Best Management Practices Guidance, Dredged or Fill Activities

U.S. ENVIRONMENTAL PROTECTION AGENCY
Water Planning Division

We have attempted to draft the guidance in a format and style that makes the information presented easy to read and understand. Please transmit any comments regarding suggested revisions or additions to Robert E. Thronson by September 14,1978. His address and phone number is:

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

DATE: JUL 13 1978

SUBJECT: Transmittal of Final Draft of "Best Management Practices Guidance, Dredged or Fill Activities."

FROM: Merna Hurd, Director
Water Planning Division

TO: State 208 Agencies
State Resources Agencies
Federal Agencies
National Environmental and Conservation Organizations
Other Concerned Groups

The enclosed document is submitted to you for final review. It has been prepared principally to provide the State agencies that will be involved in programs to control the discharge of dredged or fill materials, under authorities of Section 208 and 404 of P.L. 92-517, with guidance regarding Best Management Practices. It was designed also to provide other State agencies, Federal organizations, and concerned public groups with readily-available information on how detrimental environmental impacts resulting from projects involving the discharge of dredged or fill materials can be prevented or minimized.

The initial draft was reviewed by many State agencies, Federal agencies environmental groups, EPA Headquarters and Regional organizations, and other concerned individuals and groups. Comments received were evaluated and used to develop this final draft submitted to you.

This guidance defines the problems; discusses what adequate programs could involve; and provides information on suggested practical engineering structures, procedures, and schedules for preventing or minimizing problems that could result from the discharge. Best Management Practices presented have been subdivided into categories and described in the following chapters:

1 - Minimizing The Impairment of Water Flow or Circulation

2 - Preventing or Controlling The Runoff of Excess Sediment Loads or Turbidity Increases

3 - Ensuring Containment of Potential Pollutants Within A Mass of Dredged or Fill Materials

4 - Enhancement - - The Replacement, Relocation, or Reconstruction of Existing Environments

5 - Protecting Existing Habitat and Providing For Fish and Wildlife Propagation.

BEST MANAGEMENT PRACTICES GUIDANCE,

DREDGED OR FILL ACTIVITIES

U.S. ENVIRONMENTAL PROTECTION AGENCY
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1. Department of Agriculture, Forest Service and Soil Conservation Service
2. Department of the Army, Corps of Engineers
3. Department of the Interior, Fish and Wildlife Service and Bureau of Reclamation
4. Department of Transportation, Federal Highway Administration
5. Environmental Protection Agency, Regional Offices

Other agencies, particularly State Departments of Highways or Transportation, Conservation, Forestry, and Fish and Game, made an outstanding effort to provide information, analyses, or other input to this guidance. They include:

California

Colorado

Louisiana

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Virginia

Washington

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PREFACE

Section 404 of the Clean Water Act of 1977 (P. L. 95-217) authorizes the States to assume the responsibility for controlling the discharge of dredged or fill materials into navigable waters under their jurisdiction through individual and general permit programs. Section 208(b)(4) authorizes States to establish regulatory programs to control the discharge of such materials through the implementation of "Best Management Practices". The 208(b)(4) programs must complement and be coordinated with the States permit programs developed under Section 404. Evaluations of proposals for the discharge of dredged materials must comply with guidelines prepared by the Administrator of EPA pursuant to Section 404(b)(4)(1) and Section 307 and 403 of the Federal Water Pollution Control Act.

Before a decision can be made regarding the discharge of dredged or fill materials into waters within a State's jurisdiction, all feasible alternatives should be considered. They will include an evaluation of such factors as the necessity for the discharge; sensitivity of the area to environmental inpacts, both long and short term; effectiveness of available Best Management Practices to prevent, or minimize the impacts; and possible alternative site areas or a scheduling of operations. Applicable Federal and individual State's wetlands policy and laws, and other relevant legislation should be recognized and complied with.

This guidance document was developed to provide State 208 and 404 agencies, other State agencies, Federal organizations, and other concerned groups with the most readily available information on how detrimental environmental impacts resulting from the discharge of dredged or fill materials can be prevented or minimized through the use of Best Management Practices (BMP's).

The pollution control measures described here and included under the term "Best Management Practices" will be developed, in accordance with site-specific conditions, by dischargers and, subject to approval by a responsible State management agency, applied under a 208 regulatory program. They also may be specified, along with appropriate design criteria, as a requirement for obtaining a State 404 permit. Decisions regarding whether or not to implement dredged or fill Best Management Practices through a 208 regulatory program or a State 404 permit program will be made on the basis of the environmental sensitivity of the area in which the activities are to be conducted and its relationship with the potential for these activities to cause water pollution. If the potential to pollute the area is great, BMP's should be implemented under the 404 permit program to ensure that all possible data, opinions, and evaluations are obtained concerning the project through the review and public participation processes. There will be more assurance through this program that possible detrimental impacts resulting from the activities will be detected and identified and that criteria for the design and effective application of a BMP system will be optimized. If conditions existing at a site for dishcarging dredged or fill materials are so sensitive that available BMP's will not prevent significant environmental degradation, an alternate, less sensitive site should be used or the discharge prohibited.

C O N T E N T S

GUIDANCE FOR BEST MANAGEMENT PRACTICES TO CONTROL THE DISCHARGE OF DREDGED OR FILL MATERIALS

INTRODUCTION

The discharge of dredged or fill materials involves man's deliberate introduction of what can be considered principally naturally-occuring sedimentary, rock, or earthen materials into the waters and adjacent wetlands of the United States. Dredged materials generally are discharged for disposal purposes while fill materials are placed to provide for engineering structures of one kind or another.

Although fill generally consists of natural geologic materials, it can be made up of masses of concrete, wood, or any other substances used to displace the water and change bottom surface elevations. Fill materials are placed into wetlands or water bodies to provide adequate foundations, at required elevations, for municipal, industrial, commercial, recreational, or residential developments or structures. They can form bridge approaches, highway and railroad causeways, dams, dikes, levees, road fills across stream channels, and artificial islands or reefs; function to protect property from erosion by stream or wave action through the use of groins, rip rap blankets, revetments, breakwaters, and structural walls of one type or another; and fullfill other useful purposes. Materials dredged from a water body can become fill materials if they are used for providing adequate sites for structures. They could include small linear backfills in excavations for subaqueous utility lines or communication cables and fills of large area extent in low lands to provide surface elevations high enough for land development purposes.

Analysis of the Problem

Streams, wetlands, lakes, and other water bodies can accept, accommodate, or adapt to certain stress conditions caused by the discharge or placement of dredge or fill materials. Exceeding these conditions will cause readjustments to take place in natural processes which can initiate water pollution or other undesirable effects. Stresses imposed by the discharge of dredged and fill materials into an aquatic environment can be induced by or result from:

1. Changes in the natural flow or circulation of surface and/or subsurface waters.
2. The addition of pollutants into the water in excess quantities to cause changes in the chemical or physical characteristics of the waters.
3. Alternations of the elevation of the substrate, or bottom of the water body.

The stresses are interrelated and can be superimposed upon one another to severely damage, or even destroy wetlands or water bodies. Masses, or accumulations, of discharged dredged or fill materials often cause detrimental changes in the flow or circulation of waters. They change substrate, or bottom elevations, and obstruct or restrict the flow of surface waters or ground waters by reducing the cross-sectional areas through which they flow. Local or areawide changes in water levels, normal flunctuations, velocities, directions of movements, and other characteristics occur. They can initiate adverse effects in the production, movement, and occurrence of aquatic life and water-dependent wildlife; cause changes in the chemical and physical quality and other characteristics of the water; and function to increase normal erosion and sediment transport and deposition rates. The particles of various sizes that comprise the principal mass of dredged and fill materials (sediments) can become pollutants if moving water erodes them from their area of placement and transports them into adjacent areas. They can reduce the light-transmitting capacity of the water body to create undesirable environmental effects, blanket its bottom to smother or reduce aquatic life, and impair its quality for beneficial uses.

Dredged materials often contain additional pollution-causing materials such as nutrients, metallic compounds, pesticides, oils, and greases, or other materials. Many of them are adsorbed to the fine-grained dredged material such as silts and clays. Others form coatings on materials of any size. Fill materials may contain pollutants similar to those in the dredged materials if they are obtained from a polluted source. Even if they are obtained from a source that has not been affected by pollutants, fill materials may contain naturally-occuring substances that change status and become pollutants when transported to and placed into a different environment, particularly an aquatic one. These substances may include such mineral compounds as iron sulfide (pyrite), calcium sulfate, sodium chloride, and other materials which, through chemical or physical processes, can become soluble and be transported into adjacent area.

Some pollutants, such as nutrients, can cause accelerated eutrophication (enrichment) of waters with accompanying detrimental changes in aquatic life. Others can change the physical or chemical characteristics of the water, impart undesirable tastes to it and the aquatic life in it, and initiate undesirable environmental effects in the life cycle of all aquatic orbanisms and wildlife depending on it. As higher order organisms consume lower aquatic organisms that have ingested minor quantities of pollutants, concentration of the pollutants may occur in the higher organisms. This is termed biomagnification. Its severity is influenced by the physiology of the organisms involved and the characteristics of the pollutants.

Adequate Program Planning And Development

Advanced planning, prior to initiating the discharge or placement of dredged or fill materials into a stream and adjacent wetlands, is essential for preventing environmental problems from resulting. Often, it can prevent, through management decisions, the development of conditions that could add materially to the potential for environmental degradation. If problems can be foreseen during the planning stages, alternative sites, scheduling of operations, methods, or practices may be used to minimize them. Program planning and development probably will be done most advantageously on a multi-disciplinary type approach. Personnel with engineering, geologic, wildlife and biologic, soils, and hydrologic backgrounds should all be involved in the process to enable all possible aspects of the problems and their solutions to be considered. If personnel competent in any of these disciplines are needed and not available in the staff of the management agency, they may be obtained, on a consulting basis or some other type of arrangement, from one of the various Federal, State or local agencies that are knowledgeable in the field.

All necessary pertinent information on the proposed disposal site, and alternative sites, should be collected and evaluated. Factors to be considered include the existing environmental conditions, potential for the discharge to cause pollution, and Best Management Practices for pollution prevention or reduction. The best combination of sites, types of discharges, and management practices will function most effectively to minimize the environmental problems that could result from the activities. Sites in which insurmountable environmental problems could arise should be avoided or discharge schedules changed to reduce the potential for pollution. Often, minor changes prior to initiating an activity will serve to prevent pollution problems or habitat destruction much more effectively than remedial after-the fact measures.

An adequate Best Management Practices program for preventing environmental problems that could result from the discharge of dredged or fill materials can best be achieved through the proper development of plans by the discharger; adequate review and approval of these plans by a responsible management agency; adjustment of the plans after the review to maximize the effectiveness of the Best Management Practices prior to their application; monitoring by the management agency for adherence to the plan; and, when required, effective and aggressive enforcement of environmental laws.

Effective Best Management Practices must be based upon a consideration of all existing conditions at the site that interrelate to maintain the long-term integrity of environment there. They should achieve needed environmental protection at the least possible cost. Important factors to consider in their development include the occurrence and movement of both ground and surface waters; geologic, soils, and topographic conditions; and the existence, needs, and sensitivities of aquatic and other life occurring in the area. Proper scheduling, or timing of activities, often is as important to a Best Management Practice as an adequate design and application.

Guidance for the development, selection, and application of Best Management Practices, such as that presented in this document, can be provided by governmental agencies. On a national scale it must be general in nature such as that provided in this document. At the State, and possibly local, level the guidance will be more specific regarding local conditions. The BMP's defined in site plans, however, must be made on a site-specific basis by those most familiar and knowledgeable regarding the site area.

Guidance should always be flexible enough to allow initiative to be used for developing new, less expensive, and more effective BMP's. A flexible BMP program also allows for the application of State and local expertise towards the understanding of site-specific environmental characteristics and problems. This is essential as official guidelines often are interpreted to represent minimum standards. These standards, in reality, then tend to become enforceable criteria for performance. As long as the guidance does not become too rigid and management agencies do not begin to feel that it covers all site-specific requirements that are to be encountered, the approach is good. If, for a management agency, the guidance represents a "cookbook" to use in lieu of good professional and management experience and judgement, it will become a poor tool. They must ensure that rote and complacency do not begin to supersede the use of logic and common sense in the development and use of Best Management Practices.

Best Management Practices, Summary

Best Management Practices for preventing environmental impacts from the discharge of dredged or fill materials into waters of the United States are, to a large extent, technically feasible and readily available. After all alternatives to a project have been evaluated, based upon 404(b)(1) guidelines, and the decision has been made that the discharge, or placement of dredged or fill material is to be conducted, effective procedures, measures, and practices for preventing environmental problems can be devised and implemented. They involve practical engineering designs, structures, procedures, and schedules for operations that have been used for many years to control surface or subsurface flows of water, prevent the loss of materials from a site area, and provide for the protection and propogation of fish, shellfish, and wildlife.

Since many of the environmental concerns we have now were not of vital interest during the conduct of past engineering projects, many of the existing techniques and structures are inadequate for environmental protection or create, rather than prevent, such problems. In view of this, modification of the design of structures and procedures for their placement or construction must be considered to reverse this trend and protect the environment rather than damage it.

Environmental problems that can result from the discharge of dredged or fill materials into streams, lakes, or wetlands can be prevented or minimized only through implementation of effective Best Management Practices. Descriptions, discussions, and examples of BMP's are presented in the following five chapters of this guidance document. They include, but are not limited to operating procedures, scheduling of activities, or management practices which can be conducted or applied to ensure that: (1) stream or current flow changes are minimized, (2) increased sediment loads or turbidity levels effectively reduced, and (3) other pollutants included with dredged or fill materials are restricted from entering water bodies. BMP's may also involve (4) the relocation, reconstruction, or enhancement of an area of wetlands or a stream if no other alternatives exist and (5) protecting existing habitat and providing for fish and wildlife propagation.

Best Management Practices involving minor discharges of dredged or fill materials with relatively insignificant impacts on the aquatic environment are similar to those needed for major discharges with significant impacts. They are much less elaborate and expensive; however, and generally require no formal design or rigid application specifications. It must be emphasized here that the results desired with regard to the protection of the chemical, biological, and physical integrity of our Nation's waters are the same with either large or small discharges.

Preventing Impairment of Water Flow or Circulation

Masses of dredged or fill materials placed (or discharged) into streams, lakes, or wetlands can impair the natural movement or circulation of water in them. The degree of impairment will depend upon the volume, permeability, and location of the material that is discharged where it can reduce the cross-sectional area through which the water flows. This applies to the sub-surface flow of water as well as to surface movement.

There are several ways to reduce, or prevent, the impairment of circulation or flow. They involve one or more of the following basic techniques regarding discharge, or placement, of dredged or fill materials:

1. Minimizing the extent of individual fills or the concentration of numbers of fills.
2. Providing continuous open channels through, or around, masses of materials parallel to natural flow directions.
3. Using alternate sections of impervious fill with pervious sections or open structures to permit free flow of water.
4. Designing channel - spanning structures:
   a. To pass flood flows with no significant adverse impacts from flow restriction.
   b. To minimize debris blockage which can obstruct flow.
   c. In accordance with upstream and downstream hydraulic flow conditions (do not cause drastic changes in flow regime).
5. Aligning bridges, culverts, and other structures to limit adverse impacts from flow disruption resulting from abutments or other fills.

Preventing, or Controlling, The Runoff of Excess Sediment Loads or Turbidity Increases

Excess sediment loads or turbidity increases can occur in streams as a result of the placement of dredged or fill materials into water bodies and wetlands. The erosion and transportation of particulates can take place during the actual placement of the dredged and fill materials if no preventative measures such as cofferdams, caissons, filter cloth fences, or other preventative devices or procedures are used. To prevent in-place, or completed, dredged or fill deposits from being subjected to the erosive forces of high-velocity surface flows, effective surface protection measures such as rip rap blankets (or layers), concrete walls, and similar measures should be provided. The erosion and transport of sediments can be minimized, or prevented by one or more of the following measures or practices:

1. Placing materials on dry land by scheduling operations during low flows, using structures to exclude the water, or by temporarily diverting the stream from the site.
2. Protecting slopes that will be subject to erosion by surface flows with erosion-resisting coverings such as vegetation, rip rap blankets (with or without underlying filters), gabions, retaining walls, aprons, wing walls, and similar measures.
3. Designing bridge-supporting members such as piers, piles, etc., to minimize scour.
4. Providing filter cloth, or some other type of filtering media to remove sediment being transported from an area of placement.
5. Avoiding placement of dredged or fill material during conditions that may be extremely critical for sensitive aquatic life and wildlife such as spawning seasons or migration times.
6. Using placement procedures to prevent, or restrict, the movement of mobile equipment in the water.

Extreme care should be taken during the planning, design, and placement of a fill to ensure that structural failure does not occur during the project life to allow the material to enter a water body or adjacent wetland. Adequate criteria should establish the factors of safety to be used in the design, analysis, and placement.

Ensuring Containment of Potential Pollutants Within The Discharged Mass of Dredged or Fill Materials

At times, dredged or fill materials placed, or discharged, into streams, lakes, wetlands, or other water bodies may contain natural materials such as iron sulfide (pyrite), calcium sulfate (gypsum), and various salts. These materials are not pollutants in their source areas but can become pollutants when transported and deposited in another aquatic environment. If polluted materials can be effectively contained by effective BMP's and prevented from affecting water quality, their discharge should not be precluded, provided they are not toxic. Effective containment within the mass of materials is essential for use. It can be done by:

1. Surrounding the poor quality material during placement with walls and blankets of relatively impervious materials such as compacted fill, concrete, or similar materials. Drain blankets for pumpout of fluid may be desirable.
2. Restricting the use of poor quality materials to areas above high-water elevations and capping with relatively impervious blankets of fill to prevent infiltration of rainfall and subsequent leaching.
3. Blending poor quality materials, such as pyrite, with naturally-occurring neutralizing materials such as crushed limestone during placement.

Enhancement or Replacement, Relocation, or Reconstruction of Existing Environment

If, after evaluating all alternatives, the placement of dredged or fill materials into wetlands or other water bodies is justified; and available Best Management Practices will not effectively prevent adverse effects, enhancement or replacement of the existing environment may be feasible. This could include such practices as:

1. Creating and maintaining additional wetlands equivalent in area to those destroyed by the discharged deposits.
2. Providing shallow or deep water areas equivalent to those destroyed by the placement of materials for the maintenance of aquatic and water dependent wildlife.

3. Providing for the relocation of streams which have been designed and constructed to flow under the same gradient, hydraulic, and aquatic habitat conditions as before.

A multi-disciplinary approach is critical in determining the feasibility of enhancing or replacing, relocating, or reconstructing existing environmental conditions in a site area and developing appropriate BMP's. Competent hydrologists, geologists, biologists and wildlife specialists, engineers, soil scientists, and other personnel from 208 or 404 management agencies, the dischargers, and involved State or Federal fish and game and resource agencies should be consulted and their opinions considered and evaluated. Long-term as well as short-term results of the activities and projects must be considered.

Protecting Habitat and Providing For Fish and Wildlife Propagation

The disposal of dredged or fill materials into water bodies or wetlands can cause detrimental changes to occur in the habitat for fish and wildlife, particularly in the immediate locality of the discharge. Migration routes or access to select food sources can be blocked or restricted, propagation activities interfered with, and key ecological relationships and interdependencies disturbed.

Best Management Practices for mitigating, or preventing, these environmental problems can involve scheduling of operations to avoid creating problems during conditions that are critical for aquatic and other wildlife. This could include spawning, migration, nesting, and other periods where the effects of discharge activities could be much more critical than during other times. Other practices may involve the proper placement and management of activities as well as the modification or construction of structures and techniques to offset terrane changes, water level and flow alterations, and revision in the natural physical or biological integrity of the water bodies and wetlands due to the discharge. They could include:

1. Creating avenues for movement of aquatic life and wildlife through structures formed of dredged or fill materials.
2. Providing protective devices for wildlife when contacting or crossing structures of dredged or fill materials.
3. Creating necessary habitat improvement measures.

CHAPTER 1

MINIMIZING THE IMPAIRMENT OF WATER FLOW OR CIRCULATION

Best Management Practices to reduce, or prevent, the adverse impairment of flow or circulation of waters can involve properly locating, shaping, and orienting masses of dredged or fill materials to minimize flow disruption; limiting their unbroken extent or providing continuous open channels through them; preventing abrupt changes in the elevation of the bottom of stream channels which restrict free movement of aquatic life; and ensuring that the transmission capacity of surface or ground water systems is not adversely affected.

The discharge, or placement, of a mass of dredged or fill materials into a water body or its adjacent wetlands will alter the elevation of the bottom surface (substrate) of the water or the surface of the wetland. It will reduce the cross-section area through which surface or ground water moves and cause subsequent changes in their flow and circulation patterns. Local or areawide changes in water levels, normal fluctuations, velocities, direction of movement, and other characteristics will occur perhaps within the affected body and both upstream and downstream. The degree of the impairment of flow or circulation will depend upon the volume of materials discharged or emplaced and the reduction in cross-section resulting.

Adverse effects caused by the alteration of flow or circulation patterns may involve changes in the occurrence, movement, and natural productive capacity of aquatic life; chemical and physical characteristics of the water; and energy capacity for moving sediment and other materials through the natural water system.

Property Locating, Orienting, and Shaping Masses of Dredged or Fill materials

Dredged materials discharged for disposal and large fills placed in shallow water or wetlands for land development purposes can have a major effect on the flow and circulation pattern of water both locally and areawide. These effects can be reduced to a large extent by locating, orienting, and shaping the masses of materials so that they minimize the disruption of flow. The potential for erosion and the subsequent sediment losses will be minimized also by these practices.

Factors to be considered in designing the most advantageous shape, orientation, or location include the topography of the surface upon which the material is to be discharged or placed, direction of prevailing current or wave movement, irregularity of the contact between land and surface and the water body, and the need to minimize the length of containment dikes. These dikes must be constructed to contain the materials before any discharge of materials takes place. Large fills for land development purposes may consist entirely of fill materials derived from underwater sources and capped by a thick layer of stronger more competent fill obtained from land sources.

Areas of indentation in shorelines of water bodies can be considered for the location of deposits of dredged or fill materials. If they are sensitive wetlands they should be avoided, if at all possible. The design and proper discharge of these deposits; however, could result in the creation and development of a wetland habitat to enhance the environment as well as minimizing impairment of flow and circulation.

If the indentations are located in the straighter portions of stream channels and on the inside of stream bends, properly shaped masses of dredged or fill materials situated in them will be outside of the main currents and have a minimal effect on their flow. In lakes or other open water bodies they also will have only a minor effect on currents along the shore. Figure 1-1 illustrates how dredged materials can be placed with rip-rapped containment dikes in such indentations of a stream. In these areas, the lineal extent of the dikes can be minimized, particularly if the landward side has sufficient topographic relief to contain the materials.

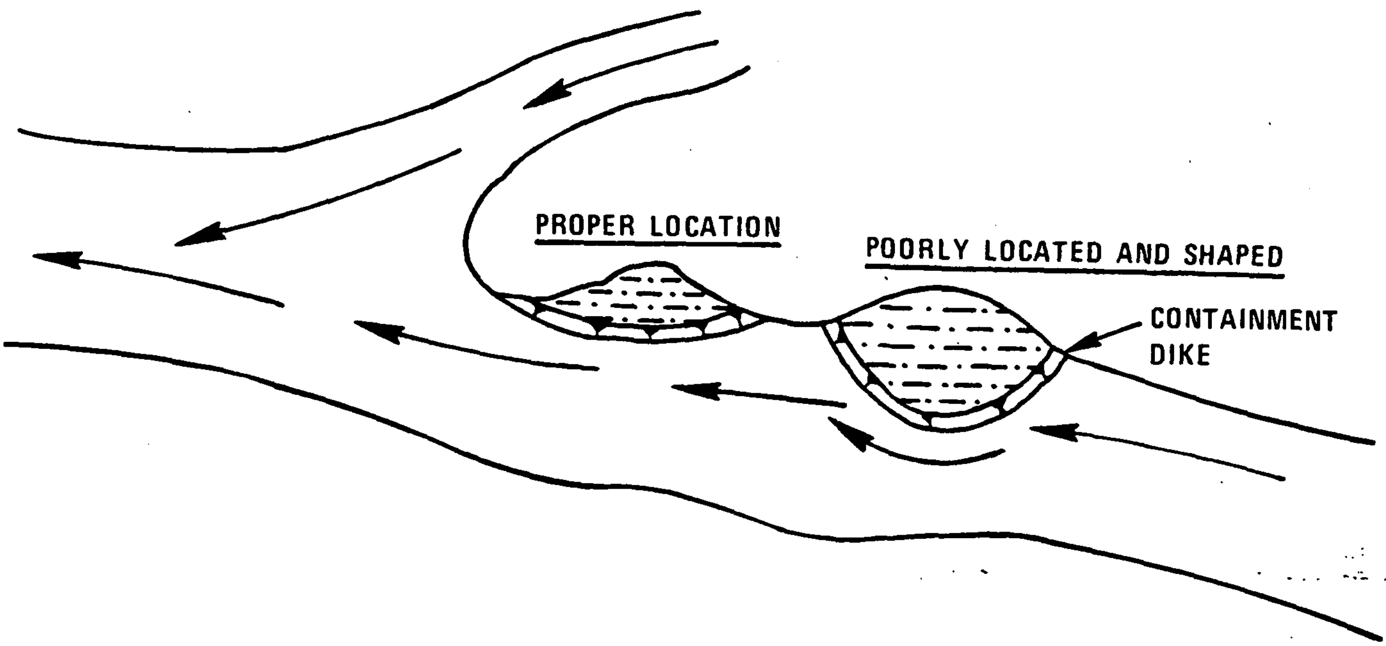


Figure No. 1-1 - Deposits of Dredged Materials Contained by Dikes Can Be Located So They Do Not Project Into Main Currents

If the areas of indentation are the result of overland erosion rather than stream meanders, or wave action in open bodies of water, they represent areas where surface drainage will concentrate. In this case, measures must provide for diverting the drainage around the contained dredged or fill materials or passing it through or beneath them. Diversions should be designed to prevent subsequent erosion by concentrated flow and to look like natural features. Passing surface water through the deposit will require a spillway over the containment dike that will not erode or cause failure of the structure and release the contained materials. If culverts, or other structures, are used to pass flows beneath the deposit, they will have to be considered in the design stages and placed during construction of the dikes and before discharge begins behind them.

