

APPENDIX A

SOIL PROPERTIES AND SOIL-WATER RELATIONSHIPS

A.1 Introduction

An understanding of how water moves into and through soil is necessary to predict the potential of soil for wastewater absorption and treatment. Water moves through the voids or pore spaces within soil. Therefore, the size, shape, and continuity of the pore spaces are very important. These characteristics are dependent on the physical properties of the soil and the characteristics of water as well.

A.2 Physical Properties of Soil

A.2.1 Soil Texture

Texture is one of the most important physical properties of soil because of its close relationship to pore size, pore size distribution and pore continuity. It refers to the relative proportion of the various sizes of solid particles in the soil that are smaller than 2 mm in diameter. The particles are commonly divided into three size fractions called soil "separates." These separates are given in Figure A-1. The U.S. Department of Agriculture (USDA) system is used in this manual (Table A-1).

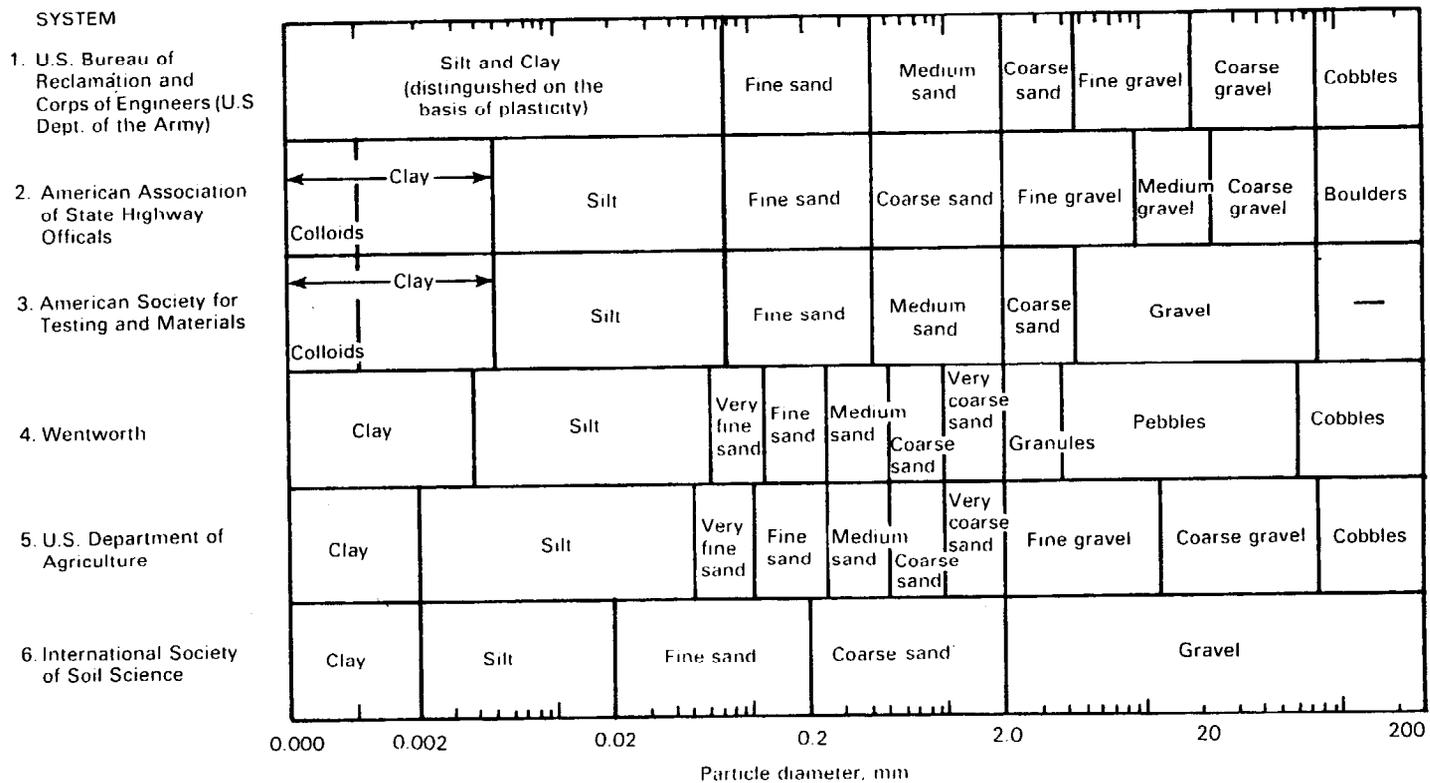
TABLE A-1

U.S. DEPARTMENT OF AGRICULTURE SIZE LIMITS FOR SOIL SEPARATES

<u>Soil Separate</u>	<u>Size Range</u> mm	<u>Tyler Standard</u> <u>Sieve No.</u>
Sand	2-0.05	10-270 mesh
Very coarse sand	2-1	10-16 mesh
Coarse sand	1-0.5	16-35 mesh
Medium sand	0.5-0.25	35-60 mesh
Fine sand	0.25-0.1	60-140 mesh
Very fine sand	0.1-0.05	140-270 mesh
Silt	0.25-0.002	---
Clay	<0.002	---

FIGURE A-1

NAMES AND SIZE LIMITS OF PRACTICAL-SIZE CLASSES ACCORDING TO SIX SYSTEMS (1)



368

^a Used in soil engineering

^b Used in geology.

^c USDA system used in this manual.

^d Used in soil science.

Twelve textural classes are defined by the relative proportions of the sand, silt and clay separates. These are represented on the textural triangle (Figure A-2). To determine the textural class of a soil horizon, the percent by weight of the soil separates is needed. For example, a sample containing 37% sand, 45% silt and 18% clay has a textural class of loam. This is illustrated in Figure A-2.

Soil textural classes are modified if particles greater than 2 mm in size are present. The adjectives "gravelly," "cobbley," and "stone" are used for particles between 2 and 75 mm, 75 and 250 mm, or 250 mm, respectively, if more than 15% to 20% of the soil volume is occupied by these fragments.

