CHAPTER 7

IMPROVEMENT OF NATURAL STREAM CHANNELS

Section I. General

7-1. Requirement. The improvement of natural streams for navigation involves channel realignment, stabilization, training structures, and in many cases the modification or replacement of existing bridges. In streams carrying large quantities of sediment, a sinuous channel is easier to develop and maintain than channels in long straight reaches or long flat bends and should be considered in the layout and planning for the project. The sinuosity of a stream varies over a wide range. However, design should be based insofar as practical on the alignment of reaches that have been reasonably stable with a channel adequate for the traffic anticipated. Channel realignment will be required to eliminate or reduce the curvature of sharp bends and the tendency for shoaling. Channel realignment involves corrective dredging, training and stabilization structures, or in some cases cutoffs.

Section II. Dredging

7-2. Corrective Dredging. Corrective dredging is used to realign the channel or bank lines and to develop cutoffs. Dredging in the channel bed involves the removal of erosion-resistant material such as gravel bars, rock outcrops, or clay plugs. Usually dredging within the channel bed without some training or contracting structures will produce only temporary results and might have to be repeated after each high-water period or significant rise in river stages.

Section III. Channel Stabilization

7-3. Bank Erosion. Channel stabilization involves the protection of the banks of streams or canals from erosion caused by currents or wash from waves created by wind and traffic. Natural streams with erodible bed and banks will tend to meander and migrate and, unless this tendency is resisted, will be constantly changing. Erosion of the channel bed along a bank will tend to undermine the bank or steepen its slope to the point that caving or sloughing of the bank occurs. Erosion and caving of banks can adversely affect channel alignment and depth, can increase sediment load and maintenance cost, and could result in the loss of valuable land and endanger local installations such as buildings, rail lines and highways, bridges, docking facilities, and flood-control levees or floodwalls.

7-4. Types of Protection. Bank protection can be a major cost in the development of a waterway for navigation and should be considered during the initial planning of the project. Some of the cost might be considered as part of the flood-control aspects, particularly if it is a multipurpose project. The type or types of bank protection vary depending on the characteristics of the stream, particularly the variations in stage and discharge and the erodibility of the streambed and streambanks. Bank protection and stabilization might consist of structures such as dikes designed to divert currents away from the bank or improve the alignment and velocity of currents along the bank. The most common type of bank protection is some type of revetment covering the bank and channel along the toe of the slope with erosion-resistant material or blanket. In canals with no currents and water level maintained reasonably constant, only a small section of the bank above and below the water line is normally required for protection against wave action. The type of revetment used should be based on experience on waterways of the same general characteristics and construction and maintenance cost.

Section IV. Cutoffs

7-5. Purpose and Method. Cutoffs are used to eliminate sharp bends, eliminate troublesome reaches, reduce the length of the navigation channel, or increase the flood-carrying capacity of the stream. Cutoffs are usually formed by dredging a pilot channel across the neck of one or more bends. The size, slope, and alignment of the pilot cut should be such that the cutoff will develop naturally to take most or all of the flow of the stream. The rate of development of a cutoff depends on the erodibility of the material through which the cutoff is made, size and shape of the pilot cut, length of the cutoff with respect to length of the channel around the bend, and location of the entrance with respect to the alignment of the existing channel. The rate of development of a cutoff can be increased by the gradual closure of the old bendway channel or by structures designed to increase the tendency for shoaling in the upper end of the existing bend and to direct flow toward the pilot cut.

7-6. Old Bendways. In planning cutoffs, the use of the old bendway for recreation and/or harbor facilities should be considered. In many cases, the general practice has been to close off the upper end of the old bend with a closure dike or embankment to eliminate the movement and deposition of sediment in the bend. Structures will usually be required in the lower end of the old bend to reduce the tendency for shoaling and the need for maintenance dredging (fig. 7-1).

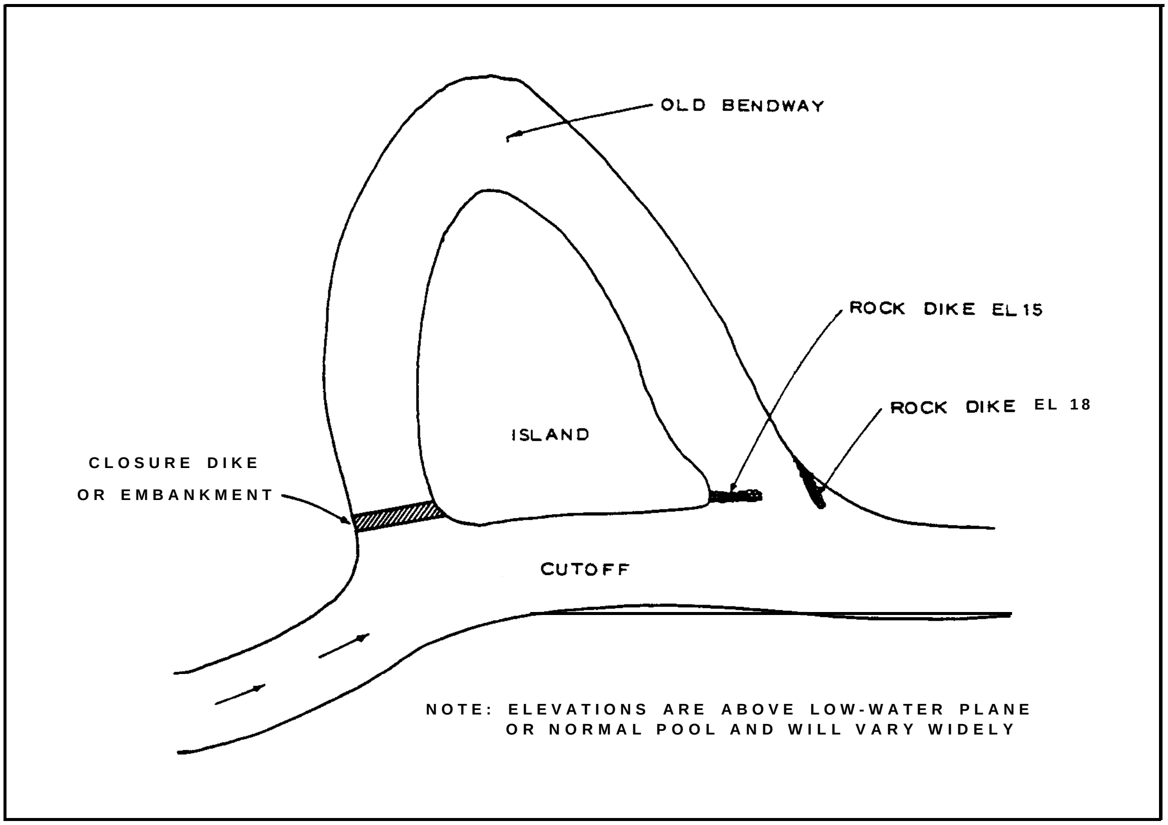

Figure 7-l. Cutoff-old bendway used for harbor or recreation

* Section V
Training Structures

7-7. Introduction

The development and improvement of the alignment, width, and depth of a navigation channel often require the use of river training structures to contract the channel, thereby temporarily increasing velocities and corresponding river depth. Training structures can also be used to realign the channel and stabilize the location of the low-water channel. These structures usually consist of some type of dikes constructed of stone. Historically, dikes were constructed of timber pile clusters or piling with a stone fill. These structures tended to have high labor costs due to the intensive manpower required for construction. Pile dikes tended to fail due to accumulation of drift or ice, rotting, corrosion of bolts and ties, lack of maintenance, and fire. For these reasons the use of pile dikes is very limited. The type or types of structures used and their configurations should be based on the characteristics of the stream, problem or problems to be resolved, and conditions contributing to the problem The design of the structures should consider the effects of the structures on currents existing in the reach, the movement of sediment, and the effects of the resulting currents on navigation.

