CHAPTER 4

ENVIRONMENTAL CONSIDERATIONS FOR DESIGN

4-1. General. This chapter presents concepts and design criteria for features and techniques that may be used to improve the net environmental effect of a channel modification design. Environmental effects of channel projects are outlined in Chapter 2, and considerations for preliminary design are discussed in Chapter 3. Detailed design criteria do not exist for most environmental features due to the limited base of experience and the complexity of environmental effects; therefore, considerable creativity and professional judgment are required. Furthermore, the guidance contained herein supplements but does not replace any of the existing guidance for hydraulic design, such as EM 1110-2-1601 and the Hydraulic Design Criteria (HDC). Detailed hydraulic design often requires use of physical or mathematical models. The guidelines below should be used by a multidisciplinary team composed of environmental professionals and designers. Nonstructural approaches such as land treatment, floodplain management, floodproofing, etc., are not discussed herein.

a. Organization. In this chapter, environmental features are grouped by the type of channel modification design with which they are most frequently associated. An understanding of the undesirable effects of a modification (as presented in Chapter 2) is required to fully appreciate the purpose and function of the environmental features for that type of modification.

b. Environmental Objectives. Channel designers should be involved with the development of project environmental objectives established during the planning stage. Environmental objectives may include specific mitigation, enhancement, or development goals for aesthetic, recreational, water quality, ecological, or historical or cultural resources. An example of a specific environmental objective would be to preserve an existing coldwater fishery. Environmental features should then be selected and designed to satisfy these specific objectives. However, whether or not specific objectives have been established, Corps policy dictates that certain general environmental objectives be pursued for all projects. A review of relevant Corps environmental policies and guidelines is given in ER 200-2-2, ER 1105-2-100, EP 1165-2-1, and EP 1165-2-501. For effective implementation, these policies and guidelines must be considered and observed in the design stage as well as in planning.

c. Environmental Guidelines. General environmental guidelines for channel modification projects include:

(1) Subject to meeting other project objectives, minimize structural channel alterations, particularly if the existing channel is reasonably stable.

(2) Because channel instability impacts aesthetics, water quality, and habitat, pay particular attention to geomorphic and sedimentation analyses for erodible channel stability.

(3) Channel layout should be a detailed process to avoid, as much as possible, destruction of valuable resources such as large trees or historically significant structures.

(4) As an example, suppose that preserving fish habitat were an environmental project objective. One way to accomplish this is to use instream habitat structures. However, instream structures are not suitable on streams with braided channels, high bed-load transport, unstable channels, steep gradients, high discharge, intermittent flow conditions, poor water quality, or no existing or prospective fishery. In addition, successful applications on streams with high suspended loads, bedrock or sand beds, low slopes, bankfull discharges between 1,000 and 10,000 cubic feet per second, extreme flow variation, or warmwater fisheries; streams that drain urban, agricultural, semiarid, or highly disturbed watersheds; or streams that freeze over may require special designs or considerable maintenance. For example, habitat structure designs that depend on scouring for their effect usually do not work well in bedrock streams, whereas some designs will not last on mobile, sandbed streams due to undercutting and flanking.

4-2. Clearing and Snagging.

a. Selective Techniques. Undesirable effects of clearing and snagging may be addressed by using design and construction techniques that allow trees and snags that do not cause significant flow obstruction to remain. "Selective" clearing and snagging is performed using labor-intensive approaches (chainsaws, boats, barges, etc.) rather than heavy equipment such as draglines and bulldozers. WES TR E-85-3 provides a summary of literature pertinent to hydraulic effects of clearing and snagging and offers suggestions for preparing specifications for selective clearing and snagging work. Design of a selective clearing and snagging project should include the selection of either the specific trees and snags or the types of trees and snags to be removed, as well as specification of the methods for disposal of the removed debris, construction methods and equipment, and access controls. Additional considerations include revegetation, bank stabilization, protection of existing vegetation, scheduling, and contractor education. The effects of selective clearing and snagging may be short-lived and thus may require more frequent maintenance at the site. This factor must be taken into consideration when considering this technique, and project formulation should provide for frequent inspection and maintenance.

b. Replacement of Riparian Vegetation. Areas cleared for channel excavation, access, disposal areas, borrow, and, sometimes, for increased flow capacity can be controlled and enhanced to improve the net environmental effects of a project by revegetation. Revegetation must be tailored to achieve specific objectives (e.g., ground cover, habitat, erosion control) through appropriate species selection, placement, and planting methods for the specific site. (Allen 1978, Allen and Klimas 1986, and Hunt et al. 1978 provide more detailed information on these topics.)

c. Preservation of Riparian Vegetation. Destruction of riparian vegetation, either natural or planted, should be minimized during and after project construction.

(1) During construction. Contractor staging areas and access routes should be carefully planned and should include existing roads and cleared areas. Heavy penalties should be assessed for unauthorized clearing, damage to, or destruction of trees. Trees to be cleared may be flagged or marked with paint.

(2) After construction. Easements may be obtained for riparian buffer strips. If the channel is in a cultivated area, compliance with the easement is more likely if the buffer strips are marked with metal posts, low windrows of excavated material, or fences. Fences usually should be passable by resident wildlife species, except where barriers are needed to prevent drowning or maiming of animals, especially large mammals (ER 1130-2-400). (Information on designing buffer strips for channel protection is provided in Steinblums, Froehlich, and Lyons (1984); fence design is discussed in Nelson, Horak, and Olson (1978) and Schimnitz (1980).

4-3. Floodways.

a. General. Floodways (sometimes called bypass or diversion channels) are excavated channels that convey floodwaters over routes that are usually shorter and straighter than those followed by the unmodified stream. Floodways normally are designed to convey flood flows only, and low and normal flows are diverted through the natural channel. Floodways may be designed as multipurpose use areas, as long as the additional use is compatible with the flooding function. Any structures placed in the floodway should be flood proof, well anchored or removable on short notice, and should not obstruct flood flows.

b. Design Considerations. Floodway channels should be sized to convey the design discharge, less the flow diverted through the natural channel during flood events. If the natural channel will be used as a low-flow channel only, a means of diverting low flows and restricting flood flows must be provided. If weirs and culverts are used, both the low-flow channel and culvert should be designed with adequate access for regular removal of sediment and blockages. Inverts of floodways designed for multiple use should be above the seasonal high-water table or should be provided with underdrains to ensure that wet conditions will not interfere with use or maintenance of the floodway. Grade control or drop structures may be needed in the floodway or at tributary junctions.

4-4. Channel Excavation.

a. General. A variety of structural methods can be used to reduce the impacts of channel modification. Because of the lack of standard terminology, some of the terms used in this section have been specifically defined for use herein. Readers should refer to these definitions, which are given in the Glossary.

b. Low-Flow Channels.

(1) General. A low-flow channel is a subchannel constructed inside a larger flood control channel to concentrate flow for biological, recreational, water quality, or aesthetic benefits, and for engineering design needs.

Low-flow channels generally do not perform well on streams with heavy sediment loads. Figure 4-1 is an example of a low-flow channel. Typical low-flow channel cross sections are shown in Figures 4-2b, c, d, and f.

(2) Size. Due to their small size, most low-flow channels are designed by adding them to the cross section required for flood conveyance. Dimensions of low-flow channels should be based on instream flow conditions required to meet engineering, biological, recreational, or water quality needs. For recreational boating, the recommended minimum depths are 2 and 3 feet for non-motorized and motorized boats, respectively; the recommended minimum widths are three times boat length for rowboats and 17 feet for canoes. If fishery or water quality needs dominate, critical instream needs (usually flow velocities and depths) should be established for the month or months during which low-flow conditions are expected. Fishery biologists familiar with local streams can assist in developing these criteria, which can be used to size low-flow channels. Biologic benefits can be further enhanced by incorporating pools and riffles and habitat structures in the design.

(3) Placement. Meandering alignments for low-flow channels are preferable for aesthetic reasons, although placement adjacent to a shady bank may be more desirable. Guidance for meander designs is given in paragraph 4-4f. For low-flow channels constructed in erodible materials, meandering and erosion may be controlled by lining the low-flow channel and the flood channel invert or by burying sills or training dikes at specified intervals. Alternatively, the toe slope of the flood channel may be protected and the low-flow channel allowed to meander freely.

c. High-Flow Channels.

(1) General. High-flow channels are flood control channels with modified cross sections that include a subchannel with high-flow berms on one or both sides (Figures 4-2g, i, j). High-flow berms are inundated infrequently and may be used for parks, trails, or other purposes compatible with their functions as flood channels.

(2) Design. If the existing channel is determined to be stable, the magnitude of its geometric parameters may be considered the regime values. It is preferable that the channel’s desired regime be maintained by the subchannel and that the high-flow berms be designed to be inundated only by flood flows that exceed the channel-forming discharge, normally equal to or larger than the mean annual discharge based on the annual series. A sedimentation analysis should be conducted to properly design this channel modification. If the existing channel is determined to be unstable, the problem of sizing the subchannel is more difficult and will require special attention in performing the sedimentation analyses.

d. Pools and Riffles.

(1) General. Profiles of natural channel inverts typically have alternating "lows" and "highs" that are referred to as pools and riffles. Under normal-flow conditions, pools and riffles provide a variety of water depths and flow conditions, which is needed to maintain biologic diversity and vigor. Pools and riffles tend to be spaced with pool-to-pool distances that fluctuate

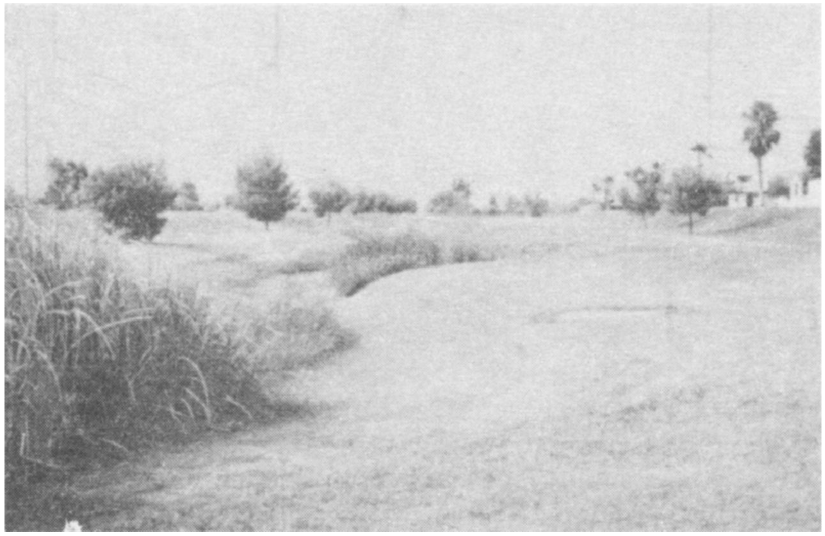


Figure 4-1. Low-flow channel, Indian Bend Wash
(USAED, Los Angeles)

about a mean value of five to seven channel widths, being typical of most streams. On meandering streams, pools are located in bends, and riffles are found in straight reaches (Figure 4-3).

