NATIONAL ENGINEERING HANDBOOK

SECTION 16

DRAINAGE OF AGRICULTURAL LAND

CHAPTER 6. DIKES

Contents

	Page
General	6- 1
Classification of Dikes	6- 1
Investigations for Dikes	6- 3
Dike location	6- 3
High water determination	6- 4
Dike foundation	6- 5
Embankment materials	6- 5
Design of Dikes	6- 5
General	6- 5
Height of dike	6- 8
Top width	6-10
Side slopes	6-10
Core trench	6-11
Banquettes	6-11
Drains	6-11
Berms	6-12
Construction	6-12
Foundation preparation	6-12
Embankment construction	6-13
Conduits	6-14
Protection from wave action	6-14
Maintenance	6-14
References	6-15

Figures

Fig. 6-1 Typical dike section	6- 8
Fig. 6-2 Wave height curve	6- 9
Fig. 6-3 Dike section with banquette	6-12

Tables

Table 6-1 Dike classification	6- 2
Table 6-2 Soil characteristics	6- 6

NATIONAL ENGINEERING HANDBOOK

SECTION 16

DRAINAGE OF AGRICULTURAL LAND

CHAPTER 6. DIKES

General

Dikes are embankments constructed of earth or other suitable materials to protect land against overflow or flooding from streams, lakes, and tidal influences, and also to protect flat land from diffused surface waters. Dikes are generally used for the following purposes:

1. To protect bottom lands along one or both banks of a stream or channel from overflow caused by high stages or backwater from the outlet.

2. To provide additional out-of-bank capacity for floodways.

3. To provide floodways across bottom lands for conveyance of upland runoff to streams.

4. To protect the shores of lakes, desilting basins and impoundments against wave action and inundation during high water stages.

5. To protect coastal areas of oceans, bays, and estuaries against overflow from diurnal and wind storm tides.

6. To protect lands in areas of high rainfall and flat topography from diffused surface waters.

Dikes are intended to protect land against overflows of intermittent occurrence and short duration and not against continuous impoundment as in the case of dams. When restricting flood flows along streams, dikes tend to increase water surface elevation, velocities, and maximum discharges within the confined stream reaches and also increase the rate of flood wave travel downstream.

Dikes complicate drainage of the lands they protect. Facilities for runoff from protected areas must be provided at all stages of flow unless adequate storage is available. Ordinarily, discharge through dikes is obtained by gravity flow through conduits equipped with automatic flap or tide gates. Such gates prevent reverse flow into protected areas when stages on the water side of dikes are higher than on the land side. When prolonged flood stages prevent gravity outflow, the runoff from protected areas must be accumulated and stored temporarily in low areas behind the dikes; be removed continuously by pumps; or disposed of by a combination of these two methods. (See Chapter 7, "Drainage Pumping" and Chapter 9, "Drainage of Tidal Lands.")

Classification of Dikes

The requirements for construction of dikes are governed by site conditions and design criteria. The design requirements are determined by value of crops and property and the hazard to life within the area to be protected. Dikes are classified as shown in Table 6-1 in accordance with these factors.

Reference is made to Engineering Standard for Dike, Code 356, SCS National Engineering Handbook, Section 2.

Table 6-1, Dike Classification

Class	Conditions	Design & Construction Requirements
I	1-Possible loss of life should failure occur. 2-High value land and improvements to be protected. 3-Complex site conditions. 4-The head of water against the dike in excess of 12 feet above normal ground, excluding sloughs, old channels and other low areas.	1-Design height equal to design water depth plus freeboard or wave height allowance of 2 feet or more. 2-Design water depth measured or computed for the greater of the record flood or the 100 year frequency flood. When loss of life or high value property damage are not a primary consideration, the greater of the 50 year frequency flood or the desired level of protection. 3-Cross section design according to site exposure to wave action and soil stability analysis. 4-Stable mineral soil required in foundation and embankment. 5-Construction according to site conditions and criteria for earth embankments. Refer to SCS National Engineering Handbook, Section 20.
II	1-Agricultural lands of medium to high capability with primary improvements in farmsteads and other valuable facilities. 2-The head of water against the dike less than 12 feet above normal ground excluding sloughs, old channels and other low areas.	1-Design water heights exceeding 4 feet to be based on a 25 year frequency or greater flood. When this degree of protection is not economically or physically feasible a flood frequency less than 25 years may be used if fuse plug sections or other suitable relief measures are included in the design. 2-Stable mineral soils required in the embankment. Organic soils permissible only as surface covering not in excess of 1 foot. 3-Cross section design based on design water height and the method of construction.