7-8. General

The use of dikes on navigable rivers meets the need for permanent structures with a low maintenance cost The dikes are effective at confining the river in a single channel, with the goal of providing depths suitable for commercial navigation at the full range of expected flows. Also, the use of dikes minimizes or eliminates dredging for channel maintenance. Channel dredging is only a temporary measure, and dikes can significantly reduce the need for maintenance dredging. Dikes function continually at all river stages and concentrate the river's energy into a single channel to control the location and depth of the navigation channel and impact the erosional and depositional characteristics of the river. The dikes not only must be capable of controlling the low-water navigation channel, but should not unduly restrict the flood-carrying capability of the river. Dikes have been known by a variety of names throughout the years, such as groins (or groynes), contracting dikes, transverse dikes, cross dikes, spur dikes, spur dams, cross dams, wing dams, spurs, * and jetties. All of these names typically apply to a river training structure that is approximately normal to the riverbank, is attached to the river bank, and contracts the natural river channel but does not transverse the entire river channel. Other types of river training structures include longitudinal dikes, L-head dikes, vane dikes, and bendway weirs or submerged sills (Figure 7-2).

7-9. Spur Dike Design Parameters

A spur dike is defined as a structure placed approximately perpendicular to the bank line to concentrate the flow into a single channel. **The** design of spur **dies must** consider parameters such as channel alignment, contraction, dike length, dike height, crest profile, crest width, side slopes, end slopes, dike angle, dike spacing, stone size, bank paving, and method of construction (Figure 7-3).

7-10. Channel Alignment and Contraction

The layout of river training structures normally depends on the limits of contraction required to maintain a self-scouring channel of adequate width and depth through the full range of flows to permit continuous navigation. It is desirable to keep the degree of contraction to a minimum so that during flood flows, velocities are not too high for safe navigation- The amount of contraction should not unduly increase flood heights, and the channel should be capable of carrying the sediment load associated throughout the full range of flows. The limits of contraction, called channel controllines or rectified channel lines, are normally determined through a combination of experience, use of model studies, and qualitative analysis of existing river cross sections and sediment data. Analytical models may also be useful in determining the impacts of various channel alignments and contractions on flood heights, velocities, and sediment-carrying characteristics. Through experience and judgment the designer can evaluate various reaches of the stream that maintain adequate depths with natural contractions, and use that information as a basis for determining the required contraction for other reaches. Using model studies, either physical or numerical models, a contraction width can be determined for the problem reach or reaches and integrated into the composite design. The qualitative analysis method is normally required when a system is converted from an open river condition to a canalized waterway using locks and dams. In this particular case, river training structures are often required in the reaches immediately downstream of the locks and dams to maintain the required channel dimensions without dredging.

7-11. General Channel Plan

After the contracted channel width has been determined, it is necessary to lay out the desired channel alignment within the existing project limits. In some cases a major channel realignment including a cutoff may be required to meet the project requirements, but in most cases the contracted channel can be laid out within the existing channel top banks (Figure 7-4). The contracted channel width is established on

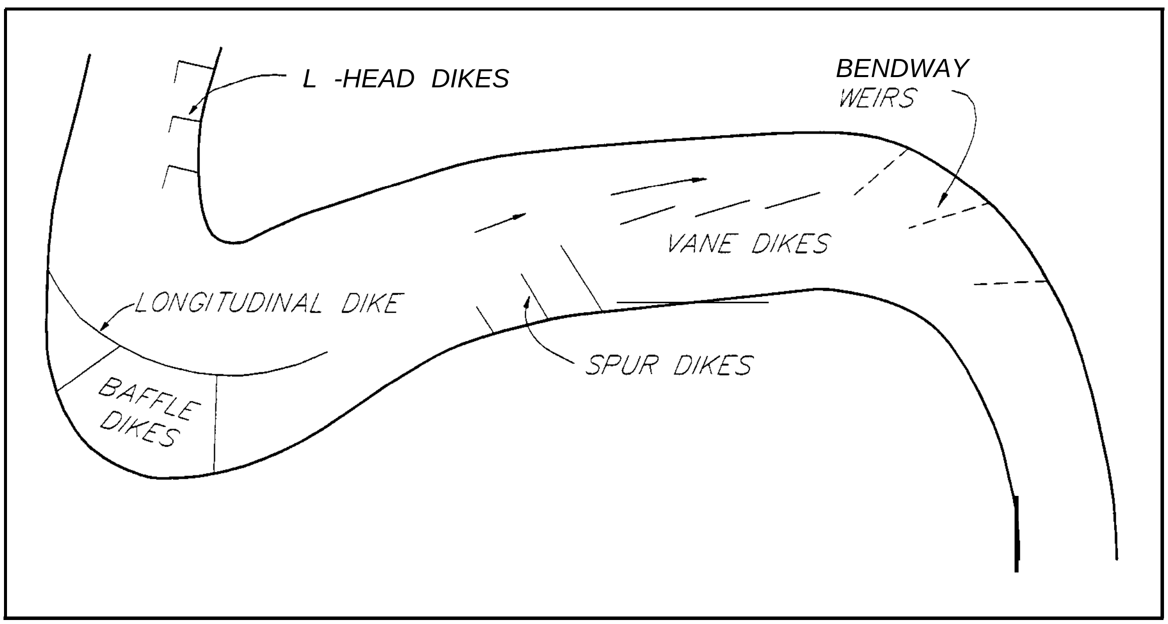

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Figure 7-2. Types of training structures in use

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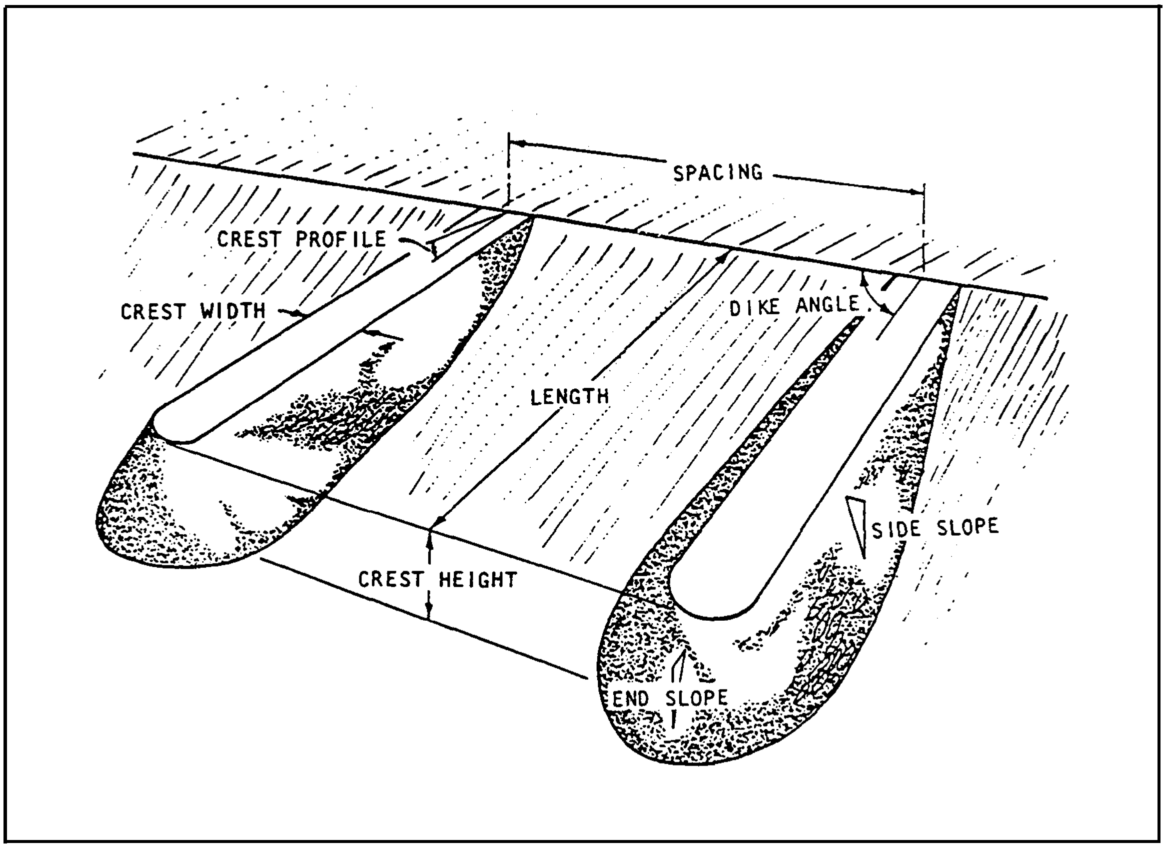