(2) Design. Pools and riffles may be placed in subchannels or low-flow channels and in larger channels with sizable fractions of gravel and cobble in their beds. Pools and riffles should not be built on high-flow berms, in floodways, or in channels with sand beds.

(a) Spacing. Spacing of pools and riffles in paved channels is not critical because of the inherent stability of the channel. In unpaved channels, maintenance requirements will be fewer if pools and riffles are spaced and located to reproduce natural channel conditions. Riffles may sometimes be placed at outcrops of erosion-resistant material. If use of natural channel pattern is not feasible because the stream or watershed is unstable under preproject conditions, pool and riffle spacing should fluctuate about five to seven channel widths (measured from the center of one pool or riffle to the next pool or riffle). Channel width should be water surface width for the 1-year return interval flow. Pools should alternate from side to side within the channel, and sediment transport conditions of the channel should not be radically different from preproject conditions. Figure 4-3 shows desired pool-riffle locations for straight and meandering streams.

(b) Size and shape. Size and shape are not as critical as spacing and may be varied to suit hydraulic and biologic needs. Pools should have a minimum low-water depth of 12 inches, and riffles should not project more than 12 to 18 inches above the mean channel invert. Generally, individual pools should not be longer than three channel widths or shorter than one. Pools that are too wide, too deep, or too long may not have the self-flushing capability for sediments that natural pools have. Riffle lengths should be one

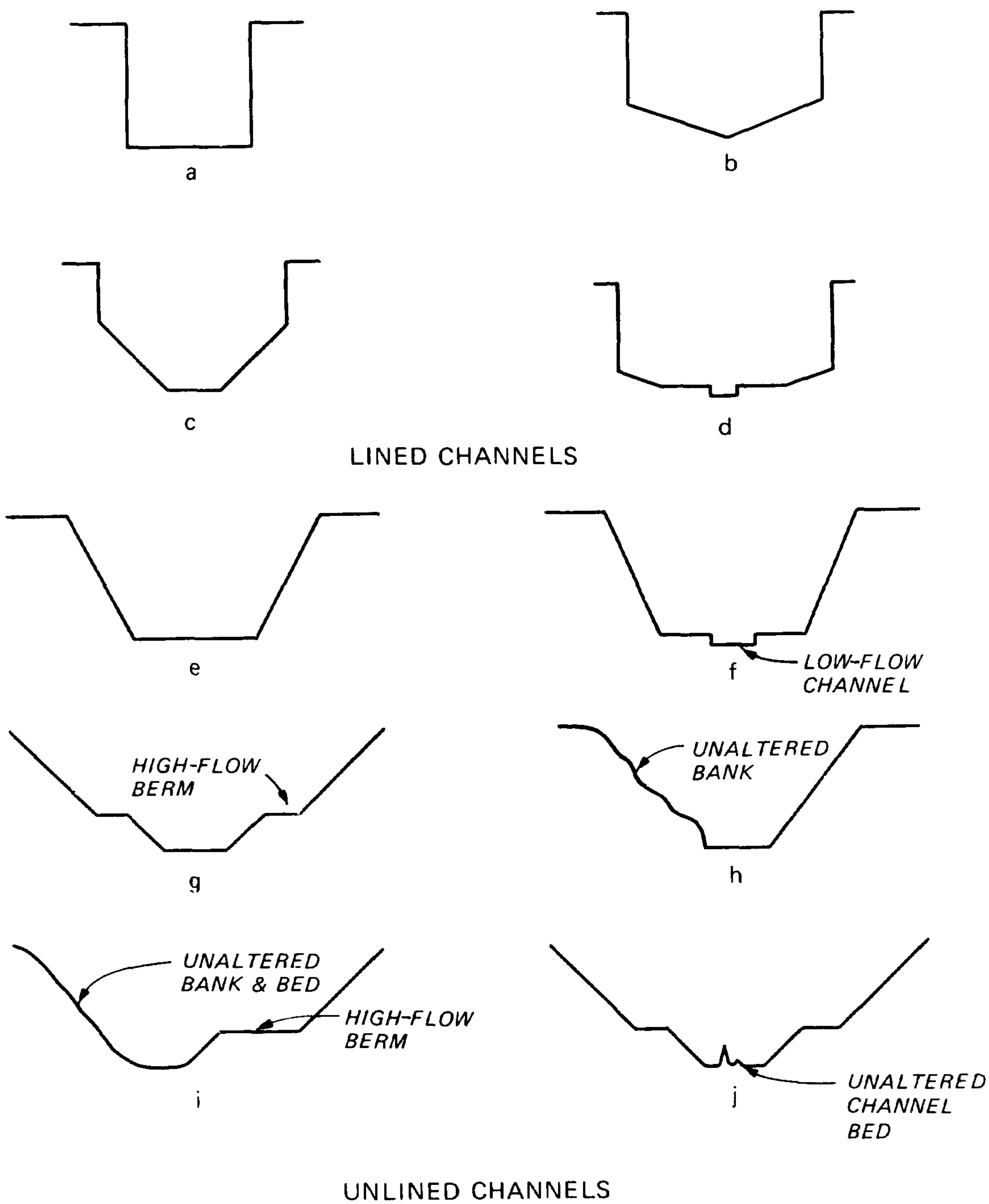
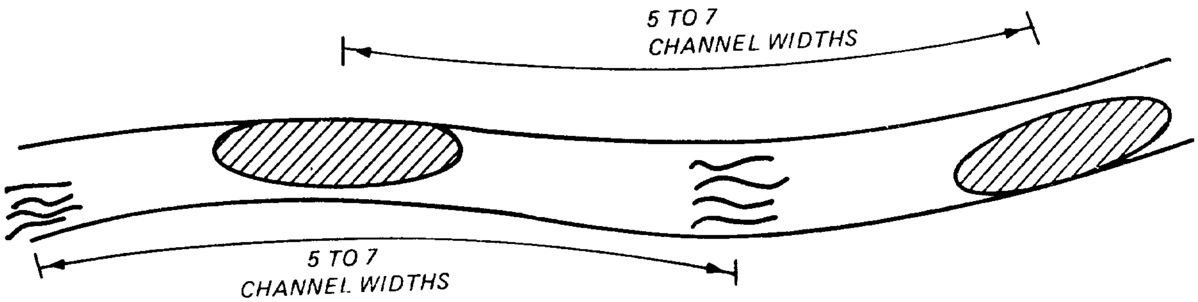
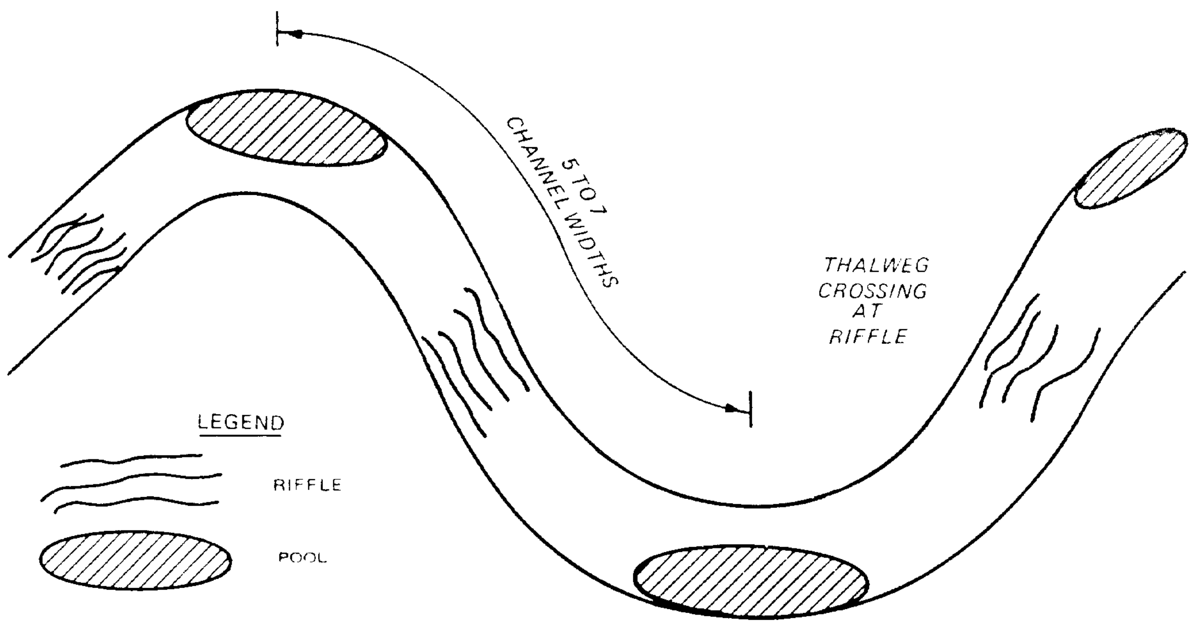


Figure 4-2. Typical flood channel cross sections. Lined channels typically have vertical walls to minimize costs and may be rectangular (a) or may have some modification to concentrate low flows (b, c., d). The most frequently used cross-sectional geometries include trapezoidal (e), trapezoidal with a low-flow channel (f), trapezoidal with a normal-flow channel and high-flow berms (g), and variations in which one bank and/or the channel bed are not disturbed (h, i, j)



a. Straight to slightly sinuous channel



b. Meandering channel

Figure 4-3. Pool-riffle location. Pools and riffles should be spaced irregularly at five to seven channel-width (center-to-center) intervals. Pools should alternate from side to side within the channel

half to two thirds that of pools, and channel width in riffle areas should be 10 to 15 percent wider than in pool areas.

(c) Materials. If riffles are to be dynamic or self-maintaining, construct them of a mixture of natural stream gravel with size distribution typical of the bed material in the unmodified channel. Otherwise, construct them of gabions, cobble, or riprap, sized based on trade-offs between considerations and environmental benefits.

e. Single-Bank Construction.

(1) General. If site conditions permit, single-bank modification is the preferred construction method for channel enlargement (Figure 4-4). The existing channel alignment is followed, and the vegetation on the opposite bank is disturbed as little as possible. Aesthetic impacts are reduced if the work is alternated from one side to the other and if clumps of vegetation are left on the work bank. Preferred equipment varies with stream size. Hydraulic hoes and other small equipment are preferable for small streams because of their maneuverability and the reduced access and rights-of-way needs. However, in some instances, larger equipment may be desirable. On large streams, floating dredges may eliminate the need for haul roads.

(2) Procedures.

