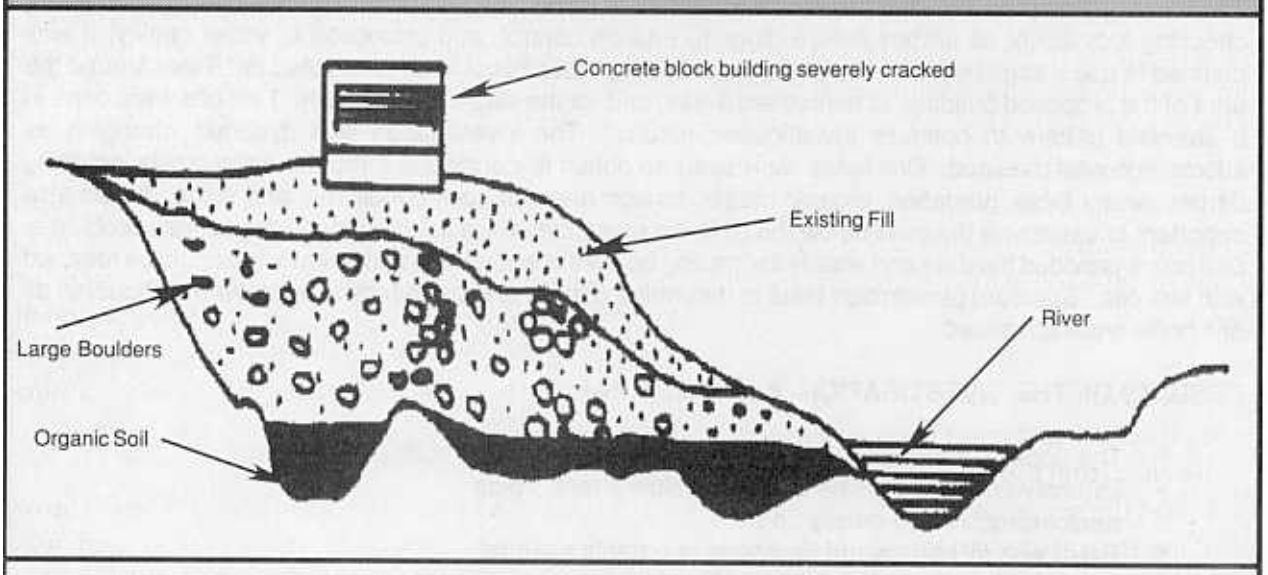
- Evidence of soil fines piping through voids and subsurface drainage channels.
- Evidence of the upper sandy soils piping into voids in the boulder fill by gravity and seepage from across the road
- Several locations of low blow count mineral soils.

SOIL EVALUATION The evaluation of the soils indicated that the location for the proposed one-story building and septic tank system was entirely unsatisfactory. It was determined that:

- Upper fill was still going into the voids in the boulder rock fill creating depressions at the surface and reducing densities of some areas.
- Drainage from across the road flowed down through voids in the nested boulders carrying material into the voids.
- Organic soils were in several locations and have not completely consolidated.
- In addition, old stream channels created varying depths of fill leading to the differential settlement.
- Slope stability would be a problem if sewage effluent was added to the existing seepage condition.

The evaluation indicated that the fill at the old concrete block building would not be suitable for a large one-story building. The area proposed for a large leach field was also not suitable. Continued differential settlement, inadequate receiving layers, coarse materials, voids, seepage problems, and slope stability indicated there was no cost effective remedy.

Based on the evaluation, the project was replanned and investigated for the site across the street. This second site was found feasible, and the project was successfully completed, with the one- story building and sewage treatment system located there. It was later learned that borrow for the brick building fill was obtained from an adjacent pit. During construction of that fill, oversize boulders were pushed to a waste area at the old stream channels which was later the concrete block building location. The waste pile, with large voids, was then covered with mineral soil. Cover material movement into voids, continued subsurface seepage, and differential settlement at the old stream channels, resulted in the site problems.



CROSS SECTION OF EXISTING FILL AT SEVERELY DISTRESSED CONCRETE BLOCK BUILDING

EVALUATION FOR SUBDIVISION AND SEPTIC SYSTEM DESIGN

12

Due to the rural aspects of New Hampshire, central sewage collection and treatment systems are not readily available for much of the population. As a result, disposal of wastewater is achieved primarily by septic systems. Septic systems depend upon soils to absorb, filter, and renovate liquid domestic and similar wastes to prevent pollution of surface and ground waters, as well as health hazards.

PAST LEGISLATION

The state of New Hampshire legislated its concern with surface water pollution as far back as 1935 with the enactment of Chapter 140:2, Public Laws (now RSA Chapter 147). This was adopted by the State Board of Health. This law applied to water bodies not already polluted by public sewers and which were greater than 10 acres in size.

> "2.(a) No privy, cesspool or septic tank shall be constructed or maintained at such distance from the edge of a body of water within the scope of these regulations, as in the Board's judgment, to entail likelihood of material pollution thereof. In general, and except where the Board may otherwise permit, a minimum distance of seventy-five feet is to be understood."

In 1938, Section 2, Chapter 140, Public Laws was amended as follows: "No privy, cesspool or other private sewage disposal system shall hereafter be constructed within seventy-five feet of a well or a human habitation other than that to which it is appurtenant, without approval by the local health officer."

Rapid development during the 1960s emphasized a need for more stringent controls over the discharge of domestic and commercial wastewater. This discharge was negatively impacting both surface and groundwater quality. See Figure 12-1.

Through a joint effort of the New Hampshire Water Supply and Pollution Control Commission, USDA Soil Conservation Service, and the New Hampshire Planning and Development Commission, N.H. RSA 149-C, governing waste disposal on islands, was enacted into law on June 11, 1965.

RSA 149-C was superseded by RSA 149-E (now RSA 485-A:29-40) on July 1, 1967 and was known as the "Shoreline Act". The intent of this law was to regulate the quality of septic systems within 1,000 feet of surface waters.

FIGURE 12 - 1 1960 s EMPHASIZED NEED FOR MORE STRINGENT CONTROLS TO PROTECT WATER QUALITY

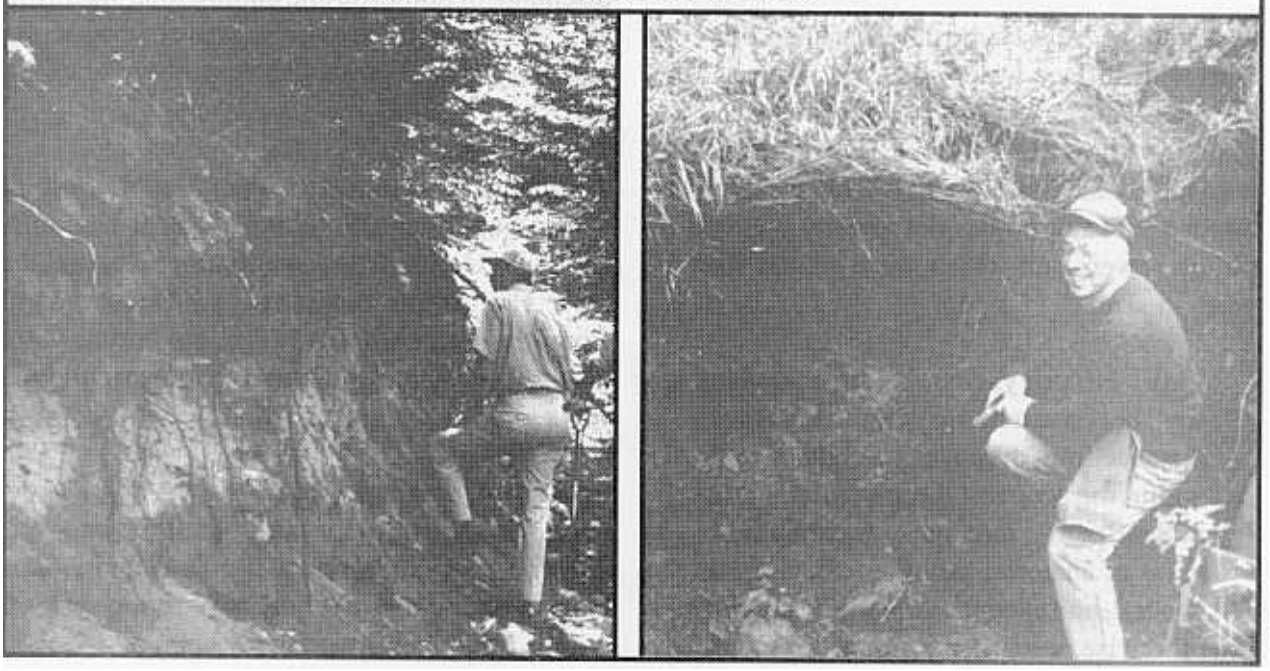
RSA 149-E was amended effective July 1, 1971, to include the requirement that all septic systems obtain approval by the then Water Supply and Pollution Control Commission.

IMPORTANCE OF SOIL AND INTENT OF LAW

Soil properties and their interpretation play a vital role in the intent of the law. Figure 12-2 shows investigation of site soil conditions.

With the enactment of Chapter 149-E, the importance of soil in determining adequate lot sizing was made evident. In 1969, minimum lot sizes were developed which relied upon soil drainage characteristics and related topography. The intended purpose of a minimum lot size criteria was to ensure that land being divided for potential

FIGURE 12 - 2 INVESTIGATION OF SITE SOIL CONDITIONS



home site construction would have adequate area to sustain the dwelling, waste water disposal, and water supply.

Concerns over groundwater recharge/recycling and diminishing groundwater sources require proper interpretation of site conditions.

Pursuant to RSA Chapter 149-E, all proposed subdivision lots of less than 5 acres and all septic system designs submitted for review must contain USDA Soil Conservation Service data, and a report of an onsite soils investigation. Generally, it is possible to design and construct a subsurface waste disposal system which will have a minimum impact upon groundwater quality and no impact upon surface water quality.

SUBSURFACE WASTE DISPOSAL

Domestic wastewater leaves a house through a sewer line which, for onsite disposal, travels to a septic tank. A septic tank is a water tight compartment which retains the wastewater and begins the treatment of sewage by settling of solids and biological activity. Baffles on the inlet and outlet of the tank prevent solid materials from entering and potentially clogging the final disposal area. See Figure 12-3 for elements of a typical subsurface system.

Within the tank, solid materials settle to the bottom and soaps, greases, etc., float to the surface. Anaerobic (without 0_2) bacterial action works to break down the digestible solids and results in a liquid (effluent) high in nutrients, pathogens, and biochemical oxygen demand (BOD).

The amount of time sewage remains in the tank (detention time) is important to the pre-treatment of sewage; the longer the detention time, the more easily the effluent can be treated when discharged. The preferred detention time is 48 hours.

Effluent is discharged from the septic tank into a distribution system intended to disperse the effluent evenly throughout the disposal area. The disposal system can consist of perforated pipes within a layer of clean stone or open bottomed "chambers" set upon a sand layer.