Figure 7-3. Stone spur dike parameters

the map with the channel control lines providing the designer with the right and left channel limits. This map is in essence the "blueprint" for the desired channel alignment. Although minor adjustments of the alignment may be necessary in the future to account for changes in the project, this map serves a master plan for the project and the eventual goal for design purposes. The most important point to be made relative to the contracted channel layout and establishment of the channel control lines is that every effort should be made to follow the natural river tendencies and to avoid a "forced" channel alignment. By following the natural pool-crossing-pool sequences and sinuosity and providing smooth transitions between bends and adequate crossing lengths between pools, dredging maintenance costs will be minimized or entirely eliminated. The design should ensure that crossing lengths are not too long, which may encourage the development of middle or alternate bars within the channel (Figure 7-5). Experience has shown that river reaches that have been over contracted, poorly aligned, or established against the natural tendencies of the particular stream tend to have high maintenance costs, poor navigation conditions, or difficulty in maintaining adequate channel dimensions. The designer should make every effort to ensure that the final layout is compatible with the existing natural channel layout and that realignments fit within these limits. At a given cross section, dike length is the major parameter that controls the amount of channel contraction, while the dike height and crest profile impact the stability of the dike system.

7-12. Dike Length

The length of spur dikes is controlled by the desired contracted channel width, since dikes extend from the bank to the channel control line on the same side of the river. There are instances where dikes may have lengths that infringe on the channel control lines, but these are special situations where some slight added contraction is required due to site specific conditions and/or where the portion of the dike river-ward of the channel control line was at a significantly blower elevation than the main portion of the

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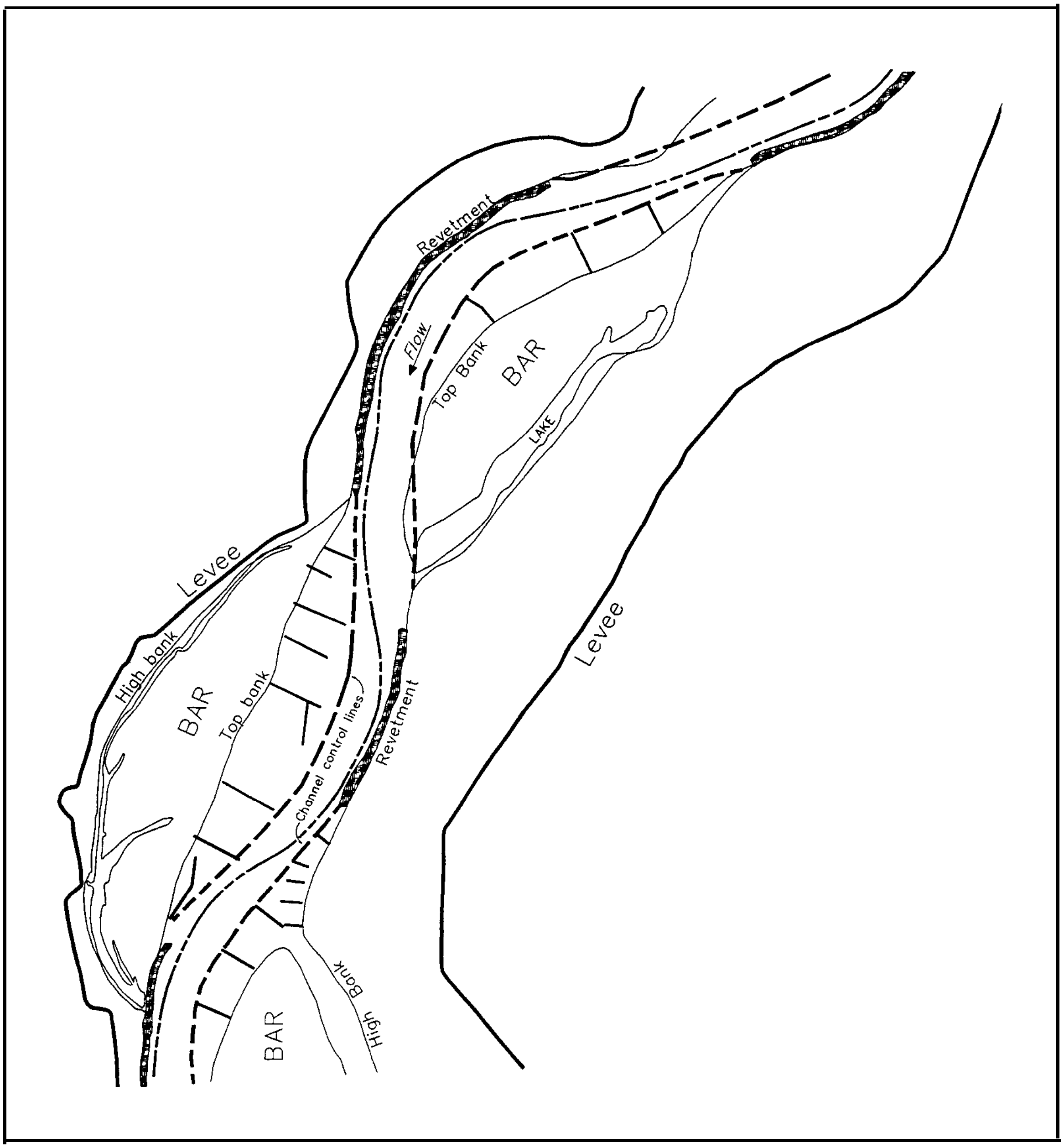

Figure 7-4. Example of layout for channel control lines

dike. Providing dike lengths to the desired channel control lines is adequate for initial construction; however, once the stream has reacted to the dikes, modifications and adjustments may be required.

7-13. Dike Height

The height or top elevation of dikes is normally associated with a sloping reference plane parallel to the water surface through the project. In open river projects the reference plane may be called Annual Low-Water Plane (ALWP), Low-Water Reference Plane (LWRP), or Construction Reference Plane (CRP). In canalized waterways the reference plane is normally called the upper pool elevation upstream of the dam and lower pool elevation downstream of the dam. The elevation of the dikes relative to the water surface can have an important bearing on the structure

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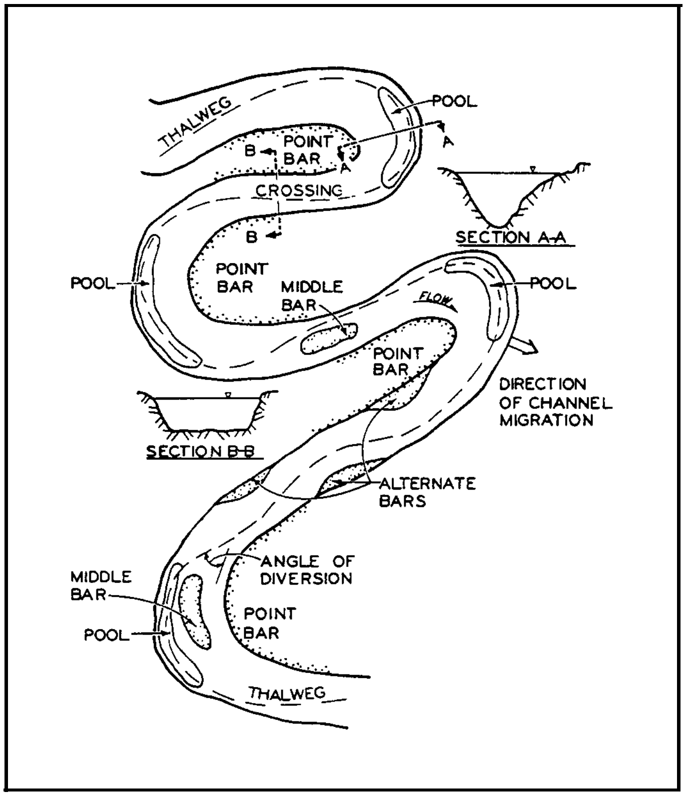