(a) Select the work bank. Factors to be considered in the selection process include habitat value of existing vegetation, shade, bank stability, and aesthetics. Trees on the south and west banks provide the most shade during critical midday and afternoon periods. Any special vegetation to be preserved should be marked.

(b) Develop design. The design should cover the selection and removal of snags from the off bank and restrictions on equipment, access, work scheduling, etc. Detailed guidelines are given in WES TR E-85-3.

f. Meandering Alignments.

(1) General. Meandering alignments may be used to improve the aesthetics and stability of flood control channels. Meander geometry is described in terms of wavelength, meander width, and radius of curvature (Figure 4-5), and measurements may be expressed in dimensionless form as multiples of channel width. Natural meander geometry can be related to stream discharge and bankfull width.

(2) Design. Meander geometry specifications include meander wavelength, meander width, stream length and gradient, and channel cross-sectional geometry. Meander geometry of subchannels sized to carry low and normal flows can be patterned after that of the former stream or of similar-sized unaltered streams nearby. Alternatively, refer to Table 3 of WES TR E-85-3 for formulas for meander geometry and to the associated text for application procedures. The formulas and procedures given in WES TR E-85-3 are not meant to replace hydraulic design procedures contained in EM 1110-2-1601.

g. Preservation and Creation of Wetlands.

(1) General. The values of wetlands are well established, and opportunities for including wetland features in flood control channel projects are numerous. Alignment of flood control channels and careful placement of dredged materials to avoid wetlands can minimize losses of these valuable habitats.

(2) Site selection. Desirable site criteria for wetland creations include flat topography, relatively impermeable soils, high ground-water table, plentiful and dependable water supply, and mast-producing hardwood trees and other vegetation with high habitat value. Alluvial floodplains

Figure 4-4. Single-bank construction. The visual effect would have been improved if clumps of trees had been left at intervals along the modified bank

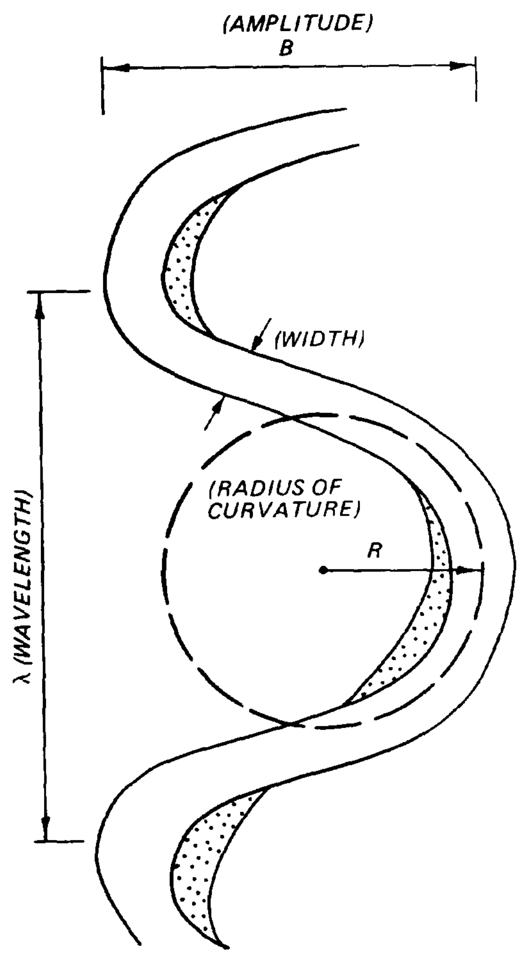


Figure 4-5. Meander geometry

possess many of these characteristics. Several procedures are available for evaluating the habitat value of a specific site (see Fish and Wildlife Service, US Department of the Interior 1980; US Army Engineer Division (USAED), Lower Mississippi Valley, 1980; and Adamus et al. 1987).

(3) Development. Wetlands may be developed with or without water-level control. Wetlands may be created by excavation, by placement of excavated material to block surface drainage, or by building containment levees. Emergency spillways should be provided for levees or dams that might overflow and erode. Gated culverts or other flow-control mechanisms allow water-level management for specific purposes such as duck habitat or timber production. Detailed information on site selection, design, and management of wetlands of various types can be found in the Wildlife Management Techniques Manual (Schimnitz 1980), "The Wildlife Improvement Handbook" (US Forest Service 1969), and in numerous Corps publications (see Environmental Laboratory 1978b and Martin 1986).

h. Preservation of Cutoff Meanders.

(1) General. When bendways with potential habitat value are cut off during flood channel construction, consideration should be given to maintaining the bendways as either lake or channel habitat (Figure 4-6). Feasibility depends largely upon water quality and sediment load. For lakes, inflow quality and quantity need to be adequate to prevent water quality problems. Water budgets for proposed cutoff bendway lakes should include consideration of inputs from and losses to ground water. Perched lakes may require much greater inflow to maintain depths and water surface areas. Engineer Manual 1110-2-1201 provides guidance on predicting the water quality of impoundments using simplified techniques. Stream-connected designs are of questionable value on streams with extremely low summer flows. Refer to EM 1110-2-1203 for discussion of bendway management techniques appropriate for larger rivers.

(2) Impoundment design. Bendway impoundments require channel blocks and appropriate flow-control mechanisms. If tributary or drainage inflow is adequate to maintain water level, only an outlet structure and emergency spillway are needed. Otherwise, a gravity-fed inflow structure or pumped inflow is required. Intake structures should be high enough to avoid heavy sediment concentrations and should be designed to minimize problems of debris jamming or blockage. Wells for supplemental water supply should be located to avoid simply recycling lake water.

(3) Stream-connected designs. Low flows may be diverted through bendways by excavating cutoff channels to depths shallower than the bendways or by using weirs in cutoff channels to divert water through bendways. Bed protection or drop structures may be needed to prevent degradation in the cutoff channel and at junctions of the cutoff channel and bendway. If sediment loads are heavy or if low flows are insufficient to maintain suitable habitat, one or both ends of the bendway may be partially blocked to restrict sediment input and to maintain water levels during low-flow conditions. A culvert placed through an earthen embankment is a simple type of partial blockage. However, culverts are easily blocked by floating debris or sediment. Weirs or sills placed across the mouth of the old bendway may also be used for partial

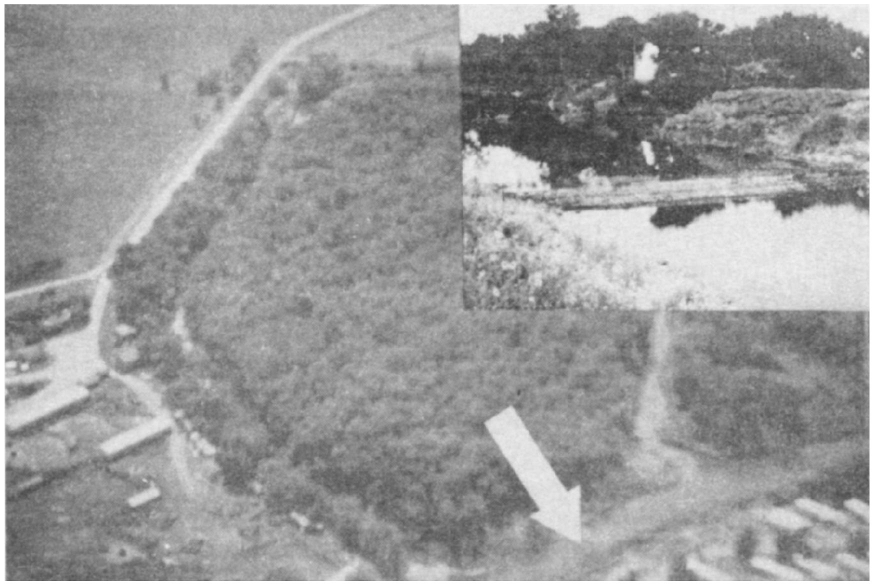


Figure 4-6. Cutoff meander, Souris River (USAED, St. Paul). Cutoff bendways can be maintained for wildlife and recreational benefits. (Inset highlights grade control structure with crest elevation sufficiently high to force normal flows through the bend)

blockage. If the old bendway makes a sharp (near 90-degree) angle with the main channel, sediment deposition will be localized near the junction, which will reduce maintenance effort. In most cases, stream-connected designs will require periodic removal of sediment to maintain the bendways as aquatic habitat. Sumps or sediment traps may be placed at bendway entrances to facilitate maintenance. Complete closure of the upper bendway entrance and constriction of the lower so that it scours on the falling stage may help to reduce rates of bendway sedimentation in some cases.

i. Placement of Excavated Material.

(1) General. Selective placement and treatment of excavated material offer opportunities to reduce impacts and enhance environmental conditions. Environmental factors that should be considered in site selection include topography of the site and its potential for flooding, proposed use of the disposal site and its compatibility with existing and proposed adjacent land uses, the presence of rare or endangered species, the chemical and physical quality of the material, and the existing site habitat value and the abundance of that habitat in the general vicinity. Excavated material should not be placed in stream courses or in designated floodways. Erosion control is discussed in paragraph 5-2 of this manual.

(2) Applications. In flat areas, excavated material may be piled and shaped to provide visual contrast and recreational opportunities such as sledding or skiing; it may be used to construct containment levees for wetland creation; or it may be windrowed to mark limits of buffer strip easements, control side drainage, or provide wildlife refuge. Although habitat

development on flood control channel projects is by no means limited to disposal areas, disposal sites offer excellent opportunities to replace lost habitat with habitat of equal or superior quality. Detailed guidance for habitat development on disposal sites is presented in Environmental Laboratory (1978a); Hunt et al. (1978); Lunz, Diaz, and Cole (1978); Ocean Data Systems, Inc. (1978); Smith (1978); and Soots and Landin (1978).

j. Water-Level Control Structures.

(1) General. Although water-level control structures may have multiple benefits, they are instream structures designed primarily to maintain water levels at a constant or near-constant elevation during nonflood periods for aesthetics, recreation, fish or wildlife habitat improvement, water quality, vegetative control, or related purposes. Earth plugs, gated structures, inflatable dams, and overflow weirs made of sheet pile, gabions, concrete, or other materials are used to control water levels.

(2) Design considerations. Water-level control structures should be designed, built, and operated so that they do not block fish movement, create problems of upstream sedimentation or downstream erosion, or reduce flow capacity under high-flow conditions. Gated structures and inflatable dams prevent most of these problems, although they may be expensive to build. Guidance for the design, construction, and maintenance of inflatable dams is available from manufacturers of these products. Weirs can be designed with low profiles to avoid reducing flood capacities and can be provided with openings or fish ladders. Fish passage problems are addressed in paragraph 4-7. Upstream sedimentation is a common problem for weirs, and streams with heavy sediment loads may require sediment traps or regular cleaning of pools.

k. Instream Habitat Structures.