FIGURE 12 - 3 ELEMENTS OF A SUBSURFACE SEWAGE SYSTEM

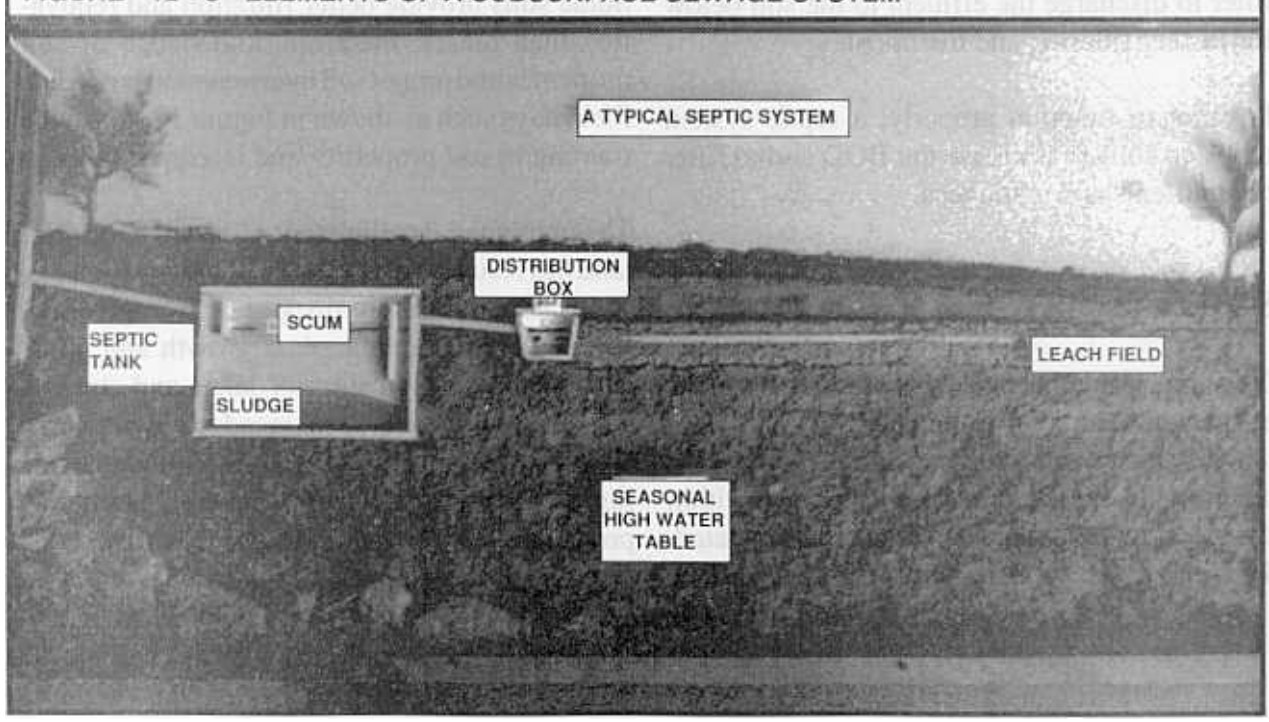


FIGURE 12 - 4 FIELD DAYS PROVIDE SOIL TRAINING

In the disposal area, an organic mat consisting of sulfides and organic slimes forms at the soil interface. This mat provides an area for aerobic bacterial action (with 0_2) and acts as a trickling filter to discharge the effluent to the soil below for further filtering and treatment.

In order to function properly, a septic system relies on soils to decrease the BOD and to filter out nutrients and pathogens.

SOIL AND SEWAGE TREATMENT

It is important that adequate treatment of the effluent be completed prior to reaching the water table. Viruses and other harmful elements contained in sewage may travel long distances within the groundwater should it become contaminated. This can result in water supply and/or surface water contamination. An adequate depth of unsaturated soil is necessary for full treatment of sewage effluent to occur.

Some soils provide better filtration and renovation than others; therefore, knowledge of soil properties and proper soil interpretation is needed. Field days such as shown in Figure 12-4 provide training in soil properties and interpretations.

The continued development of New Hampshire land has resulted in a decrease of areas which can adequately and safely dispose of sewage effluent. Increased aquatic plant growth and problems with eutrophication of lakes and streams can, in some instances, be traced to old or poorly functioning septic systems. Proper understanding and interpretation of onsite soils is vital to protecting our ground and surface waters, both now and in the future.

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GLOSSARY

AASHTO soil classification system: The American Association of State Highway and Transportation Officials System used to classify soils according to those properties that affect their use in highway construction.

Ablation Till: Loose, permeable till deposited during the final downwasting of glacial ice. Lenses of crudely sorted sand and gravel are common.

Aeration, Soil: The exchange of air in soil with air from the atmosphere.

Aerobic Conditions: (1) Conditions with oxygen gas as a part of the environment, (2) living or acting only in the presence of air or free oxygen, (3) pertaining to the activity of organisms that grow under aerobic conditions, such as aerobic decomposition.

Aggregate, Soil: Fine particles in a single mass or cluster.

Agronomy: Branch of agriculture dealing with field-crop production and soil management.

Alkalinity: The quality or state of being alkaline. The concentration of OH negative ions.

Alluvial Soil: Soils developing from water transported and relatively recently deposited material with little or no modification of the original materials by soil forming processes.

Alluvium: Soil which has been transported in suspension by flowing water and subsequently deposited by sedimentation.

Anaerobic Conditions: Absence of air or free oxygen.

Angular: Particles having sharp edges and relatively plane sides.

Aquifer: A water-bearing formation that provides economically significant quantities of water to wells or springs.

Archean: The Eon from about 3,800 to 2,500 million years ago.

Artesian Condition: Water confined under enough pressure to cause it to rise above the level where it is encountered in drilling.

ASCS: Agricultural Stabilization and Conservation Service, an agency of United States Department of Agriculture.

Aspect: The direction that a land slope faces.

Association, Soil: A group of soils geographically associated in a characteristic repeating pattern and defined and delineated as a single map unit.

Auger: A tool used for making small test holes in the earth.

Basal Till: Compact glacial till deposited beneath the ice during glacial time.

Bearing Capacity: The allowable bearing capacity of a soil is the maximum average load per unit area of a footing that will not produce failure by rupture of the supporting soil or produce excessive settlement.

Bedding: The arrangement of successive layers (beds or strata) of sedimentary material.

Bedrock: The solid rock that underlies the soil and other unconsolidated material or that is exposed at the surface.

Berm: A shelf that breaks the continuity of a slope for erosion control and slope stability.

Blocky: A form of soil structure. The natural organization of soil particles into a block-like or polyhedral shape.

BOD: Biochemical oxygen demand.

Borofibrists: A taxonomic classification of a soil. Borofibrists are organic soils in which most of the decaying plant fibers are still recognizable and are often referred to as peat. The mean annual soil temperature is lower than 47 degrees Fahrenheit.

Borohemists: A taxonomic classification of a soil. Borohemists are organic soils in which the plant fibers are in an intermediate stage of decay. The mean annual soil temperature is lower than 47 degrees Fahrenheit.

Borrow: Material excavated as a source of construction fill.

Boulders: (USDA): Rock fragments larger than 2 feet in diameter. (USCS): Particles that will not pass a 12-inch square opening.

Broadly Graded: Coarse-grained soil material that has a wide range in particle sizes,

Cambrian: Period in the Paleozoic era from about 570 to 505 million years ago.

Capillary Action: The rise or movement of water in the interstices of a soil due to capillary forces.

Capillary Fringe: The zone above the free water elevation in which water is held by capillary action.

Capillary Moisture: Moisture above the water table due to capillary action.

Capillary Rise: The height above a free water elevation to which water will rise by capillary action.

Capillary Water: Water held as a film around soil particles and in tiny spaces between particles. Surface tension is the adhesive force that holds capillary water in the soil.

Catena: A sequence, or "chain", of soils on a landscape that formed in similar kinds of parent material, but have different characteristics as a result of differences in relief and drainage.

Cemented: A hard, brittle consistency. Particles are held together by cementing substances.

Cenozoic: Era in the Phanerozoic eon from about 66 million years ago to present.

Channery: A term to describe small flat rock fragments. The dimension along the long axis ranges from .2 to 15 centimeters.

Chroma: The relative purity, strength, or saturation of color. One of the three variables of color. See Munsell color notation, hue, value.

Cirque: A deep steep-walled basin on a mountain shaped like a half bowl.

Clay: (USDA): As a soil separate, the mineral soil particles less than 0.002 millimeter in diameter. As a soil textural class, soil material that is 40 percent or more clay, less than 45 percent sand, and less than 40 percent silt. (USCS): Soil passing a No. 200 U.S. sieve that exhibits plasticity and has considerable strength when dry.

Cleavage Planes: The tendency of minerals to split along crystallographic planes. As applied to rocks, it is the property of splitting into thin parallel sheets which may be highly inclined to the bedding planes as in slate.

Clod: Soil aggregates clumped together, produced by disturbance of the soil, such as tillage.

Coarse-Grained Soil: The minus 3-inch fraction of a soil having a gradation such that more than 50 percent by dry weight is retained on a No. 200 sieve in the USCS.

Cobble: (USCS) Rock particles that passes a 12-inch opening and are retained on a 3-inch standard sieve. (USDA): A rounded or partly rounded fragment of rock 3 to 10-inches in diameter.

Coefficient of Curvature: (Cc) A coefficient used in evaluating the grading characteristics of coarse-grained soil. It is calculated by the expression $(D_{30})^2 / D_{10} \times D_{60}$

Coefficient of Uniformity: (Cu) A coefficient used in evaluating the grading characteristics of coarse-grained soils. It is calculated from the expression D_{60}/D_{10} where D_{10} and D_{60} are the particle diameters corresponding to 10 and 60 percent finer on the gradation curve.

Cohesive Soil: Soil that when unconfined has considerable strength when air-dryed and has significant cohesion when submerged.

Colluvium: Soil material, rocky fragments, or both moved by creep, slide, or local wash and deposited at the base of a steep slope.

Compact: Soil grains rearranged to decrease void space and bring them into closer contact with one another, increasing the weight of bulk material per volume.

Compaction: Densifying soil by means of mechanical manipulation.

Complex, Soil: A map unit of two or more kinds of soil in such an intricate pattern or so small in area that it is not practical to map them separately at the selected scale of mapping. The pattern and proportion of the soils are somewhat similar in all areas.

Consistence, Soil: The feel of the soil and the ease with which a lump can be crushed by the fingers. Terms commonly used to describe consistence are: loose, friable, firm, plastic, sticky, hard, soft, cemented.

Consociation, Soil: A soil map unit in which the delineated area is dominated by a single soil type.

Cretaceous: A period in the Mesozoic era from about 144 to 66 million years ago.

Cryic: A soil temperature regime. The mean annual soil temperature is higher than 32 degrees Fahrenheit but lower than 47 degrees Fahrenheit.

Deglaciation: The uncovering of land from beneath an area of glacial ice which is shrinking due to melting.

Deposition: The accumulation of material dropped because of a slackening movement of transporting agent (water, wind).

Detention Structure (Pond): A structure without a permanent pool used to reduce peak runoff by storing runoff and discharging it slowly.

Divalent (Bivalent): Having a valence of two, or the capacity of an element to combine with another as measured by two hydrogen atoms.

Diversion: Channel constructed across the slope for the purpose of interception of surface runoff.

Drainage Class (natural): Refers to the frequency and duration of periods of saturation or partial saturation during soil formation, as opposed to altered drainage. Seven classes of natural soil drainage are recognized: Excessively drained, Somewhat excessively drained, Well drained, Moderately well drained, Somewhat poorly drained, Poorly drained, Very poorly drained.

Drainage, Soil: The rapidity and extent of the removal of water from the soil by runoff and infiltration.

Drift: Material of any sort deposited by geological processes in one place after having been removed from another.

Drilling: Boring test holes with drilling equipment.

Drumlin: A low, smooth, elongated oval hill, mound, or ridge commonly composed of compact glacial till. The longer axis is parallel to the path of the glacier and commonly has a blunt nose pointing in the direction from which the ice approached.

D Size: Percentile soil particle size. The letter D represents the diameter of a soil particle. The D size subscript indicates the percentage of material in a sample finer than the D size specified on the gradation curve.

Dune: A mound or ridge of loose sand piled up by the wind on land, or by water in a stream bed.

Effluent: Partially or completely treated sewage flowing out of a treatment system or element of a system.

Eluviated Features: The movement of material from one place to another within the soil in either true solution or colloidal supension.

Eolian Soil Material: Earthy parent material accumulated through wind action; commonly refers to sandy material in dunes.

Erosion (accelerated): Erosion much more rapid than geologic erosion, mainly as a result of the activities of man or other animals or of a catastrophic nature.

Erosion (geologic): Erosion caused by geologic processes acting over long periods and resulting in the wearing away of mountains and the building up of such landscape features as flood plains and coastal plains.

Erratic: Boulders of different origin than underlying bedrock, moved and dropped by a glacier.

Esker: A narrow range of gravelly or sandy drift deposited by a stream in association with glacial ice.

Fault: A fracture along which there has been displacement of one block of earth or rock with respect to another.

Feldspar: A group of very abundant alumino-silicate rock forming minerals.

Fill: Any material deposited by human activities.

Fines: Soil particles that pass a No. 200 sieve in the Unified Soil Classification System, (USCS).

Flocculate: To aggregate or clump together individual tiny soil particles, especially fine clay, into small groups or granules.