Figure 7-5. Channel planform

performance, its impact on the stream, and its impact on the areas within the dike field. On open river portions of the Mississippi River the top elevation of dikes varies from about 10 to 15 feet above the reference plane. Normally this puts the height of the dikes approximately at the elevation of the midbank. On the Missouri River, au analytical procedure is used that assists in selecting the proper dike height. The procedure provides a design relative to a flow and/or stage-duration curve of the river and particular reach. Specifically what is being addressed is the percent of time that a given stage or discharge is equaled or exceeded. This kind of information assists in determining the chances of dikes being overtopped when constructed to various elevations, and provides a methodology for selecting the height to which certain structures should be constructed and maintained. Generally speaking, dikes constructed to lower elevations will require more maintenance then dikes constructed to higher elevations. Experience on the Missouri River has shown that dikes that are seldom overtopped will usually develop a significantly different depositional pattern downstream of the dike than those that are frequently overtopped. Areas downstream from dikes that are frequently, but not continuously, overtopped will develop a shoaling pattern within the dike field that is almost uniformly at or slightly above the normal water surface elevation. Dikes that are seldom overtopped will form a depositional pattern immediately downstream and landward of the stream end of the dike that often leaves au open water area between the deposit and the original bank line. On canalized projects the top elevation of dikes is referenced to the normal pool elevation, the minimum regulated pool elevation or some similar reference. In pools the top elevation of the dikes is about 2 or 3 feet above the pool elevation regardless of the location in the upper or lower pool. That elevation is a minimum to ensure that pilots can see the dikes and be aware of the existence of river training structures in that location.

7-14. Adjacent Dike Heights

The relationship between the height of adjacent dikes in a system, three dikes or more, is also of importance. In certain applications a stepped-down dike system (dike elevations decreasing moving downstream) promote accumulation of bed material within the dike field and provide for a continuous navigation channel adjacent to the
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dike field. In some of the dike systems on the Mississippi River a stepped-up dike system (dike elevations increasing moving downstream) has been used to follow the tendency of the bars built naturally by the river. The stepped-down system appears to be the more preferred with dike elevations decreasing by 1 foot from the dike immediately upstream.

7-15. Crest Profile

The crest profile of spur dikes, most often used, is level from the bank to the stream end; however, variations to this parameter may be preferred at times. A crest profile sloping down from the bank *to stream* end is useful if a wide range of river stages are encountered, if a decrease in the amount of contraction is advantageous as river stages increase, or if some erosion of the fill material within the dike field downstream of individual dikes is acceptable. In such cases the total drop in elevation over the length of the dike is about 5 feet. Other applications that merit consideration maintain a level crest profile over the length of the dike except for the extreme riverward end where the profile is sloped downward to reduce the channel contraction near the end of the dike and reduce the possibility of severe scour undercutting the stream end of the dike. In the past, stepped profiles (Figure 7-6) have been used on navigable rivers in the United States; however, maintenance of such structures tended to be costly to ensure such varied profiles were maintained without obvious significant benefits to do so.

7-16. Crest Width

The width of the crest of a spur dike is generally determined by the method of construction, but with a minimum design width of 5 feet. Dikes constructed from a barge usually have a crest width of 10 feet, while those constructed by truck have a crest width of 10 to 14 feet. Experience has shown in river reaches susceptible to ice flows that dikes with crest widths of less than 6 feet will have the top portion of the dikes sheared off as the ice starts moving in the stream. It is generally accepted that peaked dikes should be avoided since the loss of a small quantity of stone

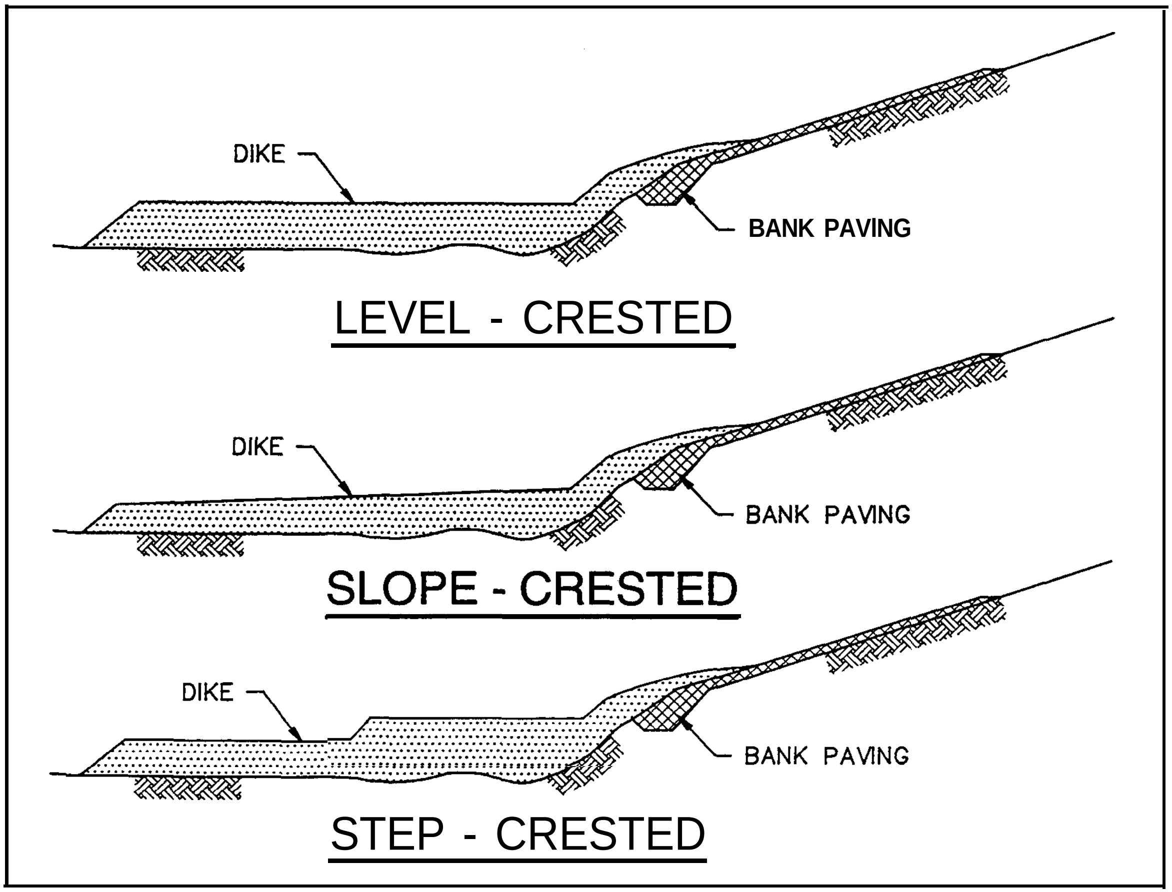

Figure 7-4. Stone spur dike crest profiles

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will produce a gap in the dike. This gap could cause scour and possible breaching of the dike with the dike becoming will produce a gap in the dike. This gap could cause scour and possible breaching of the dike with the dike becoming separated from the bank end of the dike. One other method for determining dike crest width is to design the dikes based on the stone size used and the height of the dike. In this case the crest width is allowed to vary so long as the minimum width of 5 feet is maintained. Summarizing, there is some variation in the crest widths used for spur dikes, but virtually all dikes fit withintherangeof 5 to 20 feet with the majority of dikes constructed with a crest width of 5 to 10 feet

7-17. Side Slopes

The side slopes (upstream and downstream faces) of spur dikes usually are maintained on the natural angle of repose of the stone used to construct the dikes. Although this angle varies somewhat depending on the particular stone used the angle is about 40 degrees, which produces a slope of 1V on 1.25H. Normally the side slopes used on the designs of stone spur dikes, including computation of required stone quantities, is 1V on 1.25H to 1V on 1.5H with the difference being a function of the particular stone, the dike height, and the velocities and depth of water that stone has to fall through during construction.

7-16. End Slopes

Although the slope of the stream end of a dike can be as steep as the natural angle of repose (40 degrees or 1V on 1.25H), it is advisable to construct the dike with a somewhat flatter end slope. The stream end of the dike is the point of contraction and is susceptible to the most bed scour as a result of the streamflow moving around the end of the dike. The steeper the slope on the stream end the greater the chance for loss of stone as end scour occurs. During the design it should be considered how much of the dike length can be lost due to launching of the stone at the stream end and still maintain the effectiveness of the die. Often an end slope of 1V on 5H is used where significant scour is anticipated, but in some unusual and severe scour circumstaucesanendslopeofasflatas 1V on 10H has been used.