(1) General. Habitat structures are constructed in channels to modify flow depths and velocities and to provide cover for fish. Use of habitat structures may require a larger channel dimension to provide for the flood capacity. Figure 4-7 illustrates placement of instream habitat structures. Most designs can be placed into one of four categories--sills, deflectors, random rocks, or cover. The first three types of structures are not suitable for use in channels that have dominant bed material of sand size or less.

(2) Structure types.

(a) Sills. Sills are low structures that extend across the entire width of a channel and are intended to produce upstream pools, downstream scour holes, or both. They are often designed with a gap or notch and typically have minimal backwater effects. Sills are better suited to high-gradient streams than are most other habitat structures. Sills may be constructed from logs, rocks, gabions, concrete, sheet metal, or combinations of these materials. The most common problems encountered are flanking and undermining, structural damage caused by floods or ice, and structures built too high such that they are susceptible to failure and impede flood flows and fish movement.

(b) Deflectors. Deflectors are structures that protrude from one bank but do not extend entirely across the channel. The primary purpose of

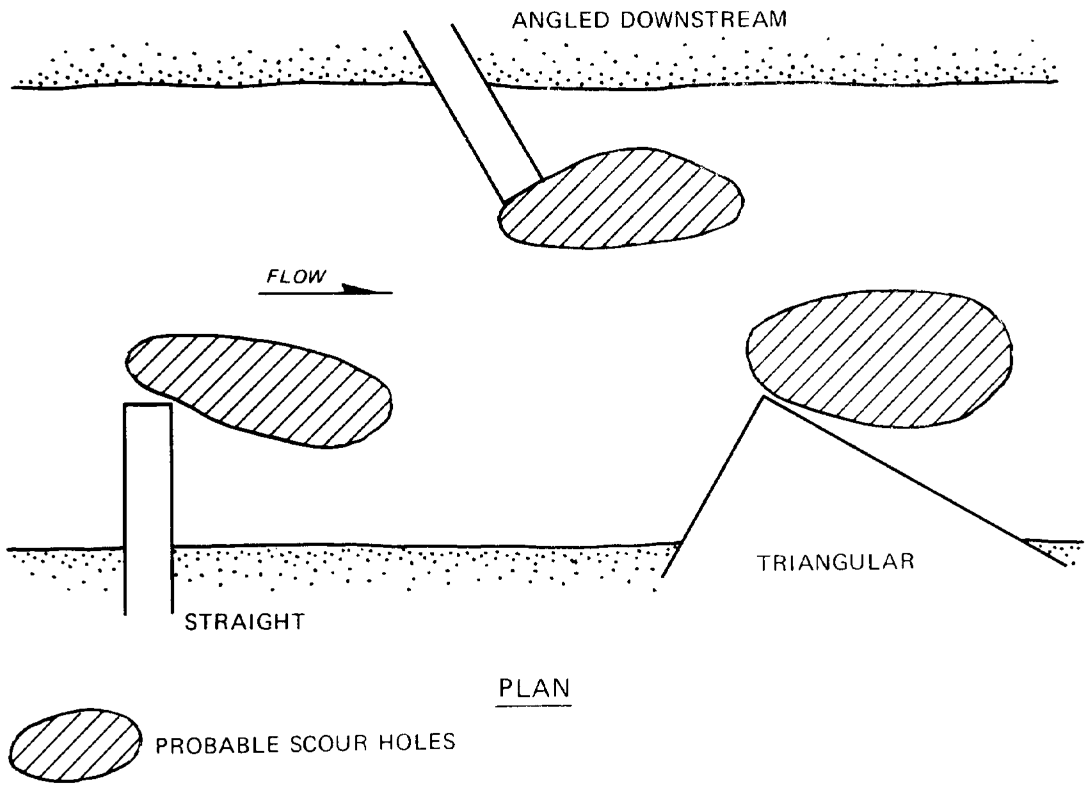


Figure 4-7. Instream habitat structures

deflectors is to scour pools by constricting the channel and accelerating flow. They may be angled upstream, downstream, or perpendicular to the bank and are often alternated from one side to the other. They may be constructed of the same materials as sills, although rock and rock-filled structures are most common. Use of deflection in some streams may create bed scour and erosion to the opposite slope that is not predictable.

(c) Random rocks. Random rocks are large boulders, gabions, or concrete objects placed in a channel well away from either bank to produce scour holes and zones of reduced velocity. Rocks should be used only if velocities are high enough to create scour holes downstream, but their use should be avoided on sand-bed streams and other streams with unstable beds. Rocks used for habitat cover should be durable enough to withstand weathering and abrasion. Rocks may be placed in channels individually or in clusters.

(d) Habitat cover devices. Cover devices include floating rafts fastened to the bank, ledges supported by pilings, anchored trees or brush mats, logs or half-logs anchored above the bed and aligned with the flow, and boulders or gabions placed in deep pools.

(3) Design. Design of habitat structures is an iterative process that involves several steps: determining feasibility of success; determining habitat potential and deficiencies; selecting the structure; planning the layout; sizing the structure; investigating effects of and on flood flows,

sediment transport, and channel stability; and designing the feature in detail. Technical Report E-85-3 (WES) provides detailed design procedures. A summary of experience with habitat structures in modified channels is given in WES TR E-82-7 and in Shields (1983).

l. Sediment and Debris Basins.

(1) General. Debris basins are constructed to trap sediment and debris that would otherwise damage or clog flood channels. Debris basins are required primarily on high-gradient streams and at sites susceptible to mud and debris slides. Sediment basins are used to reduce sediment loads and turbidity, which can adversely affect fish and other aquatic organisms, water quality, and project aesthetics.

(2) Design. Instream sediment traps are constructed by excavating short channel reaches to a greater-than-average depth and width. Debris basins usually have larger required capacities and are constructed by damming the stream, with or without accompanying excavation. Both sediment and debris basins may require periodic cleaning to maintain their trap efficiency. Access and ease of maintenance should be given priority during design. Technical guidance for the design of sediment and debris basins is presented in EM 1110-2-1601 and in Dodge (1948), Moore et al. (1960), Tatum (1963), and Pemberton and Lara (1971).

4-5. Channel Paving.

a. General. Paving is used in channels that experience supercritical flow, in urban areas where narrow, deep channels are often used, and in other situations where flow depths and velocities would be sufficient to cause general scour of channel bed and banks. Reinforced concrete is the most common paving material, but asphalt, grouted riprap, boulders set in concrete, and other materials are sometimes used.

b. Concepts for Improving Environmental Quality in Paved Channels. Environmental quality of paved channels can be improved by increasing low-flow depths, reducing water temperature, and providing resting area and cover for fish. This can be achieved by using low-flow channels (paragraph 4-4b) or pools and riffles (paragraph 4-4d), providing shade, and using materials such as boulder concrete and grouted riprap. Boulder concrete and grouted riprap may improve channel appearance as well. Aesthetic considerations for urban projects are discussed in paragraph 4-9.

4-6. Channel Side Slope Protection.

a. General. Erosion protection of some kind is required for some side slopes of nearly all flood channels. Vegetative protection usually is preferred, but structural protection is required along channels with high flow velocities and at locations subject to local scour or slope instability. Habitat value, aesthetics, water quality impacts, and channel access for people and animals should be given major consideration during selection and design.

b. Structural Protection Measures.

(1) General. Structural protection measures involve placement of natural or manufactured materials along banks to provide direct or indirect protection against scour or bank failure. Design guidance can be found in WES TR E-84-11 and in OCE (1978, 1981c) and USAED, Huntsville (1982), although not all types of designs in these references are appropriate for flood control channels. Practicable designs for flood control channels include soil treatment and stabilization, tree retards, riprap and gabions, rigid revetments such as reinforced concrete, and manufactured bank covers.

(2) Environmental aspects.

(a) Habitat value. Structural bank protection measures provide little wildlife habitat, although riprap is valuable to benthic organisms and some small fish species. Tree retards provide cover for fish, but their use is restricted largely to natural channels.

(b) Aesthetics. Aesthetic impacts of streambank protection are largely visual and may be negative or positive. Extensive use of concrete, manufactured covers, or riprap produces a scene that might be considered inferior to that of a natural stream because of the sharp contrast between these materials and naturally vegetated banks. Appearance of bank protection can be improved where soils and hydraulic conditions permit, by using materials such as stream gravel and cobble or structural designs that incorporate vegetation (paragraph 4-6d) -

(c) Water quality. Increased turbidity associated with the construction of bank protection works may have short-term negative impacts on water quality, but the major long-term impact of successful wide-scale bank protection is to reduce turbidity and sediment concentrations. Reduced sediment concentrations may prolong the life of environmental features such as fish habitat structures and may reduce the costs of channel maintenance. Water temperature increases may sometimes be related to extensive use of concrete and loss of shade.

(d) Channel access. Extensive bank protection works can affect access to the channel by people and animals. Concrete and other smooth surfaces generally increase accessibility as long as slopes do not exceed 1 vertical: 2 horizontal. Large, loose stone is probably less acceptable, but accessibility can be improved by filling large voids with smaller rock, gravel, or soil.

c. Vegetative Protection.

(1) General. Herbaceous or woody vegetation may be used to protect channel side slope areas (depending on the frequency of inundation, velocity, and geotechnical constraints to infrequent flooding) and other bank areas where velocities are not expected to exceed 6 to 8 feet per second. Information concerning maximum permissible velocities for various grasses is given in WES TR E-84-11. Figure 4-8 depicts a flood channel with vegetative bank protection. In addition to erosion resistance and environmental considerations, which are discussed separately below, other factors that need to be considered in the selection process include flood and drought tolerance, soil and

Figure 4-8. Vegetative lining, San Antonio River flood channel (USAED, Fort Worth). This completed reach contains a subchannel that conveys normal flows. The high-flow berms and banks are vegetated. Note the River Walk (Paseo del Rio) inside the flood channel

climatic conditions at the site, and availability of seed, root stock, or other propagules. Additional information concerning these matters is available in WES TR E-84-11, in Whitlow and Harris (1979), and from District offices of the Soil Conservation Service. Native plant species should be used in lieu of exotic species wherever possible. Sources for native plants have been identified by the Soil Conservation Society of America (1984) , and coordination with appropriate State agencies is essential.

(2) Environmental considerations. Terrestrial habitats can be developed to benefit target species or to promote species richness. Plant species selection depends on which goal is chosen. Mixtures of herbaceous and woody vegetation promote wildlife species diversity by providing a variety of foods and types of cover. Local, State, and Federal wildlife biologists can provide information about the food and cover value of various plants.

d. Composite Designs. Several bank protection methods incorporate vegetation into structural designs. These designs have essentially the same environmental benefits as vegetative designs. Four of the most widely used and successful of these techniques are erosion control matting, cellular concrete blocks, seeded soil-covered riprap, and stem-sprouting woody plants in combination with engineering materials. Additional information on these techniques is provided in WES TR E-84-11.

e. Construction Scheduling. Many factors should be considered when the scheduling of construction is important to the success of bank protection projects. Aquatic impacts can be reduced by scheduling work to avoid peak migration or spawning periods and to take advantage of low-flow periods. Careful scheduling is essential for successful establishment of vegetation.