Flood Plain: A nearly level alluvial plain that borders a stream and is subject to flooding unless protected artificially.

Fluvial: Of or pertaining to rivers, growing or living in streams or rivers, produced by river action, as a fluvial plain.

Foreset Bed: A layer of sediment deposited on the steep advancing slope of a dune or delta face.

Free Water: Soil water in excess of field capacity that is free to move in response to gravity.

Friable: Easy to break, crumble, or crush.

Frigid: A soil temperature regime . The mean annual soil temperature is less than 47 degrees Fahrenheit.

Frost Action: Freezing and thawing of soil moisture. Frost action can damage roads, buildings, and other structures.

GIS: Geographic Information System. Computer program to analyze and store resource data electronically.

Glacial Deposition: The accumulation of material dropped because of glacial movement.

Glacial Drift: Pulverized and other rock material transported by glacial ice then deposited. Also the sorted and unsorted material deposited by streams flowing from glaciers.

Glaciation: The process of formation, movement, and recession of glacial ice from land areas over long time spans.

Glaciofluvial Deposits: Material moved by glaciers and subsequently sorted and deposited by streams flowing from the melting ice. The deposits are stratified and occur as kames, eskers, deltas, and outwash plains.

Glaciolacustrine Deposits: Material ranging from fine clay to sand derived from glaciers and deposited in glacial lakes mainly by glacial meltwater. Many deposits are interbedded or laminated.

Glaciomarine Deposits: Material derived from glaciers and deposited as rising seas flooded coastal lowlands. Massive clayey silt.

Gradation, Soil: Proportion of material of each grain size present in a given soil.

Gradient: Change of elevation per unit length. Synonym: slope.

Grain Size: Soil particle size. The various grain sizes making up the soil texture.

GRANIT: State of New Hampshire Office of State Planning Geographic Information System.

Granite: A crystalline igneous rock with a variable composition of quartz, orthoclase feldspar, and plagioclase feldspar. Biotite and hornblende are common accessory minerals.

Granular: Soil structure in which the individual grains are grouped into spherical aggregates with indistinct sides.

Gravel: Soil particles that will pass a 3-inch sieve and be retained on a No. 4 United States Standard Sieve. (USCS). (USDA) Rock fragments from 2mm to 3 inches in size.

Gravitational Water: The water in the large pores of the soil that drains away under the force of gravity with free underdrainage.

Groundwater: Water filling all the unblocked pores of underlying material below the water table.

GPR: Ground Penetrating Radar. Instrument used to determine depth to bedrock, water table, other discontinuities.

Gully: A miniature valley with steep sides eroded by running water and through which water runs after rainfall.

Hardpan: A hardened soil horizon. The soil has a high density.

HIS: High Intensity Soil Map. A detailed, large scale soil map generally used for delineating wetlands and determining lot size by soil type.

Horizon, soil: A layer of soil, approximately parallel to the surface, having distinct characteristics. In the identification of soil horizons, an uppercase letter represents the major horizons. Numbers or lowercase letters that follow represent subdivisions of the major horizons. The major horizons are as follows: O horizon, A horizon, E horizon, B horizon, C horizon, R layer.

Hue: One of three variables of color, created by light of

certain wavelengths. See Munsell color system; chroma; value.

Humus: The well decomposed, more or less stable part of the organic matter in mineral soils.

Hydraulic Mounding: Local increase in the height of the water table due to large concentrated discharge of effluent.

Hydric Soil: Soil generally saturated near the surface creating anaerobic conditions. These soils meet the criteria for the federal definition of wetlands.

Hydrologic Soil Groups: Refers to soils grouped according to their runoff-producing characteristics. The chief consideration is the inherent capacity of soil bare of vegetation to permit infiltration.

Hydrology: The study of the circuit of water movement from the atmosphere to the earth and return to the atmosphere through various stages or processes, as precipitation, interception, runoff, infiltration, percolation, storage, evaporation and transpiration.

Hydrophytic Plants: Plants that are adapted to wet or saturated soil conditions; wetland plants.

Hydroscopic: Capable of taking up moisture from the air.

Hydrostatic: Pressure of fluid.

Igneous Rock: Rock formed by solidification of molten materials.

Impermeable: Not permitting passage of fluid through its substance.

Impervious Soil: A soil through which water, air, or roots penetrate slowly or not at all. No soil is absolutely impervious to air and water all the time.

Infiltration: The downward entry of water into the immediate surface of soil or other material.

In situ: (In place) Formed or accumulated on the spot. As a mass appears in the soil before any disturbance.

Intrusive: Pertaining to igneous rocks resulting from the emplacement of molten material into preexisting rocks.

Kame: An irregular, short ridge or hill of stratified glacial drift.

Kettle: A steep sided depression without surface drainage especially in a deposit of glacial drift.

Lacustrine: Pertaining to, produced by, or formed in a lake or lakes. Many nearly level soils have developed from the bottom deposits of now drained lakes.

Leaching: The removal of soluble material from soil or other material by percolating water.

Lee Slope: A slope facing in the direction of motion of an overriding glacier.

Liquid Limit: The moisture content at which the soil passes from a plastic to a liquid state.

Lithic: A boundary between soil and continuous, coherent underlying material which has a hardness of 3 or more (Mohs scale) when moist, the underlying material cannot be dug with a spade and chunks will not disperse in water. Example: basalt rock.

Loam (USDA): Soil texture that is 7 to 27 percent clay particles, 28 to 50 percent silt particles, and less than 52 percent sand particles.

Lodgment Till: Basal till containing cobbles or boulders oriented with their long axes generally parallel to the direction of ice movement.

Marine: Material deposited in the waters of the ocean and sea and exposed by elevation of the land or lowering of the water level.

Massive: A term used to describe nonstructure in soil. Soil particles are bound to one another by cohesive forces, but not in any recognizable structural shape.

Matrix: Natural material in which larger particles are embedded. Also, it is a term used in describing soil color patterns. The matrix color is the dominant color or background color on which mottles, spots, strengths, concretions are compared.

Mesic: A soil temperature regime. The mean annual soil temperature is 47 degrees Fahrenheit or higher, but lower than 59 degrees Fahrenheit.

Metamorphic Rock: A rock that has been greatly altered from its previous condition through the combined action of heat and pressure.

Miocene: Epoch in the tertiary period of the Cenozoic era from about 23.7 to 5.3 million years ago.

Mineral Particle: A grain of an inorganic substance occurring naturally in the earth and having a consistent and distinctive set of physical properties such as color, hardness, and crystalline structure.

Mineral Soil: A general term for a soil composed chiefly of mineral matter, in contrast to an organic soil, which is composed of chiefly organic matter.

mm: Millimeter.

Moraine: An accumulation of drift, with an initial topographic expression of its own, built within a glaciated region chiefly by the direct action of glacial ice.

Morphology, Soil: The properties of the soil including the texture, structure, consistence, color and other physical, chemical, and biological properties of the various soil horizons that make up the soil profile.

Mottling, Soil: Irregular spots of different colors that vary in number and size. Mottling generally indicates poor aeration and impeded drainage.

Muck: Dark colored, finely divided, well decomposed organic soil material.

Munsell Color Notation: A designation of color by degrees of the three variables: hue, value, and chroma.

NCSS: National Cooperative Soil Survey

Oligocene: Epoch in the tertiary period from 36.6 to 23.7 million years age.

Ordovician: The period in the Palezoic era from about 505 to 438 million years ago.

Organic Materials: In chemistry refers to the compound of carbon. Fibric, hemic, and sapric are all organic materials of different stages of decomposition.

OSHA: Occupational Safety and Health Administration.

OSP: New Hampshire Office of State Planning.

Outwash (Glacial): Stratified sand and gravel produced by glaciers and carried, sorted, and deposited by glacial meltwater.

Oversize: Stone or rock fragments larger than is allowed to be utilized in fill.

Oxidizing Environment: A chemical change involving the addition of oxygen or its chemical equivalent.

pH Value: A numerical designation of acidity and alkalinity in soil.

Paleocene: Epoch in the Tertiary period of the Cenozoic era from about 66.4 to 57.8 million years ago.

Paleozoic: Era in the Phanerozoic eon from about 570 to 245 million years ago.

Parent Material: The organic and mineral material in which soil forms.

Pathogen: A specific causative agent of a disease; bacerium or virus.

Peak Runoff: Maximum rate of runoff that occurs during a storm event.

Peat: Largely undecomposed organic matter, that has accumulated under excess moisture.

Ped: An individual natural soil aggregate, such as a granule, a prism, or a block.

Pedon: The smallest volume that can be called "a soil". A pedon is three dimensional and large enough to permit study of all horizons. Its area ranges from about 10 to 100 square feet, depending on the variability of the soil.

Perched: The surface of a local zone of saturation held above the main body of groundwater by an impermeable or slowly permeable layer or stratum.

Percolation: The movement of gravitational water down through soil.

Permeability: The ability to transmit water through saturated soil.

Permian: Period in the Paleozoic era from about 286 to 245 million years ago.

Phase, Soil: A subdivision of a soil series based on features that affect its use and management. For example, slope and stoniness.

Phyllite: A metamorphic rock.

Physical Weathering: The breakdown of rock and mineral soil into smaller fragments by physical forces such as frost action.

Physiographic Unit: A subdivision of land areas of the United States by physiographic features.

Piping: Formation of subsurface tunnels or pipelike cavities by water moving through the soil.

Plasticity: The property of a soil which allows it to be deformed beyond the point of recovery, accompanied by continuing deformation with no further increase in stress.

Plasticity Index: The numerical difference between the liquid limit and the plastic limit; the range of moisture content within which the soil remains plastic.

Plastic Limit: The moisture content at which a soil changes from semisolid to plastic.

Platiness: Consisting of soil aggregates that are developed predominantly along the horizontal axes; laminated, flaky.

Platy: Soil aggregates with thin vertical dimensions and long horizontal dimensions.

Pleistocene: Epoch in the Quaternary period of the Cenozoic era from about 1.6 to 0.01 million years ago.

Pliocene: Epoch in the Tertiary period of the Cenozoic era from about 5.3 to 1.6 million years ago.

Plucking: The process of glacial erosion by which sizeable rock fragments are loosened, detached, and transported by advancing glacial ice.

Plutonic: Pertaining to igneous rocks formed at a great depth beneath the earth's surface.

Poorly Graded: Refers to a coarse- grained soil or soil material consisting mainly of particles of nearly the same size. Poorly graded in the Unified Soil Classification System is used if well graded criteria are not satisified.

Prismatic: Prism-like structural aggregates with the vertical axes of the aggregates longer than the horizontal axes.

Probing: Using a muck probe or other shaft type rod to sound through soft soil to more dense material.

Proglacial Deposit: Material deposited immediately in front of or just beyond the outer limits of a glacier.

Quartz: A crystalline mineral of silicon dioxide (SiO_2)

Quaternary: The period in the Cenezoic era from about 1.6 million years ago to present.

Redox: A term to describe the alternating chemical process in the soil of oxidation or reduction.

Reducing Environment: A chemical change involving the removal of oxygen or its chemical equivalent.

Relic Mottles: Mottles in the soil that indicate a past high water regime that no longer exists. Often these are high chroma mottles; bright red mottles.

Relief: The elevations or inequalities of a land surface, considered collectively.

Restrictive Layers: A layer or layers in the soil that impedes the downward flow of water.

Retention Structure (Pond): A structure with a permanent pool designed to retard runoff by temporarily storing water and then releasing slowly.

Ribboning: A field test to aid in estimating soil texture. A moist soil sample is squeezed out from thumb and forefinger and soils high in clay content will form long thin "ribbon-like" threads that have cohesion.

Rill: A small steep-sided channel resulting from accelerated erosion. A rill is generally only a few inches deep and not wide enough to be an obstacle to machinery. It is smaller than a gully.

Rounded: A term describing particles whose corners have been smoothed to broad curves.

RSA: Revised statutes Annotated. Enabling state regulations in New Hampshire.

Runoff: The precipitation discharged into stream channels from an area. The water that flows off the surface of the land without sinking into the soil is called surface runoff.

Sand (USDA): As a soil separate, individual rock or mineral fragments from 0.05 millimeter to 2.0 mm in diameter. As a soil textural class, a soil that is 85 percent or more sand and not more than 10 percent clay; **(USCS):** Coarse-grained particles that pass through a No. 4 sieve as a soil separate. As a soil textural class, a coarse-grained soil with 50 percent or more of the coarse fraction being sand size.