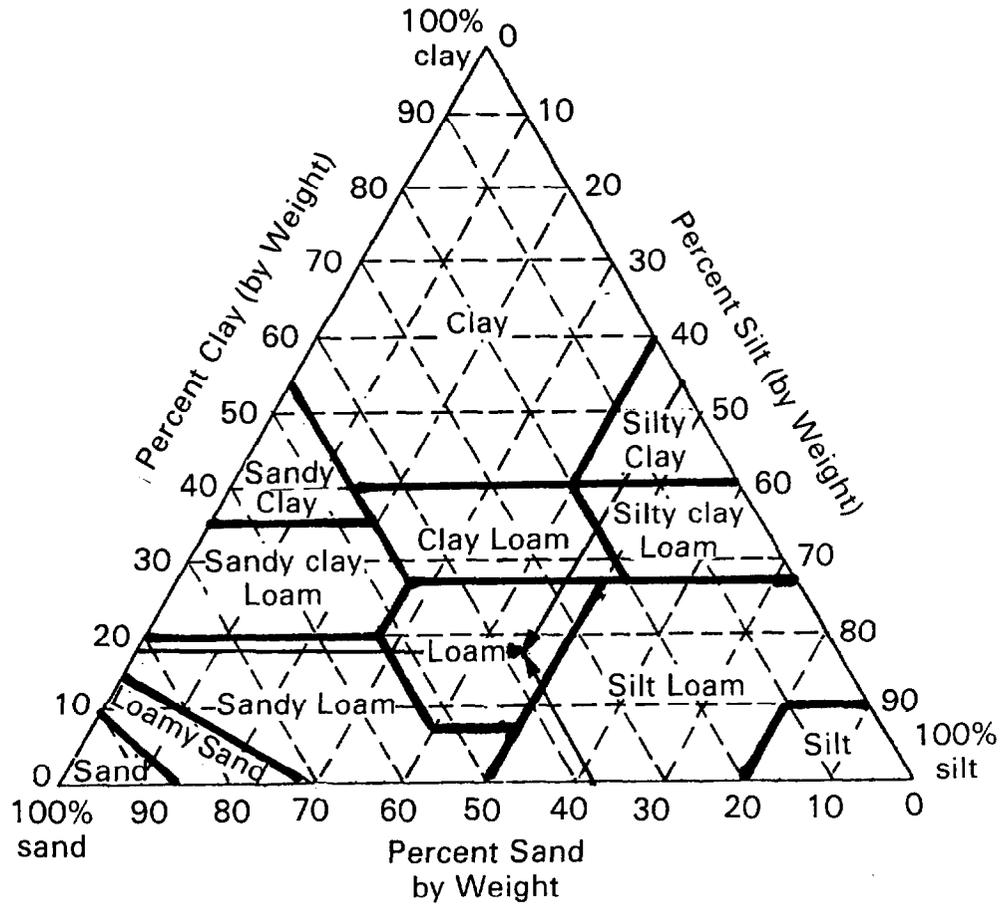
Soil permeability, aeration and drainage are closely related to the soil texture because of their influence on pore size and pore continuity. They are also related to the soil's ability to filter particles and retain or adsorb pollutants from the waste stream. For example, fine textured or clayey soils do not transmit water rapidly or drain well because the pores are very small. They tend to retain water for long periods of time. However, they act as better filters and can retain more chemicals than soils of other textures. On the other hand, coarse textured or sandy soils have large, continuous pores that can accept and transmit large quantities of water. They retain water for only short periods of time. The capacity to retain chemicals is generally low and they do not filter wastewater as well as finer textured soils. Medium textured or loamy soils have a balance between wastewater absorption and treatment capabilities. They accept and transmit water at moderate rates, act as good filters, and retain moderate amounts of chemical constituents.

A.2.2 Soil Structure

Soil structure has a significant influence on the soil's acceptance and transmission of water. Soil structure refers to the aggregation of soil particles into clusters of particles, called peds, that are separated by surfaces of weakness. These surfaces of weakness open planar pores between the peds that are often seen as cracks in the soil. These planar pores can greatly modify the influence of soil texture on water movement. Well structured soils with large voids between peds will transmit water more rapidly than structureless soils of the same texture, particularly if the soil has become dry before the water is added. Fine textured, massive soils (soils with little structure) have very slow percolation rates.

FIGURE A-2

TEXTURAL TRIANGLE DEFINING TWELVE TEXTURAL CLASSES OF THE USDA
 (ILLUSTRATED FOR A SAMPLE CONTAINING 37% SAND, 45% SILT, AND 18% CLAY)



The form, size and stability of the aggregates or peds depend on the arrangement of the soil particles and the bonds between the particles. The four major types of structures include platy, blocky, prismatic and granular. Detailed descriptions of types and classes of soil structure used by SCS are given in Table A-2.

Between the peds are voids which are often relatively large and continuous compared to the voids or pores between the primary particles within the peds. The type of structure determines the dominant direction of the pores and, hence, water movement in the soil. Platy structures restrict vertical percolation of water because cleavage faces are horizontally oriented. Often, vertical flow is so restricted that the upper soil horizons saturate, creating a perched water table. Soils with prismatic and columnar structure enhance vertical water flow, while blocky and granular structures enhance flow both horizontally and vertically.

The soil's permeability by air and water is also influenced by the frequency and degree of expression of the pores created by the structural units. These characteristics depend upon the size of the peds and their grade or durability. Small structural units create more pores in the soil than large structural units. Soils with strong structure have distinct pores between peds. Soils with very weak structure, or soils without peds or planes of weakness, are said to be structureless. Structureless sandy soils are called single grained or granular, while structureless clayey soils are called massive.

Structure is one soil characteristic that is easily altered or destroyed. It is very dynamic, changing in response to moisture content, chemical composition of soil solution, biological activity, and management practices. Soils containing minerals that shrink and swell appreciably, such as montmorillonite clays, show particularly dramatic changes. When the soil peds swell upon wetting, the large pores become smaller, and water movement through the soil is reduced. Swelling can also result if the soil contains a high proportion of sodium salts. Therefore, when determining the hydraulic properties of a soil for wastewater disposal, soil moisture contents and salt concentrations should be similar to that expected in the soil surrounding a soil disposal system.

A.2.3 Soil Color

The color and color patterns in soil are good indicators of the drainage characteristics of the soil. Soil properties, location in the landscape, and climate all influence water movement in the soil. These factors cause some soils to be saturated or seasonally saturated, affecting

TABLE A-2
TYPES AND CLASSES OF SOIL STRUCTURE

TYPE (shape and arrangement of peds)							
Class	Platelike, with one dimension (the vertical) limited and greatly less than the other two; arranged around a horizontal plane faces mostly horizontal	Prismlike, with two dimensions (the horizontal) limited and considerably less than the vertical; arranged around a vertical line; vertical faces well defined; vertices angular	Blocklike, polyhedronlike, or spheroids, or with three dimensions of the same order of magnitude, arranged around a point.				
			Without rounded caps	With rounded caps	Faces flattened, most vertices sharply angular	Mixed rounded and flattened faces with many rounded vertices	Nonporous peds
	Platy	Prismatic	Columnar	(Angular) Blocky*	(Subangular) Blocky†	Granular	Crumb
Very fine or very thin	Very thin platy; <1 mm	Very fine prismatic; <10 mm	Very fine columnar; <10 mm	Very fine angular blocky; <5 mm	Very fine subangular blocky; <5 mm	Very fine angular; <1 mm	Very fine crumb; <1 mm
Fine or thin	Thin platy; 1 to 2 mm	Fine prismatic; 10 to 20 mm	Fine Columnar; 10 to 20 mm	Fine angular blocky; 5 to 10 mm	Fine sub angular blocky; 5 to 10 mm	Fine granular; 1 to 2 mm	Fine crumb; 1 to 2 mm
Medium	Medium platy; 2 to 5 mm	Medium prismatic; 20 to 50 mm	Medium columnar; 20 to 50 mm	Medium angular blocky; 10 to 20 mm	Medium subangular blocky; 10 to 20 mm	Medium granular; 2 to 5 mm	Medium crumb; 2 to 5 mm
Coarse or thick	Thick platy; 5 to 10 mm	Coarse prismatic; 50 to 100 mm	Coarse columnar; 50 to 100 mm	Coarse angular blocky; 20 to 50 mm	Coarse subangular; 20 to 50 mm	Coarse granular; 5 to 10 mm	
Very coarse or very thick	Very thick platy; > 10 mm	Very coarse prismatic; >100 mm	Very coarse columnar; >100 mm	Very coarse angular blocky; > 50 mm	Very coarse subangular blocky; >50 mm	Very coarse granular; >10 mm	

Source: Soil Survey Staff 1960

* (a) Sometimes called nut. (b) The word "angular" in the name can ordinarily be omitted.