Table 6-1, continued

Class	Conditions	Design & Construction Requirements
II (continued)		4-Construction with material compacted by equipment travel or dumped and shaped.
III	1-Agricultural lands of relatively low capability with improvements of low value. 2-The head of water against the dike not more than 6 feet for mineral soils or 4 feet for organic soils excluding sloughs, old channels and low areas.	1-Design based on SCS State Standards considering the site conditions. 2-Construction with materials available and suitable for use.

Investigations for Dikes

The intensity of investigations for dikes depends upon the class of dike required and a careful evaluation and consideration of the site conditions present. The following is a discussion of investigations needed for dike location, determination of high water levels, foundation materials and embankment materials.

Dike location

After the classification of the dike is determined, the initial step in investigation and design is establishment of a tentative location. This involves consideration of:

1. The land use and improvements, both existing and proposed, within the area to be protected. This data may be used in evaluating economic feasibility.

2. Anticipated flood stages.

3. The manner in which drainage of the protected area will be provided.

4. Rights-of-way involved.

5. Physical problems to be encountered, especially soil conditions relating to foundation and fill for the embankment and access for construction and maintenance.

The following should be considered in the final dike location:

1. Construction on soils that provide the most favorable foundation conditions and the best embankment materials. The location of Class III dikes will generally be parallel with units of the drainage system.

2. The shortest, most feasible and economical route consistent with protecting the largest usable area.

3. Avoidance of hazards, such as sloughs, sharp eroding bends in watercourses, and direct exposure to significant reaches of open water.

4. Utilization of natural protection against waves, such as permanent stands of trees, reeds or brush. Trees and brush should not be allowed to grow on the dike however.

5. Bordering public roads or property lines for purposes of access and easements.

6. Coordination with units of the drainage system of the protected areas.

7. Use of natural storage basins within the protected areas to reduce pumping requirements and gate sizes.

8. The effect, if any, on existing dikes and adjacent lands which will result from the dike construction.

High water determination

Investigations for all classes of dikes must include a determination of the height, frequency and duration of floodwater stages. This is a logical next step after classifying and locating the dike.

High water stages along coastal areas usually result from the combination of high diurnal tides, high winds and waves. Storms along the Atlantic and Gulf Coasts may result in high water stages along the shorelines of nearby inland freshwater lakes. Flood stage records and dates are generally available from the Corps of Engineers, Coast Guard, municipal and port authorities, the Coast and Geodetic Survey of the U. S. Department of Commerce which issues annual editions of "Tide Tables - East Coast" and "Tide Tables - West Coast," and from landowners. (See Chapter 9, "Drainage of Tidal Lands"). In the absence of available records, duration of flood tides resulting from hurricanes may be assumed as about 75 hours along the southern and eastern coasts of the United States.

Flood data on streams can be obtained from the U. S. Geological Survey, other federal agencies, and state agencies. Data in the form of high water marks are frequently available from local community records, newspapers, and from landowners. Where information on flood stages of streams is not available, computations based on the hydrologic conditions of the watershed and on selected rainfall conditions can be made to approximate the discharge from which estimates of the anticipated flood stage can be made. Procedures for determining runoff are given in the SCS National Engineering Handbook, Section 4, "Hydrology" and in Section 16, Chapter 5, "Open Ditches."

Whenever floodplain runoff is restricted by dikes, the stage for design discharge must be determined. If the floodplain on only one side of a stream is diked out, the effect on depth, duration and extent of flooding on the floodplain of the opposite side must be determined. Legal complications can arise from any change in duration or stage of overflow resulting from dike construction.

Dike foundation

Foundation investigations are usually made concurrent with or shortly following tentative location of the dike. Soil borings are necessary for all classes of dike. Where standard soils surveys of the area are available, these may be used as guides for locating borings. When soil surveys are not available, selected borings should be located along the route. In some instances, it may be desirable to open a pit for a closer examination of substrata. Borings or pits should reveal (a) the elevation of the water table; (b) thickness, classification and position of each strata; and (c) the existence of any unsuitable materials. These borings should extend to a depth equal to the difference between the bottom of any existing or proposed channel or borrow pit and the design water surface. The location of excessively permeable strata should be known to determine their influence on piping, pumping costs and their relationship to the location of interior drainage facilities. Occasionally, it may be necessary to make mechanical analysis and permeability tests of the various strata encountered to obtain more complete information, using methods established for earth dams.