7-19. Dike Angle

The angle that a dike makes with the river bank is an important factor in the location and amount of scour that occurs at the stream end of the dike and the location of the channel that develops adjacent to the dike. Model tests conducted over the years indicate that when dikes are angled upstream the scour at the end of the dike will be greater and the adjacent channel will be farther from the dikes than systems that are normal or angled downstream. Dikes angled downstream are as effective as those normal to the bank; however, care must be taken with dikes angled downstream to take into account possible flanking of the bank end of the dike. In most applications dikes are constructed normal to the adjacent bank line or angled slightly downstream, about 10 or 15 degrees. The approach with such systems is that the angled dike generally reduces the attack on the entire system

7-20. Dike Spacing

The spacing of dikes within a system should be great enough that the least number of dikes (and least stone) are built while still maintaining the effectiveness of the system If the spacing is too great, the channel will tend to meander between the individual dikes. If the spacing is too small, the system effectiveness will be equal to that of the ideal spacing; however, such a system will have a greater initial cost without greater benefits when compared to the ideal system. For this reason, structure length and spacing are not considered independent parameters, as a longer structure will generally indicate that the structure spacing cau also be increased. Experience has shown that a spacing of two-thirds of the length of the upstream dike produces a system that is effective. On streams with dike lengths of about 1000 feet, spacings of 1-1/2 to 2-1/2 times the length of the upstream dike have been used. However, on larger streams, such as the Lower Mississippi River, which have extremely long dikes to reach the channel control line, this guidance would provide an undesirable spacing. In such cases a maximum spacing of 3,000 to 4,000 feet is normally used. Experience on the Missouri River indicates spur dike length is seldom uniform throughout a river reach, but that the dikes are spaced such that the flow passing around and downstream from the stream end of the structure intersects the next dike prior to intersecting the bank line. The rule of thumb used by the Missouri River designers for dikes on the convex side (outside) of bends is a spacing of 2 to 2-1/2 times the structure length. Another method used in the past on the Missouri River was to assume that the flow expanded on a ratio of 5 to 1 in the longitudinal direction from the tangent of the flow line off the stream end of the upstream dike with the next downstream dike placed slightly upstream of the intersection of this theoretical expansion line and the bank line.

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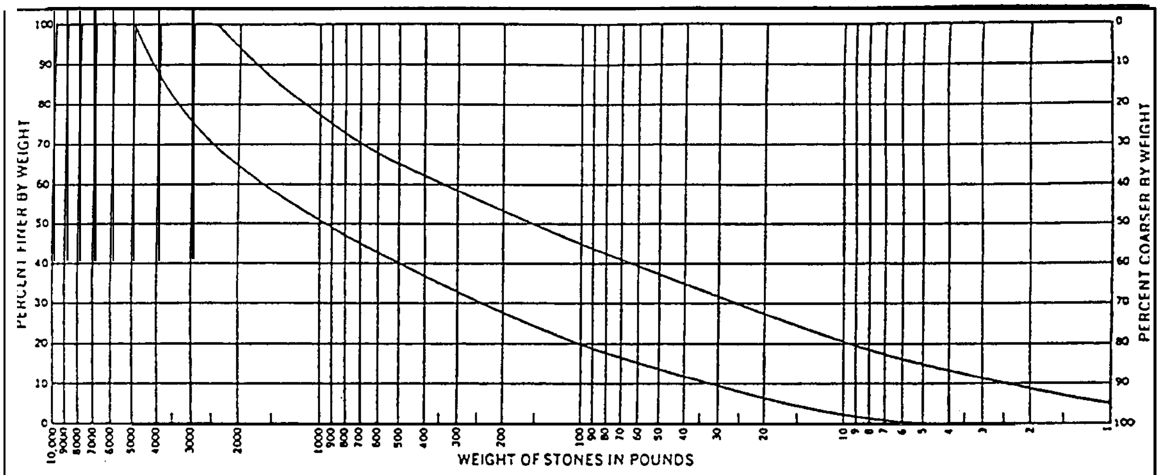

STONE WEIGHT (LBS)	CUMULATIVE % FINER BY WEIGHT
5000	100
2500	70-100
500	40-65
100	20-45
5	0-15
1	0-5

* ASSUMING STONE SHAPE MIDWAY BETWEEN A SPHERE AND CUBE

U.S. ARMY ENGINEER DISTRICT, VICKSBURG
CO., OF ENGINEERS
VICKSBURG MISSISSIPPI

GRADATION
GRADED STONE A

Figure 7-7. Quarry-run stone gradation curve

7-21. Stone Size

The stone used on spur dikes is normally classified as quarry-run stone, which has a size variation depending on the particular stone available in the area. The larger stones are used to cover the surface of the spur dike and the smaller stones are used on the internal section. On the Lower Mississippi River, quarry-run stone has 5 percent by weight passing a 1/2-inch screen, 10 percent less than 5-pound pieces, 50 percent between 400 and 1,000 pounds, and no pieces larger than 5,000 pounds- Figure 7-7 is the gradation curve used for contracting for quarry-run stone on the Lower Mississippi River. On smaller navigation projects such as the Arkansas River, the stone gradation used for spur dikes has 5 percent fines, 50 percent larger than 40 pounds, and a maximum size of 1,000 pounds. On the Missouri River, the stone used in the original construction of dikes was classified as pit-run stone with a 2,000-pound maximum size on the lower two-thirds of the structure and 500 pounds maximum for the top one-third of the structure and paving of high banks. The stone presently used on the maintenance of the Missouri River dikes has 100 percent lighter than the range of 393 to 954 pounds, 50 percent lighter than 197 to 252 pounds, and 15 percent lighter than 62 to 146 pounds. This gradation is partially a function of the improvement in construction techniques and the availability of a commercial quarry for the stone. The key for selection of the particular stone to use in the construction of the dike is the availability of material and obtaining the most reasonable price to minimize the cost. A smaller percentage of fines in the stone is acceptable if obtaining such stone is the most economical. Some of those fines may be lost during actual construction, but such losses are expected and can be taken into account when ordering the stone.

7-22. Bank Paving

The paving of the bank adjacent to the bank end of the spur dike may be required to control scalloping of the bank line and possible flanking of the structure. The riverbanks on the Mississippi River are typically paved or revetted 100 feet upstream and 200 feet downstream of a spur dike. On some smaller rivers, such as the Arkansas and Missouri Rivers, bank paving upstream and downstream of the dike * typically varies from 50 to 75 feet. Some bank grading may be required, but essentially the same procedures and methods incorporated on the stream for bank protection using revetment should be incorporated in the bank paving for a dike. If the bank end of a dike is terminated in an easily erodible material, a trench fill should be used to key the dike into the bank. This will control possible flanking of the spur dike by ensuring that the bank material remains in place during high overbank flow events.

7-23. Method of Construction

The preferred method of construction is to construct the dike in lifts for the entire length of the dike. The lifts are normally about 4 or 5 feet in height. The advantage of tbis method is that it limits any abrupt contraction of the channel and possible scour of the bed as the dike is being constructed. A die constructed to its design crest height and length in a single stage will gradually complete the channel contraction from the bank end, but may cause excessive scour at the end of the spur dike as construction is under way and result in excessive material costs. Building spur dikes in stages (or lifts) over several construction seasons will take advantage of the sedimentation that occurs downstream of the spur dike. This is a very cost effective method of construction if, during those construction seasons, a reduced effectiveness of the dike is acceptable. Dike construction can be accomplished using land-based equipment or river-based floating plant Where permissible, construction from a floating plant is often more cost-effective, as transportation of construction materials by barge is usually the least expensive. Model studies have indicated that a preplanned construction sequence may be beneficial when laying out a dike system, where the most upstream dike or dikes are constructed first, then the river is allowed to react to this construction prior to installing the next downstream structures. This procedure assists the designer in determining the most desirable structure spacing and orientation, and also can have cost benefits by taking advantage of newly formed deposits as a result of the upstream construction, thereby reducing the required volumes of dike material. Disadvantages include an extended construction period and delays in achieving the required channel dimensions.