† Sometimes called nuciform, nut, or subangular nut. Since the size connotation of these terms is a source of great confusion to many, they are not recommended.

their ability to absorb and treat wastewater. Interpretation of soil color aids in identifying these conditions.

Soil colors are a result of the color of primary soil particles, coatings of iron and manganese oxides, and organic matter on the particles. Soils that are seldom or never saturated with water and are well aerated, are usually uniformly red, yellow or brown in color. Soils that are saturated for extended periods or all the time are often grey or blue in color. Color charts have been developed for identifying the various soil colors.

Soils that are saturated or nearly saturated during portions of the year often have spots or streaks of different colors called mottles. Mottles are useful to determine zones of saturated soil that may occur only during wet periods. Mottles result from chemical and biochemical reactions when saturated conditions, organic matter, and temperatures above 4° C occur together in the soil. Under these conditions, the bacteria present rapidly deplete any oxygen present while feeding on the organic matter. When the oxygen is depleted, other bacteria continue the organic decomposition using the oxidized iron and manganese compounds, rather than oxygen, in their metabolism. Thus, the insoluble oxidized iron and manganese, which contribute much of the color to soil, are reduced to soluble compounds. This causes the soil to lose its color, turning the soil grey. When the soil drains, the soluble iron and magnesium are carried by the water to the larger soil pores. Here they are reoxidized when they come in contact with the oxygen introduced by the air-filled pores, forming insoluble compounds once again. The result is the formation of red, yellow and black spots near surfaces, and the loss of color, or greying, at the sites where the iron and manganese compounds were removed. (Examples of mottled soils are shown in Figure 3-20). Therefore, mottles seen in unsaturated soils can be interpreted as an indication that the soil is periodically saturated. Periodic saturation of soil cannot always be identified by mottles, however. Some soils can become saturated without the formation of mottles, because one of the conditions needed for mottle formation is not present. Experience and knowledge of moisture regimes related to landscape position and other soil characteristics are necessary to make proper interpretations in these situations.

Also, color spots and streaks can be present in soils for reasons other than soil saturation. For example, soil parent materials sometimes create a color pattern in the soil similar to mottling. However, these patterns usually can be distinguished from true mottling. Some very sandy soils have uniform grey colors because there are no surface coatings on the sand grains. This color can mistakenly be interpreted as a gley or a poor draining color. Direct measurement of zones of soil

saturation may be necessary to confirm the soil moisture regimes if interpretations of soil colors are not possible.

A.2.4 Soil Horizons

A soil horizon is a layer of soil approximately parallel to the soil surface with uniform characteristics. Soil horizons are identified by observing changes in soil properties with depth. Soil texture, structure, and color changes are some of the characteristics used to determine soil horizons.

Soil horizons are commonly given the letter designations of A, B, and C to represent the surface soil, subsoil, and substratum, respectively. Not all soils have all three horizons. On the other hand, many soils show variations within each master horizon and are subdivided as A1, A2, A3, and B1, etc. Some example soils and their horizons are shown in Figure A-3.

Each horizon has its own set of characteristics and therefore will respond differently to applied wastewater. Also, the conditions created at the boundary between soil horizons can significantly influence wastewater flow and treatment through the soil. Therefore, an evaluation of a soil must include a comparison of the physical properties of each horizon that influences absorption and treatment of wastewater.

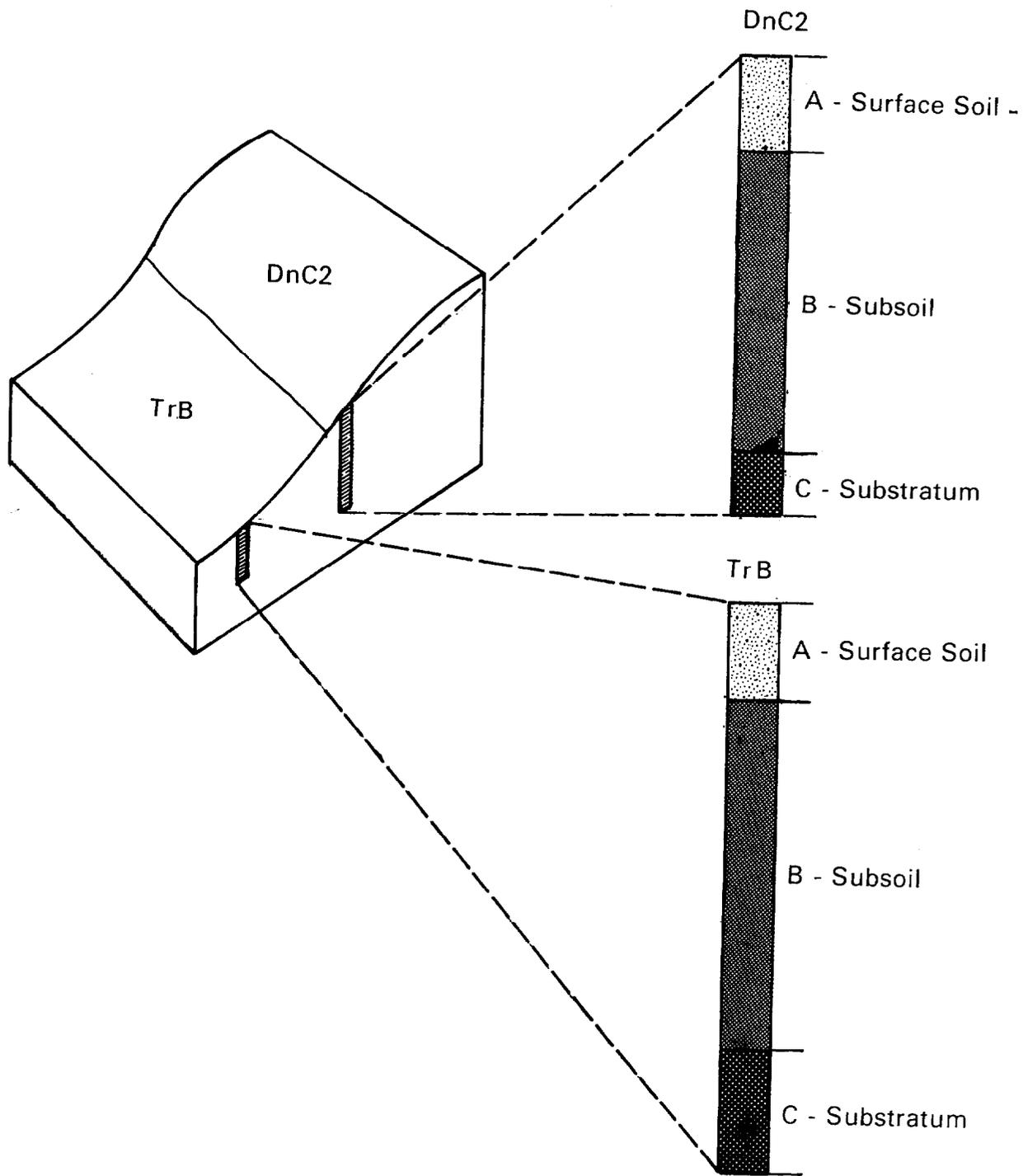
A.2.5 Other Selected Soil Characteristics