Dredged or fill materials placed in open waters must be shaped to provide the least feasible cross-sectional area to be exposed to the natural flow of water. Dredged materials can be used to create islands and perhaps shallow wetlands in areas where deeper water existed before. Figure No. 1-2 illustrates proper shape and orientation for such placements. They must be contained by dikes of some type or another. Rip-rap or some other erosion-protecting devices will be needed as either current or wave action will tend to remove the obstruction and deposit it into another area.

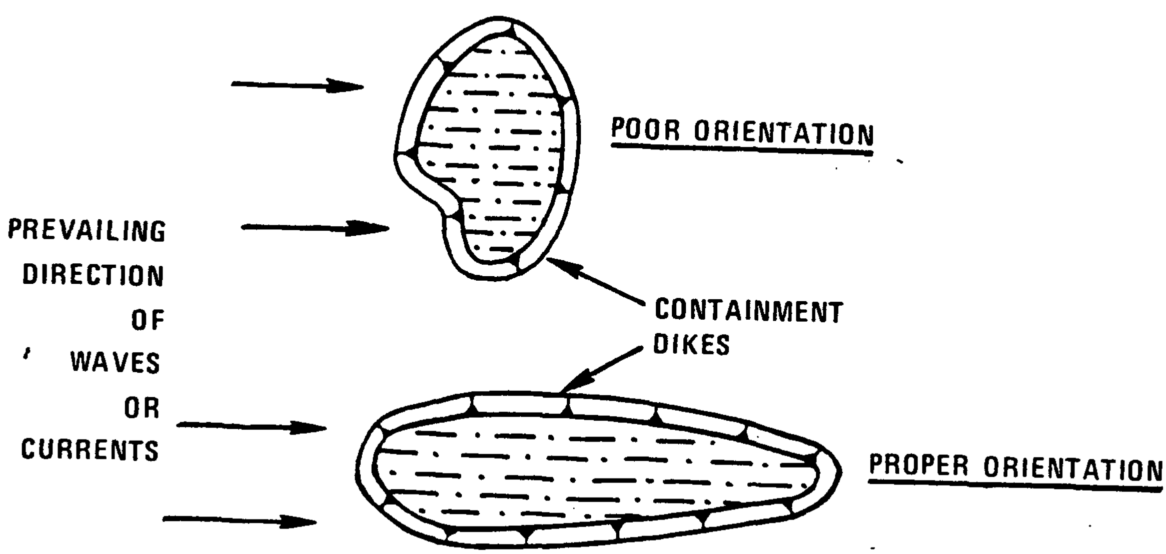


Figure 1-2 - Properly-Oriented Deposit of Dredged Materials Should Have Long Dimension Parallel To Prevailing Movement of Waves or Currents (After Reference No. 18).

Providing Flow Through Dredged or Fill Materials

Dredged or fill materials should not be discharged or placed into water bodies or wetlands over such extensive areas or alignments that they adversely disrupt the normal flow or circulation of either surface or ground waters. Extensive areas can include those used for disposing of large quantities of dredged materials or large fills for airports, subdivisions, shopping centers, and other facilities. Extensive lineal deposits include causeways for highways, and other roads, railroads, canals, and similar structures. Materials placed into these deposits may consist of that dredged from water bodies and that obtained from land sources.

Deposits of Large Areal Extent

Large masses of materials can be located and oriented to minimize changes in water flow and circulation patterns. If this is not adequate, practices should be developed to allow movement of water through these dredged and fill deposits. Open channels, culverts, systems of channels and culverts, pervious rockfill surface and subsurface sections, and alternating sections of each should be considered.

The occurrence, nature, movement, and extent of both ground and surface waters must be considered in the design of Best Management Practices to minimize detrimental flow and circulation changes. In general, the direction of ground water flow is similar to that of surface water but anomalies do occur. They must be considered to prevent the occurrence of problems at a later date.

Figure 1-3 represents a sketch of a fill for a small park incorporating open channels through which water can flow and minimize disruption due to this facility. Bridges are used for channel crossings but culvert installation also may be practical.

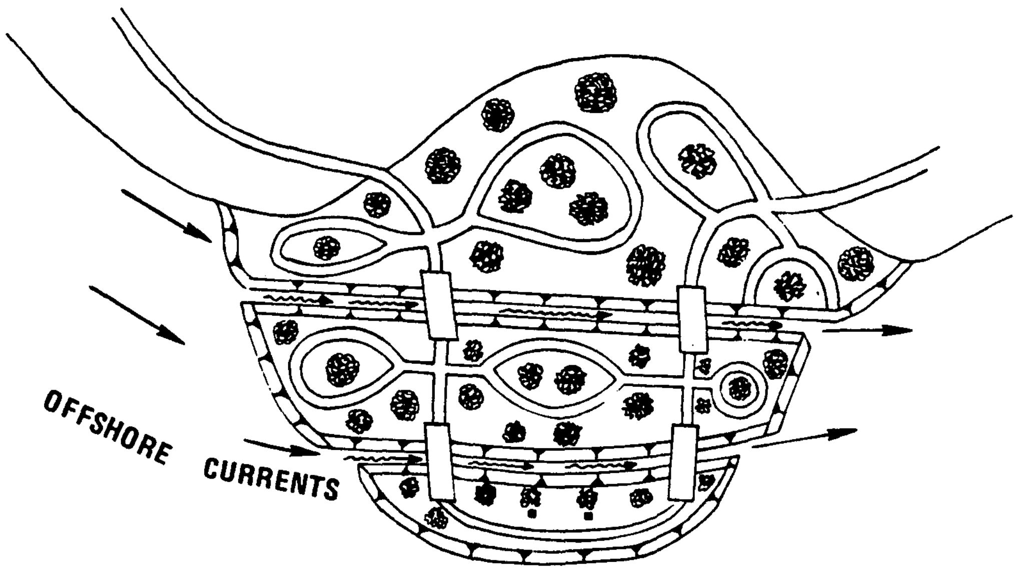


Figure 1-3 - Fill For Small Park With Open Channels Provided For Water Movement. Retaining Dikes and Channel Banks Should Be Protected With Rip-Rap

Deposits of Large Linear Extent

Fills that are installed to provide for such linear structures as causeways for highways or railroads, levees, and similar facilities generally extend across the natural drainage of streams or wetlands. Bridges or culverts usually are installed where stream channels occur. Ground water and surface flow, however, must move laterally through or over natural linear features to reach them. As a result, more extensive and drastic differential water surface elevations must occur to initiate these movements through the few open structures. Depth changes, erosion and sediment deposition, and other environmental problems may result.

Wetlands often consist of soft, compressible deposits of fine-grained silts and clays, loose sands, and organic matter. The weight of the causeway fill can cause these materials to consolidate and/or move laterally to make way for and support the fill (See Figure No. 1-4). If the fill materials used are relatively impervious compared to the natural deposits, the area through which the ground water moves will become reduced, and the flow restricted. Ground water levels on the up-gradient side of the fill will rise and force water to the surface. On the down-gradient side, water levels will be lowered. These water level changes can cause severe environmental problems on either side of the causeway.

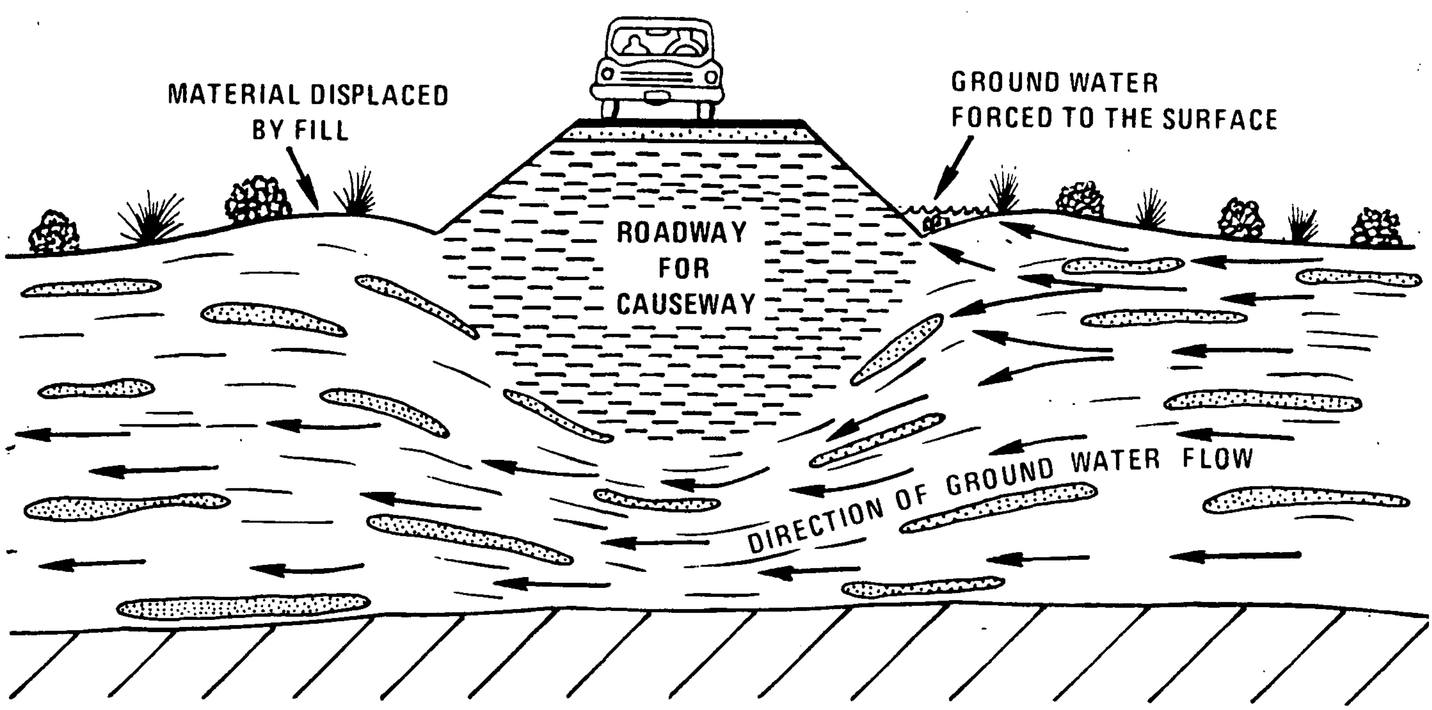


Figure No. 1-4 - Impervious Roadfill Section Placed On Wetland Consisting Of Soft Organic Sediments With Sand Lenses. The Natural Material Consolidates and Restricts Ground Water Flow.

Best Management Practices for preventing, or minimizing detrimental changes in both surface and ground water flow and circulation patterns can include such measures as using pervious fill materials and alternating sections of pervious and impervious fill and open channel sections. (See Figure Nos. 1-5 through 1-8). Perviousness, or permeability, is a function of the material. Sand, sand, and gravel, or similar materials may be used to provide a pervious fill section. The BMP's must function to prevent restriction of surface and ground water flow and circulation. Structures must be constructed to pass low flows without restricting movement of aquatic creatures and other water-dependent wildlife as well as the high discharges from floods.

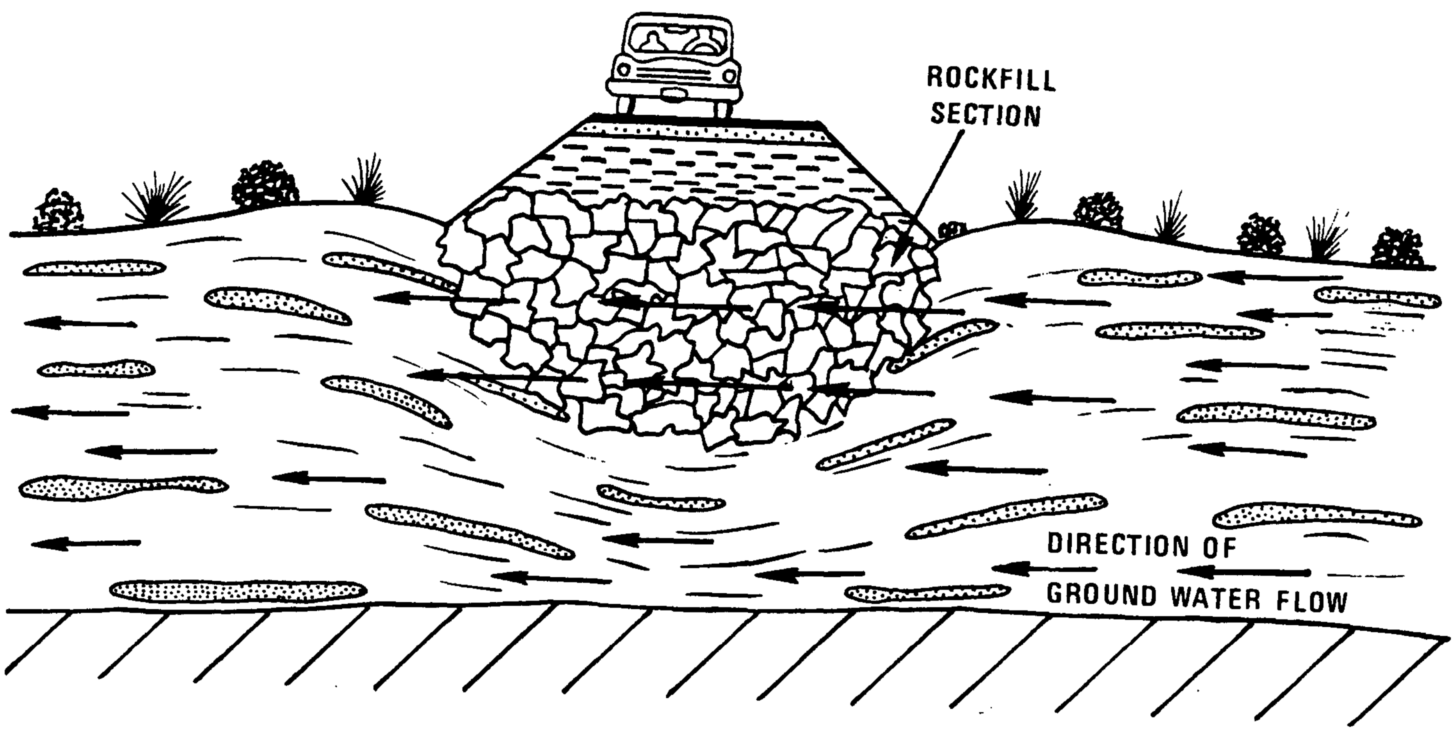


Figure No. 1-5 - Pervious Roadfill Section On Wetland Allows Movement Of Ground Water Through It and Minimizes Flow Changes.

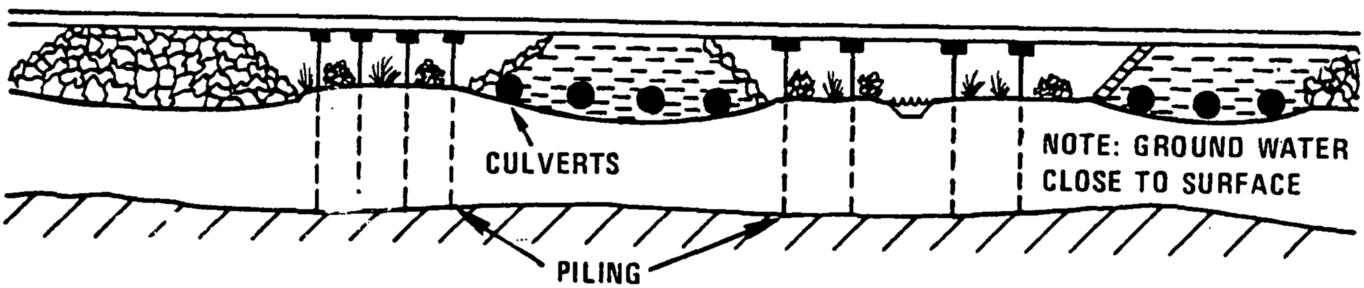


Figure No. 1-6 - Causeway Across Wetland Designed To Minimize Disruption of Surface and Ground Water Circulation. Fill Composed of Pervious Rock and Impervious Earth Materials.

Fills For Stream Crossings

Any fill, or other structure, placed into a stream channel through which water moves will restrict the cross-sectional area through which the flow moves and, to some extent, obstruct the flow and cause changes in circulation patterns. Best Management Practices include techniques for minimizing the obstruction of flow and circulation changes. For example, a bridge that spans the entire stream does not constrict the channel as it places no obstruction in it. (See Photo No. 1-1). If piers are used, they should be located and spaced to minimize the flow obstruction and channel disturbance. (See Figure Nos. 1-7 and 1-8). In forest areas during flood flows, fallen timber may be carried downstream to obstruct flows when they are trapped across bridge piers. When designing the bridge, consideration must be made of the probable length of trees or logs expected during floods. The distance between piers should exceed this length, otherwise obstruction of flow, flooding, excessive erosion, or bridge failure may result and cause damage to aquatic habitat as well as the downstream areas. If this is not feasible, arrangements should be made to remove blockages during flood flows.

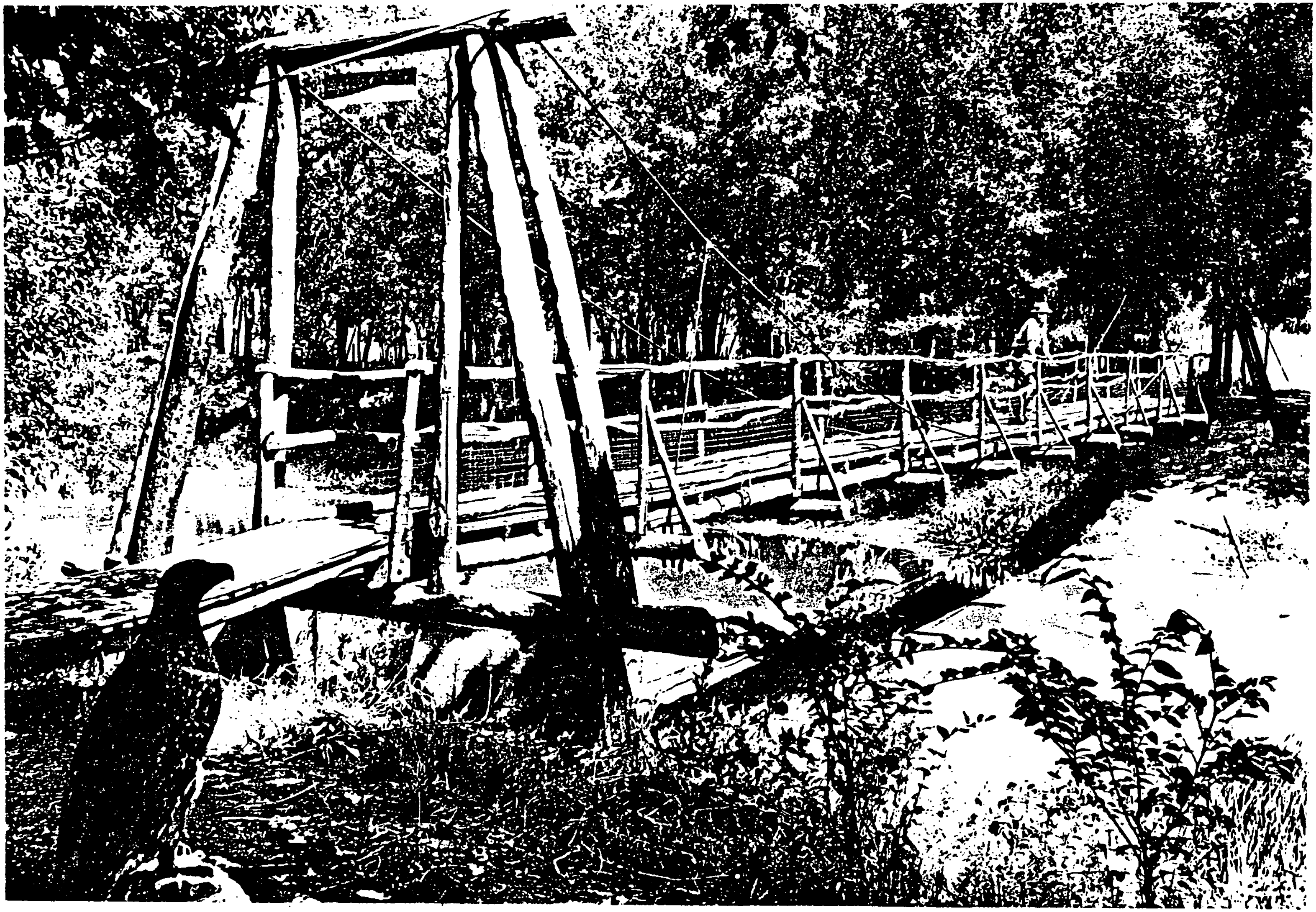


Photo No. 1-1 - Small Wooden Suspension Bridge Spanning Stream (U.S. Forest Service)

Culverts should be designed and constructed not only to pass high flows without creating environmental problems, but also the low flows. During low flows, passage for aquatic life may be restricted if this was not considered during the design stages. Species of fish occurring in the stream involved must receive consideration. If possible, the existing stream bed should be completely spanned by a half-round culvert. (See Photo No. 1-2).

BETTER ENVIRONMENTAL DESIGN

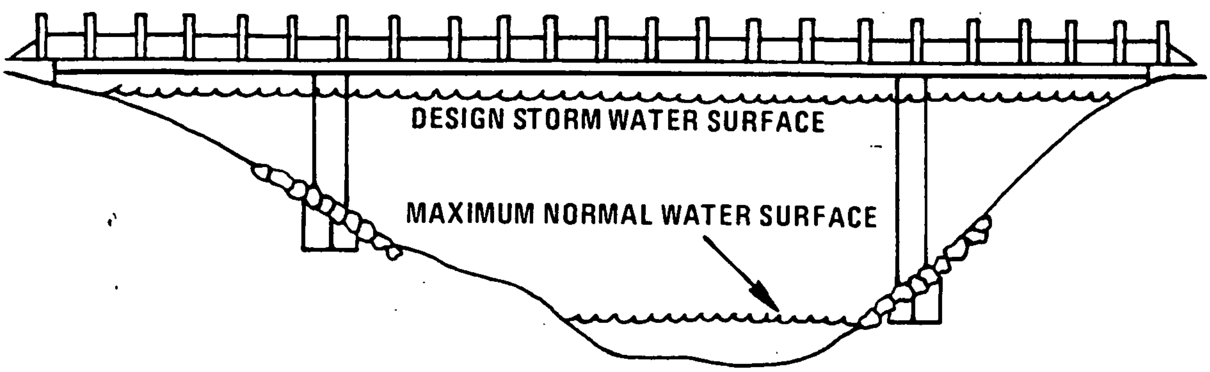


Figure No. 1-7 - Stream Crossing With No Construction Required In The Normal Channel

POORER ENVIRONMENTAL DESIGN

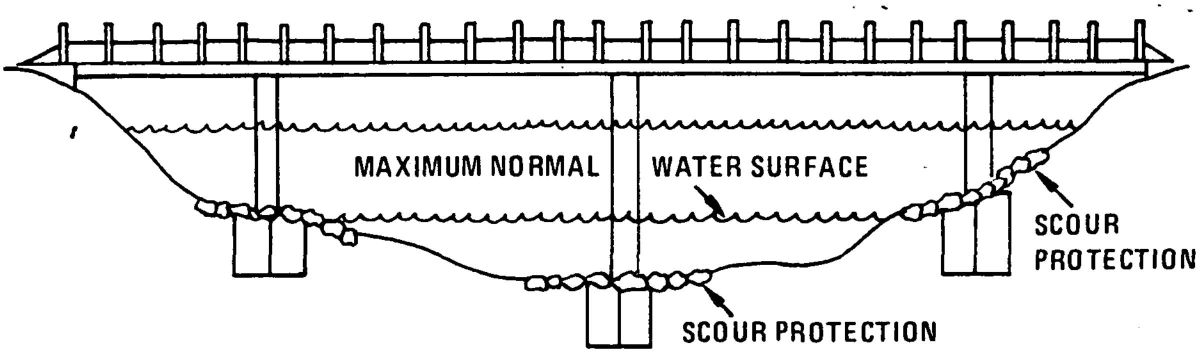


Figure No. 1-8 - Stream Crossing With Pier In Central Section Of Normal Channel

Photo No. 1-2 - View Through Large Half-round Culvert. Note Natural-appearing Stream Channel For Fish. (Reference No. 28)

If a round culvert is used, it should be installed sufficiently below the stream channel to have the water level up into the larger section of the structure. After a period of time, gravel and other sediments will fill its bottom and create a naturally-appearing channel (See Figure No. 1-9). An example of a culvert installed at too shallow a depth to allow passage of fish during low flows is shown in Photo No. 1-3.