Embankment materials

Dikes are usually constructed of fill material borrowed adjacent to and parallel with the dike. In such cases, investigations for foundation and borrow material can be combined. Where unstable soil conditions are found, it may be more economical to change the dike location rather than to employ special construction methods necessary for unstable soils. For Class I and some Class II dikes, special borrow pits outside the immediate area of construction may be required and the fill material transported to the construction site.

"Soil Characteristics," given in Table 6-2, help in appraising soil conditions, permeability, and stability when making the preliminary investigations. Frequently, simple field tests suffice for determining stability of fill materials. Such tests are outlined in Chapters 1 and 2, Section 8, Engineering Geology, SCS, National Engineering Handbook.

Design of Dikes

General

Dikes can fail by overtopping, undermining, sloughing, and seepage channels along drainage structures placed through them. The dike design should reduce the possibility of failure from these hazards as much as possible. Dikes are usually long and have substantial differences in soil conditions along their routes. Often locations cannot be changed to obtain better foundations and the soils adjacent to the dike must be used in construction. Adjustments in the design section and in construction methods must be made along the course of dikes in accordance with these soil conditions.

Ample freeboard reduces the possibility of overtopping of dikes. Undermining is minimized by locating dikes far enough away from channels to eliminate exposure to high velocities and scour. Proper side slopes and construction methods minimize sloughing. Protection against seepage along culvert and discharge pipes is improved by increasing the seep line with antiseep collars. A seep line increase of 15 percent is usually sufficient. When installing drainage pumps, discharge is handled by locating the discharge pipe over the top of dikes. If placed through the dikes, pipes should be placed above the water surface and the connections between them and the pumps made with flexible couplings.

Table 6-2, Soil characteristics

	Group Symbol	Soil Description	Suitability - Dikes	Permeability and Slopes
Coarse-grained soils - (Less than 50% passing #200 sieve)	GW	Well graded gravel and gravel-sand mixtures. Little or no fines.	Very stable - suited for shell of dike. Good foundation bearing.	Rapid - will need core.
	GP	Poorly graded gravels and gravel-sand mixtures. Little or no fines.	Stable - suitable for shell of dike. Good foundation bearing.	Rapid - may not need core for lower stages of short duration.
	GM	Silty gravels and gravel-sand-clay mixtures.	Stable - generally adequate for all stages. Good foundation bearing. Good compaction with rubber tires.	Moderate - may not need core except for long flood duration.
	GC	Clayey gravels and gravel-sand-clay mixtures.	Stable - adequate for all stages. Good foundation bearing. Good compaction with rubber tires.	Slow permeability
	SW	Well graded sands and gravelly sands. Little or no fines.	Very stable - adequate for low stages. Good foundation bearing. Compaction good with crawler tractor.	Rapid - may need core for high stages of long duration.
	SP	Poorly graded sands and gravelly sands. Little or no fines.	Stable - adequate for low stages. Generally fair foundation bearing. Use flat slopes and wide berms. Compaction good with crawler tractor.	Rapid - will need core for long duration. Use flat slopes. Protect against wave action.
	SM	Silty sands and sand-silt mixtures.	Fairly stable - adequate for low stages. Only fair foundation bearing. Use wide berms. Good compaction with rubber tires.	Moderate - use flat slope on water side. Protect against wave action.
	SC	Clayey sands and sand-clay mixtures	Stable - adequate for all stages. Generally good foundation bearing. Fair compaction with rubber tires.	Slow -

Table 6-2, Soil characteristics (continued)

