CHAPTER 6

SUBSURFACE DRAINAGE

6-1. General.

a. The water beneath the ground surface is defined as subsurface water. The free surface of this water, or the surface on which only atmospheric pressure acts, is called the groundwater table. Water is contained above an impervious stratum and hence the infiltration water is prevented from reaching a groundwater table at a lower elevation. The upper body of water is called perched groundwater and its free surface is called a perched water table.

b. This water infiltrates into the soil from surface sources, such as lakes, rivers and rainfall, and some portion eventually reaches the groundwater table. Groundwater tables rise and fall depending upon the relation between infiltration, absorption, evaporation and groundwater flow. Seasonal fluctuations are normal because of differences in the amount of precipitation and maybe relatively large in some localities. Prolonged drought or wet periods will cause large fluctuations in the groundwater level.

6-2. Subsurface drainage requirements. The determination of the subsurface soil properties and water condition is a prerequisite for the satisfactory design of a subsurface drainage system. Field explorations and borings made in connection with the project design should include the following investigations pertinent to subsurface drainage. A topographic map of the proposed area and the surrounding vicinity should be prepared indicating all streams, ditches, wells, and natural reservoirs. The analysis of aerial photographs of the areas selected for construction may furnish valuable information on general soil and groundwater conditions. An aerial photograph presents a graphic record of the extent, boundaries, and surface features of soil patterns occurring at the surface of the ground, The presence of vegetation, the slopes of a valley, the colorless monotony of sand plains, the farming patterns, the drainage pattern, gullies, eroded lands, and evidences of the works of man are revealed in detail by aerial photographs. The use of aerial photographs may supplement both the detail and knowledge gained in topographic survey and ground explorations. The sampling and exploratory work can be made more rapid and effective after analysis of aerial photographs has developed the general soil features. The location and depth of permanent and perched groundwater tables maybe sufficiently shallow to influence the design. The season of the year and rainfall cycle will measurably affect the depth to the water table. In many locations information may be obtained from residents of the surrounding areas regarding the behavior of wells and springs and other evidences of subsurface water. The soil properties investigated for other purposes in connection with the design will supply information that can be used for the design of the drainage system. It may be necessary to supplement these explorations at locations of subsurface drainage structures and in areas where soil information is incomplete for design of the drainage system.

6-3. Laboratory tests. The design of subsurface drainage structures requires a knowledge of the following soil properties of the principal soils encountered: strength, compressibility, swell and dispersion characteristics, the in situ and compacted unit dry weights, the coefficient of permeability, the in situ water content, specific gravity, grain-size distribution, and the effective void ratio. These soil properties may be satisfactorily determined by experienced soil technicians through laboratory tests, The final selected soil properties for design purposes may be expressed as a range, one extreme representing a maximum value and the other a minimum value. The true value should be between these two extremes, but it may approach or equal one or the other, depending upon the variation within a soil stratum.

6-4. Flow of water through soils.

a. The flow of water through soils is expressed by Darcy's empirical law which states that the velocity of flow is directly proportional to the hydraulic gradient. This law is expressed in equation form as:

$$V = k\, i$$

or

$$Q = v A = k i A$$

Variables in the equations are defined in appendix D. According to Darcy's law the velocity of flow and the quantity of discharge through a porous media are directly proportional to the hydraulic gradient. The flow must be in the laminar regime for this condition to be true.

b. A thorough discussion of the Darcy equation including the limitations, typical values of permeability, factors affecting the permeability, effects of pore fluid and temperature, void ratio, average grain size, structure and stratification, formation discontinuities, entrapped air in water or void, degree of saturation, and fine soil fraction can be found in TM 5-820-2/AFM 88-5, Chapter 2.

6-5. Drainage of water from soil. The quantity of water removed by a drain will vary depending on the type of soil and location of the drain with respect to the groundwater table. All of the water contained in a given specimen cannot be removed by gravity flow since water retained as thin films adhering to the soil particles and held in the voids by capillarity will not drain. Consequently, to determine the volume of water that can be removed from a soil in a given time, the effective porosity as well as the permeability must be known. The effective porosity is defined as the ratio of the volume of the voids that can be drained under gravity flow to the total volume of soil. Limited effective porosity test data for well-graded base-coarse materials, such as bank-run sands and gravels, indicate a value for effective porosity of not more than 0.15. Uniformly graded soils such as medium coarse sands, may have an effective porosity of not more than 0.25.

6-6. Backfill for subsurface drains.

a. Placing backfill in trenches around drain pipes should serve a dual purpose: it must prevent the movement of particles of the soil being drained, and it must be pervious enough to allow free water to enter the pipe without clogging it with fine particles of soil. The material selected for backfill is called filter material. An empirical criterion for the design of filter material was proposed by Terzaghi and substantiated by tests on protective filters used in the construction of earth dams. The criterion for a filter and pipe perforations to keep protected soil particles from entering the filter or pipe significantly is based on backfill particle sizes.

b. The filter stability criteria for preventing movement of particles from the protected soil into or through the filter and the exceptions to this criteria are discussed in chapter 5, TM 5-820-2/AFM 88-5, Chapter 2.