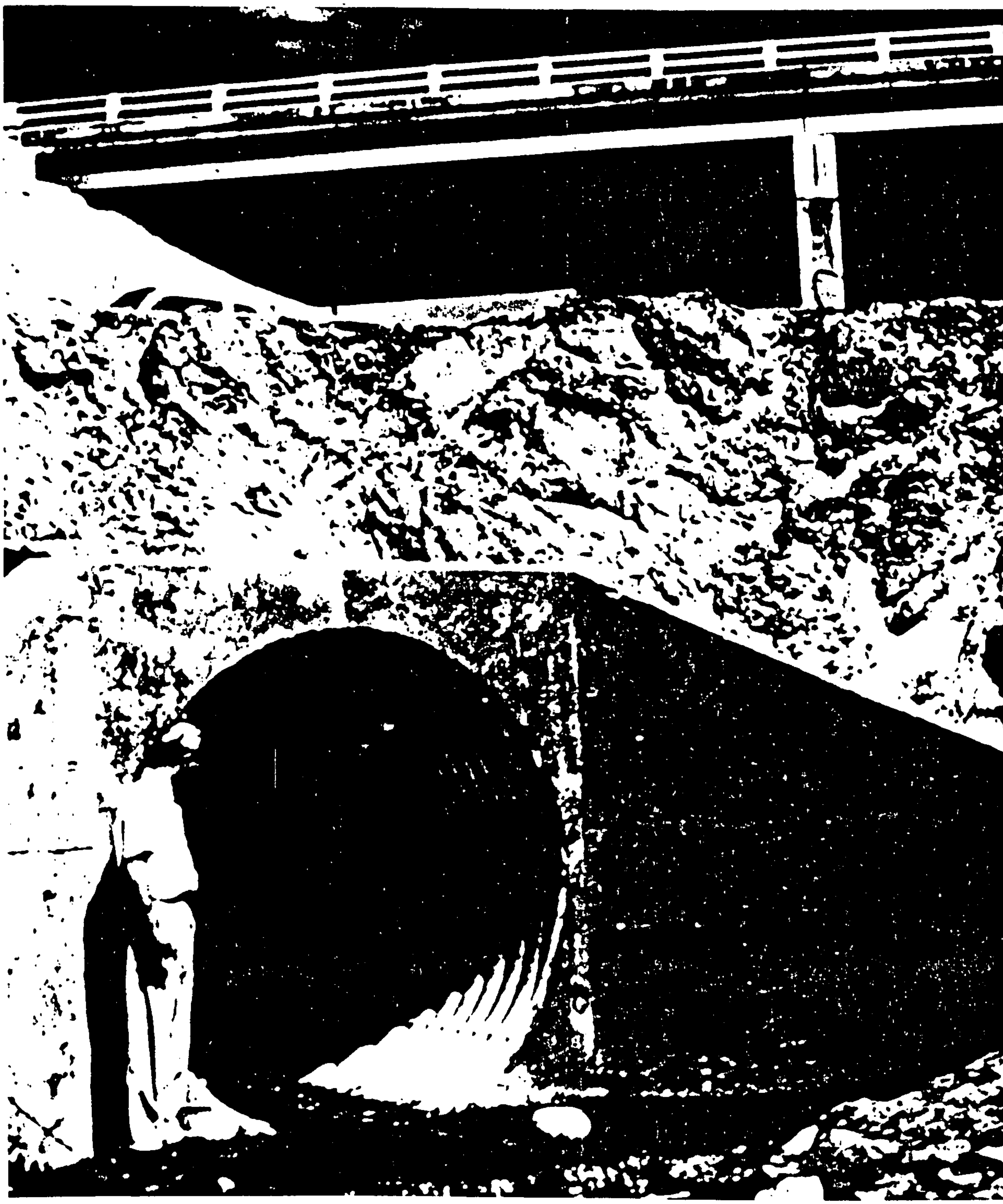


Photo No. 1-3 - Large Culvert Installed With Little Consideration For Adequate Depth of Flow For Fish Passage (U.S. Forest Service)

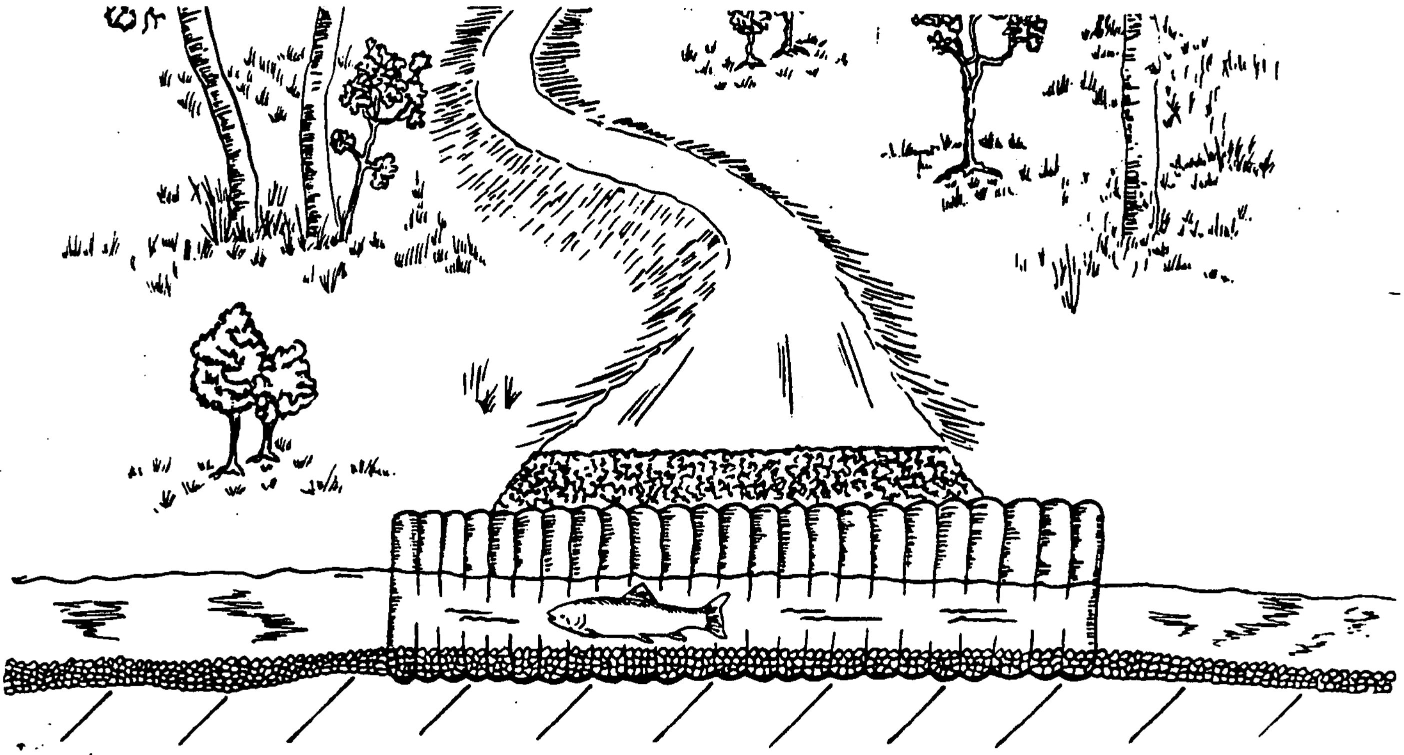


Figure No. 1-9 - Round Corrugated Culvert Placed Below Streambed To Provide Fish Passage During Low Flows (Adapted After Reference No. 10)

Culverts should also be installed with their inverts (bottoms) on the same gradient as the streambed. Steeper gradients may create velocities too great for aquatic life, and gradients that are too low will create ponding upstream and probably have a limited capacity to pass the designed flows (See Figure No. 1-10).

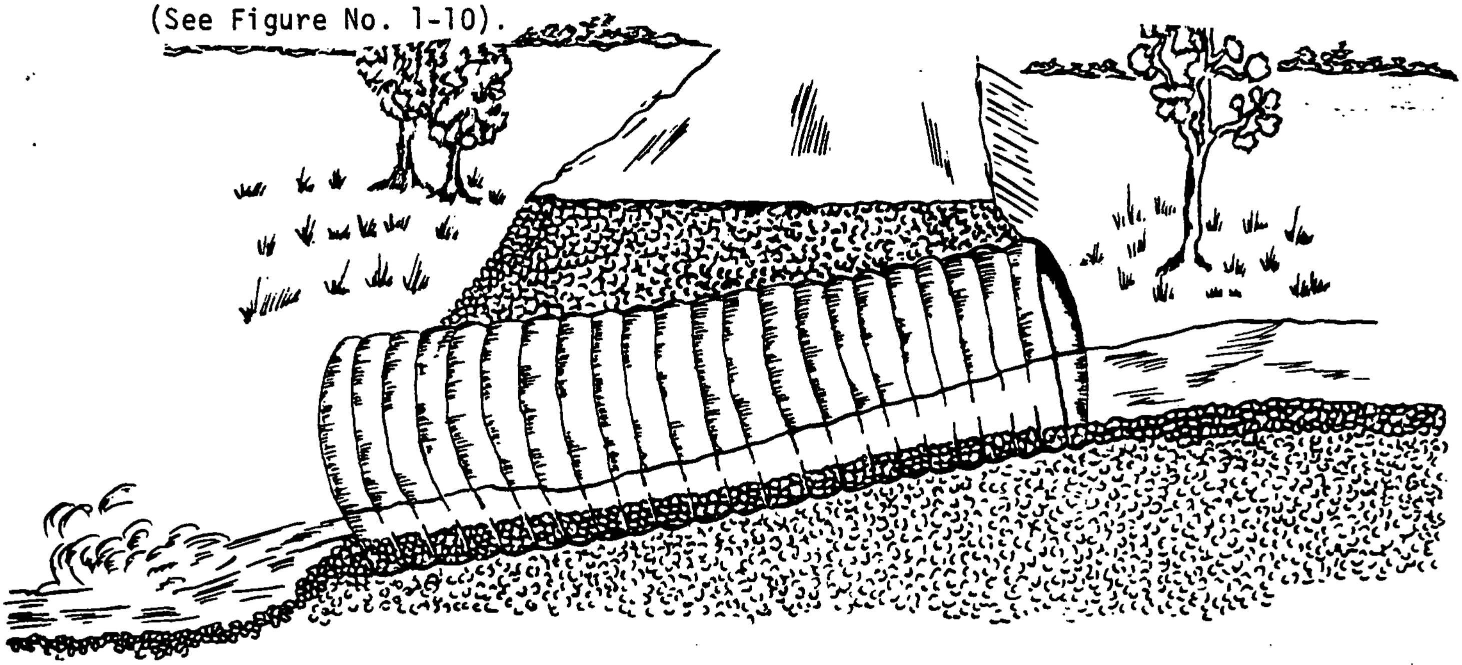


Figure No. 1-10 - Round Corrugated Culvert Placed At A Gradient Steeper Than Stream Gradient. High Velocities Result (Adapted After Reference No. 10).

Many BMP's can be used to enhance the flow characteristics through culverts to provide better conditions for fish passage. For many of the detrimental flow problems created by culvert installation there are remedial structures, or measures, that can be used to minimize them. Several are illustrated in the following illustrations (Figure No. 1-11 and Photo Nos. 1-4 and 1-5). Best Management Practices for culverts designed for passage of fish and aquatic life should include a consideration of routine maintenance to keep them clear of debris and sediment. In the absence of maintenance, the fish passage design feature can be negated.

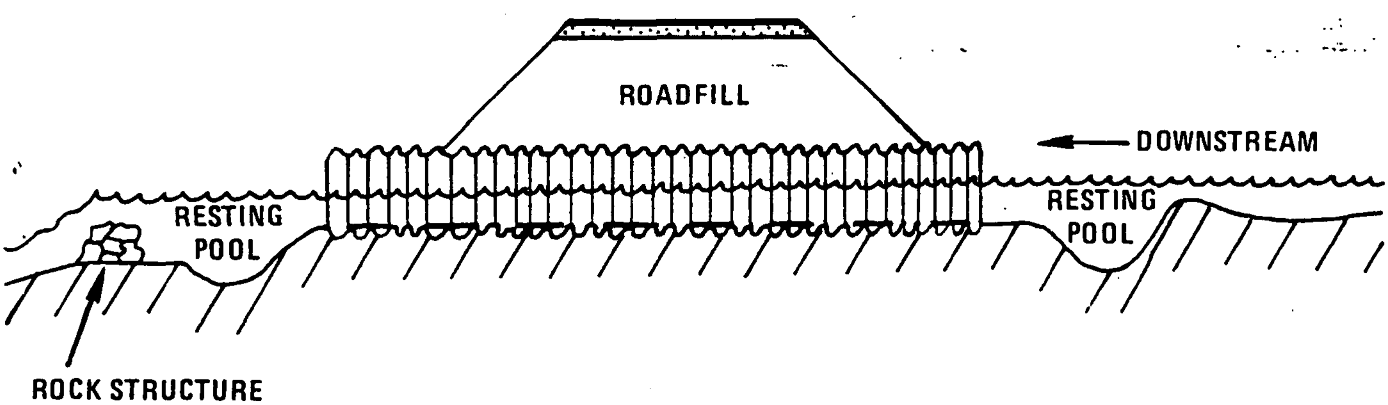


Figure No. 1-11 - Rock Barrier Structure At Discharge End of Culvert Providing Adequate Depth of Water For Fish Travel. Resting Pools Help Fish Conserve Energy

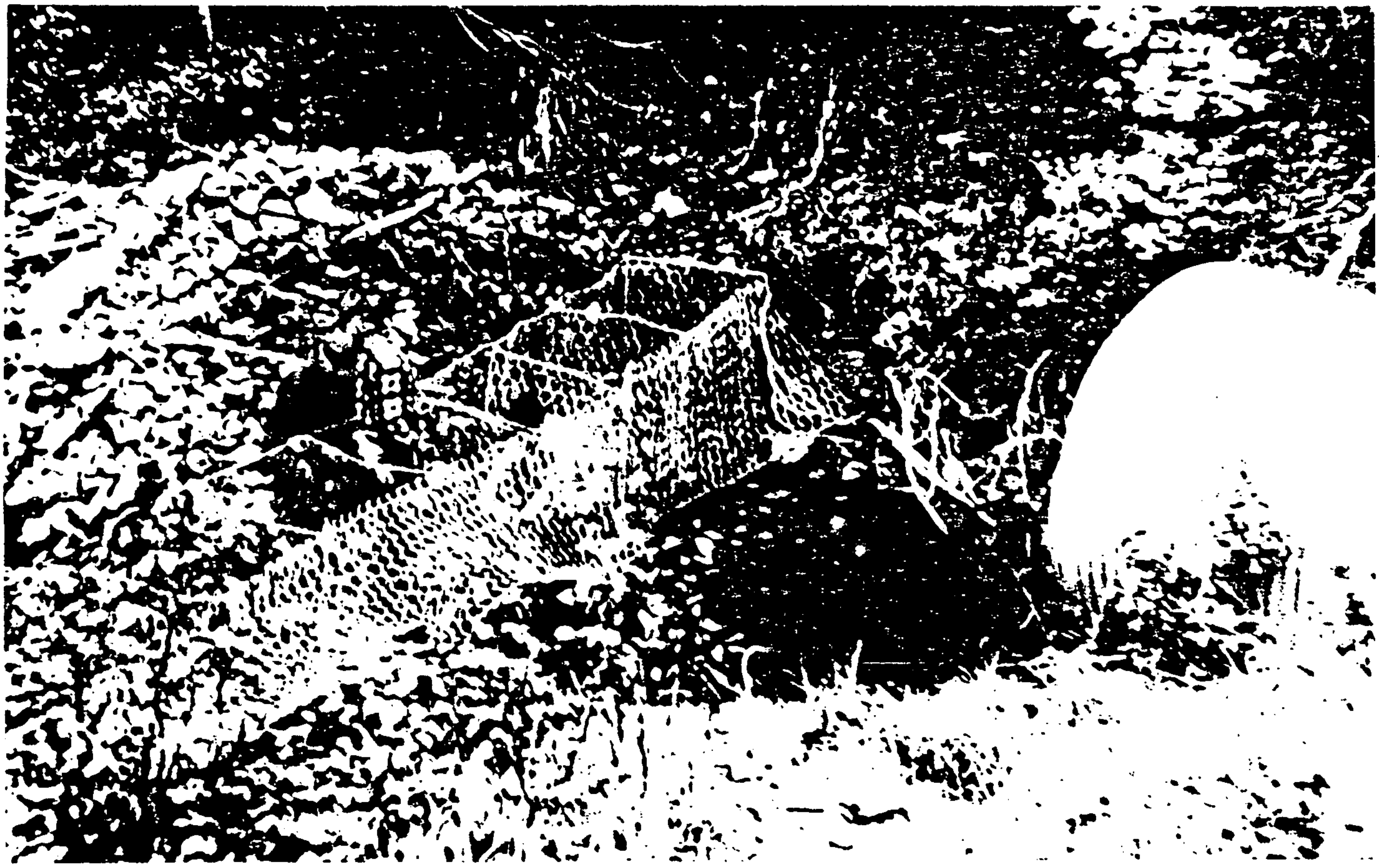


Photo No. 1-4 - Gabion Structure Being Installed To Provide Adequate Depth of Flow Through Culvert. For Detail See Figure No. 1-11 (U.S. Forest Service)

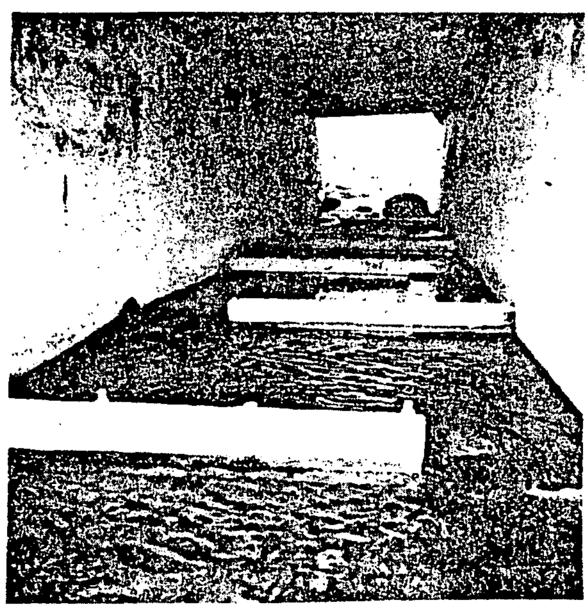


Photo No. 1-5 - Reinforced Concrete Box Culvert With Baffles To Provide Adequate Flow For Fish Migration. Note Gravel In Bottom of Culvert (Reference No. 28)

Multiple culverts should be installed through a fill of linear extent in wetlands to prevent concentration and restriction of flow. (See Photo No. 1-6). One or two large culverts through the center of the fill could transmit as much water as the many smaller ones but would require much more lateral flow changes and concentrations of discharge. One or more of the smaller multiple culverts can be placed at lower elevations than the others to provide adequate flow for passage of fish and other aquatic life during low flows.

Photo No. 1-6 - Multiple Culverts Provide More Uniform Passage of Streamflow and Prevent Concentration of Flow (Reference No. 28).

Another type of structure which minimizes stream flow restriction is shown in Photo No. 1-7. It consists of a concrete low-water bridge which permits free flow of water under it during low water. High flows will overtop the structure.

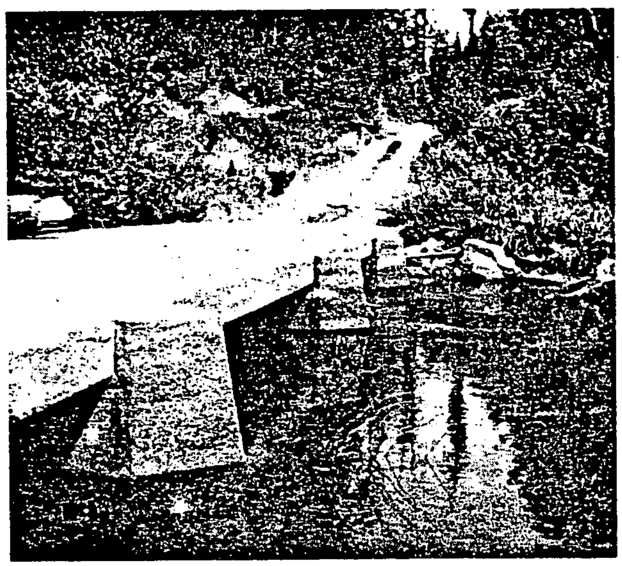


Photo No. 1-7 - Example of Low Water Bridge That Does Not Restrict Low Flows and Allows Free Passage of Aquatic Life (Reference No. 28).

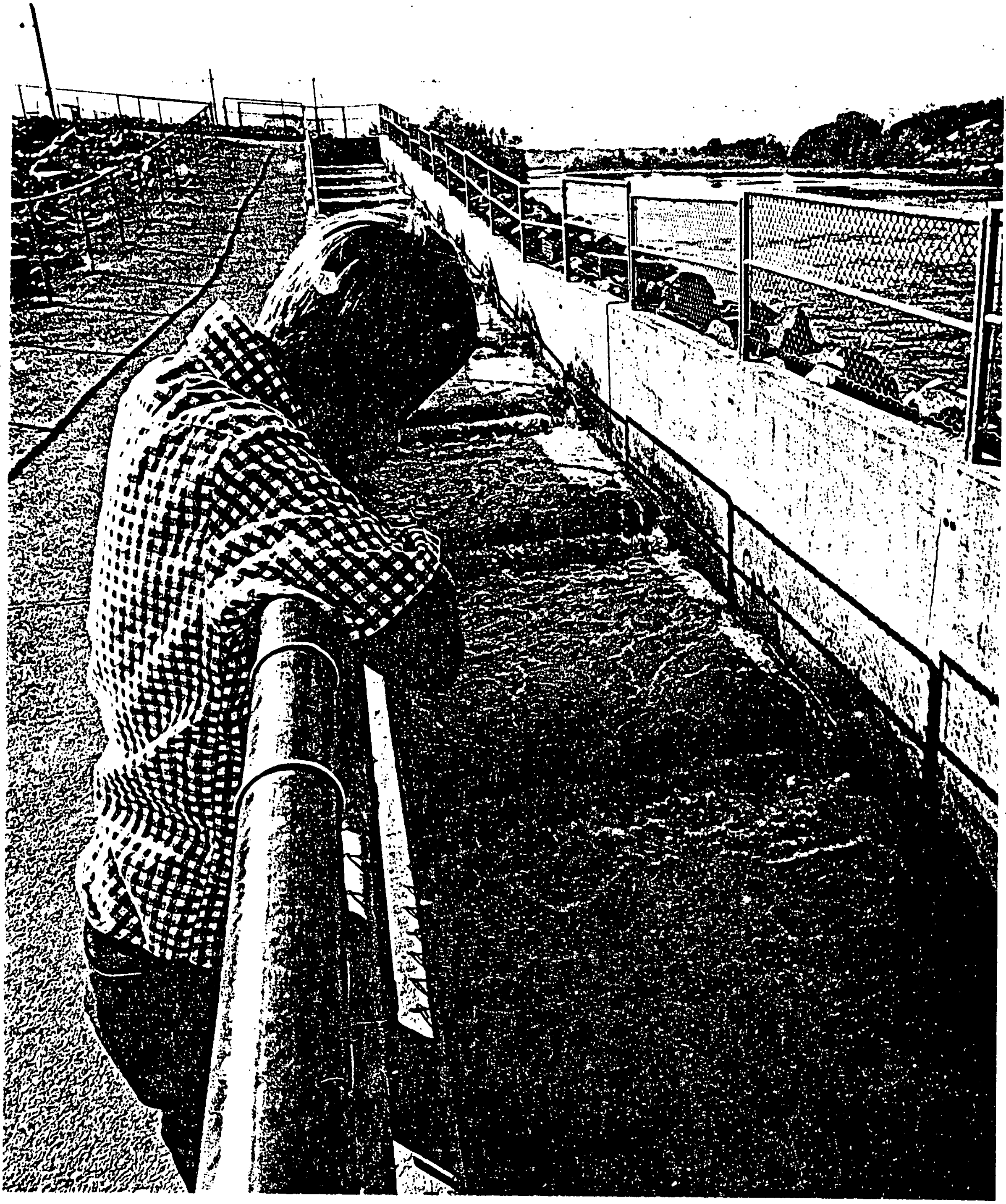


Photo No. 1-8 - Fish Ladder Allows Fish To Move Around Dam, or Other Water - Retaining Structure (U.S. Bureau of Reclamation)

Preventing Detrimental Elevation Changes In Channels

Some stream-crossing structures such as culverts and bridges create abrupt stream-channel and water surface elevation changes that can have detrimental effects on the movement of aquatic life and possibly cause other environmental problems such as erosion and sediment losses.

