NATIONAL ENGINEERING HANDBOOK

SECTION 16

DRAINAGE OF AGRICULTURAL LAND

CHAPTER 8. DRAINAGE OF ORGANIC SOILS

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CHAPTER 8. DRAINAGE OF ORGANIC SOILS

General

General investigations, design, and development of drainage facilities for organic soils follow the same procedure used in draining mineral soils. However, modifications and adjustments must be made to meet properties and problems inherent with such soils. These include depth of formation, variations in drainage capacity, water-holding capacity, combustibility, erosion, shrinkage and swelling, subsidence, and availability of outlet. Appropriate design factors should be worked out in drainage guides.

High land values, coupled with small and intensively cultivated holdings, frequently complicate design of drainage systems for such soils by (a) necessitating the fitting of the drainage pattern to varied property boundaries, (b) limiting the open channel to the least possible land area, and (c) requiring flexible water controls to suit varying operations of many owners.

Classification of Organic Soils

General properties of organic soils

Organic soils involved in drainage problems are those that are saturated with water for prolonged periods of time or have been artificially drained. Differences among such organic soils, commonly called peats and mucks, reflect their response to drainage. These differences, in turn, reflect variations in their character and origin. In the classification of organic soils, efforts have been made to indicate these differences.

The classification of organic soils followed in soil surveys of the U.S. Department of Agriculture and Land Grant Colleges is based on a number of soil properties. Major emphasis is given to the nature, arrangement and thickness of distinctive layers in the profile, mineral content, and stage of decay. Broad classes have been distinguished according to stage of decomposition as Fibric, Hemic, or Sapric. The Fibric are the least decomposed, the Sapric most decomposed, and the Hemic are in an intermediate stage of decomposition between the Fibric and Sapric. Peats are the least decomposed and mucks the most.

Classification of organic soils highly useful to the drainage specialist has been on the basis of mineral matter content, as ash residue from burning, and the botanical composition.

Mineral matter content

In the soil survey, organic soils are distinguished from mineral soils when the surface layer in its natural state has a thickness of 16 inches or more, and has either (a) 20 percent or greater organic matter content when the mineral fraction has little or no clay, (b) 30 percent or greater organic matter content when the mineral fraction has 50 percent or more clay, or

(c) an organic matter content that varies from 20 to 30 percent when the clay content of the mineral fraction ranges from 0 to 50 percent, respectively.

In land drainage, organic soils are classified by drainage specialists according to ignition loss. Peats are defined as containing 50 percent or more organic matter and mucks as containing less than 50 percent. Generally, mucks are preferred for agricultural use because they drain better, shrink less, work more easily, and need less fertilizer.

Some mineral surface soils are so high in organic matter that they behave somewhat like organic soils. Such soils usually are intermediate in character between the organic and mineral soils. However, in the soil survey they are classified in an appropriate series of mineral soils. An example is the Bayboro soils series which occurs along the Atlantic seaboard. Some members of this series so nearly approach the character of mucks or peats in the surface layers that one soil type has been called Bayboro mucky loam to distinquish it from Bayboro loam.

Botanical composition

Broad groups of organic soils are recognized on the basis of botanical composition. These groups are the sedimentary peats and mucks, sedge peats and mucks, moss peats and mucks, and woody peats and mucks. A detailed description of these groups is contained in USDA Bulletin 1419 by Dachnowski-Stokes (1).

Sedimentary peats and mucks. - Sedimentary peats and mucks consist of fine-textured, nonfibrous organic matter derived from aquatic vegetation in which are scattered remains of algae, plankton and pollen. Generally, these deposits are black or green, rather elastic, and highly colloidal. Normally accumulating in deep water, they also occur characteristically as deep layers, often in depressions with strongly sloping sides. Upon drying, these soils shrink, crack, and finally become hard. Once dry they absorb water very slowly. They lack stability and firmness under load and are expensive to drain. After being drained they are poor for crop production because of unfavorable physical properties and moisture relationships. Where sedimentary peats or mucks occur in the form of thin layers in a profile of coarser peats or mucks, they can often be broken up mechanically and mixed with the coarser materials.