Saturation: The point at which a soil will no longer absorb any amount of water without loosing an equal amount.

SCS: Soil Conservation Service. An agency of the United States Department of Agriculture.

Seasonal High Water Table: The highest level in the soil of saturation, generally occurring in the spring after snow melt. Evidence of an "average" seasonal high water table is usually determined by the high level of common distinct or prominant mottling.

Sediment: Particles deposited by water, wind, or glaciers.

Sedimentary Rock: Rock resulting from consolidation of mineral or organic sediment that has accumulated in layers, or has precipitated from solution.

Sedimentation: The action or process of forming or depositing sediment, material deposited by water, wind or glaciers.

Seepage: The movement of water through the soil. Seepage may adversely affect the specified use.

Seeps: Water escaping through or emerging from the ground along an extensive line or surface as contrasted with a spring where water emerges from a localized spot.

Seismic Refraction: A type of seismic survey based on the measurement of travel times of shock waves which have moved nearly parallel to the bedding in high velocity layers.

Shear Strength: Strength of soil that resists deformation.

Sieve Analysis: A method of determining proportions of various particle sizes by use of soil sieves.

Silt (USDA): As a soil separate, individual mineral particles that range in diameter from the upper limit of clay (0.002 mm) to the lower limit of very fine sand (0.05 mm). As a soil textural class, soil that is 80 percent or more silt and less than 12 percent clay. **(USCS):** Soil particles that pass a No. 200 sieve and that are basically nonplastic.

Silurian: Period in the Palezoic era from about 438 to 408 million years ago.

Silviculture: A branch of forestry dealing with the development and care of forests.

Skip Graded: Gradation of coarse-grained soil that does not meet well graded criteria because of a lack of some particle sizes.

Slope: The inclination of the land surface from the horizontal. Percentage of slope is the vertical distance divided by horizontal distance, then multiplied by 100. Thus, a slope of 20 percent is a drop or rise of 20 feet in 100 feet of horizontal distance.

Soil: For soil science purposes, soil is the collection of earthy materials on the surface of the planet that contains living matter and supports or is capable of supporting plants. Generally the definition applies to the upper 5 feet of the earth's surface. For soil engineering, it is all earthen material above bedrock.

Soil Profile: Vertical section of a soil, showing the nature and sequence of the various layers, as developed by deposition or weathering or both.

Soil, Series: A group of soils that have profiles that are almost alike, except for differences in texture of the surface layer. All the soils of a series have horizons that are similar in composition, thickness, and arrangement.

Solum: The upper part of the soil profile above the C horizon in which the processes of soil formation are active.

Sphagnum: A species of moss that grows in cool wet climates, noted for its ability to hold large volumes of water.

Split Tube Sampler: A soil sampler with an outside diameter of 2 inches, inside diameter of 1 3/8 inches, and a useable length of about 20 inches.

Standard Penetration: Testing conducted by driving a split tube sampler into the soil at the bottom of a clean drill hole to a distance of 18 inches. The number of blows for the last 12 inches are used for "blow count".

Stereoscope: An instrument used to view aerial photos in which the third dimension of depth can be observed by aligning overlapping photos.

Stony: Refers to a soil containing stones in numbers that interfere with or prevent tillage.

Stoss: The side of a hill facing the direction from which an ice sheet or glacier advanced. The opposite of the "lee" slope.

Stratification: The formation, accumulation, or deposition of material in layers.

Stratified Drift: Sorted and layered material of glacial origin.

Stratified Rock: Bedrock in which layers, or strata, are visible.

Structure, Soil: The arrangement of primary soil particles into compound particles or aggregates.

Subangular: A term used with blocky soil structure or rock fragments, to indicate the corners of the blocks or fragments are rounded.

Subrounded: A term describing particles which are more rounded than subangular, but which are not fully rounded.

Subsoil: The part of the solum below the surface layer and above the substratum. It is a zone of soil development referred to as the B horizon.

Substratum: The part of the soil below the subsoil.

Suite: A group of rock bodies with similar chemical and mineral compositions derived from the same molten source.

Sulfihemists: Organic soils with a high sulfate content. Generally, these soils occur in salt marshes in low coastal areas.

Surficial Geology: The study of the materials which overlie bedrock on the earth's surface.

Taxonomy: Science that deals with the orderly classification according to presumed natural relationships.

Tertiary: A period in the Cenozoic era from about 66 to 1.6 million years ago.

Test Pitting: Excavating holes for classifying and testing soil with excavating equipment or shovel.

Texture, Soil: The relative proportions of various size groups of individual soil grains in a mass of soil.

Till: Unsorted nonstratified glacial drift consisting of clay, silt, sand, gravel, cobbles and boulders transported and deposited by glacial ice.

Topography: The shape of the ground surface, such as hills, mountains, or plains including the location of natural and manmade features.

Topsoil: The upper part of the soil, which is the most favorable material for plant growth. It is ordinarily rich in organic matter.

Transect: A randomly selected line across a soil map unit in which observations are made at a predetermined interval to determine unit composition.

Transpiration: Loss of water vapor from the leaves and stems of living plants to the atmosphere.

Traprock: A dark-colored, fine-grained, nongranitic igneous rock, such as basalt.

Triassic: The period in the Mesoic era from about 245 to 208 million years ago.

Tundra: A treeless, relatively flat plain of arctic and subarctic regions in which the common vegetation is mosses, lichens, and shrubs.

Turbidity: A condition when water is clouded, or has a dark hue due to sediments.

Undifferentiated Group: Two or more soils or land types that are mapped as one unit because their differences are not significant to the purpose of the survey or to soil management.

Unified Soil Classification System (USCS): The Unified System is used to classify soil for many civil engineering purposes. Identifies coarse-grained soils primarily on the basis of gradation. Classifies fine-grained soils primarily on the basis of plasticity.

Uniformly Graded: Refers to soil material consisting of coarse-grained particles that are all essentially of the same size.

Unsaturated: A moisture condition of soil when it is not filled to capacity with water.

USDA Soil Classification System: Soil material is classified into textural classes on the basis of the proportions of sand, silt, and clay sizes in the soil that is less than 2.0 mm in diameter.

USGS: United States Geological Survey, an agency of Department of the Interior.

Value: The relative lightness or intensity of color, approximately a function of the square root of the total amount of light. One of three variables of color. See Munsell color notation, hue, chroma.

Variegated: Refers to patterns of contrasting colors assumed to be inherited from the parent material rather than to be the result of poor drainage.

Variant, Soil: A classification level of a soil within soil taxonomy. A soil variant is like a soil series, but because a small amount of acreage is involved, it is designated a variant for a similar soil series for convenience.

Varve: A sedimentary layer of a lamina or sequence of laminae deposited in a body of still water within a year.

Volcanic Rocks: Generally fine-grained igneous rocks resulting from volcanic action near the earth's surface.

Watershed: All land and water within the confines of a drainage divide.

Water Table: The upper limit of the part of the soil or underlying rock material that is wholly saturated with water.

Well Graded: Refers to soil material consisting of coarse-grained particles that are well distributed over a wide range in size. Well graded in the USCS requires specific values of coefficients of uniformity and curvature.

Surficial Geology: The study of the materials which overlie bedrock on the earth's surface.

Taxonomy: Science that deals with the orderly classification according to presumed natural relationships.

Tertiary: A period in the Cenozoic era from about 65 to 1.6 million years ago.

Test Pitting: Excavating holes for classifying and testing soil with excavating equipment or shovel.

Texture, Soil: The relative proportions of various size groups of individual soil grains in a mass of soil.

Till: Unsorted nonstratified glacial drift consisting of clay, silt, sand, gravel, cobbles and boulders transported and deposited by glacial ice.

Topography: The figure of the ground surface, such as hills, mountains, or plains including the location of natural and manmade features.

Topsoil: The upper part of the soil, which is the most favorable material for plant growth. It is usually rich in organic matter.

Transect: A geometrically selected line across a soil mapping unit in which observations are made at a predetermined interval to determine soil composition.

Transpiration: Loss of water vapor from the leaves and stems of living plants to the atmosphere.

Travertine: A dark-colored, fine-grained, homogenized igneous rock, such as basalt.

Triassic: The period in the Mesozoic era from about 245 to 208 million years ago.

Tundra: A treeless, relatively flat plain of arctic and subarctic regions in which the common vegetation is mosses, lichens, and shrubs.

Turbidity: A condition when water is clouded, or has a dull hue due to sediment.

Multiformsolated Group: Two or more soils or land types that are mapped as one unit because their differences are not significant to the purpose of the survey or to soil management.

Unified Soil Classification System (USCS): The Unified System is used to classify soil for many civil engineering purposes. Identifies coarse-grained soils primarily on the basis of gradation. Classifies fine-grained soils primarily on the basis of plasticity.

Uniformly Graded: Refers to soil material consisting of coarse-grained particles that are all essentially of the same size.

Unsaturated: A moisture condition of soil when it is not filled to capacity with water.

USDA Soil Classification System: Soil material is classified into textural classes on the basis of the proportions of sand, silt, and clay when in the soil that is less than 2.0 mm in diameter.

USGS: United States Geological Survey, an agency of Department of the Interior.

Value: The relative lightness or darkness of color, approximately a function of the square root of the total amount of light. One of three variables of color in Munsell color notation, hue, chroma.

Varegated: Refers to patches of contrasting color assumed to be inherited from the parent material rather than to be the result of poor drainage.

Variant, Soil: A classification level of a soil series in taxonomy. A soil variant is like a soil series, but includes a small amount of acreage in inclusion. It is designated a variant for a similar soil series for convenience.

Varve: A sedimentary layer of a lake or pond or a glacial deposited in a body of still water within a year.

Volcanic Rocks: Generally fine-grained igneous rocks resulting from volcanic action near the earth's surface.

Waterlands: All land and water within the confines of a drainage divide.

Water Table: The upper limit of the part of the soil or underlying rock material that is wholly saturated with water.

Well Graded: Refers to soil material consisting of coarse-grained particles that are well distributed over a wide range in size. Well graded in the USCS requires specific values of coefficients of uniformity and curvature.

APPENDIX A

USDA Soil Conservation Service
and NH Conservation District
Office Telephone Numbers and Addresses

Claremont USDA SCS Field Office and
Sullivan County Conservation District Office

25 Mulberry Street
Claremont, NH 03743

TEL: 542-6681

Concord USDA SCS Field Office and
Merrimack County Conservation District
Office

The Concord Center
10 Ferry Street
Box 312
Concord, NH 03301

TEL: 225-6401

Conway USDA SCS Field Office and
Carroll County Conservation District Office

44 Main Street
PO Box 533
Conway, NH 03818

TEL: 447-2771

Dover USDA SCS Field Office and
Strafford County Conservation District Office

USDA Agricultural Service Center
County Farm Road
Dover, NH 03820

TEL: 749-3037

Exeter USDA SCS Field Office and
Rockingham County Conservation District
Office

Federal Building
32 Front Street
Exeter, NH 03833

TEL: 772-4385

Keene USDA SCS Field Office and
Cheshire County Conservation District Office

U.S. Postal Service Building
196 Main Street
Keene, NH 03431

TEL: 352-3602

Laconia USDA SCS Field Office and
Belknap County Conservation District Office

Federal Building, Room 203
719 Main Street
Laconia, NH 03246

TEL: 528-8713

Lancaster USDA SCS Field Office and
Coos County Conservation District Office

RFD 2, Box 235
Lancaster, NH 03584

TEL: 788-4651

Milford USDA SCS Field Office and
Hillsborough County Conservation District
Office