For example, sufficient time must be allowed for plant establishment prior to high flows or dormant seasons. Some plant materials, such as root stock, are perishable if not planted promptly.

4-7. Erosion Control Structures and Culverts.

a. General. Weirs, drop structures, and culverts often create obstructions to fish movement, and consideration of fish movement during design can provide for migration or protect a viable fishery.

b. Weirs and Drop Structures. Ladder-type fishways incorporated into weirs and drop structures create flow conditions that allow fish to swim through the facility. Fishways are recommended at obstructions with heads as low as 2 feet if they are located on streams with viable fisheries. Fish ladder design requires both biologic and hydrologic data. The fish species of concern must be identified, and migration patterns, fish size, swimming speeds, and swimming depths must be known. Required hydrologic data include the operational discharge range, headwater and tailwater curves, and sediment transport. Refer to WES TR E-85-3 for information about the design of ladder-type fishways.

c. Culvert Fishways. Culverts should be designed to produce flows with adequate swimming depths and passable velocities (see Figure 4-9). Resting areas are required below and above the culvert and within the culvert if its length exceeds 100 feet. If scour is expected below the culvert, or if flow depths are expected to be insufficient for fish movement, a low sill should be constructed five to seven pipe diameters downstream of the culvert. Culverts are sized for the design discharge, and barrel velocity is determined for the expected discharge at the time of fish movement. If the velocity exceeds the sustained swimming speed of the fish, the design should be modified by adding baffles or other roughness elements to the culvert invert, reducing the culvert grade, or reducing the hydraulic radius. Additional guidance is available in McClellan (1970), Watts (1974), and Evans and Johnson (1980).

d. Aesthetic Considerations. The appearance of erosion control structures and culverts can be improved by using natural materials or natural-looking finishes. Examples include rock veneer on culvert headwalls and special form liners and colors that produce patterns similar to those of stone or wood. Additional details are given in paragraph 4-9.

4-8. Levees and Floodwalls.

a. General. Levees and floodwalls are often incorporated into flood control project designs. Levees are usually subject to water loading for periods varying from a few days to a few months a year. Refer to EM 1110-2-1601 and EM 1110-2-1913 for general design guidance for levee projects. Environmental features can be incorporated into levee design, construction, and maintenance to enhance aesthetics, fish and wildlife, or recreational resources. Detailed guidance for levee and floodwall environmental features is provided in WES TR E-85-7.

b. Levee Design and Environment. Design decisions for any levee project include choosing sites for the levee and associated facilities, determining

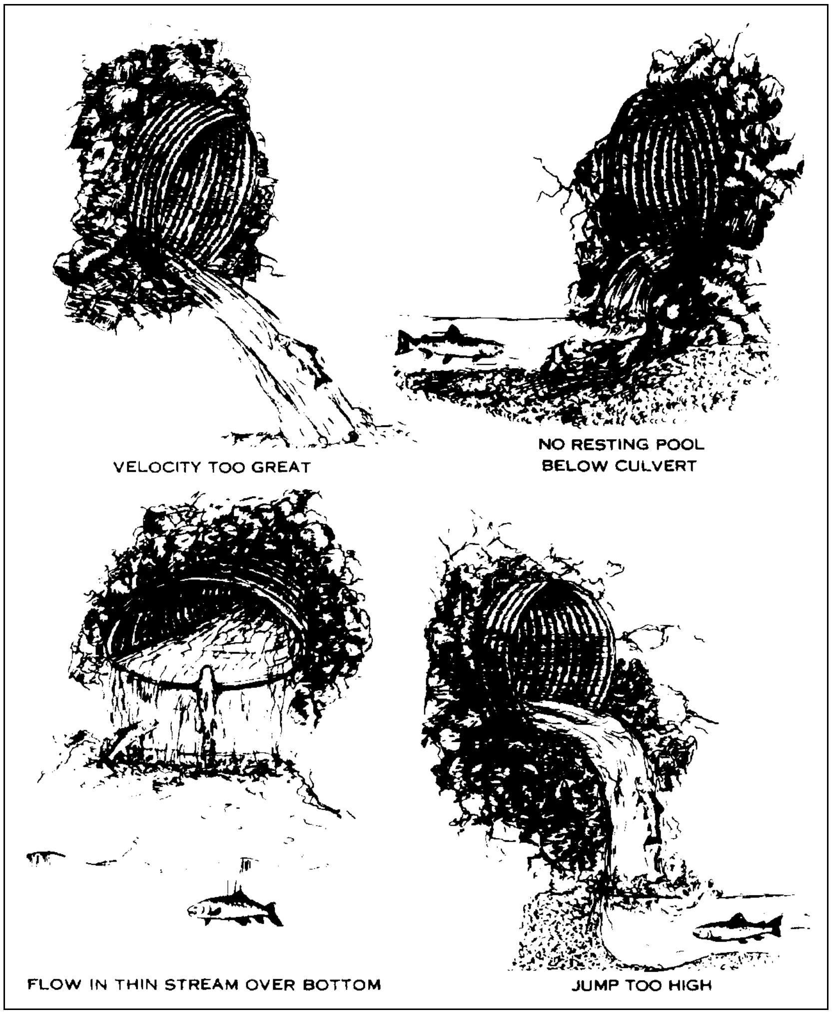


Figure 4-9. Culvert blockages to fish movement
(from Evans and Johnson 1980)

the proper size of the levee and related structures, and formulating plans of work for construction operations. Environmental considerations, as described below, can be incorporated to preserve and enhance environmental resources associated with the levee project.

(1) Avoidance of ecologically sensitive areas and cultural and historic sites. Stream valleys commonly exhibit a wealth of ecologically significant sites and cultural and historic sites. Levee alignment, borrow pit location, and related construction areas should be chosen to minimize the amount of ecologically sensitive area disturbed, subject to other design constraints. Assistance is available from the state and Federal conservation agencies in identifying and locating ecologically sensitive areas.

(2) Tree preservation. Preserving trees that already exist near the levee construction site maintains the scenic and ecological characteristics of the site and reduces the need for revegetation. Only trees that can be

expected to live should be retained, unless the tree in question has value as a den tree. Trees or groups of trees to be preserved should be selected during the design stage of project development. Unique specimens including old trees, unusual species, uniquely sized or shaped trees, and trees with special wildlife value for food, resting, and nesting deserve special attention as candidates for preservation. It is desirable to preserve blocks of trees rather than individual trees. A block of trees can serve as a screen to break up the long, monotonous, and unnatural appearance of a levee, especially where levees are visually dominating. Damage from windthrow is lessened when more trees are present. The value of stands of trees as wildlife habitat can be determined by biologists with data on tree species, size, density, age, and wildlife use. Widths of preserved areas can vary to meet both aesthetic and wildlife needs by considering viewing positions, levee dimensions, and range or habitat requirements of wildlife species to be fostered within the area. Designs should avoid high-velocity passage between tree screen and levee toe.

(3) Overdesign of channels. Overdesign of drainage ditches reduces the need for frequent ditch clearing or mowing and increases their ability to support wildlife habitat and aesthetically pleasing vegetation. Technical Report E-85-3 (WES) provides information concerning resistance factors for channels containing vegetative growth.

(4) Erosion and water quality control during construction. Appropriate erosion and sediment control techniques employed during construction can have significant water quality benefits. Refer to paragraph 5-2 for a detailed discussion of this topic.

c. Environmental Features for Fish and Wildlife.

(1) General. Fish and waterfowl habitat features include basic considerations for design of borrow pits and interior collection ponds, including optional features such as water control structures, artificial islands, fish shelters, and fish stocking. Wildlife habitat features include artificial nesting and perching structures, seeding and planting, and brush piles (Martin 1986) for wildlife habitat management techniques. Technical Report E-85-3 (WES) provides more information on these features and on marsh vegetation establishment, beneficial uses of dredged or excavated materials, land acquisition, controlled access to wildlife areas, and wildlife fence designs.

(2) Fish and wildlife considerations for borrow pit design. Levee borrow pits often fill with water after construction. Well-designed pits can become highly productive habitats. Pond characteristics associated with productivity and species diversity are surface area, shape, wetted edge, and quality and quantity of water (Figure 4-10). Refer to Aggus and Ploskey (1986) for environmental considerations for one borrow pit design based on a series of studies of lower Mississippi River mainstem levee borrow pits.

(a) Borrow pit size. Generally, a simple positive relationship exists between pond and wetland surface area and wildlife productivity. However, large borrow pits may be counterproductive to wildlife if they require destruction of scarce habitat to create relatively abundant open water. A series of small, frequent wetlands can result in higher waterfowl nest densities for the overall area than one large wetland. The Atlantic Waterfowl

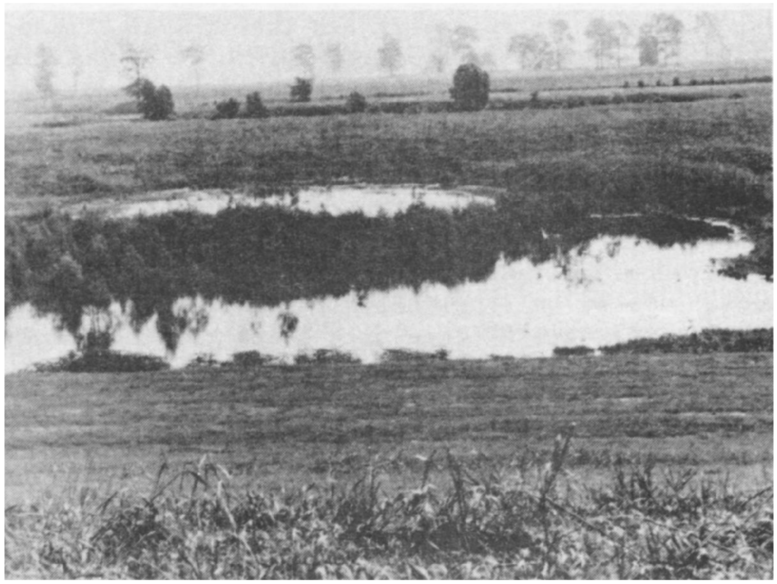


Figure 4-10. Borrow pit extensively used by wading birds

Council (1972) has provided information concerning the creation of artificial wetlands. A minimum size of 1 to 1.5 acre is recommended for waterfowl brood ponds, and 2 acres is the minimum recommended size for pits used for fishing.