Sedge peats and mucks. - Sedge peats and mucks are the residues from sedges, reeds, and grasslike plants of various sizes. Some residues also come from other plants so that these peats and mucks are commonly heterogeneous. They are generally porous, fibrous, and have a wide variety of sizes of plant remains. They decompose slowly and have less tendency to shrink and subside than do sedimentary or moss peats and mucks. They drain readily, are moderately fertile, and are generally good for agricultural use.

Moss peats and mucks. - Moss peats and mucks consist mostly of residues from sphagnum and hypnum mosses. They are spongy and fibrous though finer than sedge peats and mucks. Sphagnum peats are low in plant nutrients, strongly acid, and of little agricultural value. Hypnum peats are fairly dark in color, somewhat less acid, and better suited for crop production. Moss peats and mucks usually absorb water in amounts equaling 5 or 6 times their dry weight but may absorb as much as 20 times their dry weight. These soils are hard to drain, tend to shrink greatly as they dry out, and swell markedly when wet. If they are overdrained the organic residues pack poorly and the soil becomes droughty. Where layers of moss peat occur in profiles consisting

mainly of sedge or woody peat they retain moisture and retard movement of water toward outlets. Thus, they lead to uneven shrinkage if drains are widely spaced.

Woody peats and mucks. - Woody peats and mucks commonly consist of granular, well disintegrated residues of woody plants mixed with some wood fragments. The residues may come from deciduous or coniferous trees, from various shrubs such as heath, willow and alder, or from all of these plants. Vertical sections are relatively homogeneous as a rule though horizontal bands of slightly decayed residues may occur. These peats and mucks are less plastic and cohesive than the other three kinds. They are inclined to sloughing in the banks of deep drains. Water velocities need to be kept low in channels draining large areas. In general, woody peats and mucks have lower water-holding capacities than others and, therefore, drain more readily. Once drained and developed, they have relatively favorable physical properties and can be used successfully for crop production, especially for vegetables.

Subsidence in Drained Organic Soils

Causes of subsidence

Surface subsidence is the result of soil shrinkage by oxidation and compaction and direct soil loss by erosion and burning. Shrinkage is inevitable with drainage. Lowering of the water table permits entry of air into pores. Oxidation of the organic soil by action of aerobic bacteria converts such matter to carbon dioxide, which escapes into the atmosphere, and water. The removal of water by drainage causes weight of upper soil layers to compact lower layers. The operation of farming equipment in preparing and compacting seedbed consolidates surface layers by pulverizing the soil and eliminating larger soil voids.

Observation of many sites over many years in both the United States and Europe indicates an overall average subsidence of about 1 inch per year and that this rate varies directly with the depth of organic material exposed above the water table. Higher initial rates of subsidence occur within the first several years after drainage. These higher rates are attributable primarily to initial compaction which may be two or three times the average subsidence occurring in later years.

Allowance for subsidence in design

Subsidence, with resulting drop in surface elevation, reduces the fall available for drainage into an available outlet. By nature of most sites where organic soils are formed, an outlet for free drainage discharge is limited in depth and grade. Unless pump drainage is provided, outlet improvements may need to be carried out long distances below the benefited area. Unequal settlement of only small areas can affect a whole field. Design of an adequate drainage system must allow for subsidence over a reasonable life expectancy of the improvement. Where no local data on subsidence rates are available, an allowance for initial subsidence of a newly developed site can be estimated as 25 to 35 percent of the designed depth of drains below the existing land level. At least 10 percent should be allowed for drains constructed or reconstructed on previously drained land. Information on subsidence rates for specific areas of the United States, which are useful in design, have been published by Sutton (2), Stephens (3), Roe (4), Jongedyk (5) and others.

In designing the mains and laterals, the best procedure is to prepare, first, a rough preliminary design without considering subsidence to determine the approximate location, size, and depth of ditches and drains. Next, consider existing ground elevations and corresponding soil borings to take subsidence into account. Estimated subsidence should be determined along each channel, based on the channel depths and borings of the preliminary design. Next, the estimated subsidence should be subtracted from existing ground elevations to determine elevations of a subsided surface. Then a final design hydraulic gradient should be established for the channels with respect to a point in the outlet channel well downstream and below the improvement, where subsidence should not take place. Channel sections should then be adjusted to this gradient to provide the depth and size necessary to discharge the design flow. In some situations, changes in surface elevation after subsidence may be enough to require a complete realignment or relocation of the main and laterals.