Bulk density and clay mineralogy are other soil characteristics that can significantly influence water infiltration and percolation in soils. Soil bulk density is the ratio of the mass of soil to its bulk or volume occupied by the soil mass and pore space. There is not a direct correlation between bulk density and soil permeability, since sandy soils generally have a higher bulk density and permeability than clayey soils. However, of soils with the same texture, those soils with the higher bulk densities are more compact with less pore volume. Reduced porosity reduces the hydraulic conductivity of the soil. Fragipans are examples of horizons that have high bulk densities and reduced permeabilities. They are very compact horizons rich in silt and/or sand but relatively low in clay, which commonly interferes with water and root penetration.

The mineralogy of clay present in the soil can have a very significant influence on water movement. Some clay minerals shrink and swell appreciably with changes in water content. Montmorillonite is the most common of these swelling clay minerals. Even if present in small amounts,

FIGURE A-3

SCHEMATIC DIAGRAM OF A LANDSCAPE
AND DIFFERENT SOILS POSSIBLE



the porosity of soils containing montmorillonite can vary dramatically with varying moisture content. When dry, the clay particles shrink, opening the cracks between peds. But when wet, the clay swells, closing the pores.

A.3 Water in the Soil System

A.3.1 Soil Moisture Potential

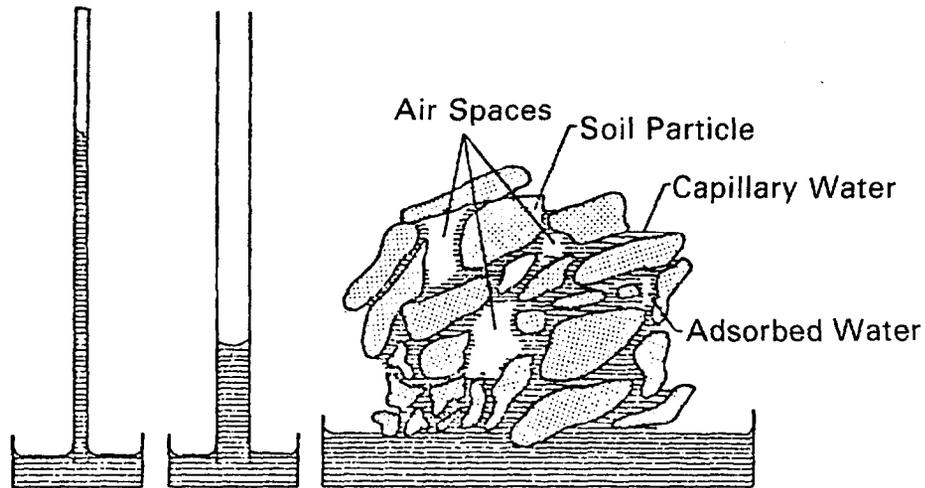
Soil permeability, or the capability of soil to conduct water, is not determined by the soil porosity but, rather, the size, continuity, and tortuosity of the pores. A clayey soil is more porous than a sandy soil, yet the sandy soil will conduct much more water because it has larger, more continuous pores. Under natural drainage conditions, some pores in the soil are filled with water. The distribution of this water depends upon the characteristics of the pores, while its movement is determined by the relative energy status of the water. Water flows from points of higher energy to points of lower energy. The energy status is referred to as the moisture potential.

The total soil moisture potential has several components, of which the gravitational and matric potential are the most important. The gravitational potential is the result of the attraction of water toward the center of the earth by a gravitational force and is equal to the weight of water. The potential energy of the water at any point is determined by the elevation of that point relative to some reference level. Thus, the higher the water above this reference, the greater its gravitational potential.

The matric potential is produced by the affinity of water molecules to each other and to solid surfaces. Molecules within the body of water are attracted to other molecules by cohesive forces, while water molecules in contact with solid surfaces are more strongly attracted to the solid surfaces by adhesive forces. The result of these forces acting together draws water into the pores of the soil. The water tries to wet the solid surfaces of the pores due to adhesive forces and pulls other molecules with it due to cohesive forces. This phenomenon is referred to as capillary rise. The rise of water is halted when the weight of the water column is equal to the force of capillarity. Therefore, water rises higher and is held tighter in smaller pores than in larger pores (see Figure A-4). Upon draining, the largest pores empty first because they have the weakest hold on the water. Therefore, in unsaturated soils, the water is held in the finer pores because they are better able to retain the water against the forces of gravity.

FIGURE A-4

UPWARD MOVEMENT BY CAPILLARITY IN GLASS
TUBES AS COMPARED WITH SOILS (2)

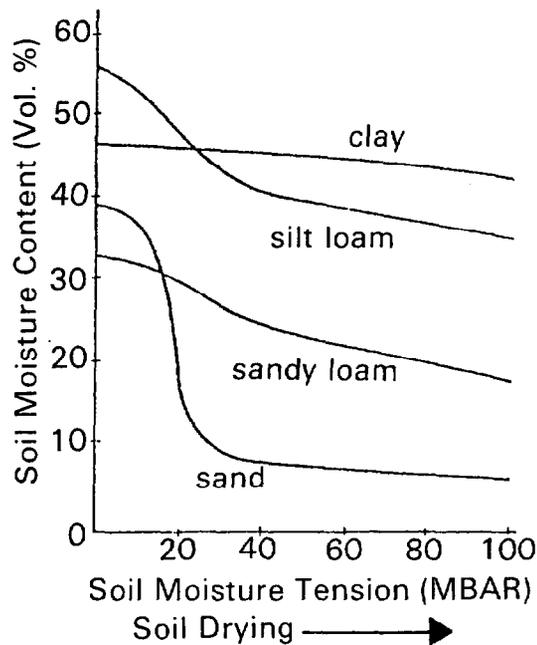


The ability of the soil to draw or pull water into its pores is referred to as its matric potential. Since the water is held against the force of gravity, it has a pressure less than atmospheric. This negative pressure is often referred to as soil suction or soil moisture tension. Increasing suction or tension is associated with soil drying.