Figure No. 1-12, obtained from the U.S. Forest Service, illustrates four different problems that anadromous fish can encounter as a result of culverts being installed above streambed elevations. All of these problems can be resolved by lowering the culvert to reduce the elevation change, decreasing the culvert gradient, increasing the depth of water in the culvert bottom, and providing for resting pools at either end. To provide adequate design at a minimal cost, information must be obtained regarding the jumping ability of the fish involved and their speed and endurance. Structural aids to provide increased water depths and other advantages are shown in Figure No. 1-11 on Page 1-15.

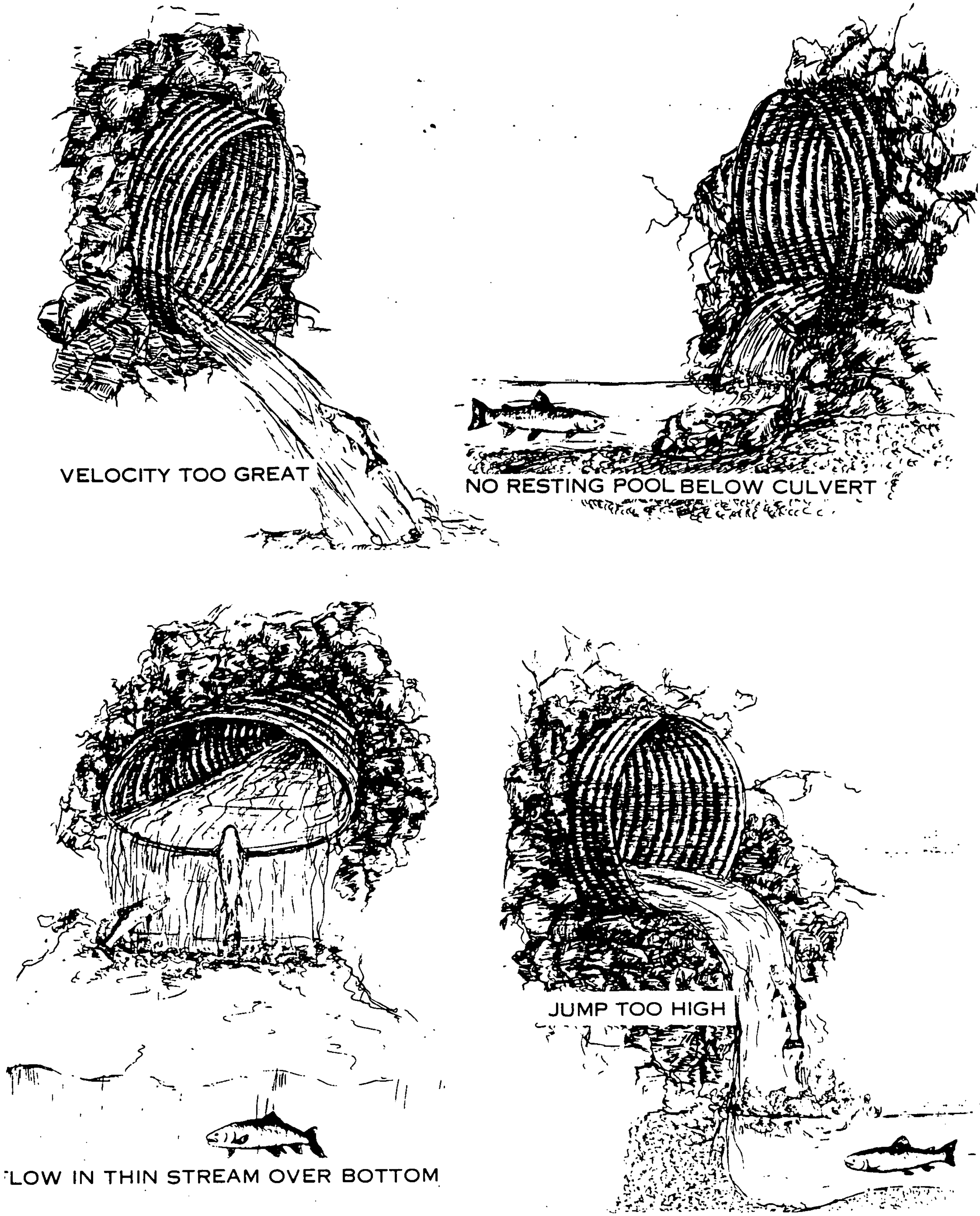


Figure 1-12 - Culvert Installations Which Restrict Fish Passage (Reference No.28)

They provide the required resting areas and depth of water for passage. Some types of bridges, particularly those with concrete aprons, or other foundation slabs can act as barriers to the movement of aquatic life. If water flowing over the apron is extremely shallow or flowing at high velocity, fish cannot move through it (See Photo No. 1-9).

Photo No. 1-9 - Bridge Foundation Slab Showing Thin, High-Velocity Flow of Water and the Extent of Jump Required for Passage (Reference No. 28).

Best Management Practices to prevent such problems can involve sloping the apron to concentrate water flow into one end and make it deeper; providing a narrow and deep low-flow channel through apron; constructing several small pools downstream from drop-off to progressively reduce abrupt elevation change; and placing rock obstructions to minimize velocities of flow.

CHAPTER 2

PREVENTING, OR CONTROLLING THE RUNOFF OF EXCESS SEDIMENT LOADS OR TURBIDITY INCREASES

Loss of sedimentary materials by erosion processes can occur during the placement, or discharge, of dredged and fill materials and after the mass of materials is actually in position. Best Management Practices to prevent or minimize this problem must receive full consideration during the entire process from planning prior to placement, through the implementation or installation period, and until the materials are stabilized and protected adequately or removed. If possible, discharge of materials should take place in areas of containment or on dry land. This can be done by scheduling the discharge during low flows, temporarily diverting, or by-passing the stream, or excluding surface waters through the use of some type of retaining structures such as cofferdams, caissons, and embankments. Following placement, the mass of dredged or fill materials must be protected from erosion by rainfall; sheet runoff; and concentrated streamflow, wave action, and water currents. Surface protection should be designed and constructed to extend above projected design flood elevation and to prevent underlying material from being eroded and transported into downstream areas.

Examples of Best Management Practices to prevent or restrict the runoff of excess sediment loads and increased turbidity are presented here, along with discussions regarding some factors to consider in their application.

During Discharge or Placement of Materials

Most dredged and fill materials consist of relatively fine-grained sediments; and moving water will erode and transport them downstream during discharge or placement. Because of this, all possible efforts should be exerted to discharge dredged material into a contained area and to place fill materials on foundations that are not submerged.

Dredged Materials

Disposal of dredged materials must be done in an area of containment so that runoff of the materials is prevented. Containment generally can be achieved through the use of dikes, or embankments, made from materials obtained in the vicinity. If disposal is in a lowland area, a dike may be required to surround the area completely. In an upland, however, a dike may be needed only across the lower boundary of the area to provide storage (See Figure 2-1). The stability of the dikes must always be considered to ensure that failure does not occur and release the contained material back into the water.

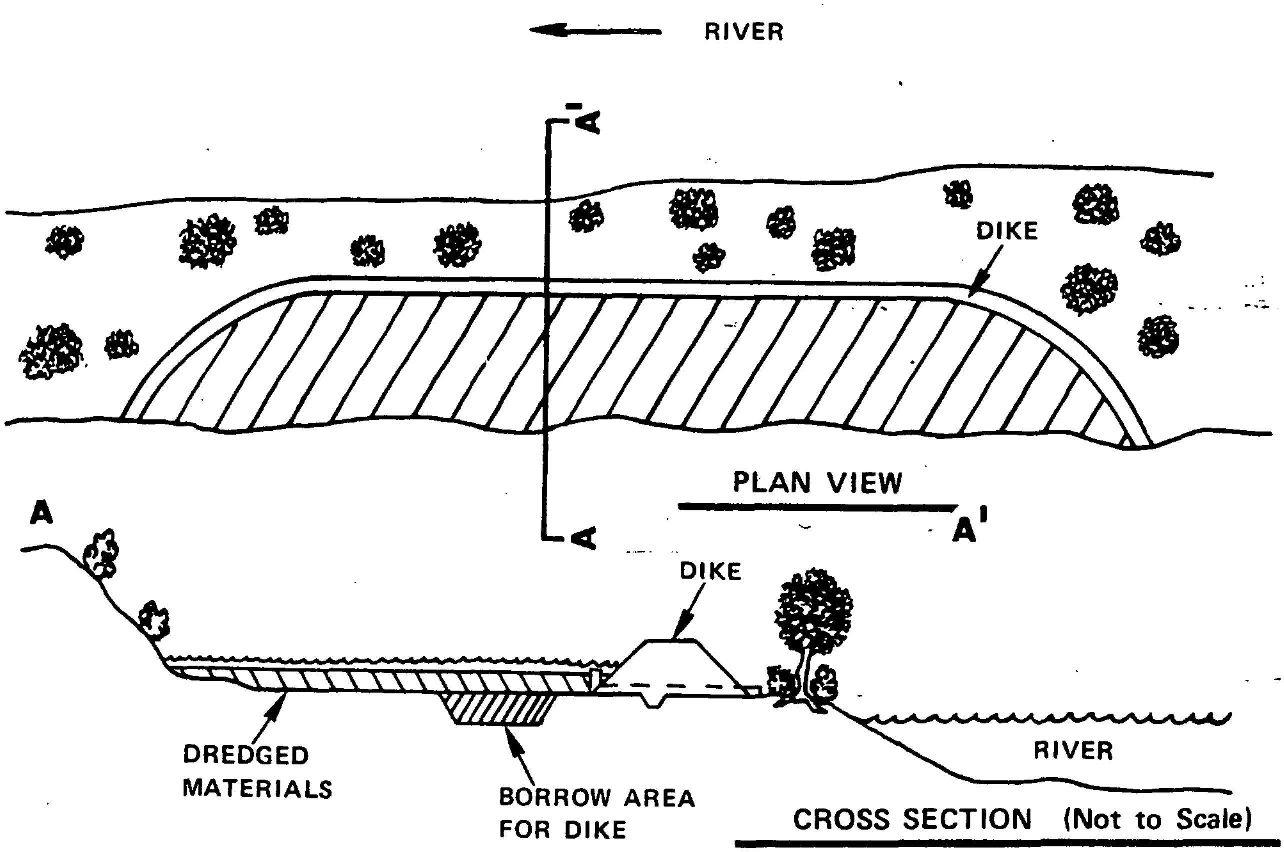


Figure No. 2-1 - Containment For Dredged Material In Upland Area Adjacent To River

Dredged materials generally consist of a slurry made up of water and solid sedimentary materials. After discharging them into the disposal area, the coarser particles settle out; and the water, containing fine-grained sediment particles (silts and clays) becomes an effluent when it leaves the containment site. Control of this effluent poses a major solid-liquid separation problem if the containment has a limited storage capacity, much of the material is fine-grained, and periodic removal of the effluent is necessary.

If the dredged materials are principally of sand, or coarser materials, the detention time in the containment may be sufficient to remove most of the sediments. In this case, an outlet pipe with the intake high in the water column will provide for removal of the relatively clear effluent (See Figure No. 2-2). An energy dissipator or level spreader should be provided below the discharge to prevent erosion and provide additional settling and filtering capacity.

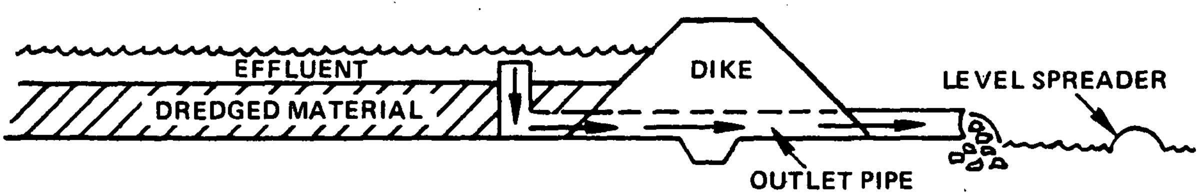


Figure No. 2-2 - Outlet Pipe For Draining Clear Effluent From Containment

Fine-grained sedimentary materials such as silts and clays stay in suspension for longer perios of time than coarser materials and need additional efforts to make them settle out. Certain chemicals added to dredged materials as they enter a containment area can cause these materials to flocculate (aggregate into small lumps) and settle out. Lime has been used as well as organic polymers. Effective use of flocculants requires that a knowledge of the fine-grained sediment particle's reaction to each floccument be obtained. In addition, a separate partition of the containment area may be necessary to provide an area for the flocculated material to settle out.

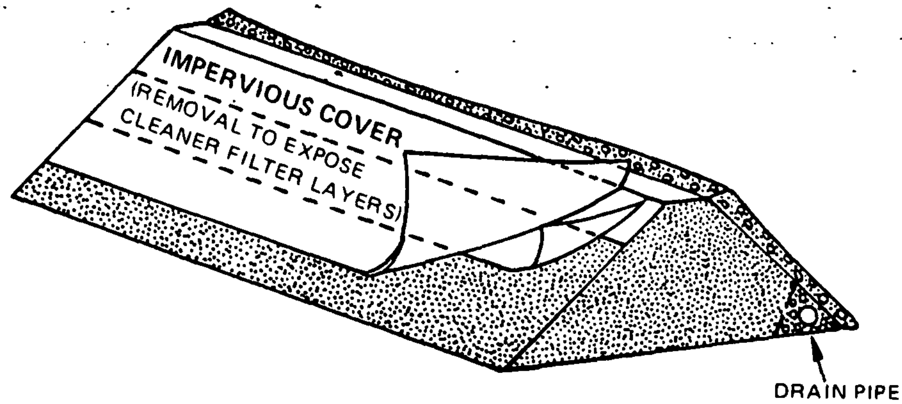
If fine-grained materials are still present in the effluent to leave the containment, filtration through pervious sand or sand and gravel sections in the dike, sandfilled weirs, filter cloth screens, and similar structures should be considered (Figure No. 2-3). The quality of effluent discharging from a given filter system is dependent on the amount of solids entering it and the filtering capacity of the medium through which it moves. Good or effective filtration is considered to achieve removal efficiencies of 90% or more in the intermediate or low ranges of effluent suspended solids (between 1 and 10 grams/liter). Proper engineering judgement is essential to obtain the optimal use of all alternaive techniques.

Another alternative to consider would be to use spray irrigating techniques to dispose of the fine-grained material and prevent its runoff into water. If done properly, the water will infiltrate soils and leave the sediments on the surface where it can be stabilized by vegetative growth.

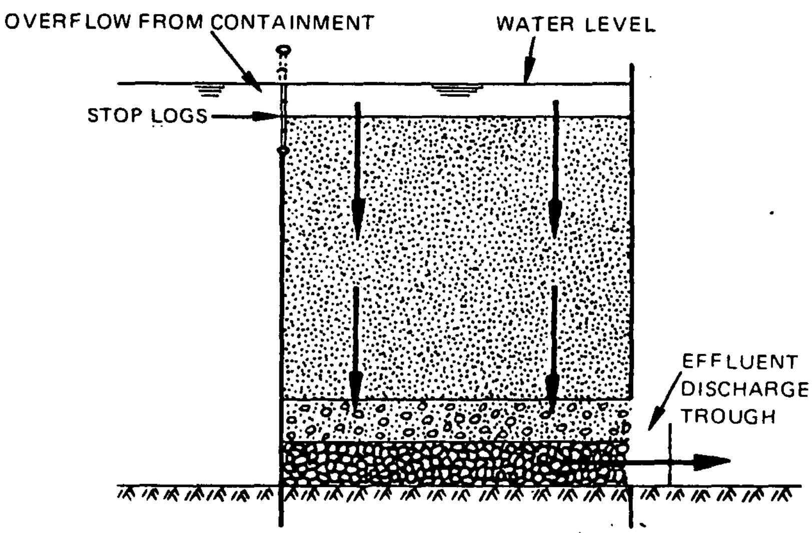
Fill Materials

To prevent the runoff of sediments and their accompanying pollutants, the preparation of foundations for and the placement of fill materials should take place on land that is not submerged, if at all possible. If the fill materials consists only of large, consolidated rock fragments that are not subject to water movement, placement into a water body may result in no sediment runoff problems.

Disturbance of the ground and movement of mobile land equipment in water bodies where excess sediment losses and runoff can occur should be



3(a) PERVIOUS DIKE WITH MULTI-LAYERED IMPERVIOUS COVER



3(b) DOWNFLOW SANDFILL WEIR

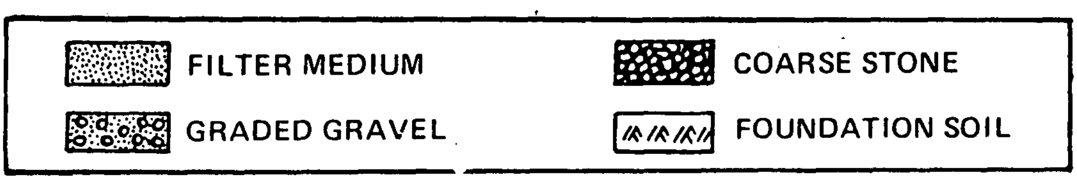


Figure No. 2-3 - Techniques For Filtering Fine-grained Sediments From Effluent (After Reference No. 17).

done only when essential and no other alternative exists. Filtering out sediment being transported in the water from the construction site may be practical through the use of filter-fabric sheeting made of polyprohylene monofilament materials or similar substances similar to produced bu manufacturers for this purpose. If possible, structures such as bridges should span the stream so that the need for piers for support located in the channel section can be avoided. (See Photo No. 2-1).

If construction activity or placement of fill must take place in the stream or other water area, foundation surfaces that are not submerged (in the dry) can be obtained by temporarily diverting the stream or by using some type of cofferdam, caisson, or other structure to exclude the water. Scheduling the activity during periods of low flow or low water levels also will enable placement of fill to take place in the dry when the potential for erosion by surface water is minimal.

The technique of temporarily diverting a stream for placement of a culvert and a road fill is shown in Figure No. 2-4 and the completed facility in Photo No. 2-2. A small section of new channel is excavated, or a flume constructed, adjacent to the existing channel. (The new channel should be lined with impervious material such as plastic sheeting, if necessary). The stream is diverted, the culvert installed, and the road embankment placed. Then the stream is diverted back into the original channel. The diversion channel is backfilled, and the road fill is completed. Temporary diversion of streamflow should be done for placement of fills ranging from minor embankments for logging roads to major ones for the construction of earth dams (See Photo No. 2-3).

Cofferdams are temporary structures to permit dewatering an area for the construction of fills and structures on foundation surfaces that are not

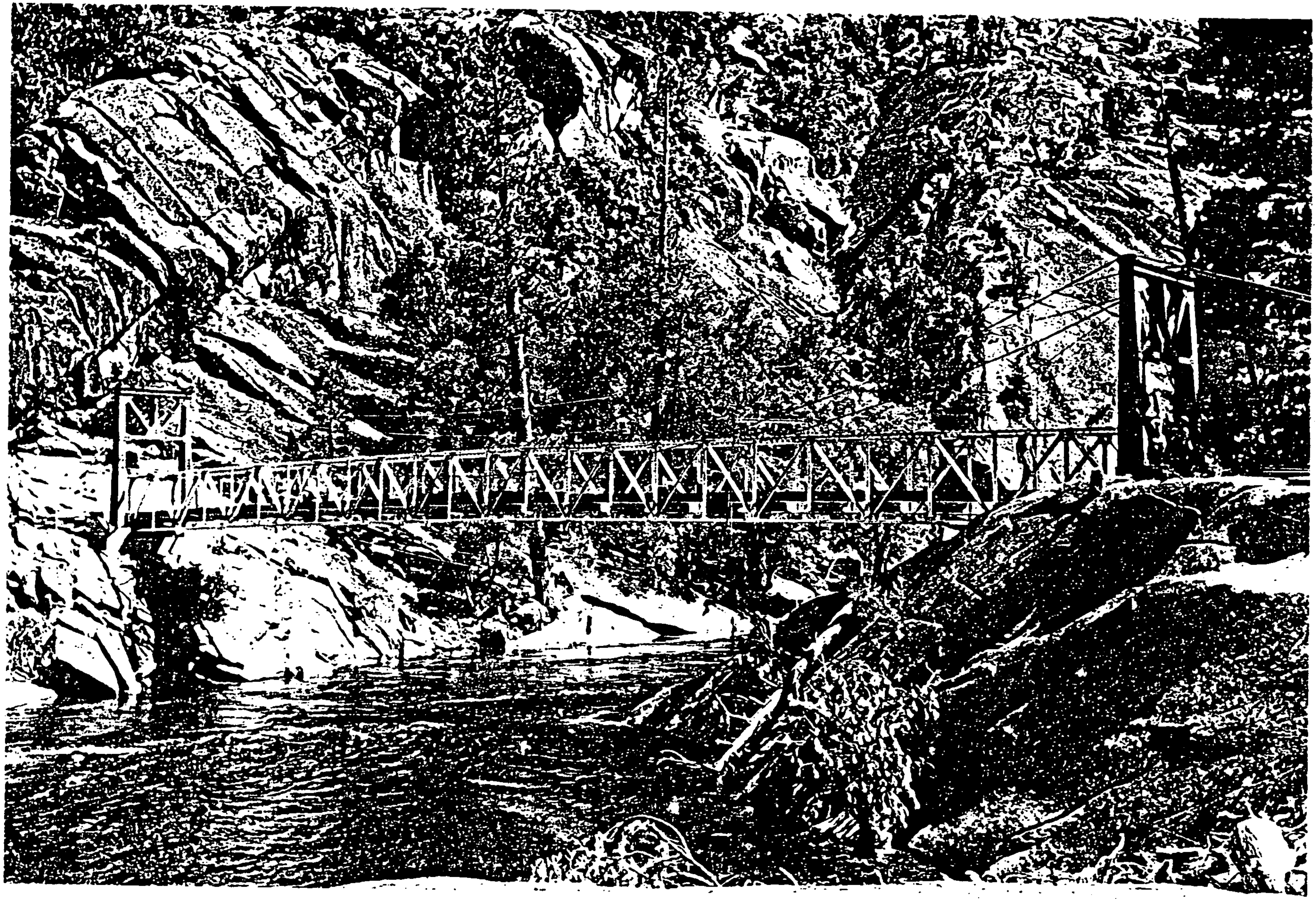


Photo No. 2-1 - Bridge Spanning Stream. No Stream Disturbance Required For Pier Construction In Channel (I.S. Forest Service)

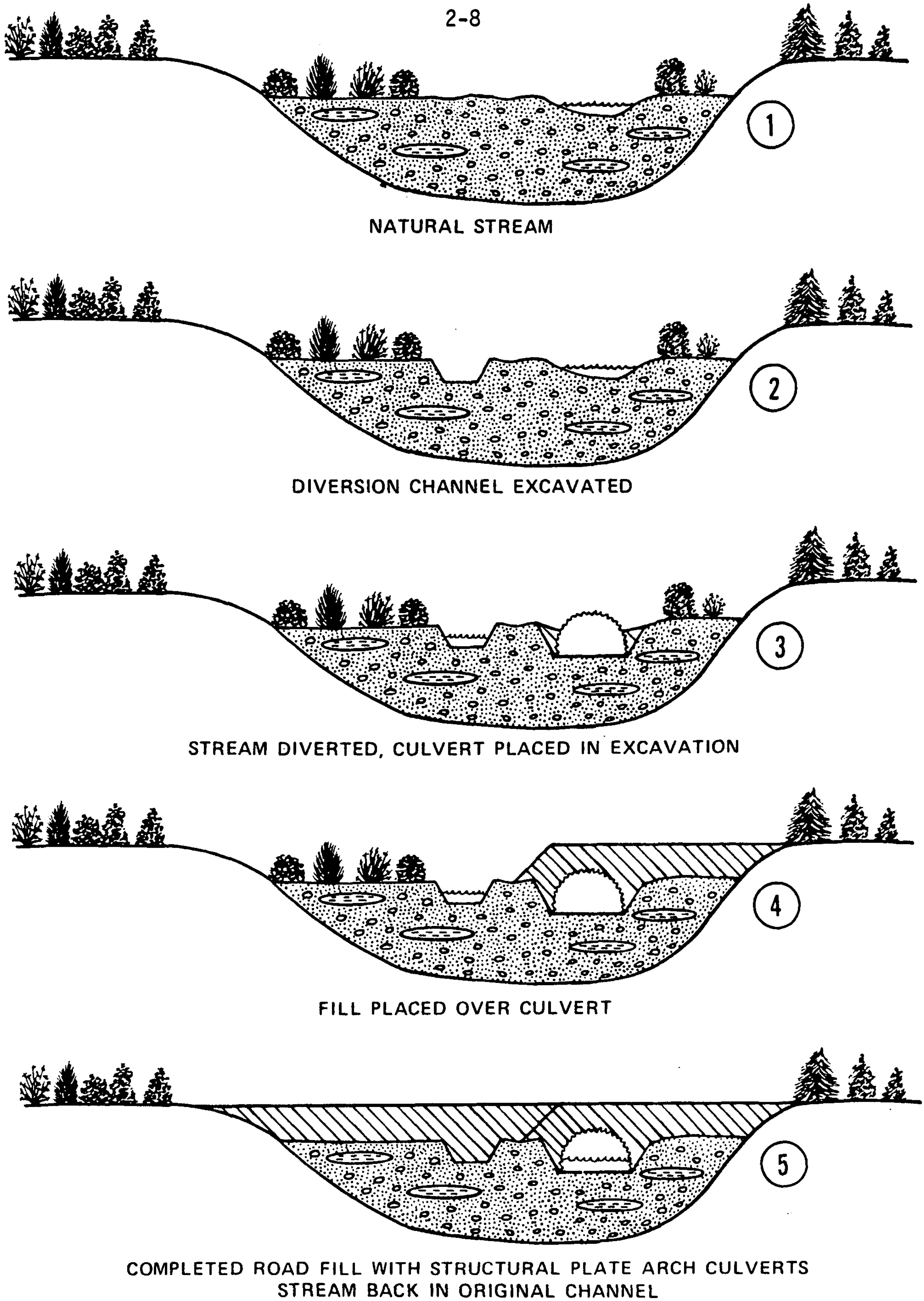


Figure No. 2-4 - Procedure For Installing Culvert When Excavation In Channel Section of Stream Will Cause Sediment Movement and Turbidity Increases