7-24. Longitudinal Dikes

Longitudinal dikes are continuous structures extending from the bank downstream generally parallel to the alignment of the channel being developed (Figure 7-2). Properly designed longitudinal dikes are the most effective type of structure in developing a stable channel since such structures are basically a false bank line; however, these structures are the most expensive to construct due to their long length and required tie-in or baffle dikes. Longitudinal dikes can be used to reduce the curvature of sharp bends and to provide transitions with little resistance or disturbance to flow. However, once in place, it is difficult and expensive to change the alignment of the dike. Figure 7-8 shows the application of a longitudinal dike on the Arkansas River. It should be noted that the tie-in dikes

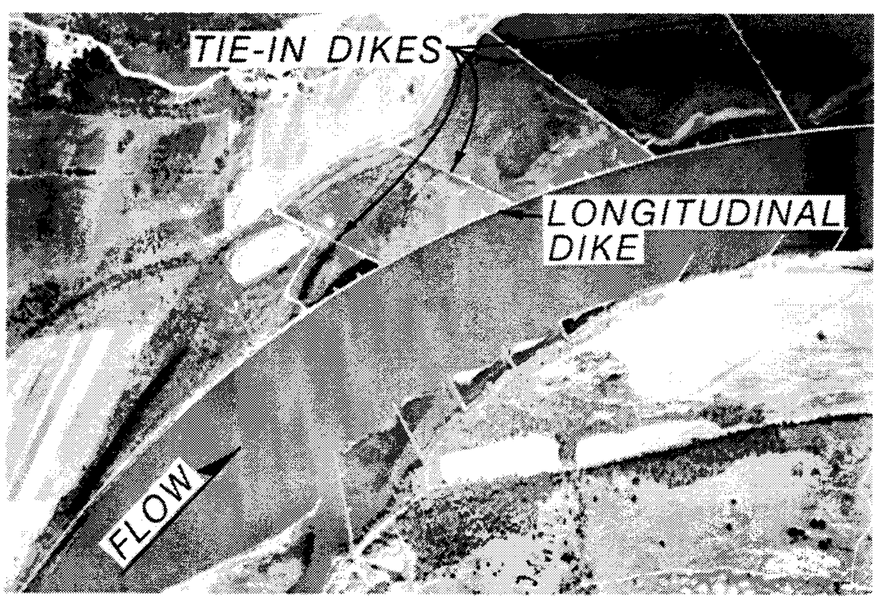

Figure 7-6. Longitudinal dike on Arkansas River

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* landward of the longitudinal dike add stability to the entire structure. These tie-in dikes can also be modified using notches or openings to enhance the habitat and maintain open water areas on the back side of the longitudinal dike.

7-25. Vane Dikes

Dies placed in the form of a series of vanes have proved effective as a means of controlling channel development and sediment movement under certain conditions (Figure 7-2). These dikes consist of segments of dikes located riverward from the existing bank with gaps between the dikes (Figure 7-9). The length of the gaps between the dikes is usually about 50 to 60 percent of the length of each vane. Usually all of the vanes in a system are of equal length. The dikes are placed at a slight angle to the direction of flow, about 10 to 15 degrees, with the downstream end of the dike farther riverward than the upstream end. The system should be placed in an area where there is or will be movement of sediment. These dikes have been used on the major navigable rivers in the United States as independent systems or in conjunction with spur dike systems. Vane dikes are often less expensive than conventional dikes since they can be placed in relatively shallow water aligned generally parallel to the channel control line and produce little disturbance to the streamflow. Figure 7-10 is au example of a vane dike system on the Mississippi River. On some of the vane dike systems that have been in place for many years some of th vanes have been connected to the bank line with a spur dike creating an L-head dike. This modification was undertaken after significant shoaling of material between the vanes and the area landward of the dikes had taken place.

7-26. L-Head Dikes

L-head dikes are spur dikes with a section extending downstream from the channel ends generally parallel to the channel line (Figure 7-2). The addition of the L-head section can be used to reduce the spacing between spur dikes, to reduce scour on the stream end of the spur dike, or to extend the effects of the spur dike system farther downstream. L-heads tend to block the movement of sediment behind the spur dike. When the L-head crest is lower in elevation than the spur dike crest, surface currents coming over the top of the L-head can cause scour on the landward side. L-head dikes have also been used to reduce shoaling in harbor entrances or to maintain an opening in the downstream end of a bypass channel. Figure 7-l 1 is an example of use of L-head dikes on the Mississippi River to reduce the effects of a major bank line discontinuity. In such an application a longitudinal dike would have been effective also; however, it is obvious from the photograph that use of L-head dikes was probably as effective, but at a much reduced cost due to significantly lower quantity o.