Other Characteristics of Organic Soils and Their Treatment

Erosiveness

Volume weight of organic soil, as compared to mineral soil, is low. Peats may contain as little as 8 to 20 pounds of dry material per cubic foot. When surface layers of peat and muck become pulverized by alternate wetting, drying, and working, they are easily moved by wind and water. Wind erosion usually is an important factor influencing organic soils. It damages young plants by abrasions and contributes to rapid silting of ditches. Susceptibility to wind erosion can be minimized by reducing surface exposure of land to the sweep of the wind. This is done by surface barriers, by vegetation and other treatment of the surface, and by maintaining as high water level in the soil as practicable, particularly in the nongrowing season.

Barriers may be fixed or movable, live or constructed materials. Effective live barriers can be plantings of green willow, Chinese elm, privet, or evergreens in rows 200 to 350 feet apart across the direction of prevailing wind. Deciduous plantings give earlier protection after planting but lack year-round protection of the slower growing evergreens. Snow fences, at close spacing, provide temporary removable barriers and occupy less cropland. Planning of barriers should be coordinated with the planning of the drainage system so that ditches are least affected by silt deposition and vegetative growth, and so that covered drains are protected from root intrusion. Interplantings of crops as rye or rows of corn and sunflower provide surface protection from wind. Intermixing fibrous and woody matter or clay as a binder in the soil surface also reduces hazard of both wind and water erosion but is costly.

Water erosion is most likely to occur when runoff from sloping land or steep uplands discharges into the area. Preventive measures should include: (a) Diversion of upland water at the outer edge of the development; (b) design and location of mains and laterals when serving large areas, so as to attain low velocities; (c) combining subsurface drains with regularly spaced ditches laid across slope, so as to break up overland water movement; and (d) use of drop structures for ditch overfalls into deeper outlet ditches or natural channels.

Combustibility

Mucks and peats burn readily when dry. Burning of tussocks, brush and timber during clearing for construction and land improvement should not be permitted except when the ground is saturated and fire can be controlled. To avoid risk of highly susceptible grass and brush fires, drainage of peat and muck land

should be deferred until ready for agriculture. Drainage systems should be designed, insofar as possible, to permit raising of the water table during dry seasons.

Absorption and water-holding capacity

Fibrous peats have high absorption and water-holding capacity. Excessive swelling when wet and poor compaction result in uneven surfaces that cause spotty areas of poor drainage or droughtiness. Construction of closely spaced drains and regulation of the water table are required to maintain uniform moisture control. Excessive drying of organic soil is dangerous in that the pasty secretion in the peaty aggregate rehydrates more slowly with decreasing water content, and, once dry, rehydration may be impossible. In organic soils overlaying marl, silty clay, clay, or fine non-water-bearing sand, an absorption cushion of organic soil should be left between the bottom of ditches and the impervious material to serve as a reservoir of moisture during drought. This cushion should be one foot thick and never less than one-half foot thick.

Design Requirements for Ditches and Drains

Mains and laterals

Main and lateral ditches should be designed to meet the general requirements of similar channels in mineral soils, with allowances for subsidence. Generally, in deep peats or moderately deep peats over open sands, mains may be spaced out as wide as 1,500 to 2,500 feet and laterals kept to possibly 500 to 600 feet. Side slopes in main and lateral ditches should not be steeper than 1 to 1. Such channels require as much width as necessary for hydraulic capacity, but bottom widths should not be less than 3 feet.

Field ditches and drains

Both ditches and subsurface drains can be used as field collectors in deep peat. However, installations of covered drains should not be considered in new drainage developments until 3 or more years after initial settlement has taken place, and then only after careful investigations show that a uniform bearing and an adequate outlet can be assured for the drains throughout.