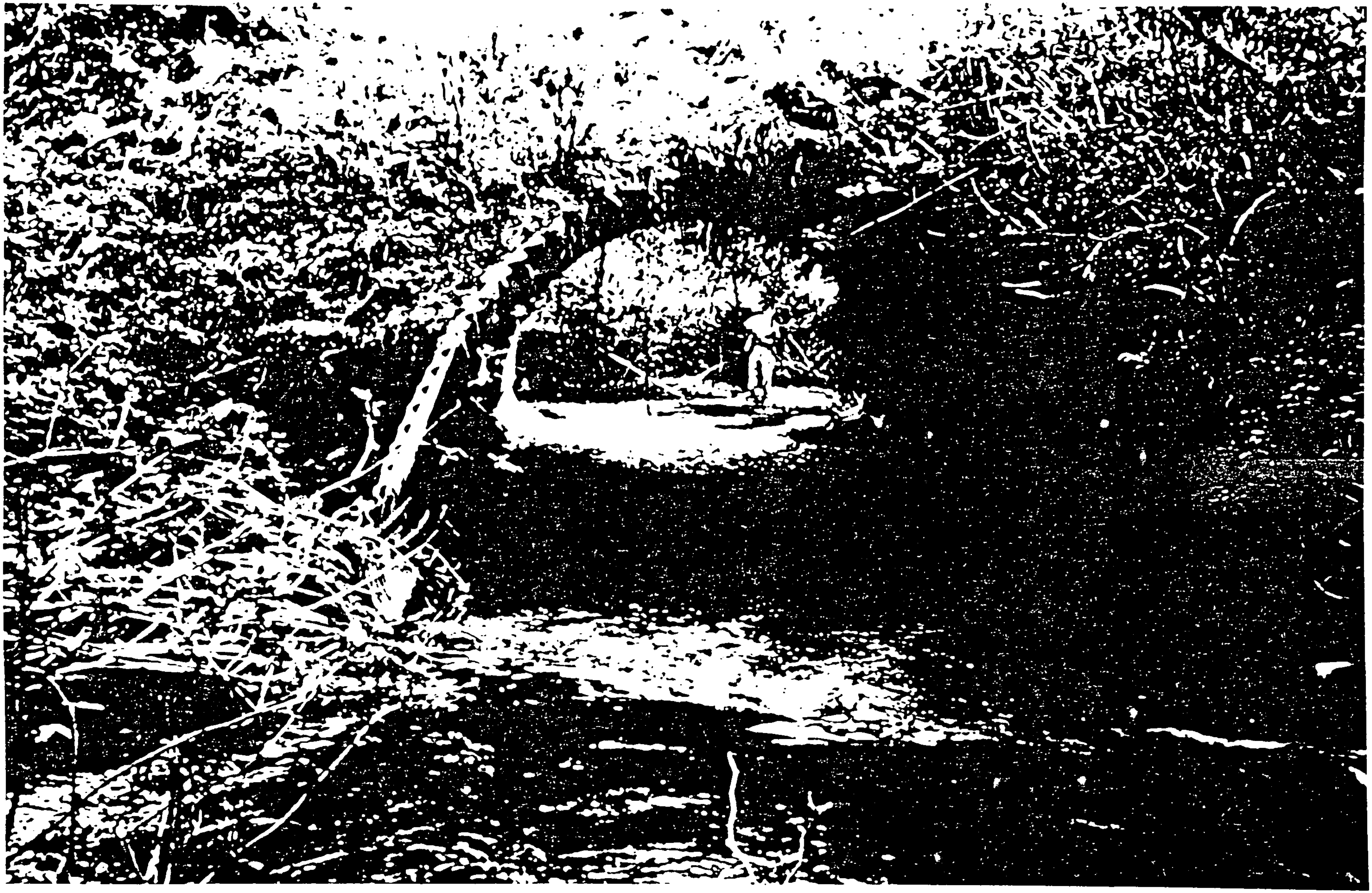


Photo No. 2-2 - Example of Completed Culvert That Does Not Restrict Streamflow or Movement of Aquatic Life (U.S. Forest Service) submerged. The type of cofferdam used depends upon the depth of water at the site, characteristics of the foundation materials, geometry of the structure proposed, and expected water-level fluctuations. Cofferdams are made of earth embankments, steel or timber sheet piling, and other watertight materials.

Caissons are similar to cofferdams. While cofferdams are removed following completion of the construction or fill placement, caissons generally form an integral part of the structure. Caisson means "box" in French. These structures can be rectangular, cylindrical, or in other configurations. They are driven, jacked, or allowed to sink under their own weight into position to exclude the water.

As none of these structures are totally impervious, particularly at contacts with natural materials, they may require pumping out water the seeps in. Proper disposal of the pumped water is essential. It may be sprayed on land or temporarily held in a detention pond until sediments have settled out.

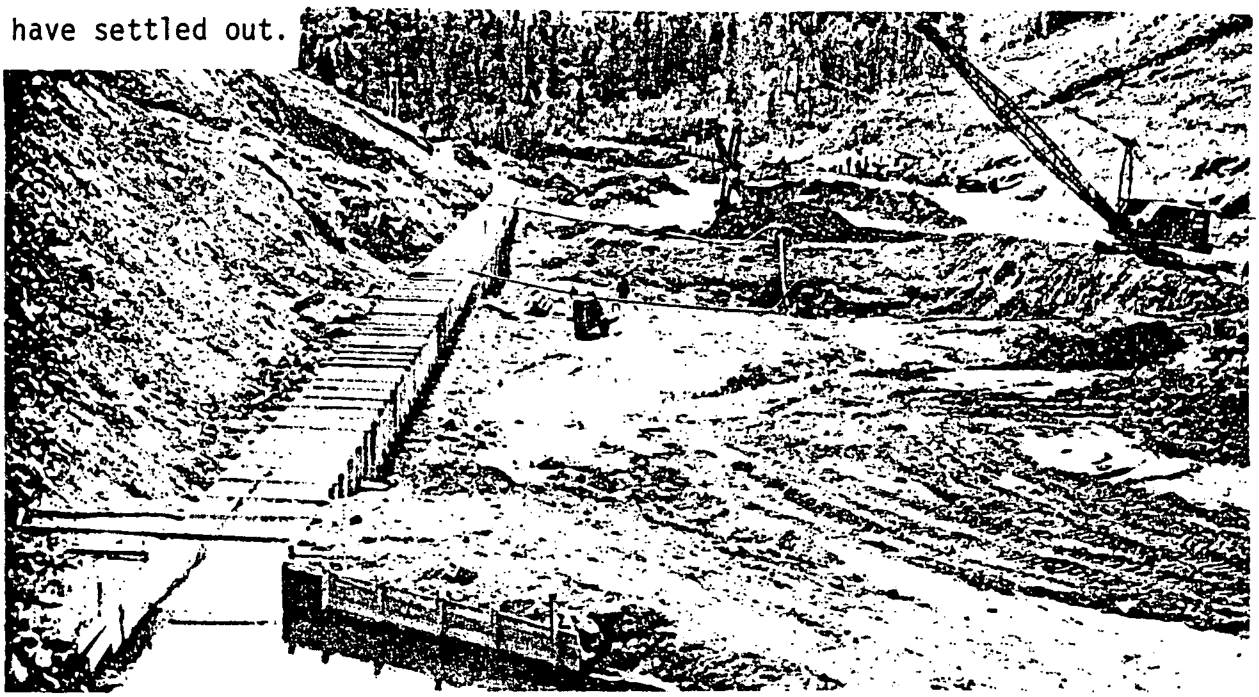


Photo No. 2-3 Flume For Temporary Diversion of Water Through an Earthfill Dam Site. (Reference No. 19).

Cofferdams used to dewater foundations of earthfill or rockfill dams often become portions of the principal structure (Figure No. 2-5). They function as barriers in the river channel immediately upstream from the dam foundation while a diversion tunnel or other structure transmits the water flow back to the channel downstream from the site. The site can be excavated, fill can be placed, and other activities can be conducted without being subjected to water flows which can cause sediment runoff and a pollution problem.

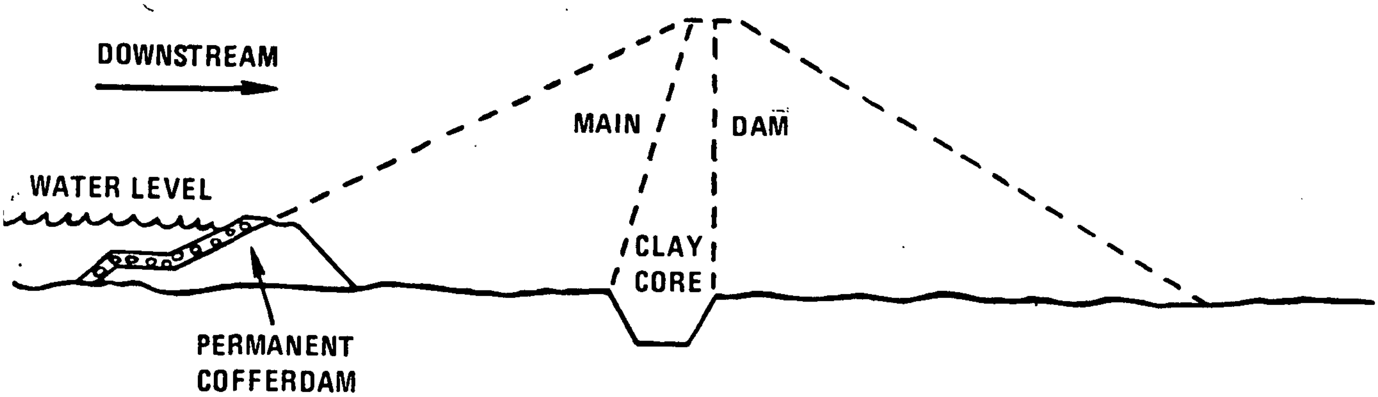
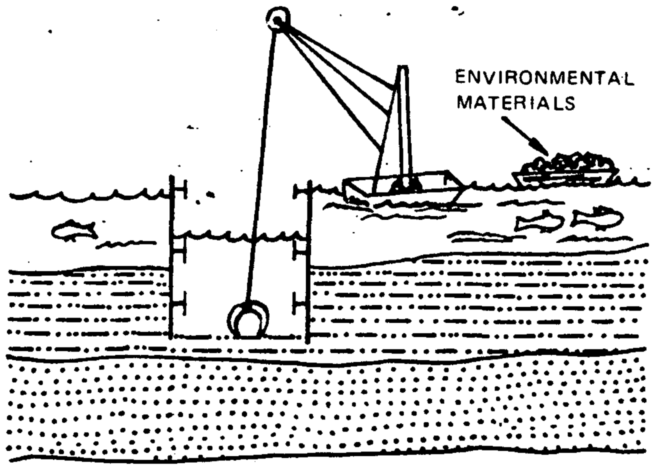
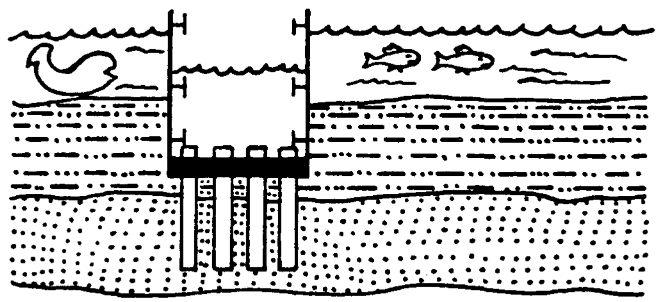


Figure No. 2-5 - Sketch Showing Cofferdam, Which Diverted Water To A Tunnel, To Be Incorporated in Main Structure

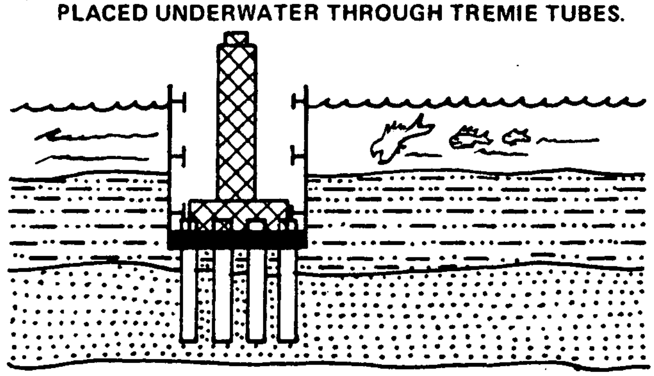
Cofferdams are used to exclude water from foundations for any type of structure. Figure No. 2-6 illustrates how a cofferdam is used to permit excavation, construction, and backfilling for a large bridge pier. Photo No. 2-4 shows a smaller, easily-constructed earthfill cofferdam used to exclude the water during construction of smaller bridge piers.



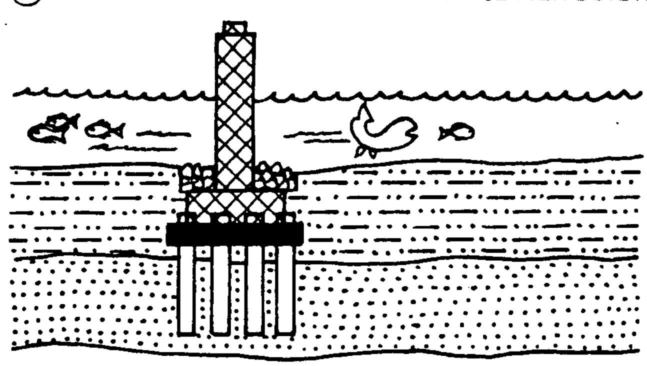
① CIRCULAR SHEET PILE COFFERDAM INSTALLED, FOUNDATION BEING EXCAVATED.



② FOUNDATION PILES DRIVEN. THEN CONCRETE SEAL PLACED UNDERWATER THROUGH TREMIE TUBES.



③ COFFERDAM DEWATERED AND BRIDGE PIER BUILT.



④ FOUNDATION BACKFILLED WITH SAND AND RIPRAP TO UNDERWATER SURFACE. COFFERDAM THEN FLOODED AND SHEET PILING REMOVED.

Figure No. 2-6 - Use of Cofferdam To Permit Installation of Bridge Pier and Prevent Runoff of Sediments Dueing Construction

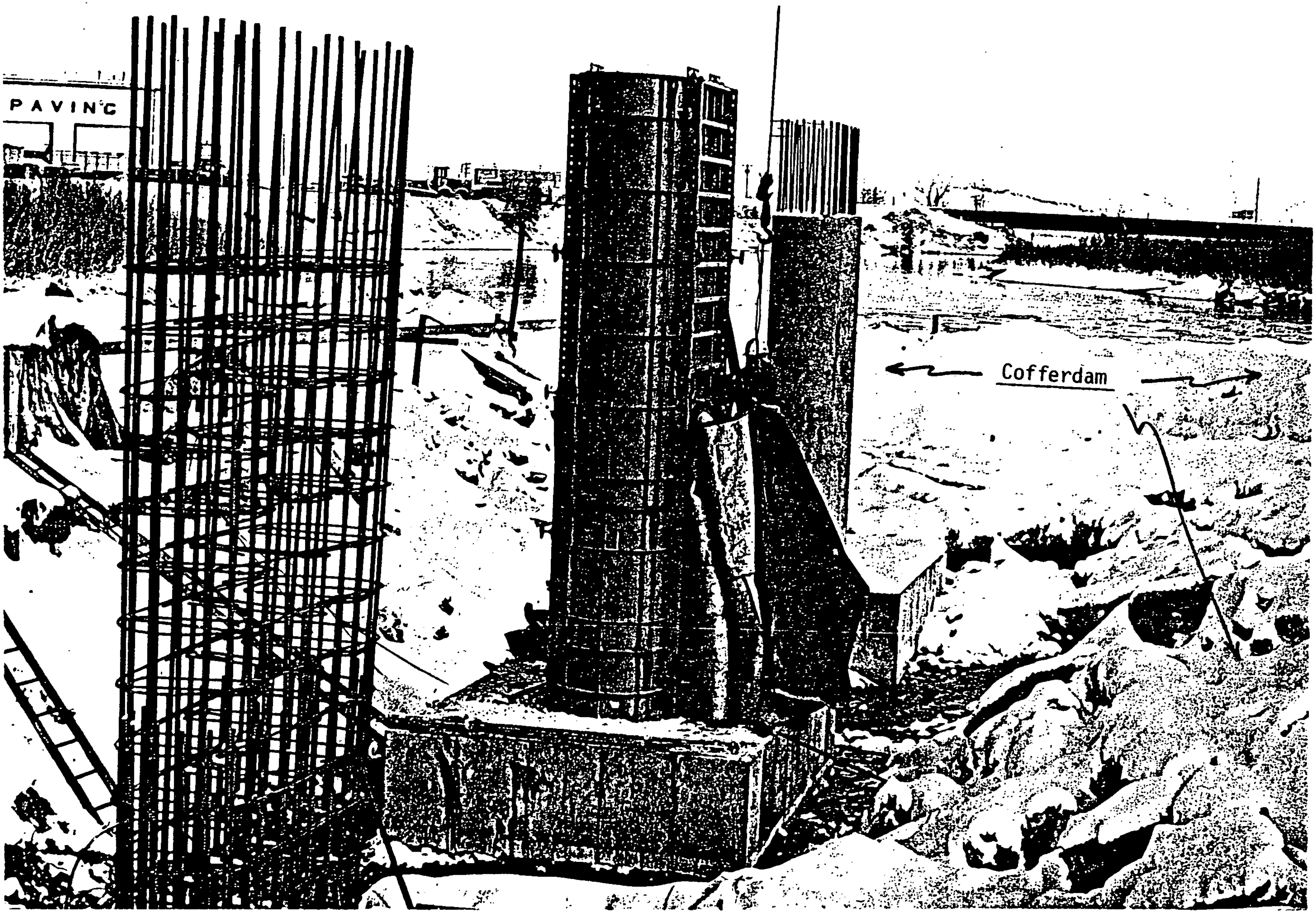


Photo No. 2-4 - Small, Easily-Constructed Earthfill Cofferdam Used to Exclude Water During Construction of Bridge Piers. (Wyoming Highway Department)

Protecting Masses of Emplaced Dredged or Fill Materials From Erosion

Surface protection must be provided to any mass of emplaced dredged or fill materials if it contains particles small enough to be eroded or transported by the action of rainfall, runoff water, or wave action. Protection from streamflow or wave action can consist of rigid structures such as concrete, stone, or wood retaining walls or panels and relatively flexible, as well as permeable, blankets of rip-rap or armor stone, systems of rock-filled wire mesh baskets (gabions), tree or brush mats, and other materials. Long term protection from rainfall, above the ordinary high water mark, can be provided by sufficient vegetative cover. Temporary protection can be obtained with layers of organic or chemical mulches or by burlap netting, or plastic sheeting.

If subaqueous trenching has been done, fill placed into the trench should not extend above the adjacent underwater surface to prevent erosion and changes in water flow. Often, erosion protection such as rip rap also may be needed. (See rip-rap protection on sketch no. 4 of Figure No. 2-6).

Rigid Fill-Protecting Structures

These structures function to retain and protect the fill material behind them and to reduce the extent of an individual fill needed for a particular purpose. Photo No. 2-5 shows reinforced concrete retaining walls for a bridge in the forest area. The angular wing walls channel water under bridge as well as provide erosion protection for the fill behind them.

Figure No. 2-7 shows a sketch of another type of retaining and protecting structure, consisting of layers of compacted earth reinforded with horizontal strips of metal. The earth layers are compacted on the strips and friction (without slippage), between the earth and the strips provides strength for the entire unit. Tensile forces are absorbed by the reinforcing strips and earth movement is therefore controlled by this stiffer material. The concrete panels function to protect the earth from erosion by water and allow free drainage of water from the fill (photo No. 2-6).

Photo No. 2-5 - Bridge in Forest Area with Abutments Supported and Protected From Erosion By Concrete Retaining Walls (U.S. Forest Service)

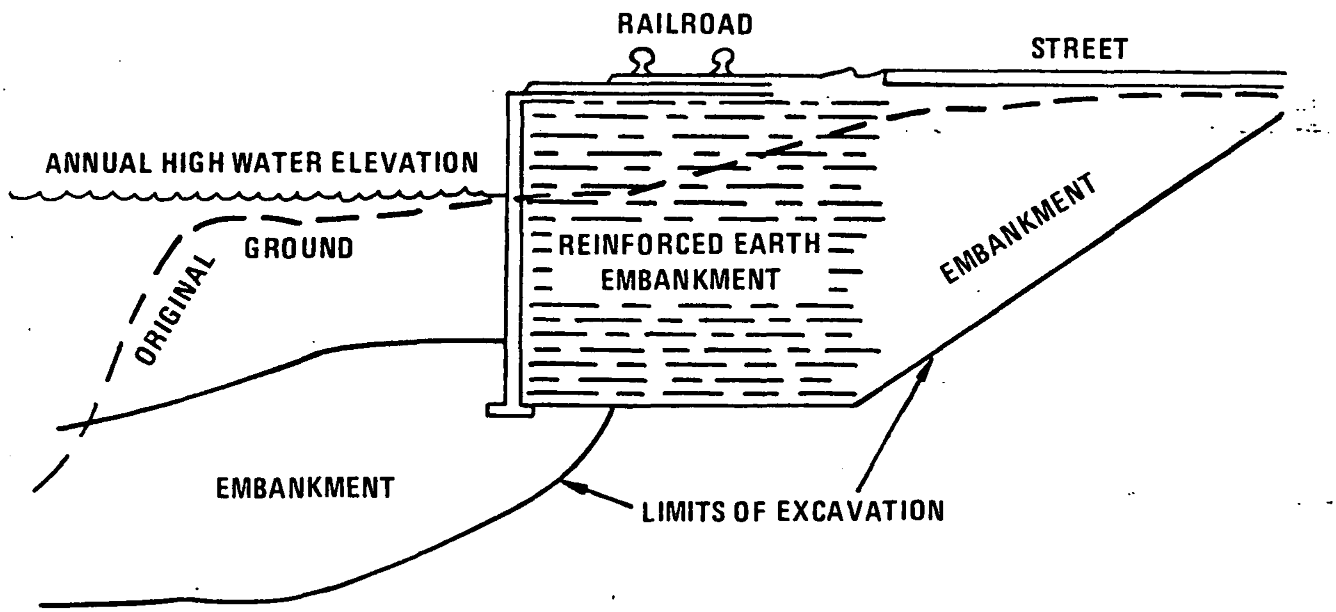


Figure No. 2-7 - Reinforced Earth Embankment Protected From Erosion By Concrete Panel Face Construction Completed Behind Dike Cofferdam to Exclude Creek (After Reference No. 24).

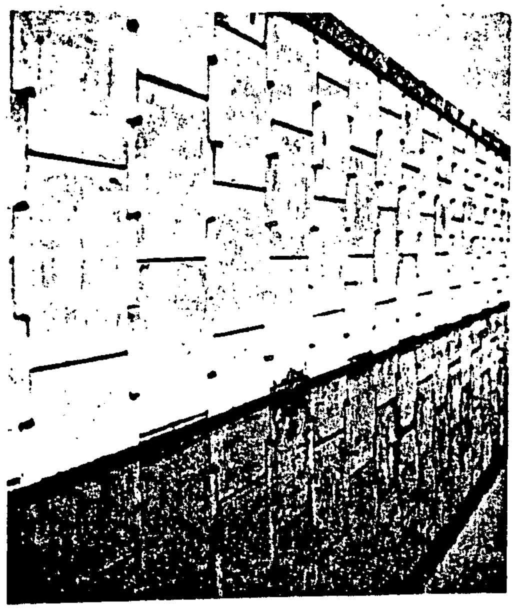


Photo No. 2-6 - Concrete panel Facing For The Reinforced Earth Embankment Showns in Figure No. 2-7 (Reference No. 24).

Concrete facing that does not function as a retaining structure can also be used to provide surface protection for masses of fill materials (See Photo No. 2-7). It generally is formed of slabs of reimforced concrete with the joints between them sealed with plastic fillers. Open cracks or holes which develop must be sealed promptly or the action of water and waves may displace or break up the slabs.