(b) Borrow pit shape. Pond and wetland shape influence wetted edge and vegetation/open water ratios that are important to wildlife productivity. Irregularly shaped pits increase wetted edge and benefit waterfowl and some terrestrial species. Irregular shapes also provide more opportunity for bank fishing and add visual diversity. Vegetation/open water ratios can be manipulated by excavating borrow pits with a variety of depths that foster or discourage vegetative growth. Water depths of 6 to 24 inches promote aquatic plant growth, provide good dabbling duck habitat, and create desirable spawning and nursery areas for fish. Depths greater than 3 feet usually discourage rooted plant growth and provide needed open-water areas. Borrow pits may be excavated with a steep drop-off at the bank to a depth of 18 to 24 inches, which is maintained for some distance from shore. At this point there is a second steep drop-off to maximum depth (Figure 4-11). This "step" design provides the needed diversity of depth while reducing the risk of drowning.

(c) Water quality and quantity. Water sources should be sufficient in quality and quantity to sustain fish populations throughout the year. Water temperature, pH, nutrient levels, sediment, and pollutants are important considerations for fish survival and productivity. Periodic inundation from flows from the main channel can be beneficial to the borrow pit fishery. Wetlands and ponds managed for waterfowl also require dependable sources of good water. Water levels are manipulated in the management of many artificial wetlands by using water-level control structures such as those described in paragraph 4-4j. Nelson, Horak, and Olson (1978) provide descriptions of water control management practices and guidance for designing structures. Additional references can be found in WES TR E-85-3.

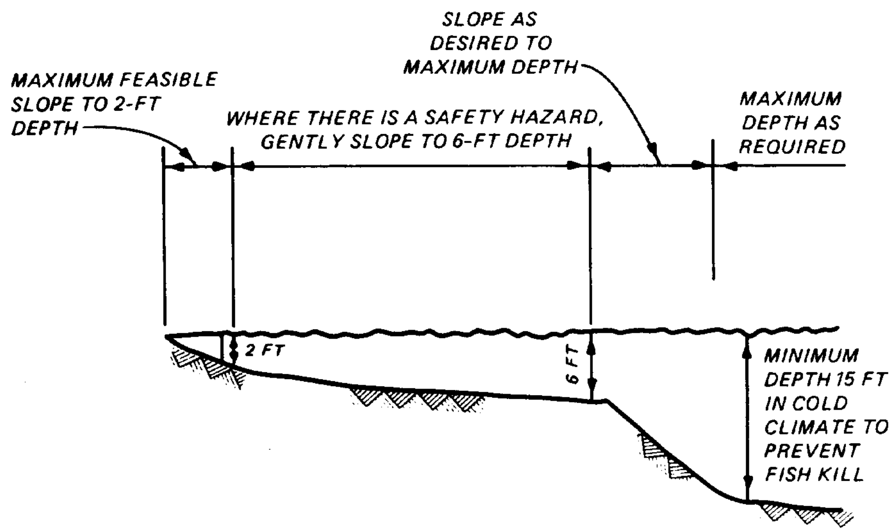


Figure 4-11. Cross section of artificial pond or borrow pit showing design for diversity of depths

(3) Fishery shelters in borrow pits. Fishery shelters constructed of brush, wood, or rubber tires can be used to provide cover, shade, and occasional spawning and feeding sites for fish. These shelters should be designed so that they do not create problems during flood flows. This may be particularly important as a temporary measure for providing cover during the period between removal and reestablishment of riparian vegetation. Refer to Nelson, Horak, and Olson (1978) for information about design and placement of fish shelters.

(4) Interior flood control collection ponds. Interior drainage collection ponds may be used as fish ponds or wildlife wetlands, as long as the standing water does not cause seepage, slope failure, health or aesthetic problems, or inspection problems (Figure 4-12). These problems can be minimized by using impervious core and fill materials that remain stable when wet. Outflow structures may be designed or operated to permanently impound water in collection ponds, or water can be retained by excavation or diking. Runoff, which is the usual water source, may be undependable and may contain varying amounts of sediment, nutrients, or chemical pollutants. Water supply and water quality problems may be alleviated by using stream water or ground water for augmenting runoff during dry periods and for flushing. Flushing rates should exchange the entire volume of water once every 2 to 3 weeks,

(5) Artificial islands. Artificial islands can be used in large ponds to increase wetted edge and to provide needed nesting and loafing areas for waterfowl (Figure 4-13). Islands also provide visual diversity. They can be created by leaving unexcavated areas, by filling, by flooding irregular topography, or by constructing floating platforms. Construction and use of floating islands are described in Will and Crawford (1970) and Fager and York (1975).

(6) Fish stocking. Ponds not connected to bodies of water with fish populations must be stocked if viable fish populations are desired. Species

Figure 4-12. Interior flood control collection pond beside levee in Lewiston, Idaho

Figure 4-13. Artificial islands add habitat and visual diversity to borrow pits and other aquatic areas. Although the island shown here is in an urban area and was landscaped for aesthetics, extensive use by waterfowl for nesting and loafing was observed

should be chosen by biologists familiar with the regional setting and with temperatures and water conditions expected in the ponds. If suitable spawning areas are not available for some of the species stocked, annual stocking may be required. Undesired species, parasites, or diseases should not be introduced into a watershed. Coordination with state and Federal fish and wildlife agencies in developing stocking prescriptions and acquiring fish is required.

(7) Nesting structures and cover. Otherwise acceptable areas for wildlife often provide poor habitat because of the lack of cover and desirable nesting and den sites. Even when care is taken to preserve vegetation, supplemental cover and nesting facilities may be necessary, especially immediately following construction. Perching structures for raptors can encourage predation on burrowing mammals such as ground squirrels. Detailed specifications for construction, placement, and maintenance of artificial cover, perching structures, and nest boxes are available in Martin (1986).

(8) Seeding and planting for wildlife. Vegetation can be planned and managed to provide food or cover that attracts desired wildlife species to the project site. Vegetation also reduces soil erosion. Information about species selection, seedbed preparation, fertilization, seed sources, plant propagation, and measures to ensure plant survival is available in Hunt et al. (1978) and Martin (1981). Seeding and planting should be coordinated with state fish and wildlife agencies. Riverside plantings will be subjected to partial and complete inundation and must, therefore, have a certain degree of flood tolerance to survive. Engineer Pamphlet 1110-1-3 and Whitlow and Harris (1979) identify flood-tolerant species.

(9) Wildlife brush piles. Brush piles provide resting and escape cover for small game and nongame wildlife. Where natural cover is limited, brush piles may be constructed for use by wildlife until natural vegetation becomes established

(a) Location. On the riverside, brush piles should be placed on the landside of stands of trees to protect them from high-velocity flows during floods. Brush piles are not recommended for areas subject to heavy flooding. Brush piles should be located within 200 to 300 feet of other escape cover and should be far enough from the levee so that they will not attract burrowing mammals to the levee toe or interfere with inspection. Long windrow brush piles are usually undesirable in areas that support big game movements.

(b) Specifications. Brush piles should be built by constructing a sturdy base of logs, stumps, or flat rocks and adding smaller limbs and branches as filler material. Brush piles for quail should be at least 15 feet in diameter and 6 to 7 feet high and should have about 6 inches of clearance at ground level. Brush piles designed for rabbits should be 4 to 7 feet high with basal diameter or minimum widths of 10 to 20 feet. Escape entrances must be available at ground level, or brush piles will lose their functional value. Refer to Martin (1986, Section 5.3.1) for detailed information on brush pile use.

d. Environmental Features for Recreation and Aesthetics.

(1) General. Recreational facilities eligible for cost sharing are restricted to facilities that promote general public use and enjoyment of the project (see paragraph 4-9c). The following discussion identifies eligible recreation features that are designed to facilitate use of the levee and associated areas for public recreation and features that enhance the appearance of the levee and related structures. Corps policy regarding recreation facilities is provided in ER 1105-2-100, ER 1110-2-400, ER 1130-2-400, and EP 1165-2-1. Additional information about aesthetic considerations, fishing access, trails, scenic overlooks, and associated facilities is contained in paragraph 4-9 of this manual.

(2) Recreational and aesthetic aspects of borrow pit design. Borrow pits can be used for fishing, hunting, boating, ice-skating, and, if water quality is sufficient, contact activities such as swimming and waterskiing. Access roads, boat ramps, beaches, parking areas, restrooms, and associated facilities stimulate use of water-based recreational facilities. Borrow pits used for swimming, ice-skating, and fishing should be designed with safety considerations in mind.

(3) Levee crowns and access roads. Levee access roads and crowns are easily developed into scenic drives and trails for hiking, jogging, biking, horseback riding, or snowmobiling. Standard widths for maintenance access are sufficient for most uses, although roads used by motorized vehicles must conform to State or local road standards. Access points should be convenient to existing roads, parking facilities, and other community structures. Access sites may consist simply of ramps leading to the levee’s crown and major recreational trail, or they may incorporate various other recreational facilities such as parking facilities, sanitary facilities, picnic areas, interpretive centers, and game fields. Trail utility is increased by rest stops consisting of benches or picnic tables, trash receptacles, water fountains, bicycle racks, and shaded areas that provide opportunities for resting and passive enjoyment of scenery.

(4) Aesthetic considerations for plantings. Well-designed landscaping can lessen the visual impact of a levee project and encourage recreational use. Concerns about root-caused seepage and erosion around the bases of trees can be addressed either by using an overbuilt cross section or by planting materials in concrete tubs or planters that limit root penetration. If tubs are used, long-term costs can be reduced by choosing plants that will not become root-bound. Additional information regarding landscaping of Corps project lands is available in ER 1110-2-400, EM 1110-2-301, EM 1110-1-400, and OCE (1981a,b).

(5) Uses for periodically flooded areas. Interior flood control areas and riverside areas that are periodically flooded may be used for recreational purposes if facilities placed there are floodproof or inexpensive enough to be expendable. Structures placed in flooded areas should be secured against flotation or should be removable.

(6) Interpretive centers, observation areas, and culturally important areas. Observation areas at scenic locations and interpretive centers located

at sites of historical or ecological significance are often used as focal points for trail systems (Figure 4-14). Interpreting points of interest along the levee gives users a sense of regional context and preserves the significance of historic events.