Chappell Professional Center
Route 13 South
Milford, NH 03055

TEL: 673-2409

Woodsville USDA SCS Field Office and
Grafton County Conservation District Office

PO Box 229
Swiftwater Road
Woodsville, NH 03785

TEL: 747-2001

North Country Resource Conservation and
Development Office

RFD 4, Box 240
Meredith, NH 03253-9416

TEL: 279-6546

Watershed Project Office

RFD 4, Box 240
Meredith, NH 03253-9416

TEL: 279-6546

APPENDIX B

Map Scales

USGS NH 7.5 - Minute Quadrangle Names

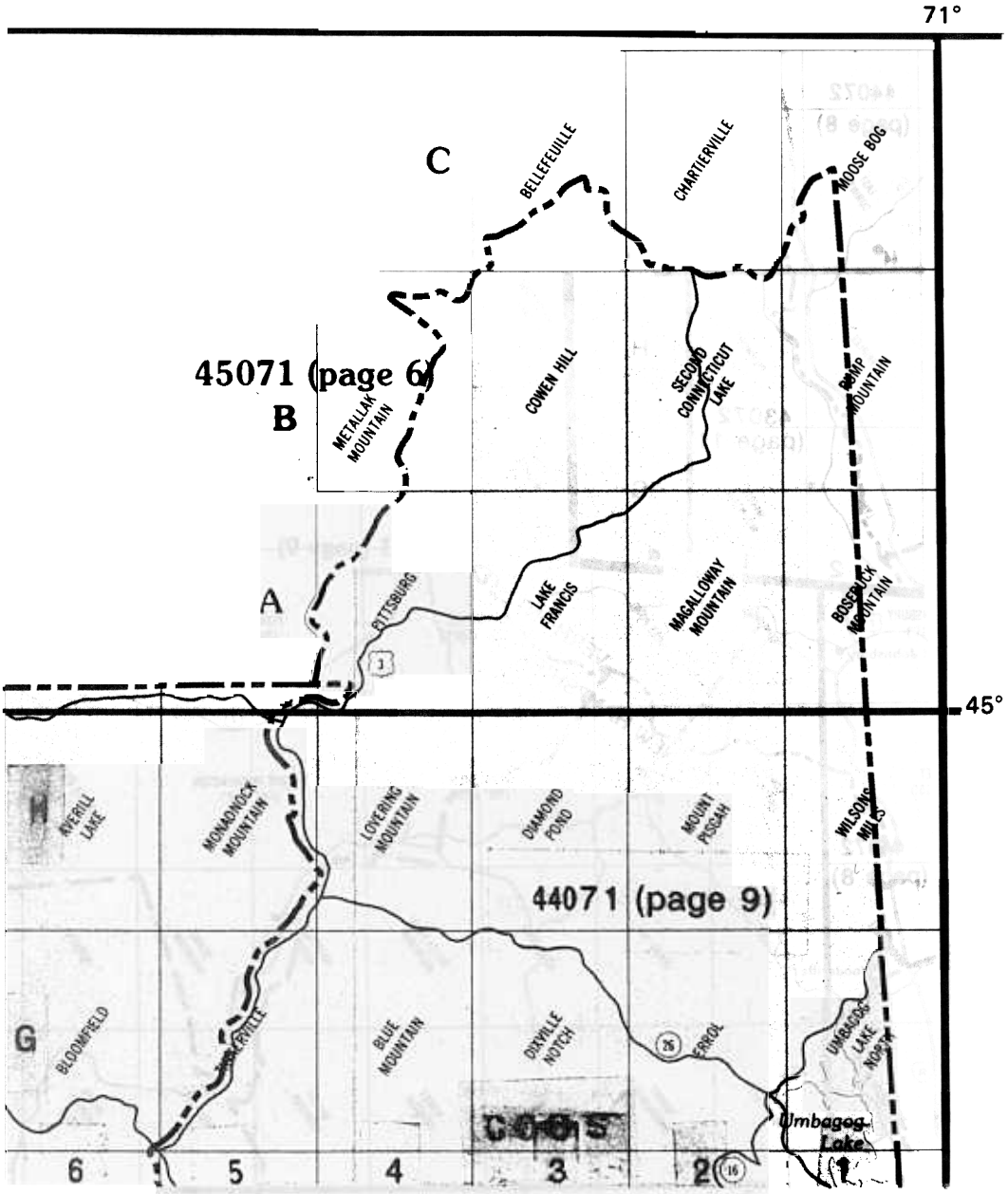
NH Department of Transportation Mapping Information

NH Department of Environmental Services
Status of Groundwater Mapping

MAP SCALES AND EQUIVALENTS

Fractional Scale	Feet per inch	Inches per 1000 Ft.	Inches per mile	Miles per inch	Meters per inch	Acres per square inch
1:500	41.667	24.00	126.72	0.008	12.700	0.0399
1:600	50.00	20.00	105.60	0.009	15.240	0.0574
1:1000	83.333	12.00	63.36	0.016	25.400	0.1594
1:1200	100.00	10.00	52.80	0.019	30.480	0.2296
1:1500	125.00	8.00	42.24	0.024	38.100	0.3587
1:2000	166.667	6.00	31.68	0.032	50.800	0.6377
1:2400	200.00	5.00	26.40	0.038	60.960	0.9183
1:2500	208.333	4.80	25.344	0.039	63.500	0.9964
1:3000	250.00	4.00	21.12	0.047	76.200	1.4348
1:3600	300.00	3.333	17.60	0.057	91.440	2.0661
1:4000	333.333	3.00	15.84	0.063	101.600	2.5508
1:4800	400.00	2.50	13.20	0.076	121.920	3.6731
1:5000	416.667	2.40	12.672	0.079	127.000	3.9856
1:6000	500.00	2.00	10.56	0.095	152.400	5.7392
1:7000	583.333	1.714	9.051	0.110	177.800	7.8117
1:7200	600.00	1.667	8.80	0.114	182.880	8.2645
1:7920	660.00	1.515	8.00	0.125	201.168	10.00
1:8000	666.667	1.500	7.92	0.126	203.200	10.203
1:8400	700.00	1.429	7.543	0.133	213.360	11.249
1:9000	750.00	1.333	7.041	0.142	228.600	12.913
1:9600	800.00	1.250	6.60	0.152	243.840	14.692
1:10000	833.333	1.200	6.336	0.158	254.000	15.942
1:10800	900.00	1.111	5.867	0.170	274.321	18.595
1:12000	1000.00	1.0	5.280	0.189	304.801	22.957
1:13200	1100.00	0.909	4.800	0.208	335.281	27.778
1:14400	1200.00	0.833	4.400	0.227	365.761	33.058
1:15000	1250.00	0.80	4.224	0.237	381.001	35.870
1:15600	1300.00	0.769	4.062	0.246	396.241	38.797
1:15840	1320.00	0.758	4.00	0.250	402.337	40.000
1:16000	1333.333	0.750	3.96	0.253	406.400	40.812
1:16800	1400.00	0.714	3.771	0.265	426.721	44.995
1:18000	1500.00	0.667	3.52	0.284	457.201	51.653
1:19200	1600.00	0.625	3.30	0.303	487.681	58.770
1:20000	1666.667	0.60	3.168	0.316	508.002	63.769
1:20400	1700.00	0.588	3.106	0.322	518.161	66.345
1:21120	1760.00	0.568	3.00	0.333	536.449	71.111
1:21600	1800.00	0.556	2.933	0.341	548.641	74.380
1:22800	1900.00	0.526	2.779	0.360	579.121	82.874
1:24000	2000.00	0.50	2.640	0.379	609.601	91.827
1:25000	2083.333	0.480	2.534	0.395	635.001	99.639
1:31680	2640.00	0.379	2.000	0.500	804.674	160.000
1:48000	4000.00	0.250	1.320	0.758	1219.202	367.309
1:62500	5208.333	0.192	1.014	0.986	1587.503	622.744
1:63360	5280.00	0.189	1.000	1.000	1609.347	640.00
1:96000	8000.00	0.125	0.660	1.515	2438.405	1469.24
1:125000	10416.667	0.096	0.507	1.973	3175.006	2490.98
1:126720	10560.00	0.095	0.500	2.00	3218.694	2560.00
1:250000	20833.333	0.048	0.253	3.946	6350.012	9963.907
FORMULAS	$\frac{\text{SCALE}}{12}$	$\frac{12000}{\text{SCALE}}$	$\frac{63360}{\text{SCALE}}$	$\frac{\text{SCALE}}{63360}$	Ft. per in. X 0.3048006	$\frac{(\text{scale})^2}{43560 \times 144}$

Adapted from USDA Soil Conservation Service TSC-NE-Engineering Drawing 510

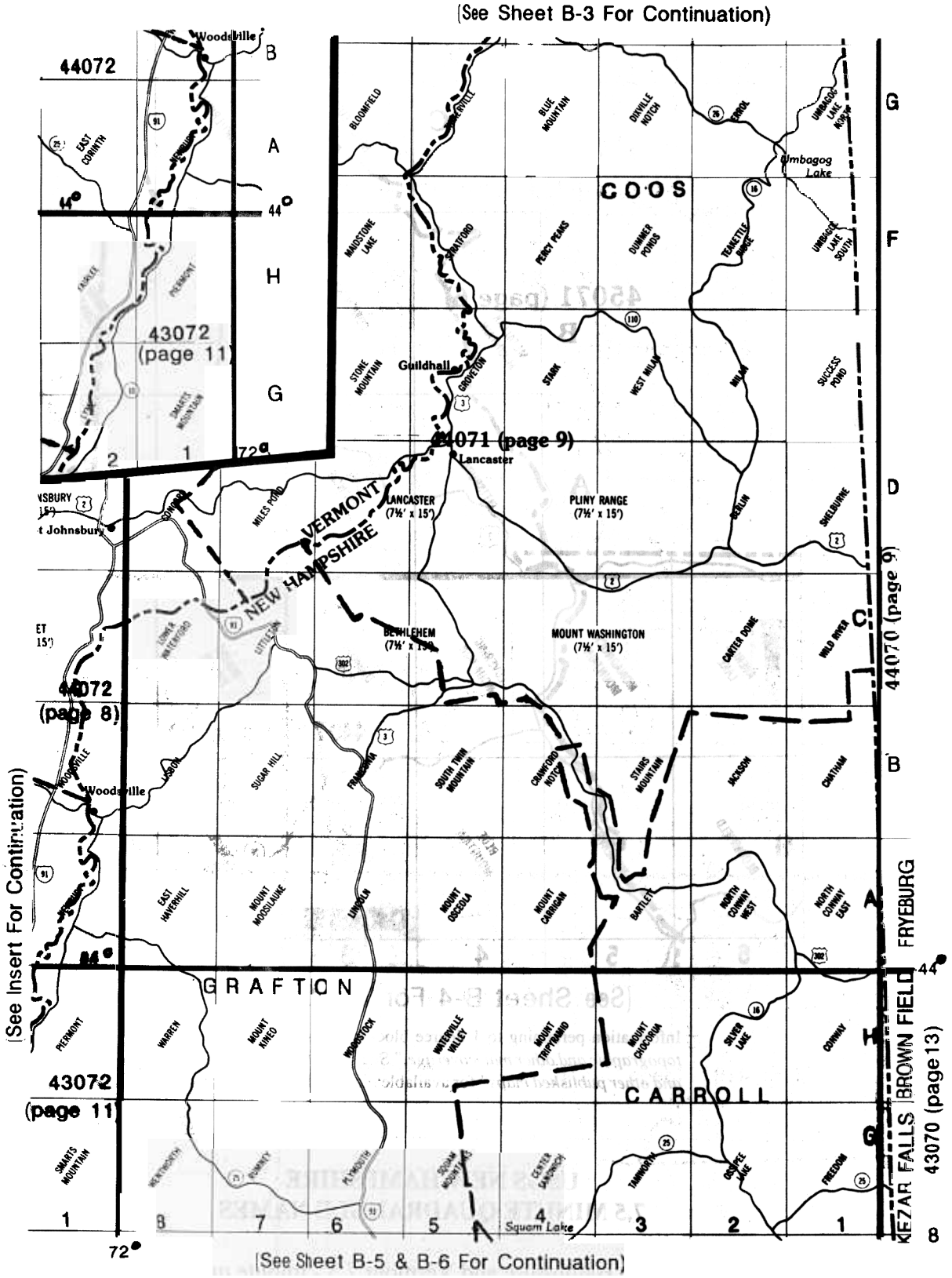


(See Sheet B-4 For Continuation)

Information pertaining to 1 degree blocks, refers to the *"Index to topographic and other map coverage."* See *"Catalog of topographic and other published maps"* for available maps and map order forms.