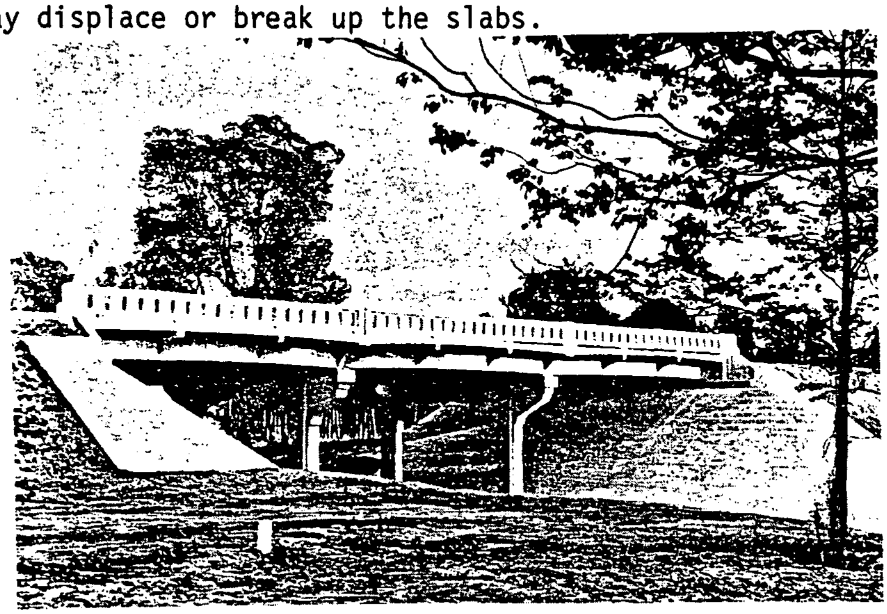


Photo No. 2-7 - Precast Concrete Panels Protect Slope From Erosion (Reference No. 4).

Flexible Fill-Protecting Structures

Rip-rap should consist of hard, dense, durable angular rocks. They protect the underlying material from the erosive energy of moving water and increase the surface roughness of the bank to reduce the velocity of moving water and cause deposition. The rock can be placed in a layer upon an exposed slope by machine or by hand. Segregation of materials should be prevented during placement (See Photo No. 2-8).

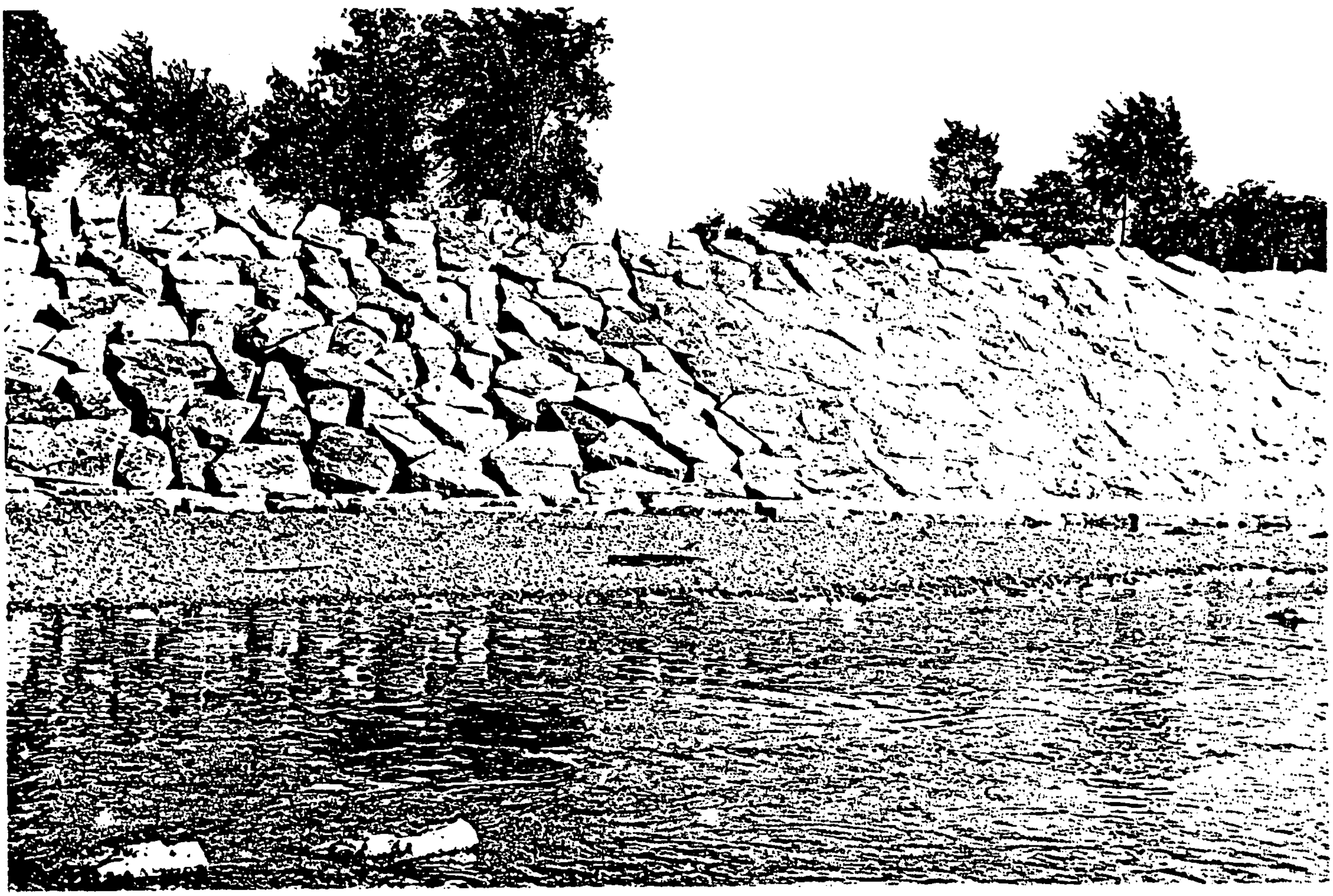


Photo No. 2-8 - Carefully Placed Rip-Rap "Armor" To Protect Roadfill From Stream Erosion. Material To The Right Has Been Sealed With Grout.

The thickness of the rip-rap blankets (layers) needed depends upon the steepness of the slope upon which they are to be placed; stream velocities or severity of wave action expected; methods of placement; and the size, shape, and specific gravity of the rock used. Some sources say the thickness of the blanket should be about 1.5 times the diameter of the smallest "immovable" rock if the rip-rap is hand placed, and 1.9 times that diameter if it is "dumped". A reduced thickness can be achieved if compaction techniques are used such as "plating" with a large flat weight. This densifies the rip-rap blanket and smoothes its surface. Provisions should be made to ensure that the toe area is secure from scour action by currents to prevent lateral sliding of the entire blanket (See Figure No. 2-8). An underlying filter blanket of sand and gravel or fine-mesh filter fabric should be provided beneath the rip-rap to prevent upward movement of the protected materials through voids between the larger rip-rap blocks.

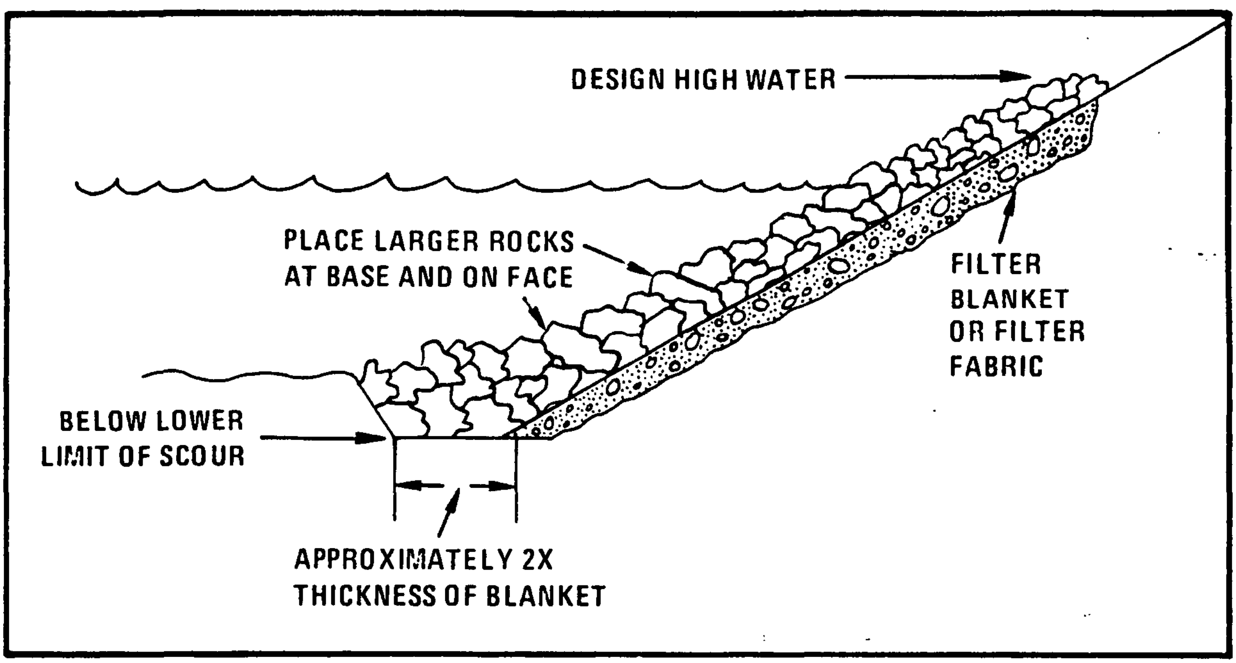


Figure No. 2-8 - Rip-Rap Blanket Protecting Slope From Erosion By Current and Wave Action. Note Filter Blanket and Toe Construction. (After Reference No. 9).

If blocks of rock large enough to remain in place during high velocity flows or heavy wave action are not available, smaller rocks can be bonded together after placement by grouting (cementing). These grouted blankets, with the rocks, cemented to one another, do not have to be as thick as loose rip-rap and they will remain in place upon much steep slopes (See right-hand side of Photo No. 2-8, Page 2-18). Wire mesh also can be laid over rip-rap when small stone is used. The mesh should be pinned in place using staples made of reinforcing rods and its lower edge held down with a weighted pipe or similar stabilizers (Figure No. 2-9). Vegetation often establishes itself in rip-rap blankets above high water as sediment particles fill in voids between the rocks to form soil.

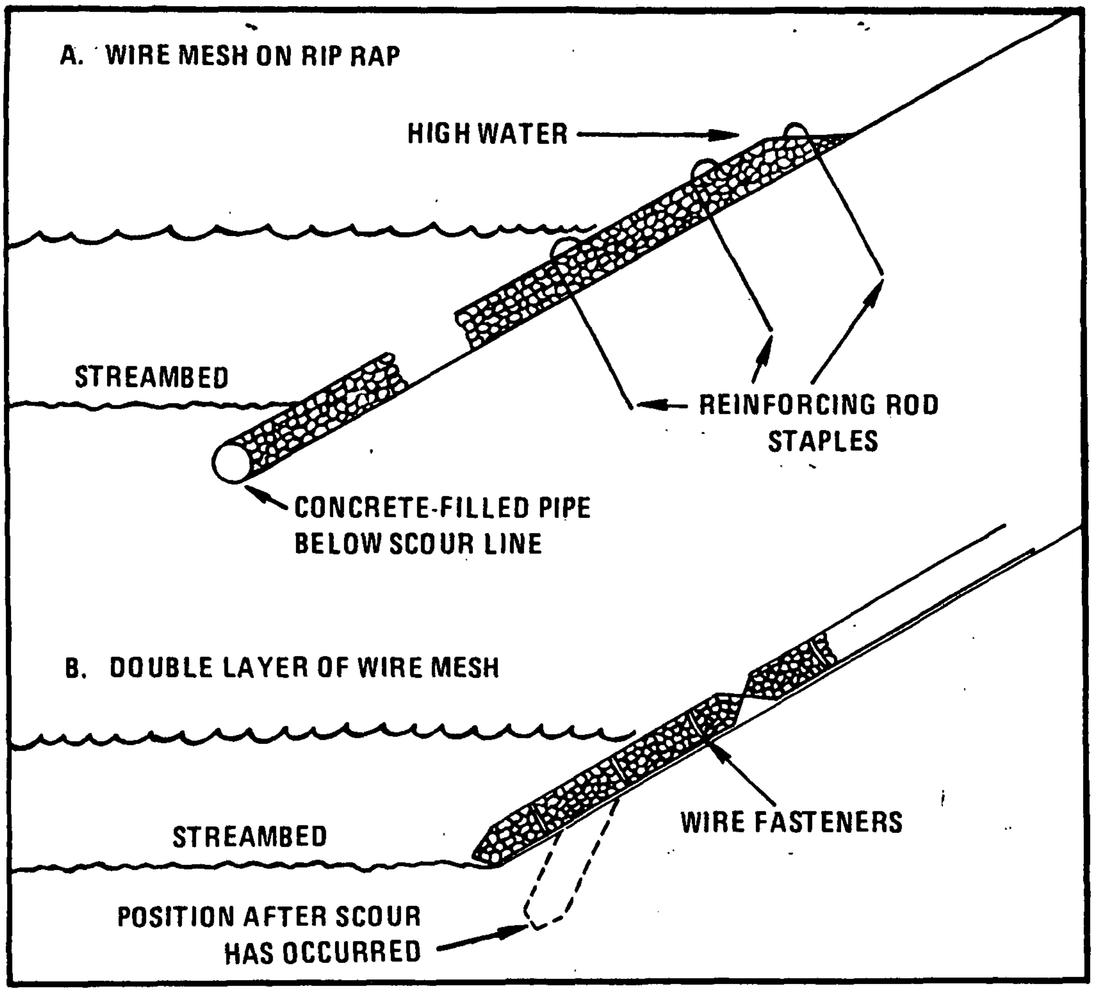


Figure No. 2-9 - Wire Mesh Stabilizing Small Rock Blanket (Reference No. 9).

Rip-rap also can be placed into pre-constructed wire mesh baskets called "gabions". The mesh should be small enough so that most of the rock cannot pass through it. Strength required of the wire mesh depends upon the desired life of the blanket and the type of support the system of baskets is to provide. Gabions can be arranged, or stacked to form steep, or near vertical walls protecting a fill (See Photo No. 2-9).

Photo No. 2-9 - Completed Gabion Wall Illustrating How Steep Protective Structures Can Be Made (Reference No. 3).

Brush mats, planted with shrubs and protected at the toe with rock rip-rap, also can be used to protect the surface of exposed fill materials (Figure No. 2-10). The mat itself has a short life; its principal purpose is to provide protective covering for both the slope and the shrubs and trees planted beneath. Slopes should be planted before matting is installed. preferably in the spring or other appropriate season. Stakes used for anching the brush mats may be made of "live" wood which can take root, grow, and protect the slope when the mat breaks up.

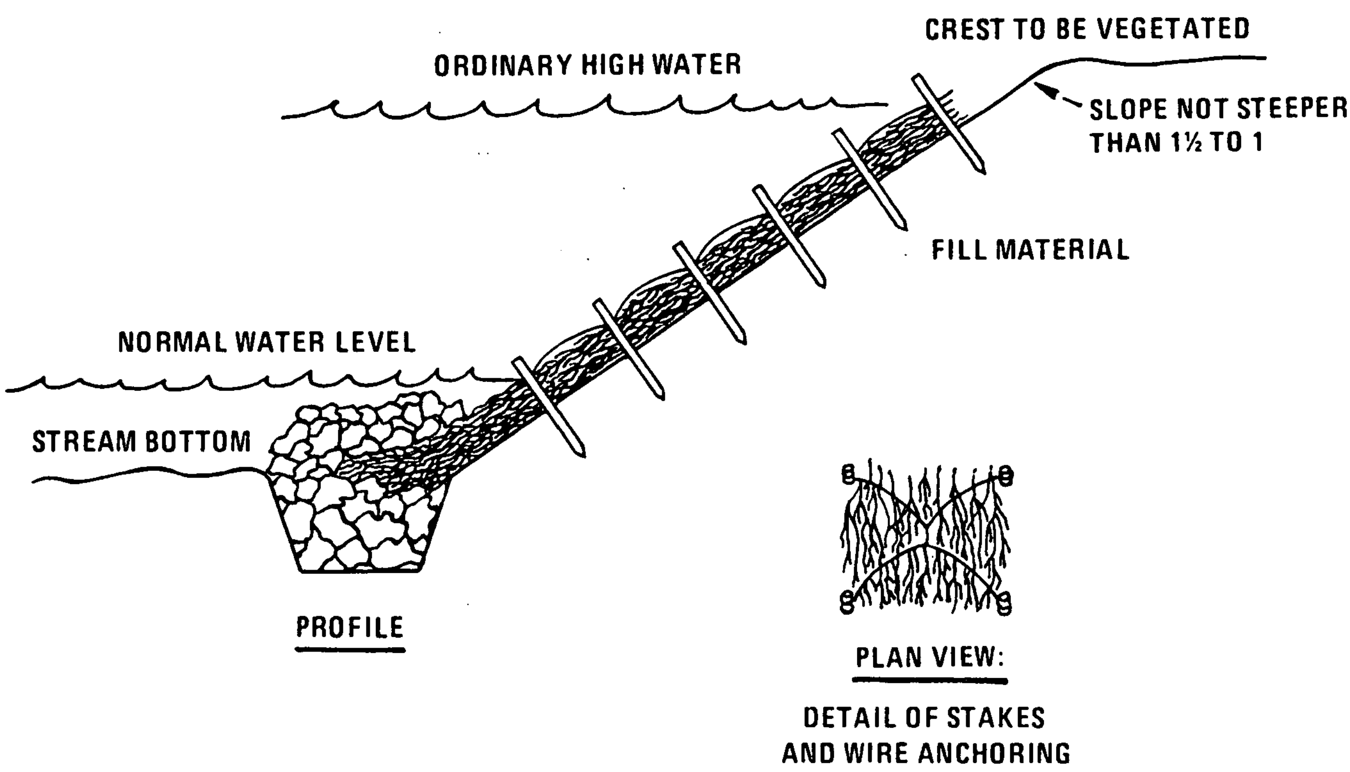


Figure No. 2-10 - Brush Mat Protecting Slope From Erosion. Brush Planted Beneath Mat Provides Protection After It Decays. (After Reference No.12).

CHAPTER 3

ENSURING CONTAINMENT OF POTENTIAL POLLUTANTS WITHIN DISCHARGED MASS OF DREDGED OR FILL MATERIALS

Naturally-occurring materials interspersed through masses of dredged or fill materials can become pollutants when discharged or placed into a new environment. Their use should be avoided if at all possible. They may include such materials as gypsum (calcium sulfate), pyrite (iron sulfide), salt (sodium chloride), or other substances. Contact of these materials with air and water can cause changes in their chemical composition and/or put them into solution. Unless Best Management Practices similar to those presented in this chapter are implemented to restrict their contact with air and water and prevent the runoff of dissolved materials, nearly water bodies will be subject to pollution. If any of these materials are subjected, geologic studies should be initiated tp identify their location, concentration, and exten so that sources of alternate materials can be located.

In arid areas, the only available fill materials consist of clay shales of marine origin which may contain quantities of gypsum, salt, or similar soluble materials, in veins or disseminated throughout beds. These soluble materials result from the evaporation of seawater following deposition. Many dry lake deposits in enclosed basins in arid areas contain high salt contents as do the sediments adjacent to the lakes. Any area where extensive evaporation of water has taken place should be suspect. If fill for bridges, culverts, or other facilities to be placed into water bodies are obtained from such geologic units, they must be considered potential sources of pollution.

Pyrite and other iron sulfide minerals, occur in many different types of rocks which may be used for fill materials. Soft easily-excavated sedimentary rock, readily usable for fill, or hard consolidated material that requires blasting to obtain such materials as rip-rap may contain quantities of iron sulfides. Sulfides are readily oxidized when exposed to air, moisture, and bacteria (thiobacilles) and can create high concentratons of mineral acids. As the acid solutions flow over adjacent fill materials, they dissolve heavy metals such as iron, manganese, copper, aluminum, and zinc to add to the pollution problem.

Formations containing any of these types of substances may underly beds of rivers that are being dredged and source (borrow) areas where fill materials are to be obtained. If they can be identified, isolated, removed and properly disposed of separately from the dredge or fill material, they will not pose a threat to the environment. If they are interspersed through the main body of materials they probably cannot be separated and will cause the entire body to be a pollutant threat. This situation probably is more characteristic of fill than dredged materials as most river beds are formed on fresh water alluvial deposits that are relatively "clean" chemically.

Best Management Practices to prevent pyrite, gypsum, or salt-bearing dredged or fill materials from causing possible water pollution when discharged or placed into water bodies or in wetlands include techniques for containing and isolating these materials from contact with air and water. It may involve installing them within relatively impervious layers (blankets) or barriers of compacted earth materials. (See Figure No. 3-1).

On steep fill slopes, where stability may be a problem or quantities of impervious soils are limited, gabions (wire mesh baskets) full of compacted soils may be considered. In these cases, the imperviosu blankets are thinner but also function to resist failure due to the tensile strength

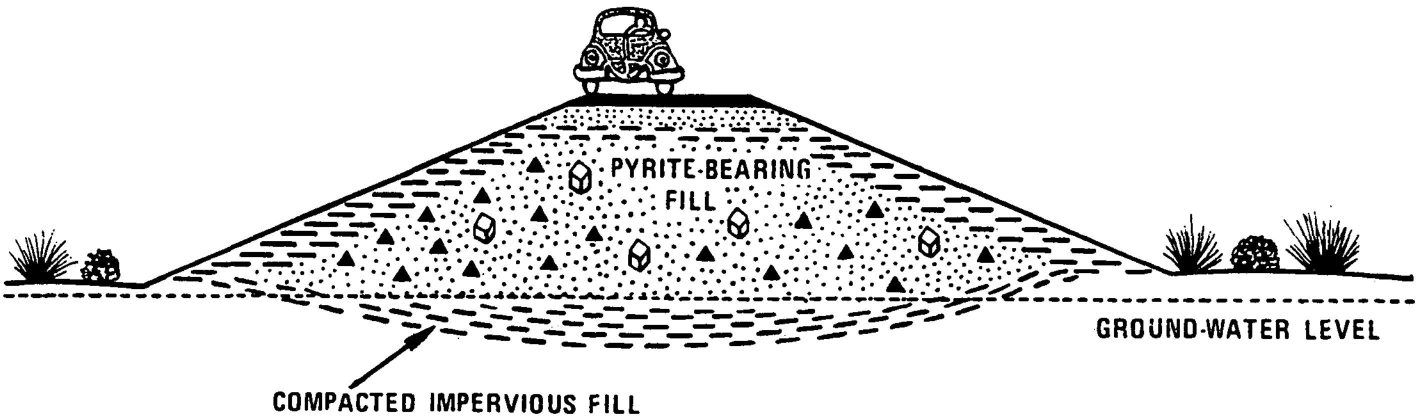


Figure No. 3-1 - Impervious Fill Surrounding Roadfill Containing Pyrite Restricts Contact With Water and Air

of the baskets. Ensuring the placement of impervious materials between gabions will be controled with this type of barrier. If fill material being contained beneath the gabion blanket, is extremely coarse-grained, a filter consisting of sand and gravel or filter cloth may be necessary to prevent downward movement and loss of the fine-grained impervious blanket materials into the fill below. (See Figure No. 3-2).

The basic premise for using impervious blankets and seals, is to provide water and air barriers to isolate the materials containing potential pollutants and prevent chemical actions from occurring. When pyrite or other sulfide minerals are involved, excluding the air and water also acts to prevent breakdown of individual particles in the fill and the exposure of fresh pyrite crystals to the elements. The impervious materials also provide exterior surfaces that are relatively easily vegetated and require little future maintenance.

An additional, and supportive, BMP available involves the chemical neutralization of potential pollutants. Agricultural lime can be blended with pyrite-bearing fill or placed in a layer on outer surfaces under the impervious soil. The addition of the lime will minimize the production of acid, partially neutralize acid being produced, and prevent toxicity to vegetation when impervious blankets are thin (See Figure No. 3-2).