(7) Other recreational facilities. Recreational designs for levee projects often include additional facilities such as fishing access, fishing structures, and boat ramps and swimming beaches, along with associated facilities such as restrooms and picnic areas. Since these uses may conflict with each other, their locations should be carefully planned. Refer to EM 1110-1-400 for design information.

e. Environmental Considerations for Levee Maintenance Activities. Levee maintenance activities generally consist of vegetation management, control of animals that burrow into the levee, upkeep of recreational areas, and levee repair. Options for vegetation management include mowing, grazing, burning, and use of chemicals. Each method fosters different vegetation and wildlife habitat types on levees and adjacent lands. Maintenance operations may be timed and carried out to achieve different environmental goals. Technical Report E-85-7 (WES) discusses levee maintenance options. General maintenance considerations are outlined in Chapter 5 of this manual.

f. Floodwalls. Floodwalls, which are constructed of masonry or concrete, serve a purpose similar to levees. Floodwalls are sometimes built on tops of levees to increase flood protection. Floodwalls can be constructed so that they can be folded or removed when water is at normal levels, to prevent obstructing views of the river or access to the riverbank (Figure 4-15). A folding floodwall consists of a series of concrete panels on hinges. The panels can be raised quickly to a vertical position using a small crane. Once in the vertical position, metal braces that are stored under each panel are bolted to the concrete for additional support. Rubber sealant and gaskets are used to fill cracks between and under panels to make the structure watertight.

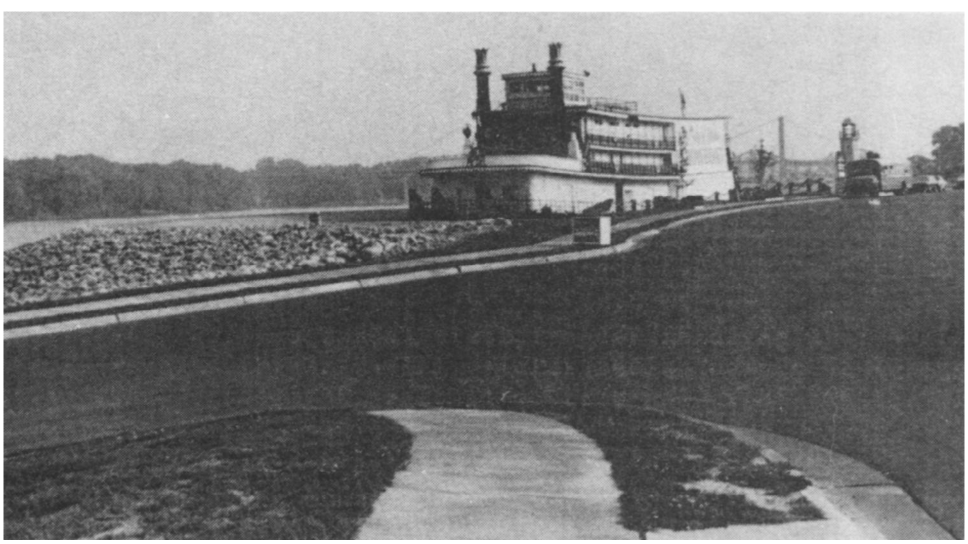
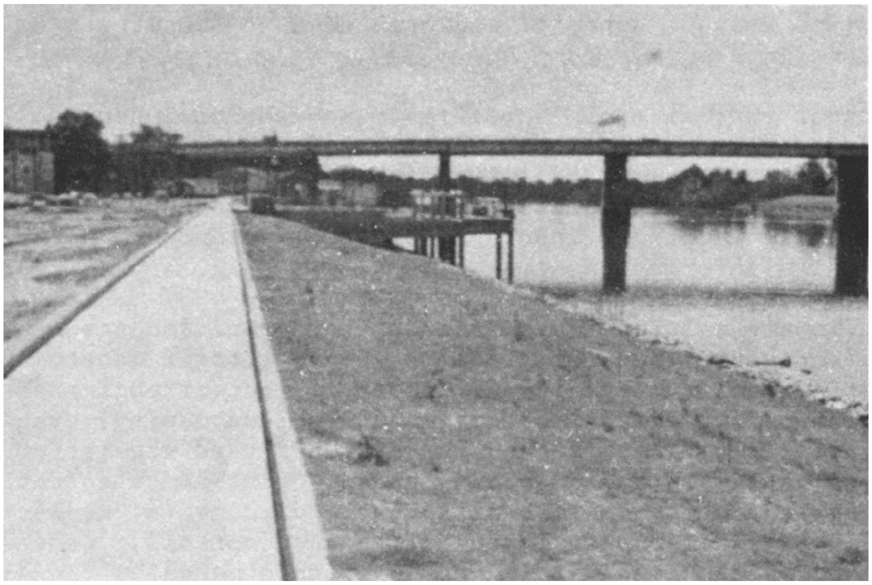
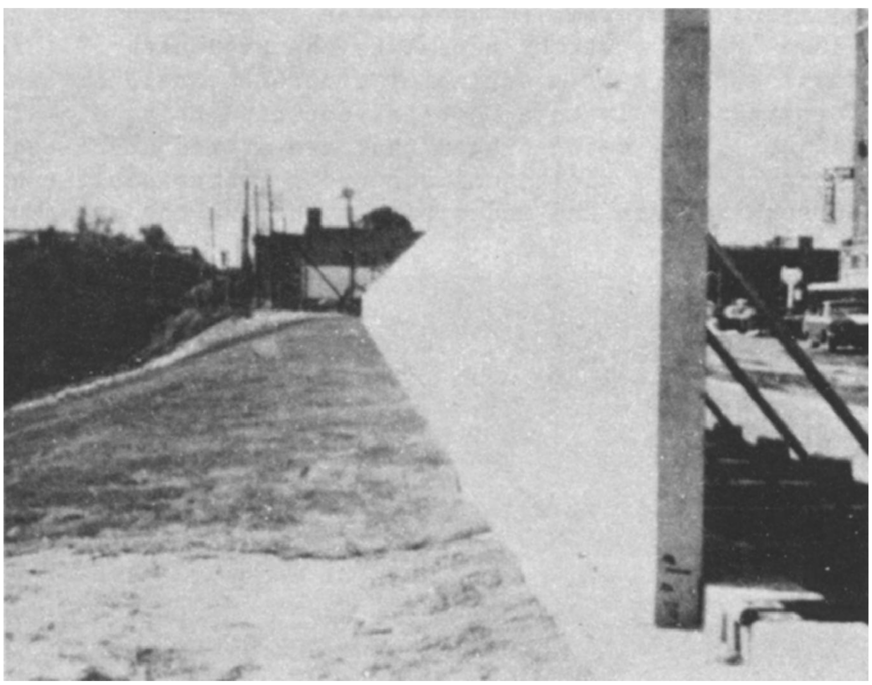


Figure 4-14. Mississippi stern-wheeler showboat that was preserved by being built into the Clinton, Iowa, levee



a. Floodwall in the collapsed position



b. Floodwall in the raised position

Figure 4-15. Monroe, La., folding floodwall
(USAED, Vicksburg)

Removable floodwalls (Figure 4-15) are designed with a base structure low enough to permit viewing and contain several openings through which users may pass. Panels are bolted onto the basic support structure during periods of flooding. Once the panels are installed and plastic sealant is applied to joints, the structure provides full protection. The appearance of concrete walls can be improved by coloring, texturing, or the use of special form liners. Aesthetic treatments for concrete are described in OCE (1969).

4-9. Special Considerations for Urban Projects.

a. General. Consideration should be given to inclusion of recreation features during the planning of water resource projects. An attractive project with well-designed recreational features can have a positive effect on public perception of a channel project (Figure 4-16).

Figure 4-16. Architectural treatment for aesthetics, pumping station in city park, Minot, N. Dak. The arrow points to a fireplace for public use

b. Aesthetic Considerations. Because of the high visibility of urban projects, consideration of aesthetics is important in project planning. Paragraph 3-6 of this manual provides guidance for visual quality assessment of a project area and evaluation of visual impacts of alternatives. The following features can be used to meet design objectives for aesthetics and to reduce adverse visual impacts.

(1) Channel linings, paved surfaces, and concrete. Vegetation may be the most visually pleasing cover for channels, banks, and large open areas. Natural materials such as gravel or cobble may be used effectively for channels requiring nonvegetative linings and for paved areas. Aesthetic concrete treatments are discussed in paragraph 4-8f.

(2) Water displays. Project designers can capitalize on the aesthetic importance of water by using falls, fountains, cascades, and reflecting ponds

as focal points. Sills and deflectors can be used to create turbulent cascades in channels. Water displays generally require several feet of head (such as at dams or grade control structures) and continual flow.

(3) Vegetation. Ground cover, usually grass, should be planted as quickly as possible following final grading. Trees and shrubs can be selected and placed for maximum visual effect. The hydraulic, geotechnical, and climatic condition at the site must be taken into consideration when selecting plants. In addition, other general considerations in the selection and placement of trees and shrubs include the following:

(a) Avoid uniform spacing.

(b) Concentrate plantings in areas of intensive use, high visibility, and superior aesthetic quality.

(c) Stake shrubs and trees and, where necessary, provide protection from rabbits, beavers, and other animals.

(d) Use exotic species with caution; experience has shown a better survival rate using native rather than exotic species.

(e) Irrigate or manually water plantings long enough to ensure survival. Performance criteria guaranteeing minimal survival rates after specified periods of time may be used in planting contracts.

(f) Select, place, space, and prune ornamental trees and shrubs planted within flood channels so that they will not hinder flood flows.

(g) Use low-maintenance varieties wherever possible.

(4) Fencing. Either design fencing to blend with the setting by using colors and substances that are natural in appearance and do not contrast with surroundings, or design it as a major visual element by using ornamental iron or wooden designs.

(5) Architectural design. Design and place structures so that they blend harmoniously with other landscape elements and with the surrounding environment. Subdued earth colors, generous use of wood, and textured finishes can be used to enhance visual effect. Structures in floodways should be designed for removal prior to flooding or should be secured against flotation, made as floodproof as possible, and designed and located for minimal flow resistance.

(6) Bridges and low-water crossings. Trail crossings should be designed so that they are attractive as well as functional. Where feasible, low-water crossings are cheaper and less visually intruding than bridges. Low-water crossings may be placed on the channel invert or raised slightly, as in stepping stone and low culvert designs. Unless they are designed to float during flood events, bridges should be above the design water surface and should not trap debris. Refer to WES TR E-85-3 for illustrations of low-water crossing designs and photographs of a floating foot bridge used over the South Platte River in Denver.

c. Recreation. Engineer Regulation 1105-2-100 limits Federal participation in recreation facilities to basic facilities that are for use by the general public and are not ordinarily provided by private enterprise or on a commercial or self-liquidating basis. Safety and maintenance factors must be taken into consideration in the design of recreation features. EM 1165-2-400 (Appendix B) provides a checklist of facilities that may be provided in recreation development at Corps water resource projects and provides cost sharing guidance for these facilities.

(1) Eligible features. Described below are some of those features eligible for inclusion in flood control channel projects.