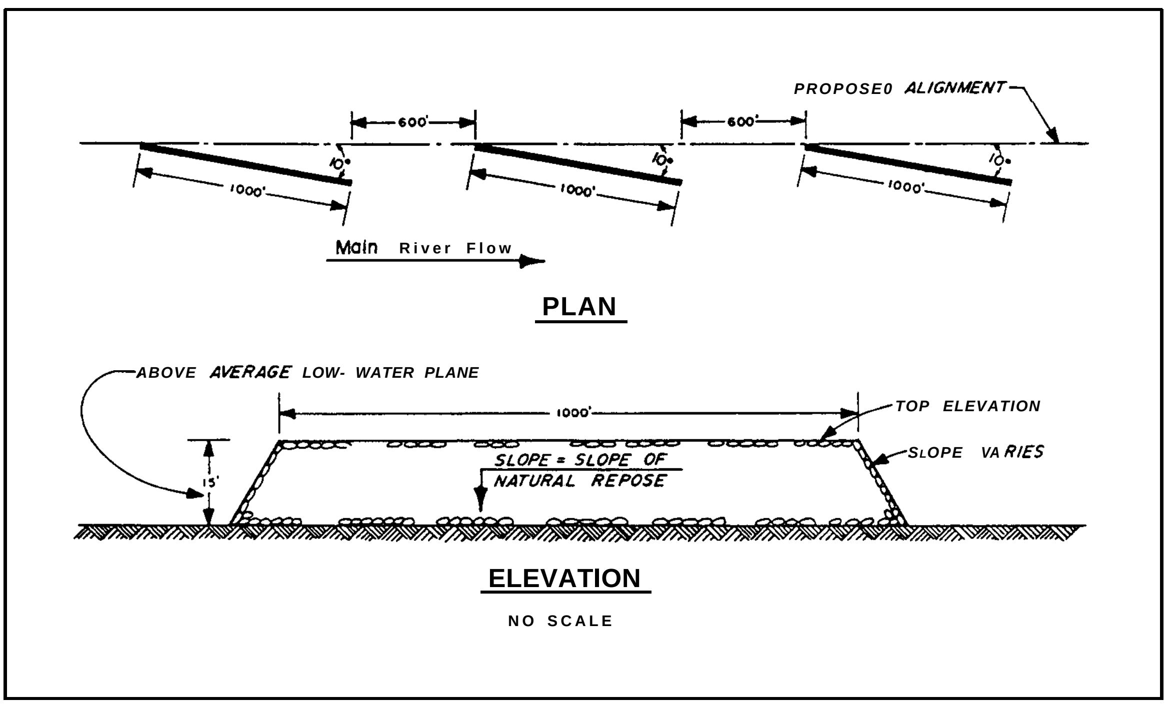

Figure 7-9. Vane dike layout

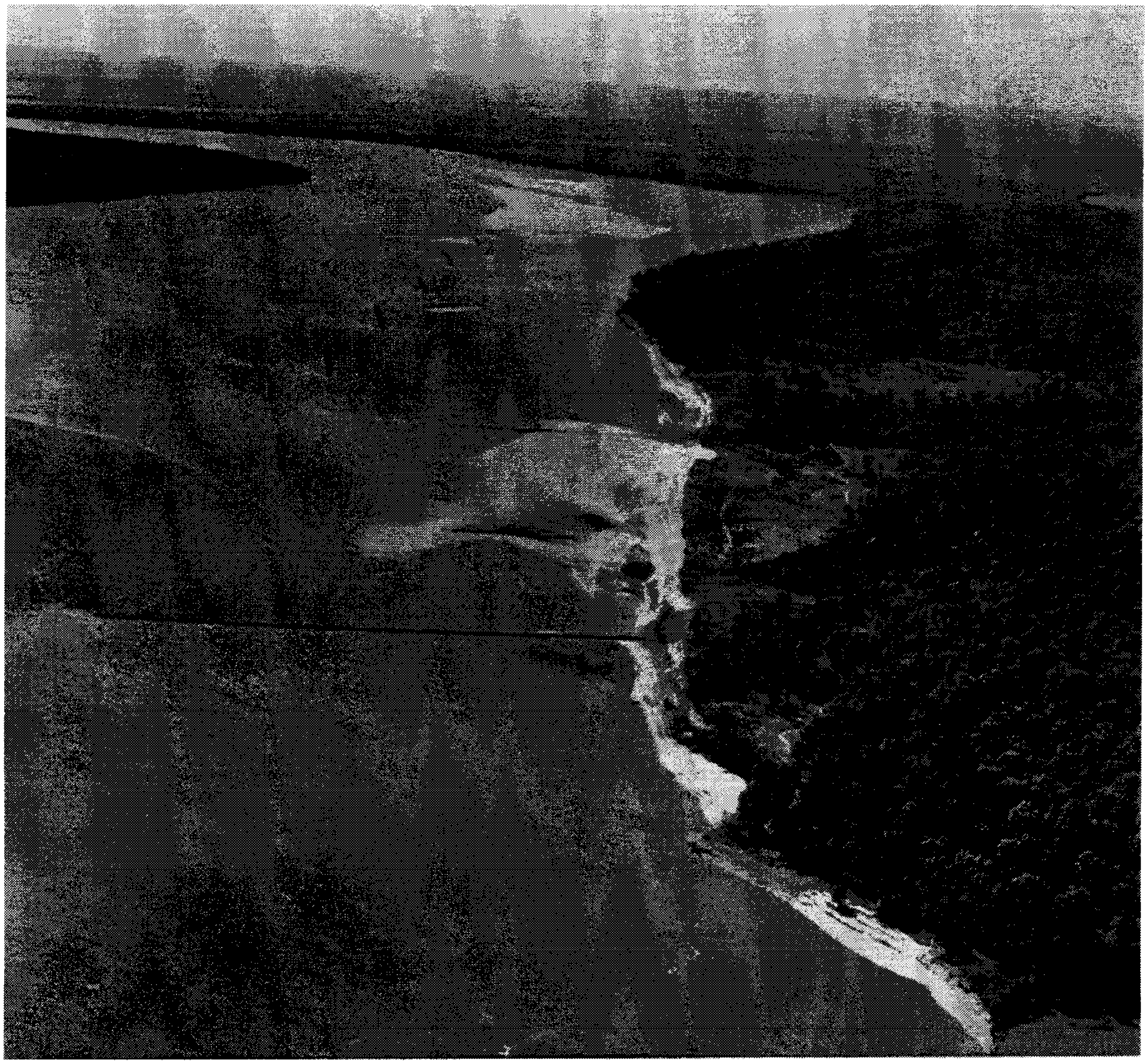

Figure 7-10. Vane dike system on the Mississippi River near Greenville, Mississippi

stone required to construct the L-head dikes verses a longitudinal dike.

7-27. Closure Dikes

River reaches that include islands and divided flow tend to have limited depths in part due to the loss of energy through the secondary channel. In the past such cases were modified by reducing or eliminating the low and medium flows from all but the main channel being developed for navigation. This was accomplished by diverting sediment into the side channels or constructing closure structures across the side channels. Sediment could be diverted into the side channel using spur dikes, vane dikes, or a combination of both. Within the secondary channel the closure dikes will further reduce the velocities in the channel and enhance the depositional tendencies in that channel. When the length of the side channel is short relative to that of the main channel, as is the case in a bendway, closure dikes across the secondary channel tend to be difficult to maintain because of the high head differential that develops across the dike and the subsequent scour downstream of the dike. In such cases, closure structures in the secondary channel should have at least two dikes. With the dikes constructed at successively lower elevation moving downstream the total drop in the secondary channel will be divided between structures, which will reduce the amount of scour that would tend to endanger a single structure (Figure 7-12).

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Figure 7-l 1. L-head dikes on the Mississippi River

7-28. Dike Notches

In recent years notches or environmental gaps have been added to new or existing dike systems to preserve open water areas for channel conveyance and environmental enhancement. The notches have created habitats that seem to be relatively large surface areas of quiet, slack water during medium to low river stages. This has been accomplished with apparently little adverse impact on the primary purpose of the dikes to maintain adequate navigable channel depths on the project The notches add to the wetted perimeter within the dike field, which helps diversify the habitat. These notches are created by removing stone from existing dikes, leaving notches during repair of damaged dikes, or designing notches in a new dike. The notches typically are constructed with a triangular or trapezoidal section with lengths varying from 20 to 100 feet (along the axis of the spur dike) and depths of 3 to 12 feet below the crest elevation of the dike (Figure 7- 13). Notches installed in closure dies have also been helpful in maintaining a limited amount of flow through secondary channels as habitat enhancement in those areas.

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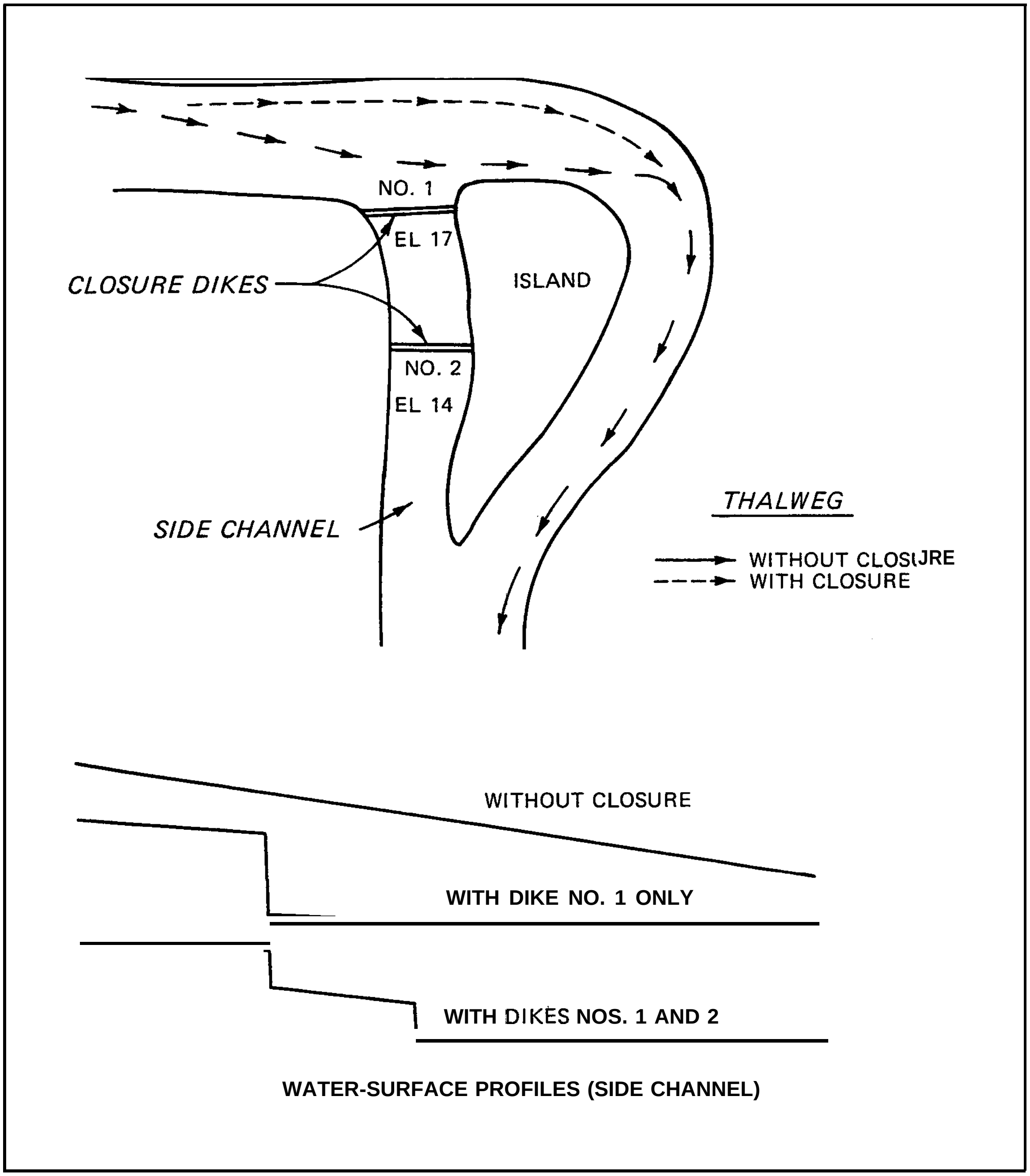