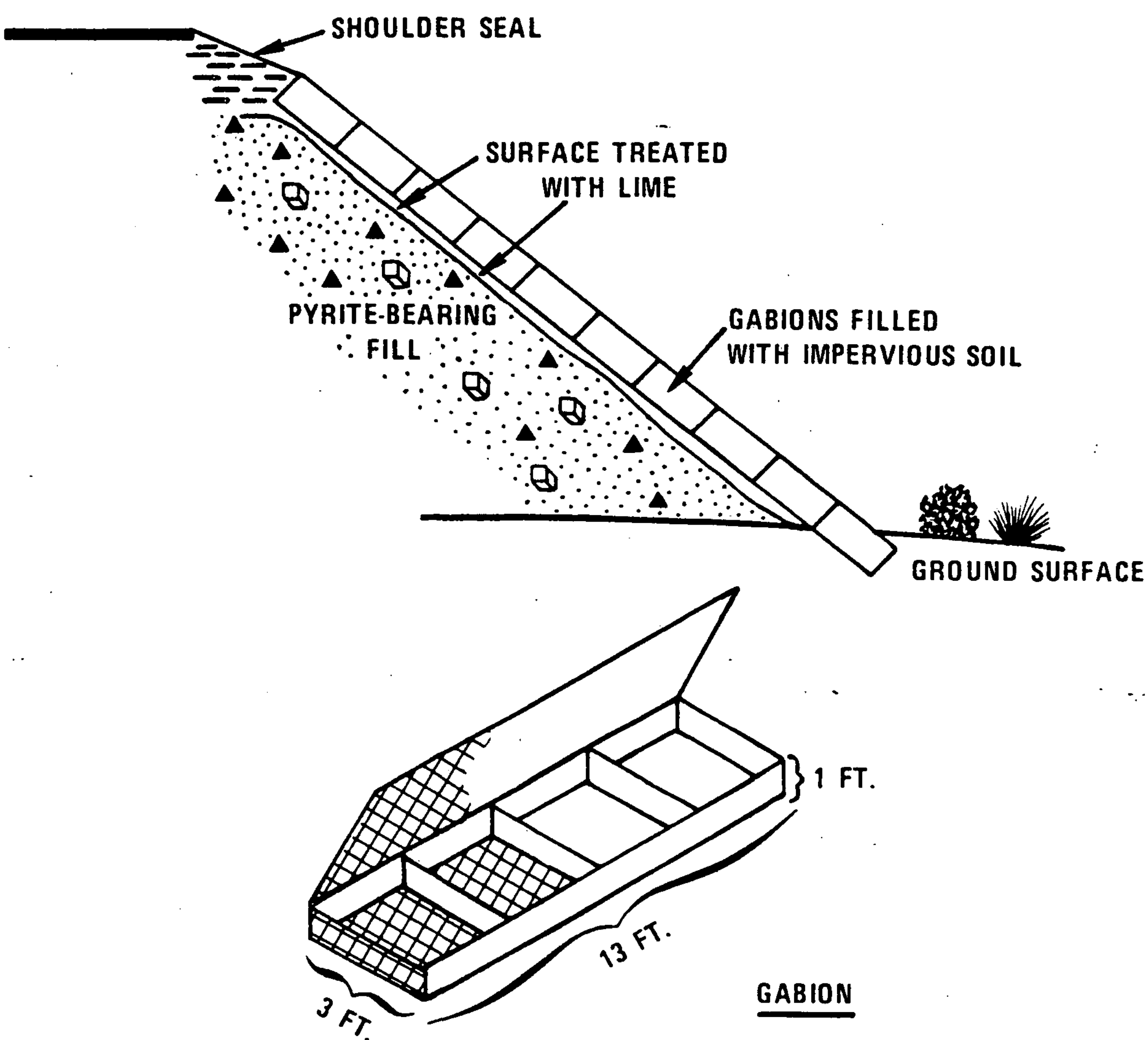


Figure No. 3-2 - Earth-filled Gabions Providing An Impervious Blanket On Roadfill Containing Pyrite (After Reference No. 29).

Blankets function as barriers which only restrict, not stop, the movement of water into or out of the materials they are designed to isolate. If different water levels are maintained on either side of these barriers for a long enough period of time, water will move through them, but only at a slow rate. As a result, the estimated time when differential water levels are to be maintained on either side of impervious blankets or barriers, as well as their degree of impermeability and thickness, must be determined to provide adequate protection. If only rainfall and sheet runoff of short duration are to be excluded, relatively thin blankets of only moderately water tight materials may be adequate. In cases where large differences in water levels occur for long periods of time on either side of a blanket or barrier, it must be a thick, highly-compacted impervious layer. If water finally moves out of the fill after being degraded by the poor-quality contained material, it will move so slowly that it probably will be diluted by the faster-moving water outside and not pose a threat to its quality.

CHAPTER 4

ENHANCEMENT OR THE REPLACEMENT, RELOCATION, OR RECONSTRUCTION OF EXISTING ENVIRONMENT

In certain extreme situations, the discharge of dredged or fill materials into water or wetlands may be necessary although the potential for severe damages to or destruction of the existing local environment may be recognized. When this situation occurs, the only alternative that remains is to consider, as a Best Management Practice, the enhancement or replacement of existing, or similar type of environment on an acre for acre basis. In other words, to artificially create an equal area of new aquatic environment for that damaged or destroyed. Limited information is available regarding these practices and their long-term effectiveness, particularly in wetlands.

Creating environmental conditions in a new area that will be similar to the natural environmental conditions that occurred in another is extremely difficult since they result from numerous interrelated surface and subsurface hydrologic, geologic, topographic, climatic, plant and animal, and other factors. Changes in one or more of the factors sets up a chain reaction which results in changes ensuing in other factors. The end result of the changes may be unpredictable unless sufficient data is available concerning the entire system.

Wetlands

In wetlands, water is the dominating factor in determining the nature of soil development and the types of plant and animal communities occurring in them. Wetland soils periodically are saturated due to fluctuations in surface or ground water bodies. As a result, knowledge of water flow into and through the wetlands is essential for evaluating the practicality of enhancing or replacing an area of wetlands. The regimen and depth of water flow and the physical and chemical character of the soils in the new wetlands should duplicate as closely as possible, those in the area damaged by the discharge or placement of dredged or fill materials. Vegetation and animal life characteristic of the adjacent wetlands may quickly migrate into the new area and establish itself. If they do not, re-establishment by transplanting probably will be essential to enable the new wetland to quickly establish itself and support communities of aquatic life and other water-dependent wildlife.

The long-term stability of a newly-created wetland should receive prime consideration. All of the factors brought into play to create it must operate conjunctively to maintain its existence and productivity. The net energy inflow into the wetland from surface and ground waters transporting nutrients, sediments, and other materials necessary for maintenance of life should be made approximately equal to the outflow if at all possible. In wetlands where the energy inflow comes from both salt water sources in coastal areas and fresh water in upland areas, the system is extremely difficult to assess and to duplicate. The interplay between saline water and fresh water and their effects upon the aquatic communities and the wetland development must be evaluated.

Streams

No stream channel relocation can be made without changing the length (and thus the gradient) and roughness of the channel. This in turn changes the velocity of flow and the energy available for channel erosion (degradation) and sediment transport. These changes may be controlled, through the use of Best Management Practices, to provide significant beneficial impact upon the aquatic environment, particularly with regard to the fish, vegetative, and invertebrate communities.

Large sediment loads often develop to become the most destructive elements. Flowing water in all streams has energy. This energy is used to modify the channel by eroding, transporting, and depositing sediments until an equilibrium has been reached between energy and resistance. During equilibrium, stream channel changes are occurring constantly but the net flows of water and debris into and out of the system are equal. Total energy is influenced by the velocity of flow which in turn is a function of the stream gradient, volume of flow, and the characteristics of the channel cross section and bed. It has been estimated that more than 95% of this energy is converted to heat by turbulence and bed and bank friction and so lost. The remaining is all that's available for eroding and transporting sediments.

If a reach of a stream is to be relocated, it must be designed so that the net inflow of water and sediment in the new section is the same as that in the older section or instability will result and detrimental channel changes will occur progressively both upstream and downstream. If the channel has been shortened, velocities will be increased and excessive erosion and transport of sediments will occur. Reduction in stream velocities can be achieved through the use of check dams to reduce gradients, by placing obstructions such as boulders in the stream to increase the roughness of the channel, or by creating meanders. Roughness also is increased by vegetation, logs, sandbars or any other irregularities in the channel section. When a channel is lengthened, the gradient of a stream is decreased and deposition of sediment loads and local filling-in, or clogging, of the bed may result. Practices for minimizing the detrimental effects in this situation may involve re-designing the channel section so it is narrower and deeper and the water reaches higher velocities to transport the sediment load through it.

All measures (BMP's) should ensure that the relocated stream is stable under the new conditions as an unstable stream will generally deteriorate the quality of the environment. It is imperative that any changes be followed by compensating Best Management Practices to minimize adverse effects of these changes. They must be designed to maintain, as closely as possible, the original channel's gradient, shape and width, alignment and aquatic productivity as these factors are all interrelated and changing one has an effect on others. Channel slopes can be changed through installation of check dams made to look like natural features such as fallen logs. (See Photo No. 4-1); width changes, particularly for the benefit of maintaining adequate depth of flow for aquatic life, can be minimized by providing dual-type channels (See Figure No. 4-1). The smaller, deeper channel on the left provides adequate depths for aquatic life during low flows. All of these practices are used to stabilize the stream regime and provide for the development and propagation of fish and wildlife nature to the area.

Large boulders and cobbles placed into a channel increase its roughness, reduce the velocity of flow, and, at the same time, provide resting places or cover for fish and other aquatic life. These rocks, placed on outside of stream bends where velocities are high, can also act as rip-rap to prevent bank erosion (See Figure No. 4-2). They should be located with extreme care so they do not cause the currents to impinge on the bank and create a more severe erosion problem.

Photo No. 4-1 - Check Dam In Stream Decreases Gradient (U.S. Forest Service)

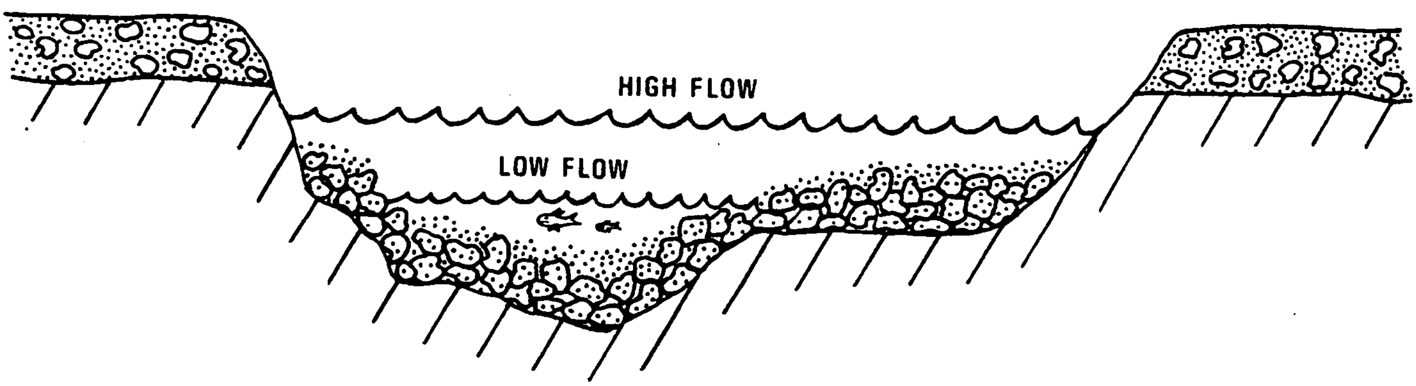


Figure No. 4-1 - Dual-Purpose Stream Channel Maintaining Adequate Depth During Low Flows (After Reference No. 27).

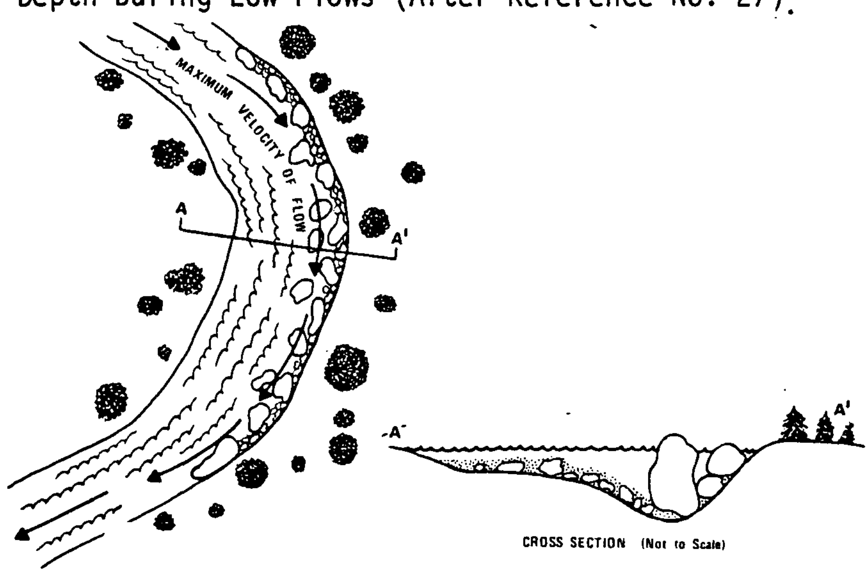


Figure No. 4-2 - Rocks Placed In Stream Section To Reduce Velocities and Prevent Erosion On Outside of Bends (After Reference No. 27).

Deflector structures can be used to divert the water into a more constrictive channel, to create pools, to simulate meander conditions, and to provide sufficient water depths during low flows. Rubble rock deflectors, log structures, and similar devices can be devised. Logs if properly used, can appear to be submerged, partially-buried fallen trees. They should be submerged permanently to prolong their life. Photo No. 4-2 illustrates rock rubble deflectors.

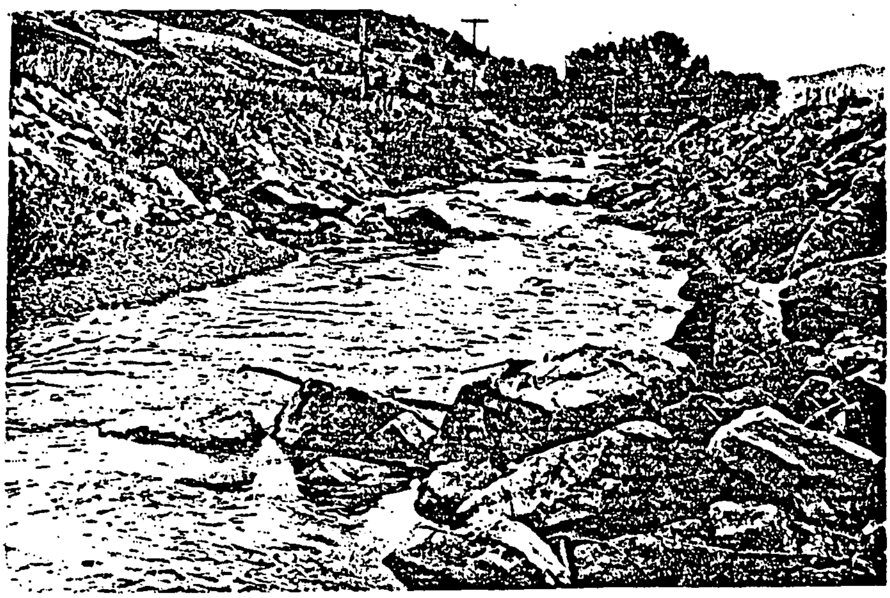


Photo No. 4-2 - Meanders Created By Rock Deflector Structures (Reference No. 27).

If a stream mut be relocated or the channel section altered to make way for some type of development, the new channel should be designed and completely constructed, in accordance with projected hydraulic conditions, prior to diverting water into it. Extreme care should be taken to ensure that the existing stream does not receive excess sediment runoff from the disturbed new channel during construction. Measures and structures to minimize detrimental changes that will occur in the new channel should be in place before it receives the stream's flow and the old channel is plugged. All structures should have a natural appearance, and vegetation, similar to that in the old channel area, should be provided for the new one. The addition of soil may be required. It should be placed so that natural conditions are duplicated.

After the new stream channel has been in operation for a period of time, alterations such as acceleration of meanders or changes in depth may begin to occur. If they appear to be initiating environmental problems, additional structures, or other Best Management Practices similar to those initially designed for the channel, can be provided to control them.

CHAPTER 5

PROTECTING HABITAT CONDITIONS AND PROVIDING FOR FISH AND WILDLIFE PROPOGATION

Water-retaining structures such as dams and reservoirs often function as complete barriers to the movement of aquatic life and water-dependent wildlife regardless of their size. Linear fills across wetlands or water bodies such as railroad or highway embankments, causeways, or even canals and aqueducts can restrict movement of wildlife even though facilities have been provided to enable water to pass through or under these structures. Deer, quail, foxes, rabbits, and other creatures can cross over or travel along these linear facilities, but only with extreme danger to their lives. Best Management Practices to prevent or minimize such environmental impacts should include providing passageways for aquatic or wildlife through, over, or possibly around such structures, preventing wildlife from gaining access to areas of potential danger, and minimizing adverse habitat changes caused by the discharge or placement of the dredged or fill materials.

A brief discussion of some of the presently available practices is presented here. At present, BMP development in this environmental problem area is an art rather than a science and many of the techniques and practices are not fully proven as effective. There is no intent in this document to imply that these are the only practices available or that they will accomplish the desired purposes in all areas and situations. Additional and more detailed information on BMP's for protecting habitat conditions and providing for fish and wildlife propogation is presented in the References on Pages 6-1 through 6-4.

Creating Passageways For Aquatic or Water-Dependent Wildlife Through, Around, Under, or Over Structures

Discharge or water from reservoirs is accomplished through outlet pipes or penstocks of some sort which pass through or under the retaining structures, surface spillways that extend around the end or over structures, and diversions that channel the water around dams for further transmission. Generally, when water moves through all these structures it does so at high velocities and the passage of aquatic life through them is difficult or impossible.

Linear fills extending across wetland or adjacent water bodies can restrict the movement of aquatic life and water dependent wildlife into or within such areas. The restrictions on wildlife movement can be minimized by providing passageways through embankments in areas where animals are known to habitually travel.

There are practices available to provide for the passage of migrating fish through or around water-retaining structures. They involve such facilities as fish ladders, fish conduits, and similar units. (See Photo No. 5-1). Once past the structures, fish are free to travel upstream to spawning beds. For some structures, fish ladders lead to holding ponds where fish are collected and transported to spawning areas.

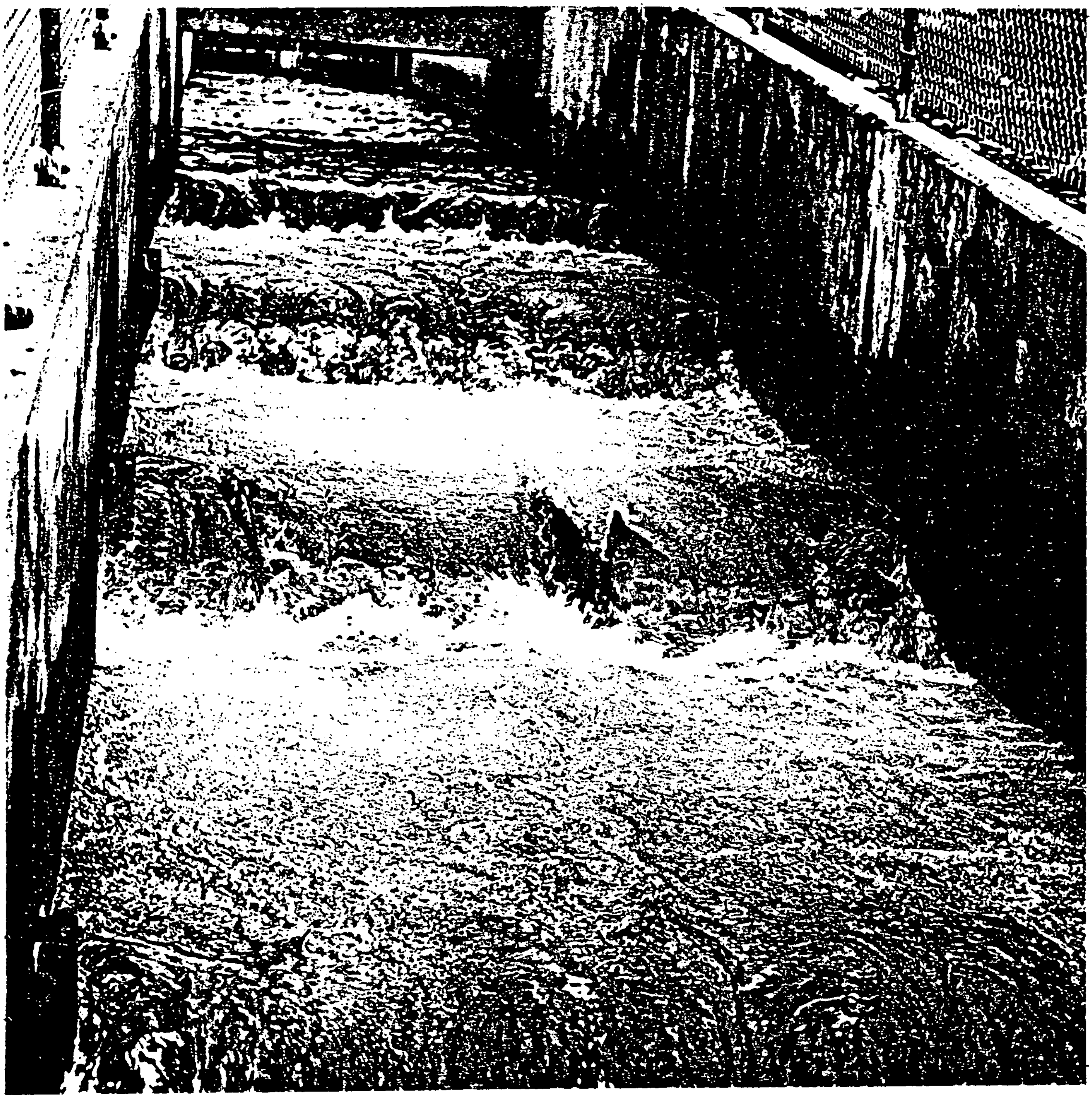


Photo No 5-1 - Salmon Migrating Upstream Use Fishladder Facility To Bypass Dam (U.S. Bureau Of Reclamation).

If the effects of a dam or reservoir on the habitat of anadromous fish are severe, manmade spawning beds may be designed into the project. Additional facilities then are required to channel the fish to these spawning beds. They can include electric barriers, fish ladders, and bypass channels.

Sometimes a reservoir floods spawning beds for anadromous fish such as salmon. In these cases, the fish ladders, or other by-passing structures terminate at fish hatcheries where the migrating fish are collected, killed, and the roe obtained. The roe is fertilized and then placed in the hatchery under controlled conditions until the fish are hatched. After having reached an appropriate stage in their development, the fish are released into the river downstream of the dam to migrate back to the ocean and complete the age-old cycle of migration that their parents had initiated.

The generation of power at hydroelectric dams results from the movement of reservoir water through penstocks and turbines to downstream areas. Migrating young fish may suffer significant losses when passing through the turbines unless these facilities have been designed for fish passage. The survival chances of the downstream migrating fish can be increased by providing facilities that bypass them into a gatewell before they enter the turbines and direct them into a channel where they can move safely downstream. Fish ladders or some similar type of structures should be provided to enable returning mature fish to migrate upstream around the dam. Additional information on such devices is presented in a document under preparation for the Fish and Wildlife Service entitled "Interim Guide To The Performance Of Fish and Wildlife Habitat and Population Improvement Measures For Western Dam and Reservoir Projects (Reference No. 22).

Linear Transportation or Conveyance Facilities

The design of passageways through or under linear embankments should be based upon the habits and needs of wildlife in order to become fully effective. Underpasses beneath, or through highway and railroad embankments in wetland or water bodies probably will be more effective if used in conjunction with fences to help guide wildlife through the openings. Many animals will be hesitant to go through such passageways unless guided and restricted by these fences. Some of them are fully capable of climbing the embankments to cross or travel along the structures. If they are able to do so, their lives will be endangered by vehicles.

Passageways for wildlife should be designed to appear as natural as possible to the animals. Their minimum widths and lengths should be based upon the size of the animals involved. Floors should be of earth or other natural materials and skylights or artificial lighting of any kind should be avoided. Photo No. 5-2 illustrates an earth-floored passageway through an embankment with fences to channel animals through the structure. In general, facilities for animal passage extend under road or railroad embankments. For water facilities such as canals and aqueducts, they extend over (See Photo No. 5-3).

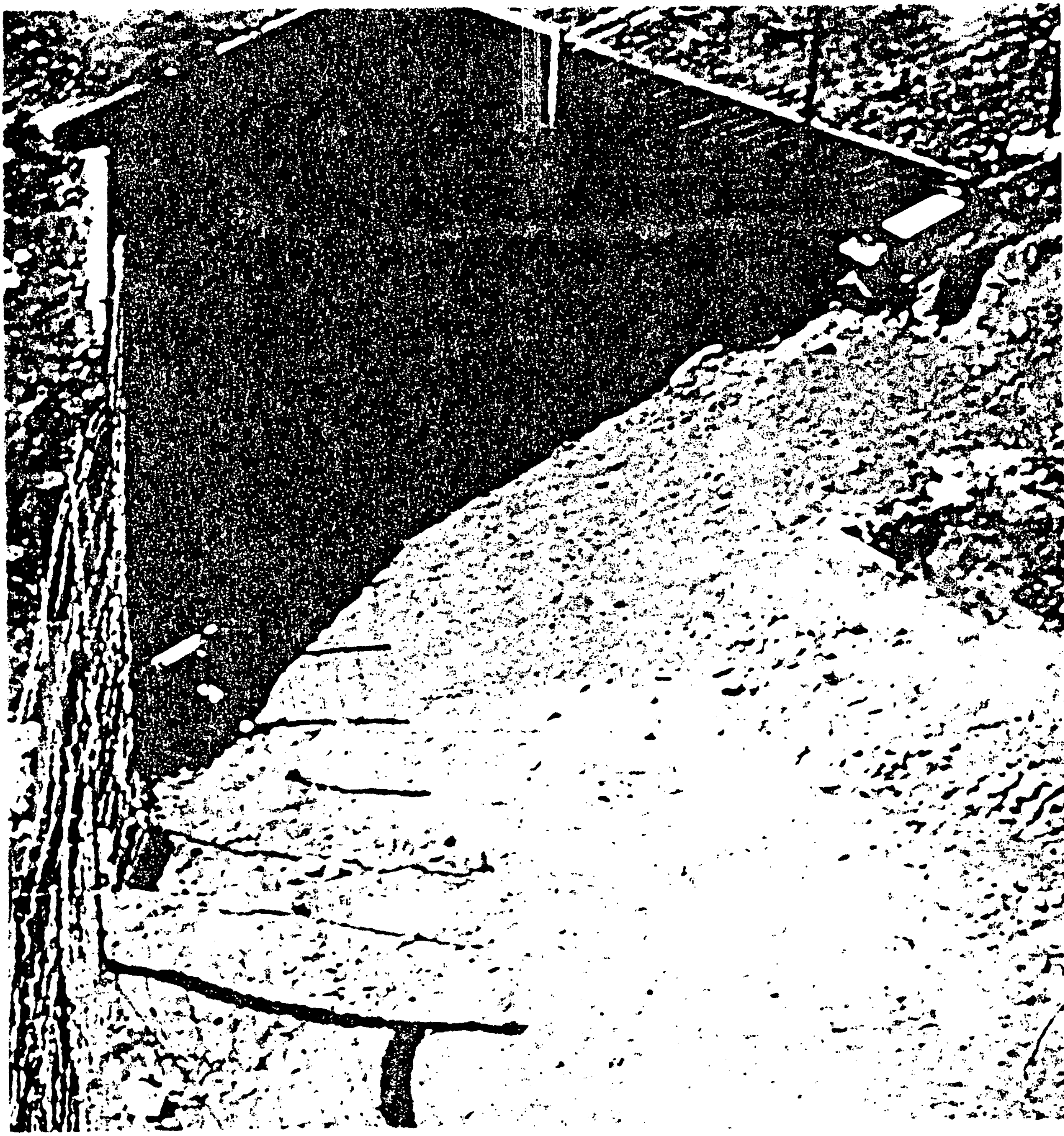


Photo No. 5-2 - Underpass For Animals Beneath A Highway. Fences At Toe Of Slopes Prevent Movement Up Embankment To Roadway. (U.S. Federal Highway Administration).