The moisture content of soils with similar moisture tensions varies with the nature of the pores. Figure A-5 illustrates the change in moisture content versus changes in moisture tensions. When the soil is saturated, all the pores are filled with water and no capillary suction occurs. The soil moisture tension is zero. When drainage occurs, the tensions increase. Because the sand has many relatively large pores, it drains abruptly at relatively low tensions, whereas the clay releases only a small volume of water over a wide tension range because most of it is strongly retained in very fine pores. The silt loam has more coarse pores than does the clay, so its curve lies somewhat below that of the clay. The sandy loam has more finer pores than the sand so its curve lies above that of the sand.

FIGURE A-5

SOIL MOISTURE RETENTION FOR FOUR
DIFFERENT SOIL TEXTURES (3)

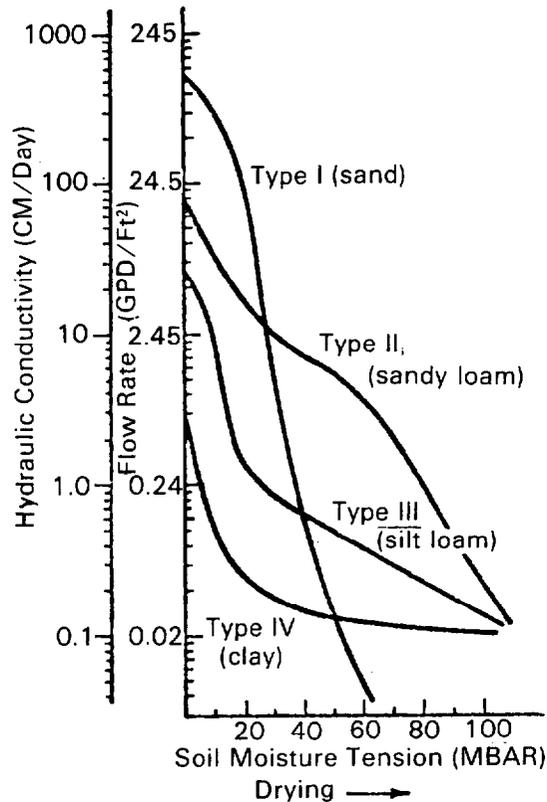


A.3.2 Flow of Water in Soil

The flow of water in soil depends on the soil's ability to transmit the water and the presence of a force to drive it. Hydraulic conductivity is defined as the soil's ability to transmit water, and is related to the number, size, and configuration of the pores. Soils with large, continuous water-filled pores can transmit water easily and have a high conductivity. While soils with small, discontinuous water-filled pores offer a high resistance to flow, and, therefore, have low conductivity. When the soil is saturated, all pores are water-filled and the conductivity depends on all the soil pores. When the soil becomes unsaturated or dries (see Figure A-5), the larger pores fill with air, and only the smaller water-filled pores may transmit the water. Therefore, as seen in Figure A-6, the hydraulic conductivity decreases for all soils as they dry. Since clayey soils have more fine pores than sandy soils, the hydraulic conductivity of a clay is greater than a sand beyond a soil moisture tension of about 50 mbar.

FIGURE A-6

HYDRAULIC CONDUCTIVITY (K) VERSUS
SOIL MOISTURE RETENTION (4)



Water movement in soil is governed by the total moisture potential gradient and the soil's hydraulic conductivity. The direction of movement is from a point of higher potential (gravity plus matric potential) to a point of lower potential. When the soil is saturated, the matric potential is zero, so the water moves downward due to gravity. If the soil is unsaturated, both the gravity and matric potentials determine the direction of flow, which may be upward, sideward, or downward depending on the difference in total potentials surrounding the area. The greater the difference in potentials between two points, the more rapid the movement. However, the volume of water moved in a given time is proportional to the total potential gradient and the soil's hydraulic conductivity at the given moisture content. Therefore, soils with greater hydraulic conductivities transmit larger quantities of water at the same potential gradient than soils with lower hydraulic conductivities.

A.3.3 Flow of Water Through Layered Soils

Soil layers of varying hydraulic conductivities interfere with water movement. Abrupt changes in conductivity can cause the soil to saturate or nearly saturate above the boundary regardless of the hydraulic conductivity of the underlying layer. If the upper layer has a significantly greater hydraulic conductivity, the water ponds because the lower layer cannot transmit the water as fast as the upper layer delivers it. If the upper layer has a lower conductivity, the underlying layer cannot absorb it because the finer pores in the upper layer hold the water until the matric potential is reduced to near saturation.

Layers such as these may occur naturally in soils or as the result of continuous wastewater application. It is common to develop a clogging mat of lower hydraulic conductivity at the infiltrative surface of a soil disposal system. This layer forms as a result of suspended solids accumulation, biological activity, compaction by construction machinery, and soil slaking (3). The clogging mat may restrict water movement to the point where water is ponded above, and the soil below is unsaturated. Water passes through the clogging mat due to the hydrostatic pressure of the ponded water above pushing the water through, and the soil suction of the unsaturated soil below pulling it through.

Figure A-7 illustrates three columns of similar textured soils with clogging mats in various stages of development. Water is ponded at equal heights above the infiltrative surface of each column.