USGS NEW HAMPSHIRE
7.5 MINUTE QUADRANGLE NAMES

Adapted from " New Hampshire and Vermont 7.5 - minute quadrangle names "
Department of interior - United States Geological Survey, Reston, VA - 1990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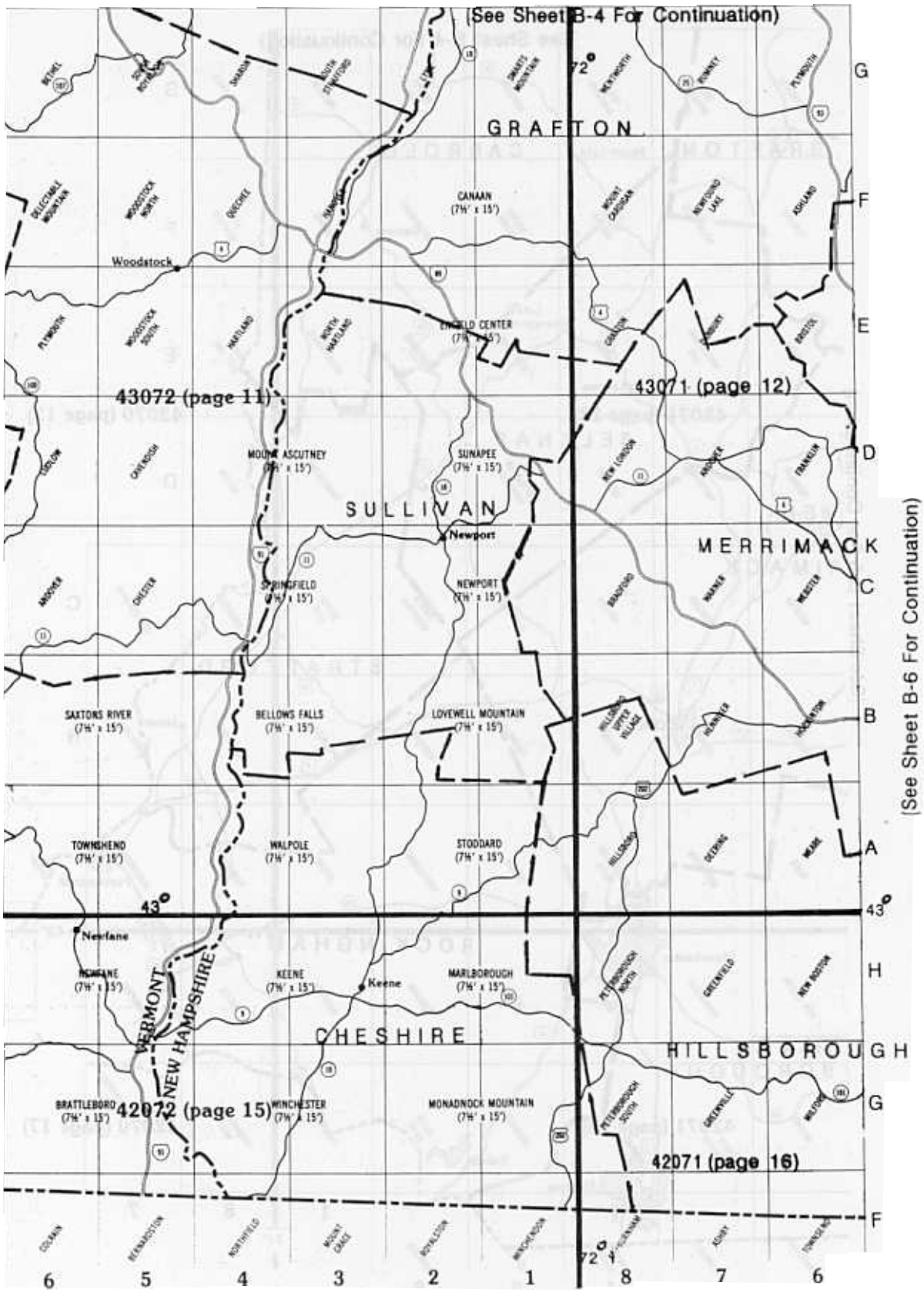
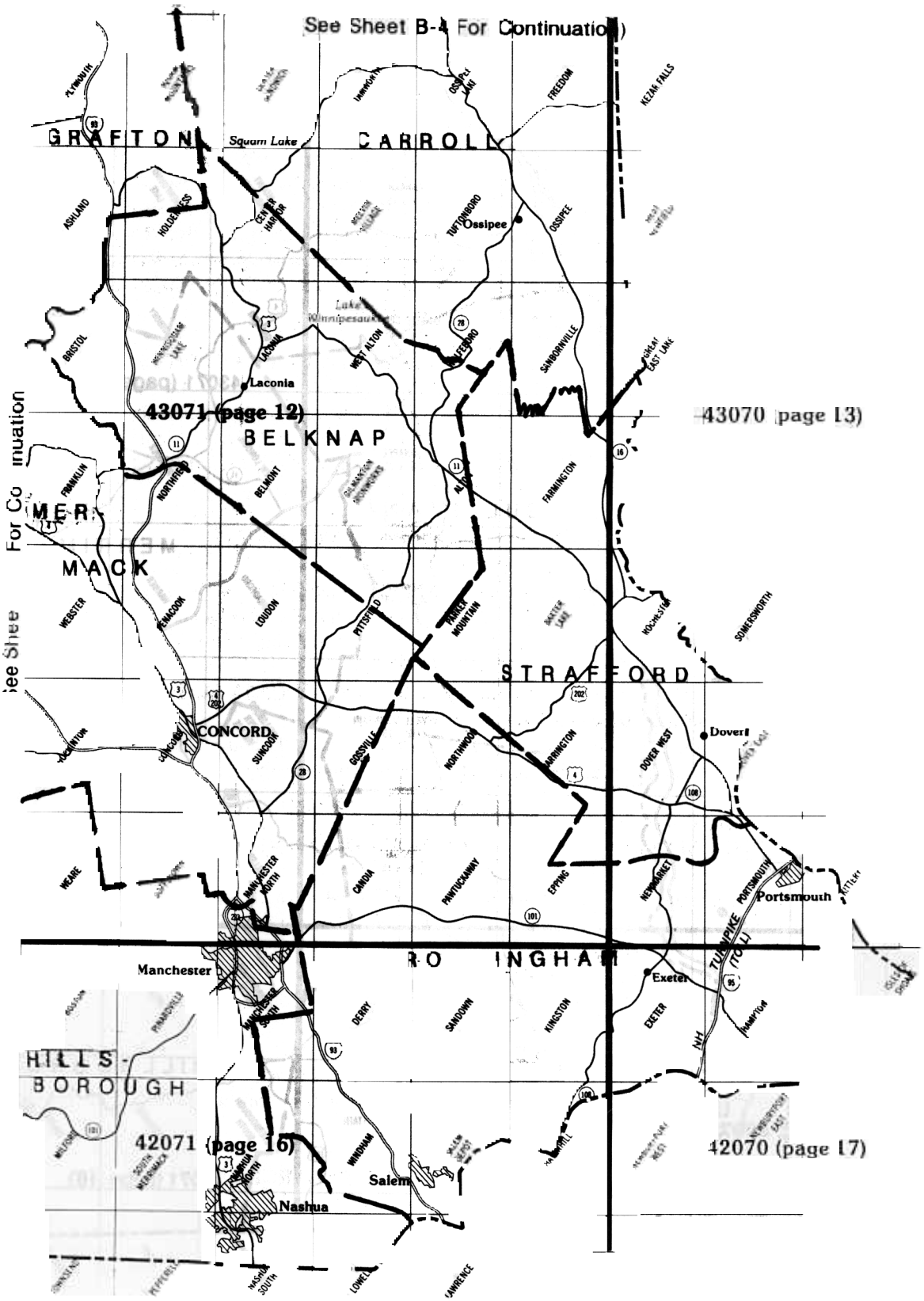
(See Insert For Continuation)
(See Sheet B-5 & B-6 For Continuation)
44072
43072 (page 11)
44071 (page 9)
44072 (page 8)
43072 (page 11)
44070 (page 9)
43070 (page 13)
Woodsville
Lancaster
Johnsburg
Umbagog Lake
Guildhall
Squam Lake
COOS
GRAFTON
CARROLL
VERMONT
NEW HAMPSHIRE
LANCASTER (7½' x 15')
PLINY RANGE (7½' x 15')
BETHLEHEM (7½' x 15')
MOUNT WASHINGTON (7½' x 15')
BLOOMFIELD
BLUE MOUNTAIN
DIXVILLE NOTCH
UMBAGOG LAKE NORTH
MAIDSTONE LAKE
PERCY PEAKS
DUMMER PONDS
TERRITORIAL RIDGE
UMBAGOG LAKE SOUTH
STONE MOUNTAIN
STARK
WEST MILAN
MILAN
SUCCESS POND
MILES POND
BERLIN
SHELBURNE
LOWER WATERFORD
SUGAR HILL
FRANCONIA
SOUTH TWIN MOUNTAIN
CRAWFORD NOTCH
STARK MOUNTAIN
JACKSON
CHATHAM
EAST HAVERHILL
MOUNT MOOSILAUKE
LINCOLN
MOUNT OSCEOLA
MOUNT CARRIGAIN
BARTLETT
NORTH CONWAY WEST
NORTH CONWAY EAST
PIERMONT
WARREN
MOUNT KINEO
WOODSTOCK
WATERVILLE VALLEY
MOUNT TRIPYRAMID
MOUNT CHOCORUA
SILVER LAKE
CONWAY
SMARTS MOUNTAIN
TAMWORTH
OSSIPEE LAKE
FREEDOM
KEZAR FALLS
BROWN FIELD
FRYEBURG


(See Sheet B-4 For Continuation)
GRAFTON
CANAAN
(7½' x 15')
Woodstock
43072 (page 11)
43071 (page 12)
MOUNT ASCUTNEY
SUNAPEE
SULLIVAN
Newport
MERRIMACK
SPRINGFIELD
NEWPORT
SAXTONS RIVER
BELLOWS FALLS
LOVEWELL MOUNTAIN
TOWNSHEND
WALPOLE
STODDARD
43°
Newfane
KEENE
Keene
MARLBOROUGH
VERMONT
NEW HAMPSHIRE
CHESHIRE
HILLSBOROUGH
BRATTLEBORO
42072 (page 15)
WINCHESTER
MONADNOCK MOUNTAIN
42071 (page 16)
72°
G
F
E
D
C
B
A
H
6
5
4
3
2
1
8
7
6
(See Sheet B-6 For Continuation)


See Sheet B-4 For Continuation)
GRAFTON
CARROLL
Squam Lake
Ossipee
Laconia
Lake Winnipesaukee
43071 (page 12)
43070 (page 13)
BELKNAP
MERRIMACK
STRAFFORD
CONCORD
Dover
Portsmouth
Manchester
ROCKINGHAM
Exeter
HILLSBOROUGH
42071 (page 16)
42070 (page 17)
Salem
Nashua

ADAPTED FROM
THE STATE OF NEW HAMPSHIRE DEPARTMENT OF TRANSPORTATION
BUREAU OF TRANSPORTATION PLANNING
J.O. MORTON BUILDING, HAZEN DRIVE
P.O. BOX 483, CONCORD, NH 03302-0483

LIST OF MAPS AVAILABLE

A series of 78 maps of New Hampshire's 10 Counties as follows;

Belknap County	5 Sheets
Carroll County	8 Sheets
Cheshire County	5 Sheets
Coos County	12 Sheets
Grafton County	15 Sheets
Hillsborough County	7 Sheets
Merrimack County	8 Sheets
Rockingham County	8 Sheets
Strafford County	5 Sheets
Sullivan County	5 Sheets
Total	78 Sheets

Each map in this series is 18" x 24" in size and has a scale of 1" = 1 mile. They depict such information as all state and town roads, cultural features, prominent elevations, streams, population of towns, state parks, etc. The maps are also available at a scale of 2" = 1 mile at a size of 36" x 48".

An index map measuring 11" x 17" is available. This map shows the breakdown of towns included on each sheet by county name and sheet number. Before ordering maps in this series it is suggested that this index map be obtained.

URBAN COMPACT MAPS and SUPPLEMENTAL INSET MAPS:

A series of maps of various scales and sizes of the more heavily populated areas of cities and towns in the state. Scales vary from 1" = 1000' to 1" = 400'. All streets and roads are shown but no surface type or cultural features are indicated. Street names are shown where possible.