Because of variation in moisture-holding capacity and other local properties of organic soil, depths and spacing of drains vary greatly and should be established in drainage guides. Depth of covered drains should be at least 4 feet after initial settlement takes place. Lines should be spaced from approximately 50 to 200 feet apart, depending on the density of the materials. The woody and grass reed peats usually drain well at about 100- to 120-foot spacings. Closer spacings are best where controlled drainage will be used. If in doubt, the wider spacings can be tried and supplemental lines interspaced later if necessary. Where covered drains are installed on a large block of land, some ditches should be left for surface water removal during flash floods.

When the depth of organic soil to the underlying mineral soil is less than 4 feet, covered drains can still be used if they can be supported continuously in the mineral soil. Drains should not be laid with support alternating in nonyielding mineral and yielding organic soils. Backfill over a drain in clay subsoil should be pervious material.

When the depth of the organic material is less than 3 feet, ditches should be used. When organic soil is situated over marl, clay or silty clay, the depth of ditch should be adjusted to provide an organic cushion of at least 1/2- to 1-foot depth beneath the bottom of the open ditch. Spacings between drains should be decreased to correspond to such lesser depths, usually 60 to 100 feet for 2-foot depths and up to 200 feet for 3-foot depths.

Field ditches can be dug using almost vertical side walls for fibrous peats. Side slopes of at least 1/2 to 1 should be used on the less stable woody peats. Side slopes of 1/4 to 1 are commonly used for field ditches.

The required capacities of covered drains are about twice those for mineral soils, so that coefficients should be about 1/2 to 3/4 of an inch in 24 hours for general field crops and 3/4 to 1 1/2 inches for truck crops.

Protection against overdrainage

When seepage or low waterflow is likely to be insufficient during drought, some water control by temporary dikes or by structures should be provided for protection against overdrainage. When an added source of water is imperative, wells, diversions or storage for irrigation may be considered.

Mole drains

Mole drains have been used successfully for subsurface drainage in Florida when drawn through fibrous organic soil. The usual depth is about 30 inches, spaced 12 to 15 feet apart. An approximate 4 1/2-inch diameter hole is obtained from a 6-inch mole. Best results are realized when the water level is kept below the mole line during construction. Use of occasional pipe vents as in regular subsurface drainage installations, placed while the lines are being drawn, prevents suction and consequent collapse of the mole hole. In Florida, moles last from 5 to 8 years.

Pump Drainage

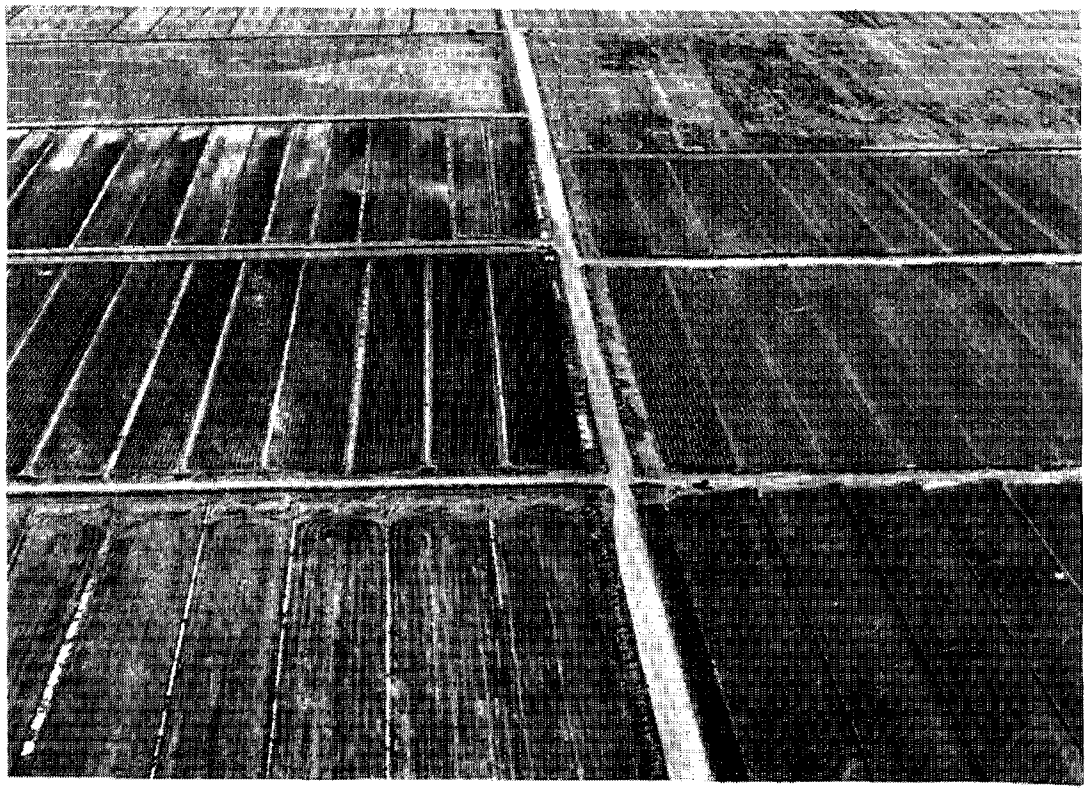
Because of limited outlet or encroachment of swamps as subsidence progresses, pumping and diking are required on many projects. (See chapters 6 and 7.) Required heads to be pumped are low, mostly ranging from 4 to 8 feet. Low cost of recent-type propeller pumps has greatly implemented pumping of small areas and also has made possible reclamation of many others without gravity outlet.