	Group Symbol	Soil Description	Suitability - Dikes	Permeability and Slopes
Fine-grained soils - (More than 50% passing #200 sieve)	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands and clayey silts of slight plasticity.	Poor stability - generally adequate for low stages. Fair foundation bearing. Dumped fill on Class III dikes only. Fair compaction with rubber tires.	Moderate - use flat slope on water side. Protect slopes against erosion forces.
	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays and lean clays.	Stable - adequate for all stages. Fair foundation bearing. Fair compaction with rubber tires. Use dumped fill on lower stages only.	Slow -
	OL	Organic silts and organic clays having low plasticity.	Very poor stability - may be adequate for Class III dikes of low height. Can use dumped fill.	Moderate - use for very low stage only. Slopes at natural angle of repose when wet.
	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils and elastic silts.	Low stability - generally adequate for all stages. Difficult to compact. Could use dumped fill for low stages. Poor foundation bearing.	Slow - use flat slopes and protect against erosion.
	CH	Inorganic clays having high plasticity and fat clays.	Fairly stable - adequate for all stages. Poor compaction, dumped fill may be adequate.	Very slow permeability. Use flat slopes on water side.
	OH	Organic clays having medium to high plasticity and organic silts.	Very low stability - Adequate only for low stages and can use dumped fill. Has poor foundation bearing and compaction.	Very slow - use for low stages only. Use flat slopes.
	Pt	Peat and other highly organic soils.	Very low stability - use only for temporary dikes. Remove from foundation for mineral soil dikes.	Variable - may vary significantly between vertical and horizontal.

Note: This table based on the Unified Classification System and field experience. Rubber tires refer to rubber tired equipment.

The cross section and density of materials affect embankment stability. High density and uniformity of fill materials for Class I dikes are obtained by systematic control of moisture and compaction during placement. Uniformity and adequate compaction of materials for Class II and Class III dikes are obtained through a study of moisture conditions at time of placement and placement methods used. Plastic soils may require added height and considerable maintenance to bring the settled fill to required height after wetting of fill takes place. Nonplastic soils and soils of low plasticity may slump excessively and thus require flatter dike slopes and raising of fills in shallow lifts during construction. Flatter slopes and special protection of the surface may be required on the water side of dikes exposed to flood stages of long duration, heavy wave action, or rapid lowering of the flood stage.

Height of dike

As shown in Figure 6-1, the design height of the dike (H) should be the sum of design high water stage (H_w) and the added height (H_v) for wave action or the freeboard (H_f) which ever is greater. H_s is an allowance for settlement which depends upon the materials used in construction and the method of construction. Maximum H_w is determined by the class of dike to be provided and H_w is based on the water surface profile, or the high water stage. Freeboard H_f is an allowance that is added to the design flood stage without consideration of wave height. Freeboard for dikes should be a minimum of 2 feet, but where wave action is expected, it should be increased to the full allowance for wave height. Wave height allowance should be based on the velocity and duration of wind, distance of open water facing the dike--fetch--orientation of the dike with respect to the angle of waves generated by prevailing winds, the depth of water, and the length of the dike. A lack of specific data on wave height and rideup on dikes requires judgment and consideration of all factors involved in a particular situation.

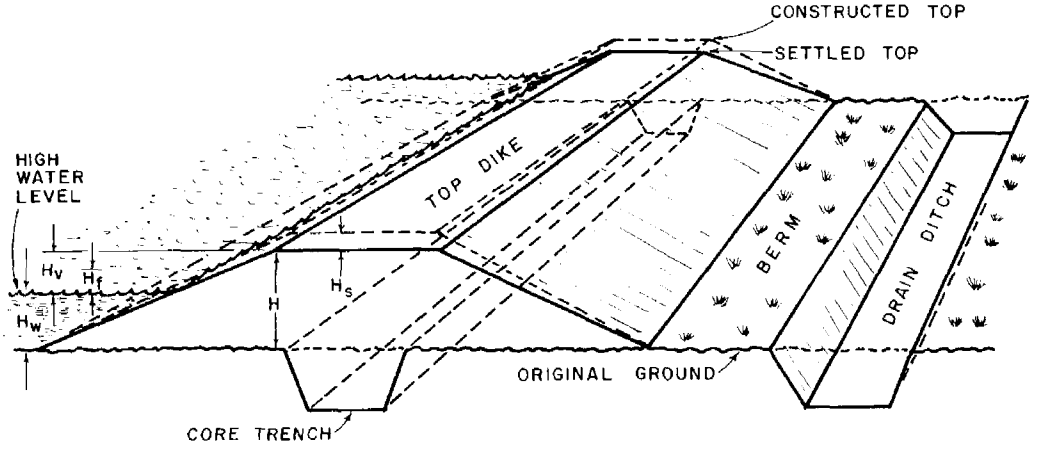

Figure 6-1, Typical dike section

Based on an American Society of Civil Engineers' report, which included a summary of emperical formulas for determination of wave height, the Bureau of Reclamation (1)* prepared a table of wave heights for selected lengths of fetch and wind velocities. Figure 6-2 is a set of curves based on the Bureau of Reclamation's analysis.