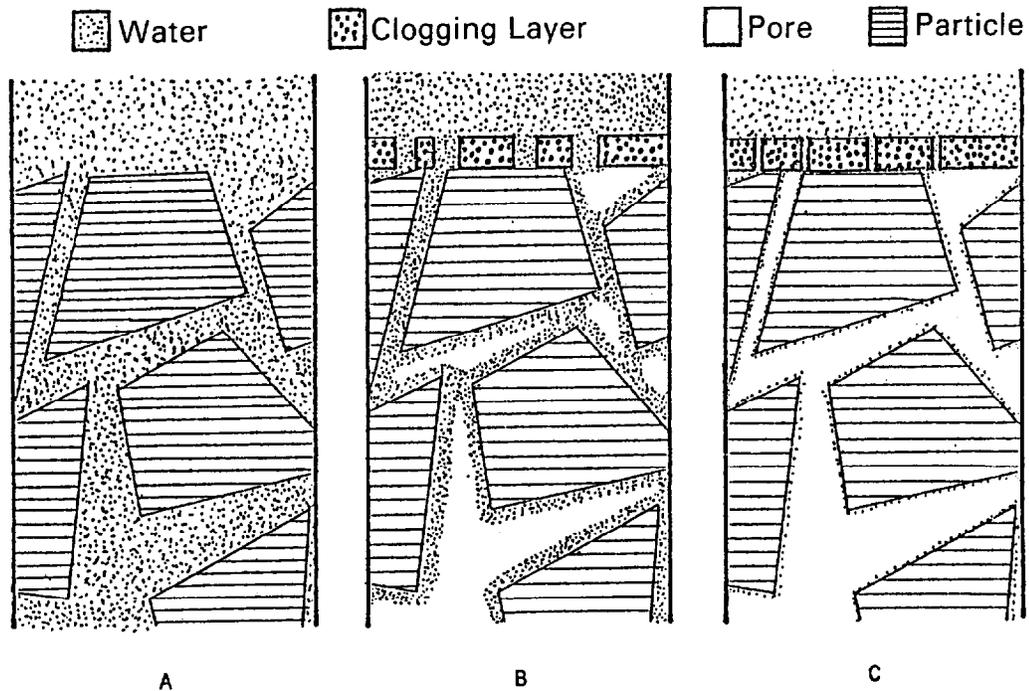
Column A has no clogging mat so the water is able to pass through all the pores, saturating the soil. The moisture tension in this column is zero. Column B has a permeable clogging mat developed with moderate size pores. Flow into the underlying soil is restricted by the clogging mat to a rate less than the soil is able to transmit it. Therefore, the large pores in the soil empty. With increasing intensity of the mat, as shown in Column C, the flow rate through the soil is reduced to very low levels. The water is forced to flow through the finest pores of the soil, which is a very tortuous path. Flow rates through identical clogging mats developed on different soils will vary with the soil's capillary characteristics.

A.4 Evaluating Soil Properties

To adequately predict how soil responds to wastewater application, the soil properties described and other site characteristics must be identified. The procedures used to evaluate soils are described in Chapter 3 of this manual.

FIGURE A-7

SCHEMATIC REPRESENTATION OF WATER MOVEMENT THROUGH
A SOIL WITH CRUSTS OF DIFFERENT RESISTANCES



A.5 References

1. Black, C. A. Soil Plant Relationships. 2nd ed. Wiley, New York, 1968. 799 pp.
2. Brady, N. C. The Nature and Properties of Soils. 8th ed. MacMillan, New York, 1974. 655 pp.
3. Bouma, J. W., A. Ziebell, W. G. Walker, P. G. Olcott, E. McCoy, and F. D. Hole. Soil Absorption of Septic Tank Effluent. Information Circular 20, Wisconsin Geological and Natural History Survey, Madison, 1972. 235 pp.
4. Bouma, J. Unsaturated Flow During Soil Treatment of Septic Tank Effluent. J. Environ. Eng., Am. Soc. Civil Eng., 101:967-983, 1975.

GLOSSARY

A horizon: The horizon formed at or near the surface, but within the mineral soil, having properties that reflect the influence of accumulating organic matter or eluviation, alone or in combination.

absorption: The process by which one substance is taken into and included within another substance, as the absorption of water by soil or nutrients by plants.

activated sludge process: A biological wastewater treatment process in which a mixture of wastewater and activated sludge is agitated and aerated. The activated sludge is subsequently separated from the treated wastewater (mixed liquor) by sedimentation and wasted or returned to the process as needed.

adsorption: The increased concentration of molecules or ions at a surface, including exchangeable cations and anions on soil particles.

aerobic: (1) Having molecular oxygen as a part of the environment. (2) Growing or occurring only in the presence of molecular oxygen, such as aerobic organisms.

aggregate, soil: A group of soil particles cohering so as to behave mechanically as a unit.

anaerobic: (1) The absence of molecular oxygen. (2) Growing in the absence of molecular oxygen (such as anaerobic bacteria).

anaerobic contact process: An anaerobic waste treatment process in which the microorganisms responsible for waste stabilization are removed from the treated effluent stream by sedimentation or other means, and held in or returned to the process to enhance the rate of treatment.

angstrom (Å): one hundred millionth of a centimeter.

B horizon: The horizon immediately beneath the A horizon characterized by a higher colloid (clay or humus) content, or by a darker or brighter color than the soil immediately above or below, the color usually being associated with the colloidal materials. The colloids may be of alluvial origin, as clay or humus; they may have been formed in place (clays, including sesquioxides); or they may have been derived from a texturally layered parent material.

biochemical oxygen demand (BOD): Measure of the concentration of organic impurities in wastewater. The amount of oxygen required by bacteria while stabilizing organic matter under aerobic conditions, expressed in mg/l, is determined entirely by the availability of material in the wastewater to be used as biological food, and by the amount of oxygen utilized by the microorganisms during oxidation.

blackwater: Liquid and solid human body waste and the carriage waters generated through toilet usage.

bulk density, soil: The mass of dry soil per unit bulk volume. The bulk volume is determined before drying to constant weight at 105°C.

C horizon: The horizon that normally lies beneath the B horizon but may lie beneath the A horizon, where the only significant change caused by soil development is an increase in organic matter, which produces an A horizon. In concept, the C horizon is unaltered or slightly altered parent material.

calcareous soil: Soil containing sufficient calcium carbonate (often with magnesium carbonate) to effervesce visibly when treated with cold 0.1N hydrochloric acid.

capillary attraction: A liquid's movement over, or retention by, a solid surface, due to the interaction of adhesive and cohesive forces.

cation exchange: The interchange between a cation in solution and another cation on the surface of any surface-active material, such as clay or organic colloids.

cation-exchange capacity: The sum total of exchangeable cations that a soil can adsorb; sometimes called total-exchange, base-exchange capacity, or cation-adsorption capacity. Expressed in milliequivalents per 100 grams or per gram of soil (or of other exchanges, such as clay).

chemical oxygen demand (COD): A measure of the oxygen equivalent of that portion of organic matter that is susceptible to oxidation by a strong chemical oxidizing agent.

chlorine residual: The total amount of chlorine (combined and free available chlorine) remaining in water, sewage, or industrial wastes at the end of a specified contact period following chlorination.

clarifiers: Settling tanks. The purpose of a clarifier is to remove settleable solids by gravity, or colloidal solids by coagulation

following chemical flocculation; will also remove floating oil and scum through skimming.

clay: (1) A soil separate consisting of particles <0.002 mm in equivalent diameter. (2) A textural class.

clay mineral: Naturally occurring inorganic crystalline or amorphous material found in soils and other earthy deposits, the particles being predominantly <0.002 mm in diameter. Largely of secondary origin.

coarse texture: The texture exhibited by sands, loamy sands, and sandy loams except very fine sandy loams.

coliform-group bacteria: A group of bacteria predominantly inhabiting the intestines of man or animal, but also occasionally found elsewhere. Used as an indicator of human fecal contamination.

colloids: The finely divided suspended matter which will not settle, and the apparently dissolved matter which may be transformed into suspended matter by contact with solid surfaces or precipitated by chemical treatment. Substances which are soluble as judged by ordinary physical tests, but will not pass through a parchment membrane.

columnar structure: A soil structural type with a vertical axis much longer than the horizontal axes and a distinctly rounded upper surface.

conductivity, hydraulic: As applied to soils, the ability of the soil to transmit water in liquid form through pores.

consistence: (1) The resistance of a material to deformation or rupture. (2) The degree of cohesion or adhesion of the soil mass.