While pumping plant design procedures are the same as those for mineral soils, higher drainage coefficients usually are needed for organic soils because of small areas and the high value of crops involved.

Dikes

Organic soils make poor dike material and should not be considered for permanent engineering structures. Fibrous peats are entirely unsatisfactory for dikes unless mixed with mineral soils, as is done in the cranberry areas of New England. Cost of construction is usually quite high in such cases. If mucks or the heavier peats are to be used, several precautions must be taken. The surface should be covered with 4 to 6 inches of sand whenever this is possible, and then kept grassed to protect from overdrying. At least 50 percent shrinkage can be expected and must be allowed for in the first year or two. The dike should then be retopped.

A minimum section with at least 1 to 1 side slopes and 8-foot minimum top should be provided. Surface materials should be removed from the base before construction. Where the dike must protect against a standing head of water during floods, the borrow pits should be kept on the outside of the dike. Safe heads may vary with peat or muck but should not exceed 4 feet. If only low heads occur outside of the dike (1 foot or less), the borrow may be taken from the protected landside. This channel then may serve as a seepage and drainage ditch. Permanent dikes constructed of organic soils should not be recommended by SCS engineers.



Controlled drainage in organic soils near Sebring, Florida

Controlled Drainage

Controlled drainage slows down subsidence and its adverse effect on the drainage system, reduces wind and fire loss, and reduces adverse effect of a fluctuating water table on crop yields. Controlled drainage permits irrigation without hindering field operations, has low labor and maintenance cost, and usually makes use of existing drainage systems with the controls as the only added installation. On the other hand, cost of closely-spaced drains for adequate irrigation, need for larger quantities of water than for overhead irrigation, and raising of undesirable salts in some localities are undesirable features. Controlled drainage is obtained by designing the system so that the water table can be maintained more or less constant at more effective depths throughout the year. Where pumps are used, control is obtained by means of the pump. It is also accomplished under gravity control

with dams or drop structures, usually of the flashboard or stoplog type. Installing dams in laterals rather than mains has the advantage of varying regulation for different fields and ownerships. Use of moles and closely-spaced subsurface drains provides more uniform control. During droughts, proper operation requires an adequate water supply from seepage or springs, or from surface supplies or wells obtained by pumping.

The water table, when controlled, can be maintained at higher levels than under free drainage. Maximum levels should be slightly below the zone of dense rooting and usually 18 inches for most grasses and shallow-rooted vegetables, 24 inches for most vegetables, and about 30 inches for deep-rooted crops as corn. The water table should be kept high in the spring to reduce wind erosion and lowered as the root system develops during the season. Adequate control requires continuous checks of water table levels, made through small observation wells located over various parts of the controlled area.

Adjustments in the rate of water removal for rainfall, etc., can be determined with reasonable accuracy. These are based on measurement of average voids in each foot of depth. Roughly, an inch of added water may provide as much as 1-foot rise in a 2- to 2 1/2-foot soil profile above the water table. Absorption and plant transpiration generally eliminate the effect of intermittent rainfalls of 1/2 inch or less.

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