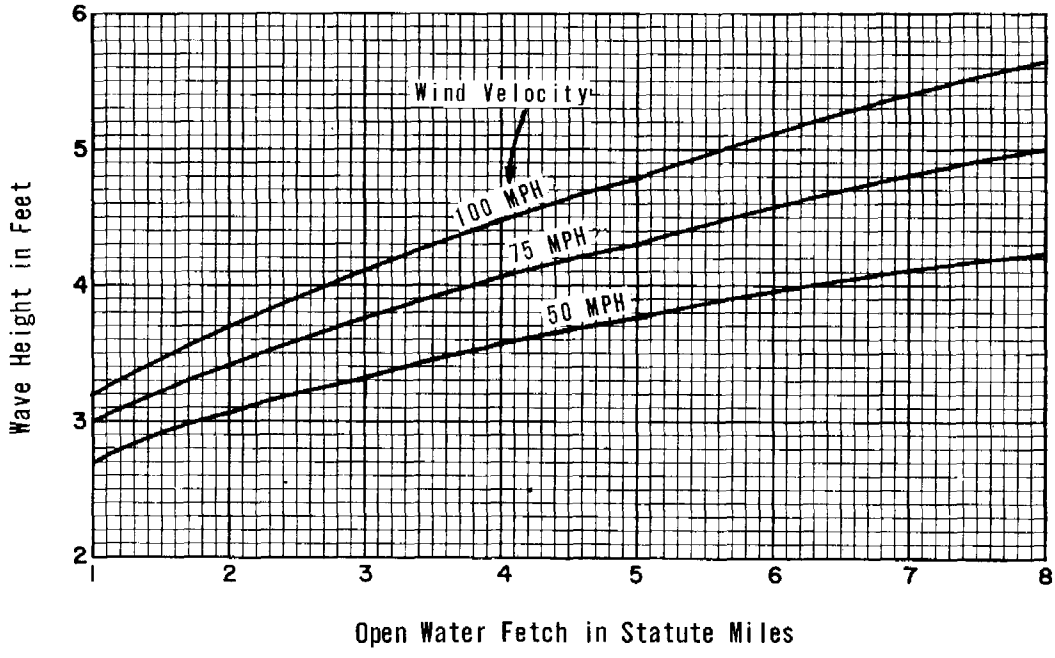

Figure 6-2, Wave height curves

The freeboard allowance for wave height should be sufficient to prevent overtopping of the dike due to wave rideup equal to 1.5 times the height of the wave as given by these curves, measured vertically from the still water level. Wind velocities for determination of allowance for wave height should range from 100 miles per hour for Class I dikes to 75 mph for Class II dikes and 50 mph for Class III dikes.

Vegetative growth between the dike and open water, if sufficiently high and dense, tends to reduce wave heights. In such instances adjustments in H_v should be made based on the type of plant growth, and the condition and permanence of the stand.

Settlement allowance H_s depends upon the soil material in the fill and foundation, and on the method of construction. The moisture content of the soil during construction is most important. Where the dike is to be compacted by construction equipment operating over the area, a settlement allowance (H_s) of not less than 5 percent of the fill height (H) should be included. Where a dumped fill is placed and shaped, the allowance should be not less than 10 percent of the height of the dike. For soils exceptionally high in organic matter, the settlement allowance should be no less than 40 percent since these soils are most likely to be placed in a near-saturated condition and are subject to shrinkage from compaction and oxidation of organic matter.

*Numbers in parentheses refer to references listed at the end of the chapter.

Top width

Top width of dikes should be varied according to soils type, degree of protection required and the depth of water controlled. Top width for Class I dikes of mineral soil should be no less than 10 feet for heights up to 15 feet and not less than 12 feet for heights above 15 feet. Top width for Class II and III dikes of mineral soil should be no less than 6 feet for designed water heights (H_w) up to 6 feet and 8 feet for heights over 6 feet. Top width for dikes of organic soil should be no less than 8 feet. Such dikes should be limited to designed water heights of 4 feet or less. Top widths should be at least 10 feet when the dike is to be used as a maintenance roadway. Additional width for "turn arounds" or passing areas should also be provided as needed.