Terms used for describing consistence at various soil moisture contents are:

wet soil: Nonsticky, slightly sticky, sticky, very sticky, nonplastic, slightly plastic, plastic, and very plastic.

moist soil: Loose, very friable, friable, firm, very firm, and extremely firm.

dry soil: Loose, soft, slightly hard, hard, very hard, and extremely hard.

cementation: Weakly cemented, strongly cemented, and indurated.

crumb: A soft, porous, more or less rounded ped from 1 to 5 mm in diameter.

crust: A surface layer on soils, ranging in thickness from a few millimeters to perhaps as much as an inch, that is much more compact, hard, and brittle when dry, than the material immediately beneath it.

denitrification: The biochemical reduction of nitrate or nitrite to gaseous molecular nitrogen or an oxide of nitrogen.

digestion: The biological decomposition of organic matter in sludge, resulting in partial gasification, liquefaction, and mineralization.

disinfection: Killing pathogenic microbes on or in a material without necessarily sterilizing it.

disperse: To break up compound particles, such as aggregates, into the individual component particles.

dissolved oxygen (DO): The oxygen dissolved in water, wastewater, or other liquid, usually expressed in milligrams per liter (mg/l), parts per million (ppm), or percent of saturation.

dissolved solids: Theoretically, the anhydrous residues of the dissolved constituents in water. Actually, the term is defined by the method used in determination.

effluent: Sewage, water, or other liquid, partially or completely treated or in its natural state, flowing out of a reservoir, basin, or treatment plant.

effective size: The size of grain such that 10% of the particles by weight are smaller and 90% greater.

eutrophic: A term applied to water that has a concentration of nutrients optimal, or nearly so, for plant or animal growth.

evapotranspiration: The combined loss of water from a given area, and during a specified period of time, by evaporation from the soil surface and by transpiration from plants.

extended aeration: A modification of the activated sludge process which provides for aerobic sludge digestion within the aeration system.

filtrate: The liquid which has passed through a filter.

fine texture: The texture exhibited by soils having clay as a part of their textural class name.

floodplain: Flat or nearly flat land on the floor of a river valley that is covered by water during floods.

- floodway: A channel built to carry excess water from a stream.
- food to microorganism ratio (F/M): Amount of BOD applied to the activated sludge system per day per amount of MLSS in the aeration basin, expressed as lb BOD/d/lb MLSS.
- graywater: Wastewater generated by water-using fixtures and appliances, excluding the toilet and possibly the garbage disposal.
- hardpan: A hardened soil layer, in the lower A or in the B horizon, caused by cementation of soil particles with organic matter or with materials such as silica, sesquioxides, or calcium carbonate. The hardness does not change appreciably with changes in moisture content, and pieces of the hard layer do not slake in water.
- heavy soil: (Obsolete in scientific use.) A soil with a high content of the fine separates, particularly clay, or one with a high drawbar pull and hence difficult to cultivate.
- hydraulic conductivity: See conductivity, hydraulic.
- impervious: Resistant to penetration by fluids or by roots.
- influent: Water, wastewater, or other liquid flowing into a reservoir, basin, or treatment plant.
- intermittent filter: A natural or artificial bed of sand or other fine-grained material to the surface of which wastewater is applied intermittently in flooding doses and through which it passes; opportunity is given for filtration and the maintenance of an aerobic condition.
- ion: A charged atom, molecule, or radical, the migration of which affects the transport of electricity through an electrolyte or, to a certain extent, through a gas. An atom or molecule that has lost or gained one or more electrons; by such ionization it becomes electrically charged. An example is the alpha particle.
- ion exchange: A chemical process involving reversible interchange of ions between a liquid and a solid but no radical change in structure of the solid.
- leaching: The removal of materials in solution from the soil.
- lysimeter: A device for measuring percolation and leaching losses from a column of soil under controlled conditions.
- manifold: A pipe fitting with numerous branches to convey fluids between a large pipe and several smaller pipes, or to permit choice of diverting flow from one of several sources or to one of several discharge points.

mapping unit: A soil or combination of soils delineated on a map and, where possible, named to show the taxonomic unit or units included. Principally, mapping units on maps of soils depict soil types, phases, associations, or complexes.

medium texture: The texture exhibited by very fine sandy loams, loams, silt loams, and silts.

mineral soil: A soil consisting predominantly of, and having its properties determined by, mineral matter. Usually contains <20 percent organic matter, but may contain an organic surface layer up to 30 cm thick.

mineralization: The conversion of an element from an organic form to an inorganic state as a result of microbial decomposition.

mineralogy, soil: In practical use, the kinds and proportions of minerals present in soil.

mixed liquor suspended solids (MLSS): Suspended solids in a mixture of activated sludge and organic matter undergoing activated sludge treatment in the aeration tank.

montmorillonite: An aluminosilicate clay mineral with a 2:1 expanding structure; that is, with two silicon tetrahedral layers enclosing an aluminum octahedral layer. Considerable expansion may be caused by water moving between silica layers of contiguous units.

mottling: Spots or blotches of different color or shades of color interspersed with the dominant color.

nitrification: The biochemical oxidation of ammonium to nitrate.

organic nitrogen: Nitrogen combined in organic molecules such as proteins, amino acids.

organic soil: A soil which contains a high percentage (>15 percent or 20 percent) of organic matter throughout the solum.

particle size: The effective diameter of a particle usually measured by sedimentation or sieving.

particle-size distribution: The amounts of the various soil separates in a soil sample, usually expressed as weight percentage.

pathogenic: Causing disease. "Pathogenic" is also used to designate microbes which commonly cause infectious diseases, as opposed to those which do so uncommonly or never.

ped: A unit of soil structure such as an aggregate, crumb, prism, block, or granule, formed by natural processes (in contrast with a clod, which is formed artificially).

pedon: The smallest volume (soil body) which displays the normal range of variation in properties of a soil. Where properties such as horizon thickness vary little along a lateral dimension, the pedon may occupy an area of a square yard or less. Where such a property varies substantially along a lateral dimension, a large pedon several square yards in area may be required to show the full range in variation.

percolation: The flow or trickling of a liquid downward through a contact or filtering medium. The liquid may or may not fill the pores of the medium.

permeability, soil: The ease with which gases, liquids, or plant roots penetrate or pass through soil.

pH: A term used to describe the hydrogen-ion activity of a system.

plastic soil: A soil capable of being molded or deformed continuously and permanently, by relatively moderate pressure, into various shapes. See consistence.

platy structure: Soil aggregates that are developed predominantly along the horizontal axes; laminated; flaky.

settleable solids: That matter in wastewater which will not stay in suspension during a preselected settling period, such as one hour, but either settles to the bottom or floats to the top.