(a) Trails. Trails for hiking, jogging, biking, and equestrian use and associated facilities such as picnic areas, parking, comfort stations, etc., are popular recreational features on flood control channel projects. Walking and biking trails should be surfaced for all-weather use, and fencing should be provided in areas where user safety could be a problem. Barricades should be provided in hazardous locations, and bollards or other devices should be used to exclude motorized vehicles. Trails for motorized vehicles, such as trail bikes and snowmobiles, should be located far enough from recreation sites so that other visitors will not be annoyed by noise. Trails that tie into existing trial systems should be compatible in appearance and constructed to equivalent standards. A good system of signs to provide direction, distances, and locations is essential. Extensive trail systems usually require grade-separated crossings at street and road intersections. Trails, trail crossings, and associated facilities should be accessible to and usable by physically handicapped persons. Potential erosion problems should be taken into consideration when designing these trails.

(b) Nature study areas. Natural areas that support unusual or unique ecosystems, possess a variety of natural conditions (geology, soils, etc.), or are rich in biological diversity are well suited for nature areas. Severed bendways, cutoff islands, and wetlands maintained in a natural state are potential nature study area locations. Interpretive displays and signs increase the value of nature areas as outdoor classrooms and learning resources. Trails, signs, and structures should not detract from the natural theme.

(c) Campgrounds and picnic areas. Flood control channel projects often are adjacent to sites suitable for development as picnic areas or campgrounds, and these facilities are popular visitor attractions. Guidance on selecting numbers and types of facilities based on anticipated use and on designing the layout and placement of facilities is available in EM 1110-2-400.

(d) Playgrounds and playing fields. Playgrounds and playing fields are well suited for flood channel projects that include parks and campgrounds.

Although Corps policy no longer permits cost sharing for special-purpose facilities such as tennis courts and softball diamonds, general-purpose playing fields can be included. Children's playgrounds can also be included, as long as they do not employ elaborate designs.

(e) Scenic overlooks. Scenic overlooks can be located at sites that provide attractive views. Overlook parking areas should contain a minimum of 10 spaces (10 by 20 feet), but no more than 30 spaces. Additional facilities that may be included are buildings, covered observation platforms, benches, toilet facilities, water supplies, trash receptacles, and signs or displays that describe the nature and extent of the project.

(f) Historic sites and structures. Historic resources must be taken into account in formulating recommendations for project authorization and implementation. Engineer Regulation 1105-2-100, Chapter 7, defines historic resources as any prehistoric or historic district, site, building, structure, or object included in or eligible for inclusion in the National Register. Preservation of historic properties through avoidance of effects is preferable to any other form of mitigation. Where historic sites exist and can be preserved, they can often be incorporated into recreational plans as centers of attraction (Figure 4-17).

(g) Fishing access areas. Fishing access areas should be located at easily accessible pools or structures that attract fish. Access areas may include parking, boat ramps, water supply and sanitary facilities, trails, and fishing structures. Platforms and steep banks should have fences or safety railings.

(h) Boating, canoeing, and rafting. Studies should be undertaken to ensure that flows and water quality are adequate before boatways are planned for flood control channels. If heavy boating use is anticipated, flood channels should be designed to provide adequate access, suitable low-flow depths, and as few obstructions as possible. Sills and fish habitat structures should be designed so that they will not be hazardous to boaters. Weirs, drop structures, and other barriers must be bypassed or modified for boat passage, or safe portages must be provided. Appropriate warning signs are needed upstream of boating hazards, obstacles, and boat chutes. Boating should be prohibited at unsafe discharges, and clearly marked staff gages or removable warning signs should be provided at all boating access points. Technical Report E-85-3 (WES) provides examples of modified structures and boatways on flood control channels. Figure 4-18 is an example of a flood control structure where boating activities have been carefully integrated into the design.

a. Espada Aqueduct, circa 1900

b. Espada Aqueduct in 1977

Figure 4-17. Espada Acequia. A flood control diversion channel was built to protect this historic Spanish aqueduct from undercutting by flood flows (USAED, Fort Worth)

4-10. Selection of Environmental Features for a Given Project.

a. Environmental Objectives and Environmental Features. Several options usually exist for meeting the environmental objectives or mitigation needs of a given project. Environmental features most often used to effectively address specific environmental objectives are shown in Tables 4-1, 4-2, and 4-3. More detailed information regarding feasibility of environmental features for specific projects is available within the ENDOW microcomputer program. The ENDOW program may be obtained by sending one formatted blank 360-KB floppy diskette to CEWES-IM-SC, PO Box 631, Vicksburg, MS 39180-0631.

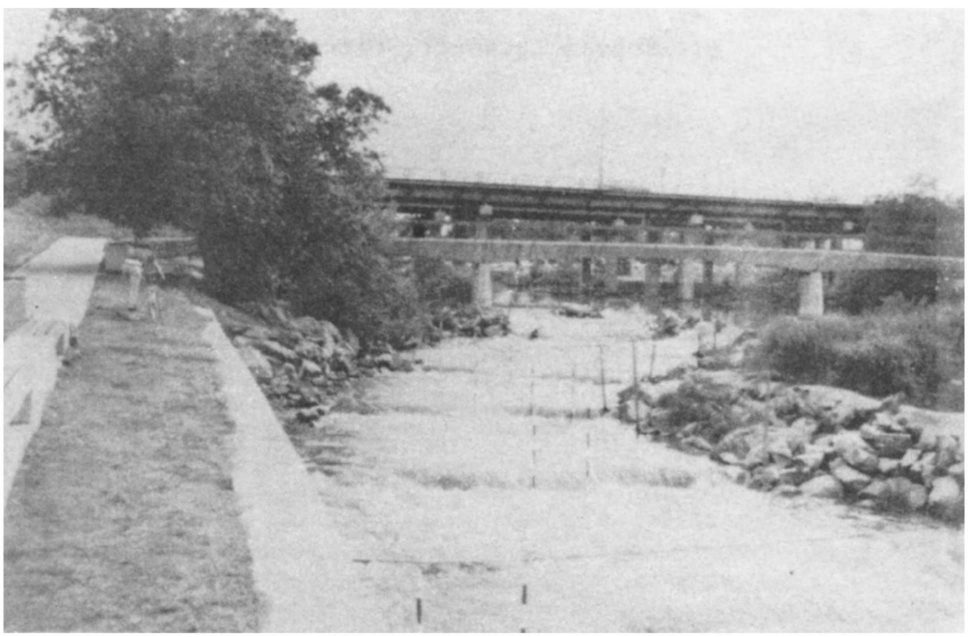


Figure 4-18. Confluence Park boat chute, South Platte River, Denver. A series of 12 pools and weirs drop 10 feet over a run of 330 feet.

Table 4-1

Environmental Features for Channel Side Slope Protection

If you wish to:	Consider using:
Maintain or improve terrestrial riparian habitat value	reinforced revetment, toe protection, bank sloping and revegetation, vegetation, stream corridor management, fencing and buffer strips, or floating plant construction
Provide stable substrate for benthic macroinvertebrates	riprap or quarry-run stone, gabions, or hard points
Provide or maintain fish habitat	tree retards, tree revetments, hard points, earth core dikes
Improve or maintain aesthetic resources	vegetation, combinations of vegetation and structure (composite revetment, excavated bench, earth core dikes, and revegetation of riprap), fencing and buffer strips, stream corridor management, selective clearing, or earth core dikes
Provide access to stream for recreation and/or wildlife	composite revetment, berm preservation and restoration, bank sloping and revegetation, channel relocation, revegetation of riprap, or stream corridor management

* Descriptions of these techniques are given in WES TR E-84-11.

This manual does not mandate use of any particular design or feature for any project. Conversely, features not associated with a specific objective in the tables below may be successfully used to achieve that objective in some situations. Innovation is encouraged.

b. Feasibility of a Given Feature. The success or failure of a given environmental feature is most strongly influenced by stream and watershed conditions. For example, although instream habitat structures are often excellent features to preserve aquatic habitat, they are not generally suitable for braided or unstable channels, ephemeral streams, streams with poor water quality, or channels with no existing or prospective fishery.

Table 4-2

Environmental Features for Channels

If you wish to:	Consider using:
Limit bed and bank erosion	meandering alignments, grade control structures, side slope protection, armor, channel lining (asphalt or concrete), vegetative plantings, or vegetative buffer strips
Avoid bed aggradation	low- and normal-flow channels, sediment traps, revegetation of disturbed areas, selective clearing and snagging, or vegetative buffer strips
Prevent ground-water table lowering	water-level control structures, greentree areas, or maintenance of oxbows
Maintain low-flow depths and velocities	low- and normal-flow channels, floodways and bypass channels, pools and riffles, instream habitat structures, water-level control structures, or sediment traps
Maintain water quality	selective clearing and snagging, single-bank construction, vegetative buffer strips, floodways and bypass channels, low- and normal-flow channels, or diversion of flow to allow dry excavation
Preserve aquatic habitat	selective clearing and snagging, instream habitat structures, single-bank modification, meandering alignments, pools and riffles, construction of substrate, fishways, water-level control structures, maintenance of oxbows, or seasonal restrictions on construction activities
Avoid loss of riparian vegetation	selective clearing and snagging, single-bank modification, greentree areas, vegetative plantings, revegetation of disturbed areas, preservation of islands formed by bendway cutoffs
Create or maintain terrestrial diversity	stream corridor management, vegetative plantings, or shaping and placement of dredged and excavated material

(Continued)

* Descriptions and additional information regarding these environmental features are contained in WES TR E-82-7 and TR E-85-3.

Table 4-2 (Concluded)

If you wish to:	Consider using:
Create wetlands	greentree areas, oxbow maintenance, placement of dredged or excavated material
Improve or preserve instream aesthetics	meandering alignments, pools and riffles, single-bank modification, water-level control structures, water displays, special materials and finishes for channel walls
Improve or preserve streamside aesthetics	selective clearing and snagging, single-bank modification, vegetative plantings, contouring dredged material disposal areas, preservation of vegetated buffer strips, special finishes for concrete, water displays
Improve or preserve instream recreation opportunities	selective clearing and snagging, low- and normal-flow channels, water-level control structures, oxbow and bendway maintenance

Table 4-3

Environmental Features for Levees and Floodwalls

If you wish to:	Consider using:
Provide fish habitat	special designs for borrow pits and collection ponds, water control structures, or fish shelters in borrow pits
Preserve or create wetlands	avoidance measures, alignment of levee to increase riverside land area, minimal clearing, overdesign of drainage ditches, artificial islands in borrow pits and collection ponds, or vegetation
Preserve or create upland habitat	avoidance measures, tree preservation, minimal clearing, overbuilt levee embankments, vegetation, brush piles, fencing, or selective vegetation maintenance and management
Provide recreation opportunities	special designs for borrow pits and collection ponds, roads and trails, interpretive features, observation areas, boat ramps, fishing access, or swimming beaches
Improve or maintain aesthetic resources	ornamental plantings, special designs for borrow pits and collection ponds, folding floodwalls, or special architectural treatments for floodwalls, pumping stations, and other structures

* Descriptions and additional information regarding these features are contained in WES TR E-85-7.