Side slopes

Side slopes of dikes are dependent primarily upon the depth and duration of water impoundment and the shearing resistance of the earth fill and foundation materials. Side slopes should be 3:1 or flatter on both sides of dikes where soils of low plasticity, such as ML and SM soils, are used in construction. Side slopes should be 3:1 or flatter on the water side when appreciable wave action is expected, or where a steeper slope would be unstable under rapid drawdown conditions. Rapid drawdown can occur when hurricanes pass a given point and gale winds shift rapidly by 180 degrees to blow away from, rather than towards a given point. Rapid drawdown can occur also when flood crests drop rapidly. Land side slopes of dikes must be flattened when fill soils of relatively high permeability are exposed to high flood stages for extended periods of time. The seepage flow through these soils may then progress from water to land side at a relatively slight angle with the horizontal and outcrop on the land side of the dike to create a hazard. This action is most severe if the foundation for the dike is less pervious than the fill.

Side slopes for Class I dikes must be determined from stability analysis of the fill and foundation materials to be used. Where severe wave action is anticipated, unprotected slopes on the water side should not be steeper than 4 horizontal to one vertical.

Side slopes for Class II dikes, where water depths against the fill are less than 6 feet, should not be steeper than 1-1/2 horizontal to one vertical if fill is compacted by hauling equipment or by special compaction equipment after placement, and not steeper than 2 horizontal to one vertical when dumped in place. Where Class II dike fills impound water depths ranging from 6 to 12 feet, slopes should not be steeper than 2 horizontal to one vertical when compaction is obtained by hauling equipment or special compaction equipment after placement and not steeper than 2-1/2 horizontal to one vertical when the fill is dumped. If the water side of dumped fills are flattened to 3 horizontal to one vertical, the land side may in this case be steepened to 2 horizontal to one vertical.

Side slopes of Class III dikes should be based on the general considerations discussed above and experience with dike construction under similar conditions. Dikes constructed from channel spoil may be shaped to the required height and to the approximate cross section specified. The required side slopes may be contained within the dumped fill if it is excess to the minimum requirements.

Core trench

Where dike foundations contain pervious strata or the soils are sufficiently pervious to be subject to piping or undermining, a core trench or foundation cutoff should be provided. The core trench should have a bottom width and side slopes adequate to accommodate the type of equipment to be used for excavation, backfill, and compaction. Backfill should be made with materials equal to or better than those required for the earth embankment. Core trenches are used in both Class I and Class II dikes but are seldom required for Class III dikes. Where pervious foundations for Class I dikes are too deep to be penetrated by a core trench to an impervious cutoff, a drainage system must be provided to insure stability. Table 6-2, is a general guide to indicate conditions where a core trench is needed.

Where Class I dikes are located on pervious foundations, which are so deep that a core trench is not feasible, other means of controlling seepage and protection of the dike from subsurface piping must be used. Ways and means for controlling underseepage include properly designed and constructed land-side banquettes or seepage berms, relief wells and drains, waterside blankets of low permeability, cutoffs and drainage ditches.

The proceedings of a symposium on "Underseepage and Its Control" are included in the Transactions of the American Society of Civil Engineers, Volume 126, 1961, Part 1, pages 1427-1568. This includes a comprehensive treatment of investigations, control measures and construction and maintenance of control measures (2). The reference should be consulted for help with complex seepage problems.

Banquettes

Where dikes cross old channels or have excessively porous fills or poor foundation conditions, the land side toe should be protected by a banquette or constructed berm. Such banquettes may be used to provide construction access and added stability if channel crossings are under water or saturated during construction. The banquette width should be no less than the height of dike above normal ground elevation, and in case of Class I dikes it must meet design requirements determined from site investigations, laboratory analysis of fill materials and compaction methods. The finished top of the banquette should be no less than one foot above normal ground and should slope away from the dike to provide for runoff from the dike. Side slope of the extended section should be no steeper than the land side slope of the dike, see Figure 6-3. When highly permeable soil is used in the embankment over a more slowly permeable foundation, the land side base of dike may need to be extended and the entire dike cross section widened from base to top, in order to keep the line of seepage within the embankment. In this case the width of the banquette does not need to be increased.