STATE MAPS (All Roads):

These maps show all state and town roads (scale permitting), county and town names and boundaries. They are available in 2 sizes, 1" = 2 miles and 1' = 4 Miles.

The 1" = 2 miles map comes in 3 sections which match together to produce a map of the state approximately 8 feet high and 4 feet wide.

The 1" = 4 miles map is a photographically reduced version of the same map. This map measures 27" x 48".

FEDERAL AND STATE SYSTEM MAPS:

Same as the 1" = 4" miles state map above with one version showing the Federal Aid Primary and Secondary Highway system and the other version the State Primary and Secondary System. Also available is a 2 color map of the State Primary and Secondary System measuring 11" x 19" showing the State Primary System in blue and the State Secondary System in orange.

FEDERAL AID URBAN MAPS:

A series of maps of varying scales and sizes of the Federal Aid Urban areas in the state. The Federal Aid routes are shown along with other streets and roads, but no cultural features are given.

TRAFFIC FLOW MAP:

This map published annually shows a selected highway system on which traffic volume figures have been printed in colors. Map measures 17" x 22".

TOWN AND COUNTY MAP:

An outline map of the State of New Hampshire showing the town and county names and boundary lines. No roads are shown. Map is available in 2 sizes: 27" x 48" and 11" x 17".

MILEAGE AND REFERENCE MAP:

A map of the State of New Hampshire showing mileage between cities, towns and villages. Map measures 14" x 24".

ACCIDENT MAPS:

Accident maps are used by police departments to code the location of accidents. The maps show road names or inventory numbers, and data for determining accident locations.

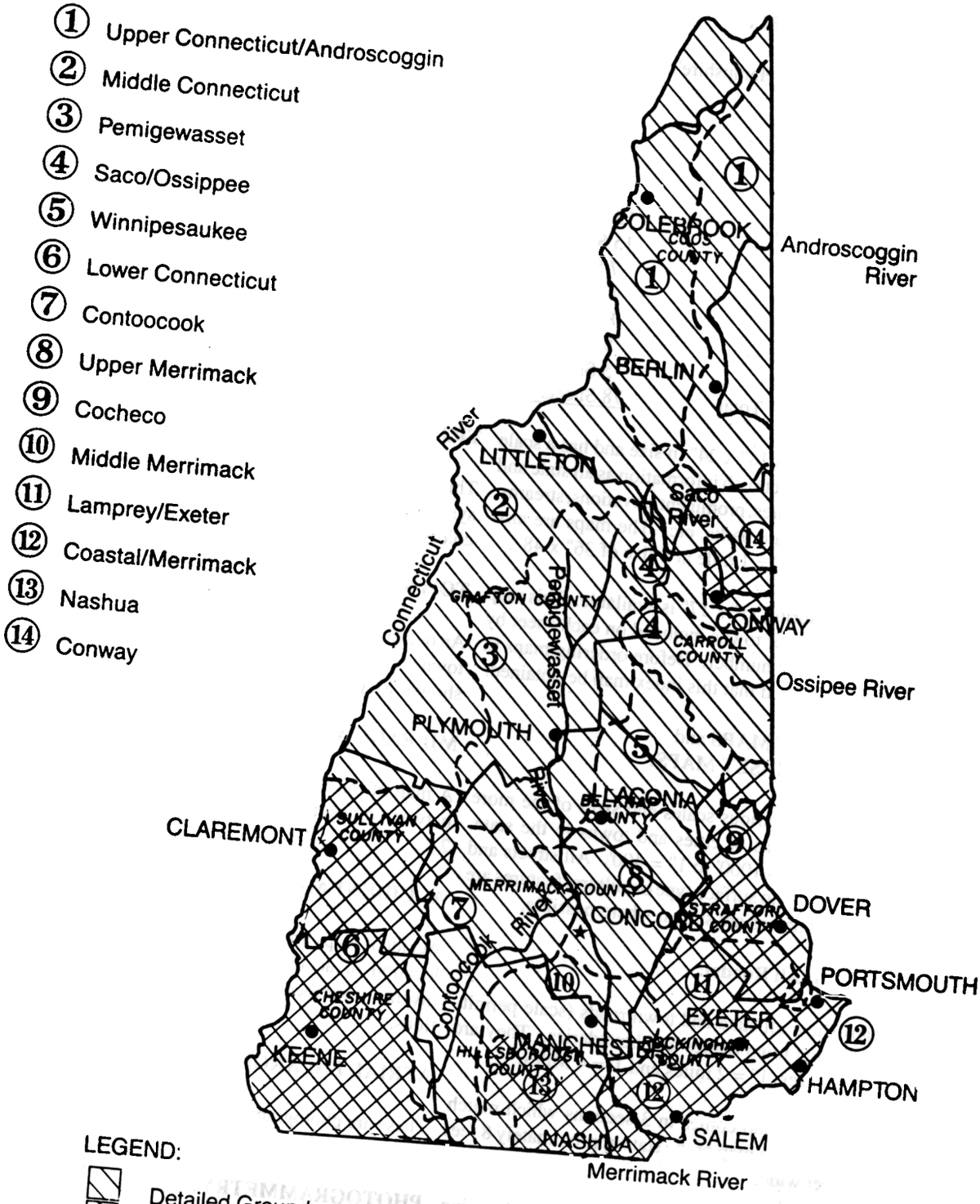
AERIAL ENLARGEMENTS:

These are photographs of the earth's surface. They vary in scale and are generally 38" x 38".

PHOTOGRAMMETRY:

Photogrammetry is processed aerial photographs. It includes contour lines and cultural features. They vary in scale and are approximately 36" x 42".

THE STATUS OF GROUNDWATER MAPPING IN NEW HAMPSHIRE



N.H. Department of Environmental Services, Water Resources Division, May 1991

APPENDIX C

Sample Test Pitting Field Guide
For Small Subsurface Sewage Systems

This appendix provides field book size pages that can be used as a brief reference during a field investigation. It includes guides for both the unified and the USDA Soil Texture Classification Systems, safety recommendations, a checklist and a sample test pit log.

It assumes that you are experienced, competent, and do work safely. This is not a complete guide and the user is urged to refer to more complete documents such as the Soil Manual for Site Evaluations in New Hampshire, 2nd Edition, OSHA Safety Regulations and other references.

The pages can be reproduced and inserted into a field book or a Munsell Color Book.

TEST PITTING FIELD GUIDE

For small subsurface sewage system site evaluations in New Hampshire. This guide is intended to serve only as a brief reference during field operations. It is assumed personnel are experienced, competent, and do work safely . The user is urged to refer to more complete documents such as the *Soil Manual for Site Evaluations in New Hampshire, 2d Edition, OSHA Safety Regulations*, and other references.

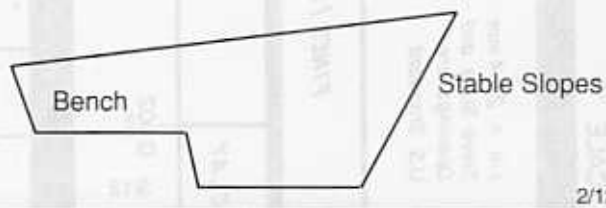
INDEX

1. Cover/Index
2. Safety Aspects
3. Particle Size Chart
4.,5. USDA Soil Texture Classification
6.,7. Unified Soil Classification (Visual - Manual)
8. Soil Consistence and Structure
9. Checklist for Logging
10. Example of Test Pit Log (USDA)
11. References
12. Notes

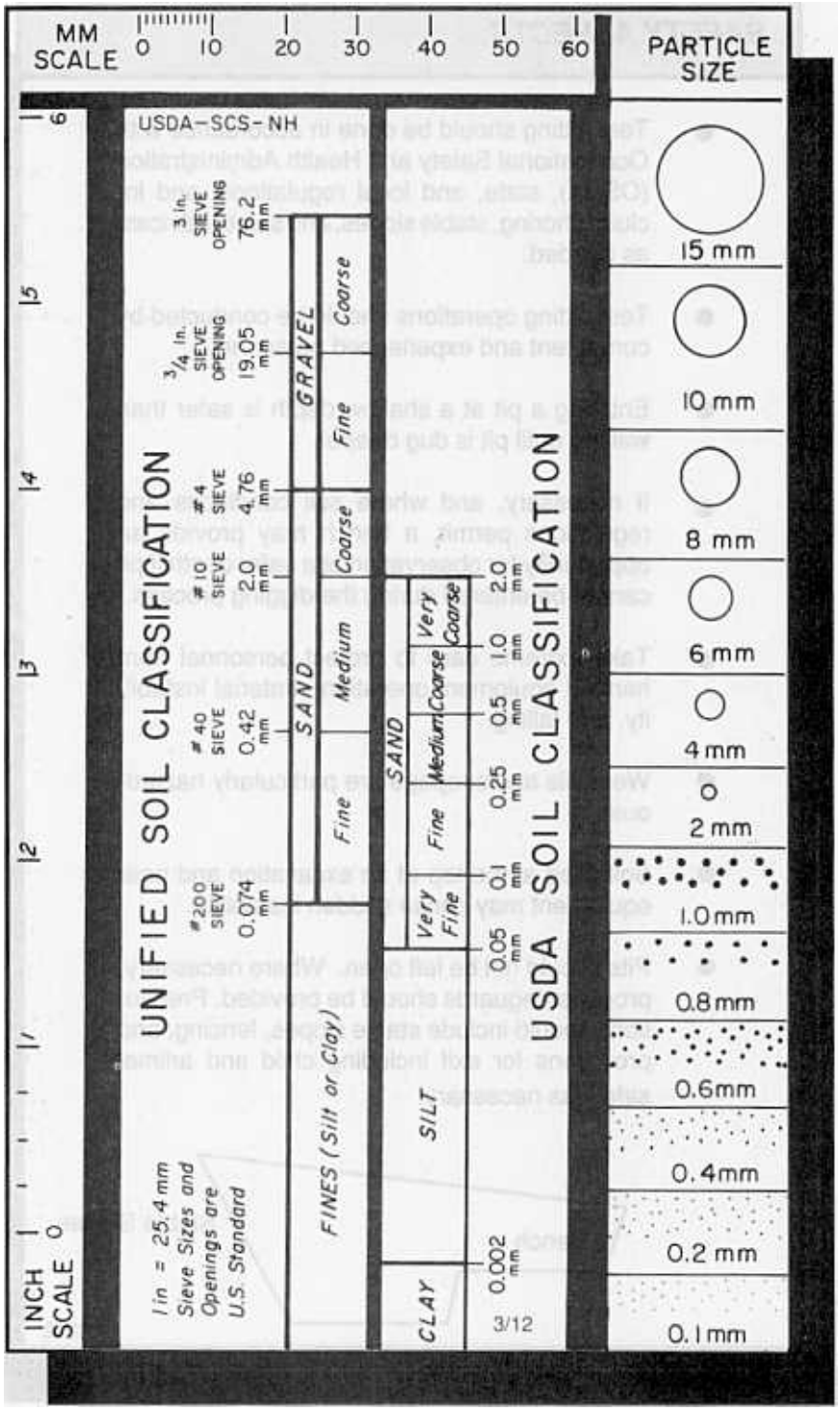
USDA Soil Conservation Service, Durham, NH, 1991

SAFETY ASPECTS

- Test pitting should be done in accordance with Occupational Safety and Health Administration (OSHA), state, and local regulations, and include shoring, stable slopes, and safety devices, as needed.
- Test pitting operations should be conducted by competent and experienced personnel.
- Entering a pit at a shallow depth is safer than waiting until pit is dug deeper.
- If necessary, and where soil conditions and regulations permit, a bench may provide an opportunity for observation at a safer depth if pit cannot be entered during the digging process.
- Take extreme care to protect personnel from harmful equipment operation, material instability, and falling.
- Wet soils and seepage are particularly hazardous.
- Soil piled at the top of an excavation and near equipment may cause sudden instability.
- Pits should not be left open. Where necessary, proper safeguards should be provided. Precautions should include stable slopes, fencing, and provisions for exit including child and animal safety as necessary.