silt: (1) A soil separate consisting of particles between 0.05 and 0.002 mm in diameter. (2) A soil textural class.

single-grained: A nonstructural state normally observed in soils containing a preponderance of large particles, such as sand. Because of a lack of cohesion, the sand grains tend not to assemble in aggregate form.

siphon: A closed conduit a portion of which lies above the hydraulic grade line, resulting in a pressure less than atmospheric and requiring a vacuum within the conduit to start flow. A siphon utilizes atmospheric pressure to effect or increase the flow of water through the conduit.

slope: Deviation of a plane surface from the horizontal.

soil horizon: A layer of soil or soil material approximately parallel to the land surface and differing from adjacent genetically related

- layers in physical, chemical, and biological properties or characteristics such as color, structure, texture, consistence, pH, etc.
- soil map: A map showing the distribution of soil types or other soil mapping units in relation to the prominent physical and cultural features of the earth's surface.
- soil morphology: The physical constitution, particularly the structural properties, of a soil profile as exhibited by the kinds, thickness, and arrangement of the horizons in the profile, and by the texture, structure, consistence, and porosity of each horizon.
- soil separates: Groups of mineral particles separated on the basis of a range in size. The principal separates are sand, silt, and clay.
- soil series: The basic unit of soil classification, and consisting of soils which are essentially alike in all major profile characteristics, although the texture of the A horizon may vary somewhat. See soil type.
- soil solution: The aqueous liquid phase of the soil and its solutes consisting of ions dissociated from the surfaces of the soil particles and of other soluble materials.
- soil structure: The combination or arrangement of individual soil particles into definable aggregates, or peds, which are characterized and classified on the basis of size, shape, and degree of distinctness.
- soil suction: A measure of the force of water retention in unsaturated soil. Soil suction is equal to a force per unit area that must be exceeded by an externally applied suction to initiate water flow from the soil. Soil suction is expressed in standard pressure terms.
- soil survey: The systematic examination, description, classification, and mapping of soils in an area.
- soil texture: The relative proportions of the various soil separates in a soil.
- soil type: In mapping soils, a subdivision of a soil series based on differences in the texture of the A horizon.
- soil water: A general term emphasizing the physical rather than the chemical properties and behavior of the soil solution.

solids: Material in the solid state.

total: The solids in water, sewage, or other liquids; includes suspended and dissolved solids; all material remaining as residue after water has been evaporated.

dissolved: Solids present in solution.

suspended: Solids physically suspended in water, sewage, or other liquids. The quantity of material deposited when a quantity of water, sewage, or liquid is filtered through an asbestos mat in a Gooch crucible.

volatile: The quantity of solids in water, sewage, or other liquid lost on ignition of total solids.

solids retention time (SRT): The average residence time of suspended solids in a biological waste treatment system, equal to the total weight of suspended solids in the system divided by the total weight of suspended solids leaving the system per unit time (usually per day).

subsoil: In general concept, that part of the soil below the depth of plowing.

tensiometer: A device for measuring the negative hydraulic pressure (or tension) of water in soil in situ; a porous, permeable ceramic cup connected through a tube to a manometer or vacuum gauge.

tension, soil water: The expression, in positive terms, of the negative hydraulic pressure of soil water.

textural class, soil: Soils grouped on the basis of a specified range in texture. In the United States, 12 textural classes are recognized.

texture: See soil texture.

tight soil: A compact, relatively impervious and tenacious soil (or subsoil), which may or may not be plastic.

Total Kjeldahl Nitrogen (TKN): An analytical method for determining total organic nitrogen and ammonia.

topsoil: (1) The layer of soil moved in cultivation. (2) The A horizon. (3) The A1 horizon. (4) Presumably fertile soil material used to topdress roadbanks, gardens, and lawns.

uniformity coefficient (UC): The ratio of that size of grain that has 60% by weight finer than itself, to the size which has 10% finer than itself.

unsaturated flow: The movement of water in a soil which is not filled to capacity with water.

vapor pressure: (1) The pressure exerted by a vapor in a confined space. It is a function of the temperature. (2) The partial pressure of water vapor in the atmosphere. (3) Partial pressure of any liquid.

water table: That level in saturated soil where the hydraulic pressure is zero.

water table, perched: The water table of a discontinuous saturated zone in a soil.

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-625/1-80-012		2.	3. RECIPIENT'S ACCESSION NO.	
4. TITLE AND SUBTITLE DESIGN MANUAL: ONSITE WASTEWATER TREATMENT AND DISPOSAL SYSTEMS			5. REPORT DATE OCTOBER 1980	
			6. PERFORMING ORGANIZATION CODE	
7. AUTHOR(S) Otis, Richard J., Boyle, William C., Clements, Ernest V., and Schmidt, Curtis J.			8. PERFORMING ORGANIZATION REPORT NO.	
9. PERFORMING ORGANIZATION NAME AND ADDRESS SCS Engineers Rural Systems Engineering 4014 Long Beach Blvd. P. O. Box 9443 Long Beach, CA 90807 Madison, WI 53715			10. PROGRAM ELEMENT NO. 2BG647	
			11. CONTRACT/GRANT NO. 68-01-4904	
12. SPONSORING AGENCY NAME AND ADDRESS U.S. Environmental Protection Agency Water & Waste Management Research & Development OWPO MERL Washington, DC 20460 Cincinnati, OH 45268			13. TYPE OF REPORT AND PERIOD COVERED Final	
			14. SPONSORING AGENCY CODE EPA/700/02 EPA/600/14	
15. SUPPLEMENTARY NOTES Project Officers: Robert M. Southworth (202)-426-2707 Robert P. G. Bowker (513)-684-7620				
16. ABSTRACT Approximately 18 million housing units, or 25% of all housing units in the United States, dispose of their wastewater using onsite wastewater treatment and disposal systems. These systems include a variety of components and configurations, the most common being the septic tank/soil absorption system. The number of onsite systems is increasing, with about one-half million new systems being installed each year. This document provides information on generic types of onsite wastewater treatment and disposal systems. It contains neither standards for those systems nor rules and regulations pertaining to onsite systems. The design information presented is intended as technical guidance reflective of sound, professional practice. The intended audience for the manual includes those involved in the design, construction, operation, maintenance, and regulation of onsite systems.				
17. KEY WORDS AND DOCUMENT ANALYSIS				
a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS		c. COSATI Field/Group
18. DISTRIBUTION STATEMENT Release to Public		19. SECURITY CLASS (This Report) Unclassified		21. NO. OF PAGES 412
		20. SECURITY CLASS (This page) Unclassified		22. PRICE

EXAMPLES OF SOIL MOTTLING (EXAMPLES A, B & C INDICATE
SEASONAL SOIL SATURATION, EXAMPLE D DOES NOT)



(A)
Extremely Prominent Mottling
in a Clayey Soil



(B)
Mottling in a Loamy Soil



(C)
Mottling in a Sandy Soil



(D)
Mottling Inherited
from Geologic Processes