Drains

Foundation and toe drains should be used where necessary to insure safety of dikes. These drains must be located on the land side of the dike and have a graded sand-gravel filter designed to prevent movement of the foundation or fill material into the drain.

Field drains must not be installed or permitted to remain, without filter protection, closer to the land-side toe of a dike than a distance equal to three times the design water height for the dike. If field drains are to be installed or remain closer than the distance stated above, they must be

protected with graded sand-gravel filters.

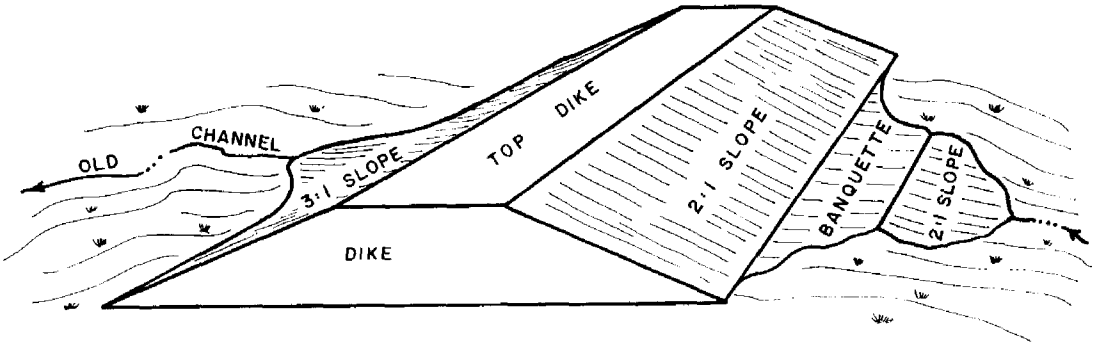

Figure 6-3, Dike section with banquette

Berms

Land-side ditches or borrow pits must be located so that the berm separating dike from borrow or channel is wide enough to protect the dike effectively. For Class I dikes, the berm and land-side ditches or borrow pits must be designed so the hazard of piping through the foundation is not increased. For Class II dikes the minimum width of berm should be 10 feet for heads of water against the dike not greater than 4 feet; and 15 feet for heads greater than 4 feet. For organic soils minimum berm width should be 25 feet. In all cases where the top width of the dike is less than 10 feet, the land-side berm should be at least 10 feet in order to be wide enough to accommodate a maintenance roadway.

Construction

Foundation preparation

The foundation area of dikes should be cleared of all trees, stumps, logs, roots, brush, boulders, or organic matter which would interfere with scarifying the area. All channel banks and sharp breaks should be sloped no steeper than one to one. Organic soil should be removed from the foundation area unless the dike is designed for and is to be constructed from organic soil.

Cutoff trenches, where used, must be excavated to lines and grades shown on the plans, and backfilled with suitable material as specified for earth embankments. Necessary compaction should be obtained by use of proper equipment adapted to the site conditions. The trench must be kept free of standing water during backfill operations. Material from the cutoff trench can be used in the land side of dike section when suitable. Where the dike crosses

old channels, objectionable foundation materials should be removed from the base section of the dike. No fill should be placed upon a frozen surface, nor should frozen earth, snow or ice be placed in the dike.

Embankment construction

For Class I dikes, the fill material must be free of all sod roots, frozen soil, stones over 6 inches in diameter, and other objectionable material. Placing and spreading of fill materials should start at the lowest point of the foundation and the fill brought up in horizontal layers or lifts of such thickness that the required compaction can be obtained with the equipment used. The resulting distribution and gradation of materials throughout the fill should have no lenses, pockets, streaks or layers of material substantially differing in gradation or texture from surrounding materials. Where materials of varying gradation and texture are necessary, the more impervious material should be placed in the water side and center portion of the fill. Moisture content of the fill materials must be such that the required compaction is obtained with the equipment used.

For Class II dikes, the fill material should be free from organic matter and any other objectionable material. The fill should begin on the lowest part of the base and continue in horizontal layers of approximately uniform thickness, preferably 6 inches thick, but no more than 18 inches thick depending upon the equipment used. The construction equipment should be operated over the area of each layer so as to break up the clods and obtain compaction. The impervious materials should be placed toward the water side of the dike. The fill materials should be moist but not too wet to hinder equipment operations. Water should be added where fill material is too dry for proper compaction.