2/12


MM SCALE
0 10 20 30 40 50 60
PARTICLE SIZE
INCH SCALE
0 1 2 3 4 5 6
USDA-SCS-NH
UNIFIED SOIL CLASSIFICATION
3 in. SIEVE OPENING 76.2 mm
3/4 in. SIEVE OPENING 19.05 mm
#4 SIEVE 4.76 mm
#10 SIEVE 2.0 mm
#40 SIEVE 0.42 mm
#200 SIEVE 0.074 mm
GRAVEL
Coarse
Fine
SAND
Coarse
Medium
Fine
FINES (Silt or Clay)
1 in = 25.4 mm
Sieve Sizes and Openings are U.S. Standard
USDA SOIL CLASSIFICATION
SAND
Very Coarse
Coarse
Medium
Fine
Very Fine
SILT
CLAY
2.0 mm
1.0 mm
0.5 mm
0.25 mm
0.1 mm
0.05 mm
0.002 mm
3/12
15 mm
10 mm
8 mm
6 mm
4 mm
2 mm
1.0 mm
0.8 mm
0.6 mm
0.4 mm
0.2 mm
0.1 mm

USDA SOIL CLASSIFICATION

USDA Texture Class	Consistence		
	Dry	Wet	
		Stickiness	Plasticity
Sand	Loose	Nonsticky	Nonplastic
Loamy Sand	Soft	Nonsticky	Nonplastic
Sandy Loam	Soft to slightly hard	Nonsticky to slightly sticky	Nonplastic to slightly plastic
Sandy Clay Loam	Slightly hard to hard	Sticky	Plastic
Sandy Clay	Hard to very hard	Very sticky	Very plastic
Loam	Slightly hard to soft	Slightly sticky to nonsticky	Slightly plastic to non plastic
Clay Loam	Hard	Sticky	Plastic
Silt Loam	Slightly hard to soft	Slightly sticky to nonsticky	Slightly plastic to non plastic
Silt	Soft to slightly hard	Nonsticky	Nonplastic
Silty Clay Loam	Hard	Sticky	Plastic
Silty Clay	Very hard	Very sticky	Very plastic
Clay	Very hard to extremely hard	Very sticky	Very plastic

For soils with approximately 20-50% particles by volume coarser than 2mm, use the following modifier with the above basic class name.

SIZE MODIFIER

Shape of Particle	Particle Size 2.0mm-3"	3-10"	10" >
Rounded & Subrounded	Gravelly	Cobbly	Stony
Irregularly Shaped -- Angular	Angular Gravelly	Angular Cobbly	Stony

For soils with 50-90% coarser than 2mm, use "very" in addition to basic classification and modifier above.
Example: sandy loam, gravelly sandy loam, very gravelly sandy loam.

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USDA SOIL CLASSIFICATION

USDA Texture Class	Other Tests Evaluated at a Wet Consistence			
	Molded ball	Ribboning	Grittiness	Smoothness
Sand	None	None	Very gritty	----
Loamy Sand	Very Weak	None	Very gritty	----
Sandy Loam	Very weak to fragile	Slight	Gritty	----
Sandy Clay Loam	Strong	Medium	Gritty	----
Sandy Clay	Very strong	High	Gritty	----
Loam	Strong to fragile	Slight to none	Somewhat gritty	Somewhat smooth
Clay Loam	Strong	Medium	Somewhat gritty	Somewhat smooth to smooth
Silt Loam	Strong	Slight	None	Very smooth to smooth
Silt	Fragile to very weak	Slight	None	Very smooth
Silty Clay Loam	Strong	Medium	None	Very smooth
Silty Clay	Very strong	High	None	Very smooth
Clay	Very strong	High	None	Smooth to very smooth

Footnotes:

1. Smoothness is not evaluated for the textural classes of sand, loamy sand, sandy loam, sandy clay loam, and sandy clay because of their sand content.

2. The descriptive term listed first is generally the reaction most often observed.

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BRIEF FIELD IDENTIFICATION FOR UNIFIED SOIL CLASSIFICATION
(All material of soil sample smaller than 3 inches)

						Unified Class
COARSE-GRAINED SOILS More than 50% by weight is of particles visible to the naked eye (Less than 50% passes the No. 200 sieve size.	GRAVELS AND GRAVELLY SOILS More than 50% of coarse fraction by weight is larger than No. 4 sieve size (4.76 mm).	CLEAN GRAVELS Does not leave a dirt stain on wet hand.	A range in grain sizes with substantial amounts of all intermediate particle sizes.			GW
			Predominantly one size or a range of sizes with some intermediate sizes missing.			GP
		DIRTY GRAVELS Leaves a dirt stain on wet hand.	Gravels with nonplastic fines or fines with low plasticity-silty gravel (for identification of fines, see characteristics of ML and MH below).			GM
			Gravels with plastic fines-clayey gravel (for identification of fines, see characteristics of CL and CH below.			GC
	SANDS AND SANDY SOILS More than half of coarse fraction by weight is smaller than No. 4 sieve size (4.76 mm).	CLEAN SANDS Does not leave a dirt stain on wet hand.	A range in grain sizes with substantial amounts of all intermediate particle sizes.			SW
			Predominantly one size or a range of sizes with some intermediate sizes missing.			SP
		DIRTY SANDS Leaves a dirt stain on wet hand.	Sands with nonplastic fines or fines with low plasticity (for identification of fines, see characteristics of ML and MH below).			SM
			Sands with plastic fines (for identification of fines, see characteristics of CL and CH below).			SC
FINE-GRAINED SOILS More than 50% by weight is of particles not visible to the naked eye. (More than 50% passes the No. 200 sieve size.	SILTS AND CLAYS (low liquid limit)		DRY CRUSHING STRENGTH	DILATANCY REACTION	TOUGHNESS NEAR PLASTIC LIMIT	
			None to Slight	Quick to Slow	None	ML
			Medium to High	None to Very Slow	Medium	CL
			Slight to Medium	Slow	Slight	OL
	SILTS AND CLAYS (high liquid limit)		Slight to Medium	Slow to None	Slight to Medium	MH
			High to Very High	None	High	CH
			Medium to High	None to Very Slow	Slight to Medium	OH
HIGHLY ORGANIC SOILS			Identified by color, odor, spongy feel and frequently by fibrous texture.			PT

Refer to American Society for Testing and Materials (ASTM) Description of Soils D-2488 for additional information.
Adapted from Basic Soil Mechanics (Course SM-10) USDA-SCS.

USDA-SCS-NH

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Brief summary of field tests for fine-grained soils for Unified Classification ASTM D2488

Use the portion of sample approximately smaller than No. 40 sieve, 0.42 mm, to determine plasticity.

Dry Strength:
Crumble dried cubed sample between fingers. Silts have very little strength. Highly plastic soils have high dry strength.

Dilatancy:
Shake horizontally a small sample of fine-grained soil by holding in one hand and striking it with the other several times. Then squeeze the sample between the fingers. Rapidity of appearance of water on the soil surface during shaking and disappearance during squeezing assists in identifying plastic or non-plastic fines. Very fine clean sands give rapid reaction. Plastic clay gives none.

Toughness:
Roll soil the consistency of putty into a 1/8 inch diameter thread. Fold and reroll just until thread crumbles. Knead pieces together until lump crumbles. Pressure required to reroll thread, strength of thread, and strength of lump is an indication of soil plasticity. Thread of non-plastic soils is very weak. Highly plastic soils, after remolding, will not crack or crumble.

UNIFIED COARSE PARTICLE GRADE SIZES

Grade Name	Grade Size	Sieve
Boulders	12" +	-
Large Cobbles	6" - 12"	-
Small Cobbles	3" - 6"	-

(Exclude fraction Larger than 3" for unified Classification)

Coarse Gravel	3/4" - 3"	-
Fine Gravel	3/16" - 3/4	# 4 - 3/4"
Coarse Sand	2.0 - 4.76 mm	# 10 - 4
Medium Sand	0.42 - 2.0 mm	# 40 - 10
Fine Sand	0.074 - 0.42 mm	# 200 - 40

SOIL CONSISTENCE

CLASSIFY CONSISTENCY FOR	IF CLOD PRESSED BETWEEN THUMB AND FINGERS
DRY SOIL CONDITION AS:	
HARD	Has moderate resistance to pressure and can be broken with difficulty
SOFT	Can be broken into powder or individual grains under very slight pressure
MOIST SOIL CONDITION AS:	
LOOSE	Has lack of cohesion by particles Does not hold together in a mass
FRIABLE	Can be crushed evenly under gentle pressure Can be pressed together into a lump
FIRM	Has distinctly noticeable resistance
VERY FIRM	Can be crushed by strong pressure
WET SOIL CONDITION AS:	
PLASTIC	Readily deforms by moderate pressure Can be pressed into a lump Will form "wire" when rolled
STICKY	Adheres to thumb and finger Tends to stretch somewhat and pull apart rather than pulling free
ANY MOISTURE CONDITION AS:	
CEMENTED AND HARD	Is bound together very strongly Is little affected by moistening

SOIL STRUCTURE

PLATY	PRISM-LIKE	BLOCK-LIKE		GRANULAR
Platy	Prismatic	Angular Blocky	Subangular Blocky	Granular

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A CHECKLIST FOR LOGGING TEST PITS FOR SUBSURFACE SEWAGE SYSTEMS

1. Test pit number or identification.
2. Date of log.
3. Name of individual logging pit.
4. General location of test pit.
5. Detailed location (reference to established points of survey).
6. Elevation of ground surface (reference to datum used).
7. Pit depths at: (a) top and bottom of layers, horizons, or changes in soil properties, (b) estimated seasonal high water table, (c) seeps, (d) changes in moisture conditions, (e) restrictive layers.
8. Depths of water table, date, and time of observation.
9. Textural description of material for each soil layer or horizon using USDA or Unified Soil Classification Systems.
10. Particle size distribution for coarse grained soil. Plasticity of fines for fine grained soils, group symbol (Unified Classification System).
11. Angularity of gravel particles (angular, subangular, subrounded or rounded).
12. Relative density (loose, firm, compact, very dense).
13. Structure of soil layers.
14. Consistence of soil layers.
15. Restrictive layers (to vertical water movement).
16. Color of moist soil (Munsell notation or terms).
17. Color and description and standard of mottles at estimated seasonal high water table.
18. Odor (organic or contaminated soils).
19. Moisture conditions of soil layers (dry, slightly moist, moist, wet).
20. Seeps with notation as to volume of flow (drip, low, high) and rate (steady, increasing, decreasing).
21. Condition of the excavation.
22. Geologic origin.

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EXAMPLE OF TEST PIT LOG FOR SEPTIC TANK SYSTEM

TEST PIT NO.:_____ DATE:_____
NAME OF PERSON LOGGING:_____
GENERAL LOCATION:_____
DETAILED LOCATION:_____
VEGETATION:_____ SLOPE:_____

USING USDA TEXTURAL CLASSIFICATION SYSTEM	ELEV. 204.5 (NGVD)
Topsoil, dark brown (10YR 3/3), fine sandy loam, many roots.	
	0.5'
Sandy loam, yellowish-brown (10YR 5/6), granular structure, friable, no stones, moist, many roots. NONRESTRICTIVE LAYER.	
EST SHWT	2.5'
Sandy loam, light brownish-gray (2.5Y 6/2), with common distinct yellowish-brown (10YR 5/6), mottles, granular structure, friable, some stones to 12" diameter, moist, some roots. NONRESTRICTIVE LAYER	
OBSERVED WATER TABLE (DATE)	4.5'
Sandy loam, light olive gray (5Y 6/2), with many distinct strong brown (7.5YR 5/6), mottles, granular structure, friable, some stones to 12" diameter, wet, sidewall caving, few roots. NONRESTRICTIVE LAYER	
	6.3'
Fine sandy loam, olive (5Y 5/4), platy structure, very firm (hardpan), occasional stones to 12" diameter, moist seeps at top of hardpan layer, no roots. RESTRICTIVE LAYER	
Bedrock	10.4'

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REFERENCES

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• Dig Safe System, Inc., in New Hampshire, telephone 1-800-225-4977.

• USDA, Soil Conservation Service, 1978, *National Engineering Handbook, Section 8, Engineering Geology*, National Technical Information Service, US Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161.

• USDA, Soil Conservation Service, 1975, *Soil Taxonomy: A Basic System of Soil Classification for Making and Interpreting Soil Surveys.* Handbook 436, as amended.

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