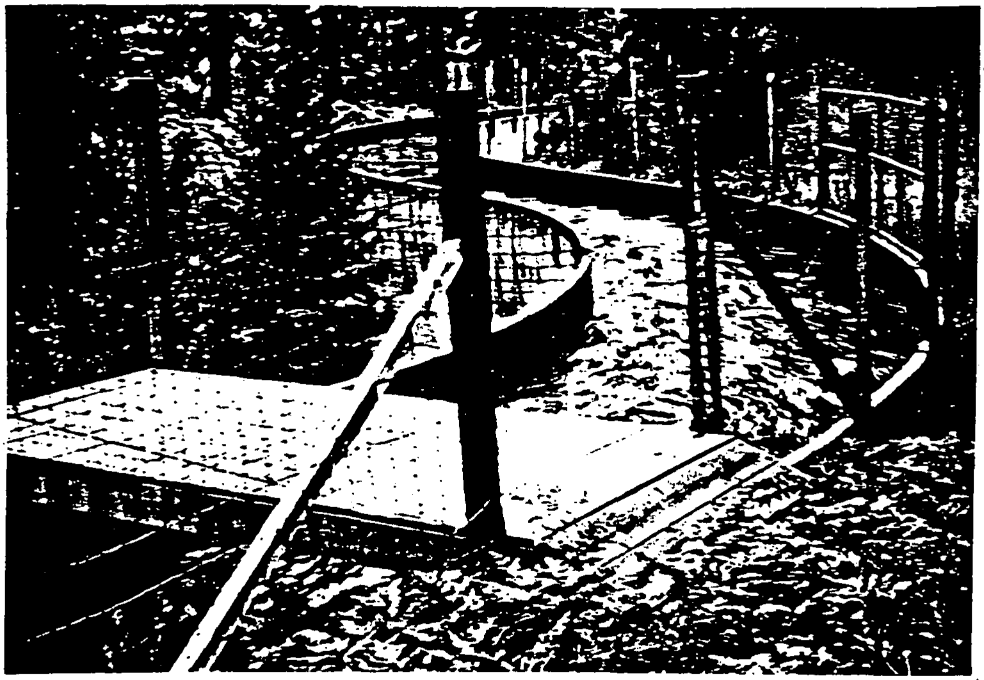


Photo No. 5-3 - Animal Crossing Extending Over Fenced Aqueduct. Wooden Floor Has Not Been Covered With Earth Yet. (U.S. Bureau of Reclamation)

Providing Protective Devices For Wildlife Contacting or Crossing Structures

Aquatic life and water dependent wildlife often place their lives in jeopardy when attempting to pass through, over, or along masses of dredged or fill materials. Some may be sucked into pumps and pumping plants, discharged over spillways, carried through siphons, or trapped in aqueducts or flumes. Others may surmount road or railroad embankments to be killed or crippled by moving vehicles. Fish can also be endangered by spillway flows which cause nitrogen supersaturation of water in spilling basins immediately downstream from the spillways.

Water Facilities

Fish and other aquatic life can be prevented from moving into intakes for water pumps through the use of various types of screens, or barriers. Large pumping plants that draw tremendous quantities of water may need more elaborate protective devices. A louvered system is shown in Photo No. 5-4. Aquatic life being carried toward the pumps by the rapid flow of water are kept out of them by the louvered screens. A second set of screens and bypass facilities function to divert fish into holding tanks. Fish are then collected, transported away from the area of influence of the pumps, and then released back into the water.

Canals, aqueducts, or other water bodies, often extend across routes used by wildlife to gain access to feeding, refuge, reproduction, or other areas. Animals attempting to cross these facilities, or drink from them, may have their lives endangered. Steep, smooth slopes on canal, aqueduct, or reservoir banks can prevent animals from escaping once they descend. Then, currents in canals and long swimming distances to escape areas in reservoirs can cause additional dangers to threaten the animals lives. Canals may have siphons, or other structures, and reservoirs often have spillways, outlet works, and penstocks that locally increase current velocities and create other hazards.

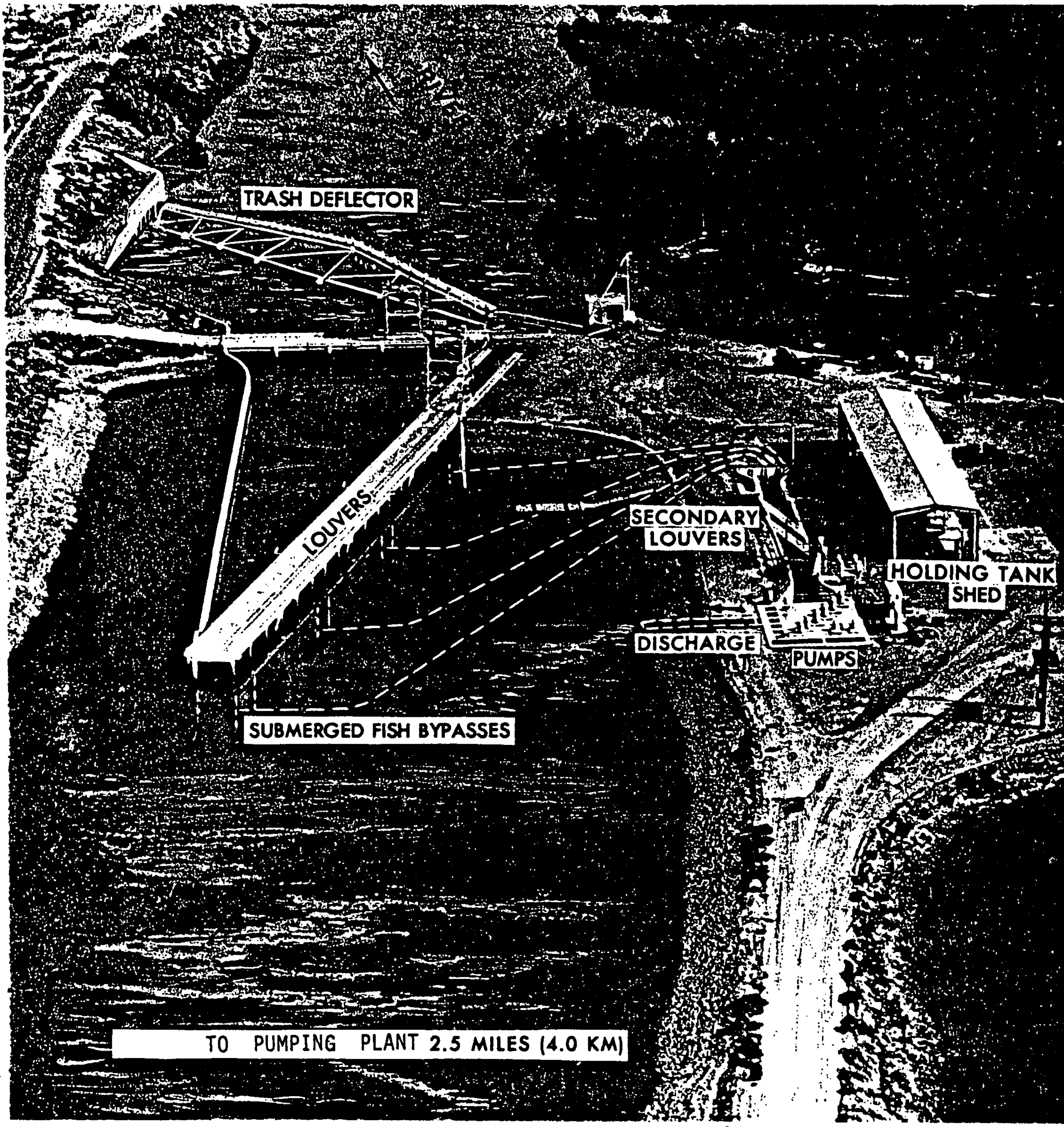


Photo No. 5-4 - System With Two Louvers To Prevent Anadromous and Other Fish From Being Carried Into Major Pumping Plant. They Are Collected In Holding Tanks and Returned To The River. (U.S. Bureau of Reclamation).

Best Management Practices have been developed and can be used to prevent wildlife from being trapped in such structures. An effective practice to prevent some animals from gaining access to and being endangered by a canal or aqueduct involves fencing. It is generally expensive, however, and will require crossing facilities such as bridges to be provided for the animals. These crossings must be located where predominant migration routes or trails exist. If migration or other movements of animals are restricted by fences without crossing facilities, they may suffer losses or deterioration in quality due to inter-breeding, loss of feed sources, or other problems.

Fences must be designed for the particular animal involved. They should be high enough to prevent animals from jumping over and sturdy enough to prevent them from being torn down. Animal bridges, or overpasses, should also be designed for the animals that are to use them. Floors should be covered with natural materials such as soil, sand, or gravel and the crossings limited in width to prevent their use by four-wheeled vehicles.

Pipelines rather than open canals should be considered across wetlands to minimize danger to wildlife, particularly in areas where wildlife tends to migrate or travel. If they can be buried, crossing by animals is greatly faciliated.

Where covered pipes or fencing are not feasible or fully effective to prevent wildlife from entering a canal or aqueduct, entrapment and escape structures may be placed into the facility. Many of these structures are designed also to enable wildlife to enter the canal, descend the slope to obtain water, and then return up the slope (See Photo No. 5-5).

The escape structures shown in the canal in the photograph consists of a ramp constructed in an indentation in the steep canal bank with an angled barrier or other device to divert swimming animals into the ramp. Other, probably less-effective, structures have been devised and used. They may be temporary or permanent. Layers of soil have been placed, as temporary escape structures down canal sides, while sandbag layers form more permanent ones. Concrete steps, or other types of ramps, and accompanying facilities can be designed into the canal slopes to function as permanent and effective escape units.

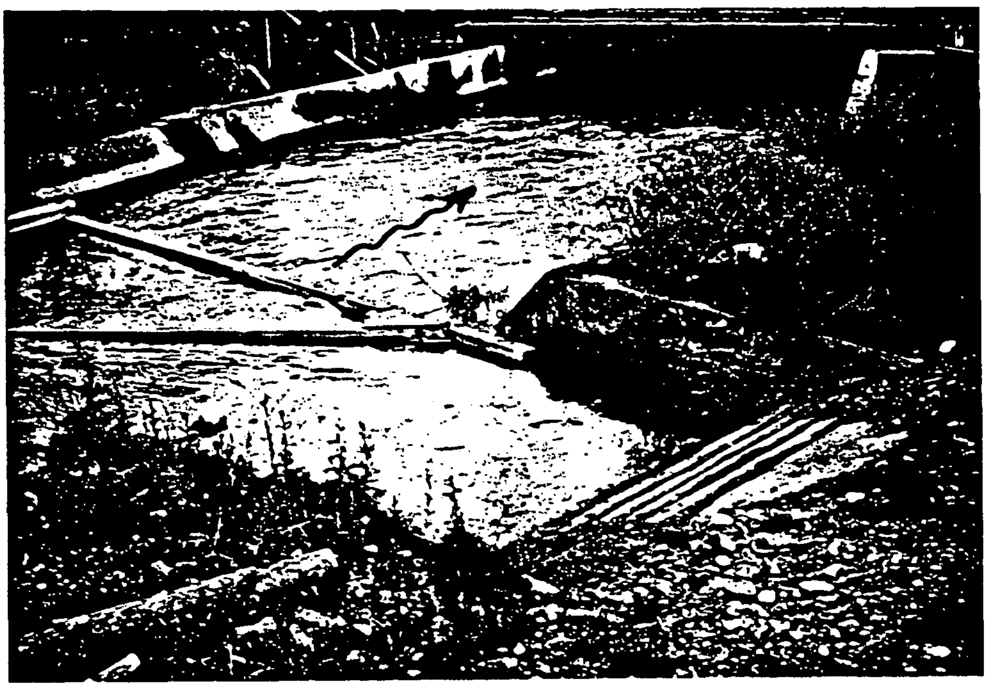


Photo No. 5-5 - Concrete Escape Ramp With Low Slope (4h:1v) Built Into Identation In Steep-Sided Canal. Note Timber Boom That Directs Swimming Animals Into Ramp. (Bureau Of Reclamation).

Transportation Facilities

Causeways extending across wetlands for highways, particulary large freeways, often are fenced at their right-of-way boundary. Animals can gain access to these structures through one avenue or another and place their lives in danger from passing vehicles. As they find their escape from the noisy vehicles on the roadway blocked by the fencing, they become panicked which places them in even more danger. Facilities have been developed and installed into the fences at certain localities to permit animals to escape back into the wetlands and safely. They consist of structures composed of baler tines and angle irons which allow deer to escape from the roadway, but prevent re-entrance.

Habitat Improvement Measures

Any structure formed by the discharge of dredged or fill materials into wetlands or water bodies changes to some extent the regimen of aquatic life and other water dependent wildlife existing in these areas. Stream-flow regimes and the chemical or physical characteristics of water can be altered, water depths changed, dry land flooded, and perhaps flooded lands dewatered. As a result of these changes, aquatic life and wildlife in the area will be affected. They may move to different localities or be replaced by other types of creatures.

The effect and magnitude of these changes may be minimized by habitat improvement Best Management Practices which remedy the problems or provide substitute areas to maintain or provide for the propogation of existing aquatic life and water oriented wildlife. They may include proper management of water and streamflow, and water and streamflow, and the provision of nesting, spawning, nursery, resting or feeding for aquatic life and water-oriented wildlife.

Proper Water Management

Dams are placed across streams to impound water for further use by man. Excess quantities of water from flood flows can be stored for later use. Peak flood flows can be reduced and low flows increased by proper operation of dam facilities. If too much water from a reservoir is diverted into other areas, however, or excessive quantities of water released for use during other periods of time, insufficient water may be available to maintain flow requirements for aquatic life during dry periods.

During the design, construction, and operation of dams and other water projects, the flow requirements to support aquatic and other water-dependent wildlife in downstream areas must be considered during the feasibility, design, construction, and operation stages and sufficient flows made available to meet these needs. Sufficient water will be needed also for flood releases to function as natural scouring media in the channel further downstream. Otherwise sediment loads brought into the main streams by tributaries may deposit as deltas at their junctions. If they form large enough deposits, they can obstruct or restrict the main channel flows. Spawning gravels also can be ruined by these deposits.

Dams on coastal streams having anadromous fish populations must consider making available sufficient quantities of water to flush open sand-bar barriers formed by offshore currents across the mouths of these streams. Unless flood flows can open these bars, anadromous fish cannot enter the stream for further upstream migration and spawning.

Preventing Detrimental Physical or Chemical Water Changes

Water that discharges over the spillway of a dam and plunges into the spillway basin or plunge pool immediately downstream can become saturated with nitrogen and cause fish kills. As the water plunges rapidly to depths, hydrostatic pressures increase. Entrained air is forced into solution by the pressure before it can rise to the surface and escape. Since air is approximately 80% nitrogen, the water becomes supersaturated with it. The oxygen content in the water is mostly metabolized by the fish and other gaseous constituents are too minor to effect them. The nitrogen can become a hazard to fish.

Anadromous fish population in rivers of the northwest have suffered from nitrogen or "gas bubble disease". If they swim at depths greater than 12 feet in the nitrogen-supersaturated water, the fish are not affected by the disease as the external pressure prevents the gas from forming bubbles in their bodies. As they swim at shallower depths, up ladders, or near the surface, however, the nitrogen gas pressure within the fish's body exceeds the water pressure and bubbles form. They cause blisters and bubbles under the skin, on the body and fins, on and under the gill covers, and in the mouth and head.

The nitrogen problem is most serious in the Columbia-Snake River reservoir system of the northwest because the river waters have an over-abundance of dissolved air in them and most of the spillage occurs during the principal upstream and downstream migration periods for the fish.

Since spillway discharges must plunge to depths to cause nitrogen supersaturation, a BMP for preventing this problem should involve designing or modifying spillways to cause the flows to be "flipped", as they are discharged, some distance downstream. Upturned deflectors, cantilevered extension or "flipbuckets" can be designed for spillway terminal structures to deflect the water in a downstream direction and prevent the discharge from plunging deeply (See Figure No. 5-1). They can even be caused to fan out into a thin sheet through the use of a flaring device. These types of spillway terminal structures provide dual benefits to the environment.

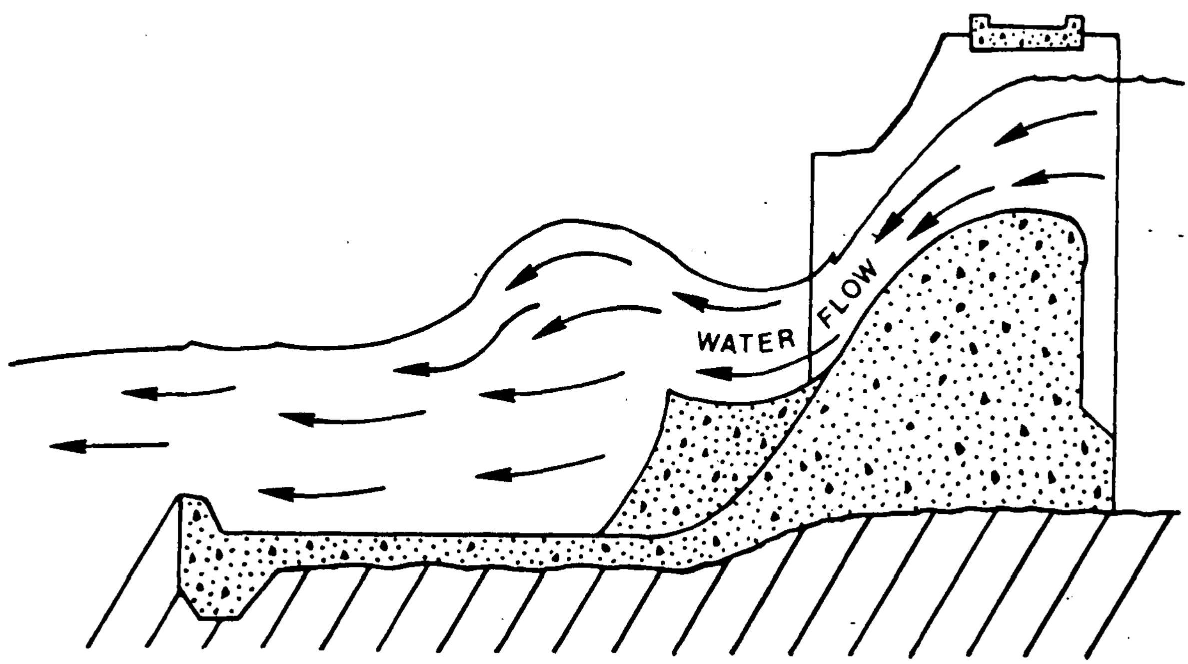


Figure No. 5-1 - Spillway Showing How "Flip" Structure Prevents Flow From Plunging To Depths.

Other remedial meaures to prevent nitrogen supersaturation and "bubble disease" can include:

1. Collecting and transporting fish overland through the length of river where nitrogen supersaturation occurs.
2. Decreasing spillway flows by providing additional reservoir storage.
3. Decreasing spillway flows by passing water through any available outlet conduit where turbulence will not entrain air.

The physical and chemical character of the water in a stream is generally changed when it is stored in a reservoir behind a dam. When released downstream, this water may initiate detrimental effects on aquatic life and possibly the regimen of the stream. The temperature of released water may be higher than stream water if obtained from the upper water-level outlets and lower if obtained from depths. Water released from outlets deep in a reservoir may also be oxygen deficient. All of these changes can be detrimental to aquatic life immediately downstream, particularly to cold-water or anadromous fish such as trout, steelhead, and salmon. Existing aquatic populations may decrease or even be supplanted by a new type of species more adapted to the changed conditions.

The physical and chemical changes in released water can be minimized, particularly with regard to temperatures and oxygen contents by providing multiple intakes for outlet facilities. These intakes, located at various depths in the reservoir, regulate releases so that problems are minimized (See Photo No. 5-6).

Higher elevation outlets release warmer and more oxygenated water while lower ones draw from colder water which contains less oxygen. The quality of the release should be based upon the needs of the aquatic life being protected.

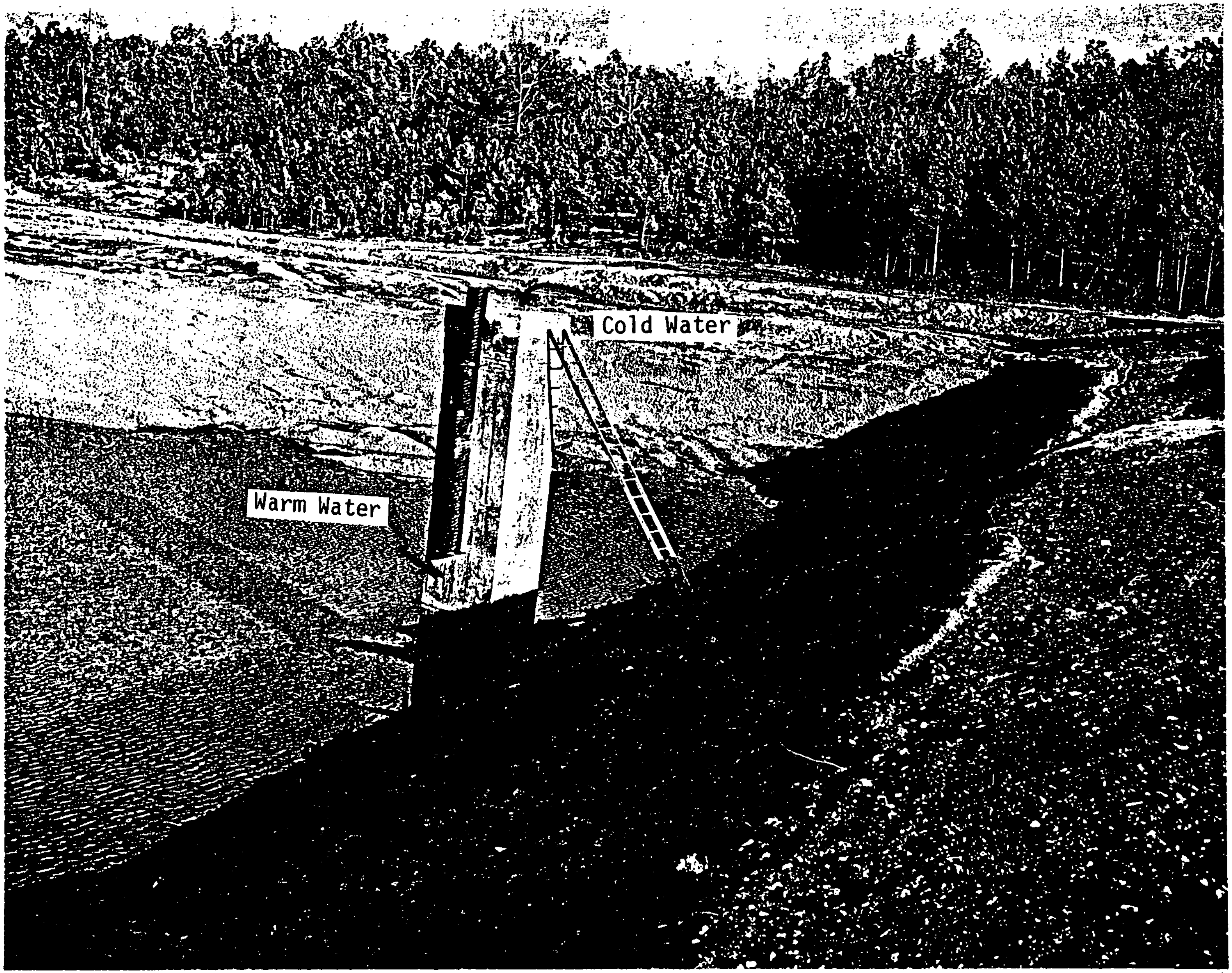


Photo No. 5-6 - Deep-water Intake Installed On Old Concrete Outlet Riser. Water Enters Lower End of Pipe From Depths And Discharges Colder Water While Water Enters From Top (U.S.D.A., Soil Conservation Service).

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