When Class II dikes are constructed with equipment such as a dragline, which is not adapted to layer construction, the fill may be dumped in place and then spread and shaped by other equipment. Excessively wet materials should be placed so they will drain. If the material slumps excessively due to wetness, the dike should be constructed in stages to allow dewatering.

Class III dikes are usually constructed from spoil excavated from drainage ditches. The foundation should be prepared the same as for Class II dikes. Core trenches are seldom used in this class of dike. The spoil is placed to the required height for the dike and shaped. If the spoil is wet, it may be several months before it drains enough to permit shaping. Where additional stability or compaction is needed, the dike should be constructed in stages.

Except when constructed from material excavated from interior drainage ditches, the borrow for dikes is usually taken from the water side of the dike. Occasionally it is necessary to obtain fill from the land side of the dike, especially when it eliminates excavating through highly permeable strata on the water side which could result in excessive seepage through the dike during flood stages. A borrow ditch on the land side may be planned as a unit of the interior drainage system and the excavated material utilized in the dike. Such a ditch should be far enough away from the dike to eliminate undermining, and in accord with the guidelines given under "Berms." Physical features, such as roads, railroads and swamps and the lack of available usable material may require that the borrow be transported from a distant point.

When the borrow pit is located along the water side of the dike, it should be interrupted at intervals by plugs, as this checks velocity of water along the toe of the dike. They should be spaced at intervals not to exceed 400 feet

for Class I dikes and 1320 feet for Class II dikes. When the borrow is significantly stratified, the material for Class I and II dikes should be zoned for placement. In this way the more pervious material can be placed in the land side area and the less pervious soil put in the center or water side of the dike.

Conduits

All conduits through a dike must be placed on a firm foundation. Selected backfill material should be placed in layers around the conduits and each successive layer thoroughly compacted. Antiseep collars which will increase the seep line by as much as 15 percent, should be used on all conduits.

Protection from wave action

Dikes in an exposed position facing open water, may at times be subject to the destructive action of waves. Protective measures to safeguard the dike are necessary. The most widely used protective measures include: (a) heavy sod cover; (b) flat slopes on the water side; (c) extra top width; and (d) location of dike behind a wide foreshore, 100 feet or more in width where possible, on which adapted wave-obstructing vegetation can be established.

An adequate protective cover of grasses should be established on all exposed surfaces of the dike where this is necessary to protect the dike against erosion by flood flows, wave action, or from rainfall and runoff on the dike. The seedbed preparation, seeding, fertilizing, mulching, and fencing should comply with technical guides for the area.

Riprap protection of agricultural dikes is generally not feasible except for Class I dikes and short exposed sections of Class II dikes. Method (d), for protection from wave action, is the most desirable because it helps to dissipate the waves before they reach the dike. Bushy vegetation is best suited for counteracting wave action. This type of protective vegetation should be established beyond the borrow ditch and not on the berm.

Maintenance

The dike should be patrolled periodically and immediately after severe flood stages. Conduits through the dike should be thoroughly inspected as they are points of weakness. Any weakness must be repaired to prevent further damage and so the dike will continue to be effective. A good sod cover over the dike can prevent erosion rills and reduce the maintenance required for the dike. Trees and bushy growth should not be permitted to remain on the dike. Rodents' damage to dikes may be severe and they should be discouraged from burrowing in the dike. Mowing or controlled grazing by cattle is desirable when the slopes are 3:1 or flatter. The grazing must be controlled or the sod will be damaged. Hogs should not be allowed on the dikes. Control of trees and bushy growth with approved herbicides will assist in the maintenance of a sod cover.

Where sand substratum exists, a heavy seepage volume may be expected. Pumps installed at such locations to provide interior drainage should be regulated to keep the elevation of the water in the interior ditches as high as possible during flood stages. By keeping the difference in elevation of the outside water and that of the inside water to a minimum, the tendency for seepage water and sand to flow into the drainage ditches, and the possibility of bank sloughing, loss of capacity in the drainage system, and dike failure will be reduced.

References

(1) UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
1960. Design of Small Dams, U. S. Government Printing Office, Washington, D. C.

(2) TURNBULL, W. J. and MANSUR, C. I.
1961. Underseepage and Its Control, Transactions of the American Society of Civil Engineers, Vol. 126, Part I, pp 1427 - 1568.