Figure 7-12. Side channel closure

7-29. Bendway Weirs

A recent development in river training structures involves the concept of bendway weirs to modify the channel in bendways. Typically the natural riverine processes will create a point bar on the inside or convex side of the bend (Figure 7-5). In certain instances the point bar will encroach into the navigation channel, requiring maintenance dredging to widen the channel and restore the design channel dimensions. Bendway weirs are submerged sills constructed in the navigation channel (within the channel control lines) angled upstream at au elevation of 15 to 20 feet below the record low water for that portion of the
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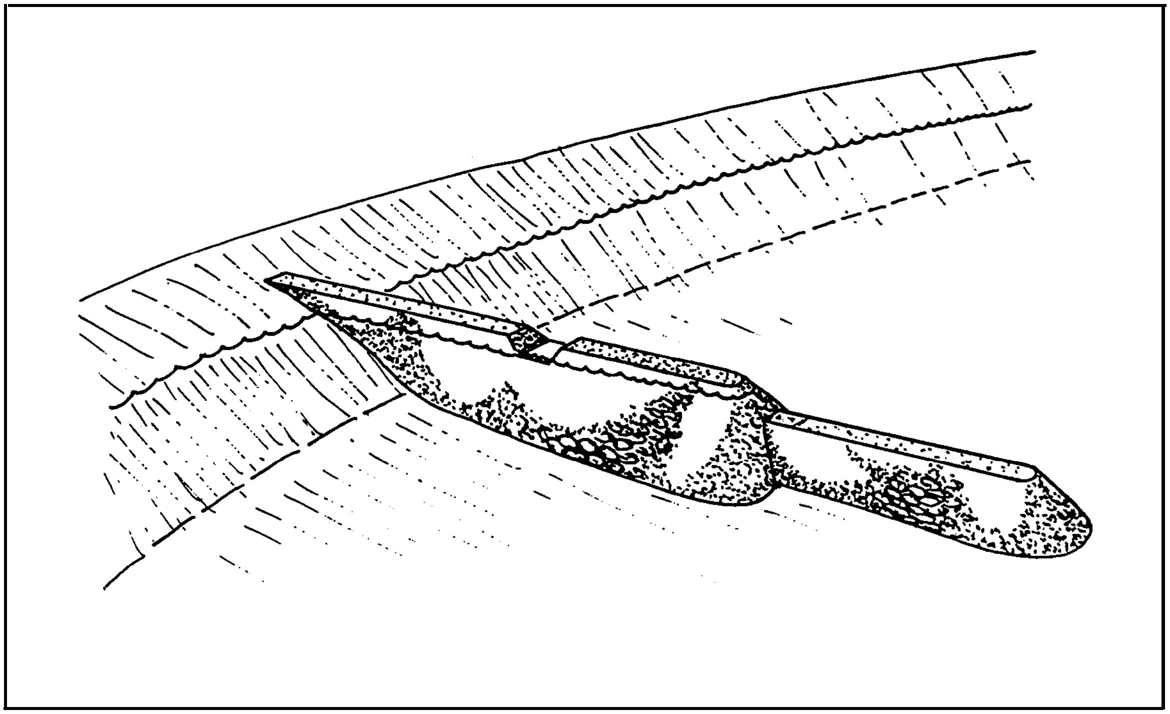

Figure 7-13. Spur dike with notch

river. The concept was model tested and developed on a portion of the Mississippi River upstream of the confluence with the Ohio River. Since being constructed in the prototype, the bendway weirs have performed exceptionally well with significant reduction in maintenance dredging quantities in a short period of tune, significant improvement in navigation channel width, increased bank line stability of the concave bank, and improvement in the crossing downstream of the weirs. The concept of installing submerged weirs or sills is not new to river training (paragraph 10-4). Previously model tests were conducted to investigate underwater sills on the convex bank of a Missouri River bend, but this new application on the concave bank in bendways and angling the structures upstream is an innovative approach in river training structures. At this time no general design guidance is available for inclusion in this manual; however, research is presently being conducted to develop appropriate design parameters. As the appropriate data are analyzed and reviewed, the design parameters for bendway weirs will be included in future manual updates.

7-30. Benefits of Bendway Weirs

Model study results indicated that installation of bendway weirs in a problem reach could potentially provide additional benefits beyond the desired one of increasing the width of the navigation channel in the bend. Since the weirs are located on the outside (concave bank) of the bend in the deep portion of the channel, some of the secondary currents that tend to concentrate flow along the outside of the bend arc broken up. This improves the flow conditions through the bends: high-velocity currents are no longer concentrated on the outside of the bend, thus the resulting currents are more evenly distributed across the channel. These lower, more evenly distributed currents make navigation conditions safer and more efficient for the towing industry. The redistribution of the currents also allows bed material to accumulate on the outside of the bend in the deep portion of the channel, which adds stability to the bank line. Tests also indicated that there may be an improvement in the navigation channel immediately downstream of the reach with bendway weirs. This change is a result of the redistribution of water and sediment in the bendway and how it now approaches the downstream reach. The fourth additional benefit may be realized by an environmental improvement in the habitat. The weirs may act like reefs, drawing lower members of the food chain and ultimately fish. The widening of the navigation channel provides a wider, shallower channel and a more usable fishery habitat. Elimination of the encroachment of the
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point bar into the navigation channel will reduce the need for maintenance dredging and the associated dredged material disposal problems. The majority of these benefits observed or concluded from the model studies have also been demonstrated in the prototype application of the bendway weir concept.

7-31. Maintenance Requirements

All dikes, regardless of the specific design or construction material used, will require periodic maintenance in order to ensure their structural integrity and intended purpose. The amount of maintenance needed varies considerably, depending upon their location in the bendway, frequency of overtopping, freeze-thaw history, material used, age of structure, and in general what is expected of the structure. The two most critical areas needing maintenance are the root or key (landward end) and the stream end of the dike. In addition, dikes that are frequently overtopped will periodically require repair of the crest of the structure and downstream toe section. Dikes that have been in place for a number of years and were adequately maintained throughout the life of the structure seem to become less prone to damage, particularly those that are part of a system of dikes that become filled with sediment and vegetation. One must never lose sight of the purpose for which the dikes were built, and if the dikes are successful in maintaining the desired navigation channel, even in a damaged condition, it may be cost effective to delay minor maintenance and continue monitoring that particular structure.

7-32. Performance and Evaluation

The true test of any technique to control a river's alignment is how well it performs the job for which it was intended. Dikes are a proven technique, and offer the designer a great deal of flexibility. Review of maintenance dredging records and talking with users of the navigation project will help the designer in the evaluation of how well the dikes achieve the desired goal, but the best evaluation of performance is readily visible by periodic field inspections. Items to note during the postconstruction field inspection include breakdown or deterioration of construction materials, undercutting of the slope, unusual scour at the landward end or stream end of the dike, changes in the crest elevation, and accumulation of trash. Modifications to a dike length or elevation can be made if it is found that such is needed. A slightly underdesigned structure or series of structures will probably be more cost effective thau overbuilding during the initial construction phase. This approach allows time for the river to demonstrate to the designer where and how much additional construction may be necessary in order to accomplish the final channel alignment, channel depth, and channel width.